DEVELOPING THE DEMONSTRATION SETS FOR ENHANCING STUDENTS' CONCEPTIONS IN THE PROPERTIES OF LASER BEAM

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DEVELOPING THE DEMONSTRATION SETS FOR ENHANCING STUDENTS' CONCEPTIONS IN THE PROPERTIES OF LASER BEAM

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ABSTRACT

The major goal of this research was to develop a new teaching module based on an Interactive Lecture Demonstration (ILD) approach to promote Thai freshmen students understanding of five basic essential properties of laser beams. The study started from the identification the basic concepts of lasers from the standard curriculum of the National Education of Thailand in 2001. Then, the open-ended questions were devised to survey students' understanding of the interesting properties of laser beams. The questions were administered to 271 Thai freshmen students. The researcher analyzed the collected data to design a new teaching module. Examples of teaching tools in this module were lesson plans, the laser demonstration sets, and worksheets. Finally, the designed teaching tools were validated and modified by the experts' suggestions and the pilot with about 300 students at a university in the north-east of Thailand.

This teaching module was used with 606 freshmen students who participated in a general physics course. It was evaluated through the student conceptual understanding and satisfaction. The results indicated that the instruction by using our laser teaching module encouraged students' learning to reach the medium learning gain, as indicated by the average of the normalized change ($\boldsymbol{c}_{ave}$). The $\boldsymbol{c}_{ave}$ was found to 0.52. Moreover, more than 70% of these students agreed that they have gained essential knowledge in the properties of laser beams from the proposed teaching module.

KEY WORDS: TEACHING MODULE/ LASER BEAM / ILD /
LBCE /PROPERTIES OF LASER BEAM

179 pages

การพัฒนาชุดสาธิตเพื่อพัฒนาความเข้าใจของนักเรียนในเรื่องคุณสมบัติของแสงเลเซอร์
DEVELOPING THE DEMONSTRATION SETS FOR ENHANCING STUDENTS' CONCEPTIONS IN THE PROPERTIES OF LASER BEAM

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บทคัดย่อ

วัตถุประสงค์ของงานวิจัยนี้คือการสร้างชุดการสอนแบบใหม่เรื่องคุณสมบัติของแสงเลเซอร์ เพื่อเพิ่มความเข้าใจของนักเรียนไทยระดับปริญญาตรี ชั้นปีที่ 1 ผ่านกระบวนการเรียนการสอนแบบบรรยายประกอบการสาธิตเชิงปฏิสัมพันธ์ (ILD) ตามการศึกษาสาระสำคัญเรื่องแสงเลเซอร์ตามหลักสูตรการศึกษาขั้นพื้นฐาน พุทธศักราช 2544 กลุ่มสาระการเรียนรู้วิทยาศาสตร์ ชุดการสอนแบบใหม่นี้มีเนื้อหาครอบคลุมคุณสมบัติพื้นฐานห้าด้านของแสงเลเซอร์ จากนั้นผู้วิจัยสร้างคำถามปลายเปิดเพื่อสำรวจความเข้าใจของนักเรียนเกี่ยวกับคุณสมบัติพื้นฐานของแสงเลเซอร์ คำถามนี้ใช้เก็บข้อมูลกับนักเรียนจำนวน 271 คน ผู้วิจัยวิเคราะห์ข้อมูลที่ได้และนำไปใช้ประกอบการสร้างสื่อการสอนในชุดการสอนแบบใหม่นี้ ตัวอย่างสื่อการสอนที่ผู้วิจัยพัฒนาขึ้น เช่น แผนการสอน, ชุดสาธิตคุณสมบัติพื้นฐานของแสงเลเซอร์, ใบความรู้และใบงาน สื่อการสอนเหล่านี้ได้รับการประเมินจากทั้งผู้เชี่ยวชาญ และการนำไปทดลองใช้กับนักเรียนกว่า 300 คนในมหาวิทยาลัยแห่งหนึ่งทางภาคตะวันออกเฉียงเหนือของประเทศไทย เพื่อปรับปรุงให้มีประสิทธิภาพมากขึ้น

ผู้วิจัยนำชุดการสอนนี้ไปใช้สอนนักเรียนจำนวน 606 คน เพื่อประเมินคุณภาพ จากการประเมินความเข้าใจด้านเนื้อหาและความพึงพอใจของนักเรียนต่อชุดการสอน พบว่า การสอนโดยใช้ชุดการสอนที่ผู้วิจัยสร้างขึ้นนี้ ทำให้นักเรียนมีการเรียนรู้เพิ่มขึ้นในระดับปานกลาง (c_{ave} เท่ากับ 0.52) และนักเรียนกว่า 70 เปอร์เซนต์เห็นด้วยว่าชุดการสอนนี้ช่วยเพิ่มความเข้าใจของนักเรียนในเรื่องคุณสมบัติพื้นฐานของแสงเลเซอร์

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CHAPTER I
INTRODUCTION

The dissertation introduction addresses a presentation of an importance for doing this research to promote Thai freshmen students' understanding of the properties of laser beam. An overview of standard content of laser for Thai high school levels and the first year university level are presented. The ideas for teaching about the properties of laser beam based on the Interactive Lecture Demonstration approach (ILD) are discussed. All above are presented in the following chapters. This chapter is contains of the purposes of this study, research questions, and the scope of this research.

1.1 Background of this study

In the recent, laser becomes a component of many instruments in daily life such as toys, media players, military weapons, medical instruments, and scientific instruments. Many students knew laser from the movies such as Star Wars, Star Trek, James Bond, etc. Many children played the toys consisting of laser without knowledge of laser hazardous protections. Many students tried to use lasers in their science projects although general light sources are suitable. For the advanced use of laser, students must understand the properties of the laser beam.

Thai students had studied the topic of laser in their high school physics course in compliance with the compulsory Thai national physics curriculum by IPST (Institute of Promotion of Teaching Science and Technology); the government organization developing science and mathematics curricular in Thailand. The laser topic was a subtopic in Atomic physics which was normally taught in the grade twelfth. Those main substances in the subtopic included stimulated emission, the principle of laser operation, directionality of laser, monochromatic, coherence, brightness, and applications of laser. Moreover, laser is mostly appeared in optics as a kind of special light source using in optics laboratories. In general, laser can be used to show general properties of light in terms of electromagnetic wave and laser is the interesting topic to teach in the application of Quantum physics.

Laser physics is a hard topic which is taught profoundly about laser. The details consists of the absorptions and the emission process, coherence, lasing process, types of laser, structure of laser, laser modes, pulsed laser, laser bean properties, non-linear optics, and laser applications (Silfvast, 2004). For better understanding in laser physics course, some laboratories bases on HeNe laser were created for students (Henningsen, 2011). These laboratories are about the spatial properties of laser beam, the optical resonators, laser operation, modes of laser beam, laser operations in other wavelengths, etc. which are suitable for senior undergraduate students.

According to the curriculum of general physics for freshman students, some topics such as the laser operation, types of laser and some properties of laser beam has been discussed in the classroom (Walker, 2008). Some interesting experiments were created to show some properties of laser beam such as the beam divergence and the brightness but many students are still confused about lasers. They are confused about the differences between laser and other light sources as well as the properties of laser beam. There are many unique characteristics of the laser beam that students do not understand thus we had selected some properties that are essential to know, visualize, and also suit with both mathematic and scientific background of students. The properties conforming with these conditions are the directionality, the divergence, the intensity, the velocity, and the monochromaticity respectively.

1.2 Purposes of the Study

The objectives of this study are;

1. To investigate the prior knowledge of students in the properties of laser beam.

2. To enhance students' understanding in the properties of laser beam.

3. To develop the demonstrations sets for teaching the properties of laser beam with the interactive lecture demonstration teaching approach.

1.3 Research Questions

To carry out the purposes of the study, the research questions will be responded.

1. What is students' prior knowledge about the properties of laser beam?
2. Can the demonstration sets improve students' understanding in the properties of laser beam?

1.4 Summary

This dissertation provides research data about teaching and learning about laser in Thailand, in particular, for high school students and freshmen students. The study addresses a new teaching module based on an inquiry approach. It consists of 5 main chapters.

Chapter I: Introduction—the significance of this research, motivation and the aim of the research study.

Chapter II: Literature Review—Physics Education Research in optics and modern physics, ILD Approach, the developed test and the normalized change.

Chapter III: Development the Teaching Module— how to construct and evaluate the new teaching module.

Chapter IV: Results and Discussions—what we have found and the benefits to the instructions

Chapter V: Conclusions—the summary of our study and suggestions.

CHAPTER II
LITERATURE REVIEWS

This chapter presents review of trends of physics education research that emphasized development of students' conceptual understanding related to optics and modern physics. The five properties of laser beam- directionality, beam divergence, intensity, speed and monochromaticity- are discussed. Finally, the assessments of students' understanding, effectiveness of ILD approach, and normalized gain that will be discussed in details respectively.

2.1 Physics education research

A large number of students have several alternative concepts in physics. This prompted the physics education researchers to reorganize and incorporate students' knowledge. Survey of students' conceptual understanding and misconceptions in a specific physics area such as kinematics, mechanics, thermodynamics, wave & sound, light & optics, quantum mechanics, electricity & magnetism etc., is an initial task before the developments and assessments of the instructional strategies and instruments (Akarsu, 2011; McDermott & Redish, 1999). Several methods such as interviews, short questionnaires, and open-ended questions, used to identify students' misconceptions and misunderstandings, have been developed (Cohen, Manion, & Morrison, 2000; Creswell, 2008). Physics Education Research actually differs from traditional education research in that the emphasis is rather on student understanding of science content than on education theory or methodology (McDermott, 2001).

2.2 Physics education research in optics and modern physics

From the review of previous researches, optics is the course which is very important for students who study science program. Especially in the first year college, students should have condensed knowledge that is enough to study in the senior level. Many years ago, there were many researchers reported that students still had problems about learning introductory optics (Rossing & Chiaverina, 2000). Most researchers tried to investigate students' understanding in optics, construct appropriate instructional tools and modify a suitable curriculum for teaching optics.

According to some literature reviews, students' conceptions in many topic in optics such as the propagating trajectory of light, the visibility process of object, shadow formation, image formation from mirrors and lens, refraction to a planar surface, color and filter, single slit diffraction, double slit interference, nature of light as electromagnetic wave have been surveyed (Ambrose, Heron, Vokos, & McDermott, 1999; Ambrose, Shaffer, Steinberg, & McDermott, 1999; F. M. Goldberg & McDermott, 1986, 1987; Hubber, 2006; Kaewkhong, Mazzolini, Emarat, & Arayathanitkul, 2010; La Rosa, Mayer, Patrizi, & Vicentini-Missoni, 1984; Saxena, 1991; Watts, 1985; Yalcin, Altun, Turgut, & Aggül, 2009). Lasers integrated in several instructional tools have been provided to improve students understanding in some topics in optics such as refraction (Adie, 1997; S. Singh, 2002; S. L. Wong & S.-y. Mak, 2008), diffraction (Michael Vollmer, 2005), speed of light (Mak & Yip, 2000), and interference (Kagawa & et al., 1997).

In modern physics and atomic physics section, the survey of students' conceptions on some subtopics such as the atomic models, photon, wave-particle duality and quantum mechanics were reported (Escalada, 1997; Fischler & Lichtfeldt, 1992; Ireson, 2000; Mannila, Koponen, & Niskanen, 2002; Mashhadi & Woolnough, 1999; Müller & Wiesner, 1999, 2002; C. Singh, 2008; Wuttiprom, Sharma, Johnston, Chitaree, & Soankwan, 2006). Since laser has become famous in daily life, in order to develop students' understanding on laser especially on the properties of the laser beam, surveying students' preconceptions in this topic becomes the first priority and then followed by the instructional tools and teaching processes.

2.3 Laser

Lasers have been well-known since 1960s when the first laser was invented (Milonni & Eberly, 2009; Thyagarajan & Ghatak, 2010). Laser has fascinated many people since it has visible properties such as brightness and long length collimated light. Nowadays, lasers have a central role in many fields of applications, for instance, medicine, industry, military, metrology, scientific research, and schooling (Billings & Tabak, 2006; Kirkland, 2007). In general, the laser theory has been taught in general physics courses and usually appears in general physics textbook for long time ago (David Halliday, 2008; Knight, 2008; Serway & Jewett, 2007; Tsokos, 2008). Laser appears frequently in optics and atomic physics sections. In optics section, lasers have been used to construct experiments and demonstrations for teaching some optical phenomena such as reflection, refraction, interference and diffraction (Adie, 1997; Craig, Johnson, & Schultz, 2007; Hunt, 2005; Klimkin & Sankin, 2005; Lisicki, Buller, Oszmaniec, & Wojtowicz, 2008; Marek, Patterson, & Schools, 2002; O'Connell, 1999; Van Hook, 2007; M. Vollmer, 2005; S. L. Wong & S. Mak, 2008). It was used as a representative of light ray because of obviously observation due to the intense light and narrow beam. In atomic physics section, laser theory such as stimulated emission, population inversion, lasing process, some characteristics of laser beam and laser applications are taught in freshmen physics classroom whereas laser experiments such as laser operation, laser characteristics and laser applications also provided just for senior college students (Beiser, 2003; David Halliday, 2008; Ennos, 1996; Henningsen, 2011; Jackson, Bauen, & Hasbun, 2001; Knight, 2008; Knize, White, & Zhdanov, 2002; Serway & Jewett, 2007; R. B. Singh, 2009). That might be the reason of safety. In general, instructor can demonstrate some simple experiments in his classroom by himself to reduce the risk of hazardous.

2.4 Properties of laser beam

Laser light is an electromagnetic wave (EM wave) which has wavelength in ultraviolet (UV), visible (VIS) and infrared (IR) regime. It has the same properties as general electromagnetic wave. The reflection of laser from objects' surface conforms to the law of reflection. It will refract when reaching the boundary of two optical media conforming with the Snell's law. The diffraction patterns are form after laser beam passing through a narrow slit or a pin hole. In the interferometer the split laser beams can combine to form the interference patterns. The polarized laser light can be created by adding the polarizer inside the laser cavity or in front of the optical aperture of laser. In addition, laser light is a kind of lights which also propagate in the air with the same speed as general electromagnetic waves.

Although there are many kinds of laser, all of them must have 3 basic components that are laser medium, energy-pumped source and optical resonators as show in Figure 2.1. Inside the laser medium, lasing atoms or molecules are pumped into the excited state. The lasing atoms or molecules will emit light to all direction, lights emitted in the axial direction of laser will reflect back and forth between optical resonators then they were amplified by the process called "stimulated emission". These lights become fundamental transverse mode of laser which has Gaussian beam profile. Some lights become higher transverse modes and other will loss. Light emitted from general light sources is emitted by the process called spontaneous emission. The different emission processes between general light source and laser cause laser light to have special properties.

According to the lasing process, only axial-emitted lights become the laser output so the laser light emitted from its optical aperture has a specific direction, this is called "Directionality" properties. Laser light will pass through the optical aperture and moreover the optical resonators of some lasers may be constructed from curved mirrors for easy adjustment. These cause the spreading out of laser beam that called "Beam divergence". In general, beam divergence angle of laser is very small angle that about 0.1 degree or 1 mill radians. The smallest beam divergence angle is in micro radian that used in astronomy. In addition, the diffraction becomes highly dominate for very small optical aperture as of semiconductor laser or generally called "Laser diode". This results in the beam divergence of semiconductor laser to large angle typically greater than 20 degrees.

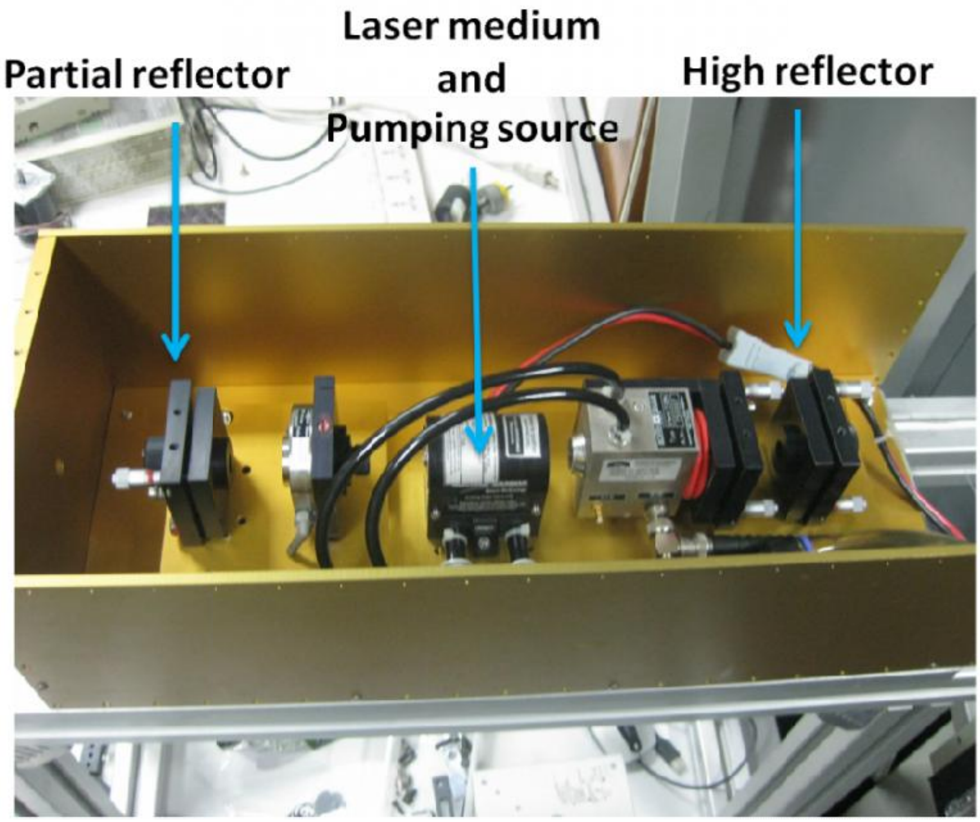

Figure 2.1 Basic components of laser system, laser medium, energy-pumped source and optical resonators.

Wavelengths of laser radiation depend on laser medium. One kind of laser medium does not radiate only single wavelength. To select laser output wavelength, the special reflectors are used as laser resonators. Laser resonators consist of high reflector called “back mirror” and partial reflector called “front mirror”. The fixed distance between optical resonator and coating materials on reflectors cause laser radiation with an expected frequency. Due to uncertainty principle, the energy gap between lasing energy levels is not a certain value so that the radiation wavelength is not absolutely constant. This causes laser to radiate with multiple wavelengths. Fortunately, this causes no trouble because this perturbation has a small effect to the wavelength of laser. For example output wavelength of HeNe laser is 632.8 ± 0.001 nm, the 0.001 nm value called “spectral width” or “line width”. In general, there are no exactly monochromatic light sources but lasers are mostly called monochromatic because of their narrow spectral width comparing to spectral widths of other kinds of light sources.

Laser light is very bright comparing to general light due to the stimulated emission process. The emitted lights are coherence. In the other word, they have the same phase and same frequency so lights will gain their intensity much greater than general light.

Figure 2.2 Comparison between laser light and light emitted from ultra bright LED in searchlight.

2.5 Theoretical Background

2.5.1 Constructivist Theory

Constructivist theory is a learning theory based on observations and scientific studies about how people learn. The excellent features of the constructivism are; learning is active and learning is the interaction of the ideas and process. The new knowledge derived from the prior knowledge. Learning is enhanced when situated in contexts that students find familiar and meaningful. This indicated that students could construct their own understanding and knowledge of the world through their prior knowledge. If students find something new, they will integrate it with their previous ideas and experiences. They may change their beliefs, or may cancel the new information as irrelevant. In conclusion, knowledge cannot be taught, but can be constructed (Bransford, Learning, Research, & Practice, 2000; Bybee, 2002; Kim, 2005). There are many renowned pioneers of the constructivist theory such as Giovanni Battista (Giambattista) Vico (1668-1744), an Italian philosopher, who presented the well-known work as a “Science of Reasoning”. Immanuel Kant (1724-1804), a Russian philosopher who constructed “Critique of Pure Reason” that is an investigation into the limitations and structure of reason itself. John Dewey (1859-1952), an American philosopher who was considered a pragmatist or instrumentalist. Jean Piaget (1896-1980), a Swiss natural scientist and his well known works is about the studying in children. Lev Vygotsky (1896-1934), Soviet psychologist and the founder of cultural-historical psychology. His famous work is the idea about “Zone of Proximal Development”.

The dominant ideas of the constructivist theory involve the understanding of the nature of a learner. The learner is considered as complex and multidimensional. The background and culture of the learner such as language, logic, and mathematical skills which learner encountered in the past impacted to the learning ability. The interaction with peers make the learner learns across environments. The learner’s ideas could be improved by improving the motivation and the responsibility for learning (Bransford, et al., 2000; Bybee, 2002).

To conform to the constructivism, instructors should act as facilitators. Instructors should create the learning environment which promote and challenge the learner’s thinking. Interactive and social processes are important for the created learning processes. The interaction between learner, task and instructor is considered as the important process influencing learner’s thinking from the social constructivist. In 1969 the education research, conducted by the National Training Laboratories (Bethel Maine), established the Learning Pyramid (modified from the Dale’ cone in 1954), which illustrates that the more active instructions, the more effective retention for such subject matters (Lalley & Miller, 2007). The Learning Pyramid displayed the average retention rates for each instructional method. Passive methods were found to provide low retention rate (lower than 50%) while the active methods such as practice by doing and teaching each other were found to provide high retention rate (greater than 75%).

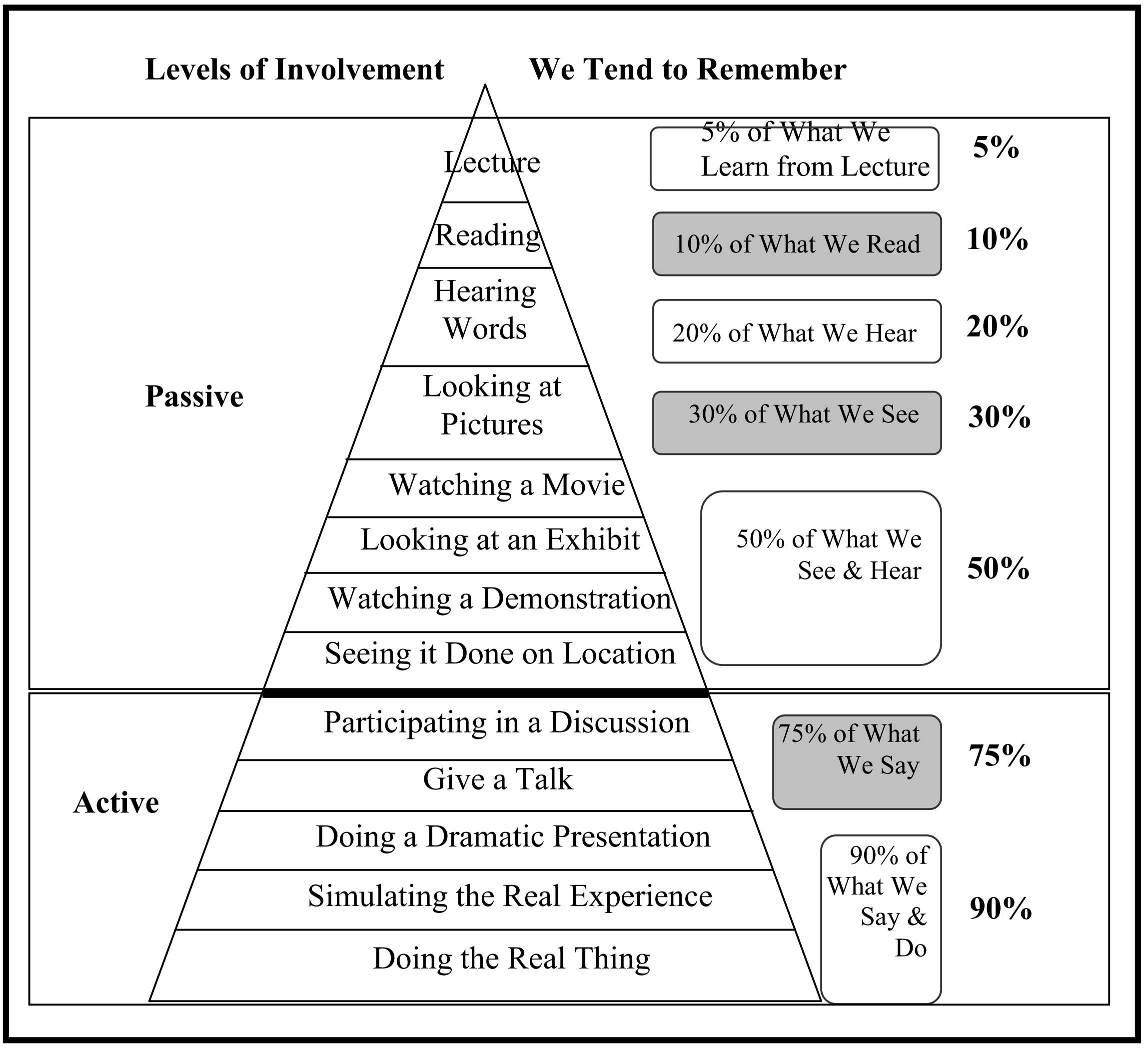

Figure 2.3 The Learning Pyramid (Lalley & Miller, 2007)

Due to the complexity of a learner, instructors should aware that each student does not learn in the same way. This means that if the teacher chooses just one style of teaching, the students will not be maximizing their learning potential. Obviously, a teacher cannot teach every student on the same level during one lesson, but implementing a variety of learning styles throughout the course allows all the students to have the chance to learn in at least one way that matches their learning style. A given subject matter is matched one proper teaching method (Dogru & Suna, 2007; Kim, 2005; Liu & Matthews, 2005; Matthews, 1998).

2.5.2 Interactive lecture demonstration

Interactive lecture demonstration (ILD) is one of the interactive approaches used to improve students' learning (Laws, Sokoloff, & Thornton, 1999; Sokoloff & Thornton, 1997; Thornton & Sokoloff, 1998). Interactive lecture demonstration approach was applied for conceptual learning in many topics in physics (Redish, 2003; Sokoloff & Thornton, 2006). One major focus was on the uses of computer-supported tools: microcomputer-based laboratory (MBL) tools, video analysis software or vector visualization software that allowed students to construct physics concepts successfully from their own experiences of physical world (Bernhard, 2003; Kozhevnikov & Thornton, 2006; Thornton, 1997; Thornton & Sokoloff, 1990; Tilya, 2003; Voogt, Tilya, & van den Akker, 2009).

Generally, ILD approach is suitably used in the physics lecture classroom for high school and university students. The features of ILD are shown in Table 2.1.

Table 2.1 The general nature of ILD approach

Feature	**ILD**
Environment	Lecture
Participants	30-300
Time investment	low
Materials	Computer, LCD, computer-assisted data acquisition devices, Standard demonstration equipments for each topic, worksheets
Demonstrating data	Real time

Besides, this approach can help to eliminate the problem of a few computers. It requires only one computer to support demonstrations for large numbers of students. The sequence of teaching steps consists of:

1. The instructor describes the demonstration and does it for the class without measurements displayed.

2. The students are asked to record their individual predictions on a prediction sheet, which will be collected at the end of the session, and which can be

identified by each student's name written at the top. (The students are assured that the predictions will not be graded, although some course credit is usually awarded for attendance and participant at these ILD sessions.)

3. The students engage in small group discussions with their one or two nearest neighbors.

4. The instructor elicits common student predictions from the whole class.

5. The students record their final predictions on the prediction sheet.

6. The instructor carries out the demonstration with the measurements (usually graphs collected with real-time data logging tools) displayed on a suitable display (multiple monitors, LCD, or computer projector).

7. A few students describe the results and discuss them in the context of the demonstration. Students may fill out a result sheet, identical to the prediction sheet, which they may take with them for further study.

8. Students (or the instructor) discuss analogous physical situation(s) with different "surface" features. (That is, different physical situation(s) based on the same concept (s).)

Each demonstration in this research follows ILD steps so more time of teaching is required (approximately 20 minutes per demonstration). The teaching steps must begin with what students know and lay basis for additional understanding. Second, ILD's must be presented in a manner such that students understand the experiments and trust the apparatus and measurement devices used. The real-time display of data can make the "abstract" concrete through immediate feedback. It allows the immediate linking of a concrete measurement of an actual physical system with the simultaneous production of symbolic representation. This linking may make the abstract concrete. There is also good evidence that the real-time display is crucial (Brasell, 1987).

The preliminary work of using ILDs was started and had been developed at Tufts and Oregon University where Thornton and Sokoloff compared the instruction method between traditional and ILDs teaching by administering Force and Motion concept evaluation (FMCE). The results displayed that the ILD-enhanced learning was persistent both at Oregon and at Tulfts. Moreover, students were assessed again after they learned with ILDs six weeks. The result was that there was no decrease in understanding. In fact, there was 6% improvement. After that the researcher has brought ILDs to use in class wildly such as (Wittman, 2002) the studied about investigating the effective of the implementation of the RTP/ILD. The FMCE scores from before and after instruction were compared by using gain. A class that FMCE score went from 20% to 40% correct would have a gain of 0.25.

In Thailand, Jairuk conducted a research about the use of interactive lecture demonstrations in force and motions His results showed that the ILD could help students improve their conceptions better than the traditional lecture (Jairuk, 2007). In 2009, Tanahoung studied the development of students' conceptions of heat and temperature using the interactive lecture demonstration. His results showed that the average normalized gain of students who had participated in the ILD classroom was greater than the traditional classroom (Tanahoung, Chitaree, Soankwan, Sharma, & Johnston, 2009). In the same year, Sujarittham did her research on enhance students' conceptions in Newton's law of motion. She created ILD for teaching about non-uniform force by integrating magnet and electro magnet to her instructional tools. Her results showed that most students in her classroom had better understanding of Newton's laws of motion. The average normalized gain of a class was 0.30 (SUJARITTHAM, 2009).

2.6 The Assessment Instrument and Method

2.6.1 Conceptual tests

In this dissertation, we construct the conceptual test as the tool for indicating an effectiveness of learning unit. There are many conceptual tests used widely in physics education research such as Force Concept Inventory (Hestenes, Wells, & Swackhamer, 1992), Mechanics Baseline Test (Hestenes & Wells, 1992), Force and Motion Conceptual Evaluation (Thornton & Sokoloff, 1997), Heat and Temperature Conceptual Evaluation (Thorton & Sokoloff, 2001), Conceptual Survey of Electricity and Magnetism (Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001), and Geoscience Concept Inventory (Libarkin & Anderson, 2006). For laser beam properties, students' knowledge about laser beam has been intensively explored by using a set of our prepared conceptual questions. The conceptual test used in this study had been developed in 2010 for using as a tool to measure students' understandings and effectiveness of a learning unit. The process of conceptual test development will be explained in chapter 3.

2.6.2 The evaluation of effectiveness of instructional approach

In physics education research, pre and post-instruction conceptual tests are generally used for evaluating the effectiveness of instructional pedagogies and practices. The average normalized gain $\langle g \rangle$ for a course is defined as the ratio of the actual average gain to the maximum possible average gain (Hake, 1998).

$$\langle g \rangle = \frac{\text{(Mean of the post-test in \%) - (Mean of the pre-test in \%)}}{\text{100-(Mean of the pre-test in \%)}} \tag{1}$$

After 6000 students were administered the Force Conceptual Evaluation, Hake presented students responses by defining three distinct levels of average normalized gain; <u>high</u> when the value is greater than 0.7, <u>medium</u> when it is between 0.7 and 0.3, and <u>low</u> for values below 0.3. Besides, an average normalized gain is also used to analyze students' responses in other topics such as thermal concept (Luera, Otto, & Zitzewitz, 2006), astronomy concepts (Willoughby & Metz, 2009). Generally, the normalized gain also has been used to analyze the individual responses of each student; it depends on the researchers' interest (Bao, 2006). The normalized gain is defined as:

$$g = \frac{\text{(post-test in \%) - (pre-test in \%)}}{\text{100-(pre-test in \%)}} \tag{2}$$

From equation (1) and (2), it is possible that the normalized gain and the average normalized gain can be a negative in case of pre-test % > post-test%. In 2007, Marx and Cummings showed the limitations of using the normalized gain and revise it to a new procedure called the "**normalized change** (***c***)". The shortcomings of normalized gain are (1) it has a low test-score bias, (2) the normalized gain equation generates a non-symmetric range of scores which makes interpretation difficult in some cases, and (3) if a student achieves a perfect pre-test score (the maximum scores), then the equation yields g = - ∞ for any post-test score (Marx & Cummings, 2007). The normalized change can be defined as equation (3)

$$c = \begin{cases} \dfrac{\%\text{ post - }\%\text{ pre}}{100\%\text{ - }\%\text{ pre}} & \text{in case of } \%\text{ post} > \%\text{pre} \\ 0 & \text{in case of } \%\text{ post} = \%\text{ pre} \\ \dfrac{\%\text{ post - }\%\text{ pre}}{\%\text{ pre}} & \text{in case of } \%\text{ post} < \%\text{ pre} \end{cases} \qquad (3)$$

The ways to obtain the normalized change of the class were (1) by calculating each student's normalized change using above equations and averaging these changes, which called the average of the normalized changes (c_{ave}), and (2) by calculating the average pre-test and post-test of the class and using these two score to calculate the normalized change of the averages ($<c>$). The reasonable investigation for small and medium groups of students was c_{ave}. However, for large numbers of students both c_{ave} and $<c>$ revealed the small difference (Marx & Cummings, 2007). Overall, the normalized change can reduce the limitations of the normalize gain. Both assessment methods have been widely used in Physics education research (Bao, 2006; Coletta, Phillips, & Steinert, 2007; Marx & Cummings, 2007). In this study, the normalized change is used to analyze students' responses. In addition to the conceptual test, the set of questions were also administered to students for recommendations about instructional teaching.

2.7 Summary

From the review of the previous research, there are many students who had misunderstandings in physics. Physicists attempt to verify a new teaching strategy and an effective curriculum that engage students to have better understanding in each branch of physics concepts. Teaching style in the class is changed from a traditional teaching to an interactive teaching based on physics education researches. Inquiry method is a one of appropriate teaching methods for learning science by inviting students to construct their own concepts with directed phenomena and experiments. Now a day, laser becomes a popular instrument in daily life. There are many applications of laser such as military, medicine, scientific research etc. Plenty of students know lasers and can use them in their works but how well they know the properties of laser beam is still in doubt. It'll be better if we can improve students' understanding on the properties of laser beam. There are certainly provides advantages to them in keeping up with the fast pace of technology change. The normalized change is used to evaluate the effectiveness of the learning unit. In the next chapter, the materials and experimental methods will be discussed.

(Grier, 1975; Horst, 1949; Tucker, 1949; Yeo & Zadnik, 2001) (DiSessa, 1993; F. Goldberg & Bendall, 1995; Henningsen, 2011; Hewson & Hewson, 1983; Posner, Strike, Hewson, & Gertzog, 1982; Silfvast, 2004; Sim & Rasiah, 2006; Turner & Carlson, 2003; Walker, 2008)

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CHAPTER III
METHODOLOGY

In this chapter, the designing of the laser beam properties' teaching tools based on interactive lecture demonstration approach will be discussed. The creating tools focus on the improving of Thai freshmen students' understanding of five basic essential properties of laser beam. The works were divided into 3 phases namely:

Phase I: Identify the basic concepts of Laser and laser beam

Phase II: Survey students' understanding of the properties of laser beam

Phase III: Design the Teaching materials

The details of each phase will be explained subsequently.

3.1 Phase I: Identify the basic concepts of Laser and laser beam

In this session, all core physics topics for general Thai high school students and Thai freshmen students will be presented, including the concepts of laser.

3.1.1 Review physics topic for Thai high school and freshmen students

From the review of Thai high school physics course in compliance with the compulsory Thai national physics curriculum by IPST (Institute of Promotion of Teaching Science and Technology); the government organization developing science and mathematics curricular in Thailand., the body of physics contents in Thai curriculum is divided into 21 lessons as followings;

1. Measurement
2. One and two-dimensional motion
3. Force, mass and the motion's laws
4. Complex motion
5. Work and Energy
6. Impulse and Momentum
7. Rotation

8. Equilibrium and Elasticity
9. Fluids
10. Heat
11. Mechanical waves
12. Sound waves
13. Interference and diffraction of light
14. Reflection and refraction of light and optical instruments
15. Electrostatic
16. Electric and Magnetism I
17. Electric and Magnetism II
18. Electromagnetic waves
19. Atomic physics
20. Nuclear Physics
21. Electronics and applications

In general, Thai first year students who participate in general physics course in their first year program will learn all topics above again. The difference between Thai high school physics and Thai college physics are the level of conceptual understanding, the linking with the complicate mathematics, and time duration of learning.

3.1.2 Identify the basic concepts of Laser

Laser usually appears in optics and atomic physics sections. In optics, laser is a kind of light source frequently used in many experiments and used as a demonstration tool displaying some optical phenomena. In atomic physics, the laser theory, the properties of laser beam and the application are discussed. Based on the act of legislation for the standard curriculum of national education Buddhist Era 2544 (in 2001), the subtopics of learning in laser topic provided for Thai high school students are illustrated in figure 3.1. Thai general physics courses in many universities in Thailand also constructed the curriculum containing of topic of laser. For the limitation of time, this topic is brushed over. Consider especially in freshmen science students, when they become senior students, many of senior projects need using of laser. Moreover laser becomes an essential part in the construction of some advance instruments mostly using in science experiments such as Ellipsometer, Atomic Force Microscopy (AFM), Interferometers etc. It certainly provides advantages in their works such as laser safety, selection of suitable laser for the projects, designing the control system of laser beam parameters etc., if they have good understanding about laser and laser beam.

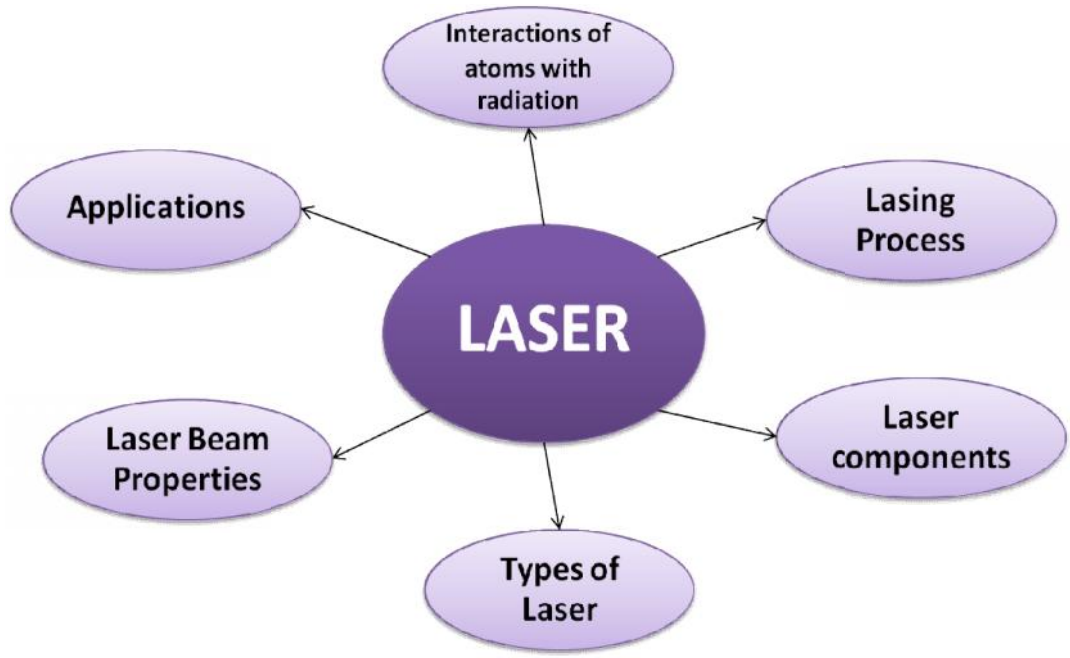


Figure 3.1 The subtopics in the Laser learning topic.

Laser beam has some properties similar to the general light has such as reflection, refraction, diffraction and interference. These topics are mostly taught and demonstrated in optics. On the other hand, it's also having the unique properties that contrast from general light. The differences arise from the emission process of light and the structure of laser. The basic essential properties of laser beam which are discussed in many popular laser textbooks are summarized and displayed in figure 3.2.

Directionality is the simplest property that many students familiar to because lasers are generally used as an accurate pointing tool. In optics, laser is usually used to demonstrate some geometrical optics phenomena such as the positioning of image formation from mirror and lens, the refraction of light and refraction angle, etc. From the survey, many students are still confused about this property. If we can improve students' understanding in directionality, it provides advantages directly in learning optics and also laser safety.

The next simple property is a speed of laser light. Many students believed that laser light has a different speed from general light due to some parameters such as intensity and frequency. Understanding in speed of laser light is important for student in order to understand some laser applications such as laser velocimeter and laser range finder.

Many students believed that laser beam does not spread out so its intensity does not decrease via distance. These two properties relate to each other. In order to understand why some optical techniques should be added in the experiments while using laser such as collimation of laser bean, students need to understand these inevitable properties.

Many students can remember that light emitted from laser is a monochromatic light. If we show many kinds of lights to them and ask them as what light(s) is/are monochromatic light? what is the advantages of the monochromatic light? Many students cannot answer these questions clearly. The simple investigating method to find the monochromatic light is needed to provide to students to answer these questions.

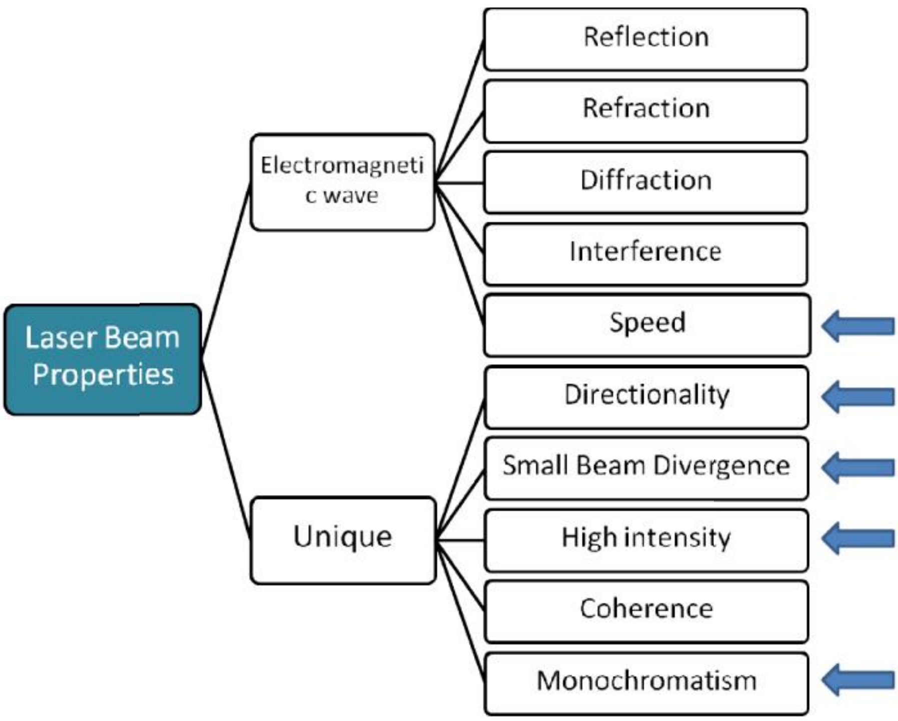


Figure 3.2 The basic properties of laser. The arrows show the selected properties.

There are other properties of laser beam that students should know such as laser mode, laser beam profile, pulse of laser etc. but in order to understand those properties require more advance scientific background and mathematical background. These are the reason of choosing only five basic essential properties - directionality, beam divergence, intensity, speed and monochromaticity – to study. In addition, these five properties often emerge in general physics textbook and are vital for freshmen students' background and obviously observed in the class. Moreover, they can then keep up with the fast pace of the technology change if they have better understanding in laser beam properties.

3.2 Phase II: Survey students' understanding of the properties of laser beam

3.2.1 The open-ended questions construction

The 13 item open-ended question was created in Thai language for surveying Thai freshmen' conceptions in five properties of laser beam: the directionality, the divergence, the intensity, the velocity, and the monochromaticity. The test was then revised twice after administering to three graduate physics students and three graduate physics education students. The validity was checked by five experienced physicists who had at least ten years experience in teaching physics from a science university in Bangkok, Thailand. The validity checking table was constructed for each expert to use during the verification. Each expert assessed the agreement of each question with the objective, and marked: agree (+1 point), in which the question and its objective correlated, not sure (0 point), or disagree (-1 point), in which the question and its objective did not correlate. Most questions asked students to provide the explanation to their answers. The Thai and English translated version of the test is shown in the appendix A and B, respectively. The scope of the questions is presented in Table 3.1.

Table 3.1 The topics and scope of the questions in the open-ended test

Topic	Scope of the questions	Question#
1. Directionality	• Determine the position that the laser light will propagate to.	1
	• Notify the difference between laser and other light sources in terms of the directionality.	2
	• Determine the position that the reflected laser light will propagate to.	7
	• Use the directionality and the law of reflection to determine the reflected ray.	8
2. Divergence	• Notify the relationship between the distance and the size of a laser beam.	3
3. Intensity	• Notify the relationship between the distance and the intensity of laser.	4
	• Compare the trend of the intensity at any distance between laser and light bulb.	4
	• Use the intensity to verify the difference between laser light and other light sources.	5, 6
4. Speed of light	• Compare speed of light from laser to other light sources.	9
5. Monochromaticity	• Identify the light source from the refraction phenomenon.	10
	• Compare the magnitude of the spectrum width by the refraction phenomenon.	11
6. Application	• Use the divergence and the line-width as a decision-making factor to determine a suitable light source for a given situation.	12, 13

3.2.2 Survey students' understanding of the properties of laser beam

The subjects were 271 first year science students from a university in Bangkok. The test was applied before learning Optics in General Physics course in November 2010. The students had already studied the topic of laser in their high school physics course in compliance with the compulsory Thai national physics curriculum by IPST.

The students' responses were analyzed and categorized. The results are present in Chapter 4.

3.3 Phase III: Design the Teaching materials

To investigate the alternative conception and encourage the freshmen students' understanding about the properties of laser beam, we created the laser teaching tools which consist of the demonstration sets based on ILD approach, student's worksheets consist of prediction sheets and data collection sheets, and the multiple choice assessment instrument.

3.3.1 Sample groups

The sample groups in this study are the first year students from the university in Phayao province. The total number of participants is about 600 in 2010 academic year. They participated in the General Physics course. They studied in variety schools that are School of Science, School of Medicine, School of Law, School of Agriculture and Natural Resources, School of Information and Communication Technology, School of medical science, and School of Allied Health Sciences. The students were divided into 3 sections. Each section had 2 lecturers. One taught in the first half of the semester and the other taught in the second half. Our teaching instructions are provided to them before atomic physics topic. The details of students in each group are shown in Table 3.2.

Table 3.2 The details of sample group

Class #	Students' Faculties
1	School of Medicine (MED), School of Allied Health Sciences (AHS)
2	School of Science (SC.T.), School of Information and Communication Technology (ICT)
3	School of Law (Law), School of Agriculture and Natural Resources (SAN), School of Medical Science (MedSci)

3.3.2 Design Instructional process

We plan to collect data and teach students the properties of laser beam using our demonstration sets with the ILD approach for 3 hours per class. The details of teaching and collecting data are shown in Table 3.3.

Table 3.3 Teaching plan

Teaching and Collecting data	Time duration
Pre-test (conceptual test)	15 minutes
Engagement students	5 minutes
ILD teaching in the directionality: Demonstration 1	20 minutes
ILD teaching in the beam divergence: Demonstration 2	20 minutes
ILD teaching in the reflection: Demonstration 3	20 minutes
ILD teaching in the intensity: Demonstration 4	20 minutes
ILD teaching in the speed of laser light: Demonstration 5	20 minutes
ILD teaching in the monochromaticity: Demonstration 6	20 minutes
Conclusions	5 minutes
Post-test (conceptual test)	15 minutes

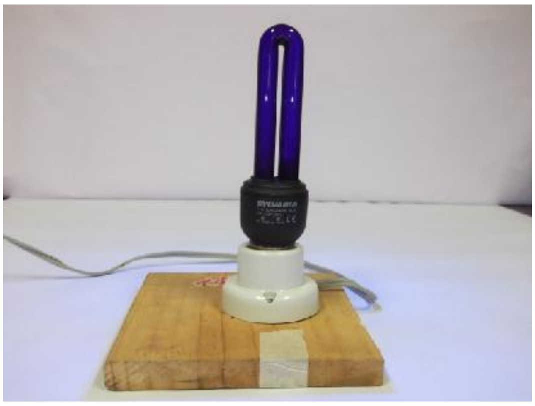
3.3.3 Design demonstration sets

To setup the demonstrations sets, we needed some equipment that consisted of:

- **Light source**
  1. UV light source: The SYLVANIA MINI-LYNX BLB 11 W was used. It emits the ultraviolet light of 300-400 nm.
  2. Helium Neon gas laser: Model: 08181093, Optlectra GmbH, output power 1 mW, wavelength 632.8 nm.
  3. Green laser pointer: A 532 nm green laser wavelength is obviously seen as a beam in dark conditions, not just the laser beam dot. The construction of this laser pointer is based on the Diode Pumped

Solid State Frequency Doubled (DPSSFD) laser technology. A high power IR laser diode at 808 nm acts as an optical pump that sent energy to a block of Nd:YVO_4 . The stimulated emission occur producing light at 1,064 nm which feeds a KTP (frequency doubler crystal) to generate the green beam at 532 nm.

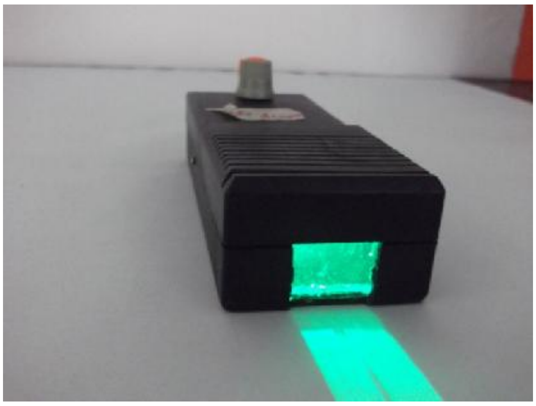
4. Green LED: The ultra bright LED with dominate wavelength 527 nm, $\Delta\lambda \cong 40\ nm$.
5. Light bulb: A 60 W PHILIPS Clear light bulb was used.
6. Searchlight: Constructed from white LEDs.



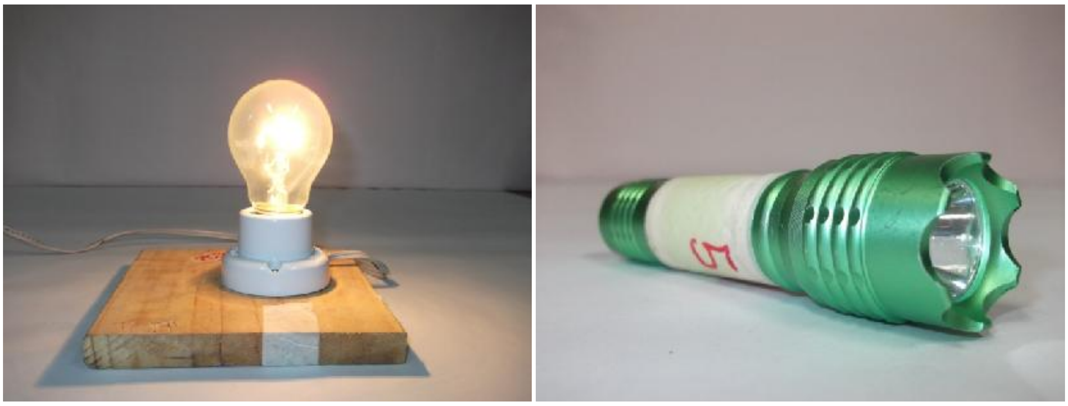
(a)

(b)

(c)



(d)



(e) (f)

Figure 3.3 All light sources used in the demonstrations, (a) UV light source, (b) He-Ne laser, (c) Green laser, (d) Green LED, (e) Light bulb and (f) Searchlight.

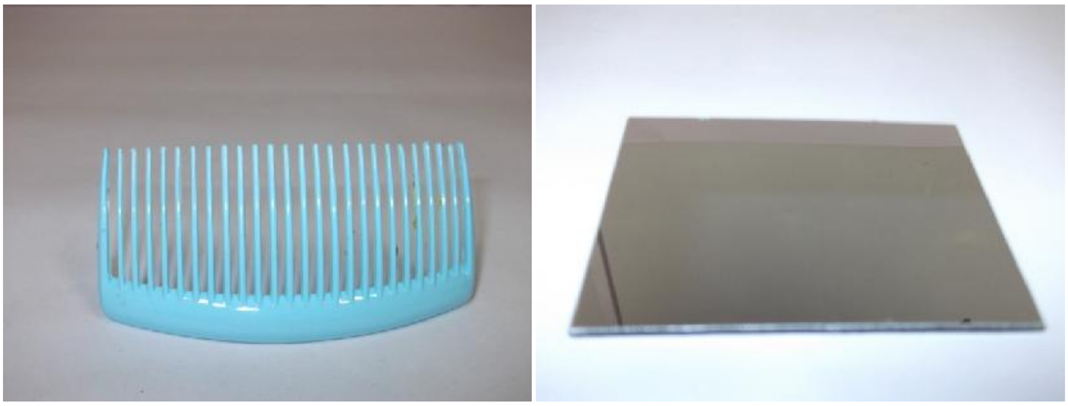
- **The fluorescent alphabets:** It's colored by the fluorescent ink that can be observed clearly under the ultraviolet light.

Figure 3.4 The fluorescent alphabets could be observed obviously under UV light.

- **Laser safety glasses:** It can protect the eyes from the hazardous reflected or scattered high powered laser light**.** In our demonstration, the selected safety glasses block attenuates the laser light of 532 nm wavelength.

Figure 3.5 Laser safety glasses.

- **Curved comb:** Light emitted from light bulb propagates to all direction. It is difficult to observe the reflection so the comb is used to produce light beams.
- **Plane mirror:** It's a front surface coated mirror which is used in the demonstrations about the reflection.



(a) (b)

Figure 3.6 (a) Curved comb, (b) Plane mirror.

- **Water tank:** It's used in demonstration 3 and 5 to help in observation of laser beam.
- **Prism:** It's used in demonstration 6 the show the dispersion of white light. It's constructed of acrylic and has a hole to fill water inside.

(a) (b)

Figure 3.7 (a) Water Tank, (b) Prism.

- **Labquest data acquisition and sensor:** The LabQuest is a portable data logger that has been designed and manufactured by Vernier Software and Technology. It can be connected to variety of sensor. In our research, we use the light sensor to measure the intensity of general light and laser light. The intensity measurement unit is lux.

Figure 3.8 The LABQUEST data acquisition and light sensor.

- **Spectrometer:** This is a spectrometer of Ocean Optics Inc. The USB4000-VIS-NIR is preconfigured for applications from 350-1000 nm wavelength range. It can display the emission spectrum of the light source.

Figure 3.9 Ocean Optics USB4000 Spectrometer with fiber optics probe.

In our teaching plan, there are six demonstration sets for teaching in five properties laser beam. The demonstrations were developed from many well-known physics textbooks (Freier & Anderson, 1972; McDermott, Shaffer, Rosenquist, & Group, 1996; McGraw-Hill, 2004; Sokoloff, Laws, & Thornton, 2004). Most of the designed demonstrations will demonstrate the property of both laser light and general light. Students can observe and compare the different between these two kinds of light immediately. Table 3.4 shows the teaching goals and the demonstration sequences.

Table 3.4 The demonstration #, the related properties of laser beam and objectives.

Properties of laser beam	**Objectives**	**Demonstration #**
Directionality	To teach about the direction of the emitted light from the light bulb and the laser.	1.1 and 1.2
Beam divergence	To teach about the divergence of laser beam	2
Reflection (direction of beam)	To teach about the reflection of normal light and laser light from the plan mirror.	3.1 and 3.2

Table 3.4 The demonstration #, the related properties of laser beam and objectives (Continue).

Properties of laser beam	**Objectives**	**Demonstration #**
Intensity VS. distance	To teach about the change of the intensity of laser beam along the axial position.	4.1 and 4.2
Speed of laser light	To teach about the speed of the laser light and general light.	5.1 and 5.2
Monochromatism	To teach about the dispersion of the white light, LED light and laser light from prism.	6.1
	To teach about the line width of white light, LED light and laser light.	6.2

Demonstration 1.1: The directionality

The set-up experiment: The UV lamp was placed on the ground in the dark room. Then five volunteers with the fluorescent alphabets were asked to stand around the UV lamp. After that the lamp was turned on.

The results of the experiment: Students in the class could see all alphabets clearly. Then we told the volunteer to walk around the lamp, students in the class also observed the alphabets clearly at every point around the lamp.

Figure 3.10 Results from demonstration 1.1, the observation of the fluorescent alphabets in front of the class.

Demonstration 1.2: The directionality

The set-up experiment: The laser was placed on the ground in the dark room. The three volunteers were asked to wear the laser safety glasses. Before turning on the laser, the volunteers were asked to place the black plate at the position that laser light would propagate to after the laser was turned on.

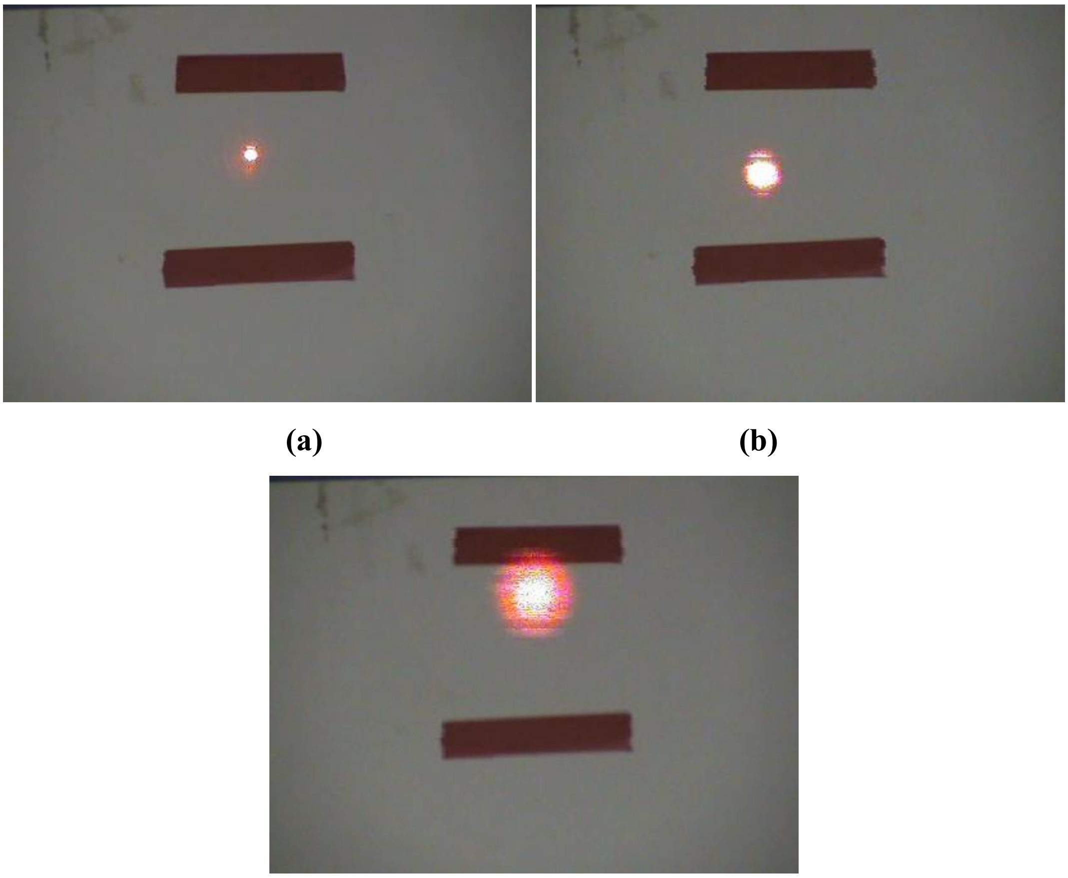
The results of the experiment: Students in the class could see a laser spot on the black plate of one volunteer who placed the board in the direction along the axial of the laser. Then we told other volunteers to move their board to make the laser spot appear. To succeed this experiment, students found that they had to bring their board to the same direction as the first volunteer.

Figure 3.11 Students found the position to place the board for observing the spot of laser in demonstration 1.2.

Demonstration 2: The beam divergence

The set-up experiment: The Helium Neon laser was placed at 2 m from the screen then turned on the laser. The students would see the laser spot on the screen. Then the laser was moved to 10 m and 20 m from the screen respectively.

The results of the experiment: Students in the class could see that the laser spot on the screen was slightly bigger when the laser was moved far away from the screen.



(a) (b)

(c)

Figure 3.12 The spot of laser beam in demonstration 2 when observing a laser spot at (a) 2 m, (b) 10 m, and (c) 20 m far away from the source.

Demonstration 3.1: The reflection

The set-up experiment: The light bulb was placed in front of the plane mirror. Then the comb was placed between the light bulb and the mirror to produce the light beam. Then we would sketch the straight line along the incident and the reflected bean.

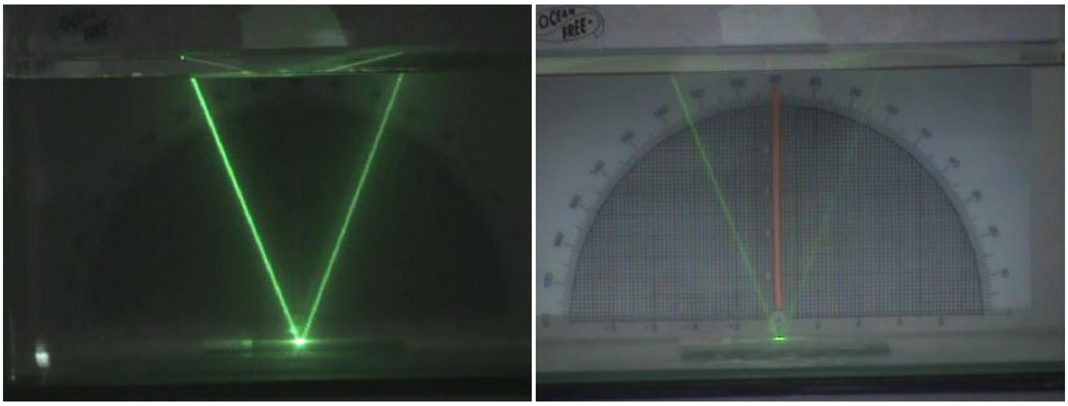
The results of the experiment: Students could see that there was many incident and reflected beams. Each incident beam had a different incident angle. They also learned from the demonstration that the angle of incident is the angle between the normal line and the incident ray; the angle of reflection is the angle between this normal line and the reflected ray.

(a) (b)

Figure 3.13 The results from demonstration 3.1 (a) The incident rays and the reflected ray of the light bulb, (b) The measurements of the incident angles and the reflected angles.

Demonstration 3.2: The reflection

The set-up experiment: The laser was placed obliquely to the surface of the water. The plane mirror was put at the bottom of the tank. The protractor was placed behind the tank to show the angle of incident and the angle of reflection. Then the laser was turned on.



(a) (b)

Figure 3.14 (a) The incident rays and the reflected ray of the laser from demonstration 3.2, (b) The immediately displaying of the incident angles and the reflected angles.

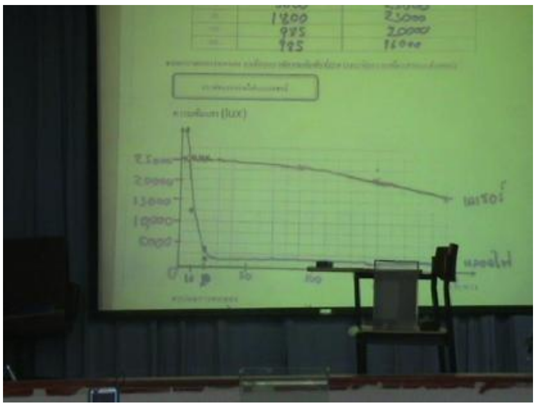
The results of the experiment: Students could see that there is only one incident and reflected beams. They also found that the angle of incident is equal to the angle of reflection.

Demonstration 4.1: The intensity VS. Distance

The set-up experiment: The light bulb was turned on and placed in front of the class. The intensity of light were measured at 5 cm, 10 cm, 15 cm, 20 cm, 100 cm, and 200 cm from the bulb. Finally, the graph between the intensity and the distance was sketched.

The results of the experiment: Students could see that the intensity of light emitted from light bulb decreased rapidly.

(a) **(b)**



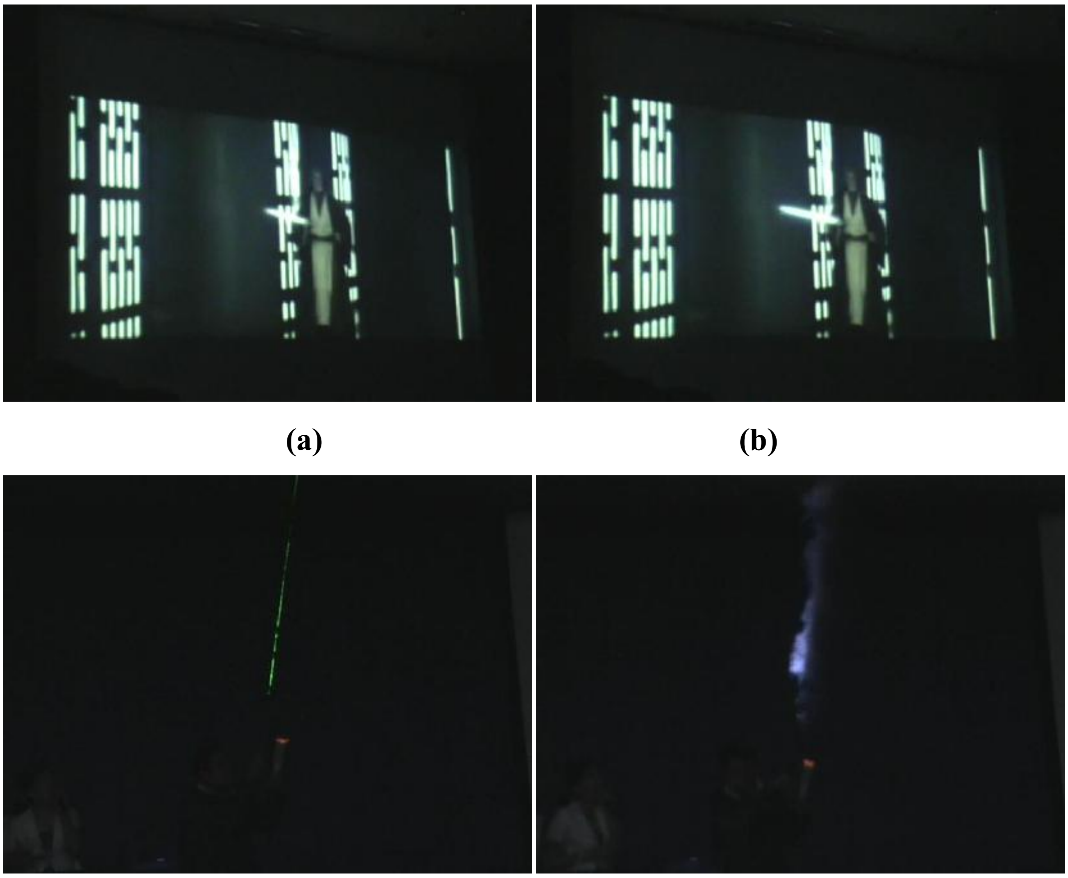
(c)

Figure 3.15 (a) The demonstration setup to measure the intensity VS. axial distance, (b) The real time measurement of the intensity and (c) Graph plotting between the intensity and the distance of light emitted from light bulb and laser.

Demonstration 4.2: The intensity VS. Distance

The set-up experiment: The laser was turned on and placed in front of the class. The intensity of laser light was measured at 5 cm, 10 cm, 15 cm, 20 cm, 100 cm, and 200 cm from the light source. Finally, the graph between the intensity and the distance was sketched.

The results of the experiment: Students could see that the intensity of light emitted from laser slightly decreased. The intensity of both general light and laser light decreased along the axial distance, but the intensity of laser light decrease slower than the other.



(a) **(b)**

(c) **(d)**

Figure 3.16 (a) and (b) Show the growth of the light saber from Star Wars, (c) The laser beam emitted in a smoke and (d) The searchlight beam emitted in a smoke from demonstration 5.1.

Demonstration 5.1: The speed of laser light

The set-up experiment: The video clip about the light saber from star wars, which light travel slowly, was shown. Then we turned on the laser pointer and the searchlight in the smoke to present the real situation and to compare with the video.

The results of the experiment: Students could see that both laser beam and light beam emitted from a searchlight travel with very high speed unlike seeing in the movie. It could not conclude that which one traveled faster by observing with bare eyes.

Demonstration 5.2: The speed of laser light

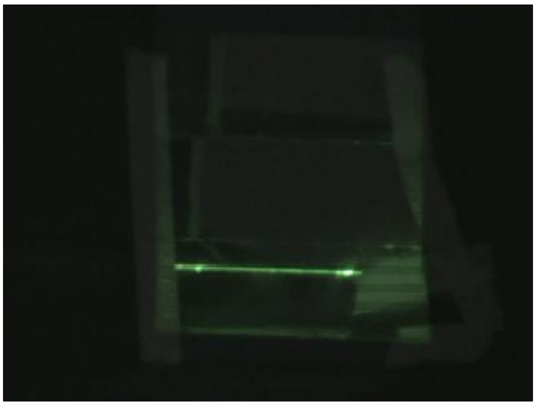
The set-up experiment: Laser was hidden in one side of the water tank. After that the laser was turned on suddenly so that students could see the laser beam in the water. Students then were asked to predict which side that the laser was hidden.

The results of the experiment: Students could see that laser beam traveled with very high speed. It could not conclude which side that the laser was placed by observing with bare eyes. These were the engagement to the students to concern about the speed of light. Now they would believe that light traveled with very high speed. The next step we opened the video about the measurement the speed of light and laser which showed that light from both sources had the same speed. Why didn't we show the real experiments about measuring the speed of light to students? The reason was about the complication of the experiment, students must have some advanced knowledge to understand it.

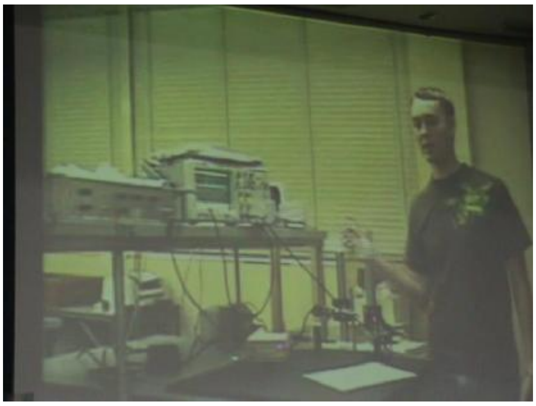
Demonstration 6.1: The monochromaticity

The set-up experiment: White light, Green light emitted from LED and green laser light were emitted through the prism. The students would observe the refracted light on the scene and compare about the different between these three kinds of light.

The results of the experiment: Students could see that the white light would disperse to be colorized as rainbow. Other two green lights were observed unchanged.



(a) **(b)**



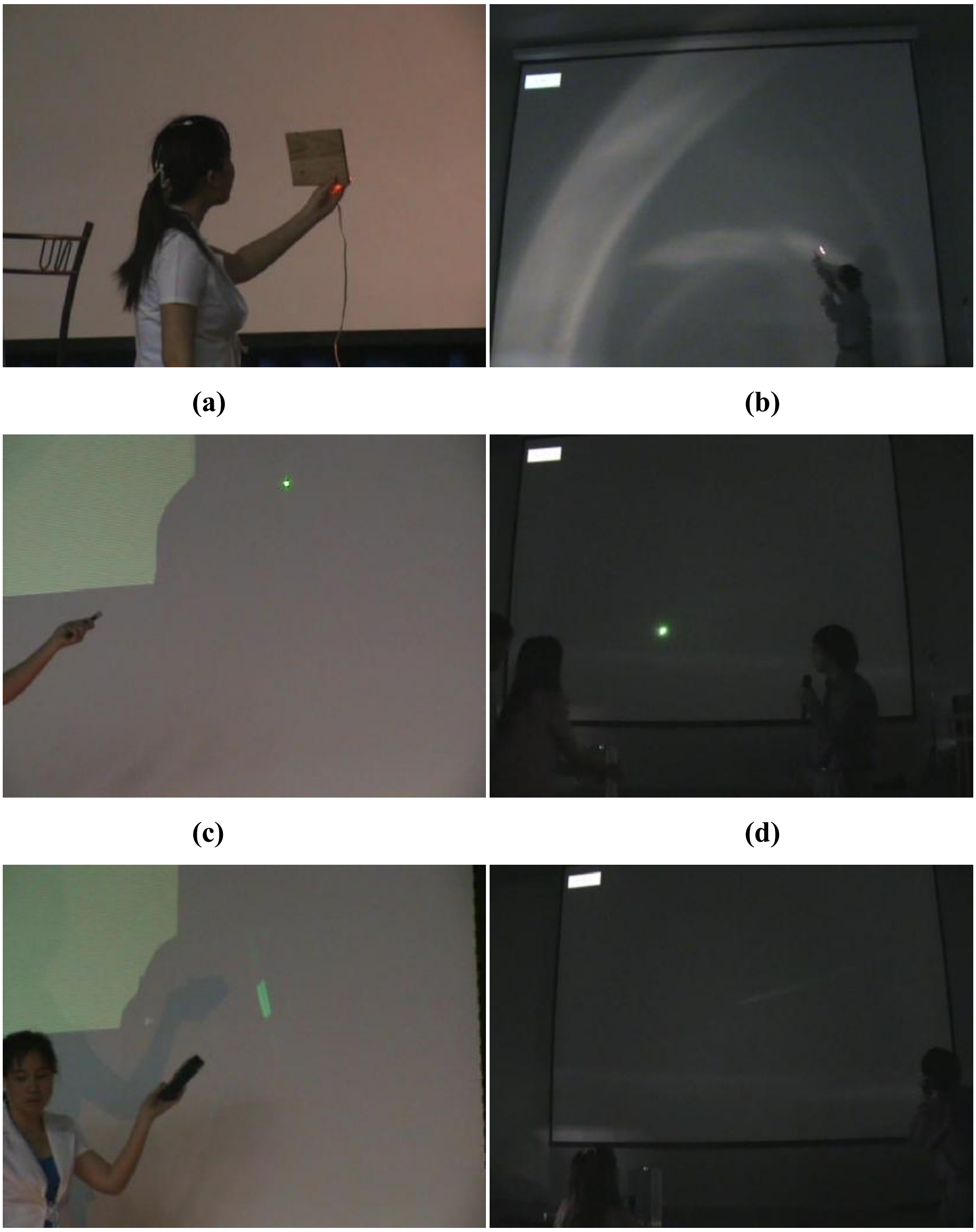
(c)

Figure 3.17 (a) Setup of the demonstration 5.2, (b) The observed laser beam in the water tank, (c) The movie presents the measurement of the speed of light.

Demonstration 6.2: The monochromaticity

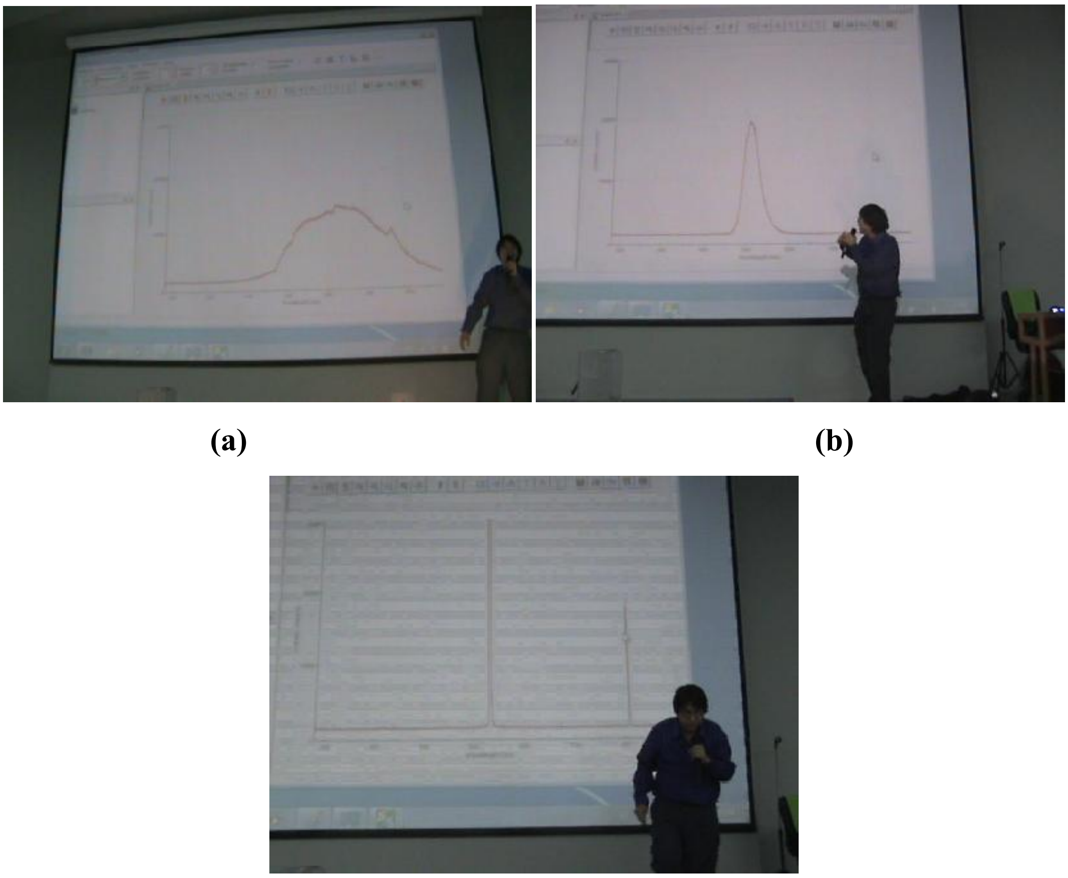
The set-up experiment: White light, Green light emitted from LED and green laser light were emitted through the spectrometer. The students would observe the emission spectrum of these three light sources and compare about the different spectral width between these three kinds of light.

The results of the experiment: Students could see that the white light had the widest spectrum range that about 300-800 nm. The Green light emitted from LED had the spectrum range about 450-550 nm. The green laser had the narrowest spectrum range about 530-540 nm. The light with narrow emission spectrum like that of the laser is called monochromatic light.



(a) (b) (c) (d) (e) (f)

Figure 3.18 The results from Demonstration 6.1 (a), (c) and (e) show the observation of the light emitted from light bulb. Laser and LED incident on a screen respectively, (b), (d) and (f) show the observation of the light emitted from light bulb. Laser and LED propagate though the prism before incident on a screen respectively.



(a) (b)

(c)

Figure 3.19 Graph display the spectrum of (a) white light emitted from light bulb, (b) green light emitted from LED and (c) Green light emitted from laser from Demonstration 6.2.

3.3.4 Design student's work sheets and prediction sheets

Our instructional processes were designed base on Interactive Lecture Demonstration (ILD) that required students to predict the result of the demonstration before showing the real demonstration. The prediction sheets were created for each demonstration. There are three parts of prediction sheet 1) The descriptions of a question which help student to understand the demonstration and know what they should concentrate on. 2) The individual prediction space. 3) The space for the prediction after discussion with their peer. The example of the prediction sheet is shown in figure 3.20. The whole of the prediction sheets are shown in Appendix C.

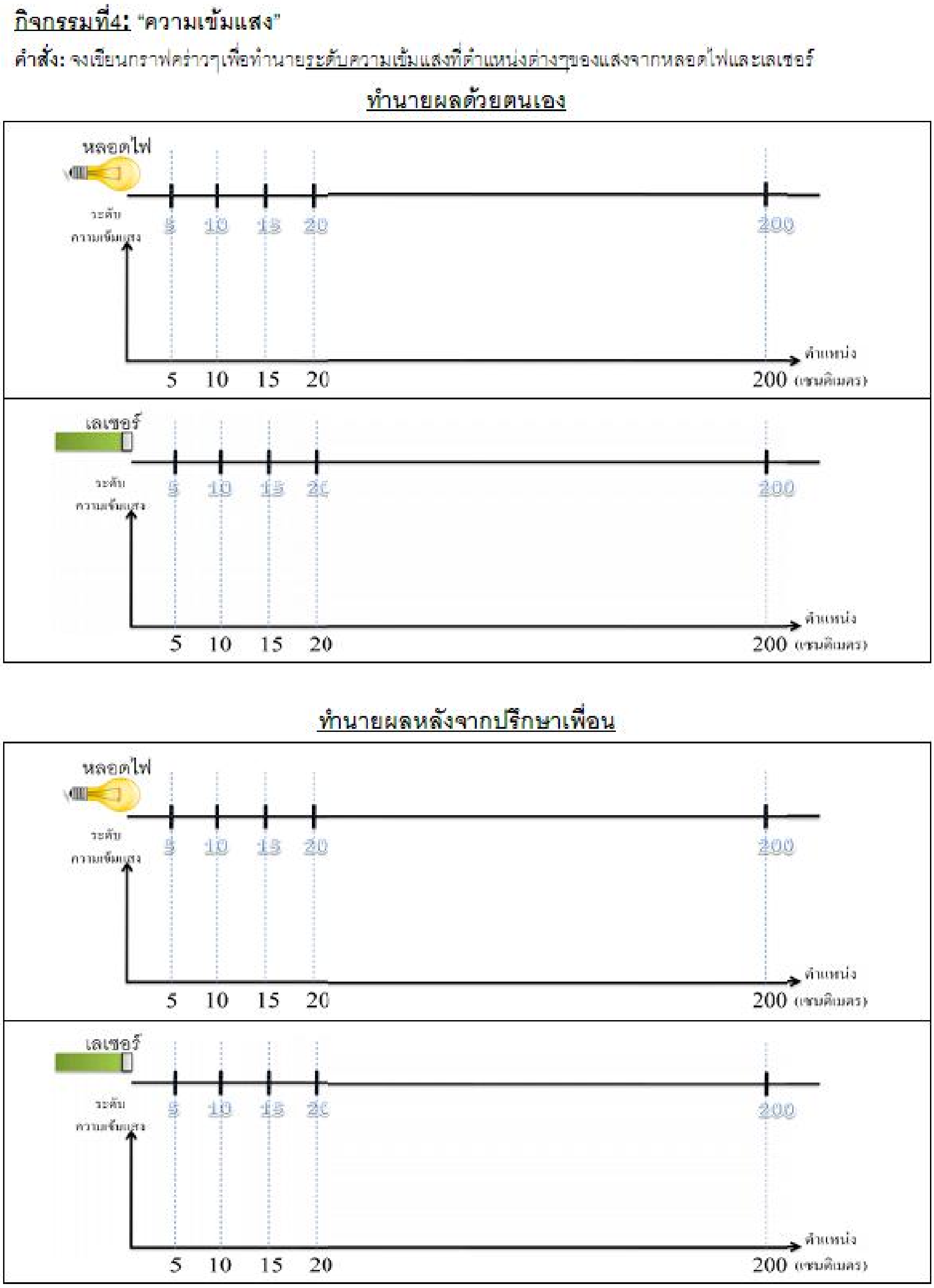


Figure 3.20 The prediction sheet of the demonstration 4.

We would present the results of all demonstrations after the step of prediction. To help the students recording the answer, the worksheets were created and distributed to them. The worksheet contained the path of recoding results and conclusions as shown in Figure 3.23. The complete worksheets are shown in Appendix D.

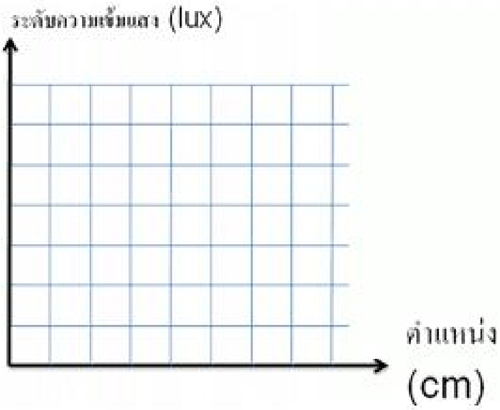
คำสั่ง: จงเปรียบเทียบความเข้มแสงของ**หลอดไฟ**และ**เลเซอร์**ที่ตำแหน่งต่างๆ

บันทึกผลการทดลอง:

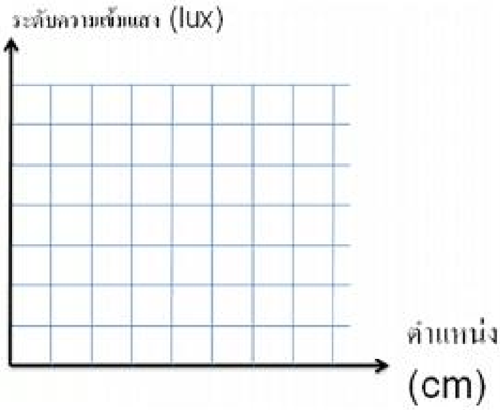
ที่ตำแหน่ง (เซนติเมตร)	ค่าความเข้มแสง (lux)	
	หลอดไฟ	เลเซอร์
5		
10		
15		
20		
150		
200		

จากตารางผลการทดลอง *จงเขียนกราฟความสัมพันธ์ระหว่างระดับความเข้มแสงและตำแหน่ง*

กราฟของหลอดไฟ



กราฟของเลเซอร์



สรุปผลการทดลอง

Figure 3.21 The worksheet of the demonstration 4.

3.3.5 Develop the assessment instruments: The Laser Beam Conceptual Evaluation (LBCE)

The conceptual test was developed from the results of the open-ended questions. It's called Laser Beam Conceptual Evaluation (LBCE). It consisted of 13 multiple choice questions. All questions were used as a pre-test and post-test. The LBCE in both Thai and English version are shown in Appendix E and f, respectively.

To constructing a test the researcher needs to undertake an item analysis to clarify the item validity, the item discrimination, the item difficulty and the item reliability of each item of the test.

3.3.5.1 Item Validity

Each item was measured for content validity by using the Rovinelli and Hambleton (1977) formula called the Index of the Item-Objective Congruence (IOC index) (Rovinelli & Hambleton, 1977). The IOC index is computed using the following equation;

$$IOC_k = \frac{\Sigma R}{N}$$

Where, IOC_k is the index of the Item-Objective Congruence of item *k*, ΣR is the total score of item *k* from the content experts and N is the number of content experts.

3.3.5.2 Item difficulty index

The item difficulty index of the test can be calculated using the following formula:

$$P = \frac{N_{correct}}{N_{total}}$$

Where, $N_{correct}$ is the number of students who answered the item correctly, N_{total} is the number of students who attempted the items. The item difficulty index is a measure of the difficulty of the constructing test. The higher P value is the higher percentage of students giving the correct answer. If P is zero, it means no students answer the item correctly. An average difficulty index of all items is:

$$\overline{P} = \frac{1}{k}\sum_{i=0}^{k} P_i$$

Where, $\overline{P}$ is an average difficulty index of all items, P_i is difficulty index of each item and k = number of all items. The range of difficulty index is 0 to 1. The index becomes near zero if the test is difficult while becoming near 1 if the test is easy. The best value of the difficulty index is 0.4 to 0.6 that means the test is not easier or harder.

3.3.5.3 Item discrimination index

In constructing a test the researcher will need to undertake an item analysis to clarify the item discrimination and the item difficulty of each item of the test. Item discrimination refers to the potential of the item in question to be answered correctly by those students who have a lot of the particular quality that the item is designed to measure and to be answered incorrectly by those students who have less of particular quality that the same item is designed to measure. An item with high discrimination will enable the researcher to see a potentially wide variety of scores on the items. An item with low discrimination will show scores on that item poorly differentiated (Yeo & Zadnik, 2001). For each item we compute the following:

$$D = \frac{N_H(top27\%) - N_L(buttom27\%)}{N * 27/100}$$

Where N_H is the number of *correct scores* from the high scoring groups, N_L is the number of *correct scores* from the high scoring groups and N is the half of the summation between number of student in both group. The average discrimination index ($\overline{D}$) of all items can be calculated from:

$$\overline{D} = \frac{1}{k}\sum_{i=1}^{k} D_i$$

Where k is the number of all items. The range of the item discrimination index is possibly from -1.0 to 1.0. The minus discrimination index indicates that the item measure something that out of the objective of the test. The higher value of item discrimination index indicates that the test can differentiate novice students from expert students. In general, the value should greater than 0.3.

3.3.5.4 Kuder-Richardson's formula 20 test Reliability index (KR-20)

The KR-20 is a method for the reliability calculations. The number shows how consistent participants' responses are among the questions on the test. This calculates an index based on the number of items, the proportion of the responses to an item that are correct, the proportion that are incorrect, and the variance of the two (Horst, 1949; Tucker, 1949). The formula of KR-20 can be stated as:

$$KR-20=\left(\frac{k}{k-1}\right)\left(1-\frac{\sum pq}{s^2}\right)$$

Where k is number of items on the test, p is the proportion of the responses to an item that are correct, q is the proportion of the responses to an item that are incorrect, s^2 is the variance of the test (Variance is the standard deviation squared.).

This index lies in the range of 0-1. The higher values indicate that there is a strong relationship between items on the test. The test is reliable if it has KR-20 greater than 0.70 (Grier, 1975).

3.4 Summary

This chapter was discussed about the details of this research in detail. Firstly, the basic concepts of laser were identified from the standard curriculum of national education Buddhist Era 2544. Then we created the open-ended questions to explore students' understanding of such concepts. After that the instructional process, teaching tools and the assessment instruments were designed.

Freier, G. D., & Anderson, F. J. (1972). *A demonstration handbook for physics*.

Grier, J. B. (1975). The number of alternatives for optimum test reliability. *Journal of Educational Measurement, 12*(2), 109-112.

Horst, P. (1949). A generalized expression for the reliability of measures. *Psychometrika, 14*(1), 21-31.

McDermott, L. C., Shaffer, P. S., Rosenquist, M. L., & Group, U. o. W. P. E. (1996). *Physics by inquiry: an introduction to physics and the physical sciences*: J. Wiley.

McGraw-Hill. (2004). *Glencoe Science: Waves, Sound, and Light, Student Edition*: Glencoe/McGraw-Hill.

Sokoloff, D. R., Laws, P. W., & Thornton, R. K. (2004). *RealTime Physics, Active Learning Laboratories Module 4: Light and Optics*: John Wiley & Sons.

Tucker, L. R. (1949). A note on the estimation of test reliability by the Kuder-Richardson formula (20). *Psychometrika, 14*(2), 117-119.

Yeo, S., & Zadnik, M. (2001). Introductory thermal concept evaluation. *The Physics Teacher, 39*, 496-503.

CHAPTER IV
RESULTS AND DISCUSSIONS

The results and discussions chapter addressed what we have found after using the designed teaching module with Thai freshmen students, including the benefits to the instructions. We presented the results together with the discussions of the collected data. In addition, students' understanding of the concepts and students' satisfaction of the module are reported.

4.1. Interpreting students' pre-conceptions from open-ended test

We decided to analyze the students' responding following the properties of the laser beam that is directionality, beam divergence, intensity, speed, monochromaticity and the simple application that is light source selection. The 13 items open ended test, was applied to 271 Thai freshmen science students in academic year 2010. The details were shown in Chapter 3. The categorization method and the results are presented as follows.

4.1.1 Categorization method

According to our test, most questions were designed to ask the students to provide the answer and supporting explanations. For obvious understanding and analyzing students' responses, they were categorized into different levels of understanding. The classification criteria of the students' responses were adapted from the five-criteria that appeared the following references (Calik & Ayas, 2005; Costu, 2005; GÖNEN & KOCAKAYA, 2010; Ozmen, 2008; Tanahoung, Chitaree, & Soankwan, 2010). For each question, the categorization method is start with grouping students who provided the correct answer then group the same explanation together so we would get the responses in Correct answer, Correct explanation (CCl, l = 1, 2, 3,…) and the correct answer and incorrect explanations with some scientific knowledge would be group in Correct answer, Incorrect explanation (CIm, m = 1, 2, 3,…) categories. Then the irrelevant responses that are the answers with haphazard explanations and the answer without explanation are group as No Understanding (NU) category while the answer sheets without any responses were group as No Response (NR) categories. Finally, others students' responses were group by both answer and explanations that contain the scientific knowledge, so we would get the Incorrect Answer (IAn, n = 1, 2, 3,…) categories. The criteria of classification were concluded in Table 4.1. The above criteria were used with questions that asked students providing both answer and explanation. The students' responses from others question that asked students providing only answer were grouped by using the kinds of the answer.

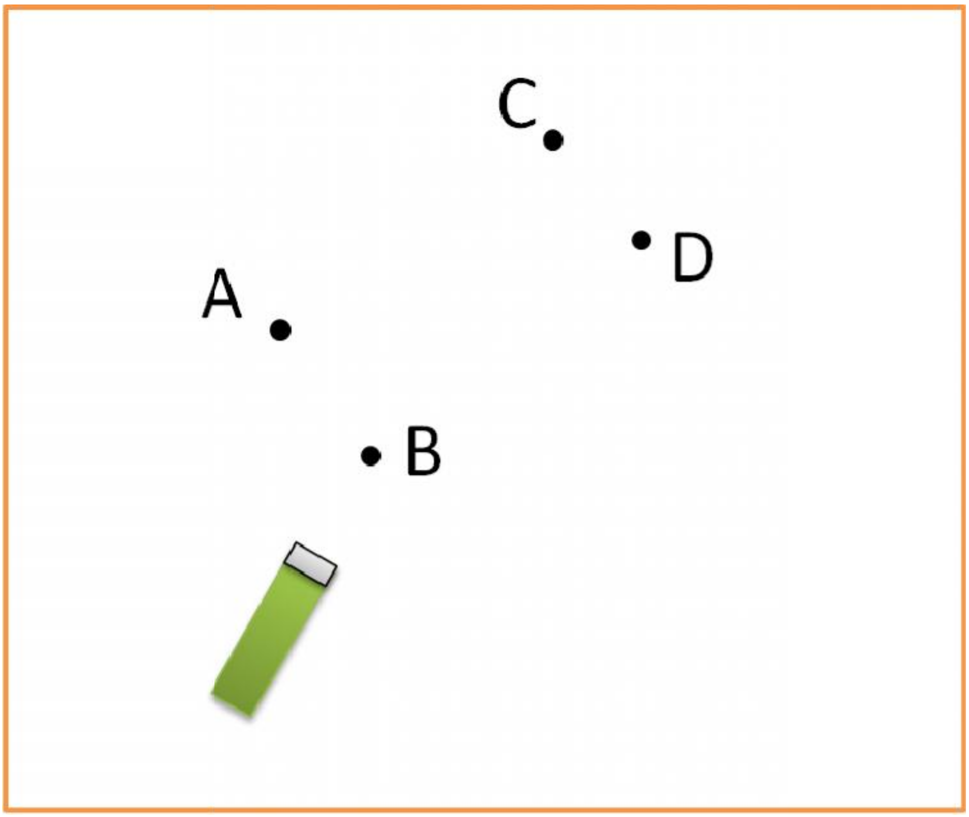
Table 4.1 The classification criteria of student responses to the open-ended questions

Understanding's level	**The criteria of classification**
• Correct answer, Correct explanation (CCl, l = 1, 2, 3,…)	Response that includes all acceptable scientific answers and explanations. l is the integer to show the model number of the correct answer and explanation.
• Correct answer, Incorrect explanation (CIm, m = 1, 2, 3,…)	Response that contains the correct answer and incorrect, illogical or no explanations. m is the integer to show the model number of the incorrect explanation that relate to scientific knowledge.
• Incorrect Answer (IAn, n = 1, 2, 3,…)	Responses that contains incorrect answer. n is the integer to show the model number of the incorrect answer with interesting explanations that relate to scientific knowledge.
• No Understanding (NU)	Irrelevant response, Answer which has no explanation.
• No Response (NR)	No answer.

4.1.2 Analysis of students' responses in Directionality

The generally well-known property of laser is the directionality which is different between laser light and normal light. The directionality was asked in Question 1 as follows.

<u>Question 1:</u> The laser is placed as shown in the picture and then the switch is turned on. Which point(s)can the laser light propagate through? Explain your answer.



The question asked about the direction that the laser beam will propagate to. The student who will answer this question correctly should understand the following points:

- Laser beam travels in a specific direction,
- Laser beam propagates through any positions that lie in its way and,
- The directionality is mainly influenced by the optical resonators of laser.

The correct answer is that laser beam will propagate thought point B and point C because it has the directionality. Laser beam will propagate though the specific direction. It will propagate thought every point that lies in this direction. Table 4.2

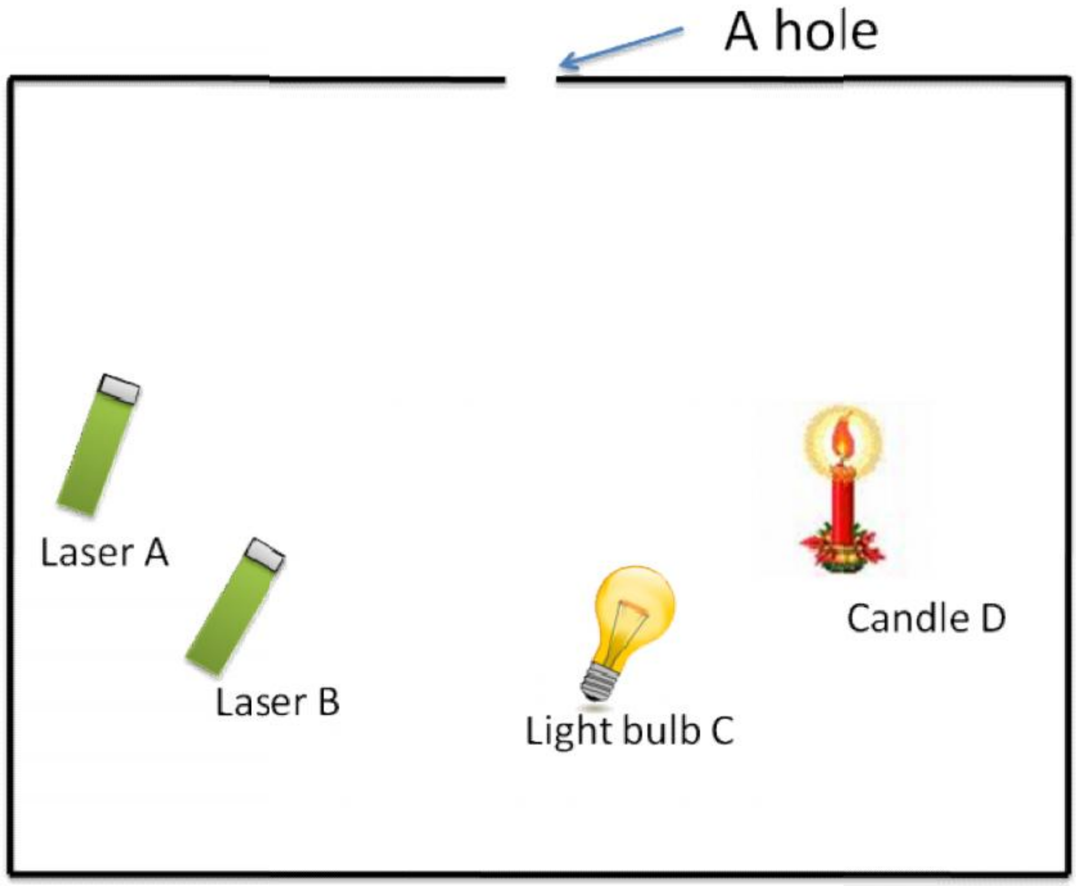
shows the category of percentage of students' answers and explanations to Question 1. The results were found that 55% (category CC) of students could give responses both answer and reason. The light emitted from the laser does not propagate to other points except points B and C because generally the laser bean does not spread out. Moreover, 20% (categories CI1 category) of the students gave a correct answer but failed to express proper explanation. Lasers emit light which is not only travel in a straight path but also travel to the specific direction. Consider other kinds of light source such as light bulb, it emits light that has a trajectory in a straight path but all of the emitted lights do not travel to a specific direction. Students in IA1 category thought that at every points had objects lay on that place so laser cannot pass to other points behind point B. IA2 student gave an explanation about the compelling of laser beam that is laser beam trajectory is compelled to be a straight line so laser light does not spread out. In fact, the laser components- the optical resonators which consist of two mirrors, placed on the front and the back of laser, involving in the directionality of laser beam. During emission process inside the laser medium, light is emitted in all direction. Lights that are radiated parallel to the axial of the laser medium will reflect back and forth between the optical resonators causing a laser beam, other lights are loss. According to the explanation above, the laser structure seems to influence the light emission from the laser to travel in a specific direction. For IA3 explanations, he give an explanation about refraction, he had an idea about the object placement as IA1 students, the different view was some light would travel forward to C and other light would refract from the object at B then the refracted light will travel to A and D. The data above show that most students (about 75%) were familiar with the directionality of laser but some students needed to improve their knowledge in this concept. The directionality of laser is a common property that can be obviously observed. For example a portable green or red laser can be attaching to the weapon as a tool for pointing the target due to the directional property of the laser beam. Many students may be familiar with this property but they cannot give a proper explanation. In addition, all students' responses did not associate to the optical resonators and the lasing process which are the main principle of the directionality property.

Table 4.2 Percentages of students who gave responses to Question 1 in each category

Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
CC	B&C	• Laser beam trajectory is in a straight path without spreading the beam. Laser has a property that it will emit light in a straight path. Laser will propagate to the direction that point B and C lie on.	150 (55%)
CI1	B&C	• Laser is light and light travels in a straight path.	53 (20%)
IA1	B	• Laser points to only point B. Laser travel in a straight path. It cannot pierce through an object.	16 (6%)
IA2	B	• Laser is a high energy light. Its trajectory is compelled to be a straight line so laser light does not spread out.	1 (0%)
IA3	All points	• Laser propagates through B and C because it trajectory is in a straight path. It travel though A and D because of the refraction of the beam.	1 (0%)
NU		• -	48 (18%)
NR		• -	2 (1%)

CC: Correct answer, correct explanation
CI: Correct answer, Incorrect reason
IA: Incorrect Answer
NU: No Understanding
NR: No Response

<u>Question 2:</u> **Laser A, Laser B, Light bulb C and candle D are placed in the dark room that has a hole on one side of the wall as shown in the picture below. The wall of the room is a non-reflected wall. When we turn on all light source and kindle the candle, Light emitted from which light sources can propagate through the outside of the room. Explain your answer.**



The question asked about the direction that the laser beam will propagate to. The student who will answer this question correctly should understand the following points:

- Laser beam travels in a specific direction,
- Light bulb and candle radiate light around themselves.

The correct answer is laser B, Light bulb C and Candle D. Laser B was aligned to point to the hole. When it is turned on the beam will propagate thought the hole directly because it has the directionality. Light bulb C and Candle D can emit light to all direction so a part of their emitted light can propagate through this hole.

The results were found that 54% (category CC) of students could give a correct answer with a reasonable explanation. They understood about the direction of the emitted light from all light sources. 5% (categories CI1) of the students gave a correct answer without proper explanations. Students in these categories did not provide the explanations of direction of the emitted light from Light bulb C and Candle D. They paid their attention to the occurring phenomena when light pass through the hole as the diffraction and interference. 6% (IA1 category) of the students had a correct understanding about the direction of the emitted light from all light sources but they believed that Candle D emitted light with low intensity so its emitted light cannot propagate through the outside of the room. This is the common believe of many people about the low power light source. In general, human can see a candle light about 1.5 kilometers away with their bare eyes. It means that light emitted from a candle can travel very far. This is much larger scale than the size of the general room in our daily life. So light emitted from the Light bulb C and Candle D can be detected outside the room. 6% (IA2 category) of the students had a correct understanding about the direction of the emitted light from laser but they had no idea of the direction of the emitted light from Light bulb C and Candle D. Students in IA3 category did not understand about the non-reflecting wall. Their idea was that light can reflect from every surface. The category of percentage of students' answers and explanations to Question 2 are summarized in Table 4.3.

Table 4.3 Percentages of students who gave responses to Question 2 in each category

Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
CC	B&C&D	• Laser B travel in a straight path, C & D radiate light in all direction.	147 (54%)
CI1	B&C&D	• Laser B travels in a straight path, Light from C & D diffract or interfere.	14 (5%)

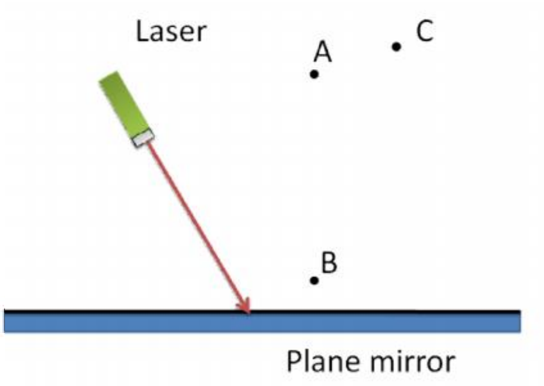
Table 4.3 Percentages of students who gave responses to Question 2 in each category (continue)

Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
IA1	B&C	• Laser B travel in a straight path, Light bulb C and Candle D radiate light in all direction. But light radiate from D has low intensity.	16 (6%)
IA2	B	• Laser B points directly to the hole	15 (6%)
IA3	All	• The emitted light from light sources that are put in the dark room can propagate through the outside of the room.	2 (1%)
NU	-	-	77 (28%)
NR	-	-	0 (%)

CC: Correct answer, correct explanation NU: No Understanding
CI: Correct answer, Incorrect reason NR: No Response
IA: Incorrect Answer

The data from Table 4.2 and Table 4.3 show that more than 50 % of students have good understanding and about 40 % of them need more learning in the directionality property of laser. They need learning in advance in the lasing process and laser components to understand the cause of the directionality.

Question 7: Laser is placed as shown in the picture below. Which point(s) is the reflected light will propagate through?



This question asked about the direction that the reflected laser beam will propagate to. The student who will answer this question correctly should understand the following points:

- Laser beam travels in a specific direction,
- Laser beam reflects correspond to the law of reflection,

The correct answer is that the laser beam can propagate thought point C due to the law of reflection which states that the incident angle equal to the reflected angle. The results were found that 62% (category CC) of students could give a correct answer with a reasonable explanation. They understood the law of reflection so they could investigate the reflected beam by applying this law. 3% (CI1 and CI2 category) of the students could investigate the direction of the reflected ray and the position which this ray passing through. CI1 students had a trouble about the definition of the law of reflection while CI2 students' aspect about laser is interesting. They thought that laser beam consists of particle which is an advance idea in modern physics. Students in IA1 category (7%) had the same explanation as CI1 but they need more carefully measurement of the angle because the angle between the incident beam and the line from the incident point pass through point B is greater than 90 degree. Student from IA2 and IA4 categories had the same idea. They thought that the trajectory of the reflected light depend on the energy of laser. Although, high energy lasers and low energy lasers are incident to the plane mirror with the same angle of incidence, they will reflect with different angle of reflection. For IA3 category, students used the idea of scattering that always occur in diffuse reflections to answer this question. In general, the reflection of light from the surface coated plane mirror which normally learn in the General physics classrooms is a specula reflection that there is no light scattering during reflection. The category of percentage of students' answers and explanations to Question 7 are summarized in Table 4.4.

Table 4.4 Percentages of students who gave responses to Question 7 in each category

Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
CC	C	• Laser beam does not spread out and incident angle = reflected angle	168 (62%)
CI1	C	• Point C perpendicular to the incident ray.	4 (2%)
CI2	C	• Laser beam is a beam of particles causing of Incident angle = reflected angle	3 (1%)
IA1	B	• Reflected ray perpendicular to the incident ray.	20 (7%)
IA2	All points possible	• Depend on the energy of laser.	2 (1%)
IA3	All points possible	• Light can scatter.	1 (0%)
IA4	A	• Laser light has high intensity so it reflects with steep angle.	1 (0%)
NU	-	-	58 (22%)
NR	-	-	14 (5%)

CC: Correct answer, correct explanation NU: No Understanding

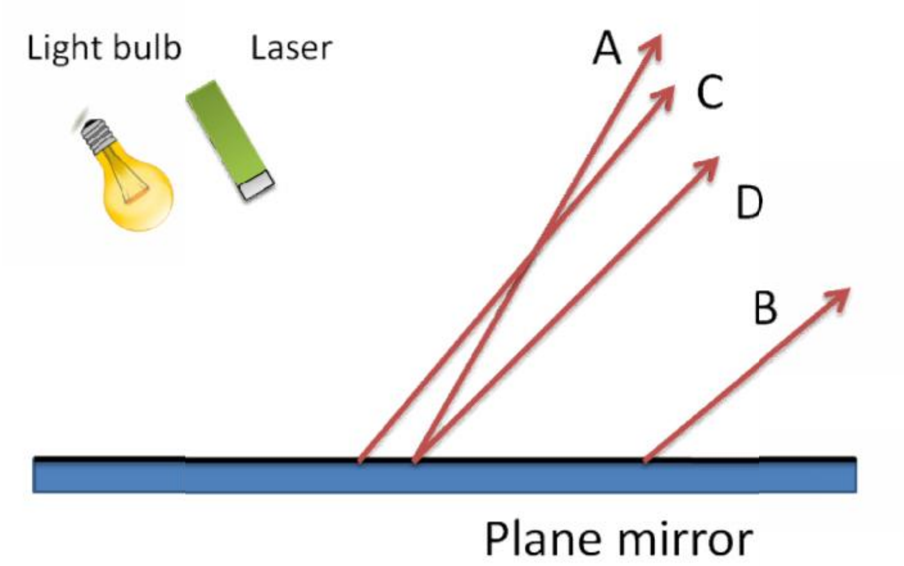
CI: Correct answer, Incorrect reason NR: No Response

IA: Incorrect Answer

Question 8: The light bulb and laser are placed as shown in the picture below. When we turn on both light sources, we find the reflected rays A, B, C and D.

8.1 Which reflected ray(s) come from the light bulb?

8.2 Which reflected ray(s) come from the laser?



Question 8.1 asked students to investigate the incident light ray that cause the reflected ray that corresponds to the law of reflection. The student who will answer this question correctly should understand the following points:

- Laser radiates light in a specific direction so it must get only 1 incident ray.
- Laser beam reflects corresponding to the law of reflection.
- If we know the angle of reflection we can find the incident ray by finding the incident angle.

The correct answer is ray A is emitted from laser due to the law of reflection which states that the incident angle equal to the reflected angle. The results showed that 50 % (category 1) of students answered correctly. They understood the law of reflection so they could investigate the incident ray beam by applying this law. Consider category 2, we found that many students answer ray D. Students in this group need a careful measurement of the angle to investigate the correct answer. The 7% of students (category 3) answered both ray A and ray D. This would be a correct answer for the diffuse reflection. The category of students' answers and explanations to Question 8.1 are summarized in Table 4.5.

Table 4.5 Percentages of students who gave responses to Question 8.1 in each category

Category	Answer	Number of students (271)
1	A	136 (50%)
2	D	87 (32%)
3	A&D	18 (7%)
4	Etc. (C, B, A&B&C, all points, none …)	25 (9%)
No response	-	5 (2%)

Question 8.2 asked students to investigate the incident light ray that cause the reflected ray that corresponds to the law of reflection. The student who will answer this question correctly should understand the following points:

- Light bulb radiates light in all direction so it is possible to gets more than 1 incident ray.
- Light reflects corresponding to the law of reflection,
- If we know the angle of reflection we can find the incident ray by finding the incident angle.

The correct answer is ray B, ray C and ray D are emitted from light bulb due to the law of reflection which states that the incident angle equal to the reflected angle. The results were found that only 13 % (category 1) of students answered correctly. They understood in law of reflection so they could investigate the incident ray beam by applying this law. Consider category 2, we found that many students answer all ray emitted from light bulb. They might think that the light bulb emit amount of light ray to all direction around so all ray in the instruction come from this light bulb. Considering the next category, 18% (category 3) of students answer ray C which is the most obvious answer. Students in this group need a careful thinking about other rays. To help students in both groups reach a correct answer, they need to be reminded about the careful measurement of the reflected angle of ray A, the drawing of the incident angle that has the same magnitude as reflected angle and the sketch of the incident ray to find the correct light source. The category of students' answers and explanations to Question 8.2 are summarized in Table 4.6.

Table 4.6 Percentages of students who gave responses to Question 8.2 in each category

Category	Answer	Number of students (271)
1	B&C&D	34 (13%)
2	All	125 (46%)
3	C	49 (18%)
4	Etc. (A&C&D, A&B&C, D, …)	58 (21%)
No response	-	5 (2%)

4.1.3 Analysis of students' responses in Divergence of the Laser Beam

General lasers emit a narrow laser beam which spreads out in a small angle. This property of laser clearly distinguishes it from other light sources. It is the key feature used in many applications. Laser pointing is one application which needs a laser with a small divergence angle to point precisely at an object. The question about the divergence of laser beam is in the Question 3 presented as follows.

Question 3: The laser light is emitted from the top of mountain A to the top of mountain B which is 10 kilometers apart. Sketch the picture to show the shape of the laser beam propagating to mountain B and explain your answer.

The question asks about the shape of the emitted laser beam. Normally, the students who will answer this question correctly should understand the following points:

- The laser beam size noticeably changes when the distance largely changes,
- Laser beam diverges with a small constant angle and,
- Laser beam divergence is caused by the diffraction from the resonator aperture.

The correct answer is laser beam has a little spreading out due to (1) the diffraction of light from aperture and (2) The optical resonators that are not both plane mirrors, the curved mirrors were used in some laser system to help in advance adjustment of laser parameter. The best answer from students' responses which is close to the correct answer is shown in category CC in table 4.7. There is only 2% of student in this category. They gave only the explanations of the laser beam shape. 3% (CI1 category) of students believed that light emitted from laser would propagate in a straight trajectory. The divergence of the laser beam is caused from the refraction from some molecules in the air. For the incorrect answers in IA category, 70% (IA1-IA5 categories) of the students drew a straight line or beam to represent the laser beam that mean students believed that laser beam will propagate without changing of its shape. Their main reason (IA1 category) is that if laser still propagates in the same medium, the refraction or diffraction does not occur, the laser beam remains propagating in a straight path without changing of the beam shape. 1 & (IA2 category) thought that laser beam has high energy so it can propagate for far distance without diverging. The interesting category is IA3 which is only one category those students gave an explanation referring to the laser structure. They believed that the laser light was constrained to emit only the light propagating in a straight path. In general laser system, the laser beam is constrained to diverge due to the 2 factors mentioned above. We cannot avoid the divergence of laser beam. The IA4 and IA5 students gave an explanation quite similar to IA1 students. IA5 added some explanations about the intensity in their responses. It implied that students had concept about the relationship between intensity and distance. Furthermore, the difference between the sketched answer in IA1-IA3 categories and IA4-5 is implied that IA1-IA3 students did not paid attention to the size of a laser beam while IA4-IA5 students believed that laser beam had a measureable beam size. In addition, 1% (IA6 category) of the students sketched a decreasing laser beam size in their answers. It is interesting in terms of non-uniform intensity along the cross-section of laser beam. If this light enters through the high light absorption medium the changing of the beam size might occur. For IA7 students, they believed that laser emit light in all direction from the aperture but most of the emitted light travelled along the axial distance. All students' responses are displayed in Table 4.7.

Table 4.7 Percentages of students who gave responses to Question 3 in each category

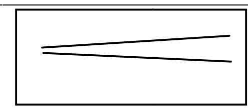
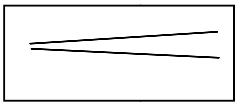
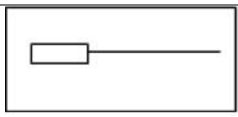
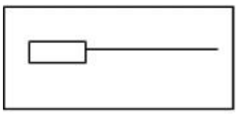
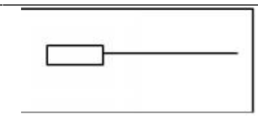
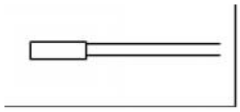
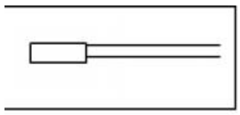
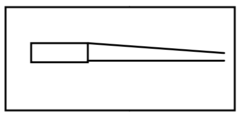
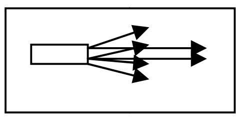
Category	Answer model	Thai to English translation of students' Explanations	Number of students (271)
CC		• Laser beam will diverge a little bit	5 (2%)
CI1		• Light trajectory is in a straight path. When it travels in the air it may refract by the effecting of some molecules in the air causing a spreading of the laser beam.	8 (3%)
IA1		• Light trajectory is in a straight path. If it travels in the same medium, light does not refract or diffract.	149 (55%)
IA2		• Laser beam has high energy, it does not diffract of interfere.	4 (1%)

Table 4.7 Percentages of students who gave responses to Question 3 in each category (continue)

Category	Answer model	Thai to English translation of students' Explanations	Number of students (271)
IA3		• Light emitted from laser is forced to travel in a straight line without spreading. But its intensity will decrease.	2 (1%)
IA4		• Laser light is a straight beam shape because light trajectory is in a straight path.	18 (7%)
IA5		• Laser light is a straight beam shape. The intensity will decrease when travelling for far distance.	17 (6%)
IA6		• Some of light is absorbed causing decreasing of the beam shape.	3 (1%)
IA7		• Light emitted from the origin point in all direction.	2 (1%)
NU	-	-	47 (17%)
NR	-	-	16 (6%)

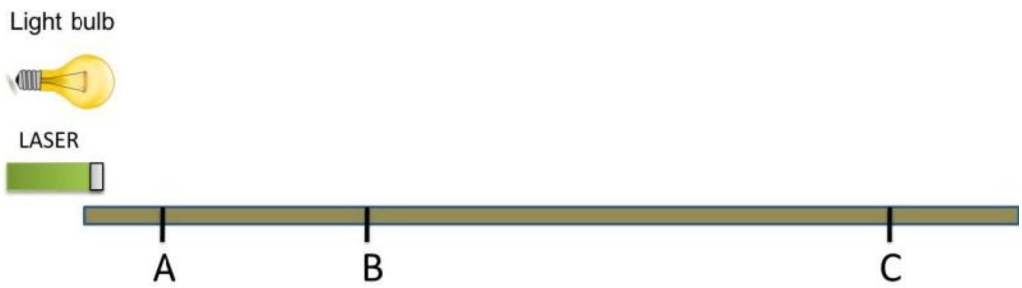
CC: Correct answer, correct explanation
CI: Correct answer, Incorrect reason
IA: Incorrect Answer
NU: No Understanding
NR: No Response

The results above show that many students lack of the idea about the beam divergence of laser. They should improve their understanding after they learn and understand both the diffraction of light and laser components.

4.1.4 Analysis of students' responses in Intensity

A number of students knew that the intensity of the general light will decrease along the axial distance from the light sources but many of them might not be familiar with the intensity of the laser light. This topic contains Question 4, 5 and 6 as follows.

Question 4: The laser and the light bulb is placed as shown in the picture



4.1 Compare the intensity of the light emitted from light bulb at points A, B and C?

4.2 When the laser and the light bulb are turned on, the intensity of the emitted light from both light sources at point A is equal. Compare the intensity of the laser beam at points B and C to that at point A?

4.3 When the laser and the light bulb are turned on, the intensity of the emitted light from both light sources at point A is equal. Compare the intensity of the laser beam and the intensity of the light emitted from light bulb at points B and C respectively?

Question 4.1 asks about the intensity of the light emitted from light bulb along the axial distance. The students who will give the correct answer should understand that:

- The intensity distribution of the light emitted from light bulb is not constant along the axial distance.
- The light intensity will decrease nonlinearly with the axial distance.

The correct answer is the light intensity at A > at B > at C. The results found that 78 % (category 1) of students answered correctly. It means that most students had knowledge about the relationship between the intensity of the emitted light and the distance. Consider 22% of students, who gave other answer, they required the more knowledge in this concept before learning in advance. All students' responses are summarized in Table 4.7.

Table 4.8 Percentages of students who gave responses to Question 4.1 in each category

Category	Answer	Number of students (271)
1	A > B > C	211 (78%)
2	C > B > A	5 (2%)
3	A = B = C	1 (0 %)
4	Etc. (B > A > C, A is the greatest,…)	2 (1%)
No understanding	-	50 (18%)
No response	-	2 (1%)

Question 4.2 asks about the intensity of the laser beam along the axial distance. The students who will give the correct answer should understand that:

- The intensity distribution of the laser beam is not constant along the axial distance.
- Laser intensity will decrease slower than the general light along the axial distance.

The correct answer is the light intensity at A > at B > at C. It was found that only 16% (category 1) of the students answered correctly. The intensity of laser light at other positions is less than that of position A due to the beam divergence. 73% of the students (category 2) believed that the intensity of the laser beam at positions A, B, and C are equal. Many students might be familiar with a bright laser spot at a distance. This might mislead students to conclude that laser intensity does not change with the distance. In addition, if the change in the distance is only a few meters, the intensity of laser light insignificantly decreases. The decrement of the intensity is very difficult to detect by bare human eyes. Moreover, some students (category 3) answered that the intensity of the laser beam at positions B and C are greater than that at position A. Students' answers in Question 4.2 are presented in Table 4.9.

Table 4.9 Percentages of students who gave responses to Question 4.2 in each category

Category	Answer	Number of students (271)
1	Less intensity than at position A	43 (16%)
2	Intensity at A, B, and C are equal	199 (73%)
3	Greater than intensity at position A	4 (4%)
No Understanding	-	25 (9%)

Question 4.3 asks about comparison of the intensity of the laser beam and light emitted from light bulb along the axial distance. The students who will give the correct answer should understand that:

- Laser intensity decreases with slower rate than the light emitted from light bulb along the axial distance.
- If the intensity of the emitted light from both light sources at point A is equal, the intensity of the laser beam at point B and C are greater than the intensity of the light emitted from light bulb at points B and C respectively.

The correct answer is the light intensity of light emitted from laser is greater than that from light bulb at both point B and point C. The results show that 76% (category 1) of the students answered correctly. This shows that most students had an ability to compare the intensity between two light sources. 6% of the students (category 2) believed that the intensity of the laser beam equal to light bulb at all points while 2% of the students (category 3) believed that the intensity of the laser beam lass than which of light bulb. Students' answers in Question 4.3 are presented in Table 4.10.

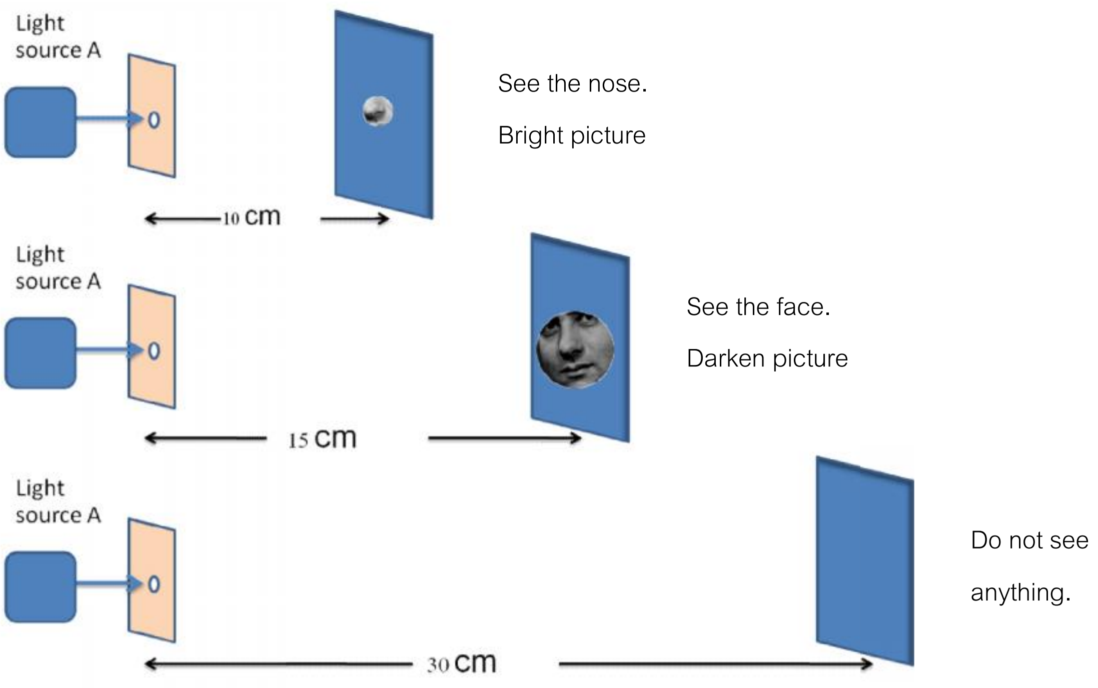
Table 4.10 Percentages of students who gave responses to Question 4.3 in each category

Category	Answer	Number of students (271)
1	Intensity of laser is greater	206 (76%)
2	Equal	15 (6%)
3	Intensity of laser is smaller	5 (2%)
No Understanding	-	44 (16%)
No response	-	1 (0%)

Table 4.10 Percentages of students who gave responses to Question 4.3 in each category (continue)

The results from question 4 show that for simple question that directly ask about the intensity of one light source, students could answer comfortably. For a more complicated question some students had confusion that display from the percentage of No Understanding category.

<u>Question 5:</u> Observe a picture in the dark room; a paper with a hole is placed in front of light source A as shown in the picture below. Then we carry the photograph to the distance 10 cm from the paper and watch the photograph. After that the distance is change to 15 and 30 cm respectively. The observation results are show in the picture. What kind of the light source A? Explain your answer.



Question 5 asks about the application of the intensity of the general light along the axial distance. The students who will give the correct answer should understand and apply their knowledge that:

- The intensity distribution of the general light is not constant along the axial distance.
- By changing of the distance the significant decreasing of the intensity can easily be identify with bare eyes so we will see the different picture when the distance be changed.

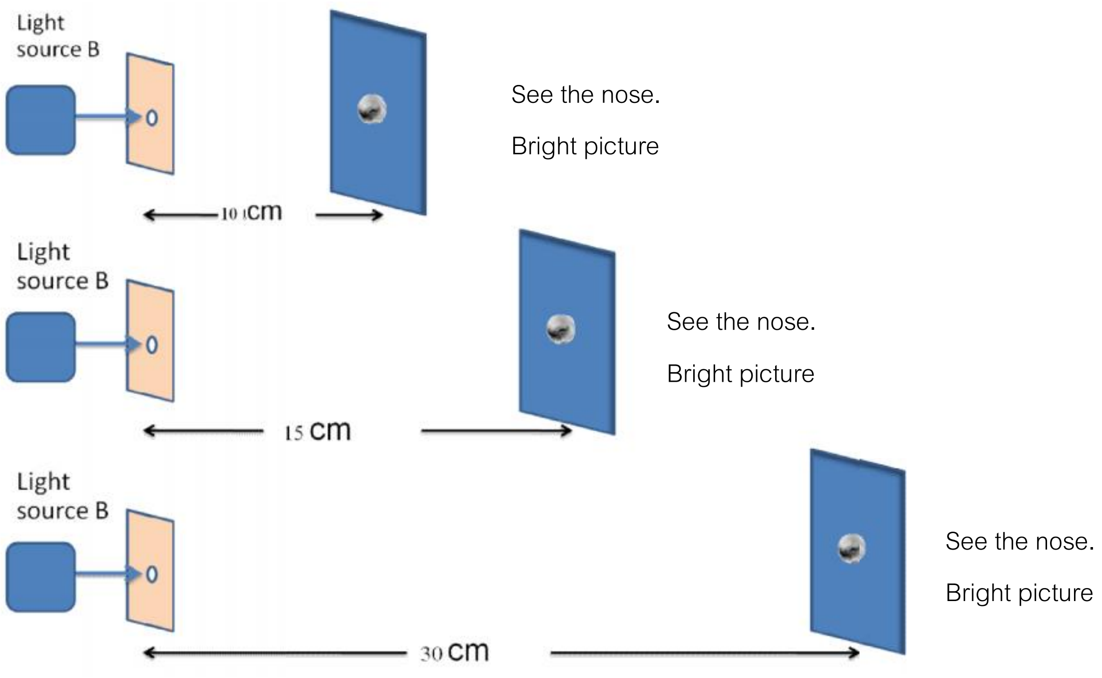
The correct answer is the light source should be a general light source such as candle nad light bulb because the intensity decreases rapidly via distance. The results showed that 57 % (CC category) of students answered correctly. Student had a concept about the relationship between the intensity via distance and they could apply to explain the situation. In this question the most important key is the intensity because most students would familiar with reading a book or watching a picture. If we could not read or watch clearly, we would move closely to the lamp. 1% (category IA1) of students thought that the light source should be a laser because light trajectory is in a straight path. They might know about the beam divergence if a laser but did not have an idea about the magnitude of the beam divergence and the beam size so they used a picture of high power searchlight to display the picture of laser. All students' responses in Question 5 are displayed in Table 4.11.

Table 4.11 Percentages of students who gave responses to Question 5 in each category

Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
CC	Candle, light bulb, projector	• The intensity decrease rapidly with respect to distance because the spreading of light. There is low light intensity at far point so we cannot see a picture.	155 (57%)
CI1	-	• -	0 (0%)
IA1	Laser	• Light trajectory is in a straight path.	2 (1%)
NU	-	-	91 (34%)
NR	-	-	23 (8%)

CC: Correct answer, correct explanation
CI: Correct answer, Incorrect reason
IA: Incorrect Answer
NU: No Understanding
NR: No Response

<u>**Question 6:**</u> **Observe a picture in the dark room; a paper with a hole is placed in front of light source B as shown in the picture below. Then we carry the photograph to the distance 10 cm from the paper and watch the photograph. After that the distance is change to 15 and 30 cm respectively. The observation results are show in the picture. What kind of the light source B? Explain your answer.**



Question 6 asks about the application of the intensity of the laser beam along the axial distance. The students who will give the correct answer should understand and apply their knowledge that:

- The intensity distribution of the laser beam is not constant along the axial distance.
- For small range of the distance the very small decreasing of the intensity cannot be distinguish with bare eyes so we will see the same picture at all distance.

The correct answer is the light source should be laser or high power light source because the intensity and the beam size do not significantly decrease in a short distance. The results showed that 44 % (CC category) of students answered correctly. They could relate the beam size (beam divergence) and the intensity to explain the situation. For CI1 students, they had the idea about the directionality of laser but they lacked of the explanation in the intensity. In real life, human is familiar with intensity more than the beam divergence. When we could not read or watch clearly, we would move closely to the lamp to increase the intensity. We had never adjusted the beam divergence for better reading or watching. CI3 students thought that laser light is focused to have a constant intensity. 1% (IA1 category) of students the suitable light source is parallel light generating light source. They thought that other kinds of light will spread out after passing through the hole except parallel light. All students' responses in Question 6 are displayed in Table 4.12.

Table 4.12 Percentages of students who gave responses to Question 6 in each category

Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
CC	Laser, high power search light	• Laser has high intensity. The beam size and intensity do not change.	118 (44%)
CI1	Laser	• Light does not spread and has trajectory in a straight path.(Don't mention about intensity)	51 (19%)
CI2	Laser	• Laser light cause from focus light to a small point,	2 (1%)
IA1	Parallel light emitted light source	• Parallel light does not spread out after propagate through the hole.	2 (1%)
NU	-	-	61 (23%)
NR	-	-	36 (12%)

CC: Correct answer, correct explanation NU: No Understanding
CI: Correct answer, Incorrect reason NR: No Response
IA: Incorrect Answer

According to the result above, most students understood the relationship between the intensity and distance of general light while they did not believe that the intensity of laser would decrease via distance. They needed more evidence to help them improve their understanding in this topic.

4.1.5 Analysis of students' responses in Speed of Laser Light

In general, most students are expected to be familiar with the speed of light. It is interesting to pose the question about the speed of laser light to investigate such students' idea. The question is showed as follows:

Question 9: Compare the speed of light emitted from a light bulb and the speed of light emitted from a laser when they both propagate in air. Explain your answer.

This question involves the comparison between speed of light emitted from a laser and a light bulb. The students who will give the correct answer should understand that:

- Laser light and light emitted from light bulb are electromagnetic wave and
- They propagate in air with the same speed.

The correct answer is both light has the same speed because they are electromagnetic wave and both of them propagate in the air. In other medium except air the speed of electromagnetic wave depends on their wavelength. It was found that 26% (CC category) of the students could give complete correct answer and correct explanation. Students in this group understood well about speed of electromagnetic wave that depends on the optical medium and wavelength of the considering wave. All light has the same speed in air but may be different in other media such as water, glass, etc. 28% (CI1 category) gave the reason that both lights emitted from the laser and the light bulb are electromagnetic wave propagating with speed of light, without mentioning about the medium. They needed reminding about the relationship between the refractive index and speed of electromagnetic wave for improving their understanding. CI2 students mentioned that light with the same frequency will propagate with the same speed. In the other word, lights with different frequency propagate with different speed. Astonishingly, 9% (categories IA1-IA4) of the students believed that the speed of light emitted from light bulb is less than the speed of light emitted from the laser. 4% (category IA1) of the students connected the speed of light to the intensity. They believed that light with high intensity propagates faster than one with low intensity. 2% (category IA2) of the students thought that the observer can see a laser light brighter than light emitted from a light bulb while propagating to a far distance because it arrives to the observation point later than the light emitted from the laser. Therefore, they concluded that the light emitted from light bulb has lower speed than the laser light does. 2% (category IA3) of the students believed that the laser light has higher frequency so it has greater speed. 1% (category IA4) of the students believed that light emitted from the laser is accelerated to gain its speed. IA5 students believed that light emitting from the laser propagates with activated electron's speed that is less than the speed of light. According to the results, it was found that frequency and intensity were dominant parameters that caused confusion about speed of light. These also showed that about 60% of students still confused about speed of light. All students' responses are presented in table 4.13.

Table 4.13 Percentages of students who gave responses to Question 9 in each category

Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
CC	Equal	• Both are the electromagnetic wave. They travel in air with the same speed.	73 (27%)
CI1	Equal	• Both are electromagnetic wave or light. They travel with the same speed of light.	76 (28%)
CI2	Equal	• Both are visible light with the same frequency so their speed is equal.	1 (0%)
IA1	Less	• Light from light bulb has less intensity than laser. Laser has higher energy.	12 (4%)
IA2	Less	• When the distance increases the light emitted from the light bulb will propagate slower until it evanesces, but the laser light still retains the same speed. (Relate the intensity to speed)	6 (2%)

Table 4.13 Percentages of students who gave responses to Question 9 in each category (continue)

Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
IA3	Less	• From $v \propto f$, light emitted from the laser has higher frequency than the normal light so the speed of the laser light is greater than the speed of the normal light	6 (2%)
IA4	Less	• Light emitted from the laser is accelerated so it has higher speed than the normal light.	4 (1%)
IA5	Greater	• Light emitted from the light bulb propagates with speed of light but laser light propagates at a speed equal to the activated electron.	1 (0%)
IA6	Greater	• The laser light has higher intensity thus it has a shorter wavelength so it has slower speed due to a shorter wavelength.	1 (0%)
IA7	Cannot specify	• Depends on the intensity and energy of the light source.	1 (0%)
NU	-	-	72 (27%)
NR	-	-	18 (7%)

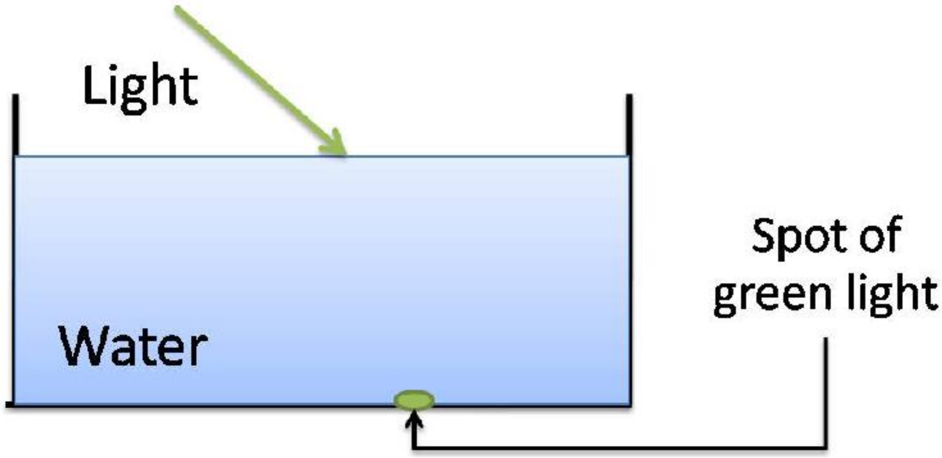
CC: Correct answer, correct explanation NU: No Understanding
CI: Correct answer, Incorrect reason NR: No Response
IA: Incorrect Answer

The results showed that most students knew that light and laser were electromagnetic wave so they had the same speed. But many of them did not have the complete idea. They lack of the idea about the effect of optical media to the speed of electromagnetic wave. Moreover, the results also showed that about 40% of students were confused about speed of light.

4.1.6 Analysis of students' responses in Monochromaticity

Laser light is usually called "monochromatic light". It has single frequency. For real laser, it does not radiate only one wavelength of light but the emission contains a smaller spectral width than the light emitted from other light sources. This property causes some phenomena that can obviously be seen such as diffraction and interference. The concepts in this topic were asked in Question 10 and 11 as follows.

Question 10: The light from unknown light source propagates from air through water in a tank as shown in the picture. The observer can see only the spot of green light at the bottom of the tank.



Is the unknown light source a laser? Explain your answer.

The question is mainly about the monochromaticity. The students who give correct answer to this question should understand that:

- Light refracts when propagating from air to water,
- Lights with different wavelengths will refract with different angles, and
- If a beam of light composes of variety of wavelengths passing through a dispersive medium the dispersion will occur.

There are two correct answers for this question. Firstly, the light source is laser. The refracted light does not disperse to be multiple color, laser light refract and produce a spot of green light at the bottom of the tank. There are 24% (CC1 category) of the students gave the answer this way. Students were familiar with this situation because the refraction of laser is generally shown on textbooks and internet. Secondly, the light source in the question possible laser or green light emitting light source. Both of them will refract without clearly observable of dispersion. Laser light and general light which have the same wavelength will refract with the same angle of refraction. There is 2% (CC2 category) of the students giving this answer. The CC2 students had good understanding in refraction property of light and could apply this concept to explain the situation that is not often occurring in daily life. The refraction of green light except laser is abbreviated. In case of those who gave correct answer and incorrect reason, the study showed that 10% of students presented their reasons that the light can refract so it is emitted from a laser. These students should mention about dispersion. In general, all light will refract when travel thought the different optical media but the dispersion does not occur for all of them, It occur for only light with large spectral width. Furthermore, some students (IA1 category) believed that the direction of a laser beam does not change when it propagate through a different medium. IA2 students thought that laser light must be only red color. Many students were familiar with only red color laser because they were usually appeared in daily life such as in presentation, in some toys etc. In the future, students will be familiar with other color of laser light such as green and blue that used in modern kinds of multimedia. Student responses to question 10 are presented in table 4.14.

Table 4.14 Percentages of students who gave responses to Question 10 in each category

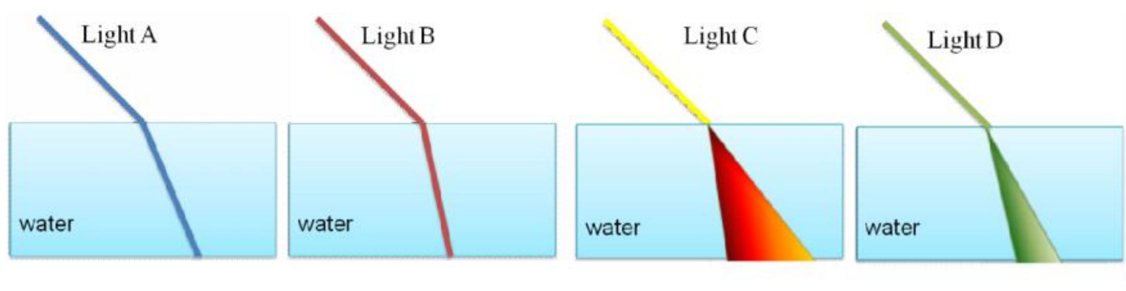
Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
CC1	Yes	• All refracted light does not spread out. It is in the same region of the spectrum band. This is one property of laser light.	65 (24%)

Table 4.14 Percentages of students who gave responses to Question 10 in each category (continue)

Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
CC2	Nonessential	• Light can refract, it does not depend on the light source. If green light is radiated to the water, the observer can see the green spot at the bottom of the water tank. This situation can be found when the laser light is used.	6 (2%)
CI1	Yes	• Laser light can refract.	28 (10%)
IA1	No	• Laser light does not change the direction when travelling to a different medium.	17 (6%)
IA2	No	• There are only red laser.	2 (1%)
NU	-	-	111 (41%)
NR	-	-	42 (16%)

CC: Correct answer, correct explanation NU: No Understanding
CI: Correct answer, Incorrect reason NR: No Response
IA: Incorrect Answer

Question 11: The emitted lights from 4 kinds of light sources are propagated through the water. We can observe the phenomena as shown in the picture bellow.



Which light has the smallest spectral width? Explain your answer.

Question 11 is mainly about the refraction of the monochromatic light. The students who give correct answer to this question should understand that:

- Light refracts when propagating from air to water.
- Multiple wavelengths light will refract with a range of angles. The spectral band of the refracted light will be seen (This phenomena is called dispersion).

The correct answer is Light A and B because they does not disperse after travelingl thought the different optical media. The famous phenomena corresponding to this answer are the spreading of white light after pass through the prism. On the other hand, laser light which has narrower spectral width still be a narrow beam after the refraction. Moreover these phenomena were usually discussed in many general physics textbooks that most science students should be familiar with. Surprisingly, it was found that only 7% (CC category) of the students could give complete correct answer and correct explanation. They could relate the dispersion of light to the spectral width. 27% (IA1, IA2, IA3, IA4, IA6 and IA7 categories) of students related the spectral width to angle of refraction. Moreover, some students in these groups confuse about angle of refraction, they thought that it was the angle between refracted light and the boundary between two isotropic media. These students needed reminding about the normal line, angle of incident and angle of refraction before learning about spectral width. IA5 students thought that light with small spectral width will have large dispersion after travelling though the different optical media. They had contrary idea to real situation. To have better understanding, they needed more reminding about spectrum and dispersion of white light and laser light before asking them to compare the spectral width of both light. All students' responses in Question 11 are presented in table 4.15.

Table 4.15 Percentages of students who gave responses to Question 11 in each category

Category	Answer	Thai to English translation of students' Explanations	Number of students (271)
CC	A,B	• The dispersion does not occur for A and B while C and D refract with wide angles depend on wavelength.	20 (7%)
CI	-	• -	0 (0%)
IA1	A	• Have the smallest refraction	24 (9%)
IA2	A	• Have the largest bending from the normal line. And the refracted light appears as a beam.	4 (1%)
IA3	B	• Have the smallest refraction	19 (7%)
IA4	B	• Have the largest bending, Have a smallest angle of refraction.	18 (7%)
IA5	C	• The widest spread of light	7 (3%)
IA6	C	• Have the smallest refraction	5 (2%)
IA7	C	• Have the largest refraction	4 (1%)
NU	-	-	114 (42%)
NR	-	-	56 (21%)

CC: Correct answer, correct explanation NU: No Understanding
CI: Correct answer, Incorrect reason NR: No Response
IA: Incorrect Answer

From above results, there are only one fourth of students that had good understanding about spectral width and the related phenomena- the refraction and dispersion. Other students confused in this topic. They needed more learning to help them improve their understanding in this topic.

4.1.7 Analysis of students' responses in light source selection

To select a suitable light source for given situation is a simple way to probe students' understanding in properties of laser beam. These two questions would ask students to provide the suitable wavelength, spectral width and divergence of light source for a given situation.

Question 12: If we need a light source for pointing slides during the presentation.

12.1 We should select the light source emit light with wavelength _________nm.

12.2 We should select the light source emit light with narrow spectral width, wide spectral width or can use both?

12.3 We should select the light source emit light with small divergence angle, large divergence angle or can use both?

Question 12.1 is mainly about the selection of light source by given situation (choose the right wavelength with the right situation). The students who give correct answer to this question should understand that:

- The selected light source must emit light in a visible region (400-700 nm).
- The emitted light can be either a single wavelength or multiple wavelengths.

The correct answer can be both light with single wavelength and light with multiple wavelength but they must be in visible regime. We need to point something in presentation slides so we should see the light spot on that place. The results were found that 61 % (category 1 and 2) of students answered correctly. They understood that human can see light with wavelength 400-700 nm. Students in category 3 answered wavelength in UV regime while students in category 4 answered wavelength in IR regime. The 4% of students (category 5) provided various answers. These groups needed reminding about electromagnetic spectrum and their classification. The students' answers in Question 12.1 are summarized in Table 4.16.

Table 4.16 Percentages of students who gave responses to Question 12.1 in each category

Category	Answer	Number of students (271)
1	Single wavelength in visible region (400-700 nm)	101 (37%)
2	Spectrum band in visible region (400-700 nm, 500-600 nm, etc.)	65 (24%)
3	Single wavelength in region $\lambda < 400$ nm	9 (3%)
4	Single wavelength in region $\lambda > 700$ nm	10 (4%)
5	Etc.(Spectrum band $\lambda < 400$ nm, spectrum band that intersect between VIS and UV or IR region, …)	12 (4%)
No response	-	74 (27%)

Question 12.2 is mainly about the selection of light source by given situation (choose a right spectral width with right situation). The students who give correct answer to this question should understand that:

- The selected light source can have small spectral width.
- The advantage of small spectral width is it can be seen absolutely from the background.

The correct answer is the emitted light should have narrow spectral width that make pointing light contrast from the background. The results showed that 5% (CC1 category) answer in this way. They had the ideas about seeing color and color of light. CI1 students knew that the pointing light should have high intensity but they thought that light with small spectral width will be intense light. In fact, some light source such as Sodium lamp radiates light with small spectral width but the intensity of the radiated light does not differ from that of the white light bulb. Consider CI2 category, students answered that it does not depend on the spectral width; the emitted light must be visible light. These students didn't care about the contrast between point light and background light. We need to point something to make people emphasize on it so the contrast of pointing light is important. Next category is IA1 which contained of students who believed that pointing light had small spot size because it has large spectral width. In fact, the spot size of the light depends on beam divergence angle, focusing instruments and wavelength of it. The smaller beam divergence angle the smaller spot size. The alternative way to have small light spot is adding convex lens to focus light. The spot size of focusing light depend on the wavelength. The smaller wavelength the smaller spot size. The disadvantage of this method is the size of light spot is rapidly change when we change the distance between light source and screen. IA2 students knew that the pointing light should have high intensity but they thought that light with large spectral width will be intense light. The CI1 and IA2 students related the spectral width to the intensity of light. The students' answers in Question 12.2 are summarized in Table 4.17.

Table 4.17 Percentages of students who gave responses to Question 12.2 in each category

Category	Answer	Reasons	Number of students (271)
CC1	Narrow	• It can be seen absolutely from the background.	14 (5%)
CI1	Narrow	• Light with small spectral width has high intensity.	21 (8%)
CI2	Independent on a spectral width	• The emitted light needs to be in a visible region.	6 (2%)
IA1	Wide	• The emitted light will be a small spot.	8 (3%)
IA2	Wide	• Light with large spectral width has high intensity.	2 (1%)
NU	-	-	141 (52%)
NR	-	-	79 (29%)

CC: Correct answer, correct explanation NU: No Understanding

CI: Correct answer, Incorrect reason NR: No Response

IA: Incorrect Answer

Question 12.3 is mainly about the selection of light source by given situation (choose a right spectral width with right situation). The students who give correct answer to this question should understand that:

- The selected light source should emit light with small divergence angle.
- The advantage of small divergence angle is help pointing the target accurately.
- The disadvantage of the large divergence angle is the intensity will decrease rapidly. When pointing to the far object, it is hard to see where is the region that we point to.

The correct answer is light with small divergence angle that can produce a small point of light striking the interested area. It provides accurately pointing. The results showed that 25% (CC category) of the students could give complete correct answer and correct explanation. Many students were familiar with laser pointer which used in the classroom or seminar. Laser pointer can point the target accurately because it has small spot and it can be seen easily because of high intensity. Consider another group, IA1 students thought that the pointing light appear on the slide should have much brighter than background so it needs amount of light striking to that area. They also believed that light with large beam divergence could emit light much than one with small beam divergence. They lack of the idea of intensity. Moreover they didn't thought about the accuracy of pointing, the large beam divergence produce the large spot of light. The students' answers in Question 12.3 are summarized in Table 4.18.

Table 4.18 Percentages of students who gave responses to Question 12.3 in each category

Category	Answer	Reasons	Number of students (271)
CC1	Small	• It can point the target accurately. If it has large divergence angle the intensity will low.	67 (25%)
CI		• -	0 (0%)
IA1	Large	• It emit amount of light,	5 (2%)

Table 4.18 Percentages of students who gave responses to Question 12.3 in each category (continue)

Category	Answer	Reasons	Number of students (271)
NU	-	-	110 (41%)
NR	-	-	88 (32%)

CC: Correct answer, correct explanation NU: No Understanding
CI: Correct answer, Incorrect reason NR: No Response
IA: Incorrect Answer

Question 13: If we need a light source for surveying the ancient drawing in the cave.

13.1 We should select the light source emit light with wavelength _________nm.

13.2 We should select the light source emit light with narrow spectral width, wild spectral width or can use both?

13.3 We should select the light source emit light with small divergence angle, large divergence angle or can use both?

Question 13.1 is mainly about the selection of light source by given situation (choose a right wavelength with right situation). The students who give correct answer to this question should understand that:

- The selected light source must emit light in a visible region (400-700 nm).
- The emitted light should be multiple wavelengths light because we need to see a color picture.

The correct answer is light with wide emitting wavelength in visible regime or white light. We need to see the real color of picture so we needed light source such as searchlight sport light, lamp, candle. The results were found that 21 % (category 1) of students answered correctly. Students in this group might be familiar with using searchlight to surveying or searching something in the dark places. In general, we are more familiar with the word “searchlight emitted white light” than “searchlight emitted light with wavelength 400-700 nm”. It might hard to tell about emitting wavelength of light source. Students in category 2 answered a part of spectrum in visible regime while students in category 3 answered single wavelength in visible regime. It is true that we can see things in the dark place by using these lights but the color that we see is different. To help these two group of students the reminding about color and vision of color is needed. The 6% of students (category 4) provided various answers. These groups needed reminding about electromagnetic spectrum, their classification, color and vision of color. The students’ answers in Question 13.1 are summarized in Table 4.19.

Table 4.19 Percentages of students who gave responses to Question 13.1 in each category

Category	Answer	Number of students (271)
1	Whole wavelength in visible region (400-700 nm)	58 (21%)
2	Part of spectrum in visible region (400-600 nm, 500-600 nm, etc.)	8 (3%)
3	Single wavelength in visible region (400-700 nm)	75 (28%)
4	Etc.(Single wavelength $\lambda < 400\ nm$, Single wavelength $\lambda > 700\ nm$, …)	15 (6%)
No response	-	115 (42%)

Question 13.2 is mainly about the selection of light source by given situation (choose a right spectral width with right situation). The students who give correct answer to this question should understand that:

- The selected light source can have wide spectral width.
- The wide spectral width light can help seeing the real color of an object.

The correct answer is the emitted light should have wide spectral width that make searching light show real color of picture. The results showed that 3% (CC1 category) answer in this way. They had the ideas about seeing color and color of light. In fact, seeing color is complicated. It depends on many factors such as emission spectra of light source, the surface of object, background light, angle of observation. For simple case, we could assume that light with large spectral width (visible) will reflect real color of object. CI1 students knew that the survey light should illuminate to large area but they thought that light with wide spectral width can do that. In fact, the spectral width of light does not effect to the area of illumination, the beam divergence and diffraction lead light to spreading out. Consider CI2 category, students know that they should select the light source emitted light with wide spectrum because light with narrow spectral width have very high energy that can damage the picture. These students might knew that laser emitted light with narrow spectral width and intense light and they believed that laser beam has high energy enough to damage the picture. In fact, the laser pen emitted light with output power about 5-200 milliwatts that could not damage general objects except eyes. Next category is IA1 which contained of students who knew that selecting light source should emitted intense light because we survey in the dark place. The key idea of asking about spectral width is the vision of color. These two groups of students (CI2 and IA1) should mention about the spectral width. The students' answers in Question 13.2 are summarized in Table 4.20.

Table 4.20 Percentages of students who gave responses to Question 13.2 in each category

Category	Answer	Reasons	Number of students (271)
CC	Wide	• White light is a visible light. It is suitable for using in dark area. We can see the real color of the picture under the white light.	9 (3%)
CI1	Wide	• It has a large spreading out so we can observe wider area.	38 (14%)

Table 4.20 Percentages of students who gave responses to Question 13.2 in each category (continue)

Category	Answer	Reasons	Number of students (271)
CI2	Wide	• Light with narrow spectral width have very high energy that can damage the picture.	3 (1%)
IA1	Narrow	• Light with narrow spectral width have high energy so it can use for far distance.	7 (2%)
NU	-	-	97 (36%)
NR	-	-	117 (43%)

CC: Correct answer, correct explanation NU: No Understanding
CI: Correct answer, Incorrect reason NR: No Response
IA: Incorrect Answer

Question 13.3 is mainly about the selection of light source by given situation (choose a right spectral width with right situation). The students who give correct answer to this question should understand that:

- The selected light source should emit light with large divergence angle.
- The advantage of large divergence angle is help seeing in a large area. We can see the entire picture.

The correct answer is light with large divergence angle. If we want to see the entire picture or the whole area inside the cave, we should use light source that can radiate to large area such as searchlight or sport light. Light source with small beam divergence is not suitable. The results showed that 27% (CC category) of the students could give complete correct answer and correct explanation. Many students were familiar with searchlight which used in the dark room, in the cave or in the camp. It helps us to surrounding against stumble and colliding. Consider students idea in CI groups, CI1 students believed that light with large beam divergence could emit light much than one with small beam divergence. They lack of the idea of intensity. CI2 students related the beam divergence angle to the emitting spectrum of light source.

These students needed more reminding that the emission spectra of light source does not related to the cause of the beam divergence. Another interested group is IA1 is which students explain their answer with intensity concept. They thought that the light with large divergence angle will be dull so we cannot see picture well. IA1 students might be familiar with special searchlight that added lens on the front of it. The emitted lights are compelled by the lens so the divergence angle of this searchlight was smaller than general one. This special searchlight provided more intense light but the area that light radiate to will be decrease so the entire picture cannot be seen. The students' answers in Question 13.3 are summarized in Table 4.21.

Table 4.21 Percentages of students who gave responses to Question 13.3 in each category

Category	Answer	Reasons	Number of students (271)
CC	Large	• Light spread out help to see the entire picture. We can see large area.	72 (27%)
CI1	Large	• Light source with larger divergence angle will emit more light than one with smaller divergence angle.	4 (1%)
CI2	Large	• Light source with larger divergence angle will emit wider spectral band light so it is advantage for survey.	2 (1%)
IA1	Small	• If light has large divergence angle, it will be dull so we cannot see picture well.	7 (2%)
NU	-	-	81 (30%)
NR	-	-	105 (39%)

CC: Correct answer, correct explanation NU: No Understanding

CI: Correct answer, Incorrect reason NR: No Response

IA: Incorrect Answer

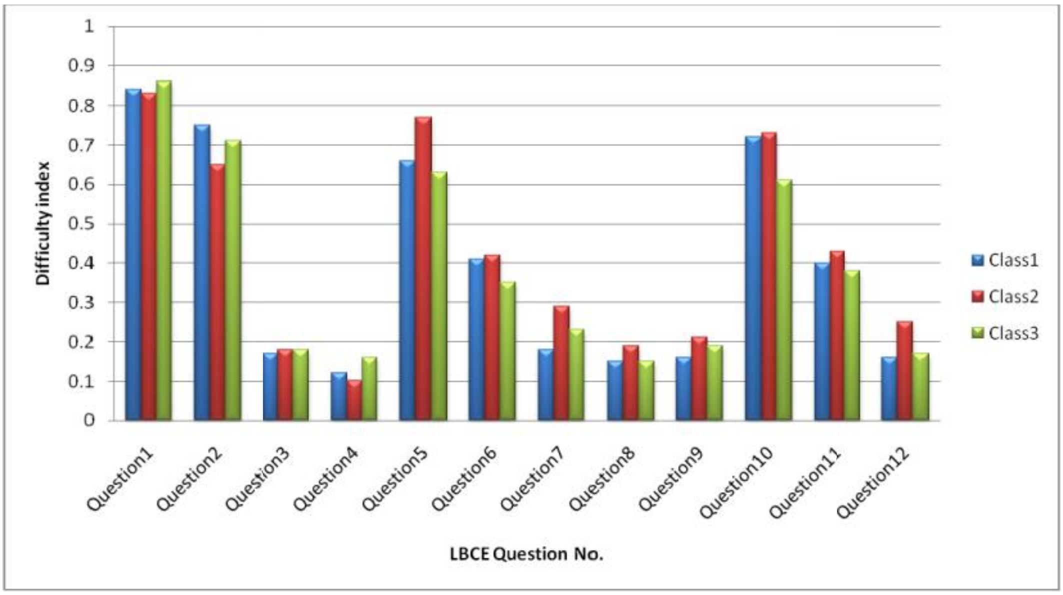
To answer both questions above student would integrate the concept about spectrum of visible light, spectral width if light related to the vision of color and the beam divergence related to the area of illumination. The results show that many students could not integrate the above concepts to answer the questions. In order to reach the correct answer, students required more understanding in the beam divergence and the spectral width.

The data from students' responses in the above six topics exhibits that students have different understanding levels about some essential properties of laser beam. The directionality is the most understanding topic. Others are difficult topics for the students. In addition, a large number of students can give the correct answers with dissatisfactory reasons to the open-ended questions.

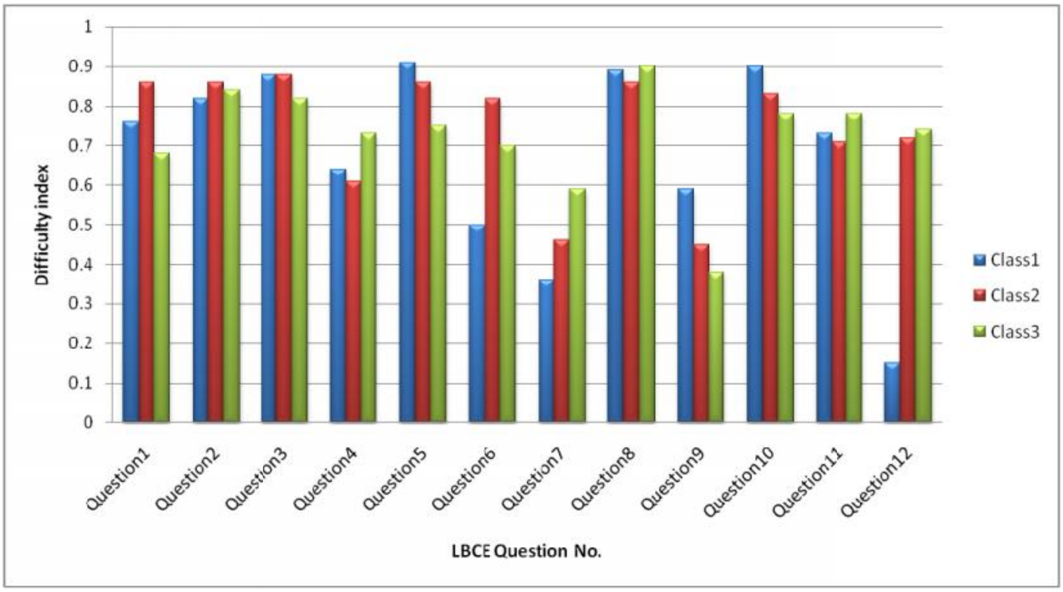
4.2 Analysis of the Laser Beam Conceptual Evaluation (LBCE)

The Laser Beam Conceptual Evaluation (LBCE) was subjected to the traditional analysis of both individual items and the overall test. The following analysis was carried out on post-test results. According to the open ended results, it could implied that many freshmen students in Thailand had alternate conceptions for many questions and they also lacked of ideas in some topics about the properties of laser beam causing low pretest scores.

The difficulty and discrimination index are two standard quality measurements of items on a test. The Difficulty reflects how difficult the item is. It is usually measured by ending the percentage of students who get the item correct. The range of the difficulty is from.0 to 1. The difficulty equals to 0 if no one answers correctly and it equals to 1.0 if everyone answers correctly. The difficulty index of the LBCE are presented in Figure 4.1



(a)



(b)

Figure 4.1 The Difficulty indices of LBCE calculated from (a) pre-test score, (b) post-test score.

A difficulty value of 0.5 is usually an ideal for the good test, but any real test will have items that range in difficulty. The accepted value is in the range of 0.4-0.6. The difficulty indexes calculated from both pre-test and post-test score are displayed in Figure 4.1. The values of many items from the pre-test are generally lower than 0.3. These corresponded to the above reason that the analysis was carried out on post-test results.

Discrimination index indicate of how well an item differentiates between excellent and novice students. For large number of samples (n > 100), it can be calculated by subtracting between the number of students in the top 27% of the score range who got the item correct and the number of students in the bottom 27% of the overall score range who got the item correct then dividing by half the sum of these two groups. Discrimination values range from 0.0 to 1.0. The discrimination index of the LBCE are presented in Figure 4.2

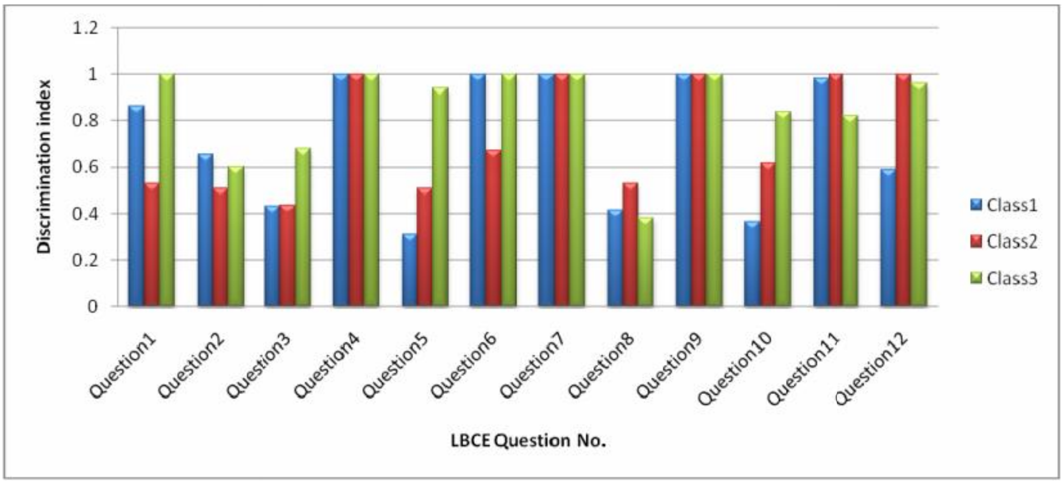


Figure 4.2 The Discrimination indices of LBCE calculated from post-test score.

For the items on the LBCE, students in all classes had discrimination values ranging from approximately 0.4 to 1.0. All of the items had values greater than 0.3, which is the lower limit for acceptability. The difficulty of an item has a strong effect on the discrimination of the item. The discrimination index is approximately 1.0 when a difficulty value is around 0.4-0.6. If the value of difficulty index is either greater or lower than this range, the value of discrimination index will be decreased (Sim & Rasiah, 2006).

The validity and the reliability are standard overall measurements of the quality of a test. The validity reflects how well the test measures what it contends to measure. There are several different ways to estimate the validity of a test. In evaluating the LBCE, 5 college physics professors in a university in Thailand were invited to judge the item objective congruence. We constructed a table for each expert to use during the item validation. Each expert assessed the agreement of each item with the stated purpose for the item, and marked: agree (+1 point), in which the item and its purpose correlated, not sure (0 point), or disagree (-1 point), in which the item and its purpose did not correlate. Then we calculated the Index of the Item-Objective Congruence (IOC index) for indicating the validity of the test. Turner and Carlson suggested that a generally accepted value might be a minimum of 0.75 (Turner & Carlson, 2003). The calculated value of IOC index for LBCE is 0.88. Thus our items with Index of Item-Objective Congruence $\geq$ 0.80, equivalent to overall agreement that the item matched its stated objective, were selected for inclusion on the questions. We also modified our questions based upon expert suggestions. An example of the table for validation the Index of Item-Objective Congruence by an expert was shown in Appendix G.

The reliability indicates of how consistently the test will reproduce the same score under the same conditions. On a reliable test, two students who are matched in knowledge and skill will get the same score. In other words, either two different students or the same student at two different times will get the same score on a reliable test. According to the dispersion of the item difficulty of LBCE test, the reliability (consistency) of a multiple-choice test can be indicated by Kuder-Richardson formula 20 (KR 20). Reliability values for tests run between 0 and 1.0. Reliabilities in the range 0.9 to 1.0 are rare. Values in the range 0.8 to 0.9 are very high and indicate a test that can be used for both individual and group evaluation. Values in the range 0.7 to 0.8 are common for well-made cognitive tests. Values in the range 0.6 to 0.7 are considered weak for cognitive tests, but are acceptable for personality tests. A range of 0.5 to 0.6 is common for well-made classroom tests. The KR 20 post-test estimated for the LBCE are around 0.36, which indicated that the LBCE is not reliable so it needs to be improved.

The main objective of our research is the developing of the demonstration sets and the instructional process in the considered topics. The developments of the assessments are an interesting works being done in the future. In order to improve the test, The simple way to do it deleted some items from the test, the KR-20 if item deleted are presented as shown in Table 4.22. Question 9 provided the greatest affect to the KR-20 value of LBCE. In order to have better reliable test, we designed to improve in three ways such as 1. Create more questions, 2. Develop some choices in LBCE and 3. Increase the number of samples.

Table 4.22 The KR-20 if item deleted of LBCE (2010)

Deleted Question #	KR-20 if item deleted	Deleted Question #	KR-20 if item deleted
1	0.36	7	0.35
2	0.31	8	0.32
3	0.33	9	0.39
4	0.31	10	0.36
5	0.34	11	0.35
6	0.33	12	0.35
		Undeleted	0.36

4.3 Results and Discussions for the Laser Beam Conceptual Evaluation (or called the LBCE)

In 2010, we used the LBCE to measure students' understanding of properties of laser beam concepts in a university in the North of Thailand, after our designed instruction. We had three classes with different students, Class1 consisted of students from School of Medicine (MED) and School of Allied Health Sciences (AHS), Class2 consisted of students from School of Science (SC.T.) and School of Information and Communication Technology (ICT) and Class3 consisted of students from School of Law (Law), School of Agriculture and Natural Resources (SAN) and School of Medical Science (MedSci). There were 606 students (Class1: 214, Class2: 205, Class3: 187) who filled out both pre- and post-test of the LBCE. The findings were showed in Table 4.23. The first column (in the left hand side) of the table shows the statistical tests namely; pre-test mean score (M_{pre}), post-test mean score (M_{post}), the standard deviations (SD_{pre}, SD_{post}), the t-test (*t-value, Sig. (2-tailed)*), and the average of the normalized changes ($\boldsymbol{c}_{\text{ave}}$) and its standard deviation (SD_c). The others show the results from 606 students in teaching university, which are divided into Class1, Class2, Class3 and total.

Table 4.23 The LBCE scores for 606 students in Class1, Class2 and Class3 of physics course with the t-test and the normalized change (Results in 2010)

Statistics	Students *(in 2010)*			
	Class1 (n=214)	***Class2 (n=205)***	***Class3 (n=187)***	***Total (n=606)***
M_{pre}	4.73	5.03	4.61	4.80
SD_{pre}	1.61	1.47	1.68	1.59
M_{post}	8.16	8.92	8.70	8.58
SD_{post}	1.76	1.77	1.82	1.81
t-value	24.54	29.34	24.54	44.68
**Sig. (2-tailed)*	< 0.01	< 0.01	< 0.01	< 0.01
$\boldsymbol{c}_{ave}$	0.46	0.55	0.54	0.52
SD_c	0.25	0.24	0.27	0.25

* We considered at the 99% confidence interval of the difference.

The results revealed that post-test mean scores (M_{post}) were greater than the pre-test mean scores (M_{pre}) of all classes, proved by the paired t-test at 0.01 significant level. We calculated the students' overall improvement via the average of the normalized changes ($\boldsymbol{c}_{ave}$) and found that it is in the medium learning gain ($\boldsymbol{c}_{ave}$ = 0.52). We also found that the learning gain of SC.T. students and ICT. Students (Class2) ($\boldsymbol{c}_{ave}$ = 0.55) was the greatest. These supported that the new instruction, based on the designed teaching module constructed by the researchers, enhanced student learning to the middle gain region, in particular, science students.

The Results obviously illustrated that our laser teaching module, based on Interactive Lecture Demonstration approach, facilitated students learning gain as examined by the normalized change. Our teaching module concentrated on the enquiring knowledge by learners, as the key ideas of the active teaching methods. The teaching processes in the module were constructed following the alternative concepts of students. Students always discussed to exchange ideas during our teaching. These are the ways to promote the conceptual change (DiSessa, 1993; Goldberg & Bendall, 1995; Hewson & Hewson, 1983; Posner, Strike, Hewson, & Gertzog, 1982).

Students' interested vocation influenced students' learning gain proved by the ANOVA at 0.01 significant level (*F = 8.46, P-value = 0.000237*). We found that SC.T. and ICT.students, got higher scores of the LBCE of pre-test and post-test than other who had interested in other vocation. By using the similar teaching process in the module, three groups of students have exposed the different learning gain but all in middle gain region. This revealed that a teaching process suitable for all.

To illustrate how much is these students gain after the instruction by using our laser teaching module, we calculated the average of the normalized changes (c_{ave}) for a given concept, as shown in Table 4.24. Table 4.24 shows 6 concepts of the LBCE, including their questions in the first and second columns, respectively. The last four columns show the average of the normalized changes (c_{ave}) in each concept for three classes of students and total students. Results from total manifested that most concepts of the LBCE showed c_{ave} greater than 0.30. It indicated that the instruction by using our teaching module in all concepts enhanced students' learning to the middle gain area. Especially, our instruction could enhance students' learning to the high gain area in concept of beam divergence and speed of light. Consider students from Class1 who came from School of Medicine (MED), School of Allied Health Sciences (AHS), they had low learning gain in concept of directionality (c_{ave} = 0.15) and applications (c_{ave} = 0.23). Consider students from Class1 who came from School of Law (Law), School of Agriculture and Natural Resources (SAN), School of Medical Science (MedSci), they had low learning gain in concept of monochromaticity (c_{ave} = 0.29), Students from class2, who came from School of Science (SC.T.), School of Information and Communication Technology (ICT), had learning gains greater than 0.30 in all concepts. Moreover, they also had the greatest total learning gain (c_{ave} = 0.56). This revealed that a teaching process might not suitable for all, because of the complexity of learners. The results also indicated that our teaching module was proper for science students more than other students. Overall, the directionality was the topic having the lowest student learning gain (c_{ave} = 0.32) while the speed of light was the topic having the highest student learning gain (c_{ave} = 0.86)

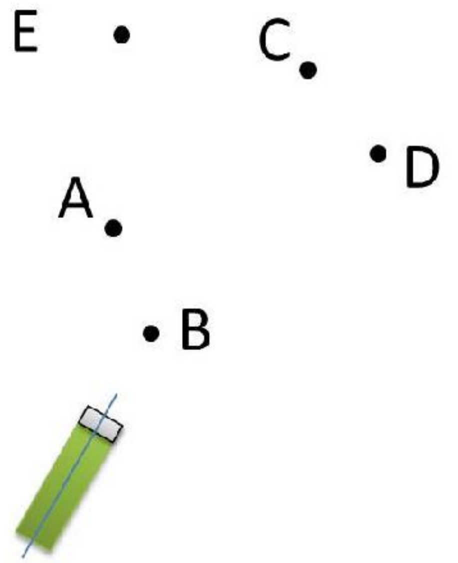
Table 4.24 The average of the normalized changes (c_{ave}) in each concept of the LBCE resulted from the instruction by using our teaching module for science (n=137) and non-science (n=78) students

Concepts	Question #	Class 1 (MED, AHS) (n=214)	Class 2 (SC.T., ICT) (n=205)	Class 3 (Law, SAN, MedSci) (n= 187)	Total (n=606)
		c_{ave}	c_{ave}	c_{ave}	c_{ave}
1. Directionality	1, 2, 6, 7	0.15	0.45	0.36	0.32
2. Beam Divergence	3	0.86	0.86	0.78	0.83
3. Intensity	4, 5	0.63	0.55	0.57	0.59
4. Speed of light	8	0.87	0.83	0.88	0.86
5. Monochromatic	9, 10	0.54	0.32	0.29	0.39
6. Applications	11, 12	0.23	0.56	0.67	0.48
All concepts	1-12	0.46	0.55	0.54	0.52

To show what students in each group have thought both before and after the instructions by using our teaching module, we analyzed pre-and post-tests of the LBCE in each concept. We compared the percentages of students, who chose each choice, between pre-and post-tests of the LBCE, including between Class 1 (MED, AHS), Class 2 (SC.T., ICT) and Class 3 (Law, SAN, MedSci) students. Again, the 6 concepts of the LBCE are; (1) Directionality (Question 1, 2, 6 and 7), (2) Beam divergence (Question 3), (3) Intensity (Question 4 and 5), (4) Speed of light (Question 8), (5) Monochromaticity (Question 9 and 10), and (6) Applications (Question 11 and 12). These will be demonstrated respectively.

(1) Directionality (Question 1, 2, 6 and 7)

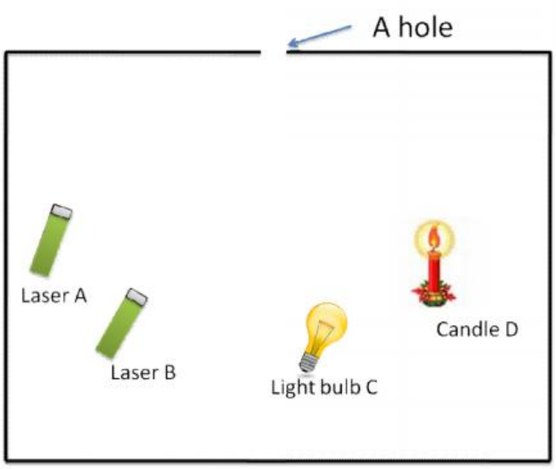
Question 1: The laser is placed as shown in the picture and then the switch is turned on. Which point(s) can the laser light propagate through?



A. All points
B. Point B
C. Point A, B, C and E
D. Point B and C

Correct answer for Question 1 is choice D.

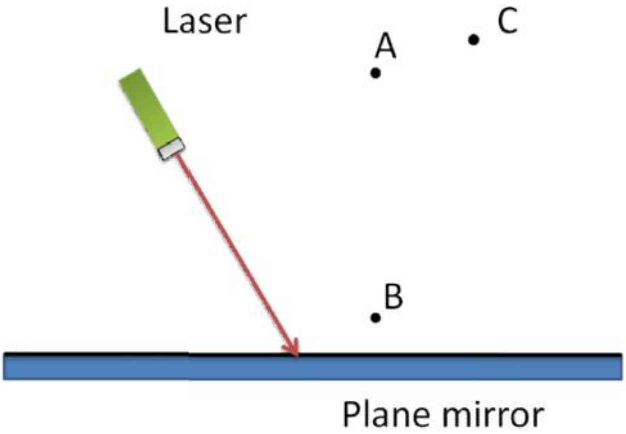
Question 2: Laser A, Laser B, Light bulb C and candle D are placed in the dark room that has a hole on one side of the wall as shown in the picture below. The wall of the room is a non-reflected wall. When we turn on all light source and kindle the candle. Which light sources can radiate light through the outside of the room?



A. Laser B
B. Laser B, Light bulb C and Candle D
C. Light bulb C and Candle D
D. All Light source, but Laser A must emit very intense light.

Correct answer for Question 2 is choice B.

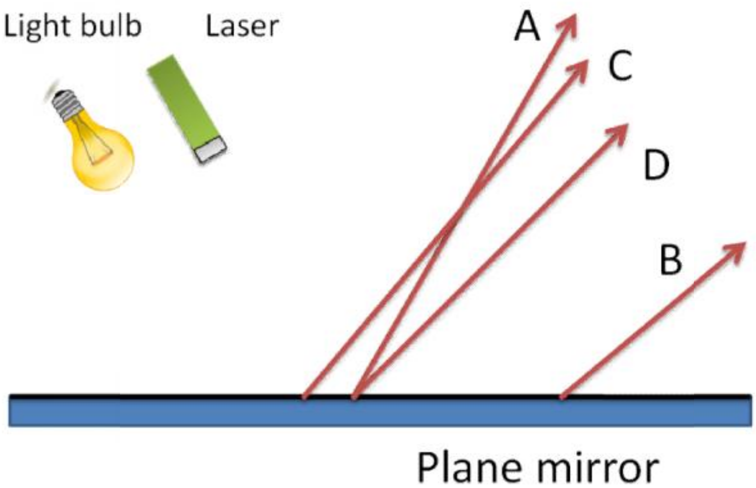
Question 6: Laser is placed as shown in the picture below. Which point(s) is the reflected light will propagate through?



A. Point A
B. Point B
C. Point C
D. All points

Correct answer for Question 6 is choice C.

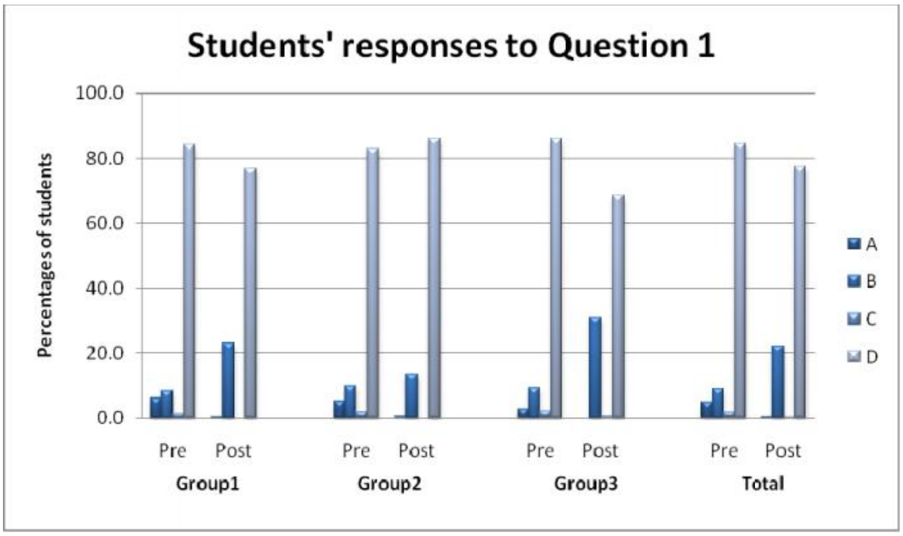
Question 7: The light bulb and laser are placed as shown in the picture below. Then we turn on both light sources. Which contain of the **correct** statement?

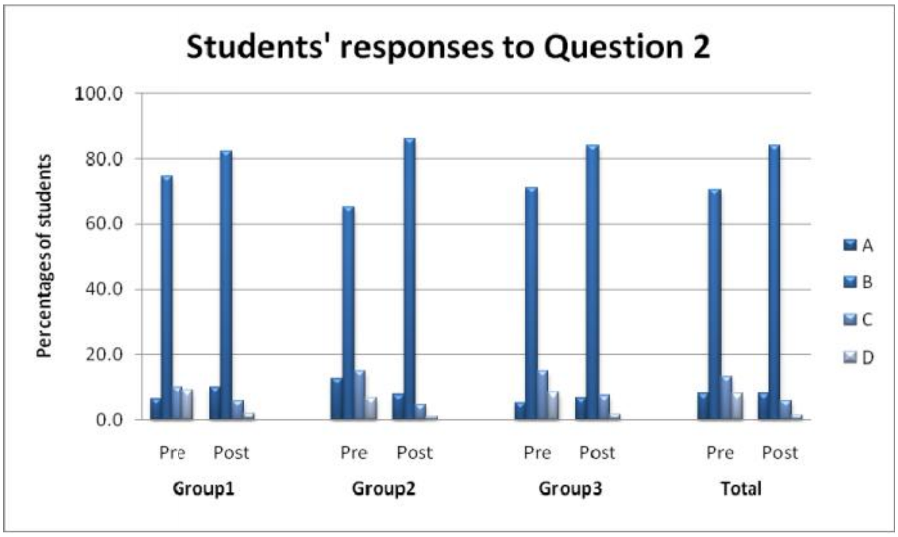


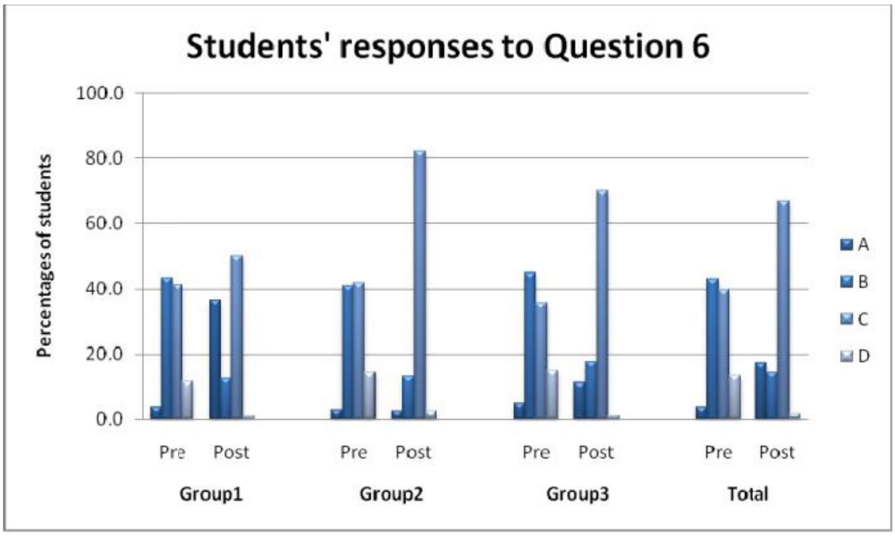
A. Ray A is emitted from laser.
B. Ray A, B, C and D are emitted from light bulb.
C. Ray B, C and D are certainly emitted from light bulb; Ray A is emitted from both light bulb and laser.
D. Ray A and D are emitted from laser; Ray B and C are emitted from light bulb

Correct answer for Question 7 is choice A.

For this concept, results in figure 4.3 displayed that most students knew about the direction of the emitted light from light source (Q1 & Q2). The results also show the decreasing of correct responses in Question 1. It indicated that students had trouble with demonstration 1.2. In this demonstration, we used the screen to show the direction of laser light. Laser light could not pass through the screen so some students answer choice B that laser pass through only point B. Consider in the complex situation-light reflects from mirror, many students had better understanding after learning with our teaching modules. Question 7 is more complicate than Question 6, it needed to find four incident rays for reaching the correct answer so the improvement of students in this question also less than of Question 6. Moreover, many students believed that Ray A come from light bulb without using the law of reflection to trace back the source of this ray.







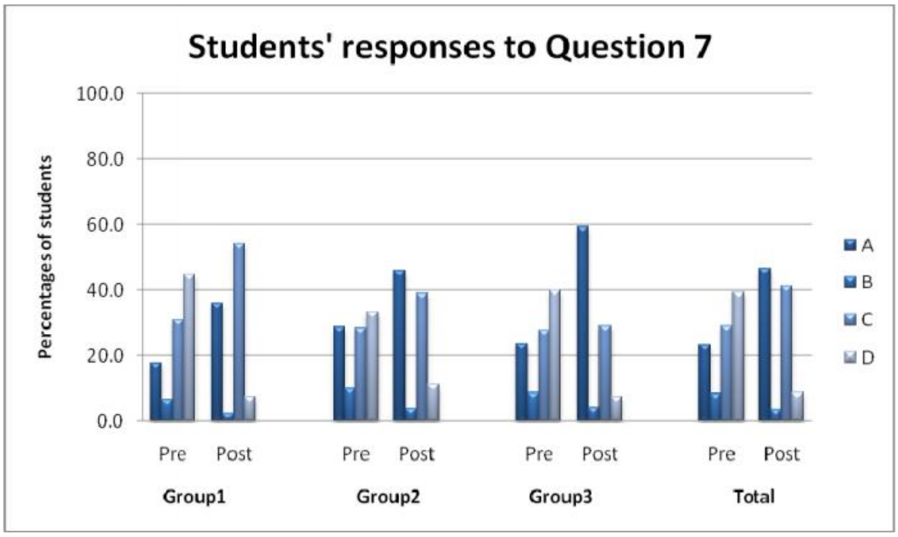


Figure 4.3 The percentages of Group1, Group2, Group3 and total students, who chose each choice of pre-and post-tests of the LBCE in the concept of Directionality (Question 1, Question 2, Question 6 and Question 7).

(2) Beam divergence (Question 3)

Question 3: The laser light is emitted from the top of mountain A to the top of mountain B which is 10 kilometers apart. Which choice shows the picture of laser beam?

A.

B

C.

D.

Correct answer for Question 3 is choice B.

Figure 4.4 shows the students' responses in Question 3. The results displayed that many students strongly believed that laser beam is a parallel beam before class. In the other word, laser light travels without diverging. After the instruction, most students changed their model of beam shape to the correct one. It indicated that our instructional module in beam divergence had high efficiency for learning in this concept.

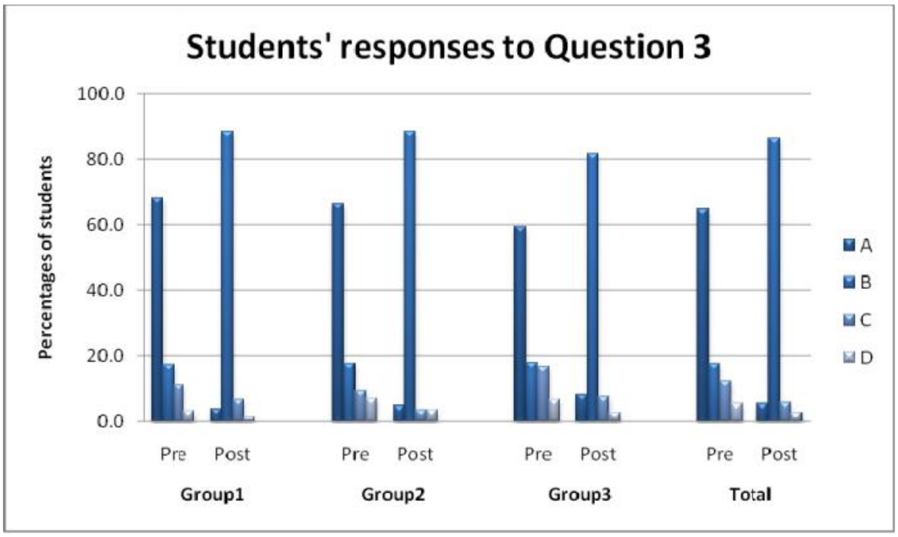
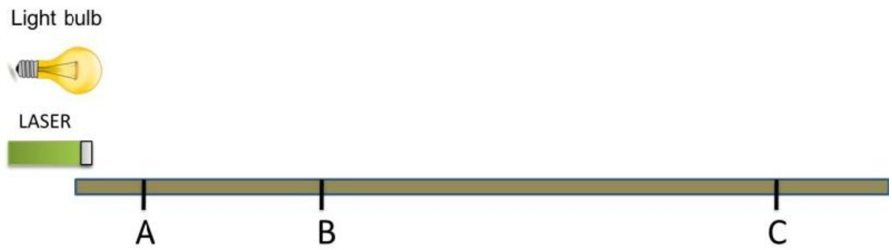


Figure 4.4 The percentages of Group1, Group2, Group3 and total students, who chose each choice of pre-and post-tests of the LBCE in the concept of Beam divergence (Q3).

(3) Intensity (Question 4 and 5)

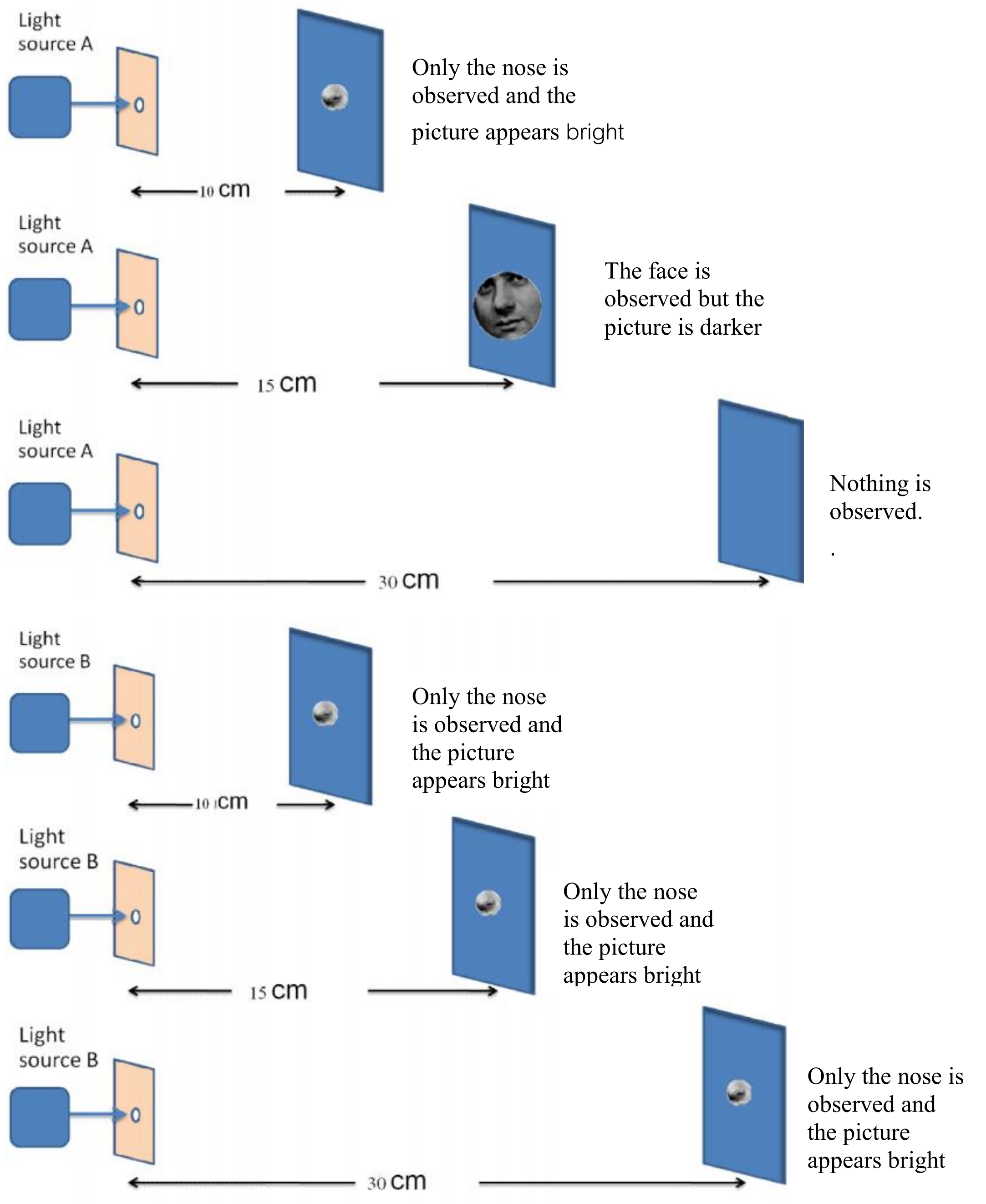
Question 4: The laser and the light bulb is placed as shown in the picture. Which choice contain the **correct** statement?



A. Intensity of light emitted from light bulb are the same at all position; Intensity of light emitted from laser are the same at all position.
B. Intensity of light emitted from light bulb are the same at all position; Intensity of light emitted from laser at A > at B > at C.
C. Intensity of light emitted from light bulb at A > at B > at C; Intensity of light emitted from laser are the same at all position.
D. Intensity of light emitted from light bulb at A > at B > at C; Intensity of light emitted from laser at A > at B > at C

Correct answer for Question 4 is choice D.

Question 5: Observe a picture in the dark room; a paper with a 2 mm diameter hole are placed in front of light source A and light source B as shown in the picture below. Then we carry the photograph to the distance 10 cm from the paper and watch the photograph. After that the distance is change to 15 and 30 cm respectively. The results are show in the picture.



Which choice contain the **<u>correct</u>** statement?

A. Both light sources are light bulb but light bulb B has higher power than light bulb A.

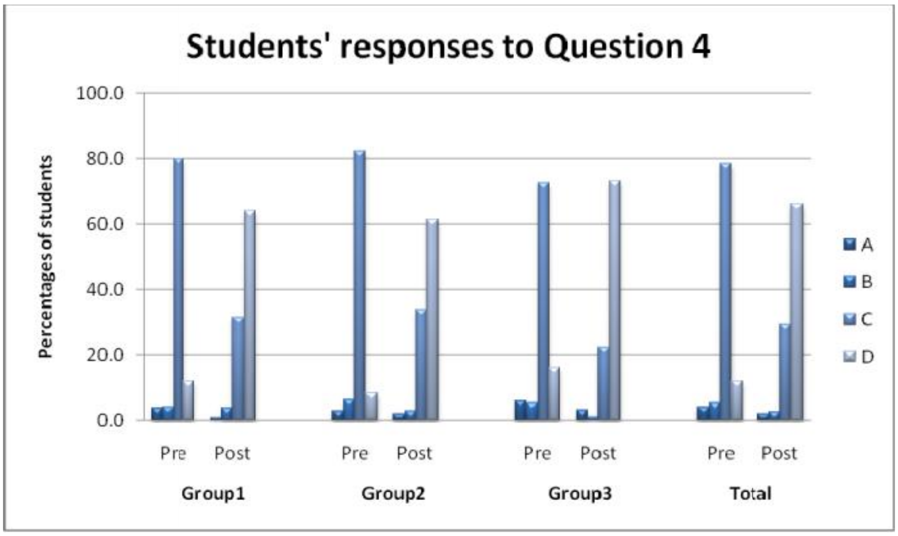
B. Both light sources are laser but laser B has higher power than light bulb A.

C. Light source A is light bulb; Light source B is laser.

D. Both light sources can be either light bulb or laser.

Correct answer for Question 5 is choice C.

Figure 4.5 shows the students' responses in Intensity concept. The results displayed that many students answer choice C for Question 4 in pre-test. It indicated that most students understood the decreasing of the intensity as the distance increases of general light but many students had strongly believed that the intensity of laser beam is constant though radiate to far distance. The intensity related closely to the beam divergence angle. According to pre-test of Question 3, a lot of students answer that laser beam still has the same size when the distance changes. From this reason, many students believed that Light source B in Question 5 being laser. The intensity is the amount of light per unit area. If the beam size is constant that is the incident area is constant and light does not dissipate during travelling so the intensity of light is constant. The pre-test answer of Question 3 and 4 were in harmony to this point. In our instructional process we also discussed with students about this relationship that cause large change in students' responses to the correct answer.



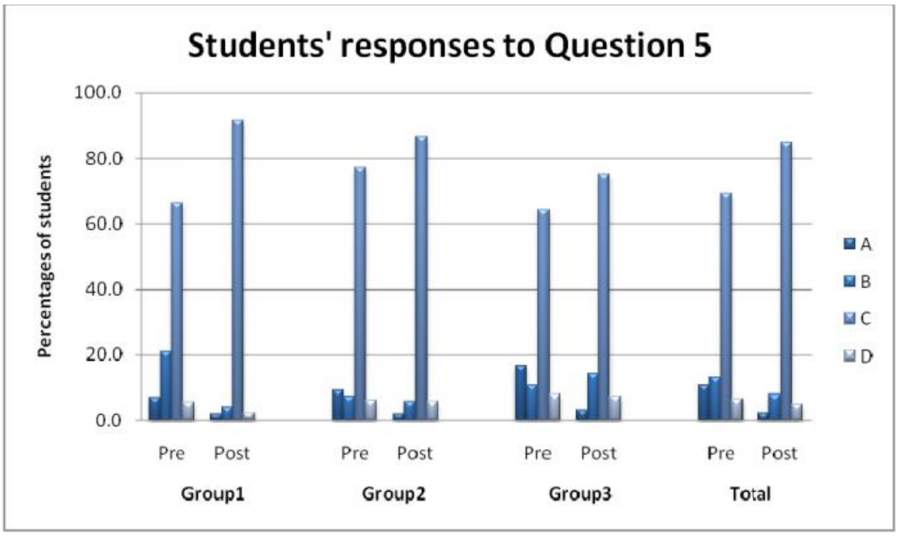


Figure 4.5 The percentages of Group1, Group2, Group3 and total students, who chose each choice of pre-and post-tests of the LBCE in the concept of Intensity (Question 4 & Question 5).

(4) Speed of light (Question 8)

Question 8: Which choice contain the **correct** statement?

A. Speed of light emitted from laser is greater than light emitted from light bulb because laser light can appear on the screen very far away.

B. Speed of light emitted from laser is greater than light emitted from light bulb because laser light has higher intensity.

C. Speed of light emitted from laser and light emitted from light bulb are equal because both of them are electromagnetic wave.

D. Speed of light emitted from laser is greater than light emitted from light bulb because laser light has higher energy.

Correct answer for Question 8 is choice C.

Figure 4.6 shows the students' responses in speed of light concept. The results displayed that many students answer choice B followed by choice D for Question 8 in pre-test. Many students believed that laser light has higher speed than general light due to its high intensity or high energy. According to the post-test responses, a lot of students changed their answer to the correct choice. It implied that our demonstration could help them to have more understanding in the speed of laser beam conception.

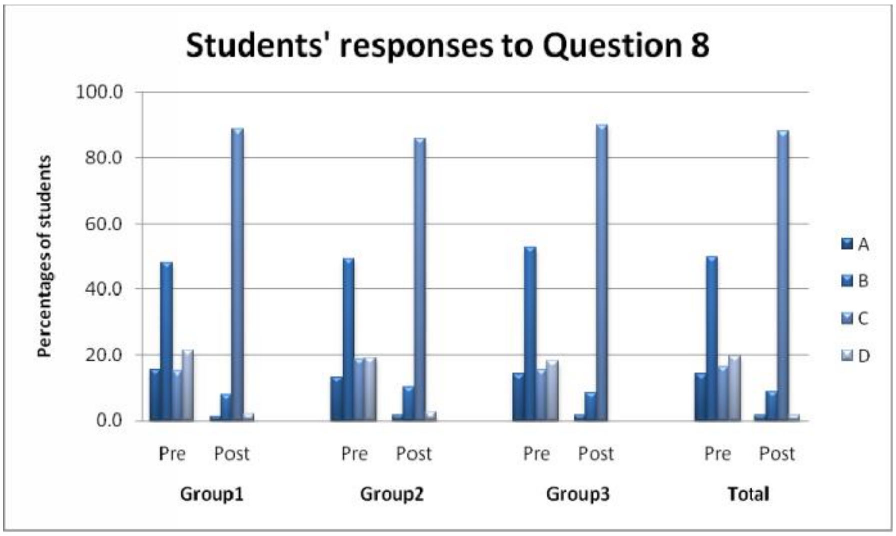
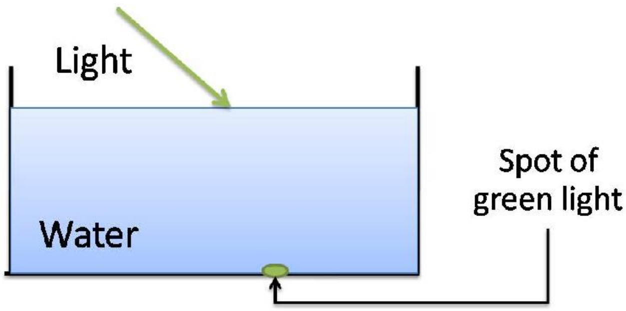


Figure 4.6 The percentages of Group1, Group2, Group3 and total students, who chose each choice of pre-and post-tests of the LBCE in the concept of Speed of light (Question 8).

(5) Monochromaticity (Question 9 and 10)

Question 9: The light from an unknown light source propagates from air through water in a tank as shown in the picture. The observer can see only the spot of green light at the bottom of the tank. Which choice contain the **<u>correct</u>** statement?

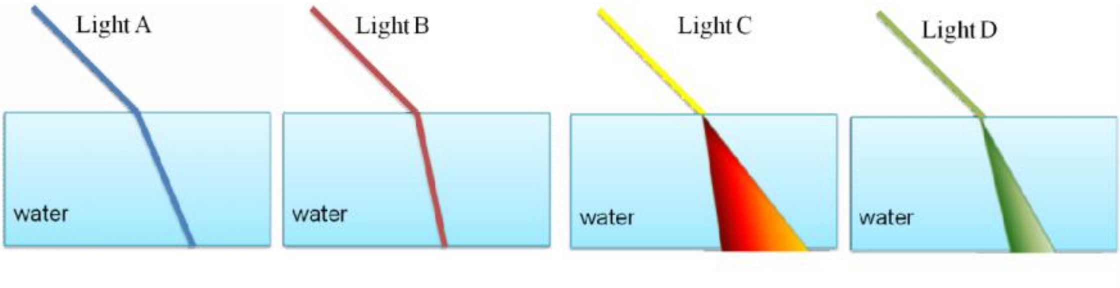


A. The unknown light is laser light because it refract when propagating to the different media.
B. The unknown light is laser light because it does not disperse to be multiple colors light.

C. The unknown light is not laser light because laser light does not refract when propagating to the different media such as from air to water.
D. The unknown light may be multiple wavelengths light but other color light except green are completely scattered.

Correct answer for Question 9 is choice B.

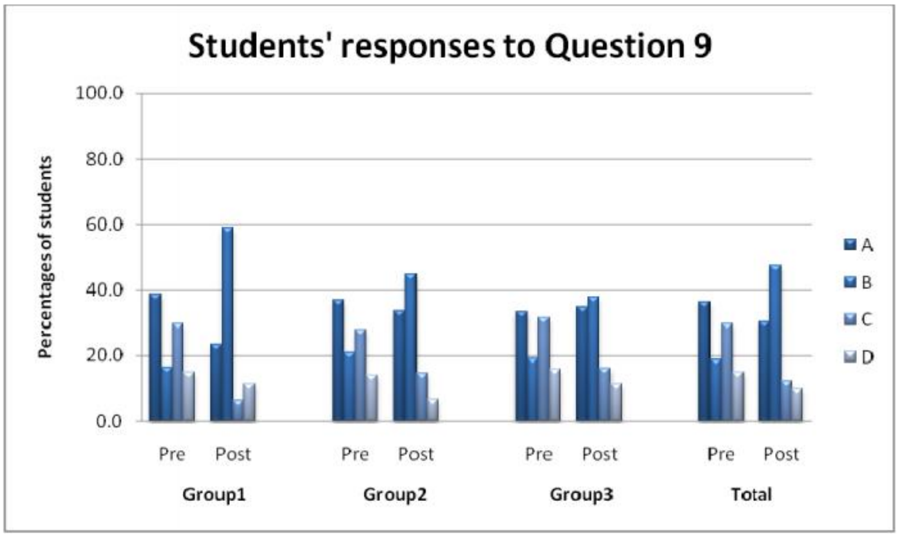
Question 10: The emitted lights from 4 kinds of light sources are propagated from air to water. We can observe the phenomena as shown in the picture bellow. Which choice contain the **correct** statement?



A. Light C has equal spectral width as light D
B. Light A has the narrowest spectral width because it refracts with the smallest bending than others.
C. Light B has the widest spectral width because it refracts with the largest bending than others.
D. Both Light A and Light B have the narrowest spectral width because they do not disperse after propagate from air to water.

Correct answer for Question 10 is choice D.

Figure 4.7 shows the students' responses in monochromatic concept. Consider Question 9, the results displayed that many students answer choice A in pre-test and small number of students thought about the dispersion. Many students had knowledge in refraction of light but some of them thought that laser beam has different behavior when propagating to different media. In fact, laser light behaves as general light that could refract conform to Snell's law. One dominant property of laser light is monochromatic that related to dispersion. So the designed demonstration will start with showing dispersion of white light followed by showing the spectrum of the emitted light from different light source to show the different between monochromatic light and general light. After instructional process, many students changed to the correct concepts. According to Question 10, high percentage of students answered that both A and B is laser. Many students had been familiar with these phenomena; laser is usually used to show the refraction of light by emitting to the water and show the monochromatic of light by emitting to the prism.



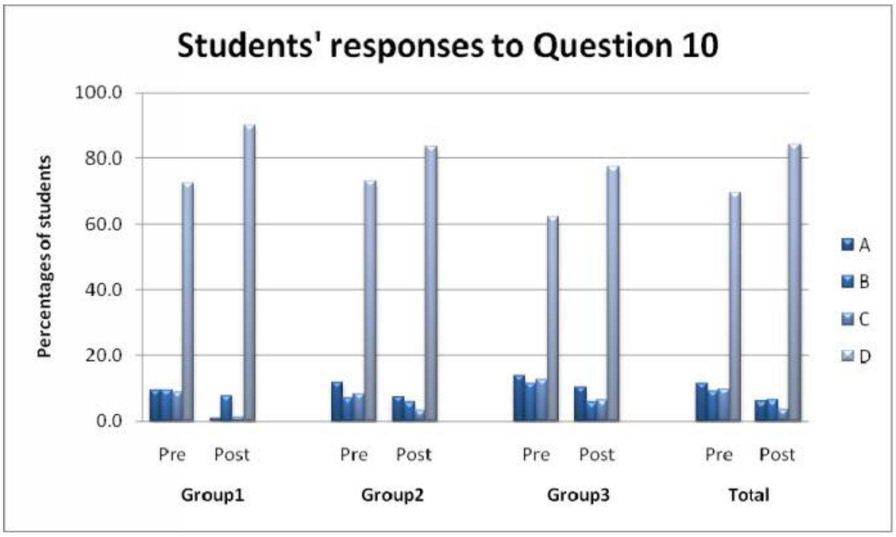


Figure 4.7 The percentages of Group1, Group2, Group3 and total students, who chose each choice of pre-and post-tests of the LBCE in the concept of Monochromaticity (Question 9 & Question 10).

(6) Applications (Question 11 and 12)

Use the following informations to help answering Question 11 and 12

Light source	Wavelength of the emitted light (nm)	Beam divergence angle (Degree)
A	730-1500	0.2
B	350-730	40
C	550-560	0.1
D	540-560	50

Question 12: If we need a light source for pointing slides during the presentation**.** Which light is/are suitable for this work? Why?

A. Light source A because it has small beam divergence angle.
B. Light source C or D because both has narrow spectral width.
C. Light source C because it has small beam divergence angle.
D. Light source B because it emits visible light.

Correct answer for Question 11 is choice C.

Question 13: If we need a light source for surveying the ancient drawing in the cave. Which light is/are suitable for this work? Why?

A. Light source A because it emits multiple wavelength light.
B. Light source D because it has large beam divergence angle.
C. Light source B because it emits visible light.
D. All can be used because they can emit light to illuminate in the dark place.

Correct answer for Question 12 is choice C.

Figure 4.8 shows the students' responses in light source selection applications by integrating their knowledge about monochromatic, spectrum of light, vision and beam divergence concept. In order to choose the correct answer, students should know the dominant property of light that suitable for the given situation. Consider Question 9, the pointing light should be visible and has accuracy to point to the target. the results displayed that about 40% of students who answer choice C in pre-test, had understood about these idea. After the instruction, number of students with correct answer was double. In case of surveying the ancient drawing in the cave, we need to see the color and the whole picture so the first dominant property of light source is radiating broadband visible light. The second is radiating light to large area. In the other word, the selected light source must radiate visible light with wide spectral width and large divergence angle. The pre-test results showed that the divergence angle became the most important factor. After they learnt with our designed instruction, percentage of the correct responses was increased. It meant that our activity could help students to have more understanding about the selection of light source.

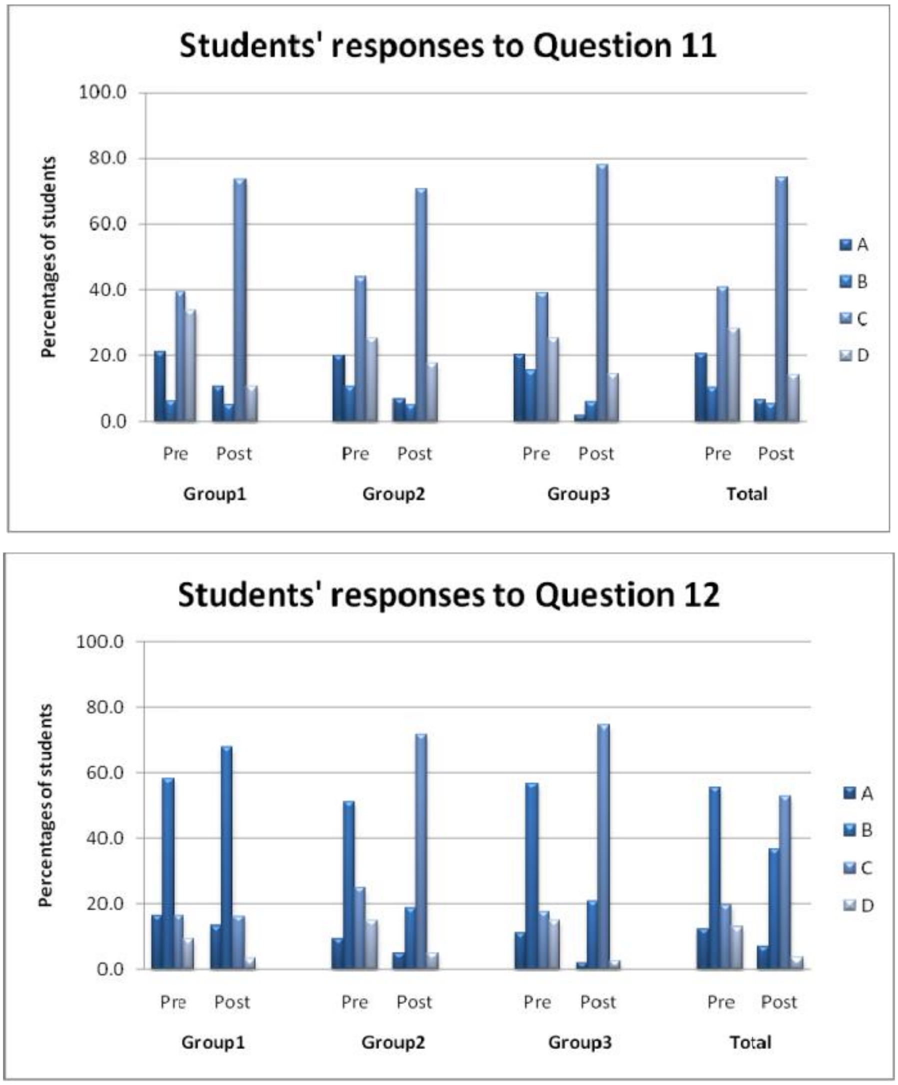


Figure 4.8 The percentages of Group1, Group2, Group3 and total students, who chose each choice of pre-and post-tests of the LBCE in the concept of Applications (Question 11 & Question 12).

The results of the LBCE revealed that the instruction by using our teaching module improved students' understanding in the properties of laser beam into the middle learning gain, examined by the average of the normalized changes. This teaching module was suitable for all students. The teaching processes involving the concepts of directionality should be revised. Overall, alternative concepts were reduced after the finishing of the laser classes.

4.4 Results and Discussions for the Students' Satisfaction

We evaluated students' satisfaction of the teaching module by using the satisfaction questionnaire. The questionnaire was composed of 5 Likert scale items, and 2 open-ended questions. The Likert scales were divided as 1 (strongly disagree), 2 (disagree), 3 (fair), 4 (agree) and 5 (strongly agree). Students were free to select a scale for an item. The satisfaction questionnaire was provided in Appendix H. Students took around 5-10 minutes to fill out this document after finishing of class. The items of this satisfaction questionnaire were analyzed to find what students thought about our teaching module, as shown in figure 4.9.

Figure 4.9 shows histogram plotted between the 5 items of the satisfaction questionnaire (x-axis) and the percentage of students, who selected 1 (strongly disagree), 2 (disagree), 3 (fair), 4 (agree) and 5 (strongly agree) for each item (y-axis). Results (n=227) exposed that more than 70% of these students agreed/ strongly agreed that this teaching module helped them learn the topic of the properties of laser beam. According to the results, most students preferred the illustration of real life situation corresponding to the learning topic (item 5), the demonstration sets (item 1) and the instructional documentary (item2). Moreover, from the open-ended questions of the satisfaction questionnaire, some students said that the performing demonstrations were very interesting, and they had more understanding due to this instructional process.

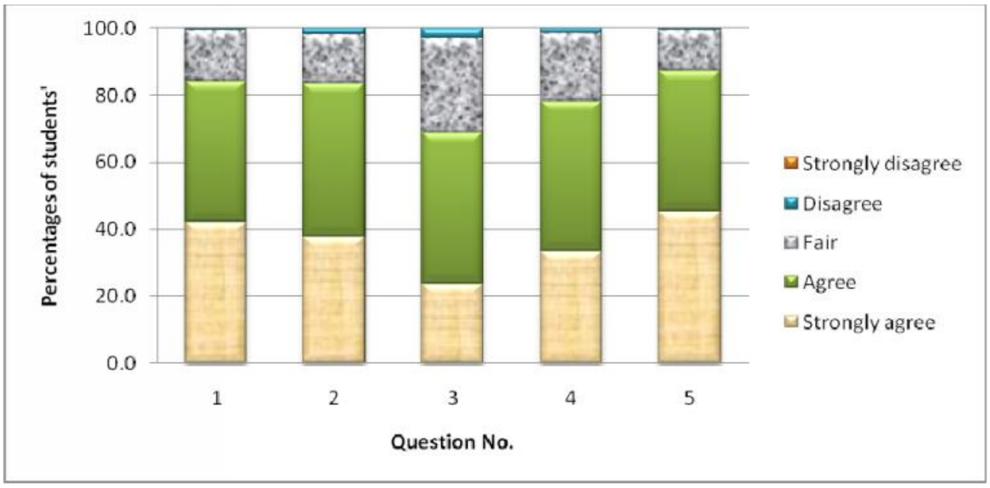


Figure 4.9 The percentage of students (n=227), who selected 1 (strongly disagree), 2 (disagree), 3 (fair), 4 (agree) and 5 (strongly agree) for each question of the satisfaction questionnaire.

4.5 Results and Discussions for the Observation via the Video

We recorded the students' responses in classes through the video. After finishing each class, we watched the class videos to adjust ourselves and modify the teaching process for the next classes. Examples of the modification are adding some video clip to show the applications of laser corresponding to learning topic and adding the total summary at the end of classes. Discussing about events, movies and stories could engage students to think about the science concepts. From the video we can see that, when the instructor displayed the video about surveying underwater event, students stopped their own activities, started watching, and discussing among them about the scientific ideas of the video. Overall, students took pleasure in doing the activities in our teaching module.

4.6 Summary

In this study, after our teaching module based on Interactive Lecture Demonstration (ILD) approach was developed, it was used with the freshmen students (n=606) in Thailand. After the instruction, we evaluated students learning gain by using the Laser Beam Conceptual Evaluation (LBCE). We also evaluated students' satisfaction by using the satisfaction questionnaire, including observing students' behaviors in the classes via the video. Findings revealed that the instruction by using our teaching module, in particular, for concepts of the five basic essential properties of laser beam, facilitated students' learning into the middle gain, justified by the normalized change. Moreover, most students agreed that this teaching module help them to learn this topic. However, from what we found we would suggest that our teaching module of laser beam properties was more appropriate for all freshmen students, especially science students.

CHAPTER V
CONCLUSION

The whole ideas of this research will be summarized in this chapter. The research questions, as mentioned in the first chapter, will be answered. Then we will present the applications of this research for instruction, including its limitations. Eventually, the recommendations for further direction will be provided.

5.1 Summary of this Research

This research was organized to enhance Thai freshmen students understanding of the properties of the laser beam. The researchers have developed the new laser teaching module based on the Interactive Lecture Demonstration (ILD) approach that is suitable for large classroom. The module consisted of 6 subtopics of laser beam properties; (1) directionality, (2 beam divergence, (3) intensity, (4) peed of laser light, (5) monochromaticity and (6) Applications: The selection of light source. In each subtopic, we have provided both the lesson plan and the teaching tools. We devise the assessment instrument called the Laser Beam Conceptual Evaluation (LBCE). The questions of the LBCE were developed from the some popular physics education textbooks, and the research based questions constructed by the researchers.

The 12 four-choice questions of the current version of the LBCE consisted of 6 concepts mentioned above. The validity and reliability tests of the LBCE were determined via the Item-Objective Congruence Index (IOC index) and the KR-20 reliability test. We have tested the module with graduated students, and modified it from the students' suggestions and experts' advice. Ultimately, we applied the teaching module of laser beam properties with 606 freshmen students who had different interesting vocation in a university in the northern part of Thailand. The outcomes revealed that the created instruction constructed by the researchers, could improve students' understanding in the considering topic. Clearly, the overall normalized change was catagorized in the middle region. Moreover, the satisfaction questionnaire results exhibited that more than 70% of these students agreed that they have improved their knowledge in the properties of laser beam from our teaching module.

5.2 Answering the Research Questions

The following discussions aim to reply the research questions. We clearly illustrate both the question and its responses.

Research Question #1: What are students' alternative conceptions about the properties of laser beam?

Answer:

We explored Thai freshmen understanding of the five properties of laser beam by using the open-ended questions (n=271). Findings exposed some alternative concepts held by these students, as shown in Table 5.1.

Table 5.1 Some alternative concepts held by students

Property of laser beam	**Students' alternative conceptions**
Directionality	1. Laser is light and light travels in a straight path. 2. Laser light can be spreading out in the air by refraction. 3. Have some confuses in Law of reflection. 4. Direction of reflected light depends on the energy of light. 5. Laser light does not change the direction when travelling to a different medium.
Beam divergence	1. Laser light trajectory is in a straight path. When it travels in the air it may refract by the effecting of some molecules in the air causing a spreading of the laser beam.

	2. Laser beam shape still remains after travelling to far distance. 3. Laser beam size will be smaller after travelling to far distance due to the absorption of some light.
Intensity	1. The intensity the laser beam is not constant along the axial distance. 2. Although, we give the intensity of two lights at the reference point, students cannot compare the intensity at the other points. 3. Students cannot relate the intensity to the beam divergence angle and area of illumination.
Speed of laser light	1. Laser light has higher speed than general light because light emitted from light bulb has less intensity than laser. Laser has higher energy. 2. Students relate the intensity of light to the speed of propagating 3. Speed of the laser light is greater than the speed of the normal light due to laser light has either higher frequency or energy.
Monochromaticity	1. Laser light does not change the direction when travelling to a different medium. 2. There are only red laser. 3. Students relate the angle of refraction to the spectral width of light. 4. Students cannot compare the spectral width of light from the dispersion.
Applications: The selection of light source	1. Students cannot identify the first dominant properties of light suitable for the work. 2. Students relate the spectral width to the area of observation. 3. Students relate the divergence angle to the emission

	spectra of light source. 4. Students have confusion about spectral width and the vision of color.

Research Question #2: Can the demonstration sets improve students' understanding in the properties of laser beam?

Answer:

Yes, the teaching module can increase student conceptual understanding of in the properties of laser beam. This is proved by the normalized change which is categorized in the middle region.

5.3 Applications for Instruction

The researchers intended to design the efficiency teaching module of five properties of laser beam for Thai freshmen students. Since, instructors and educators, who are interested, can apply the module in various options. These are;

(1) Instructors warn their students about laser safety and hazardous of laser.

(2) In optics or atomic physics classes, instructors can use this module to teach students in topic of laser.

(3) Instructors can use the Laser Beam Conceptual Evaluation (LBCE) to evaluate students understanding of such topics.

(4) Instructors can take a question from the Laser Beam Conceptual Evaluation (LBCE) as a quiz in such an active learning classroom as peer instruction.

(5) Instructors can use the alternative concepts, found in this research, to set up a new teaching process, which is more suitable for their students.

(6) Instructors can use our teaching tool as a prototype for development a new one.

5.4 Limitations of this Research

Although this research is forcefully conducted and revised to achieve the statistically reliable study, here are some limitations.

(1) The Laser Beam Conceptual Evaluation (LBCE) should be revised for better reliability. Although the major work involve in the construction of the teaching module, the development of the assessment instrument is also important. The proper evaluation of the LBCE is essential. Therefore, the LBCE has been analyzed by using some standard statistical tests. Many evaluation methods used in field of education may be suitable for the evaluation of the LBCE.

(2) The teaching processes, involving directionality should be revised to achieve a higher gain.

(3) We collected data from groups of students in the northern and central parts of Thailand; therefore the alternative concepts, exhibited in the research, came only from specific groups of students.

5.5 Recommendations for Further Research

The recommendations for further directions are the re-making of the teaching process for the directionality, and the development of the LBCE to reach the standard assessment test of properties of laser beam by adding more questions in other essential properties and develop the existing question to be more reliable. Moreover, modifying the teaching tools to be a laser teaching kit is extremely interesting.

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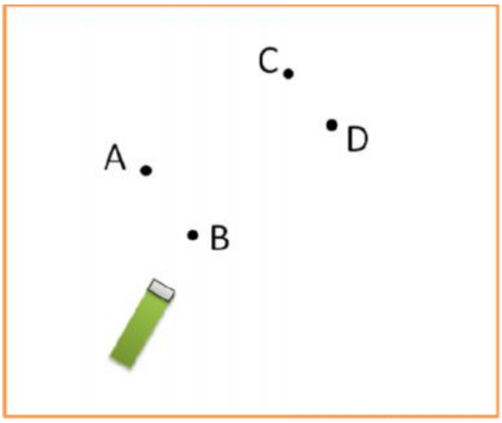
APPENDICES

APPENDIX A
THAI VERSION OF THE OPEN ENDED TEST

แบบทดสอบประเมินความเข้าใจเรื่อง “คุณสมบัติพื้นฐานของแสงเลเซอร์”
กลุ่มวิจัยฟิสิกส์ศึกษา
ภาควิชาฟิสิกส์ คณะวิทยาศาสตร์ มหาวิทยาลัยมหิดล

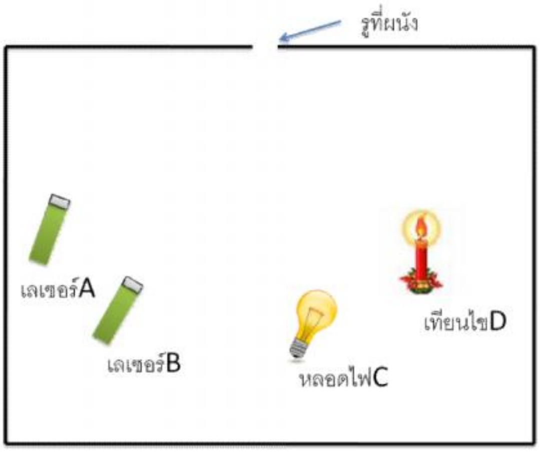
คำชี้แจง **จงตอบคำถามข้อ 1-12 ในช่องว่าง อย่าลืมกรอกชื่อ-นามสกุล**

1. เมื่อวางเลเซอร์ไว้ดังรูป จากนั้นเปิดสวิตช์ แสงเลเซอร์จะผ่านจุดใดได้บ้าง



คำตอบ

2. แหล่งกำเนิดแสง 4 ชนิดวางอยู่บนพื้นในห้องมืดสนิทโดยที่มีรูอยู่บนผนังด้านหนึ่งดังรูป แสงจากแหล่งกำเนิดใดมีโอกาสเล็ดลอดออกจากรูที่ผนังห้องนี้ได้บ้าง

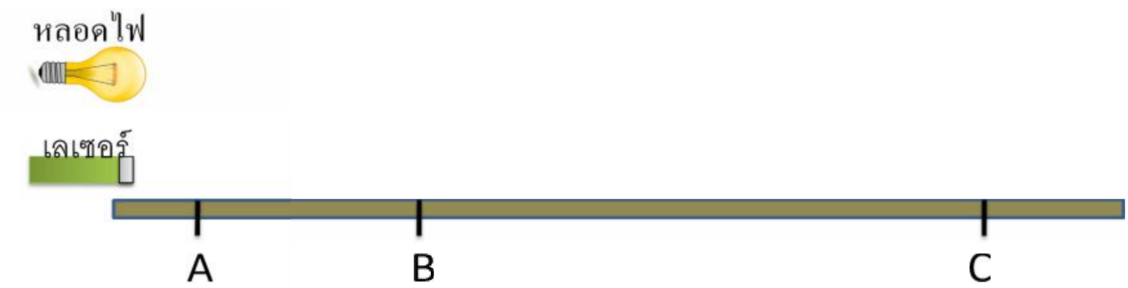


คำตอบ

3.เมื่อฉายแสงเลเซอร์จากยอดเขา A ไปยังยอดเขา B ที่อยู่ห่างกัน 10 กิโลเมตร ลักษณะของลำแสงเลเซอร์จะเป็นอย่างไร ให้นักศึกษา**<u>วาดภาพ</u>**ประกอบพร้อมทั้งอธิบาย

<u>อธิบาย</u>

4.จากรูปเมื่อเปิดสวิตช์หลอดไฟและเลเซอร์

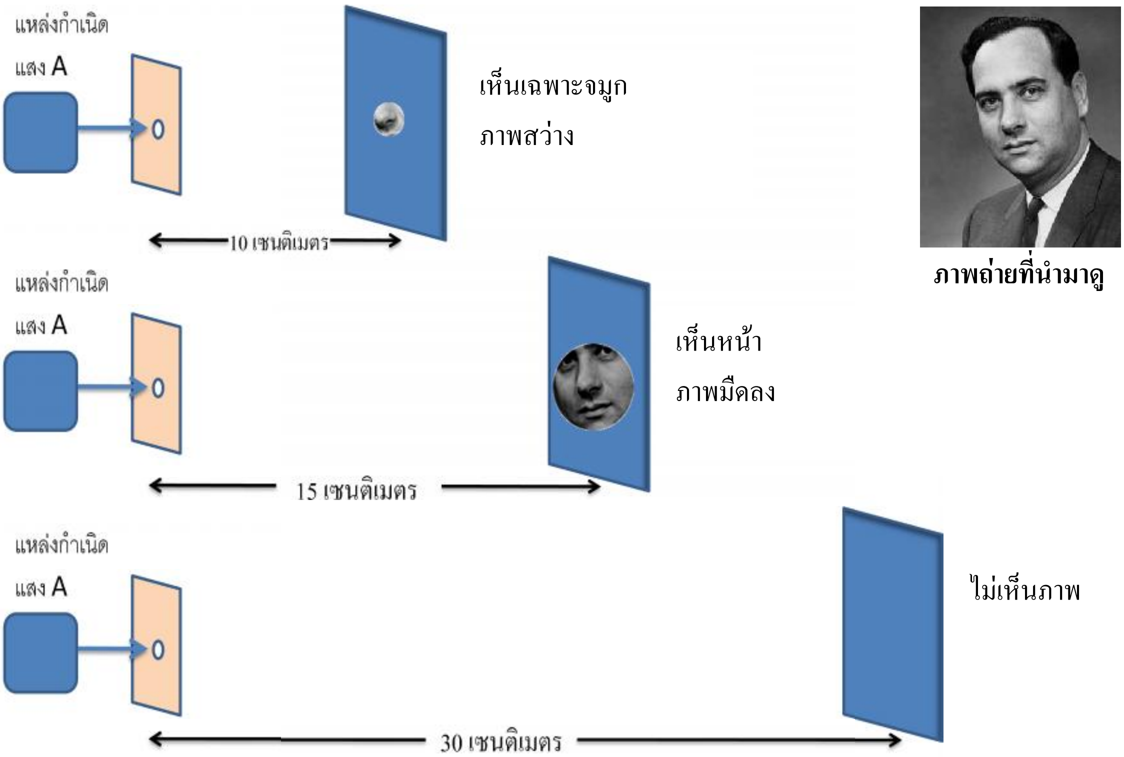


4.1 จงเปรียบเทียบความเข้มแสงของหลอดไฟที่ตำแหน่ง A, B และ C

4.2 เมื่อเปิดสวิตช์เลเซอร์และหลอดไฟแล้วพบว่าความเข้มแสงของแสงจากหลอดไฟและแสงเลเซอร์ที่ตำแหน่ง A มีค่าเท่ากัน ความเข้มแสงของแสงเลเซอร์ที่ตำแหน่ง B และ C จะเป็นอย่างไรเมื่อเทียบกับความเข้มแสงของแสงเลเซอร์ที่ตำแหน่ง A

4.3 เมื่อเปิดสวิตช์เลเซอร์และหลอดไฟแล้วพบว่าความเข้มแสงของแสงจากหลอดไฟและแสงเลเซอร์ที่ตำแหน่ง A มีค่าเท่ากัน ความเข้มแสงของแสงเลเซอร์ที่ตำแหน่ง B และ C จะเป็นอย่างไร เมื่อเทียบกับความเข้มแสงของแสงจากหลอดไฟที่ตำแหน่ง B และ C ตามลำดับ

5. ถ้าเจาะรูบนแผ่นกระดาษให้แสงจากแหล่งกำเนิดแสง A ส่องผ่าน จากนั้น นำภาพถ่ายไปดูที่ระยะ 10, 15 และ 30 เซนติเมตรจากรูที่เจาะไว้ตามลำดับ พบว่าจะมองเห็นภาพดังแสดงในรูป



แหล่งกำเนิดแสง A เป็นอะไรได้บ้างพร้อมให้เหตุผลประกอบ

คำตอบ แหล่งกำเนิดแสง A

คือ____

เพราะ____

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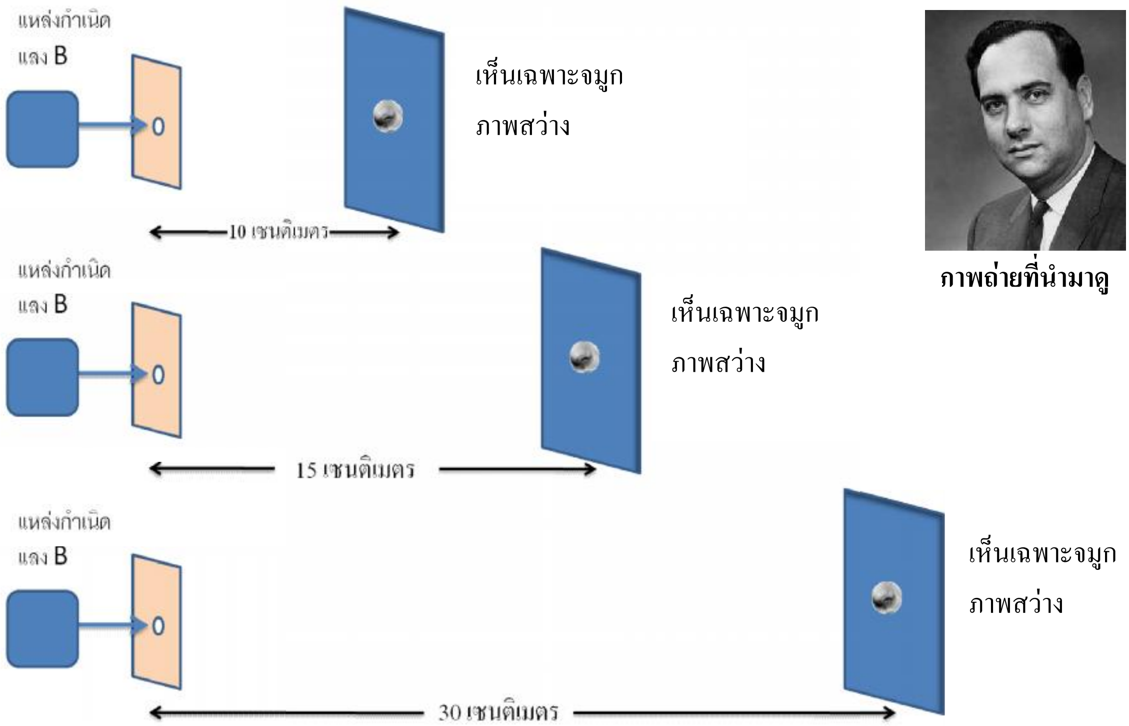
6. ถ้าเจาะรูบนแผ่นกระดาษให้แสงจากแหล่งกำเนิดแสง B ส่องผ่าน จากนั้น นำภาพถ่ายไปดูที่ระยะ 10, 15 และ 30 เซนติเมตรจากรูที่เจาะไว้ตามลำดับ พบว่าจะมองเห็นภาพดังแสดงในรูป



ภาพถ่ายที่นำมาดู

แหล่งกำเนิดแสง B เป็นอะไรได้บ้างพร้อมให้เหตุผลประกอบ

คำตอบ แหล่งกำเนิดแสง B

คือ____

เพราะ____

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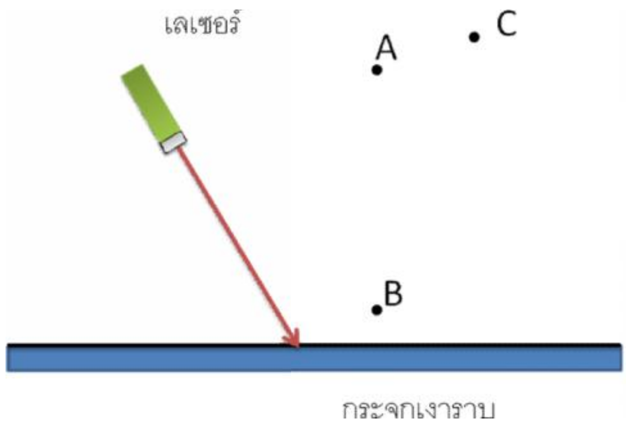
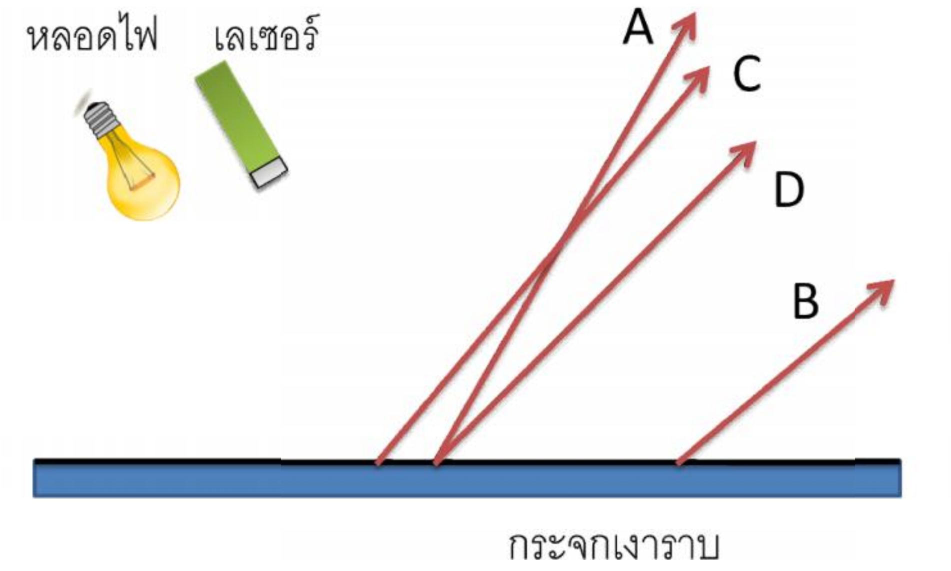
7. เมื่อวางเลเซอร์ไว้ดังรูป จะพบแสงสะท้อนที่จุดใดได้บ้าง



คำตอบ

8. ถ้าวางหลอดไฟและเลเซอร์ไว้ที่ตำแหน่งดังรูป เมื่อฉายแสงจากแหล่งกำเนิดแสงทั้งสองตกกระทบกระจกเงาราบ พบว่าเราสามารถลากแนวรังสีสะท้อนของแสงที่เกิดขึ้นได้ดังรูป รังสีสะท้อนเส้นใดมาจากเลเซอร์

และรังสีสะท้อนเส้นใดมาจากหลอดไฟ (สามารถตอบซ้ำกันได้)



รังสีสะท้อนที่มาจากเลเซอร์ คือ ____

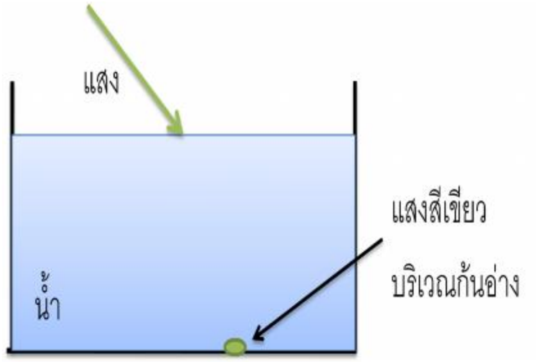
รังสีสะท้อนที่มาจากหลอดไฟ คือ ____

9. จงเปรียบเทียบอัตราเร็วของแสงจากหลอดไฟและอัตราเร็วของแสงเลเซอร์ พร้อมทั้งให้เหตุผลประกอบ

คำตอบ อัตราเร็วของแสงจากหลอดไฟ **มากกว่า น้อยกว่า เท่ากับ** อัตราเร็วของแสงเลเซอร์

อธิบาย

10. เมื่อฉายแสงชนิดหนึ่งลงน้ำที่อยู่ในอ่างอาบน้ำโดยฉายแสงเอียงทำมุมกับผิวน้ำดังรูป จะสังเกตเห็นแสงสีเขียวที่ก้นอ่างโดยไม่เห็นแสงอื่นเลย

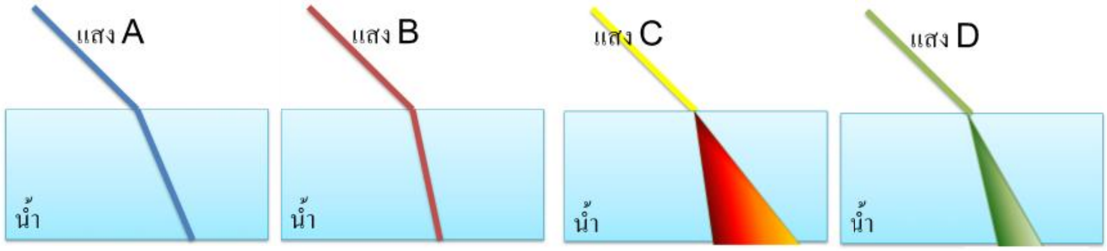


แสงที่ฉายลงในน้ำนี้เป็นแสงเลเซอร์หรือไม่ อธิบายเหตุผลประกอบ

คำตอบ

อธิบาย

11. ฉายแสงจากแหล่งกำเนิดแสง 4 ชนิดลงในน้ำปรากฏผลดังรูป



แสงใดมี **ช่วง** ความยาวคลื่นแคบที่สุด อธิบายเหตุผลประกอบ

คำตอบ แสงที่มี **ช่วง** ความยาวคลื่นแคบที่สุดคือ_______________________________

อธิบาย

12. ถ้าต้องการแหล่งกำเนิดแสงที่ใช้สำหรับชี้สไลด์นำเสนอผลงาน

12.1 ควรเลือกใช้แหล่งกำเนิดแสงที่ปล่อยแสงความยาวคลื่นเท่าใด

ตำตอบ ความยาวคลื่น_______________________นาโนเมตร

12.2 ควรเลือกแหล่งกำเนิดแสงที่ปล่อยแสงที่มี**ช่วง**ความยาวคลื่นกว้างหรือแคบ หรือไม่ขึ้นกับ**ช่วง**ความยาวคลื่น

ตำตอบ

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12.3 ลำแสงมีมุมบานมากหรือน้อย หรือมุมบานไม่มีผล

<u>คำตอบ</u>

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13. ถ้าต้องการแหล่งกำเนิดแสงที่ใช้สำหรับให้แสงสว่างในถ้ำเพื่อสำรวจภาพวาดโบราณ

13.1 ควรเลือกใช้แหล่งกำเนิดแสงที่ปล่อยแสงความยาวคลื่นเท่าใด

<u>คำตอบ</u> ความยาวคลื่น____________________________นาโนเมตร

13.2 ควรเลือกแหล่งกำเนิดแสงที่ปล่อยแสงที่มี**<u>ช่วง</u>**ความยาวคลื่นกว้างหรือแคบ หรือไม่ขึ้นกับ**<u>ช่วง</u>**ความยาวคลื่น

<u>คำตอบ</u>

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13.3 ลำแสงมีมุมบานมากหรือน้อย หรือมุมบานไม่มีผล

<u>คำตอบ</u>

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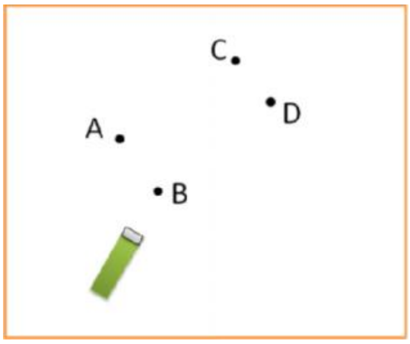
APPENDIX B
ENGLISH TRANSLATED VERSION OF THE OPEN ENDED TEST

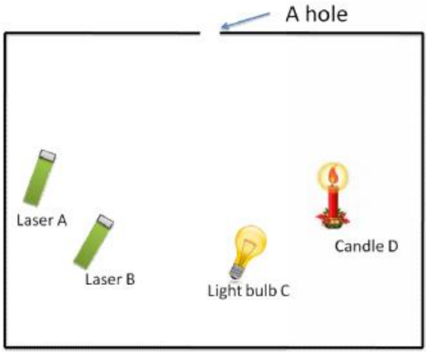
LASER BEAM CONCEPTIONS SURVEY
PHYSICS EDUCATION NETWORL OF THAILAND (PENThai)
DEPAERMENT OF PHYSICS, MAHIDOL UNIVERSITY, THAILAND

INSTRUCTION: Answer Question 1-13

Question 1: The laser is placed as shown in the picture and then its switch is turned on. Which point(s) can the laser light propagate through? Explain your answer.

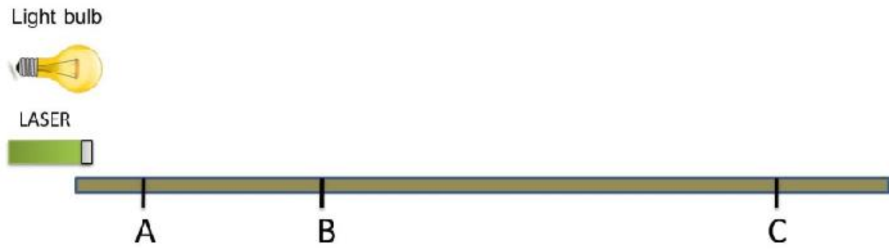


Question 2: Laser A, Laser B, Light bulb C and Candle D are placed in the dark room that has a hole on one side of the wall as shown in the picture below. Light cannot be reflected be the wall. When we turn on all light source and light the candle, Light emitted from which light sources can propagate through the hole to go outside of the room?. Explain your answer.



Question 3: The laser light is emitted from the top of mountain A to the top of mountain B which is 10 kilometers apart. Sketch the picture to show the shape of the laser beam propagating to mountain B and explain your answer.

Question 4: A laser and a light bulb are placed as shown in the picture. Both light source are switched on



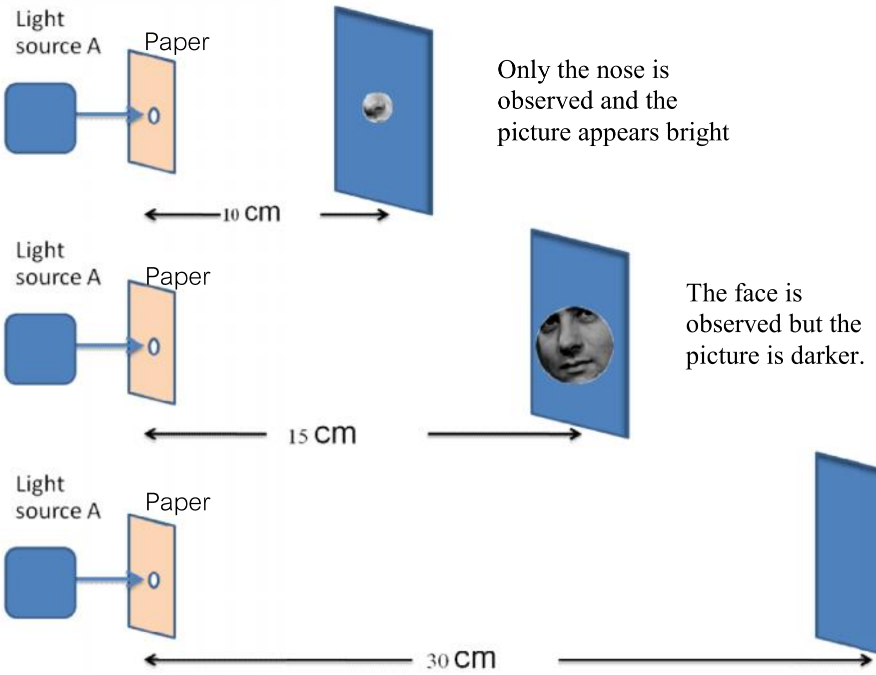
4.1 Compare the intensity of the light emitted from the light bulb at points A, B and C?

4.2 If the intensity of the emitted light from both light sources at point A is equal, compare the intensity of the laser beam at points B and C to that at point A?

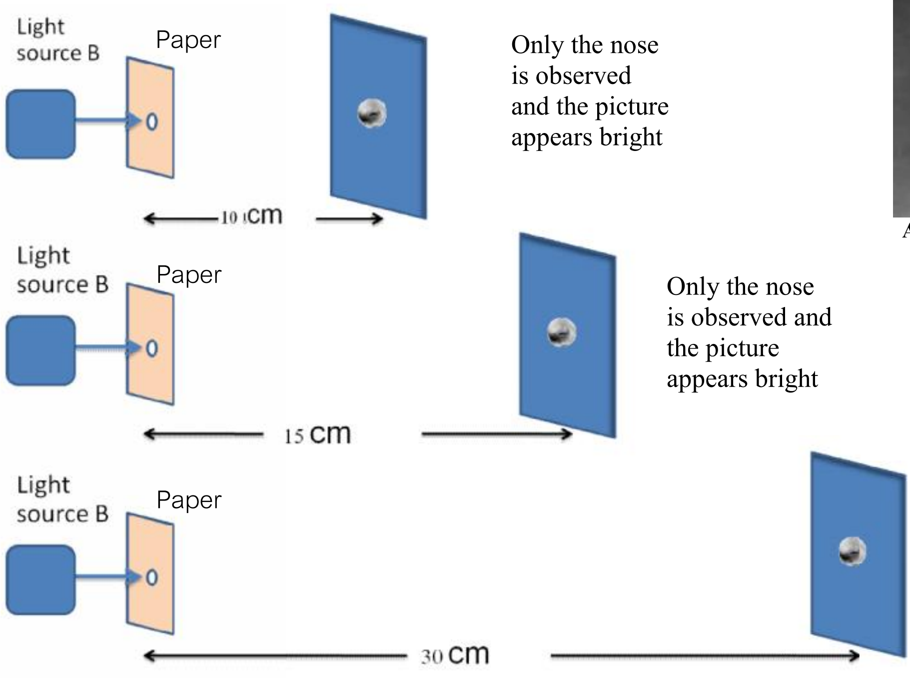
4.3 If the intensity of the emitted light from both light sources at point A is equal, compare the intensity of the laser beam and the intensity of the light emitted from the light bulb at points B and C, respectively?

Question 5: Observe a picture in the dark room; a paper with a hole is placed in front of light source A as shown in the figure below. Then we place a photograph at a distance 10 cm from the paper and observe the photograph. After that the distance is changed to 15 and 30 cm respectively. The observation results are show in the figure. What can the light source A be? Explain your answer.

A photograph used.

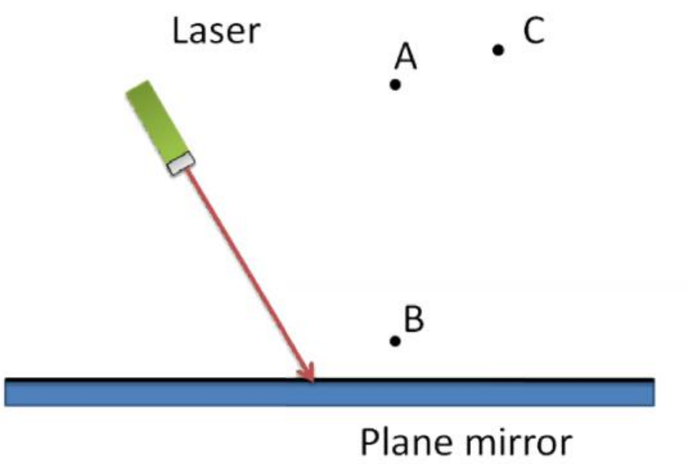


Question 6: Observe a picture in the dark room; a paper with a hole is placed in front of light source A as shown in the figure below. Then we place a photograph at a distance 10 cm from the paper and observe the photograph. After that the distance is changed to 15 and 30 cm respectively. The observation results are show in the figure. What can the light source A be? Explain your answer.

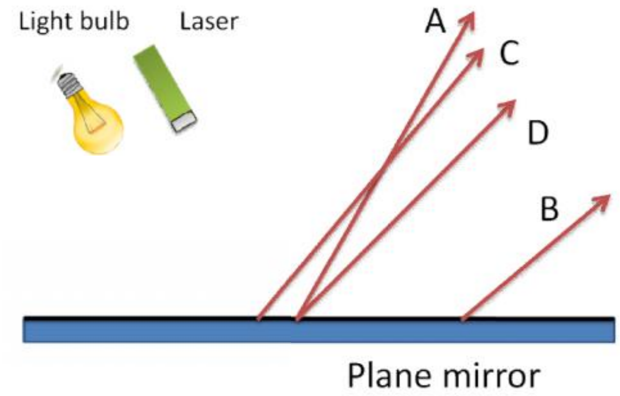


A photograph used.

Question 7: A laser is placed as shown in the picture below. Which point(s) will the reflected light propagate through? Explain your answer.

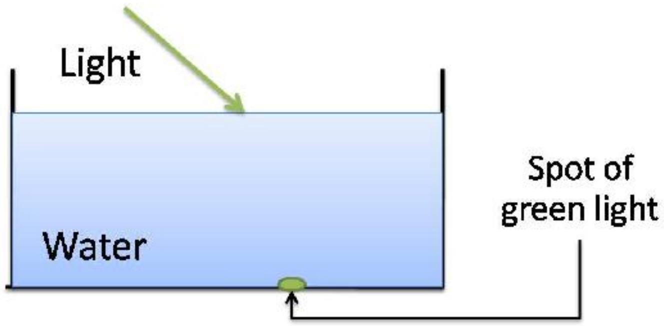


Question 8: A light bulb and a laser are placed as shown in the picture below. When we turn on both light sources, we find the reflected rays A, B, C and D. Which reflected ray(s) come from the light bulb? Which reflected ray(s) come from the laser?



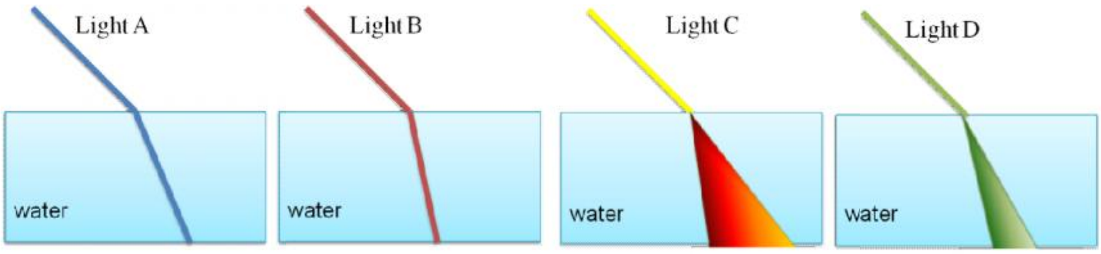
Question 9: Compare the speed of light emitted from a light bulb and the speed of light emitted from a laser when they both propagate in air. Explain your answer.

Question 10: The light from an unknown light source propagates from air through water in a tank as shown in the picture. The observer can see only the spot of green light at the bottom of the tank.



Is the unknown light source a laser? Explain your answer.

Question 11: The emitted lights from 4 kinds of light sources are propagated through the water. We can observe the phenomena as shown in the picture bellow.



Which light has the smallest spectral width? Explain your answer.

Question 12: If we need a light source for pointing slides during the presentation,

12.1 we should select the light source emitting light with wavelength _________nm.

12.2 should we select the light source emitting light with a narrow spectral width or wide wild spectral width or can we use both?

12.3should we select the light source emitting light with a small divergence angle or large divergence angle or can we use both?

Question 13: If we need a light source for surveying the ancient drawing in a cave,

13.1 we should select the light source emitting light with wavelength _________nm.

13.2 should we select the light source emitting light with a narrow spectral width or wide wild spectral width or can we use both?

13.3should we select the light source emitting light with a small divergence angle or large divergence angle or can we use both?

APPENDIX C
THE PREDICTOPN SHEETS

กิจกรรมที่1: “ลักษณะการเดินทางของแสงออกจากแหล่งกำเนิดแสง”

คำสั่ง: จงวาดรังสีแสดง<u>ลักษณะการเดินทางของแสง</u>จาก***หลอดไฟ***และ***เลเซอร์*** พร้อมอธิบายรูป

<u>ทำนายผลด้วยตนเอง</u>

หลอดไฟ

อธิบาย

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ด้านหน้า

เลเซอร์

อธิบาย

<u>ทำนายผลหลังจากปรึกษาเพื่อน</u>

หลอดไฟ

อธิบาย

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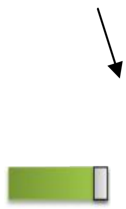
ด้านหน้า

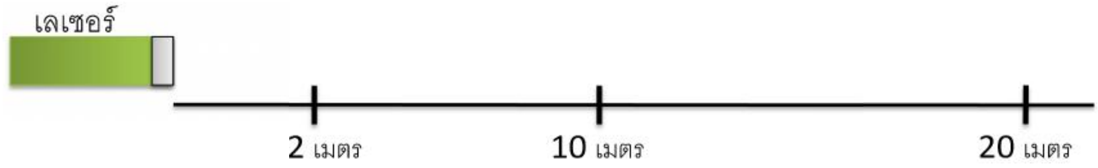


เลเซอร์

อธิบาย

กิจกรรมที่2: “ลักษณะของลำแสงเลเซอร์”

<u>คำสั่ง</u>: จง**<u>เปรียบเทียบ</u>**ขนาดของจุดแสงเลเซอร์ที่เห็นบนฉากที่วางห่างจากเลเซอร์เป็นระยะ 2 เมตร, 10 เมตร, และ 20 เมตร ตามลำดับ



<u>ทำนายผลด้วยตนเอง</u>

คำตอบ

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<u>ทำนายผลหลังจากปรึกษาเพื่อน</u>

คำตอบ

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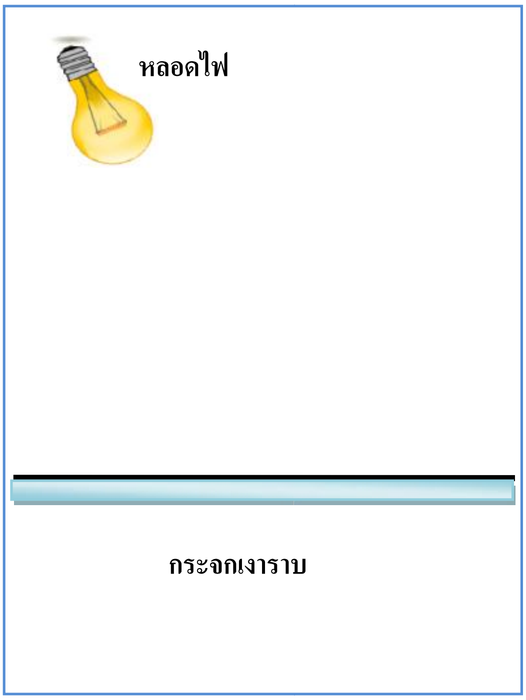
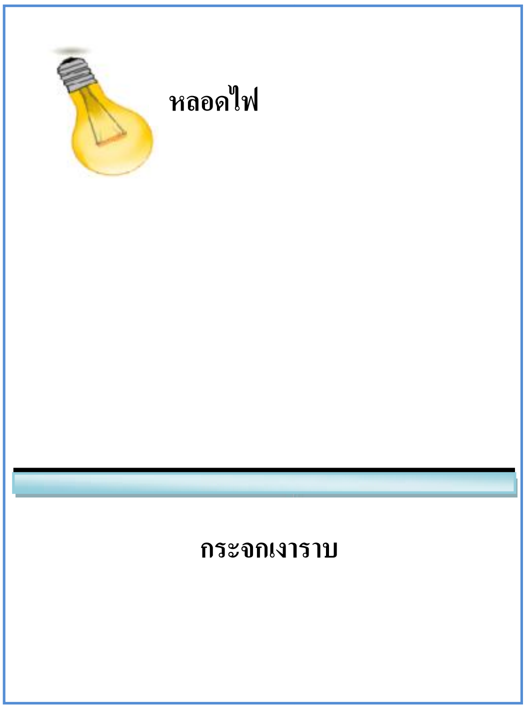
<u>กิจกรรมที่3</u>: “การสะท้อนของแสง”

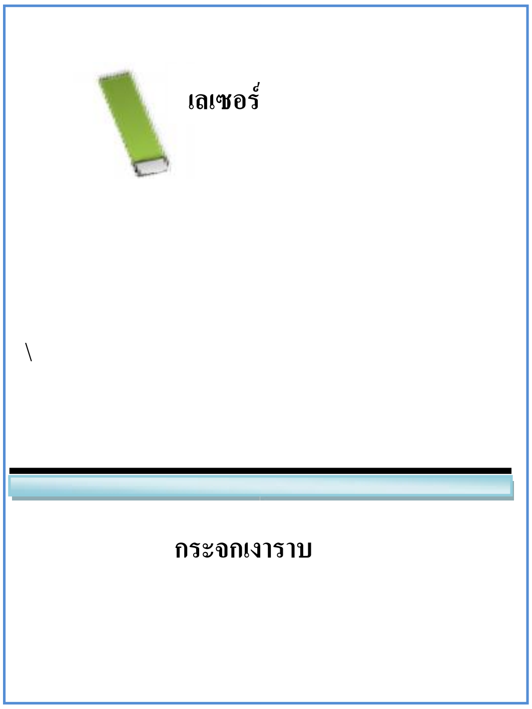
คำสั่ง: จงวาด<u>รังสีของแสง</u>เพื่อแสดง<u>แนวรังสีตกกระทบและแนวรังสีสะท้อน</u>ของแสงจากหลอดไฟและเลเซอร์ พร้อมอธิบายรูป

<u>ทำนายผลด้วยตนเอง</u>



<u>ทำนายผลหลังจากปรึกษาเพื่อน</u>

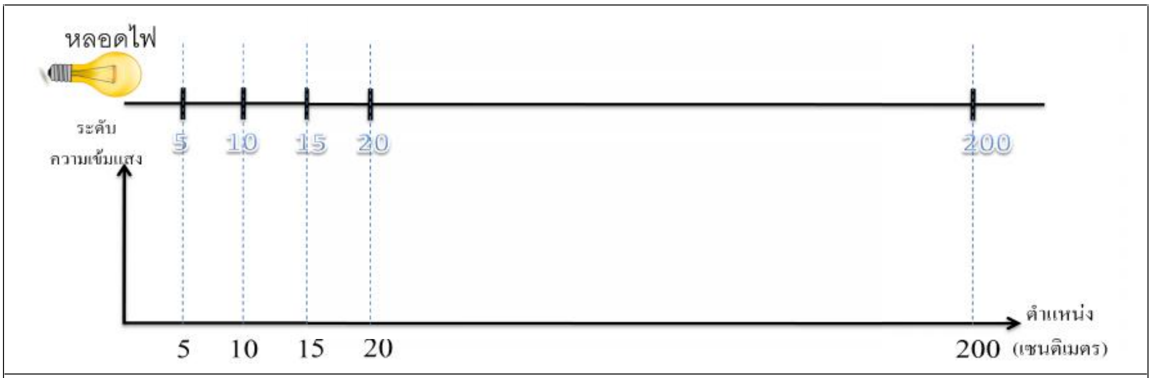


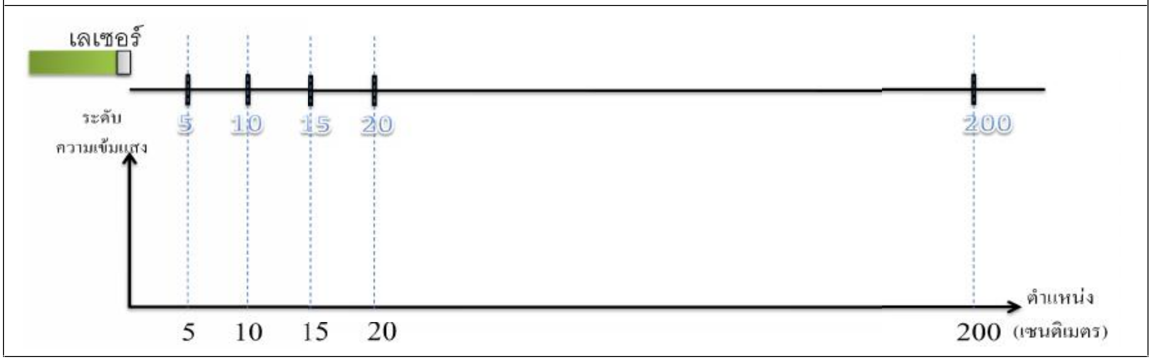


<u>กิจกรรมที่4</u>: "ความเข้มแสง"

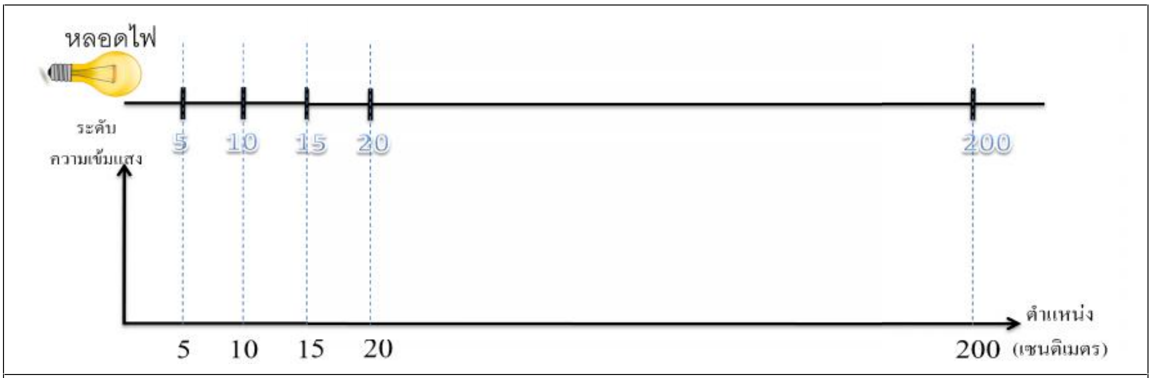
คำสั่ง: จงเขียนกราฟคร่าวๆเพื่อทำนาย<u>ระดับความเข้มแสงที่ตำแหน่งต่างๆ</u>ของแสงจากหลอดไฟและเลเซอร์

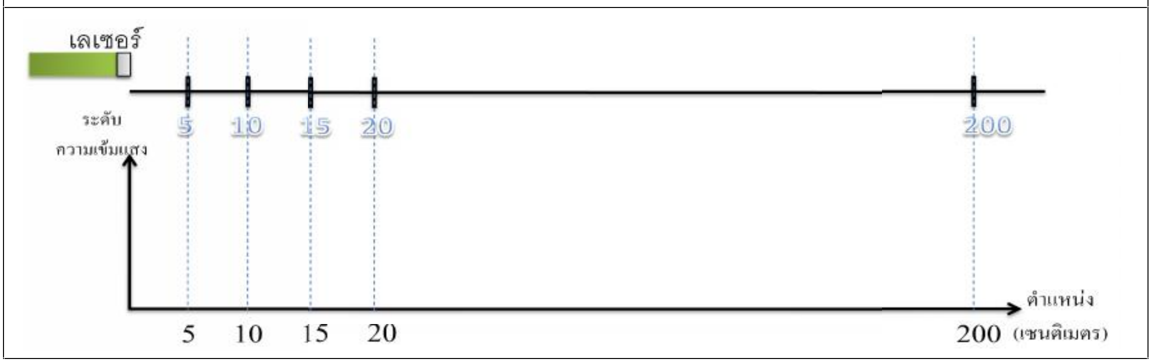
<u>ทำนายผลด้วยตนเอง</u>





<u>ทำนายผลหลังจากปรึกษาเพื่อน</u>





กิจกรรมที่5: "อัตราเร็วของแสงเลเซอร์"

คำสั่ง: จงเปรียบเทียบ**อัตราเร็ว**ของ***แสงจากหลอดไฟ***และ***แสงเลเซอร์***ที่ตำแหน่งต่างๆ

ทำนายผลด้วยตนเอง

☐ **มากกว่า**

อัตราเร็วของแสงเลเซอร์ ☐ **เท่ากับ** อัตราเร็วของแสงจากหลอดไฟ

☐ **น้อยกว่า**

เพราะ

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ทำนายผลหลังจากปรึกษาเพื่อน

☐ มากกว่า

อัตราเร็วของแสงเลเซอร์ ☐ เท่ากับ อัตราเร็วของแสงจากหลอดไฟ

☐ น้อยกว่า

เพราะ

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<u>กิจกรรมที่6:</u> "แสงเอกรงค์"

คำสั่ง: จงวาด**<u>รูปแสดงสีของแสงที่ปรากฏบนฉาก</u>** เมื่อนำแสงจากแหล่งกำเนิดสามชนิด คือ หลอดไฟ, ไดโอดเปล่งแสง(LED)สีเขียว, และเลเซอร์สีเขียว ส่องผ่านปริซึมดังรูป พร้อมอธิบายรูปที่วาด

<u>ทำนายผลด้วยตนเอง</u>

ฉากของหลอดไฟ **อธิบายรูป**	**ฉากไดโอดเปล่งแสง** (LED)**สีเขียว** **อธิบายรูป**	**ฉากเลเซอร์สีเขียว** **อธิบาย** ....

<u>ทำนายผลหลังจากปรึกษาเพื่อน</u>

ฉากของหลอดไฟ **อธิบาย**	**ฉากไดโอดเปล่งแสง** (LED)**สีเขียว** **อธิบาย**	**ฉากเลเซอร์สีเขียว** **อธิบาย** ....

APPENDIX D
THE WORK SHEETS

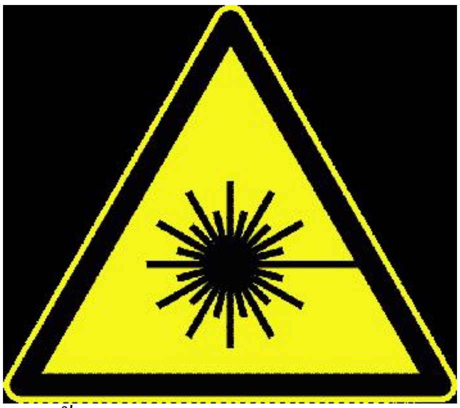
เอกสารประกอบการ-เรียนการสอน

เรื่อง

“คุณสมบัติพื้นฐานของเลเซอร์”

Light Amplification by Stimulated Emission of Radiation

ข้อควรระวังในการใช้เลเซอร์



เลเซอร์ที่ใช้ในการทดลองนี้ มี**ความเข้มสูงอันตรายมาก** โดยเฉพาะต่อสายตาของผู้ทดลอง ดังนั้น **ห้ามมองเลเซอร์โดยตรง** หรือ **นำเลเซอร์ไปฉายใส่ผู้อื่นเด็ดขาด**

กิจกรรมที่1: "ลักษณะการเดินทางของแสงออกจากแหล่งกำเนิดแสง"

คำสั่ง: จงเปรียบเทียบลักษณะการเดินทางของแสงจาก***หลอดไฟ***และ***เลเซอร์***

บันทึกผลการทดลอง: จงวาดรังสีแสดงลักษณะการเดินทางของแสงจากหลอดไฟและเลเซอร์ พร้อมอธิบายภาพ

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กิจกรรมที่2: "ลักษณะของลำแสงเลเซอร์"

<u>คำสั่ง</u>: จงอธิบายลักษณะของลำแสงเลเซอร์ที่ฉายออกมา

บันทึกผลการทดลอง: จงวาดรูปแสดงลักษณะของลำแสงเลเซอร์พร้อมอธิบายภาพ

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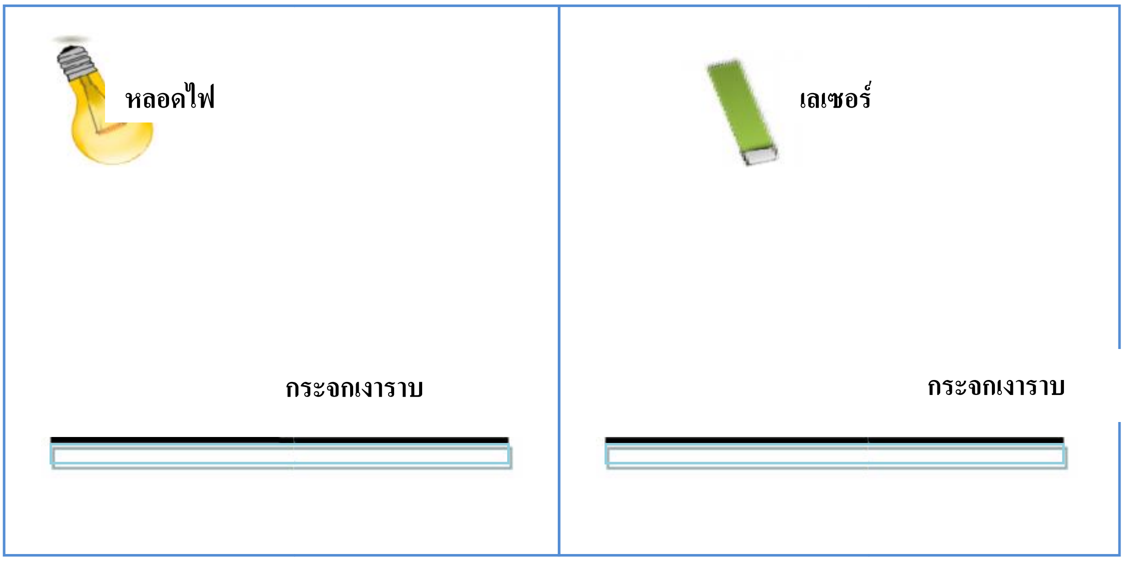
กิจกรรมที่3: "การสะท้อนของแสง"

<u>คำสั่ง</u>: จงเปรียบเทียบ<u>การสะท้อนของแสง</u>เนื่องจากกระจกเงาราบของ***หลอดไฟ***และ***เลเซอร์***

บันทึกผลการทดลอง: จงวาดรังสีของแสงเพื่อแสดงแนวรังสีตกกระทบและแนวรังสีสะท้อนจากหลอดไฟและเลเซอร์



สรุปผลการทดลอง

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กิจกรรมที่4: “ความเข้มแสง”

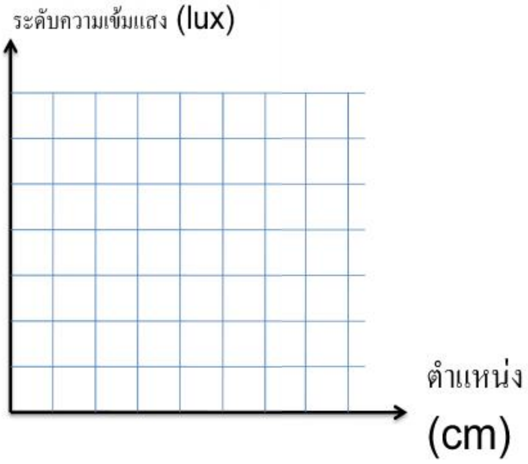
<u>คำสั่ง</u>: จงเปรียบเทียบ<u>ความเข้มแสง</u>ของ***หลอดไฟ***และ***เลเซอร์***ที่ตำแหน่งต่างๆ

บันทึกผลการทดลอง:

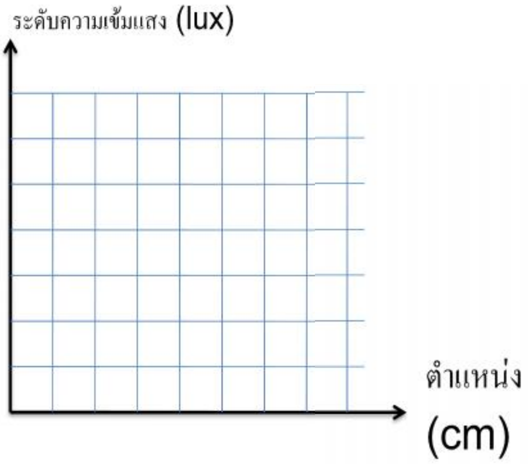
ที่ตำแหน่ง (เซนติเมตร)	ค่าความเข้มแสง (lux)	
	หลอดไฟ	เลเซอร์
5		
10		
15		
20		
150		
200		

จากตารางผลการทดลอง *<u>จงเขียนกราฟความสัมพันธ์ระหว่างระดับความเข้มแสงและตำแหน่ง</u>*

กราฟของหลอดไฟ



กราฟของเลเซอร์



สรุปผลการทดลอง

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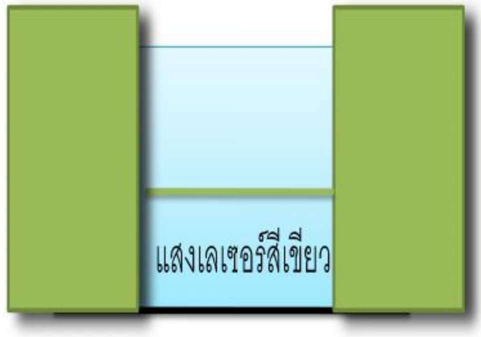
กิจกรรมที่5: "อัตราเร็วของแสงเลเซอร์"

<u>คำสั่ง</u>: จงเปรียบเทียบ**<u>อัตราเร็ว</u>**ของ***แสงจากหลอดไฟ***และ***แสงเลเซอร์***ที่ตำแหน่งต่างๆ

บันทึกผลการทดลอง:

		
เมื่อเปิดสวิตช์จะเห็นแสงเลเซอร์ค่อยๆพุ่งออกมาหรือไม่	**เมื่อเปิดสวิตช์จะเห็นแสงไฟฉายค่อยๆพุ่งออกมาหรือไม่**	**บอกได้หรือไม่ว่าแสงเลเซอร์สีเขียวพุ่งไปทางใด**
คำตอบ	**คำตอบ**	**คำตอบ**

สรุปผลการทดลอง

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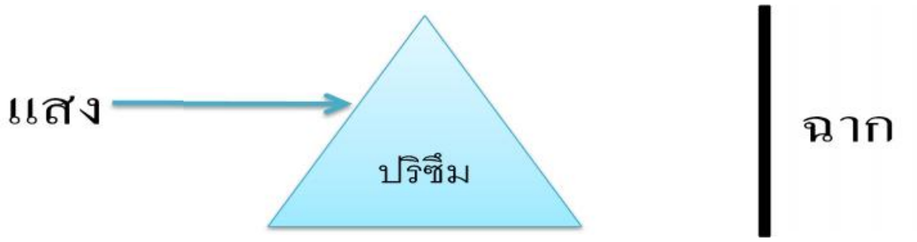
กิจกรรมที่6: "แสงเอกรงค์"

ตอนที่1

คำสั่ง: จงเปรียบเทียบลักษณะของแสงที่หักเหออกมาจากปริซึมของแหล่งกำเนิดแสงสามแบบ คือ ***หลอดไฟ, ไดโอดเปล่งแสง(LED)สีเขียว,*** และ***เลเซอร์สีเขียว*** เมื่อนำฉากไปรับ



บันทึกผลการทดลอง: จงวาดรูปแสดงลักษณะและสีของแสงที่ปรากฏบนฉาก

หลอดไฟ	ไดโอดเปล่งแสง(LED)สีเขียว	เลเซอร์สีเขียว

สรุปผลการทดลอง

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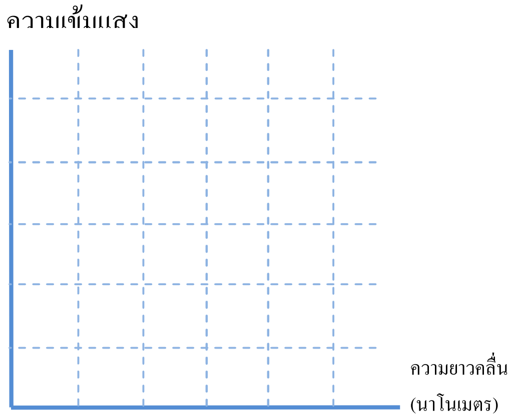
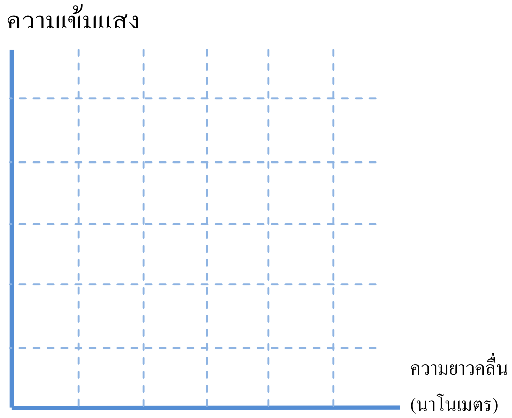
<u>ตอนที่2</u>

<u>คำสั่ง</u>: จงเปรียบเทียบ<u>ช่วงความยาวคลื่น</u>ของ***ไดโอดเปล่งแสง(LED)สีเขียว*** และ***เลเซอร์สีเขียว***

บันทึกผลการทดลอง: จงเขียนกราฟที่แสดงสเปกตรัมของแสงจากไดโอดเปล่งแสง(LED)สีเขียว และ เลเซอร์สีเขียว





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สรุปผลการทดลอง

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APPENDIX E
THAI VERSION OF LASER BEAM CONCEPTION EVALUATION (LBCE)

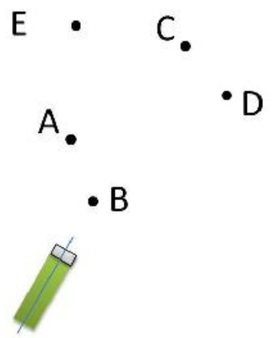
แบบทดสอบประเมินความเข้าใจเรื่อง "คุณสมบัติพื้นฐานของแสงเลเซอร์"

กลุ่มวิจัยฟิสิกส์ศึกษา

ภาควิชาฟิสิกส์ คณะวิทยาศาสตร์ มหาวิทยาลัยมหิดล

<u>คำชี้แจง</u> จงตอบคำถามข้อ 1-12 ในช่องว่างของกระดาษคำตอบ อย่าลืมกรอกชื่อ-นามสกุลลงในกระดาษคำตอบ ส่งกระดาษคำถามและกระดาษคำตอบคืนทั้งคู่ ห้ามเขียนคำตอบหรือบันทึกใดๆลงในกระดาษคำถาม

1. เมื่อวางเลเซอร์ไว้ดังรูป จากนั้นเปิดสวิตซ์ แสงเลเซอร์จะผ่านจุดใดได้บ้าง



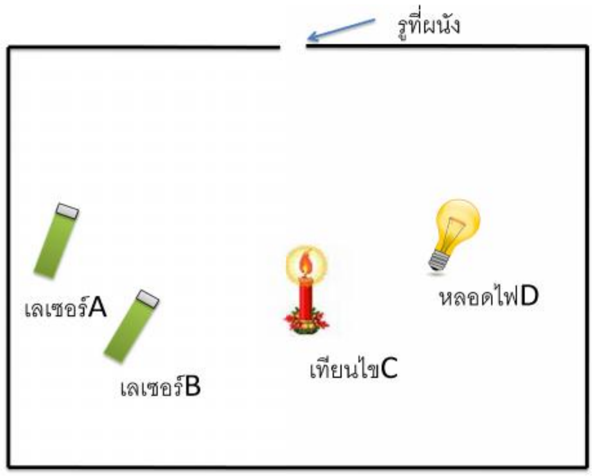
ก. ทุกจุด

ข. จุด B เท่านั้น

ค. จุด A, B, C และ E

ง. จุด B และ C

2. แหล่งกำเนิดแสง 4 ชนิดวางอยู่บนพื้นในกล่องมืดสนิทและผนังกล่องไม่สะท้อนแสง โดยที่มีรูอยู่บนผนังด้านหนึ่งดังรูป แสงจากแหล่งกำเนิดใดมีโอกาสเล็ดลอดออกจากรูที่ผนังห้องนี้ได้บ้าง



ก. เลเซอร์ B เท่านั้น

ข. เลเซอร์ B, เทียนไข C, และ หลอดไฟ D

ค. เทียนไข C และ หลอดไฟ D

ง. ทุกแหล่งกำเนิดแสง โดยที่เลเซอร์ A จะต้องสว่างมากๆ

3.เมื่อฉายแสงเลเซอร์จากยอดเขา A ไปยังยอดเขา B ที่อยู่ห่างกัน 10 กิโลเมตร ลักษณะของลำแสงเลเซอร์จะเป็นไปตามรูปใด

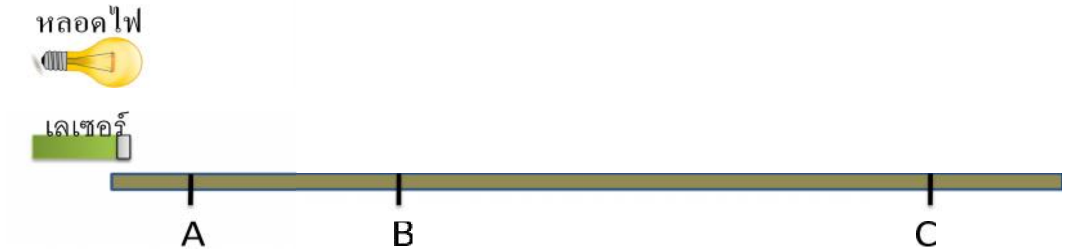
ก.

ข.

ค.

ง.

4. จากรูปเมื่อเปิดสวิตช์หลอดไฟและเลเซอร์



ข้อสรุปใดถูกต้อง

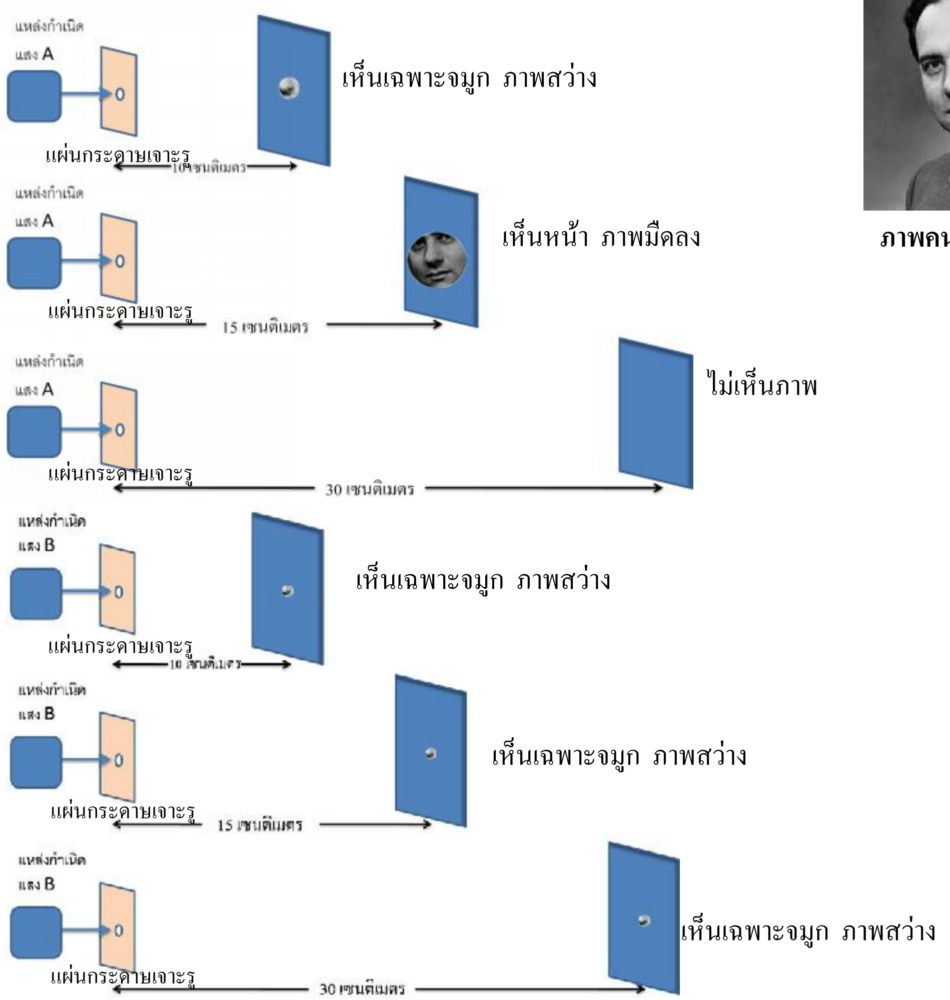
ก. ความเข้มแสงของหลอดไฟเท่ากันทุกตำแหน่ง, ความเข้มแสงของแสงเลเซอร์เท่ากันทุกๆตำแหน่ง

ข. ความเข้มแสงของหลอดไฟเท่ากันทุกๆตำแหน่ง, ความเข้มแสงของแสงเลเซอร์ที่ A > ที่ B > ที่ C

ค. ความเข้มแสงของหลอดไฟที่ A > ที่ B > ที่ C , ความเข้มแสงของแสงเลเซอร์เท่ากันทุกตำแหน่ง

ง. ความเข้มแสงของหลอดไฟที่ A > ที่ B > ที่ C , ความเข้มแสงของแสงเลเซอร์ที่ A > ที่ B > ที่ C

5. ทำการทดลองในห้องมืดโดยเจาะรูขนาดเส้นผ่านศูนย์กลางประมาณ 2 มิลลิเมตรบนแผ่นกระดาษเพื่อให้แสงจากแหล่งกำเนิดแสง A และ B ส่องผ่าน จากนั้นนำภาพคนไปดูที่ระยะ 10, 15 และ 30 เซนติเมตรจากรูที่เจาะไว้ตามลำดับ พบว่าจะมองเห็นภาพดังแสดงในรูป



ภาพคนที่นำมาดู

ข้อใดต่อไปนี้ถูกต้อง

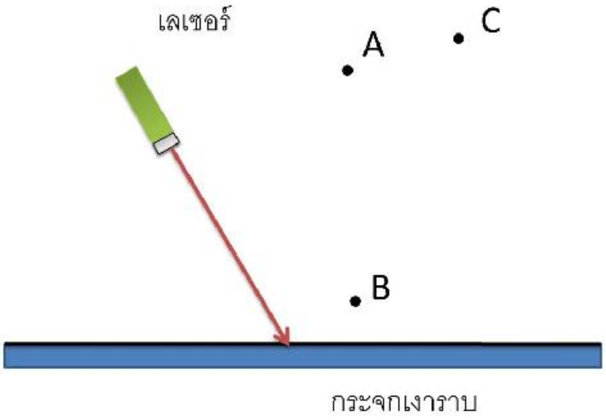
ก. แหล่งกำเนิดแสง A เป็นหลอดไฟ แหล่งกำเนิดแสง B เป็นหลอดไฟที่มีกำลังสูงกว่า A

ข. แหล่งกำเนิดแสง A เป็นเลเซอร์ แหล่งกำเนิดแสง B เป็นเลเซอร์ที่มีกำลังสูงกว่า A

ค. แหล่งกำเนิดแสง A เป็นหลอดไฟ แหล่งกำเนิดแสง B เป็นเลเซอร์

ง. แหล่งกำเนิดแสงทั้งสองเป็นได้ทั้งหลอดไฟและเลเซอร์

6. เมื่อวางเลเซอร์ไว้ดังรูป จะพบแสงสะท้อนที่ผ่านจุดใดได้บ้าง



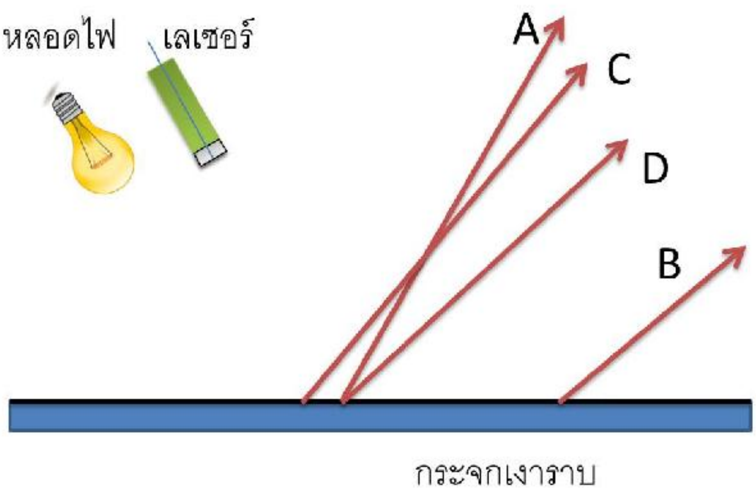
ก. A

ข. B

ค. C

ง. ทุกจุด

7.ถ้าวางหลอดไฟและเลเซอร์ไว้ที่ตำแหน่งดังรูป เมื่อแสงจากแหล่งกำเนิดแสงทั้งสองตกกระทบกระจกเงาราบ จากนั้นเราสามารถลากแนวรังสีสะท้อนของแสงที่เกิดขึ้นได้ดังรูป คำกล่าวในข้อใดถูกต้อง



ก. รังสี A เกิดจากเลเซอร์

ข. รังสี A, B, C, D เกิดจากหลอดไฟ

ค. รังสี B, C, D เกิดจากหลอดไฟเท่านั้น รังสี A เกิดจากเลเซอร์หรือหลอดไฟก็ได้

ง. รังสี A, D มาจากเลเซอร์ รังสี B, C มาจากหลอดไฟ

8. ข้อใดต่อไปนี้ถูกต้อง

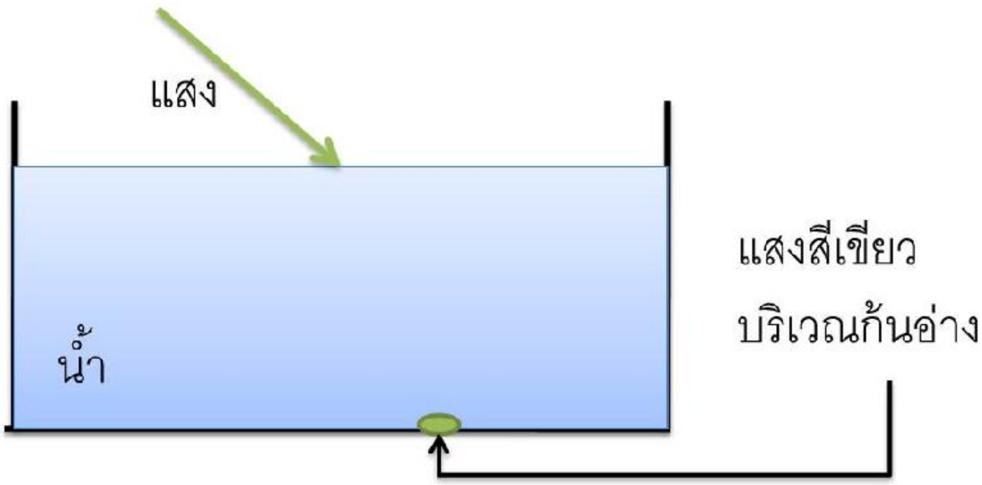
ก. อัตราเร็วของแสงเลเซอร์มากกว่าแสงจากหลอดไฟจึงไปปรากฏบนฉากไกลๆได้

ข. อัตราเร็วของแสงเลเซอร์มากกว่าแสงจากจากหลอดไฟเพราะเลเซอร์มีความเข้มแสงสูงกว่า

ค. อัตราเร็วของแสงทั้งสองเท่ากัน เพราะต่างก็เป็นคลื่นแม่เหล็กไฟฟ้า

ง. อัตราเร็วของแสงเลเซอร์มากกว่าแสงจากจากหลอดไฟเพราะแสงเลเซอร์มีพลังงานสูงกว่า

9. เมื่อฉายแสงชนิดหนึ่งลงน้ำที่อยู่ในอ่างอาบน้ำโดยฉายแสงเอียงทำมุมกับผิวน้ำ จะสังเกตเห็นแสงสีเขียวที่ก้นอ่าง ดังรูป ข้อสรุปใด<u>ถูกต้อง</u>



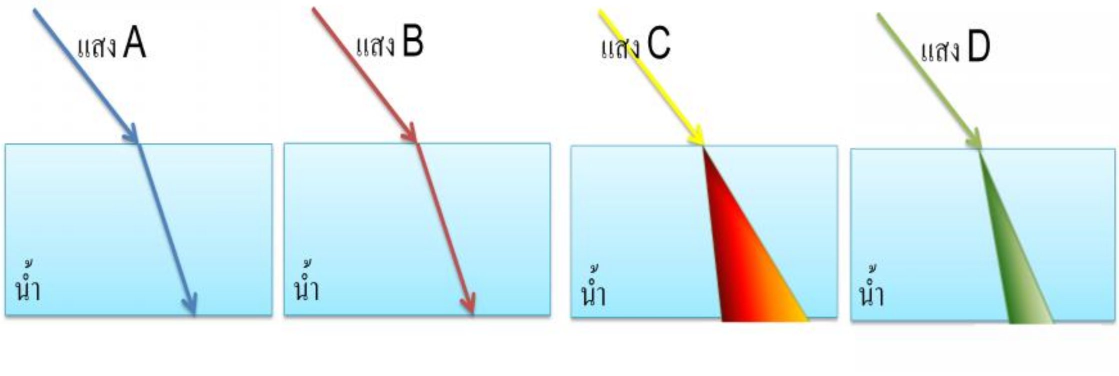
ก. แสงดังกล่าวเป็นแสงเลเซอร์เพราะเกิดการหักเหได้

ข. แสงดังกล่าวอาจจะเป็นแสงเลเซอร์เพราะไม่เกิดการกระจายเป็นหลายสี

ค. แสงดังกล่าวไม่เป็นแสงเลเซอร์เนื่องจากแสงเลเซอร์มีพลังงานสูงจะไม่เกิดการหักเหเมื่อเดินทางผ่านน้ำ

ง. แสงดังกล่าวอาจจะประกอบจากแสงหลายสีแต่สีอื่นกระเจิงไปหมด

10. ฉายแสงจากแหล่งกำเนิดแสง 4 ชนิดลงในน้ำปรากฏผลดังรูป



ข้อสรุปใดถูกต้อง

ก. แสง C มีช่วงความยาวคลื่นใกล้เคียงกับแสง D

ข. แสง A มีช่วงความยาวคลื่นแคบที่สุดเพราะหักเหน้อยที่สุด

ค. แสง B มีช่วงความยาวคลื่นแคบที่สุดเพราะหักเหมากกว่าแสงอื่น

ง. แสง A แยะ B มีช่วงความยาวคลื่นแคบที่สุดเพราะไม่เกิดการกระจายแสงหลังจากหักเหผ่านน้ำ

ใช้ข้อมูลต่อไปนี้ตอบคำถามข้อ 11-12

แหล่งกำเนิดแสง	ความยาวคลื่นของแสงที่ฉายออกมา (นาโนเมตร)	มุมบานของลำแสง (องศา)
A	730-1500	0.2
B	350-730	40
C	550-560	0.1
D	540-560	50

11. ถ้าต้องการแหล่งกำเนิดแสงที่ใช้สำหรับชี้สไลด์นำเสนอผลงาน ควรเลือกใช้แหล่งกำเนิดแสงในข้อใด

ก. แหล่งกำเนิดแสง A เพราะลำแสงมีมุมบานน้อย

ข. แหล่งกำเนิดแสง C หรือ D เพราะให้แสงที่มีช่วงความยาวคลื่นน้อย

ค. แหล่งกำเนิดแสง C เพราะลำแสงมีมุมบานน้อย

ง. แหล่งกำเนิดแสง B เพราะให้แสงในช่วงที่ตามองเห็น

12. ถ้าต้องการแหล่งกำเนิดแสงที่ใช้สำหรับให้แสงสว่างในถ้ำเพื่อสำรวจภาพวาดโบราณ ควรเลือกใช้แหล่งกำเนิดแสงในข้อใด

ก. แหล่งกำเนิดแสง A เพราะให้แสงหลายความยาวคลื่น

ข. แหล่งกำเนิดแสง D เพราะลำแสงมีมุมบานมาก

ค. แหล่งกำเนิดแสง B เพราะให้แสงในช่วงที่ตามองเห็น

ง. .เลือกใช้ได้ทุกอันเพราะสามารถให้แสงสว่างในที่มืดได้

กระดาษคำตอบ

แบบทดสอบก่อนเรียน

แบบทดสอบประเมินความเข้าใจเรื่อง “คุณสมบัติพื้นฐานของแสงเลเซอร์”

ชื่อ-สกุล ____

รหัสนักศึกษา ____

คณะ

____

มหาวิทยาลัย ____

1.________________	7.________________
2.________________	8.________________
3.________________	9.________________
4.________________	10.________________
5.________________	11.________________
6.________________	12.________________

กระดาษคำตอบ

แบบทดสอบหลังเรียน

แบบทดสอบประเมินความเข้าใจเรื่อง "คุณสมบัติพื้นฐานของแสงเลเซอร์"

ชื่อ-สกุล ____

รหัสนักศึกษา ____

คณะ

____

มหาวิทยาลัย ____

1.________________ 7.________________

2.________________ 8.________________

3.________________ 9.________________

4.________________ 10.________________

5.________________ 11.________________

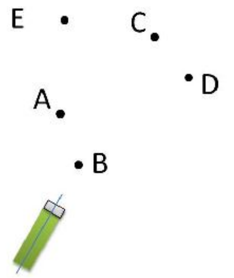
6.________________ 12.________________

APPENDIX F
ENGLISH VERSION OF LASER BEAM CONCEPTION EVALUATION (LBCE)

LASER BEAM CONCEPTIONS SURVEY
PHYSICS EDUCATION NETWORL OF THAILAND (PENThai)
DEPAERMENT OF PHYSICS, MAHIDOL UNIVERSITY, THAILAND

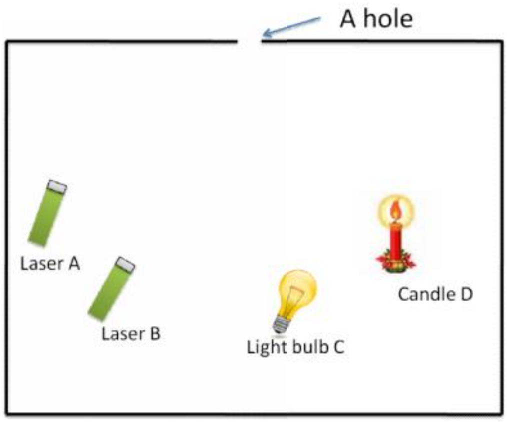
INSTRUCTION: Fill the correct answer in the answer sheets. Do not write anything inside the question paper.

Question 1: The laser is placed as shown in the picture and then its switch is turned on. Which point(s) can the laser light propagate through?



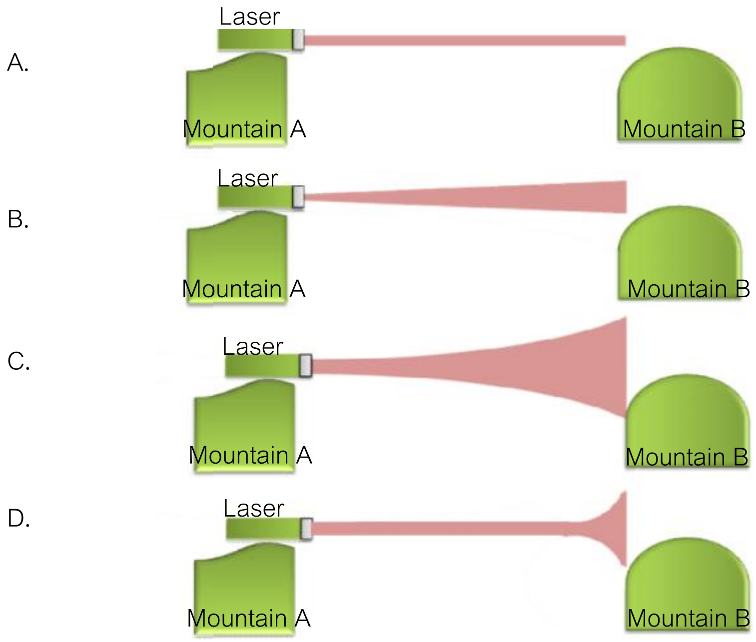
A. All points
B. Point B
C. Point A, B, C and E
D. Point B and C

Question 2: Laser A, Laser B, Light bulb C and Candle D are placed in the dark room that has a hole on one side of the wall as shown in the picture below. Light cannot be reflected be the wall. When we turn on all light source and light the candle, Light emitted from which light sources can propagate through the hole to go outside of the room?

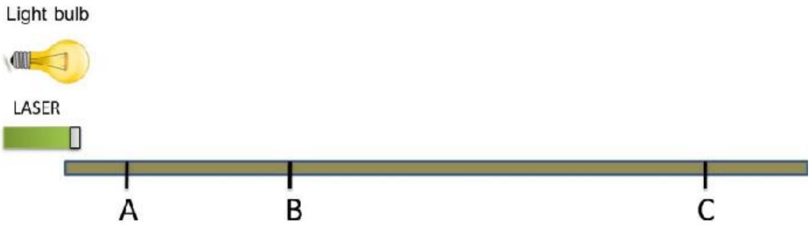


A. Laser B
B. Laser B, Light bulb C and Candle D
C. Light bulb C and Candle D
D. All Light source, but Laser A must emit very intense light.

Question 3: The laser light is emitted from the top of mountain A to the top of mountain B which is 10 kilometers apart. Which choice shows the picture of laser beam?



Question 4: A laser and a light bulb are placed as shown in the picture. Both light source are switched on, which choice contain the **correct** statement?



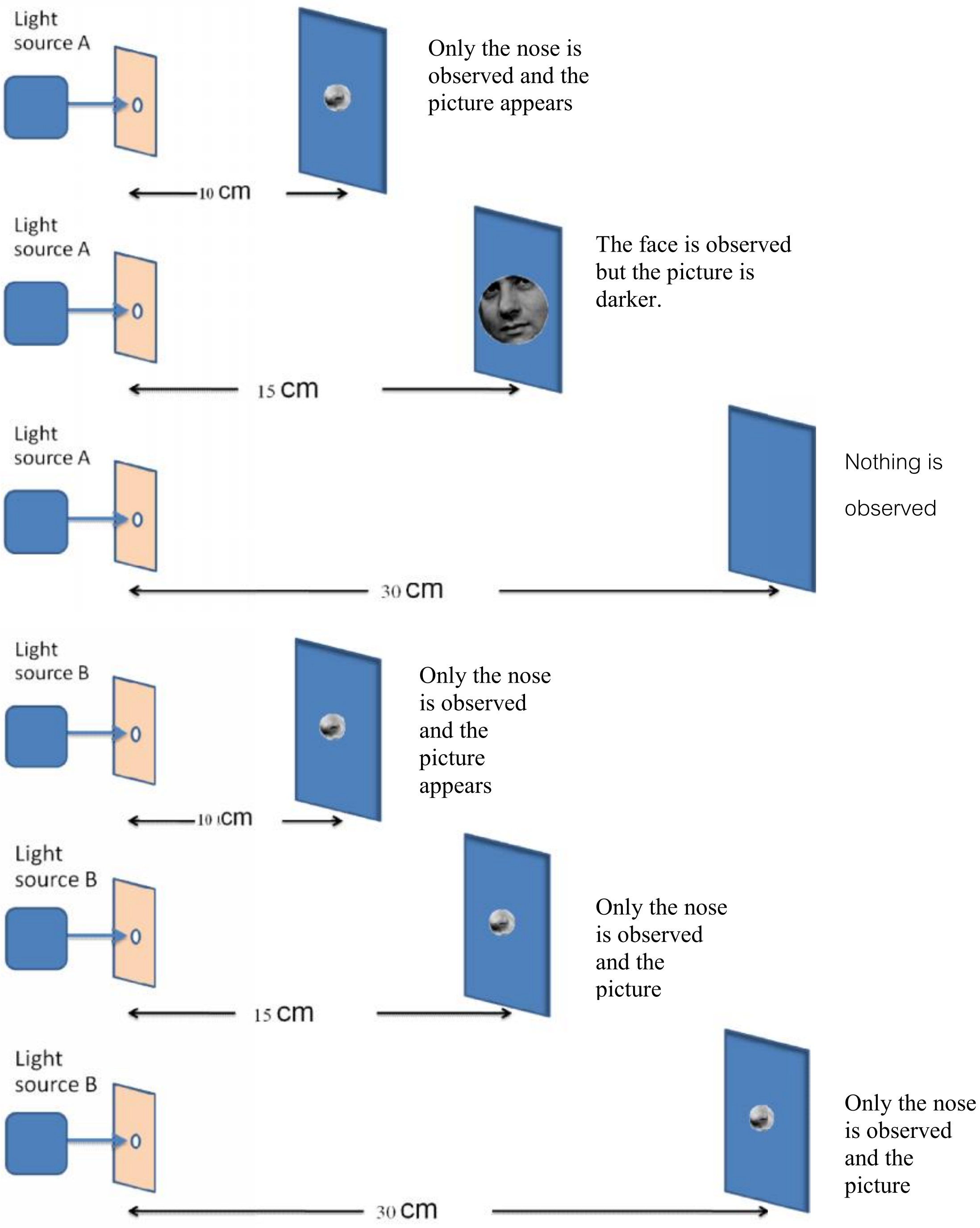
A. Intensity of light emitted from light bulb are the same at all position; Intensity of light emitted from laser are the same at all position.

B. Intensity of light emitted from light bulb are the same at all position; Intensity of light emitted from laser at A > at B > at C.

C. Intensity of light emitted from light bulb at A > at B > at C; Intensity of light emitted from laser are the same at all position.

D. Intensity of light emitted from light bulb at A > at B > at C; Intensity of light emitted from laser at A > at B > at C

Question 5: Observe a picture in the dark room; a paper with a hole is placed in front of light source A and B as shown in the figure below. Then we place a photograph at a distance 10 cm from the paper and observe the photograph. After that the distance is changed to 15 and 30 cm respectively. The observation results are show in the figure. What can the light source A and B be?



Which choice contain the **<u>correct</u>** statement?

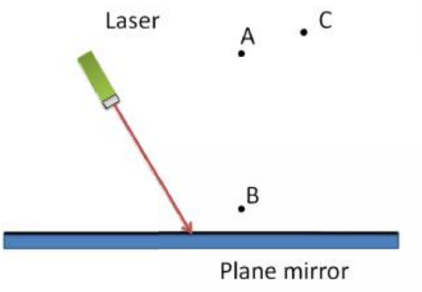
A. Both light sources are light bulb but light bulb B has higher power than light bulb A.

B. Both light sources are laser but laser B has higher power than light bulb A.

C. Light source A is light bulb; Light source B is laser.

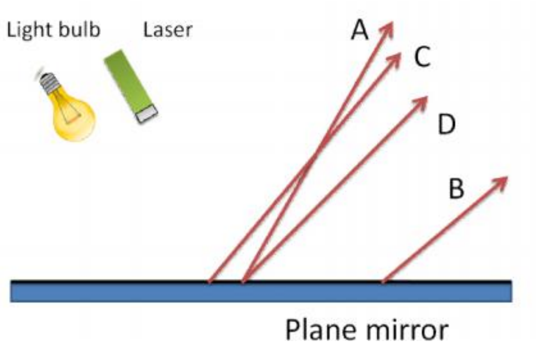
D. Both light sources can be either light bulb or laser.

Question 6: A laser is placed as shown in the picture below. Which point(s) will the reflected light propagate through?



A. Point A
B. Point B
C. Point C
D. All points

Question 7: A light bulb and a laser are placed as shown in the picture below. When we turn on both light sources, we find the reflected rays A, B, C and D. Which choice contain the **<u>correct</u>** statement?



A. Ray A is emitted from laser.
B. Ray A, B, C and D are emitted from light bulb.
C. Ray B, C and D are certainly emitted from light bulb; Ray A is emitted from both light bulb and laser.
D. Ray A and D are emitted from laser; Ray B and C are emitted from light bulb

Question 8: Which choice contain the **correct** statement?

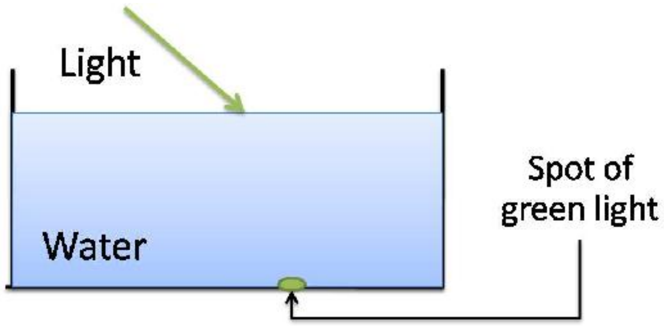
A. Speed of light emitted from laser is greater than light emitted from light bulb because laser light can appear on the screen very far away.

B. Speed of light emitted from laser is greater than light emitted from light bulb because laser light has higher intensity.

C. Speed of light emitted from laser and light emitted from light bulb are equal because both of them are electromagnetic wave.

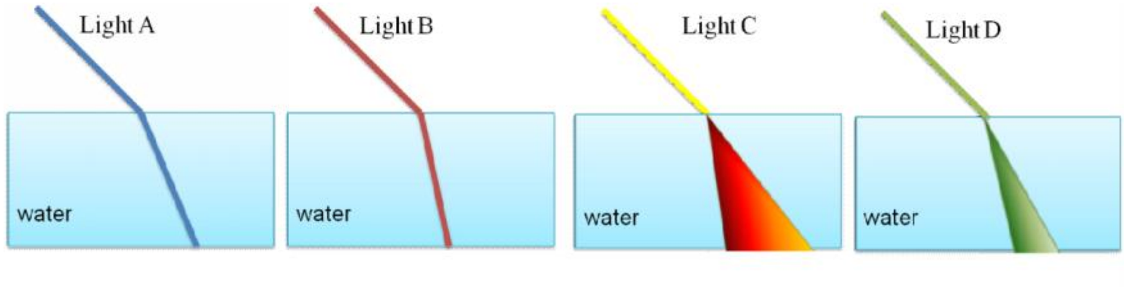
D. Speed of light emitted from laser is greater than light emitted from light bulb because laser light has higher energy.

Question 9: The light from an unknown light source propagates from air through water in a tank as shown in the picture. The observer can see only the spot of green light at the bottom of the tank. Which choice contain the **correct** statement?



A. The unknown light is laser light because it refract when propagating to the different media.
B. The unknown light is laser light because it does not disperse to be multiple colors light.
C. The unknown light is not laser light because laser light does not refract when propagating to the different media such as from air to water.
D. The unknown light may be multiple wavelengths light but other color light except green are completely scattered.

Question 10: The emitted lights from 4 kinds of light sources are propagated from air to water. We can observe the phenomena as shown in the picture bellow. Which choice contain the **correct** statement?



A. Light C has equal spectral width as light D
B. Light A has the narrowest spectral width because it refracts with the smallest bending than others.
C. Light B has the widest spectral width because it refracts with the largest bending than others.
D. Both Light A and Light B have the narrowest spectral width because they do not disperse after propagate from air to water.

Use the following informations to help answering Question 11 and 12

Light source	**Wavelength of the emitted light (nm)**	**Beam divergence angle (Degree)**
A	730-1500	0.2
B	350-730	40
C	550-560	0.1
D	540-560	50

Question 12: If we need a light source for pointing slides during the presentation, which light is/are suitable for this work? Why?

A. Light source A because it has small beam divergence angle.
B. Light source C or D because both has narrow spectral width.
C. Light source C because it has small beam divergence angle.
D. Light source B because it emits visible light.

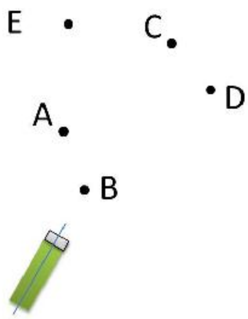
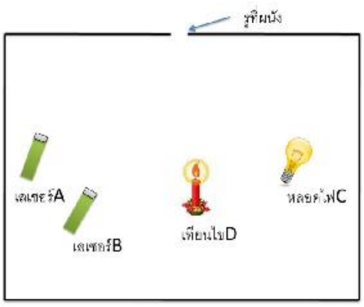
Question 13: If we need a light source for surveying the ancient drawing in a cave, which light is/are suitable for this work? Why?

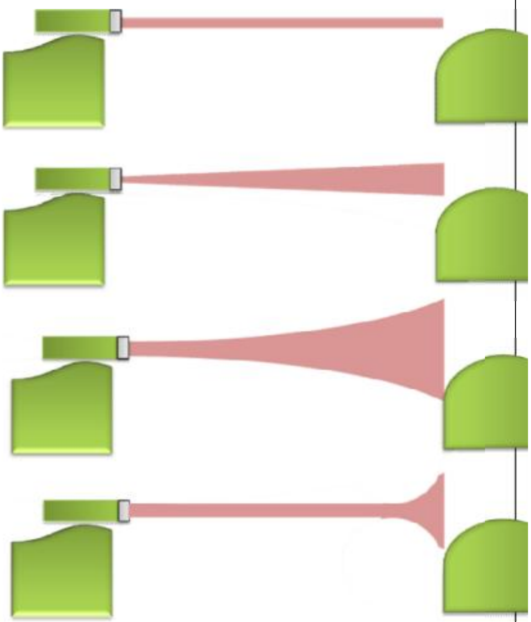
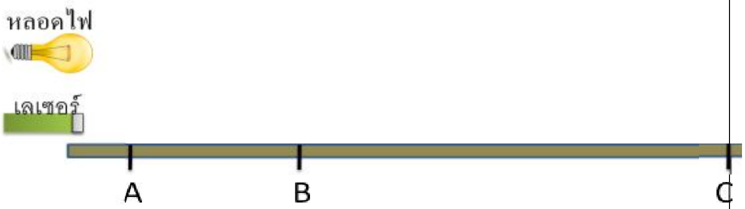
A. Light source A because it emits multiple wavelength light.
B. Light source D because it has large beam divergence angle.
C. Light source B because it emits visible light.
D. All can be used because they can emit light to illuminate in the dark place.

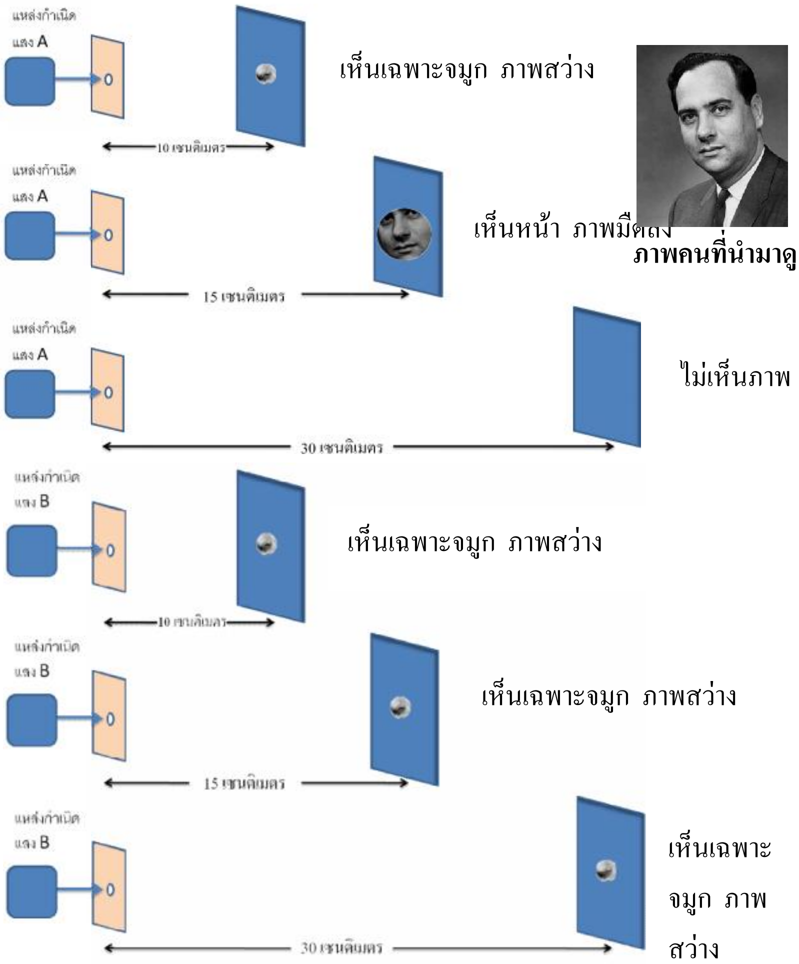
APPENDIX G
TABLE FOR VALIDATION THE INDEX OF ITEM-OBJECTIVE CONGRUENCE BY EXPERTS

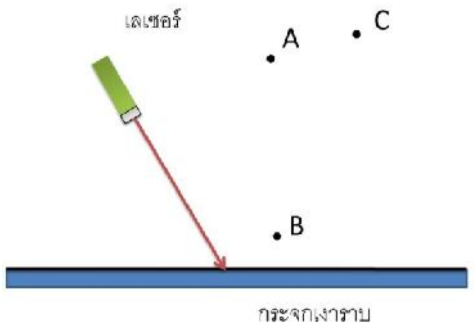
ตารางพิจารณาความสอดคล้องระหว่างคำถามกับจุดประสงค์

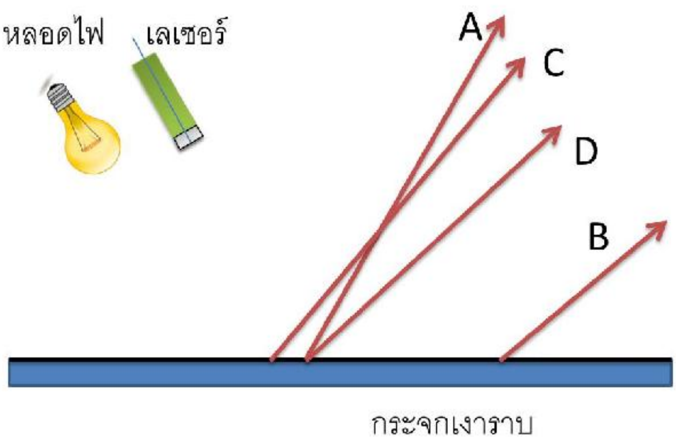
คำชี้แจง ตารางนี้ออกแบบเพื่อให้ผู้เชี่ยวชาญพิจารณาว่าคำถามนั้นๆ วัดได้ตรงตามจุดประสงค์หรือไม่ โดยถ้า "แน่ใจว่าตรง" ให้ทำเครื่องหมายในช่อง " +1 " แต่ถ้า "แน่ใจว่าไม่ตรง" ให้ทำเครื่องหมายในช่อง " -1 " และถ้า "ไม่แน่ใจว่าตรงหรือไม่" ให้ทำเครื่องหมายในช่อง " 0 "

จุดประสงค์	คำถาม	การพิจารณา		
		+1	0	-1
นักเรียนอธิบายได้ว่าแสงเลเซอร์เดินทางเป็นเส้นตรง มีทิศทางที่แน่นอน	1. เมื่อวางเลเซอร์ไว้ดังรูป จากนั้นเปิดสวิตซ์ แสงเลเซอร์จะผ่านจุดใดได้บ้าง  ก. ทุกจุด ข. จุด B เท่านั้น ค. จุด A, B, C และ E ง. จุด B และ C			
นักเรียนอธิบายได้ว่าแสงเลเซอร์เดินทางเป็นเส้นตรง มีทิศทางที่แน่นอน	2. แหล่งกำเนิดแสง 4 ชนิดวางอยู่บนพื้นในกล่องมืดสนิทและผนังกล่องไม่สะท้อนแสงโดยที่มีรูอยู่บนผนังด้านหนึ่งดังรูป แสงจากแหล่งกำเนิดใดมีโอกาสเล็ดลอดออกจากรูที่ผนังห้องนี้ได้บ้าง  ก. เลเซอร์ B เท่านั้น ข. เลเซอร์ B, เทียนไข C, และหลอดไฟ D ค. เลเซอร์ B และ เทียนไข C ง. ทุกแหล่งกำเนิดแสง โดยที่เลเซอร์ A จะต้องสว่างมากๆ			

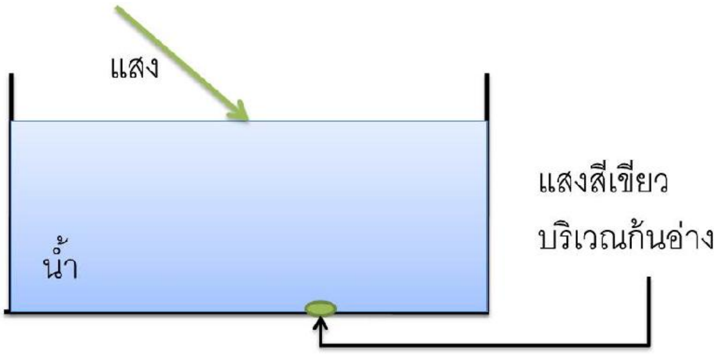
จุดประสงค์	คำถาม	การพิจารณา		
		+1	0	-1
นักเรียนสามารถอธิบายลัษณะการบานออกของลำแสงเลเซอร์ได้	3.เมื่อฉายแสงเลเซอร์จากยอดเขา A ไปยังยอดเขา B ที่อยู่ห่างกัน 10 กิโลเมตร ลักษณะของลำแสงเลเซอร์จะเป็นไปตามรูปใด ก. ข. ค. ง. 			
นักเรียนสามารถบรรยายเปรียบเทียบความเข้มแสงของเลเซอร์และหลอดไฟที่ระยะต่างๆได้	4. จากรูปเมื่อเปิดสวิทช์หลอดไฟและเลเซอร์  ข้อสรุปใดถูกต้อง ก. ความเข้มแสงของหลอดไฟเท่ากันทุกตำแหน่ง, ความเข้มแสงของแสงเลเซอร์เท่ากันทุกๆตำแหน่ง ข. ความเข้มแสงของหลอดไฟเท่ากันทุกๆตำแหน่ง, ความเข้มแสงของแสงเลเซอร์ที่ A > ที่ B > ที่ C ค. ความเข้มแสงของหลอดไฟที่ A > ที่ B > ที่ C , ความเข้มแสงของแสงเลเซอร์เท่ากันทุกตำแหน่ง ง. ความเข้มแสงของหลอดไฟที่ A > ที่ B > ที่ C , ความเข้มแสงของแสงเลเซอร์ที่ A > ที่ B > ที่ C			

จุดประสงค์	คำถาม	การพิจารณา		
		+1	0	-1
นักเรียนสามารถอธิบายลักษณะความเข้มแสงของแสงจากหลอดไฟและแสงเลเซอร์ได้	5. ทำการทดลองในห้องมืดโดยเจาะรูบนแผ่นกระดาษให้แสงจากแหล่งกำเนิดแสง A และ B ส่องผ่านจากนั้น นำภาพคนไปดูที่ระยะ 10, 15 และ 30 เซนติเมตรจากรูที่เจาะไว้ตามลำดับ พบว่าจะมองเห็นภาพดังแสดงในรูป  ข้อใดต่อไปนี้ถูกต้อง ก. แหล่งกำเนิดแสง A เป็นหลอดไฟ แหล่งกำเนิดแสง B เป็นหลอดไฟที่มีกำลังสูงกว่า A ข. แหล่งกำเนิดแสง A เป็นเลเซอร์ แหล่งกำเนิดแสง B เป็นเลเซอร์ที่มีกำลังสูงกว่า A ค. แหล่งกำเนิดแสง A เป็นหลอดไฟ แหล่งกำเนิดแสง B เป็นเลเซอร์ ง. แหล่งกำเนิดแสงทั้งสองเป็นได้ทั้งหลอดไฟและเลเซอร์			

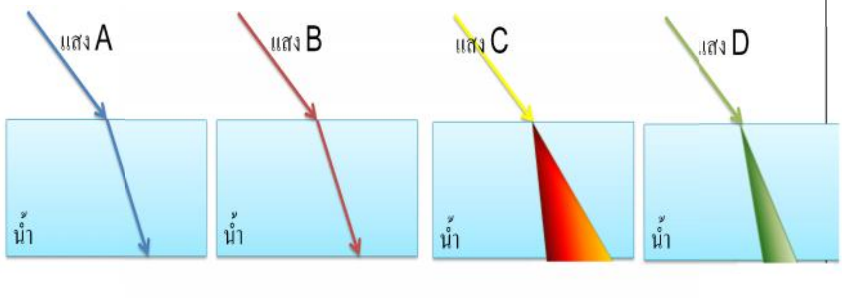
<table>
<tr><th rowspan="2">จุดประสงค์</th><th rowspan="2">คำถาม</th><th colspan="3">การพิจารณา</th></tr>
<tr><th>+1</th><th>0</th><th>-1</th></tr>
<tr><td>นักเรียนสามารถอธิบายการสะท้อนของแสงเลเซอร์ที่กระจกเงาราบได้</td><td>6. เมื่อวางเลเซอร์ไว้ดังรูป จะพบแสงสะท้อนที่จุดใดได้บ้าง


ก. A
ข. B
ค. C
ง. ทุกจุด</td><td></td><td></td><td></td></tr>
<tr><td>นักเรียนสามารถอธิบายการสะท้อนของแสงเลเซอร์และแสงจากหลอดไฟที่กระจกเงาราบได้</td><td>7.ถ้าวางหลอดไฟและเลเซอร์ไว้ที่ตำแหน่งดังรูป เมื่อแสงจากแหล่งกำเนิดแสงทั้งสองตกกระทบกระจกเงาราบ จากนั้นเราสามารถลากแนวรังสีสะท้อนของแสงที่เกิดขึ้นได้ดังรูป คำกล่าวในข้อใด<u>ถูกต้อง</u>


ก. รังสี A เกิดจากเลเซอร์
ข. รังสี A, B, C, D เกิดจากหลอดไฟ
ค. รังสี B, C, D เกิดจากหลอดไฟเท่านั้น รังสี A เกิดจากเลเซอร์หรือหลอดไฟก็ได้
ง. รังสี A, D มาจากเลเซอร์ รังสี B, C มาจากหลอดไฟ</td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th rowspan="2">จุดประสงค์</th><th rowspan="2">คำถาม</th><th colspan="3">การพิจารณา</th></tr>
<tr><th>+1</th><th>0</th><th>-1</th></tr>
<tr><td>นักเรียนอธิบายได้ว่าแสงเลเซอร์และแสงจากหลอดไฟมีอัตราเร็วเท่ากัน</td><td>8. ข้อใดต่อไปนี้<u>ถูกต้อง</u>
ก. อัตราเร็วของแสงเลเซอร์มากกว่าแสงจากหลอดไฟจึงไปปรากฏบนฉากไกลๆได้
ข. อัตราเร็วของแสงเลเซอร์มากกว่าแสงจากจากหลอดไฟเพราะเลเซอร์มีความเข้มแสงสูงกว่า
ค. อัตราเร็วของแสงทั้งสองเท่ากัน แต่ความเข้มแสงของเลเซอร์มากกว่าจึงเห็นเฉพาะแสงเลเซอร์บนฉากไกลๆ
ง. อัตราเร็วของแสงเลเซอร์มากกว่าแสงจากจากหลอดไฟเพราะแสงเลเซอร์มีพลังงานสูงกว่า</td><td></td><td></td><td></td></tr>
<tr><td>นักเรียนสามารถอธิบายได้ว่าแสงเลเซอร์เป็นแสงที่มีช่วงความยาวคลื่นแคบจึงไม่เกิดการกระจายเป็นหลายสีเมื่อหักเหผ่านน้ำ</td><td>9. เมื่อฉายแสงชนิดหนึ่งลงน้ำที่อยู่ในอ่างอาบน้ำโดยฉายแสงเอียงทำมุมกับผิวน้ำ จะสังเกตเห็นแสงสีเขียวที่ก้นอ่าง ดังรูป ข้อสรุปใด<u>ถูกต้อง</u>


ก. แสงดังกล่าวเป็นแสงเลเซอร์เพราะเกิดการหักเหได้
ข. แสงดังกล่าวอาจจะเป็นแสงเลเซอร์เพราะไม่เกิดการกระจายเป็นหลายสี
ค. แสงดังกล่าวไม่เป็นแสงเลเซอร์เนื่องจากแสงเลเซอร์มีพลังงานสูงจะไม่เกิดการหักเหเมื่อเดินทางผ่านน้ำ
ง. แสงดังกล่าวอาจจะประกอบจากแสงหลายสีแต่สีอื่นกระเจิงไปหมด</td><td></td><td></td><td></td></tr>
</table>

จุดประสงค์	คำถาม	การพิจารณา		
		+1	0	-1
นักเรียนสามารถบอกความสัมพันธ์ระหว่างช่วงความยาวคลื่นของแสงและลักษณะของลำแสงหักเหได้	10. ฉายแสงจากแหล่งกำเนิดแสง 4 ชนิดลงในน้ำปรากฏผลดังรูป  ข้อสรุปใดถูกต้อง ก. แสง C มีช่วงความยาวคลื่นใกล้เคียงกับแสง D ข. แสง A มีช่วงความยาวคลื่นแคบที่สุดเพราะหักเหน้อยที่สุด ค. แสง B มีช่วงความยาวคลื่นแคบที่สุดเพราะหักเหมากกว่าแสงอื่น ง. แสง A แยะ B มีช่วงความยาวคลื่นแคบที่สุดเพราะไม่เกิดการกระจายแสงหลังจากหักเหผ่านน้ำ			

ใช้ข้อมูลต่อไปนี้ตอบคำถามข้อ 11-12

แหล่งกำเนิดแสง	ความยาวคลื่นของแสงที่ฉายออกมา (นาโนเมตร)	มุมบานของลำแสง (องศา)
A	730-1500	0.1
B	350-730	40
C	550-560	0.1
D	540-560	40

จุดประสงค์	คำถาม	การพิจารณา		
		+1	0	-1
นักเรียนสามารถเลือกคุณสมบัติที่จำเป็นที่สุดสำหรับการประยุกต์ใช้แสงเลเซอร์สำหรับชี้เป้าหมายได้	11. ถ้าต้องการแหล่งกำเนิดแสงที่ใช้สำหรับชี้สไลด์นำเสนอผลงาน ควรเลือกใช้แหล่งกำเนิดแสงในข้อใด ก. แหล่งกำเนิดแสง A เพราะลำแสงมีมุมบานน้อย ข. แหล่งกำเนิดแสง C หรือ D เพราะให้แสงที่มีช่วงความยาวคลื่นน้อย ค. แหล่งกำเนิดแสง C เพราะลำแสงมีมุมบานน้อย ง. แหล่งกำเนิดแสง B เพราะให้แสงในช่วงที่ตามองเห็น			
นักเรียนสามารถเลือกแหล่งกำเนิดแสงที่มีช่วงความยาวคลื่นเหมาะสมที่สุดสำหรับให้แสงสว่างได้	12. ถ้าต้องการแหล่งกำเนิดแสงที่ใช้สำหรับให้แสงสว่างในถ้ำเพื่อสำรวจภาพวาดโบราณ ควรเลือกใช้แหล่งกำเนิดแสงในข้อใด ก. แหล่งกำเนิดแสง A เพราะให้แสงหลายความยาวคลื่น ข. แหล่งกำเนิดแสง D เพราะลำแสงมีมุมบานมาก ค. แหล่งกำเนิดแสง B เพราะให้แสงในช่วงที่ตามองเห็น ง. .เลือกใช้ได้ทุกอันเพราะสามารถให้แสงสว่างในที่มืดได้			

APPENDIX H
THE SATISFACTION QUESTIONNAIRS

แบบทดสอบประเมินความเข้าใจเรื่อง "คุณสมบัติพื้นฐานของแสงเลเซอร์"

แบบสำรวจความพึงพอใจต่อกิจกรรมการเรียนการสอน

เรื่อง คุณสมบัติของแสงเลเซอร์

แบบสำรวจนี้ไม่มีผลต่อเกรดและคะแนนของนักเรียน แต่จะเป็นประโยชน์ต่อการพัฒนาการเรียนการสอนเรื่องคุณสมบัติของแสงเลเซอร์ จึงขอความร่วมมือให้นักเรียนลงความคิดเห็นต่อข้อความข้างล่างตามระดับความคิดเห็นระหว่าง 1 (ไม่เห็นด้วยอย่างยิ่ง) ถึง 5 (เห็นด้วยอย่างยิ่ง) ที่ส่งเสริมให้นักเรียนเข้าใจเนื้อหาเรื่องนี้ โดยใส่เครื่องหมาย ✓ ลงตามระดับความคิดเห็น

1: ไม่เห็นด้วยอย่างยิ่ง	2: ไม่เห็นด้วย	3: ปานกลาง	4: เห็นด้วย	5: เห็นด้วยอย่างยิ่ง

	วิธีการต่อไปนี้ช่วยให้นักเรียนเข้าใจเนื้อหาเรื่อง คุณสมบัติของแสงเลเซอร์	**1**	**2**	**3**	**4**	**5**
1	การมีชุดสาธิตประกอบการสอน					
2	การให้ใบกิจกรรม(หรือใบงาน)ประกอบการเรียนการสอน					
3	การให้ร่วมงานเป็นกลุ่มและแลกเปลี่ยนความคิดเห็นกับเพื่อน					
4	การให้มีการทำนายเหตุการณ์ก่อนและตามด้วยการสาธิตจริง					
5	การยกตัวอย่างเหตุการณ์จริง					

9.วิธีการเรียนการสอนแบบอื่นๆ ที่นักเรียนคิดว่าช่วยส่งเสริมความเข้าใจได้ดีขึ้น

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10. ความพึงพอใจต่อการเรียนการสอนในครั้งนี้ (เขียนอธิบายพร้อมยกตัวอย่าง)

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BIOGRAPHY

NAME	Jintawat Tanamatayarat
DATE OF BIRTH	21 March 1981
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