Laser Energy Transfer: Moving Towards the Future At The Speed of Light

A Module on the theory and innovations of Laser Energy Transfer. Topics discussed are basic quantum theory, laser power, laser propulsion and laser fusion. An exciting and interactive way to present lasers. A multimedia approach that makes the laser come alive.

Amanda DiCarlo
Christopher DiLoreto
Joey Pavlovski
Magdalena Tywoniuk

University of Windsor
thinking forward

TABLE OF CONTENTS

Table of Contents 2

Introduction to the Module 3

List of Equipment and Supplies 4

Preparing For The Presentation 5

The Presentation 6

- Overview: The Flow Chart 6
- Getting Started (building the foundation) 6
- Laser Power 8
- Laser Propulsion 9
- Laser Fusion 10
- Wrapping it up 12

References 12

Manuscript Date: March 21, 2010

INTRODUCTION TO THE MODULE

This MMIM on ***Laser Energy Transfer*** is designed as a way to make you an ambassador of Physics to senior level high school students (grades 11 and 12). You will be able to bridge the gap between rudimentary physics and the seemingly boundless and unreachable world of current physics research. This presentation is designed as an easy way to make physics attractive to these students and spark their interest in pursuing a physics career.

This module will provide students with an insight into the basics of modern quantum physics and how it applies to the real world. A lot of the students' current knowledge is built into the presentation to make laser concepts very approachable. It is strongly suggested that you present the idea that the students are learning "Quantum Physics" as a WOW factor. As having this kind of intellectual credibility amongst their friends and family members will surely peak their interest. The students will also receive a take-home handout over viewing the theory and a data disk with a laser game, simulations and links to share with others.

The objective is to convey a sense of excitement and possibility through the technology and theory that underlie Laser energy transfer. The goal is not to create a stuffy classroom atmosphere, but present a relaxed, almost peer-to-peer conversation about this new physics. It is through your sense of excitement and interest, as if you are explaining a new finding to a colleague that you want to engage the students. The module will help you do this through various multimedia and activities that supplement each section of the module. The PowerPoint, handouts and videos, will visually capture the students and prevent your presentation from becoming dry or heavy-handed. The simulations and videos will be a reprieve for both you and the students from the 'talking-head' aspect of the presentation. The activities are the primary way you will engage the students and filled with questions and ideas for the students to answer.

Note that the presentation relies on the students own Ontario Science Curriculum and should serve as a good guide for any elaboration or addition that you might make to this presentation. As well you must keep a few goals and objectives in mind as you work through the module:

- This presentation takes 60-90 minutes to complete, you should move at a pace that keeps the presentation dynamic.
- The presentation focuses mostly on the 12th grade curriculum. Since the goal is to expand ideas, make sure that a presentation involving grade 11 students involves more clarification and perhaps interludes of question –taking.
- Ask the teacher for assistance in engaging the students and promoting questions. The goal is to make the presentation comfortable and interactive, so the teacher will be a good resource with which the students are already at ease.
- Setup your activities ahead of time and check that everything is working. Problems with or rushing around with lasers will inevitably lead to unsafe situations.

- The objective of this module is that it be self-contained with a predetermined flow. Therefore, each section builds on the previous one and the goal is to complete all of these. Make sure that you check the equipment list and order all the things that are needed.

Finally, the main objective is that you ENJOY yourself, so the students can get a sense of enthusiasm and pride for physics on your part.

List of Equipment and Supplies

Reusable Equipement Available From University of Windsor Physics Department

- Light Vane (See Figure 4)
- Projector for Power Point Presentation

Reusable Equipement Included In The Presentation Kit

- Presentation Disk (Containing PowerPoint Presentation and handout)
- 200 mW Laser Pointer
- Handheld Flashlight
- Ball Bearings of Various Sizes
- Curved Platform

Equipment Which Needs Replacing or Additional Preparation

- Balloons, Tape, Magic Markers
- Handouts – A copy is provided on the Presentation Disk. Copies must be printed for all students.
- Laser Key Chains – If laser key chains will be distributed and there are not enough laser key chains included with the presentation for all students, additional keychains may need to be purchased.
- Data Disks – The Data Disk for students will need to be copied to be distributed.

Preparing For The Presentation

- 1 Month Before Presentation
  - Contact the teacher to determine, the grade level and number of students
  - Ask what parts of the curriculum have been covered thus far.
  - Prepare the presentation announcements for the teacher to handout to the students.
  - Ask the teacher what context the presentation will have in his/her lesson plan.
  - Determine the date and room of the presentation obtain permission and pass on the information to the teacher.

- 3 Weeks Before Presentation
  - Check your equipment list against available equipment
  - Contact the university physics department to determine which equipment is still working and available to borrow.
  - Place orders for equipment that needs replacing or must be renewed.

- 2 Weeks Before Presentation
  - Check which parts of the presentation need to be reprinted, such as the handouts and place the order.
  - Check which parts of the presentation need to be copied to data disk and any labels that need to printed and affixed.

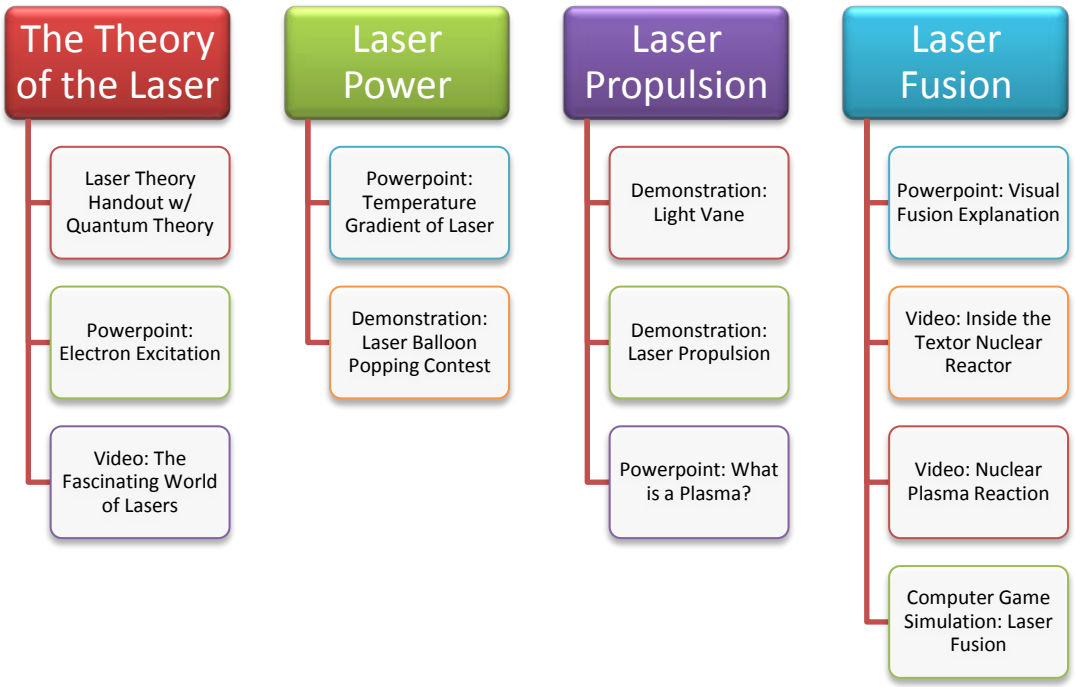
- 1 Week Before the Presentation
  - Run through all experiments and double check that equipment works smoothly.
  - Run through presentation and time it to make sure that fits within the allotted time.

- Day Before Presentation
  - Check and prepare the assigned room for the presentation, setting up chairs and clearing space. Set up all equipment and do a finally run through of presentation.
  - Check that handouts, data disks and all components are available and ready.

- Day of Presentation
  - Go for it!
  - Don’t forget to secure all equipment at the end of the presentation

THE PRESENTATION

OVERVIEW: THE FLOW CHART



GETTING STARTED (BUILDING THE FOUNDATION)

- Thank everyone for coming and introduce the members of you team.
- Tell the students that it is the 50th Anniversary of the birth of the Laser.
- Ask the students how many of them have seen a laser in a movie before? (*Prompt them for the answers.)*
- Then ask the students how many of them use lasers? Tell them that they use them every day and inquire if they know where they use them?
- Surely you will get a lot of answers to these

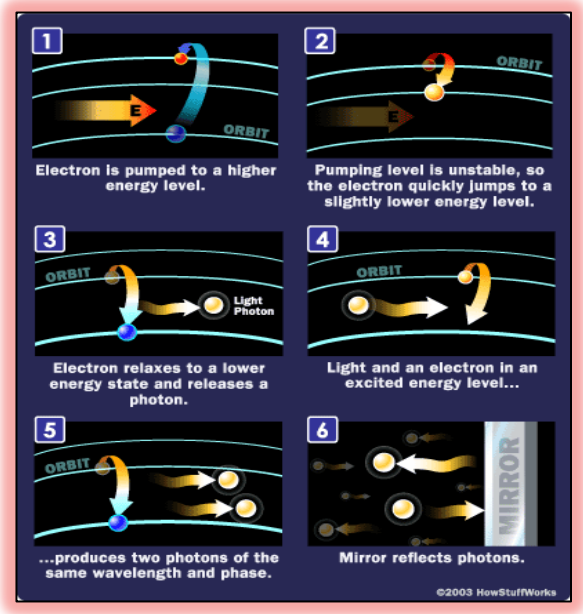


FIGURE 1 - VISUAL REPRESENTATION OF STIMULATED EMISSION.

questions. Tell the students they seem to know quite a lot about lasers, seeing and using them all the time. Surprise them, and ask them if maybe one of them can explain to you how a laser actually works. (*Of course you will get no answers, but the realization of the simple fact that they use them all the time and can't explain them will open the door to a conversation.)*

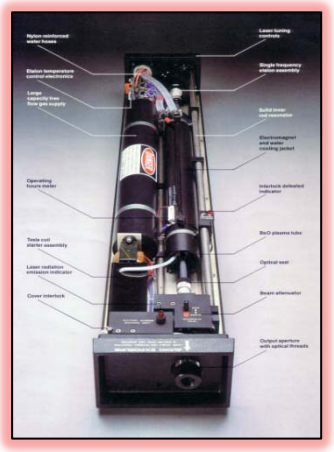


FIGURE 2 – THE INSIDE OF A LASER.

- **HANDOUT:** Tell the students you will explain this process and distribute the handout that covers the theory on laser function. Tell the students that after today they can now amaze everyone by telling them they are studying Quantum Theory.

- **POWERPOINT:** Start the introduction, incorporating Planck's law, and the process of stimulated emission outlined on the power point containing figure 1. Include the properties of a laser beam: monochromatic, coherent, and collimated.

- Show the students your working laser and all the parts where these things occur. Then show the slide with figure 2 and explain where the internal processes take place.

- **VIDEO:** Embedded into the power point is a quick 5 minute video explaining the laser at a higher level that will expand the ideas you have explained. Move to the slide containing the video as in figure 3.

- Tell the students you will now show them the amazing things that lasers can do!

FIGURE 3 – THE FASCINATING WORLD OF LASERS VIDEO

LASER POWER

- Ask the students whether they have heard that lasers can be dangerous? (*Perhaps use an available photo or cartoon to introduce this topic!)*

- Begin with something to which the student can relate. They must routinely use flashlights, and they probably have never burned through anything by shining the flashlight on it. However, they must have seen that a harmless ray of sunlight shining through a lens can burn an ant. So what is the difference here?

- **Power Point:** Reinforce the concept of highly focused light as in the sunlight/lens case above. Then explain that a laser has a highly polarized/ focused beam of monochromatic light. Explain that this kind of light can heat up one area of a material creating a steep temperature gradient and make it exhibit different properties than the area surrounding it.

- **Demonstration:** This will illustrate the concept of power transfer by a laser with a demonstration.

    - Set up two balloons, one black and one white. Tape them to a surface like a table at the same distance and in the same orientation.
    - Shine a flashlight on the balloons. Observe that nothing happens.
    - Based on the beginning section of the presentation, ask students if they were paying attention and who can explain why the laser appears to be the colour that it is?
    - Tell the students that two of your team members (presenters) are going to engage in a competition of laser prowess. They will battle it out to see who pops their balloon faster. Assign each a balloon then time their performance.
    - The black balloon will pop faster. Ask the students whether this team member has amazing skills or whether there is another reason that he won. Then explain that the dark balloon more readily absorbs this frequency of light and the other reflects it.
    - Pose the question: Based on optical principles of absorption and reflection, how could we modify the white balloon in order to decrease the time it takes to pop? Solution: Colour a spot on the balloon surface black with a magic marker so that more of the laser light will be absorbed.

      Tip: Hold the laser extremely steady and focused or affix it in position so that it is shining on the same area the majority of the time. Also, turn off the lights to increase the effect.

      For visual effect and excitement: instead of a single balloon, use a line of white balloons and a line of black balloons. In this case, the time difference will be more noticeable.

LASER PROPULSION

- Now you can tell the students that we shall explore the future of the laser. The goal of this section is to let the students see the opportunities that are available to them if they choose to pursue physic s as a career.

- Begin by asking the student about force. What is it about force which will make something move? What is required? Mass? Something Solid? (*Allow students to make suggestions.)*

- **Demonstration:** This experiment illustrates the ability of light to transfer momentum and energy.
    - Place the light mill (shown in figure 4) at the front of the audience.
    - Explain that the light mill, also known as Crooke's Radiometer, is an instrument for demonstrating the conversion of light energy into mechanical work. Ask how they think this might be possible?
    - First, shine the flashlight on the bulb to attempt to rotate the light vane within. This might work since the light vane is very lightweight. However, if it doesn't work, then the laser can surely be used to rotate the light vane. Ask students why the laser seems to push the black side of the light vane fans rather than the metal side.

FIGURE 4 - LIGHT VANE

- They have learned about kinematics and perhaps electrostatic force in their science classes. Now that they have seen the propulsion power of light, tell them that the following experiment is even more astonishing, Proceed with the demonstration shown in figure 5.

- **Demonstration:** This demonstration can be done or the video version[2] can be shown if obtaining the curved surface is too difficult.
    - Place the ball bearing at the edge of the curved platform as shown in the figure 4.
    - Shine the laser pointer on it until it is pushed off the edge and rolls down the surface. *You may try to stop it*

FIGURE 5 – THE LASER PROPULSION SURFACE AND BALL BEARING.

or slow it down on the other side to extend the demonstration if you wish.

- Ask the students if they saw the same things as you: the light push the ball bearing. Of course they did and they will say yes. Then ask them how this can be if the light has NO MASS?! (*They probably will not have considered this before and it might add some wow value at this point.)*
- Explain that this is something that is a Quantum Phenomenon and covered by the rules of Quantum Theory. Move on to the power point with the relativistic equations and propulsion derivation.

- **PowerPoint:** Draw the students' attention to the slide that contains the equations for a relativistic transfer of momentum from a light photon to a solid object.
- Explain that there is a lot of research into laser propulsion. It is actually something that NASA is very interested in to power space-craft in the future. Why? There are a couple reasons to mention. (Ask the students if they know before spoiling the answers!)
- Explain to the students that the fuel in this process creates no pollution and the fuel can even be air! Then the second reason must be that it's extremely CHEAP!
- You will need to explain what plasma is; a gas which receives an input of energy from a laser and ionizes the atoms, so they are free to move around. The plasma can conduct electricity and has its own properties.
- Move to the slide with figure 5 containing a picture of plasma.
- Discuss the current achievements that light propulsion research has achieved as outlined on the same slide.

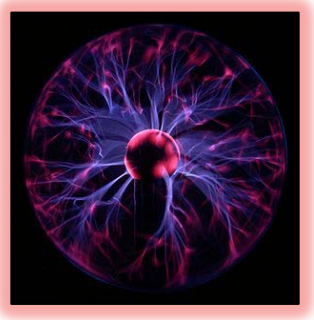


FIGURE 5 – PLASMA LAMP CONTAINING EXCITED GAS.

LASER FUSION

- Show the students a fiery picture of the sun in figure 6 and tell them that this is a process that physicists can reproduce with lasers.
- Comment on how the sun strangely resembles the picture of the plasma.

- **Power Point:** Find the slide that contains the picture of the sun and the visual process of what happens in nuclear fusion.
- Lead the students through the concept by addressing the parts they already know about. Begin by telling them what they know about Coulomb force and charges. They know that atoms repel each other. Why? (*You can ask them to explain, which they surely can)*. Obviously they will mention

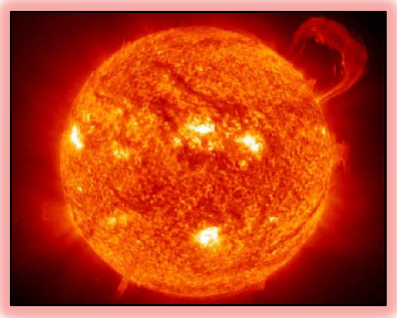


FIGURE 6 – NUCLEAR FUSSION ON THE SUN.

the like charges of electrons and the like charges of the protons repelling each other.

- Ask them if they think that two positive nuclei could actually be pushed together (*it will be interesting to just hear their answers.)*
- Explain the concept of the coulomb barrier that is formed by the coulomb repulsion between the nuclei and the amazing amount of energy that is needed to get those atoms to overcome it and fuse. In fact, we are trying to do this so that we can use the huge amount of energy that is released when the fusion actually occurs.
- Comment on how hydrogen on the sun constantly fuses in this way. Where is the energy required for this process produced? It comes from the gigantic mass of the sun and pushes the atoms together.
- Tell the students that on earth we use lasers to create plasmas, and as these plasmas expand outward, they create a compressive force on the atoms in their bulk and force the nuclei together.

FIGURE 7 – THE INSIDE OF THE TEXTOR FUSION REACTOR.

- **Video:** Ask the students whether they have ever seen a nuclear reactor? Have they been in one? Well they will be because we have a 360 degree view of the inside of a nuclear reactor.[3] Then we shall also show them what a plasma fusion reaction looks like in that reactor.

- **Activity:** This portion of the presentation includes an interactive laser computer game in which students try to fuse two atoms together by the use of model lasers.
  - Explain the controls necessary to play the game and discuss game strategies. For example, based on what students have learned in the demonstration, in which directions should the point the lasers on the game to force the atoms together?
  - Ask for a student volunteer to be try the game on the overhead projector, as a demonstration.
  - Tell students that everyone will get to experiment with the game after the wrap-up of the presentation.

WRAPPING IT UP

- Allow students to ask any final questions they may have.
- With the consent of the teacher, hand out laser key chains to students to take home.
    - Laser key chains only have 1 mW power, so students should not expect that they can perform in the same manner as the laser used in demonstrations. However, are there any experiments that might be successful with the laser key chains? Hint: Light Mill experiment. (Allow students to try this themselves after the presentation. If one key chain does not do the trick, perhaps two or three students shining their laser key chains on the light mill will do the trick?)
- Hand out the copies Data Disk provided.
    - The disk contains additional information for ambitious students.
    - It also contains the laser fusion game. If sufficient computer access is available, allow students time to try the game after the presentation.

REFERENCES

1. The Fascinating World of Lasers. [Instructional Video, March 22, 2010]. *Berthold, Leibinger, Stiftung*. Retireved from http://www.leibinger-stiftung.de/2.video_faszination_laser.html
2. Laser Propulsion. 2008. [Public Video, March 22, 2010]. *Posted by hflewell, YouTube*. Retrieved from http://www.youtube.com/watch?v=Ui-oEW2s1iQ
3. TEXTOR Fusion Reaction. 2007. [Public Video, March 22, 2010]. *Posted by StephenDonelly88, YouTube.* Retrieved from http://www.youtube.com/watch?v=EQeBgL9lR6w&feature=related
4. How Lasers Work. (n.d.) In *How Stuff Works.* Retrieved from http://www.howstuffworks.com/laser.htm
5. Siegman, A.E. (1986). *Lasers.* CA: University Science Books