LASERS

OSA Educational Resources … *Exploring the Science of Light*

Optical Society of America

Optical Society of America (OSA)

Founded in 1916, OSA brings together optics and photonics scientists, engineers, educators and business leaders. OSA is dedicated to providing its members and the scientific community with educational resources that support technical and professional development. OSA's publications, events and services help to advance the science of light by addressing the ongoing need for shared knowledge and innovation. The Society's commitment to excellence and continuing education is the driving force behind all its initiatives.

OSA's Education Outreach

Education outreach is one the most important and significant ways OSA supports and inspires young scientists. A variety of materials and programs have been developed to address the needs of students from elementary school through 12th grade. We invite you to explore the education resource pages at www.osa.org and welcome your comments and suggestions. Contact OSA's educational programming staff at opticseducation@osa.org.

The OSA Foundation

Inspiring the next generation of scientists and engineers

The future's great scientists are among the children of today and tomorrow. These children live and study around the world. Some have the resources and support needed to succeed, but many others do not. The OSA Foundation believes all students should have access to quality education resources and everyone should have the opportunity to explore scientific studies and career paths.

The Foundation focuses on advancing youth science education by providing students with access to science educators and learning materials through interactive classroom and extracurricular activities. To learn more about the Foundation and its funded programs or to request support for your program, please visit www.OSA-Foundation.org, e-mail foundation@osa.org or call +1.202.416.1421.

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Daniel Eversole, Univ. of Texas at Austin, USA; Irene Georgakoudi, Tufts Univ., USA; Halina Rubinsztein-Dunlop, Univ. of Queensland, Australia, and Ali Serpenguzel, Koç Univ., Turkey.

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LASERS

Imagine a light beam as powerful as all the electric power plants in the world put together, focused into a beam the diameter of a pin, but for just a few millionth of a millionth of a second. What would it do? How would you produce such a light beam?

The term LASER is an acronym for Light Amplification by Stimulated Emission of Radiation and represents an optical source that produces photons (particles of light) in a coherent beam. Unlike a light bulb that scatters light, a laser light is typically monochromatic, meaning that it consists of single wavelength or color and is emitted in a narrow beam. Many types of lasers have been invented, ranging from gaseous to liquid to solid state gain media. How do we make a laser?

To make a laser we need a couple of mirrors, some type of a gain medium and a source of energy to initialize a process. This energy is needed to activate the process of stimulated emission in the medium. Light bounces back and forth between the mirrors, gaining in intensity each time it passes through the medium, until high intensities are reached.

Some lasers deliver continuous radiation (streams of photons); others can produce very intense and extremely short pulses of light just femtoseconds long. With the energy squeezed into such a short time, power peaks as high as terawatts can be produced. These high intensity pulses can ionize air and transmit light through the atmosphere (as seen here) without diffraction (or spreading), enabling the beam of light to be guided as far as hundreds of meters.

Definitions

Coherent Beam
A beam of light whose photons all have the same wavelength, phase, and direction.

Diffraction
A phenomenon that occurs whenever a light wave is obstructed in any way. Often diffraction fringes can be seen when a small aperture or object blocks light waves.

Femtoseconds
A femtosecond is one billionth of one millionth of a second. For context, a femtosecond is to a second, what a second is to about 32 million years.

Gain Medium
A gain medium is either a gas, liquid or solid that provides means for optical gain which is generated by stimulated emission on transitions from higher to lower states. It can amplify the power of light.

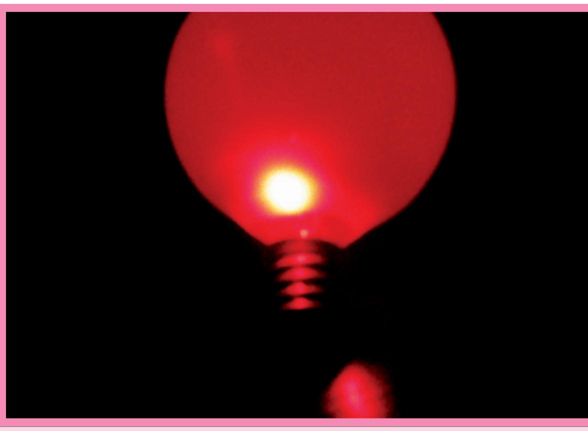
Ionize
Ionization is the physical process of converting an atom or molecule into an ion by changing the difference between the number of protons and electrons. An ion is an atom or molecule that has lost or gained one or more electrons, making it negatively or positively charged. If an atom loses an electron(s), it becomes a positive ion. If an atom gains an electron(s), it becomes a negative ion.

Plasma Channel
Plasma channels are formed when a high-powered laser operates at a certain frequency, providing enough energy for an atmospheric gas to break into its ions. A plasma channel has a low electrical resistance and, once formed, will permit continuous current flow if the energy source that heats the plasma can be maintained.

Terawatts
A terawatt is 1000 billion watts, a quantity of energy that would require more than 500 nuclear reactors or thousands of coal-burning plants to produce.

Wavelength
The distance from the peak of a wave crest to the peak of the subsequent wave crest, or from one trough to the next trough.

EXPERIMENTS Lasers can make light do amazing things!



What You Need

- Key chain laser or small laser pointer
- Clean plastic soda bottle
- Water
- Cornstarch
- Frosted incandescent light bulb
- Old CDs or DVDs (unscratched and scratched)
- Various smooth and textured glass objects (wine glass, goblet, vases)
- Ice cube
- Room with adjustable lighting

LASER ALERT!
Lasers – including laser pointers – are not toys and should be handled with care. Never look into a laser or aim it at people or animals. To see if a laser pointer is on, aim it at the wall or the floor.

To protect your eyes from laser beam scattering and reflections, you should wear ski goggles or sunglasses with large lenses that have UV protection.

Fast Fact
Popular science fiction films often show laser battles showcasing starfighters shooting beams of light at each other. This light show serves as an excellent visual and leaves movie-goers wide-eyed and excited about laser technology. Unfortunately, lasers actually would not be visible in space. This is due to the lack of matter necessary to cause "scattering," the effect that gives the laser the appearance of a beam of light.

1. Reflection in a Bottle

What To Do

1) Fill a plastic water or soda bottle with water.
2) Add a sprinkle of cornstarch.
3) Turn down the room lights and turn on the laser.
4) Aim the beam through the bottle. Do you see the original beam in the bottle? Can you find the reflection beam and the pass-through beam?

2. Light the Light Bulb

What To Do

1) Turn down the room lights and turn on the laser.
2) Aim your laser at a frosted incandescent light bulb. What do you see? What other types of light bulbs work well?

3. Reflections

What To Do

1) Turn down the room lights and turn on the laser.
2) Shine your beam over the surface of an old CD or DVD. Do you see multiple reflections? Does it work better with a scratched or smoother surface?

4. Scattering Your Laser Beam

What To Do

1) Turn down the room lights and turn on the laser.
2) Pass the beam through several textured objects such as wine glasses, clear glass vases, or ice cubes. What happens to the beam when passed through the different types of objects?

Career Profiles

CAREERS CHANGING OUR WORLD

James Fujimoto, Ph.D., Research Laboratory of Electronics, Massachusetts Institute of Technology, USA

In work that could improve the diagnoses of many eye diseases, MIT researchers under the leadership of James Fujimoto have developed a new type of technique for taking high-resolution, 3-D images of the retina, the part of the eye that converts light to electrical signals that travel to the brain. The new imaging system is based on Optical Coherence Tomography (OCT), which uses light to obtain high-resolution, cross-sectional images of the eye to visualize subtle changes that occur in retinal disease. Conventional OCT imaging typically yields a series of two-dimensional cross-sectional images of the retina, which can be combined to form a 3-D image of its volume.

The system works by scanning light back and forth across the eye, measuring the echo time delay of reflected light along micrometer-scale lines that, row by row, build up high-resolution images. Commercial OCT systems scan the eye at rates ranging from several hundred to several thousand lines per second, but a typical patient can only keep the eye still for about one second, limiting the amount of three-dimensional data that can be acquired.

Now, using the new laser, researchers in Fujimoto's group report retinal scans at record speeds of up to 236,000 lines per second, a factor of 10 improvement over current OCT technology. Future clinical studies, as well as further development, may someday enable ophthalmologists to routinely obtain three-dimensional "OCT snapshots" of the eye, containing comprehensive volumetric information about the microstructure of the retina. Such snapshots could potentially improve diagnoses of retinal diseases such as diabetic retinopathy, glaucoma and age-related macular degeneration.

James Fujimoto is a principal investigator in the Research Laboratory of Electronics (RLE) at the Massachusetts Institute of Technology (MIT). He received his S.B., S.M., and Ph.D. in electrical engineering from MIT in 1979, 1981, and 1984 respectively. He joined the MIT faculty in 1985 as Assistant Professor of Electrical Engineering. Since 1994, he has been Professor of Electrical Engineering at MIT and Adjunct Professor of Ophthalmology at Tufts University. His area of research involves the development and application of femtosecond laser technology, studies of ultrafast phenomena, and laser medicine and surgery. His research group in RLE and collaborators invented optical coherence tomography and pioneered its development. Dr. Fujimoto was awarded the *Discover* Magazine Award for Technological Innovation in medical diagnostics in 1999, and was co-recipient of the Rank Prize in Optoelectronics in 2002.

This profile was created using an article written by Elizabeth A. Thomson, MIT News Office, April 30, 2007.

Shawn Bowman, Laser Technician, Northrop Grumman, USA

Shawn Bowman is a laser technician. He chose this profession because he always had an interest in technology and was curious about lasers and optics. Currently, Shawn is employed by Northrop Grumman, a defense contractor in the USA.

The education and hands-on experience with lasers Shawn received at Central Carolina Community College really helped him prepare for his job. Learning to set up optical benches, operate high-powered lasers, and perform difficult optical alignments was especially useful. In his everyday work, he assembles, aligns, tests, and troubleshoots complicated laser systems that are used by the United States military.

Shawn finds that aligning lasers and troubleshooting laser systems is very rewarding. Also, knowing that the laser systems he works on are being used by the men and women who defend his country makes him very proud of his work. Shawn is glad he decided to attend college for a two-year degree in lasers and photonics. That education has provided him with many valuable and exciting opportunities.

Andy McGrew, Senior Laser Technician, Lead Operator for National Ignition Facility, USA

Andy McGrew has an exciting job at the National Ignition Facility at the Lawrence Livermore National Laboratory (LLNL), Livermore, CA. He has been with LLNL for 5 years helping to maintain direct operational control of the National Ignition Facility, a $3.5 billion laser used in high energy density plasma physics and fusion research to help solve our country's energy problems.

Andy oversees all activities necessary during the laser shot operations. He coordinates facility work teams; directs all shot activities during main laser firing, manages the safety interlock system, and runs the highest level of system control software. It's a real challenge and he is proud that his Laboratory trusts him with all this responsibility. Andy believes his interest in light and optics when he was young led him to this job. Besides working in a job he really likes, Andy earns a base salary of nearly $70,000 a year. That's not bad! And after 5 years on the job, he is working as a Senior Laser Technician and a Lead Operator for the National Ignition Facility.

Additional OSA Resources for Students, Teachers and Parents

OPTICS: Light at Work

This 15 minute DVD is geared toward 12 and 13 year old students, and is a great resource for raising awareness of optical science, along with its applications and many career opportunities. In addition to introductory information about the science of optics, the video highlights real world applications of optical technology, from everyday items like remote controls, cell phones and bar code scanners, to space exploration, innovations in solar energy and new frontiers in medicine. A variety of career options are highlighted through clips from a diverse group of scientists currently working in the field. Helpful advice and encouragement to students is included throughout.

Laser Technology: Changing Daily Life, Forging New Opportunities

This 42-minute CD-ROM traces the fast-paced history of the laser and includes exciting visual depictions of laser applications. Targeted to high school and post-secondary students, the CD focuses on the characteristics of diode, solid-state and gas lasers and the properties that make them useful in a variety of applications including telecommunications, entertainment, biomedicine and the military.

Optics Discovery Kit

The Optics Discovery Kit provides educators with classroom tools and optics lessons. The kit features 11 experiments that demonstrate basic principles of optics. Components include: lenses, color filters, polarizers, optical fibers, a mirror, a hologram, a diffraction grating and an anamorph. Also included are teacher and student guides. The new updated version will be available January 2008.

Terrific Telescopes Kit

Terrific Telescopes is an education packet based upon the Hands-On Optics (HOO) program. The kit's activities give students the opportunity to learn about the properties of lenses such as the focal length and the "flippoint". The lessons and materials also demonstrate how to use a single lens and other household objects as magnifiers. Students are encouraged to discover how to combine two lenses together to create a simple refracting telescope. The educator-led activities include demonstrations of how light bends and how lenses are used to create colorful images. A teacher's guide with step-by-step instructions is included with the kit.

Optics Suitcases

Developed by the OSA Rochester Local Section, the Optics Suitcase is an innovative, interactive presentation package designed to introduce middle school students to a variety of science concepts. The suitcase provides students with packets of materials that can be taken home to show to friends and family members as a reinforcement of the classroom lessons. To view the Suitcase Teaching Guide, and to read articles about outreach programs that have successfully used these materials, visit: www.opticsexcellence.org.

Educational Website

OSA hosts an educational website for students, teachers and parents. All material is designed to spark students' interest in science. The site features optics experiments, tutorials, demonstrations, games, optical illusions, career profiles, reference materials and more. Visit www.opticsforkids.org to continue your exploration of optics.

For more information about ordering any of these products please contact opticseducation@osa.org.