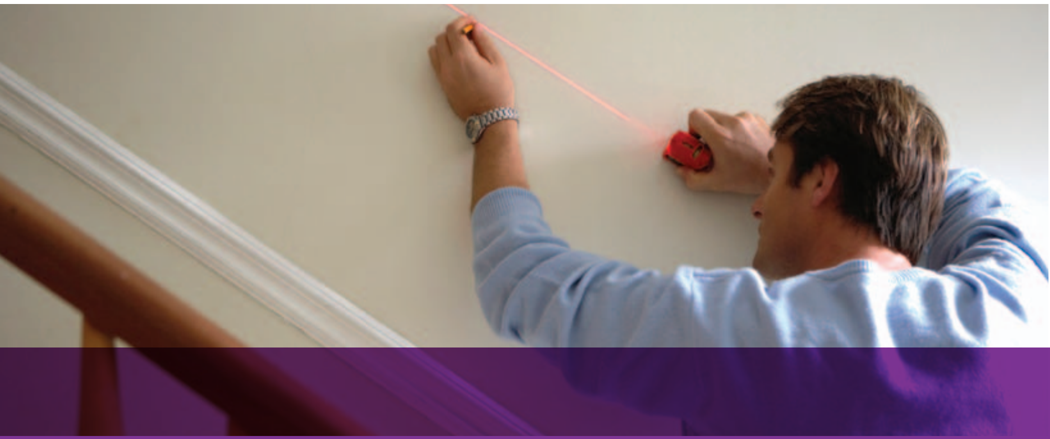


LASERS

in Everyday Life

The Acoustical Society of America

OSA

LASERFEST

THE ACOUSTICAL SOCIETY OF AMERICA (ASA)

The Acoustical Society of America is dedicated to increasing and advancing the knowledge of acoustics – the science of sound. ASA includes physicists, engineers, biologists, psychologists, geophysicists and scientists who work in music, speech, architecture, medicine, bioacoustics, noise control and oceanography. This diversity of topics, along with the opportunities provided for the exchange of knowledge and points of view, is one of the Society's strongest assets. Whether it is the study of humpback whale songs, the design of concert halls, the study of music and musical instruments or a wide range of sound-related studies, they will be investigated by ASA members.

THE OPTICAL SOCIETY (OSA)

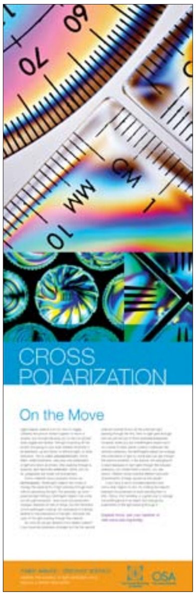
Founded in 1916, OSA brings together optics and photonics scientists, engineers, educators and business leaders. OSA is dedicated to providing its members and the scientific community with educational resources that support technical and professional development. OSA's publications, events and services 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.

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.



This poster series was created by the Acoustical Society of America and The Optical Society.

Special thanks to the following volunteers for donating their time and expertise to this poster and guidebook:
Stefan Andersson-Engels, Lund University, Sweden; Brad Bower, Bioptigen, Inc., USA; Anna Consortini, University of Florence, Italy; Judy Donnelly, Three Rivers Community College, USA; Sailing He, Zhejiang University, China; Paulina Kuo, National Institute of Standards & Technology, USA; Irina Novikova, College of William & Mary, USA; Luis Roso, University of Salamanca, Spain; Jay Sharping, University of California at Merced, USA

Special support was provided by:
The National Center for Optics and Photonics Education
www.op-tec.org

OP-TEC
National Center for Optics and Photonics Education

Get the Point

LASERS HAVE MANY USES IN THE WORLD AROUND US. You probably know about laser pointers (perhaps you have a cat that chases one!) but you may not know about lasers, like the ones in your DVD player. Light from a laser behaves differently than light from the sun or from a flashlight. One big difference is that light from a laser is typically collimated, meaning that it spreads (or diverges) very slowly compared to the light from a flashlight. We take advantage of the ability of lasers to stay in tight beams whenever we use laser pointers and laser level guides.

The "anti-spreading" property of lasers arises because laser beams are spatially coherent which means that photons of the beam together act as waves with constant waves over the cross-section of the beam. Scientists often describe the way lasers propagate through space using the theory of Gaussian beams.

Another related property of lasers is their ability to be focused very tightly into really small spots. The power density in focused laser spots can be enormous, which allows lasers to be used in surgery to make small, precise cuts and in machining to weld or cut dense materials.

The small focused spots also make lasers very useful for reading and writing information from CDs and DVDs. Data on these disks are saved as a pattern of tiny pits. A laser beam can be scanned across the pattern to read out the data. The reflection from the disk will be deflected or diverged, which reduces the reflected signal and thus delivering the information needed to produce the right sounds and images. The focused laser spot needs to be about the same size as the pit, which means that smaller laser spots allow for smaller pits and higher data densities. Lasers with shorter wavelengths generally can be focused to smaller spots. The progression from CDs to DVDs—and now to Blu-Ray disks—has been related to advances in laser technology; CDs and DVDs use red lasers (780 nm and 650 nm wavelength, respectively) and Blu-Ray disks use blue-violet lasers at 405nm wavelength.

Definitions

COLLIMATED
Collimated light is light whose rays are nearly parallel, and therefore will spread slowly as it propagates.

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

PHASE
A particular stage in a periodic process or phenomenon. The fraction of a complete cycle elapsed as measured from a specified reference point and often expressed as an angle.

GAUSSIAN BEAMS
A beam of electromagnetic radiation whose wave front is approximately spherical at any point along the beam and whose transverse field intensity over any wave front is a Gaussian function of the distance from the axis of the beam.

FOCUS
A point at which rays of light or other radiation converge or from which they appear to diverge, as after refraction or reflection in an optical system: *the focus of a lens*. Also called *focal point*.

DEFLECTED/DIVERGED
To separate or cause to separate and go in different directions from a point.

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.

Exploring Laser Beams

ACTIVITY 1

Laser or Flashlight?

Here are some explorations you can try. First, find a small flashlight and a laser pointer. Be very careful that you don't aim the laser at another person or reflect the laser light at anyone's eyes. These experiments work best if you turn off other lights in the room.

Stand next to a wall and shine the flashlight so it makes a round spot on the wall. Measure the diameter of the bright part of the spot of light. Now have a friend hold the flashlight at least 3 meters from the wall while you measure the new diameter of the spot of light. Repeat this experiment with the laser pointer. Which kind of light spreads more? One characteristic of most lasers is that the beam is *collimated*, that is, it doesn't spread much as it travels.

ACTIVITY 2

What are laser speckles?

For the next experiment you will need an old CD and a piece of white paper taped to a wall. Very carefully shine the laser onto the CD so that the reflected beam strikes the paper. Now repeat this experiment with the flashlight. What difference do you notice? Another characteristic of laser light is that it is *monochromatic*, or, one color. The white light of the flashlight contains all the colors of the rainbow.

Finally, spread out the laser beam by shining it through a piece of wax paper or frosted glass. Shine the spread out laser beam onto a piece of white paper. Repeat with the flashlight beam. The flashlight makes a flat-looking spot of light but the laser light "sparkles." This effect is called *laser speckle* and it is due to a property of the laser light called coherence.

WHAT YOU NEED

- Wax Paper
- Flashlight
- Laser Pointer
- Ruler
- White Paper
- Old CD

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.

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.

SPECIAL THANKS TO THE NEW ENGLAND BOARD OF HIGHER EDUCATION (NEBHE) FOR PROVIDING THESE HANDS-ON ACTIVITIES. TO LEARN MORE ABOUT NEBHE, VISIT WWW.NEBHE.ORG.

Mildred 'Millie' Dresselhaus

BROUGHT UP IN A POOR SUBURB OF THE BRONX, the young Millie Dresselhaus went to some of the worst schools in New York City. "Things weren't looking too well for me, I was born in the depression—we were one of the many families on welfare." One of the positive things that happened to her was music. As a very young child, Millie received a music scholarship to attend a music school in a settlement house in Greenwich Village, New York. Through that experience she met middle class America—an echelon of society she didn't have any contact with otherwise. She quickly saw that what she was getting in her neighborhood wasn't what "luckier" children were receiving. She decided to switch to a better school, and at the age of 13 enrolled in Hunter College High School for girls.

After graduating from Hunter College, Millie was awarded a Fulbright Fellowship which allowed her to spend a year at the Cavendish Laboratory, Cambridge University from 1951–1952. She received her master's degree at Radcliffe College in 1953. After receiving her PhD, with a thesis on superconductivity 1958, Professor Dresselhaus began her career at the Lincoln Laboratory, where she studied magneto-optics in semiconductors, and carried out a series of experiments which led to a fundamental understanding of the electronic structure of semi-metals, especially graphite. Graphite is a nanomaterial composed of sheets of specially structured carbon atoms a called graphene. Graphene sheets can be rolled up to form carbon nanotubes. She is currently an Institute Professor of Electrical Engineering and Physics at MIT.

Millie Dresselhaus, a laser pioneer.

With the advent of lasers in the 1960s, Professor Dresselhaus was among the first to use lasers for magneto-optics experiments. In collaboration with Ali Javan, inventor of the continuous wave (CW) laser, she and their joint student Paul Schroeder carried out a high resolution magneto-optics experiment, using circularly polarized light from a helium-neon laser, and in 1968, created a new model for the electronic structure of graphite. These laser studies were the stepping stones to her entry into the field of Raman spectroscopy many years later. Raman spectroscopy is a light scattering technique, where a photon of light interacts with a sample to produce scattered radiation of different wavelengths.

"As for now, I'm still at the forefront of carbon science. I've been very active in the nanotube area. In 2004 and 2005, I entered the graphene domain. Ironically that's where I started back in 1962; we just didn't have samples of monolayer graphene then. These days I'm working mostly on the photophysics of graphene," says Professor Dresselhaus.

Her research has always been multifaceted. "I have another side of me and that's the energy side—this started when I was assistant secretary of the DOE. They asked me to do a hydrogen study, because President [George W.] Bush had the idea that hydrogen was going to be an important energy source, and that led to a whole bunch of other studies. I got back into the science policy area because of that," she says.

Professor Dresselhaus has made promoting opportunities for women in science and engineering a high priority throughout her career. She received a Carnegie Foundation grant in 1973 to encourage women's study in traditionally male-dominated fields, such as physics. The same year she was appointed to the Abby Rockefeller Mauze chair, an Institute-wide chair, endowed in support of the scholarship of women in science and engineering.

Reflecting upon her experiences as a woman in physics, Professor Dresselhaus says, "When I first started at Hunter College—that was pretty much a women's college, so I had the idea that women could study physics as well as men. When I got to Cambridge University, there were only a few women but we were doing alright. I didn't really know I wasn't supposed to do physics until I joined the mainstream. When I got my degree in 1958 it was pretty lonely—we [women] were only two percent of the physics community then."

In 1984, Professor Dresselhaus was appointed president of the American Physical Society. "I tried to move APS into a more interdisciplinary mode. I found it one of the most challenging things to overcome, the fact that everyone was so strongly focused in their own avenues of physics."

She continues, "I think we are doing better as physicists at talking to each other and with other fields—because physics doesn't exist by itself, and I think we need to be mindful about that. And I think some of the big discoveries in front us will be in those borderline areas".

After her term as APS president, Professor Dresselhaus served as Chair of the APS

Millie with her first love, music.

Committee on the Status of Women in Physics. Along with former APS Executive Officer Judy Franz, she co-chaired the committees of visiting women physicists, which started in the early 1990s and continues into the present. These committees assess and make recommendations for improving the status of women in physics, with a particular emphasis on undergraduate and graduate students.

In addition, Professor Dresselhaus has also served as President of the American Association for the Advancement of Science, Treasurer of the US National Academy of Sciences, and Chair of the Governing Board of the American Institute of Physics. She has received numerous awards, including the US National Medal of Science and 25 honorary doctorates worldwide. She served as the Director of the Office of Science at the US Department of Energy in 2000–2001, and has co-authored many books on carbon science.

Commenting on her research career, Professor Dresselhaus says, "If I had never gotten into physics I think I would have gone into school teaching—my entire career I've been very involved with students." When she's not working in her lab at MIT, Professor Dresselhaus enjoys spending time with her large family of four children and five grandchildren, and playing the violin in chamber music groups.

"One of my granddaughters is an undergraduate working on carbon nanotubes—just like grandma! I'm having a great time watching her. If I had to do the whole thing over again, I'd do it exactly the same way."

Margaret Murnane

MARGARET MURNANE HAS A FASCINATING STORY TO TELL—if you can keep up with her. In a sense, Murnane is the fastest person who ever lived. An optical physicist at the University of Colorado, she builds lasers that flash for ten quadrillionths of a second—the fastest things that humans have ever created.

Margaret Murnane, helping scientists build more accurate microscopes and faster computers. Photo courtesy University of Colorado.

Murnane grew up in the countryside of Ireland. Her father, an elementary school teacher, encouraged her love of math and science by giving her math puzzles, and then rewarded her with chocolates if she solved them. Her high school offered physics, which was unusual for a girls' school in Ireland. "Physics was my worst subject in high school," Murnane said. But she had known since she was nine that she wanted to be a physicist —she said it gave her the "excitement of discovery." She went on to college in Cork, Ireland, and graduate school at the University of California at Berkeley.

At Berkeley, she studied with a young professor who had just started to work with lasers. Lasers are essentially devices for amplifying light—the light that comes out is a bright beam that is highly directional. "I love working with lasers because they're so appealing visually," Murnane said. "The kind of lasers I first worked with were very beautiful red, crimson and orange colors."

In her first year at Berkeley, she met Henry Kapteyn, an American graduate student. They married, and found physics jobs together first at Washington State University, and then at the University of Michigan. In 1999, they were both hired by the University of Colorado, where they now run a lab together. "It's wonderful because we really have a team," Murnane said. Their students call Murnane and Kapteyn, the two heads of the lab, Mom and Dad."

In the lab, Murnane, Kapteyn, and their students make lasers whose beams flash like a strobe light—except that each flash is a trillion times faster. These lasers, like camera flashes, shine strobe lights that let Murnane record some of the fastest motions in our natural world. These motions include the dance of electrons as they swarm around molecules, or as they hop from site to site in materials. Murnane builds lasers quick enough to capture the movements of even an electron. Her newest laser and x-ray beams flash for less than a femtosecond—or less than 0.000000000000001 seconds. To put that time in perspective, if ten femtoseconds felt like one minute, one minute would feel like the age of the universe.

Murnane loves living in Colorado. "In ten minutes, you can be in the foothills of the Rockies," she said. She enjoys biking, skiing and hiking, and she has traveled throughout the world with her husband. She still enjoys the thrill of discovery in physics. "It's not easy to predict the outcome of our experiments," she says. "Nobody else knows the answer, so it's up to you."

Ryan Renfrew

SOME PEOPLE STRUGGLE to figure out what career they want to pursue. Ryan Renfrew is not one of those people. At the age of 13, as he began to work with his father on classic cars, he discovered what would become an intense fascination with electronics and optics.

Thanks to that early discovery, Ryan was able to get a jumpstart on his photonics education. "My high school had a collaborative program that I was able to complete during my senior year," he recalls. "The accreditation program allowed me to complete my first term of college while still in high school. The day I graduated, I started my second term of college at Indian Hills Community College (IHCC)." Ryan was 19 when he graduated from IHCC, at the time the youngest ever to graduate from the college. Even before he graduated, he had been offered thirteen very different jobs from companies throughout the United States, with annual starting salaries ranging from $32,500 to $58,000. Ryan could choose from fields as diverse as semiconductor manufacturing, laser applications for the automotive industry, and medical laser installation and maintenance. Whatever he chose, Ryan would earn enough money to make him financially independent—as a teenager!

Ryan now works for Cymer, Inc., at the site where the majority of research and development for the computer company Intel is conducted. "At Cymer, we are in charge of all specifications, all installations, and all upkeep on the lasers used by Intel," he explains. "It is an exceptionally high-pressure group because all the development is done here." While Ryan obviously thrives in high-pressure environments, he sees the pressure as both the most fun and the most challenging part of his career. "Once you're responsible for a particular project or a particular individual, it's very hard to walk away. I'm on call 24 hours a day most days. That is probably the least favorite part of my job, but it's also what keeps me here."

From Ryan's perspective, photonics is an extremely competitive field. "Everybody is advancing and trying new and different things to try to stay in front of the other guy," he says. "It's all a bit of a competition. I believe if you go back and look at people like us in sixth or eighth grade, we were all like that even then. I think it requires a particular personality, whether good or bad!" If there is some particular personality trait that causes people to thrive in photonics, it's safe to say that Ryan Renfrew has it. Ryan Renfrew received an associate in applied science degree in laser electro-optics technology from Indian Hills Community College in Ottumwa, Iowa, in 2000. He now lives in Hillsboro, Oregon, with his wife, Rachael, and son, Clayton. Clayton likes to do whatever Dad likes to do, which includes bowling, softball, fishing, hiking, and working on cars.

On following your instincts: "If more people just did what they enjoyed, they'd be more successful at it. I feel confident in saying there's something of interest for many people in photonics. Anyone can succeed in whatever career field they feel confident in."

—RYAN RENFREW, JULY 15, 2009

Ryan Renfrew, hard at work.

Additional 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 video/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 video/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.

OPTICS SUITCASES

The OSA Rochester Local Section developed the Optics Suitcase in 1999. The *Optics Suitcase* is an innovative, interactive presentation package designed to introduce primary school students to many of the concepts of optics as well as other sciences. The cornerstone of the *Suitcase* is the give-away theme packets which the students are encouraged to show to friends and family members, therefore reinforcing the lessons learned from the presentation. Reprints of articles about the Rochester Section's outreach and a copy of the *Optics Suitcase* guide for presenters are available at www.opticsexcellence.org/SJ_TeamSite/index.html; you can also view a video of Dr. Steven Jacobs using the *Suitcase* on the osapod.libsyn.com/.

EDUCATIONAL WEBSITES

OSA hosts award-winning educational websites for students, teachers and parents. The material is designed to spark students' interest in science. OpticsForKids.org features optics experiments, tutorials, demonstrations, games, optical illusions, career profiles, reference materials and more. The Optics and Photonics Education Directory, OpticsEducation.org, is a high-powered search engine of schools that offer advanced studies in optics and related topics.

FOR MORE INFORMATION ABOUT ORDERING ANY OF THESE PRODUCTS PLEASE CONTACT OPTICSEDUCATION@OSA.ORG.

OSA

The Optical Society
2010 Massachusetts Ave, NW
Washington, DC 20036 USA
Tel: +1 202.223.8130
Fax: +1 202.223.1096
www.osa.org