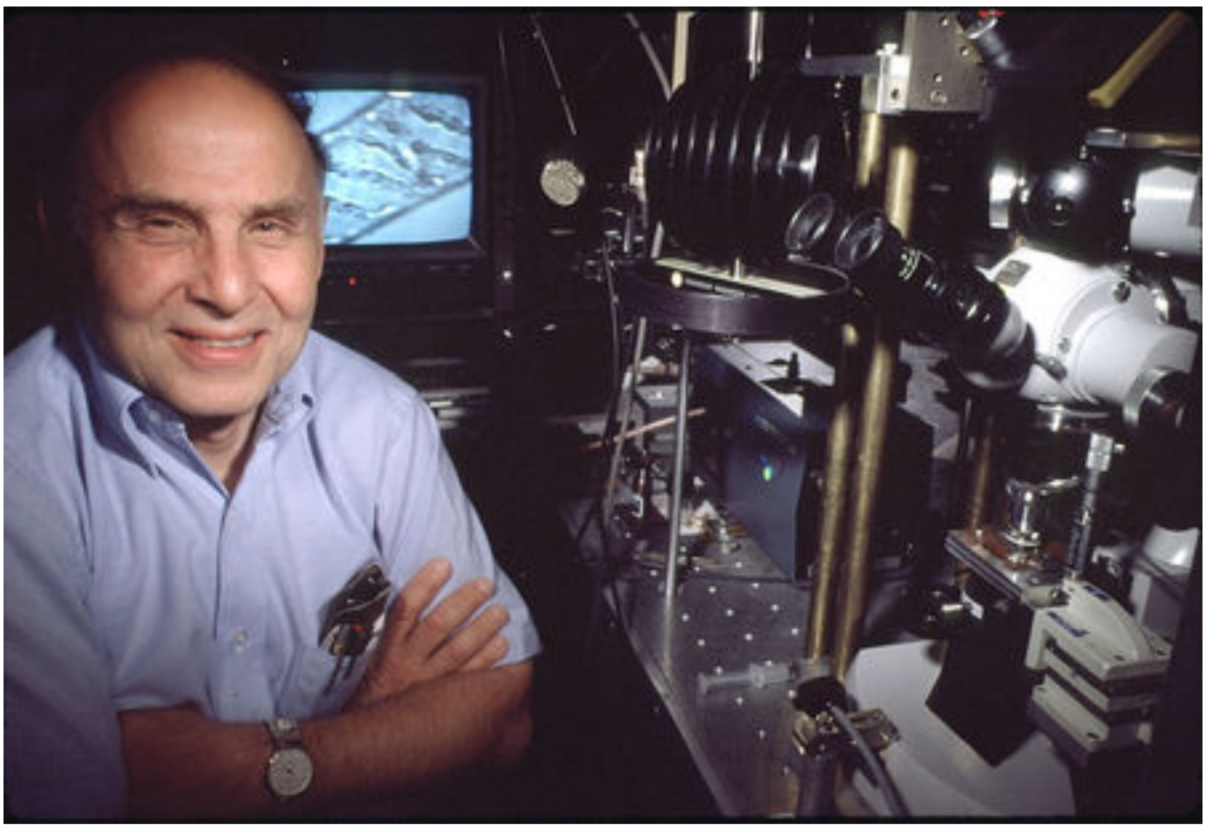
Turning lasers into versatile tools earns trio Nobel Prize in Physics

By Daniel Clery, Adrian ChoOct. 2, 2018 , 5:00 AM

If you've had laser eye surgery and chucked your clunky glasses, you can thank some of the winners of this year's Nobel Prize in Physics. The award honors a trio of physicists who invented laser tools that have become ubiquitous in research laboratories and beyond. Among them are the oldest person ever named a Nobel laureate and the first woman to share the physics prize in 55 years.

Arthur Ashkin, 96, received half of the $1 million prize for the invention of optical tweezers, a technique that uses focused laser beams to hold and manipulate tiny objects, including viruses, bacteria, and individual cells. Recognition of the advance, which Ashkin made in 1986 at the famed Bell Laboratories in Holmdel, New Jersey, "is well overdue," says Philip Jones, an optical physicist at University College London.



Arthur Ashkin

Nokia Bell Labs

The other half of the prize honors Gérard Mourou, 74, of the École Polytechnique in Palaiseau, France, and Donna Strickland, 59, of the University of Waterloo in Canada, for their invention of chirped pulse amplification (CPA), a technique that boosts the intensity of ultrashort laser pulses. Strickland is the first woman to win the physics Nobel since Maria Goeppert Mayer won it in 1963. "Finally," says Anne L'Huillier, an atomic physicist at Lund University in Sweden.

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Optical tweezers use the subtle forces of light to tug on tiny objects. The electric field in laser light can polarize a transparent material, such as plastic or cellular cytoplasm. The polarized material then experiences a force drawing it to where the electric field is strongest, typically the middle of the beam. Move the beam, and you can pull on the object.

Ashkin did his original work with microscopic plastic beads, which can be latched onto the end of a DNA molecule to stretch it out. But optical tweezers can also pluck and prod living cells themselves. Caroline Adiels, a biologist at the University of Gothenburg in Sweden, employs them to measure the mechanical properties of yeast, bacteria, and diatoms. "I use the technique on a daily basis," she says. Similarly, Jones is using the technique to test his hypothesis that red blood cells in patients with type 2 diabetes are abnormally stiff, one reason why the condition often damages fine blood vessels in the eyes.

Gérard Mourou

Christophe Ena/AP Photo

Mourou and Strickland invented CPA when physicists were struggling to boost the intensity of very short laser pulses. Once a laser pulse grows too intense, it distorts the properties of the amplifying medium, preventing further amplification, explains John Collier, a laser physicist and director of the Central Laser Facility (CLF) at Rutherford Appleton Laboratory in Didcot, U.K.

Strickland was Mourou's graduate student at the University of Rochester in New York when, in 1985, the two found a clever way around this problem. Their scheme first splits a laser pulse into its frequency components by, say, reflecting it off a diffraction grating. Those spread-out components can then be run through an amplifier without overburdening it. Finally, the beefed-up components are recombined into a short pulse far more intense than the original.

CPA is now the basis for most femtosecond laser systems—including those used in laser eye surgery, in which a pulse of laser light quickly slices open the lens before the surrounding tissue has time to heat up. "I'm glad the committee has recognized this science, which is creating so much value," says Toshiki Tajima, a laser physicist at the University of California, Irvine. By packing energy into such a short pulse, the lasers can also achieve petawatts of power, which is useful for creating high temperatures, powerful electromagnetic fields, and other "extreme conditions that you wouldn't otherwise find on Earth," Collier says.

Donna Strickland

UNIVERSITY OF WATERLOO

Scientists around the globe are racing to build the most powerful laser, with CPA as an essential tool. Researchers in South Korea have tested a laser with a whopping 4 petawatts of power, Collier says. CLF has plans to replace its current 1-petawatt laser with a 20-petawatt system, and physicists in China aim to build a Station of Extreme Light with a 100-petawatt laser. At that level, the light could "break the vacuum" and tear particle-antiparticle pairs from empty space. Mourou has played a central role in pushing for such laser facilities, including Europe's Extreme Light Infrastructure, a €850 million network of laser labs in development in the Czech Republic, Hungary, and Romania.

Both L'Huillier and Adiels praised the award for recognizing the contributions of women in physics. "Tiny steps, taking forever, but at least something is happening," Adiels says. Whereas 206 men have won or shared the physics prize, only three women—including Strickland—have ever received that honor. That skewed tally appeared to surprise her when she was told of it at the preconference announcing the prize. "Is that all?" Strickland asked. "Really?"

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