Love AT FIRST Light

Donna Strickland '89 (PhD), a self-described "laser jock," receives the Nobel Prize, along with her advisor, Gérard Mourou, for work they did at the Laboratory for Laser Energetics.

By Lindsey Valich

Donna Strickland '89 (PhD) still recalls the visit she took to the Ontario Science Centre when she was a child growing up in the town of Guelph, outside Toronto. Her father pointed to a laser display. "'Donna, this is the way of the future,'" Strickland remembers him telling her.

Lloyd Strickland, an electrical engineer, along with Donna's mother, sister, and brother, was part of the family that "continually supported and encouraged me through all my years of education," Donna Strickland wrote in the acknowledgments of her PhD thesis, "Development of an Ultra-Bright Laser and an Application to Multi-Photon Ionization."

She was captivated by that laser display. And since then, she says, "I've always thought lasers were cool."

Her passion for laser science research and her commitment to being a "laser jock," as she has called herself, has led her across North America, from Canada to the United States and back again. But it's the work that she did as a graduate student at Rochester in the 1980s that has earned her the remarkable accolade of Nobel Prize laureate.

When Strickland entered the University's graduate program in optics, laser physicists were grappling with a thorny problem: how could they create ultrashort, high-intensity laser pulses that wouldn't destroy the very material the laser was used to explore in the first place?

Working with former Rochester engineering professor Gérard Mourou, Strickland developed and made workable a method to overcome the barrier. They called it "chirped pulse amplification." The groundbreaking research was recognized this fall by the Nobel Prize committee with the 2018 Nobel Prize in Physics.

Strickland, now at the University of Waterloo in Canada, and Mourou, now at the École Polytechnique in France, share one half of the prize. The other half of this year's award went to renowned physicist

NOBEL PURSUITS: Strickland, pictured in her laboratory at the University of Waterloo, has been captivated by lasers since childhood. "I've always had fun playing with them," she says. "I do often think of it as playing, not work."

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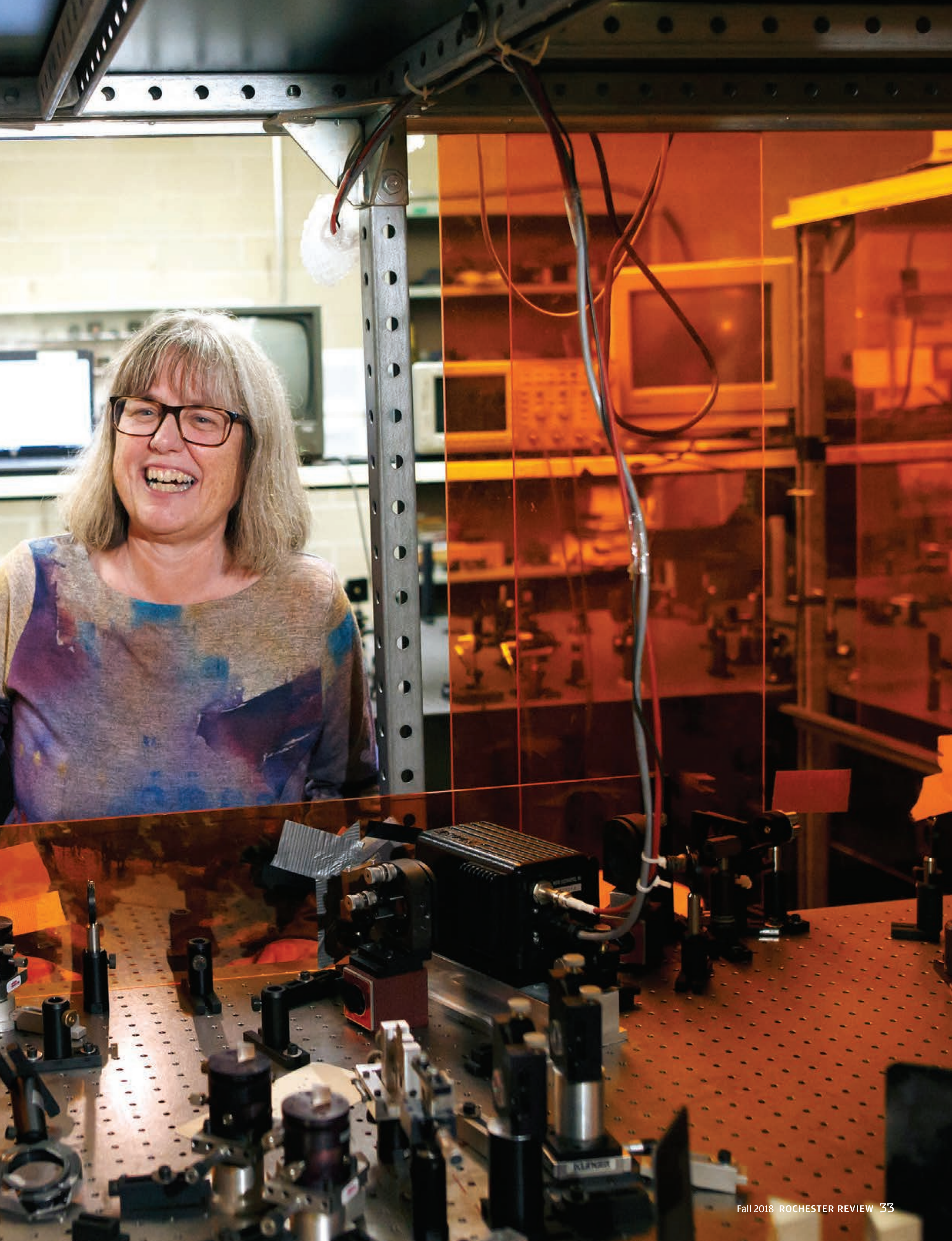


Rochester's Nobel Laureates

Twelve people with ties to Rochester—alumni, faculty members, and former faculty members—have been named Nobel laureates across a range of categories that includes physics, medicine or physiology, and economics.

2018 Prize in Physics: Donna Strickland '89 (PhD) and Gérard Mourou, who developed a way to amplify the power of lasers, ushering in applications in medicine, optics, imaging, research, and other areas. Carried out at Rochester's Laboratory for Laser Energetics, the work formed the basis of Strickland's doctoral dissertation, with Mourou as her advisor.

2018 Prize in Economic Sciences: Paul Romer, a former assistant professor of economics at Rochester, was recognized as a pioneer in developing ways to better understand how technology influences economic decision making.

2017 Prize in Economic Sciences: Richard Thaler '74 (PhD), a founder of the discipline of behavioral economics.

2002 Nobel Prize in Physics: Masatoshi Koshiba '55 (PhD), a physicist who led work to detect the subatomic particles known as neutrinos.

1997 Nobel Prize in Physics: Physicist and former Secretary of Energy Steven Chu '70, who developed methods to cool and trap atoms with laser light.

1993 Nobel Prize in Economic Sciences Robert Fogel, a member of the Rochester economics faculty in the 1960s and 1970s, pioneered quantitative analyses of social history.

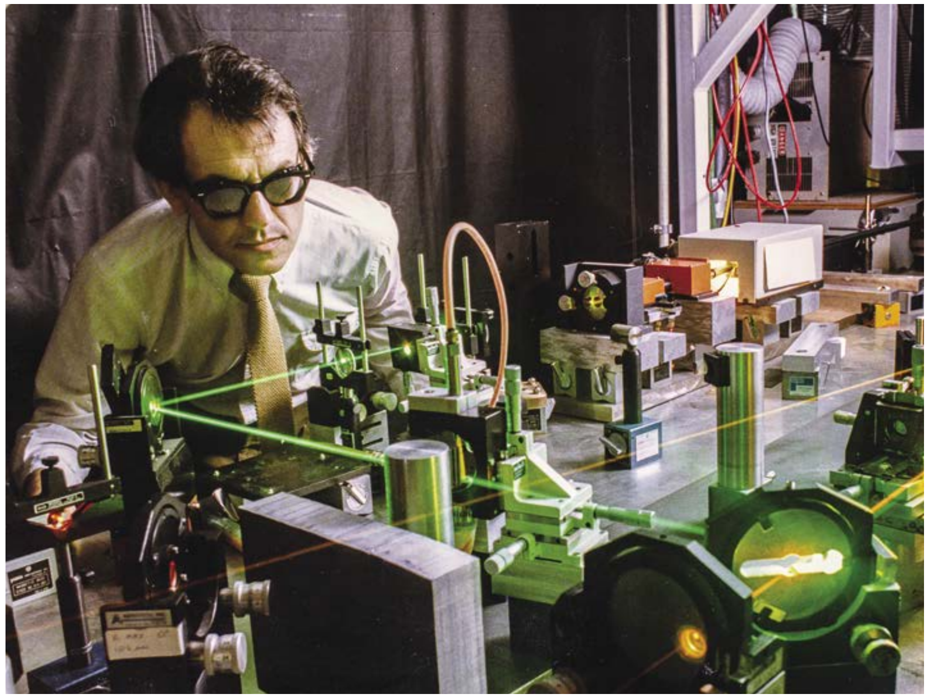
1976 Nobel Prize in Physiology or Medicine: Carleton Gajdusek '43, who is credited with discovering the infectious disease mechanism of prions.

1959 Nobel Prize in Physiology or Medicine: Arthur Kornberg '41M (MD), who first discovered a way to synthesize DNA.

1955 Nobel Prize in Chemistry: Vincent du Vigneaud '27 (PhD), a biochemist, for research on sulfur-containing compounds.

1943 Nobel Prize in Physiology or Medicine: Biochemist Henrick Dam for his discovery of vitamin K.

1934 Nobel Prize in Physiology or Medicine: George Whipple, founding dean of School of Medicine and Dentistry, for his work to develop a therapy for anemia.



LASER FOCUS: Mourou, pictured in 1987 in Rochester's Laboratory for Laser Energetics, calls research a passion. "Science is not a 9-to-5 job," he says. "It's something you think about all the time."

Arthur Ashkin of Bell Laboratories for his work to develop an equally field-changing way to use light, a technique known as "optical tweezers." The technique involves using lasers to cool atoms to a temperature where they can be studied individually. Results of the work done at Bell Laboratories were first published in 1986 and included contributions by Steven Chu '70, who went on to win his own Nobel Prize in Physics in 1997.

Strickland's selection for the Nobel Prize was newsworthy for an additional reason: she was the first woman laureate in physics since 1963 and only the third since Marie Curie received the prize in 1903.

Into the Limelight

The problem Strickland and Mourou overcame was one that would have ignited the imagination of any physicist who, like Strickland, experiences scientific discovery as a form of play. When it comes to lasers, she says, "I've always had fun playing with them. I do often think of it as playing, not work."

But their solution had important practical ramifications. In the 30 years since Strickland and Mourou conducted the research, chirped pulse amplification has made it possible to use lasers effectively in a wide range of medical, scientific, and commercial applications.

"Gérard Mourou and Donna Strickland invented a laser technique that transformed laser technology and continues to have lasting impacts on society," says Wendi Heinzelman, dean of the Hajim School of Engineering & Applied Sciences.

Strickland has been getting used to the limelight. And as she told the British publication the *Guardian*, she doesn't like too much focus to be placed on her gender. The fact that she is only the third woman ever to receive the physics Nobel—joining Curie, who received the prize for research on radiation, and Maria Goeppert-Mayer, who won in 1963 for discoveries concerning nuclear structure—is much less interesting to her than the science that earned her the award.

But many observers point out that, prior to winning the Nobel, Strickland was under-recognized, given the significance of her contribution.

"I hope and believe the awarding of the Nobel Prize in Physics this year begins a trend where more women are recognized for their seminal contributions in science and engineering," says Heinzelman.

A Nobel Collaboration

Strickland received her undergraduate degree at McMaster University in Ontario, and came to Rochester for her graduate degree because of the University's reputation as one of the top schools globally for studying optics and light. One day on campus, a fellow graduate student mentioned the lab of Gérard Mourou.

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"I told someone at the Institute of Optics that I wanted to study lasers, and he said, 'I know just the guy you'll want to work with,'" Strickland recounts. As she told the University of Waterloo, when she walked into Mourou's lab at the Laboratory for Laser Energetics, "it was full of these red and green lasers. I just said, 'Oh my God. It's like working around a Christmas tree all the time. How fabulous is that?'"

As laser science grew as a discipline in the 1980s, researchers were incrementally increasing the intensity of laser pulses, resulting in damage to the amplifying material. Mourou had come up with an idea to clear the hurdle by perfecting the technique known as chirped pulse amplification. The technique involved a three-part sequence: stretching a laser pulse thousands of times so that the power was low; amplifying the pulse to higher intensities; and then compressing the pulse in time back to its exact original duration.

Mourou knew the pulse needed to be perfectly compressed, yet still retain its amplification, in order to make the technique work more effectively. "If you can do it exactly, then you can go to much higher power," Mourou says.

He had the idea to put amplification in the middle of the process—a novel concept at the time, according to Strickland. "Different people were trying to get short pulses amplified in different ways, but it was thinking outside the box to stretch first and then amplify," she says.

Chirped pulse amplification, however, was only a theory. Strickland and Mourou still had to make it work. At the LLE, Strickland tested different laser systems to create laser pulses that were short and high powered, but that wouldn't destroy the amplifying material. In 1985, she succeeded, demonstrating the stunning advance in laser power with the table-top terawatt laser, or "T-cubed laser."

At the time, Strickland didn't recognize the research would interest an audience outside the laser-physics community: "I was aware that it was going to be big for scientists working in high-intensity laser physics," she says, "but I didn't know it would have relevance for the general public so quickly."

Changing the Field of Laser Science

Chirped pulse amplification has since paved the way for the shortest and most intense laser pulses ever created, making it possible to build more compact and precise laser systems.

"Gerard's original motivation was to take a football field-sized laser and compress it down to the size of a tabletop," says Wayne Knox, professor of optics and former Institute of Optics director, who was Mourou's first PhD student and worked in his Ultra-Fast Laser Group. "Now we've compressed them even further. I have in my lab a laser the size of a bread box that uses this technology."

Making the accelerators more compact, yet powerful, changed the field of laser science by allowing laser technologies to be used more broadly, especially in medical settings. Chirped pulse amplification is instrumental, for example, in laser eye surgeries such as Lasik, to quickly slice open the lens of an eye without damaging the surrounding tissue. It's used to accelerate protons in proton therapies to treat deep-tissue tumors, like those that develop in the brain. Beyond its medical applications, chirped pulse amplification is important in more precise machining of materials such as the cover glass used in smartphones. Mourou has also developed a technique to treat radioactive waste using the technology.

But the technique is also essential in basic physics research. Today, Strickland and Mourou's discovery continues to help shape the direction of research in high-powered lasers of the kind housed at the LLE, says Mike Campbell, director of the laboratory. "The development of chirped pulse amplification by Gérard and Donna has created numerous new applications in science and industry and has catalyzed research around the world in high-peak-power lasers."

Scientists use ultrafast lasers to create the extreme conditions found in space, allowing them to study star formation and the inner workings of distant planets. The technique also allows physicists to take ultrafast images of split-second processes at the molecular level in order to study how atoms behave.

"CPA is really a fundamental advance," says Jonathan Zuegel, senior scientist at the LLE and director for laser development and engineering.

Interestingly, despite her seminal contribution, Strickland still wears glasses. As she told the *Guardian*, she refuses to get the corrective eye surgery made possible by her laser research: "I have great faith in lasers, but no one's putting one near my eye."

For his part, Mourou hopes to encourage even more students in the field of ultrafast laser science to pursue their scientific interests.

"It's amazing when you think about it, because this Nobel-winning work was Donna's thesis," he says. "One thing about research is that it is a passion. Science is not a 9-to-5 job; it's something you think about all the time, and it's very demanding."

And, as he and Strickland found, "You have to work hard at it, and you have to love it." R

ECONOMICS PRIZE

Understanding the Costs of Innovation

A former economics professor shares the Nobel Prize.

Paul Romer, a former assistant professor of economics at Rochester and now a professor at New York University, has been named a recipient of this year's Nobel Prize in Economic Sciences.

An assistant professor of economics at Rochester from 1982 to 1988, Romer shared the award with William Nordhaus, a professor of economics at Yale University.

In making the announcement in October, the Royal Swedish Academy of Science recognized Romer for his work on the economics of technological change, research that was first outlined in a 1990 paper.

THE TIDE OF TECH: Romer was awarded the Nobel Prize in economics for work he began as a faculty member at Rochester on incentivizing technological innovation.

Mark Bils, the Hazel Fyfe Professor in Economics who briefly worked with Romer in Rochester, says the paper, "Endogenous Technological Change," was written while Romer was at the University.

"Paul wrestled with how firms get rewarded for the high upfront costs of innovating," Bils says. "Paul's answer, that the return to research requires market power and possibly government incentives, freed the growth literature to incorporate how technology grows, not just how physical and human capital accumulate."

After Rochester, Romer went on to appointments at the University of Chicago, the University of California at Berkeley, and Stanford University before his appointment at NYU's Stern School of Business. He earned his PhD from the University of Chicago in 1983. —Peter Iglinski '17 (MA)

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