faculty spotlight

Molding the Boundaries of Light

By Helen Yang

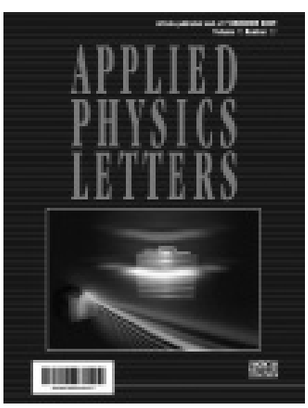
If anyone embodies the DaVinci spirit of invention and love of learning in multiple disciplines, that person would Frederico Capasso, one of the most eminent researchers in applied physics and optics. Known for inventing the quantum cascade laser—a tool now used in major atmospheric research, and for holding more than fifty patents, Capasso has been called "one the most creative and influential applied physicists in the world." (1)

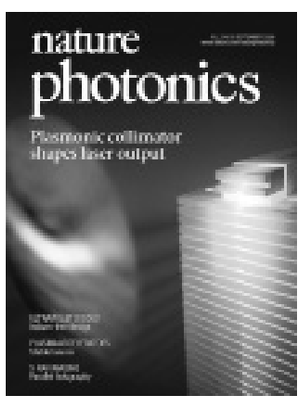
After spending twenty-seven years at Bell Laboratories, Professor Capasso joined the Harvard School of Engineering and Applied Sciences faculty in 2003. He has taught graduate courses in quantum technology, photonics, lasers and looks forward to teaching undergraduates next fall.

Currently on Sabbatical for the fall semester, Professor Capasso declares that he is "twice as busy" than when he was working. Despite this, he did take the time to sit down with HSR one October afternoon for a lively chat on his research and take on science.

When did science first strike you as interesting?

"When I was six years old, my dad gave me a book on nuclear energy written by a science writer famous back in those days. This was immediately after WWII, when science had proven its ability to be both good and bad. It was a time when nuclear and atomic physics were hot topics. Nuclear engineering was thought to be able to solve the future's energy problems. So, my dad was enthusiastic about it all, so he gave his young son this book. I remembered that I devoured it, even though I didn't understand most of the science, but I became so enamored with it that I decided I wanted to be a scientist—and I never changed my mind after that. I wasn't particularly gifted scientifically, even through high school, but this book gave me this passion for discovering the wonderful world hidden from sight.





▲ Top, Federic Capasso. Bottom, publications containing work from the Capasso lab.

credit: Capasso lab

So, the message is very clear, getting kids early on to become interested in science is crucial, not just intellectually, but emotionally interested in science."

What do you mean by, science is emotional?

"The fact that science is beautiful; it's not just about calculating or doing experiments. There is a beauty associated with the way our world is put together. There is a passion that you can't exactly quantify. You can't measure enthusiasm or excitement on a meter. It is this excitement that needs to be fostered in younger generations of scientists."

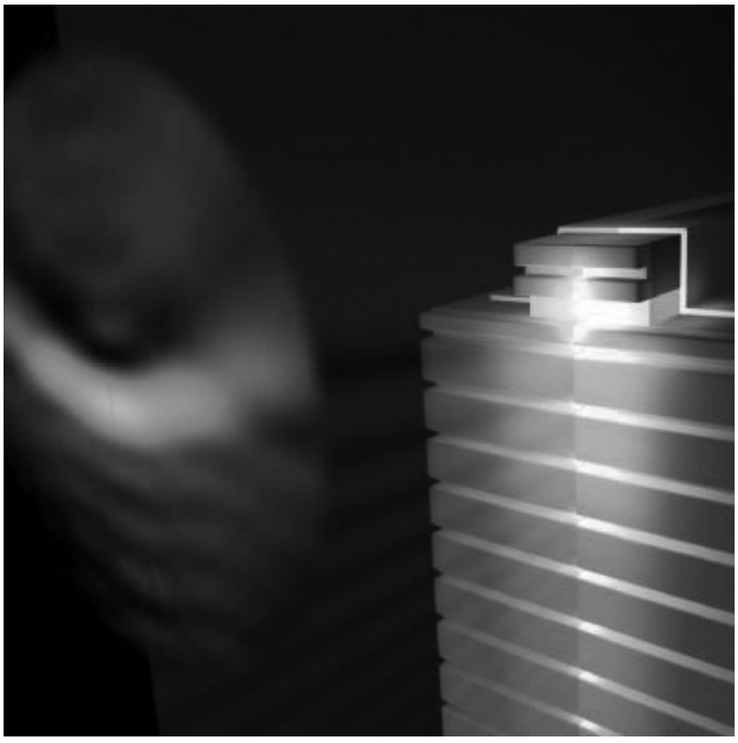
Plasmonics, photonics, electrodynamical forces—your research interests are many and varied. How would you describe yourself and your work?

"Intellectually, I'm interested both in fundamental science and applications, in working with industry. I like to cover the whole range. Nature does not make distinctions between physics, chemistry, and biology, between what's applied and what's pure, so why should we? All these divisions in science are simply a way to measure knowledge.

I do not like to be pigeonholed—I am neither an engineer nor a physicist nor an inventor. I am scientist working on interesting problems. I love technology and I am proud of what we have been able to do with it. And as a professor and as a researcher, my job is to cover science broadly, teach a deeper understanding of nature, and see what you can do with it."

Where is the frontier in optics today?

"Currently, optics is undergoing a true revolution. Even though the equations for light have been known since the nineteenth century, we are now applying them in novel ways. In the field of optics, we have always been limited by the wavelength of light. For example, what we can see with our eyes is limited to the wavelength of visible light, so we can use X-rays or infrared rays to "see" much smaller things.



▲ An example of light engineering: a cartoon of a quantum cascade laser with a collimator that reduces vertical divergence.

credit: Capasso lab

However, even then we are limited to their wavelengths. Over the years, I realized that there is a lot of interesting optics that you can do, at scales much smaller than the wavelengths. That is very exciting. Eight years ago, people would have looked at you in a weird way. Now, this exciting field is called sub-wave physics, or sub-wave photonics.

The big question is, by using sub-wavelength photonics, how can we modify the laser so that we can literally contour the shape of the beam? The frontier that my group [the Capasso Group] is opening up is called light engineering. We are creating all kinds of properties of light that are man made by understanding the laws of physics. We have been successful in creating a laser that can concentrate light in a spot thirty times smaller than its wavelength. Currently, we are working to create a laser that can emit multiple wavelengths of light in multiple directions."

"We should not have artificial barriers between these imaginary divisions. The goal is to create links between fields that have always been held apart."

What kinds of applications can you imagine being produced from these ground-breaking research in optics?

"The challenge is to design a meta-material that allows you to do super focusing, or focusing light well below its wavelength. Five years ago, people would have told you, "Frederico is out of his mind; he doesn't understand physics." I'm interested in demonstrating that it's possible to create a laser that can focus light to a dimension much smaller than the wavelength itself. That's the long haul. I don't know when it'll happen. But when that becomes possible, we are well on our way to creating discs with a terabyte memory. In the future, we will have discs with two to three hundred gigabyte of space. It's only a matter of time."

What are some current trends in science?

"In the old days, science was simple. People had to make their own instruments, so at the same time they had to be engineers and physicists. I wish to keep this mentality alive and well. However, as science became more specialized, an imaginary hierarchy was created, in that pure science is superior to applications, that physics is more abstract and therefore superior to biology, for instance. Our future is to reduce the barrier between departments. It's passé, it's wrong, and it's plain unproductive to say that physics is over here, chemistry is over there, we can't work together.

We should not have artificial barriers between these imaginary divisions. The goal is to create links between fields that have always been held apart. New fields are coming together, often in the nano-scale, and we should be creative in how we utilize these interface. Harvard is ahead of the game, and the new dean of SEAS, Cherry Murray, is working hard to reduce these barriers by encouraging inter-departmental cooperation."

You hold more than fifty patents. What kind of advice would you give to aspiring inventors?

"My father once said: "Make sure your brain never becomes a coat hanger, something that other people attach their ideas to." I would say the most important thing is to be curiosity driven. Fall in love with something that you really like. Find out what the important problems are there to solve that can make an impact in society. Be creative, and try to understand the real world problems. You have to believe that what you're doing is the most important thing. You have to believe that what you do can make a real change. Just being smart is not enough, because smart is fairly cheap nowadays. Science—and inventing—requires commitment, discipline, and curiosity."

In the words of Professor Capasso, science is an "emotional" entity, to be felt across multiple academic disciplines and with one's intellect and zeal. After an afternoon spent in his office and laboratory, it is evident to *The Harvard Science Review* that he embodies his own philosophy thoroughly and we eagerly anticipate more groundbreaking work from his lab in the future. H

—Helen Yang '12 is a History and Science Concentrator in Adams House.

1. The King Faisal Foundation (2005), vol. 2009. [http://www.kff.com/EN01/KFIP/1425H2005G/KFIPWinners5SCI1425H2005G.html]