SNEAD: You actually manipulate light to make devices. How do you force light to make things?

LIPSON: Light usually likes to propagate in straight lines. So how do we tell light, “No, no, don’t go straight! Turn left. Turn right.” How do we distribute light? This is a very hard thing to do, especially at extremely small distances. Since light likes to go in a straight line, we can put it in a fiber, and then bend the fiber so very little that light doesn’t notice it’s bending.

Now, how do we make little devices? A lot of what I do is for computer applications. That’s chip scale. We use a special combination of two very different materials—oxide (basically glass) and silicon. These are the same materials used for microelectronics. It happens that this combination is fantastic for bending light.

Light always wants to travel in a straight line, unless we use this combination of materials to force it to bend. We etch down the silicon to form miniaturized fibers on the chip. About 10 thousand times smaller, the silicon fibers are now called the waveguide, and light travels through them. We actually make tiny tubes of silicon through which light travels, and we bend the silicon so that light stays in the silicon and travels around.

Once you know you can bend light using these special materials, what’s next?

Our goal is to make photonics or optics for applications in microelectronics, where they’re really needed. The microelectronics industry today is limited by heat dissipation. The industry can’t really increase the performance of next-generation computers because computers are getting hotter. But if we use light to propagate information, we can transmit a lot of information very fast with very low power dissipation. That’s our goal.

Is that what you mean by all-optical information systems?

Little devices, including an all-optical switch, all-optical modulators, even cloaking devices—this is what the ability to manipulate light can yield. And Lipson has invented many little “light” devices for use in the microelectronics industry.
Yes, all-optical switches, all-optical modulators—all the little devices that compose the entire link of sending, distributing, switching, modulating, and detecting information. Everything is controlled by light.

You’ve made many devices by controlling light, making it do what you want.

We’re getting very close to where we can build systems that are made of all our devices, exhibiting formats that no one ever dreamed could be done with standard technologies. The amount of information we could send using a system made of these elements would be unbelievable. We are talking about supercomputers on a little chip, for example.

Right now, what would be your dream device?

Now that we know how to control light, we are looking at other areas outside of microelectronics where our research can be applied. We can control light using similar materials for a completely different application. For example, using light we have demonstrated cloaking—the Harry Potter phenomenon.

The cloaking device is used for hiding defects in objects. In the fabrication world, an interesting application is for masking. Say you make a mistake, and you don’t want to refabricate an entire thing. That’s okay—we can put something on top of the defect and mask it out.

Based on our work, a group at MIT demonstrated cloaking using the same principle, but now on a larger scale. They can actually hide something big—on the centimeter scale. Now we know that bigger things can be cloaked.

Of the many devices and techniques you’ve invented, which one excited you most?

We have about 20 patents based just on the way we bend or use light. One of the most popular devices—it got a lot of attention and has had a big impact—is the modulator, which translates electrical signals to optical signals. We were the first to demonstrate a very small, very low power modulator.

This device opened a new field, silicon photonics, which was rather exotic when it began. Silicon was not used as an optical material. It was only used as a microelectronic material. But once we demonstrated it, we got lots of followers. All major industries and universities now have research in this area.

How do you show us, the nonscientists, what you see? How do you create images?

We can actually take pictures of some of the larger devices with high-resolution microscopes that are sensitive to the infrared light that’s being guided. You can really see light going by.

You also developed a laser with your husband, Alex Gaeta, professor of applied and engineering physics.

It’s not exactly a laser—it’s an oscillator. It emits like a laser. The idea is that we send light into the chip, and light travels around and around. We make a wave and a loop, and it gets amplified. As a result, we get a whole series of colors all with the properties of a laser, meaning they are very directional and are collimated.

These oscillators could be used for computer applications, to provide the light that is needed to send the large amounts of information across the chip. For optics, it’s critical to have many colors of light. That’s the beauty of light—we can transmit information using not just one color, but many colors, all propagating together, which gives us much more bandwidth, much more information.

I note that one application of your work is sensing. Are you looking at making sensing devices?

That’s another application of manipulating light on a chip. We have a project with Antje Baumann in Biological and Environmental Engineering, and we work on sensing analytes using optics.

It’s a spectrometer on a chip that could detect the spectrum using very little specimen, instead of putting on a specimen and waiting for a few days. Our sensor will be so sensitive that it will work with just a few analytes. This is an important, very fast measurement for detecting diseases early.
The beauty of this research is its great combination of fundamental physics with very clear applications. I like that a lot. And I can make a difference using interesting physics—invent a completely different technology based on basic principals of physics and apply them directly to applications.

I believe that, as researchers, we have the chance to open up new areas to explore and show the possibilities. And we’re definitely going in this direction, making sure that Cornell is always a leader.
We have recently demonstrated that light can have sufficient force to move and control mechanical oscillators—the type that are embedded in our cell phones, for example. We showed that this ability can enable synchronization between such mechanical oscillators. Because light can propagate at long distances this means that, in the future, a cell phone with such a mechanical oscillator could force another phone in a completely different city hundreds of miles away to tune to the same channel, as long as they were linked in some way through light.

**And you’re starting a company?**

Yes, with Alex Gaeta. The name of the company is Picoluz. It’s *pico*, meaning little, and *luz* for light. I’m Brazilian, and Gaeta is Spanish, so altogether it’s “luz.” The company is based on little photonic devices for nonlinear applications—for example, amplifiers and light meters—all based on nonlinear properties of silicon photonics. The market is instrumentation for making measurements in the lab.

**You do so much, and you’re a mother, as well.**

When I got the MacArthur Fellow award, it was the first time my boys really connected to my scientific world. They came home from school saying, “Ima,”—they call me mother in Hebrew—“Everybody’s asking us about you!” My youngest son came home with a congratulatory note from his teachers. It felt wonderful. Among scientists, there are not many female scientists and definitely not many mother scientists. To get this endorsement from my kids is very special. They’re ages 7 and 15, and both want to be scientists, although I’m not sure they really have a choice [lots of laughter].