# Silicon lasers: the final frontier

People have been trying to get silicon to lase since the first semiconductor laser in the 1960s. Thanks to recent breakthroughs, silicon lasers are finally beginning to take flight. **Amber Jenkins** spoke to Haisheng Rong, Victor Krutul and Manny Vara at Intel to find out more.

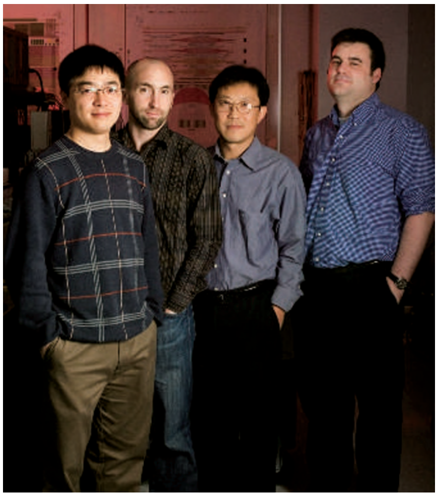
**Silicon photonics is all the rage right now. Why the interest in silicon lasers?**
Optical communication has changed our lives. By hooking a laser up to a transatlantic cable, you can drive an optical signal for thousands of kilometres and transmit a lot of data with very low loss. The problem is that conventional communication lasers are made from exotic semiconductor materials that are not produced in bulk, so they are too expensive for interconnects or to put into computers or servers where we cost things in 'pennies per pin'.

Today most optical functions can be performed in silicon using components such as waveguides and modulators, but the laser is really the final frontier. We make hundreds of millions of silicon chips per year; if we can use existing CMOS manufacturing facilities to make silicon lasers, we can drive the price down and open up mass-market applications to optical technology.

**What was the impact of your first continuous-wave silicon Raman laser?**
When we started working on the silicon laser two years ago, we took a different route. Most people had attempted to create a laser based on stimulated emission, but we used stimulated Raman scattering instead. Demonstrating the first continuous-wave Raman laser in silicon was a technological breakthrough. More importantly, it was a psychological breakthrough. Up to that point, people didn't believe that a practical laser could be made using silicon. Our work said to the field: "There is hope after all."

**How have things progressed since then?**
Our first silicon laser was really a proof-of-concept demonstration, a bit like the first flight taken by the Wright brothers when they invented the aeroplane — we showed it was possible, but there were still lots of practical issues. It was a simple construction — a silicon waveguide and a linear laser cavity. But the cavity design did not enable integration with other photonics components on chip, and the laser required relatively high power to operate [about 200 mW].

Since then we've put wheels on the plane, and built a stronger engine so that it can take off on a normal runway. We've boosted the laser's power output by five times to more than 50 mW, decreased its lasing threshold by ten times and scaled down its size from 5 cm to 1.5 cm. Using a ring cavity, we've integrated the entire cavity onto a chip — crucial for connecting it to other components. More importantly, we no longer need an external power supply to achieve lasing. The device has become 100% optical and can be used in applications that don't have access to external power, such as remote sensing,



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Pioneers of silicon lasers. From left to right: Shengbo Xu, Simon Ayotte, Haisheng Rong and Jonathan Doylend.

**How has the environment at Intel shaped this progress?**
As photonics researchers, we are very lucky to work closely with fabrication-process engineers. They give us valuable insights into the manufacturing techniques that enable us to get optical functions out of the chip. Working in a company such as Intel, which makes silicon chips for a living and makes them very well, we have that entire infrastructure behind us. It's a nice combination to have and helps us to translate research and development into high-volume, low-cost end products more quickly.

**Where next for your silicon laser?**
In the short term, we need to address interface issues — how to get light in or out of the chip more efficiently. It's very challenging to keep losses within the waveguide small when you shrink it to tiny proportions, but we can overcome this. In the longer term, we want to make the laser cavity more tunable. With the proper design one can envisage shifting the emitted wavelength to the mid-infrared range and creating a room-temperature mid-infrared laser. This would open up a lot of applications.

**What kinds of applications are in store for the silicon laser?**
Historically Raman lasers have been less popular than their traditional counterparts, but they can cover spectral gaps not accessible to conventional lasers. In biomedicine, a silicon Raman laser could be important for detecting specific molecular transitions. Alternatively, doctors and dentists could use a Raman laser that emits several wavelengths for different purposes: one wavelength for tooth ablation, say, and another for tissue incisions.

**How will silicon lasers affect people's lives?**
The killer application for silicon lasers is information — delivering huge amounts of data, and fast. In the future we can imagine some form of silicon lasers sitting alongside processors inside high-performance servers around the world, helping to transmit data from one computer to another in record time. You might be able to download the entire content of a film in a couple of seconds rather than the half a day it can take at present. But aside from computers, by siliconizing photonics we can take optics to places no-one thought possible, influencing optical communications, wireless technology, sensing, lab-on-a-chip research and even healthcare. These things will profoundly affect people. The silicon laser is a key part of this vision.

*Amber Jenkins is an associate editor of* Nature Photonics *and is based in San Francisco.*
*e-mail: a.jenkins@naturesf.com*

*Rong and his co-workers have an article on Raman silicon lasers on p232 of this issue.*