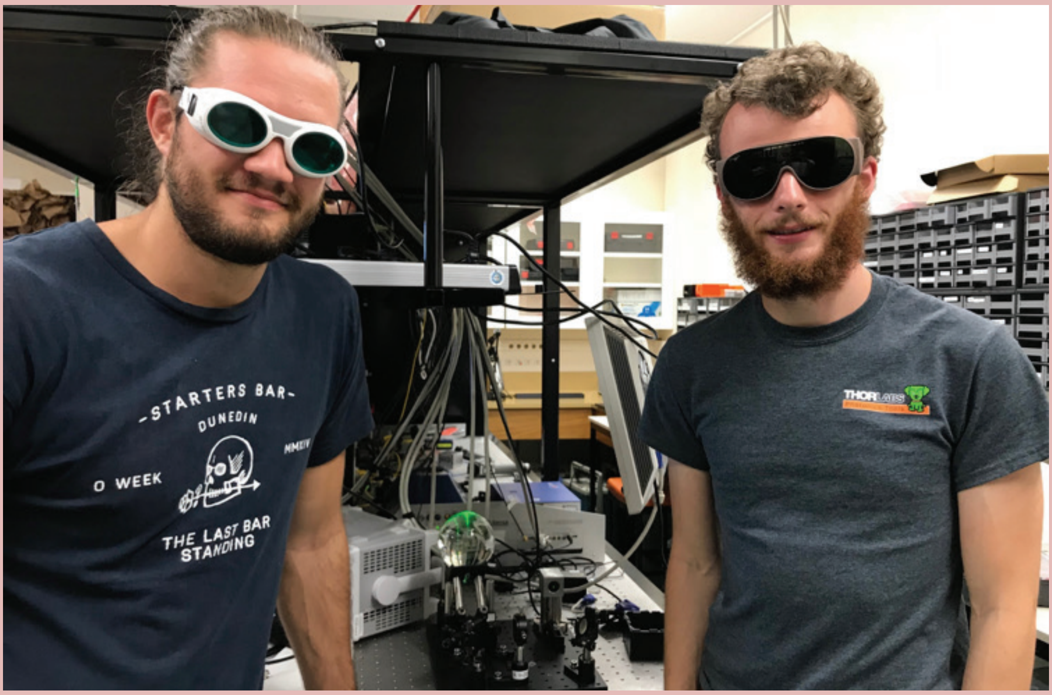
World Leading Collaboration on the Hottest Topic in Optics: Combs of Light in Crystal Discs

A team of Dodd-Walls Centre researchers have devised a new way to transform a single colour of laser light into hundreds of different colours using tiny disks of crystal. The resulting new type of 'microresonator optical frequency comb' could improve the energy efficiency of the internet, which currently sucks up vast amounts of energy to encode and transport data. They could also enable ultra-precise new methods of imaging and spectroscopy and could one day be used in portable devices to detect diseases, chemicals or explosives.

Last year the researchers were awarded nearly one million dollars of Marsden Fund money to develop and test this exciting new technology. With the help of the Dodd-Walls Centre and the Royal Society of New Zealand, the collaborative team of researchers from The University of Auckland and the University of Otago have already recruited a postdoctoral fellow and a Masters student in Otago and one Ph.D. student in Auckland to work on the project.

"We're trying to get a lot of hands on board so the knowledge is spread around the student body," said Harald Schwefel, one of the Principal Investigators on the team. "It's cool stuff. I'm confident it will lead to applications and start a new field."



Dodd-Walls Centre Ph.D. students Ian Hendry of The University of Auckland *(left)* and Luke Trainor of the University of Otago *(right)* working together on optical frequency comb experiments.

Optical frequency combs are one of the hottest topics in optics today. The reason is that several applications are in desperate need of different colours (or frequencies) of laser light. For example, the internet. Every email, cell phone call and website visit is encoded into data and sent around the world by laser light. In order to improve bandwidth and fit more data down an optical fibre the signal needs to be split into different frequencies of light that can be read separately. Miro Erkintalo, another Principal Investigator on the project explains the difficulty:

"Lasers only emit one colour at a time. What this means is that, if your application requires many different colours at once, you need many lasers. All of them cost money and consume energy. The idea of these new frequency combs is that you launch one colour into the microresonator (the crystal disc) and out comes a whole range of new colours."

One of the best things about these microresonators is that they operate at very low powers measured in milliwatts. The technology therefore has full potential to dramatically reduce the energy consumption of applications requiring many lasers with different colours – such as the internet.

Another use for the frequency combs is high-precision spectroscopy — using laser light to study and identify the chemical composition, properties and structure of materials including diseases, explosives and chemicals. In order to detect many important molecules, laser light is required in the mid-infrared frequency range. Unfortunately, lasers operating in that region are scarce. The new microresonators show potential to deliver a whole array of laser frequencies within this range.

This project is the first of its kind in the world. Up till now researchers have only explored microresonator optical frequency combs based on so-called 3rd order nonlinear effects. In these devices, the range of frequencies you get out centres around the input frequency. So if you shine near-infrared laser in, you'll get near-infrared light out plus a range of frequencies around the input. But with these new crystal devices (based on 2nd order effects) you can theoretically generate frequency combs in totally different regions of the spectrum. You could shine a green laser in, for example, and generate a frequency comb in the infrared. This would make it possible to reach many previously unobtainable colours.

The idea for the project sprung from a serendipitous meeting of researchers within the Dodd-Walls Centre. Harald who works at the University of Otago is a world expert in crafting crystalline resonators to alter the colour of laser light. He had observed optical frequency combs in his crystals before and wanted to explore them further. Miro is world renowned for his theoretical models explaining 3rd order optical frequency combs. Along with his colleagues at The University of Auckland he has been studying them for a number of years. The idea for the new 2nd order frequency combs emerged from Miro's collaboration with researchers in Italy who had observed 2nd order phenomena in large optical resonators about a metre wide and made with mirrors. Miro had been developing models to explain them. It struck both Miro and Harald that they had two parts to the same puzzle.

"We realised that Harald had a unique ability to create microresonators that are exactly suitable for this kind of experiment," Miro explains. "We had the experience in Auckland to do experiments and I had done the modelling so we thought it would make a good collaboration."

At this stage the team is excited to lay the groundwork and test the stability, spacing and dynamics of the combs. For the future there is potential to develop a niche industry around the research with commercialisable intellectual property and products.

"The technology we're exploring is something entirely new, so there's a lot of basic physics and engineering we need to unravel," said Miro. "But of course, that's how all great things start."

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