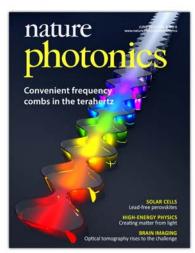
Terahertz laser frequency combs

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The development of optical frequency combs has had a revolutionary impact on high-precision metrology and spectroscopy, and the development was recognized with a Nobel Prize in 2005. At visible and near-infrared frequencies, the combs are often formed based on mode-locked lasers whose periodic pulse trains in the time domain naturally lead to frequency combs from the duality relation in Fourier transform. More recently, a new type of frequency comb was developed using nonlinear optical sideband generation based on four-wave mixing (FWM) [1]. In these devices, a coherent *cw* laser source is used to pump a microresonator with high quality factor and equally spaced cavity modes. When the pump lasing frequency coincides with a cavity mode, the cavity-enhanced FWM generates multiple sidebands in a bifurcate fashion at other cavity modes.

In 2012, a mid-infrared frequency comb was developed based on FWM in a quantum cascade structure [2]. A straightforward implementation of this scheme will likely fail at THz frequencies because of the much stronger group-velocity dispersion due to the proximity to the *Reststrahlen* band. By using a carefully designed and fabricated integrated dispersion compensator, we were able to develop laser frequency combs at THz [3]. This breakthrough will enable the creation of compact terahertz spectrometers that replace the bulky systems currently in use. With comb-based spectrometers, we can achieve the high resolution (~kHz) and S/N ratios of laser spectroscopy, the broadband capabilities of FTIR (>1 THz), all with no mechanical moving parts. This development will enable a wide range of applications not currently possible.



- [1]. T. J. Kippenberg, R. Holzwarth, and S. A. Diddams, "Microresonator-based optical frequency combs", *Science* **332**, 555 (2011).
- [2]. Andreas Hugi, Gustavo Villares, Stéphane Blaser, H. C. Liu, and Jérôme Faist, "Mid-infrared frequency comb based on quantum cascade laser", *Nature* **492**, 229 (2012).
- [3]. D. Burghoff, T.-Y. Kao, N. Han, C. W. Chan, X. Cai, Y. Yang, D. Hayton, J.-R. Gao, J. L. Reno, and Q. Hu, "Terahertz laser frequency combs" *Nature Photonics* **8**, 462 (2014).