Terahertz quantum cascade laser frequency combs

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Optical frequency combs—light sources whose lines are evenly spaced—have proven to be remarkable tools for spectroscopy and for metrology. Traditionally, these combs were generated using mode-locked solid-state lasers, which can provide very stable combs with hundreds of thousands of comb lines, but at the cost of being relatively large (~10 cm). However, in the last few years there has been interest in new chip-scale frequency combs, such as microresonator combs and semiconductor mode-locked sources. At long wavelengths, it has been shown that quantum cascade lasers (QCLs) are capable of forming a comb state that does not possess the properties of conventional mode-locking, wherein the dispersed cavity modes of a Fabry-Perot cavity synchronize by four-wave mixing [1].

By incorporating proper dispersion engineering, we have shown that it is possible to create QCL frequency combs at terahertz (THz) wavelengths, which enable offer broad bandwidths in a compact package [1]. These combs are particularly attractive as sources for compact spectroscopy: by using a dual-comb technique, it is possible to perform high-sensitivity spectroscopy without moving parts [2]. In addition, due to the semi-continuous nature of the temporal output of these lasers, it is possible to continuously track the instantaneous phase and timing signals of a dual-comb waveform, enabling computational self-correction of the dual-comb signal even without a reference. Provided the signal-to-noise ratio of the acquired dual-comb signal is high enough to enable self-correction, one does not require stability for many spectroscopic measurements [3].

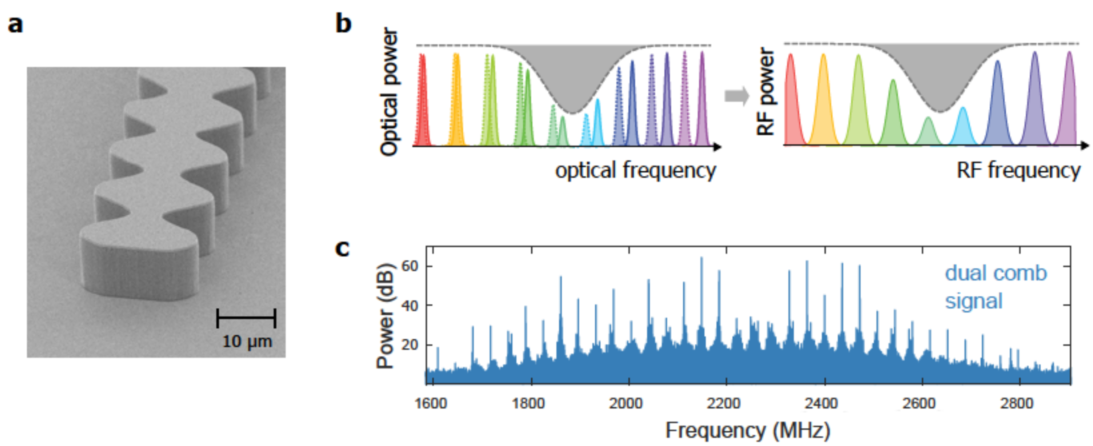

Figure 1. (a) SEM of a THz double-chirped mirror. (b) Schematic version of dual comb spectroscopy. (c) THz QCL dual comb spectroscopy, measured on a hot electron bolometer (HEB).

[1] A. Hugi et al., Nature **492**, 229 (2012).
[2] D. Burghoff et al., Nat. Photonics **8**, 462 (2014).
[3] Y. Yang et al., Optica **3**, 499 (2016).
[4] D. Burghoff et al., Sci. Adv. **2**, e1601227 (2016).

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