

Intensity noise power spectral density of terahertz harmonic frequency combs side modes

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Abstract: We assess the intensity noise power spectral density of terahertz quantum cascade lasers, operating as 8th order harmonic frequency combs, retrieving a reduced intensity noise difference between individual side modes.

Quantum cascade lasers (QCLs) are considered ideal candidates for the emission of quantum correlated optical modes. In a simplified picture, pairs of photons are generated into symmetric side-modes around a central mode, so those “twin” modes should exhibit correlated amplitude fluctuations and, ideally, reduced intensity-difference noise, i.e. two-mode squeezing, owing to the inherent four-wave-mixing processing occurring in the heterostructure gain medium. In QCL combs this prospect is especially intriguing because the giant intersubband $\chi^{(3)}$ nonlinearity is intrinsic to the gain medium. QCL combs hence provide a credible physical platform in which quantum correlations between symmetric modes may emerge.

Here, we present an experimental study of the intensity noise of terahertz frequency QCLs. We measured the intensity noise power spectral density (INPSD) of THz QCLs operating in high (8th order) harmonic frequency comb[1] (HFCs, see Fig.1a,b) regime, employing state of the art, graphene nano-detectors integrated on optical platforms, with record minimum detectable powers (≈ 20 pW), approaching the sub-shot noise range[2].

The retrieved INPSD (Fig.1c-e), show that that INPSD of the side mode 1 (Fig.1d) is very similar to the INPSD of the entire THz QCL beam (Fig. 1c), while the INPSD of side mode 2 is significantly larger (Fig.1e), a result that may be evidencing the presence of quantum correlation effects between the lines of the harmonic FC devices[3,4]. A discussion of the experimental approaches to achieve sub-shot noise intensity noise in a balanced detection set-up will be provided.

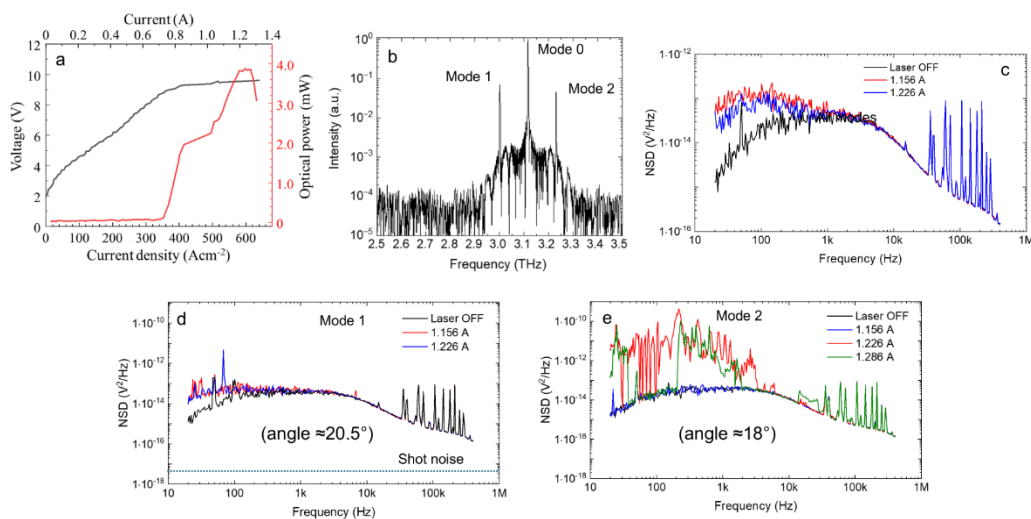


Figure 1 a-b) Light-current-voltage curve (a) and Fourier transform infrared emission spectrum acquired by driving the QCL in continuous wave (CW), at a current $I = 1.22$ A and a heat sink temperature of 30K (b) of the 8th order harmonic FC (HFC) The spectra were acquired from the free-running laser feeding the full beam into a Fourier Transform IR spectrometer. c-e) Measured intensity noise power spectral density (INPSD) of the HFC (c), and of individual mode 1 (d) and mode 2 (e) after separating the QCL beam with a blaze grating set to an angle of 20.5° (d) and 18° (e), respectively. The black dashed line in figures (d) depicts the corresponding detector shot noise level, 4.02×10^{-18} .

References

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