

# Phase-locking of a 3THz quantum cascade laser to an optically generated Terahertz reference

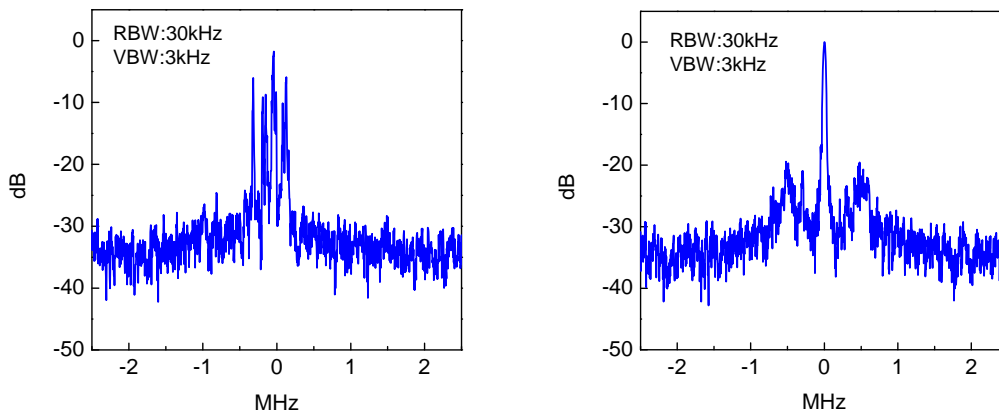
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Compact and high spectral purity sources at Terahertz (THz) band are required for various applications such as broadband wireless communication, remote sensing and high-resolution spectroscopy. THz-quantum cascade lasers (THz-QCLs) are promising light sources in terms of compactness, low power consumption and high brightness. Even though the THz-QCLs need to be cooled down to low temperature for continuous-wave oscillation, they can emit higher output power (a few mW or more) than other sources based on a frequency-multiplying or a photomixing of two lights. The THz-QCLs have relatively narrow linewidth of 10-100 kHz in free-running. Further linewidth narrowing will open the way for advanced applications. A simple solution for the narrowing is a phase-locking to a stable reference. We have successfully demonstrated a phase-locking of the THz-QCL to a THz reference.

We used the QCL emitting a 3THz continuous wave at a heat-sink temperature of 15K. As a stable THz reference, an optically generated THz continuous wave was employed. Coupling two optical modes of an optical frequency comb into a uni-travelling carrier photodiode (UTC-PD), a THz continuous wave was generated by photomixing. By selecting two optical modes whose frequency gap is 3THz, the UTC-PD emitted a 3THz continuous wave with an output power of about 100nW. The THz waves from the QCL and the UTC-PD were superimposed on a hot electron bolometer (HEB) mixer. The HEB mixers consist of strips of thin film superconducting material and function as a THz heterodyne mixer at liquid-helium temperature (4K). The beat signal between the THz-QCL and the THz reference was obtained from the IF port of the HEB mixer. The error signal for the phase-locking is obtained by comparing the beat signal with the microwave reference, and it was fed back to a bias current for the THz-QCL. In this way, the 3THz QCL was phase-locked to the optically generated THz reference. The THz-QCL and the HEB mixer devices employed in this research were fabricated in the Photonic Device Lab of NICT.



Beat signal between THz-QCL and THz reference, (left) free-running and (right) phase-locked