Beam patterns of distributed feedback surface-plasmon THz quantum cascade lasers

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THz quantum cascade lasers (QCLs) become the choice of solid-state local oscillators (LO) beyond 2 THz because of their frequency coverage, compactness, high power efficiency, and narrow linewidth. They have been successfully demonstrated as LO in laboratory's tests using a hot/cold load.[1] Until now only QCLs based on Fabry-Perot cavity have been investigated as LO, including their beam patterns. However, to perform a spectroscopic measurement, QCLs with a stable single–mode emission at a precisely designed wavelength are desirable. For this purpose, a distributed feedback (DFB) structure, which is based on the first order Bragg gratings incorporated into the waveguide, needs to be introduced into QCLs.

Here we report the first beam pattern measurements of 3.4 THz DFB surface plasmon QCLs. The beam patterns are known to be crucial for coupling the radiation to a mixer.

The QCLs used are developed by University of Neuchâtel[2]. The active region is based on a bound-to-continuum design, while the DFB structure is based on strongly coupled surface grating fabricated with wet etching and metal coverage. Two QCLs with ridge widths of 100 μm or 200 μm have been studied and both lase in single-mode at 3.4 THz. To measure the far-field beam patterns, we use a similar setup as for the metal-metal waveguide QCLs[3], but with a reduced surface area of the pyroelectric detector to improve the angular resolution. We found that the beams follow nearly the diffraction limit, if measured with a poor angular resolution and a coarse scanning. However, we observed the interference patterns, characterized by a strong modulation in the intensity with a (intensity) minimum in the pointing direction of the laser, if measured with a relatively high angular resolution and a fine scanning. We also notice that the interference patterns behave in a very much different way as in metal-metal waveguide QCLs[3,4], suggesting a different physical origin. Such beam patterns make heterodyne mixing using the DFB QCLs and an NbN HEB mixer extremely challenging.

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