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Terahertz interferometry and imaging using self-mixing in a quantum cascade laser

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1. Background

The terahertz (THz) frequency quantum cascade laser (QCL) is a high power (>100 mW) semiconductor source of narrowband, coherent THz radiation, which is well-suited for applications [1] in two-dimensional (2D) and three-dimensional (3D) THz imaging. However, exploitation of THz QCLs, to date, has been limited by the need to use cryogenically-cooled bolometers to achieve high sensitivity detection. We have addressed this through the design of a compact and simplified imaging system, based on a self-mixing (SM) scheme [2] in which the QCL is not only used as the THz source, but also as an interferometric detector. In this SM arrangement, the radiation emitted from the laser is coupled back into the emitting facet after being reflected off an external object. This leads to a perturbation in the QCL threshold gain, emitted power, lasing spectrum and terminal voltage [3], each of which can be monitored. Importantly, unlike when using bolometers, the detection is coherent. This opens up the possibility of sensing displacement, surface morphology and reflectivity with high precision [4, 5].

2. 2D and 3D imaging using self mixing

In our self-mixing experiments, THz radiation is focused onto the sample, which is itself raster-scanned transverse to the beam. At each position, perturbation of the QCL voltage through optical feedback from the target is recorded. Fig. 1 illustrates 2D imaging of a scalpel blade, with adjacent fringes corresponding to a change of $\lambda/2$ in the depth of the surface. To acquire a 3D image, the sample was also scanned longitudinally. The phase of the resulting fringes was used to extract the relative displacement of the sample surface, enabling a 3D image to be reconstructed. Exemplar fringes and a fitted SM function [6] for phase and amplitude extraction are demonstrated in Fig. 2.

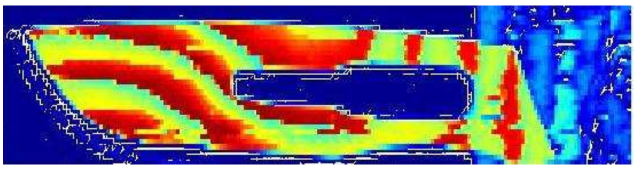

Fig. 1 2D image of a scalpel blade at 2.6 THz

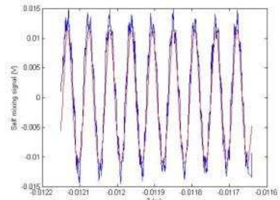

Fig. 2 Data from one pixel of a 3D image, with a fitted curve for phase and amplitude extraction

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