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Three-Dimensional Terahertz Tomography using Quantum Cascade Lasers

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Terahertz (THz) radiation is an interesting tool in science and practical applications, due to the transparency of many materials in this spectral region. Thus, contactless and non-destructive depth measurements of multilayer systems are possible. A quantum cascade laser (QCL) is a compact THz radiation source, which is electrically pumped and consists of alternating semiconductor layers.

Here, we present a method to obtain three-dimensional information by combining a THz QCL with a Michelson-interferometer (recently done in one dimension [1]). Light is coupled into the interferometer with a parabolic mirror, guided through and recorded with a 2D focal plane array which was previously used for spectral measurements [2]. Combined with this setup, it allows the collection of spatial resolved depth information. Therefore the setup can be used for depth measurement and interface detection of THz-transparent samples. By inserting a sample in one arm of the Michelson-interferometer, the optical path of the light is changed due to the different refractive index of air compared to that of the sample. Also changes of the refractive index within the sample can be detected. Figure 1a shows schematically the setup.

As a radiation source, we use a THz QCL processed in a double metal waveguide based on the InGaAs/InAlAs material system [3]. The alternating semiconductor layers form a quantum well structure in which InGaAs represents a well and InAlAs refers to a barrier. The device is operated in pulsed mode and a maximum output power of 587 mW could be achieved by adding a hyperhemispherical GaAs lens to the device facet. The QCL is working up to temperatures of 130 K and is lasing at a center frequency of around 3.85 THz. In Figure 1b the frequency spectrum of the used device is shown.

[1] A. W. M. Lee, T. Y. Kao, D. Burghoff, Q. Hu, J. L. Reno, Terahertz tomography using quantum-cascade lasers, in: Opt. Letters 37, 217 (2012).
[2] M. Brandstetter, S. Schoenhuber, M. Krall, M. A. Kainz, H. Detz, T. Zederbauer, A. M. Andrews, G. Strasser, K. Unterrainer, Spectrally resolved far-fields of terahertz quantum cascade lasers, in: Opt. Express 24, 25462 (2016).
[3] C. Deutsch, M. A. Kainz, M. Krall, M. Brandstetter, D. Bachmann, S. Schoenhuber, H. Detz, T. Zederbauer, D. McFarland, A. M. Andrews, W. Schrenk, M. Beck, K. Ohtani, J. Faist, G. Strasser, K. Unterrainer, High-Power Growth-Robust InGaAs/InAlAs Terahertz Quantum Cascade Lasers, in: ACS Photonics 4, 957 (2017).

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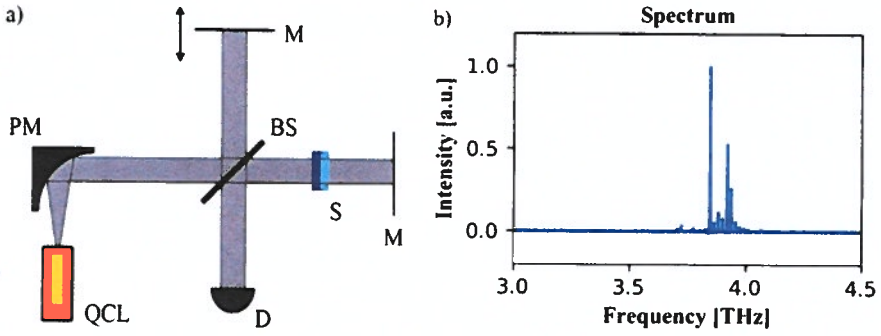

Fig. 1:
a) Schematic Setup: The QCL produces the THz radiation. The light is coupled into the interferometer by a parabolic mirror (PM). The beamsplitter (BS) divides the intensity 50/50 in the reference arm with the movable mirror (M) and the sample arm with the sample (S) and the fixed mirror (M). The 2D focal plane array (D) acquires the signal.

b) Frequency spectrum of the QCL device in pulsed mode at operation temperature of 60 K.