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Spectroscopic Sensing with Ring Quantum Cascade Lasers

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Unipolar quantum cascade lasers (QCLs) are compact and versatile light sources emitting in the mid-infrared and terahertz spectral range. This makes QCLs desirable light sources for spectroscopy and chemical fingerprinting, since all molecules exhibit resonances in these regions, due to their atomic bonds and rotations. The laser energy is designed by bandgap engineering, in contrast to bandgap lasers, and is therefore broadly tunable.

Ring QCLs [1] consist of a ring-shaped waveguide with a second order distributed feedback (DFB) grating on top. The latter selects the lasing mode and provides vertical light emission. Due to the relatively large emitting area, these lasers provide a strongly collimated emission beam. We present several techniques for efficient light extraction from these ring QCLs including integrated phase shifts [2], allowing a centered maximum intensity, and metamaterial-induced manipulation of the substrate-emitted light [3], to improve output power.

In the last years, these lasers have proven to be mature and reliable light sources, suitable for spectroscopic applications. In combination with bi-functional quantum cascade hetero-structures [4], ring QCLDs are utilized for compact on-chip gas sensor systems [5,6] as shown in Fig. 1. This sensor concept monolithically combines surface-emitting and –detecting elements on a single-chip and paves the way for compact hand-held quantum cascade gas sensors [7]. This approach reduces the need for additional optical components and their alignment.

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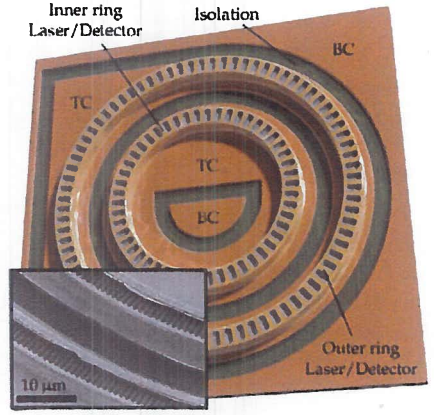

Fig. 1: 3D rendered view and SEM image (inset) of an on-chip ring QCLD gas sensing system. [6]. The same monolithic structure can be used as both the laser and detector. The ring cavity can be used for both vertical emission and substrate emission.