Quantum-Cascade Photonic Crystal Laser

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***Abstract*—The realization of terahertz (THz) quantum-cascade laser operating at photonic crystal modes is shown. The devices are showing stable single-mode operation under all driving conditions and a tuning range from 2.25 to 2.65 THz.**

I. Introduction And Background

THE terahertz (THz) spectral region has drawn a lot of attention due to the large number of possible applications such as real-time imaging[1], heterodyne detection[2] or spectroscopy. These applications require high-power, narrow-band sources with a defined emission characteristic. Quantum cascade lasers (QCLs) are capable of delivering high output powers in this spectral region. However, it is important to find a way to precisely control the emission in terms of frequency and stability. Standard distributed-feedback lasers (DFBs) have shown their potential to solve some of these challenges[3]. Nevertheless, the use of 2-D photonic crystal (PhC) lasers should increase the performance further as their gain enhancement is predicted to be larger compared to 1-D DFBs[4].

Here we present THz-QCLs which are lasing on true PhC-modes. Unlike in previous work[5,6], the PhC are not used as frequency selective mirrors but as the gain medium itself[7].

II. Results

The PhC used is built up by a triangular lattice of dielectric rods surrounded by air with a filling factor of 33 %. The rods are etched through the active region of the THz-QCL by reactive etching. Thereby, a vertical etching profile with smooth sidewalls is achieved. The 2-D crystal is embedded in a double-metal waveguide to prevent out-of-plane scattering. Thereby, we achieve a very high confinement for the optical mode. This allows us to realize devices with a side length of only 5 periods of the PhC, this corresponds to the free-space wavelength of approximately 100 µm.

The period of the PhC has been varied from 22 to 35 µm. The devices are lasing at the flat-band region at the K-point in the lowest band. Thereby, we are able to achieve stable single-mode emission under all driving conditions. These devices allow us to tune the emission from the gain maximum at 2.65 THz, measured at a Fabry-Perot resonator, to 2.25 THz. Spectra for two different periods are shown in Fig. 1. This gives us a 400 GHz tuning range, where the emission can be chosen without a regrowth of the sample. Despite the large tuning range, all devices are lasing at least up to liquid-Nitrogen temperature in pulsed mode operation.

These devices have a large potential for applications due to the precise frequency selection, stable operating conditions, the huge tuning range and reasonably high operating temperatures.

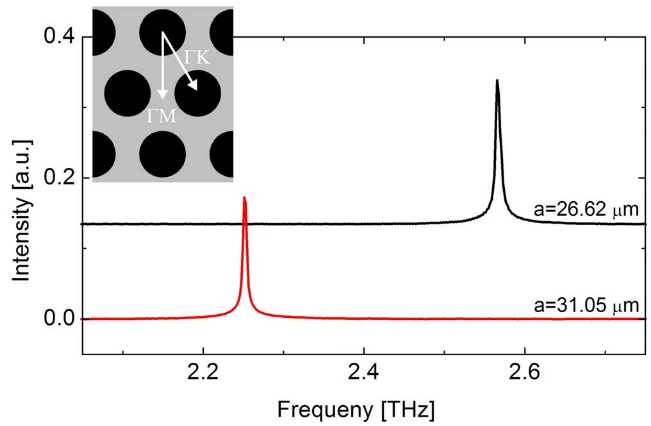

Fig. 1. Spectra for PhC with a period of 22 and 31 µm respectively. The emission frequency is defined by the PhC itself. The inset is showing a schematic of the PhC with the main crystallographic directions.

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978-1-4244-2120-6/08/$25.00 ©IEEE.