Far Field Beam Patterns of Terahertz Quantum Cascade Lasers

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Improving the far field beam pattern of terahertz (THz) Quantum Cascade Laser (QCL) is a key issue for application such as THz imaging or the use of THz QCLs as local oscillators in heterodyne receiver systems [1]. In this work we have modeled and measured the far field patterns of the two types of optical cavities used in THz QCLs, namely the so-called single metal (SM) and double-metal waveguides (DM). The ridges of DM devices are usually much narrower (down to 30?m)[Jesse], yielding a lower power dissipation, an important requirement for space-borne applications [1].

Calculation of the field distribution inside the cavity was carried out using a TDFE (Time Domain Finite Element) code [2]. For the experiment, devices emitting at 2.0 and 2.9THz were mounted on the cold finger of a He-flow cryostat made of polyethylene, thus perfectly transparent to THz radiation. This setup allowed us to scan the far field over nearly the complete solid angle around the devices, by using a Golay cell detector mounted on a fully motorized 2 dimensional rotation stage.

We find that far fields from SM devices are diffraction limited, with an emission cone of relatively small divergence (approximately 30 degrees FWHM for a 2.9THz SP device), showing a good agreement with simulations. Instead in DM devices, emission covers practically the complete solid angle, including the device top, and is characterized by a complex interference fringe pattern. We observe concentric rings in the plane parallel to the laser facets, in agreement with recent measurements from Adam *at al.* [3]. The latter were recently modelled by Orlova *et al* [4], using an analytical approach based on a "wire laser model", which explains the far-field rings structure as due to the interference between the waves exiting the front and rear facets of the laser. Our calculations reproduce this same structure pointing out the existence of a coupling, via the laser facet, between the intracavity field and the surface plasmon formed at the metal/air interface on the device top. Finally, preliminary results are presented on the realization of a horn antenna [5] mounted at the end of a DM QCL waveguide, in order to realize an adiabatic transition between the confined optical mode and free space, leading to a better directionality and radiation out-coupling. In particular, we shall highlight the crucial role played by the confined lateral modes on the coupling with the antenna.

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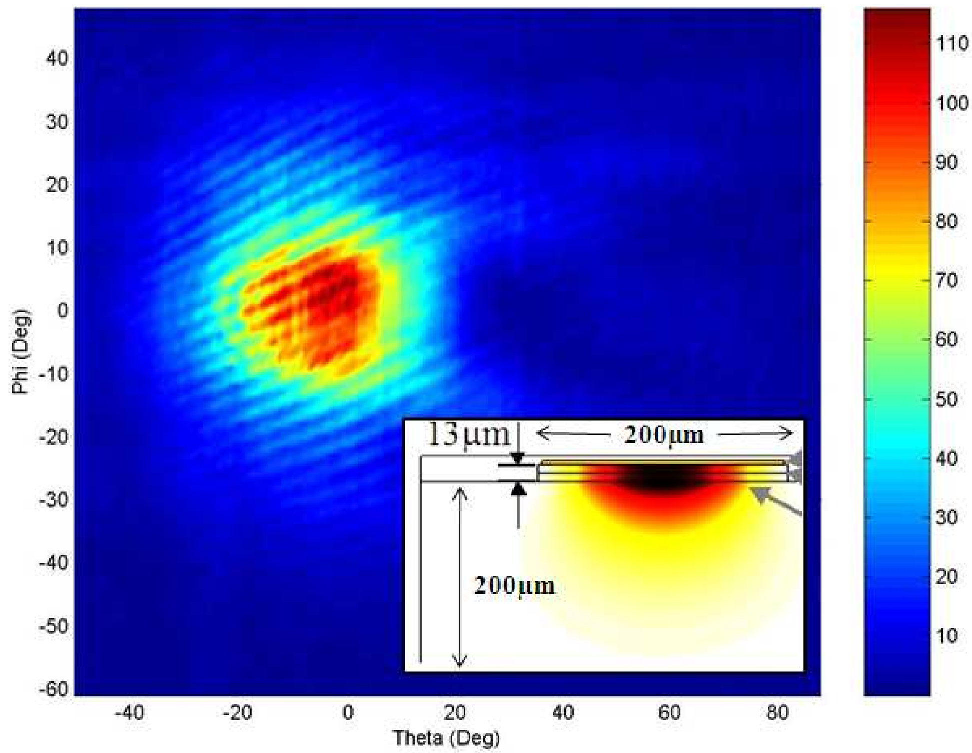

FIG. 1: Far Field beam pattern of a 2.9 THz QCL in a SM waveguide. Angles $\theta = 0, \varphi = 0$ and $\theta = 90, \varphi = 0$ correSMond to the ridge front and top, reSMectively. The waveguide dimensions and the optical mode intensity inside the cavity are shown in the inset. The device length is 3mm long, and the far field was collected at maximum power, with 3% duty cycle.

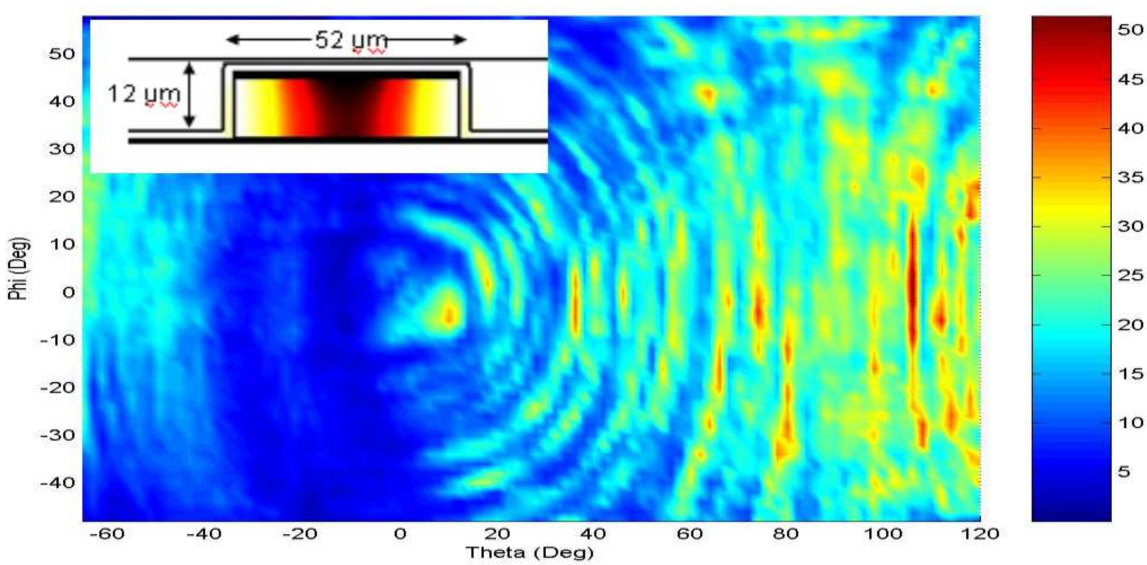

FIG. 2: Far Field beam pattern of a 2 THz QCL in a DM waveguide. The waveguide structure and the optical mode dimensions and the optical mode intensity inside the cavity are shown in the inset. The device length is 3mm long, and the far field was collected at maximum power, with 50% duty cycle