Directional beam pattern from a double metal Quantum Cascade Laser with a TEM-Horn Antenna

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Abstract— **We present the operation and the far field radiation pattern of a 2.9THz double metal quantum cascade laser (QCL) with a micro TEM-horn antenna. An improvement of both the radiation pattern and the collected power level (typically a factor of 2 with f/1 optics) are observed in comparison with the QCL without antenna.**

I. Introduction And Background

THE realization of semiconductor THz radiation sources with high power levels and a directional beam is still a challenging research field. This is despite the fact that there are many applications such as THz spectroscopy for gas or biological bodies (proteins, DNA etc) where such sources would be required. Here we address this problem with an approach based on the combination of a THz QCL with a Transverse Electromagnetic-Horn Antenna (TEM-HA) [1]. Preliminary results have been demonstrated in Ref. 2 and 3. There we showed that efficient coupling to the antenna relies on the suppression of higher order lateral modes in the QCL laser cavity. In this work we put into practice this solution demonstrating that a highly directional, single lobed far field pattern can be obtained by judicious tailoring of the ridge cavity width. We believe that the technological advantage of the approach presented in this work compared to alternative techniques based on macroscopic Silicon lenses and horns, lies in the possibility of fully integrating the antenna on the QCL device [4,5].

II. Results

We have simulated and measured the far field of a double metal QCL with an active region composed of GaAs/AlGaAs epilayers with a total thickness of 14µm, a ridge width of 41µm and a length of 2mm. The operating frequency is f=2.9 THz. The radiation pattern of the laser without horn antenna is shown on Fig1.(b). As can be seen there is a nearly total lack of directionality. The slight lift of the first radiation lobe with respect to the laser facet (0 deg) is due to the fact that a ~1mm long ground plane was left in front of the facet. Next, (see Fig. 1(a)), we have added on the same QCL a 1mm long metallic triangle, forming a TEM-Horn Antenna with the ground plane in front of the ridge.

Experimental and simulated far field patterns are shown on Fig. 1 (c) and (d) respectively. Compared to Fig. 1(b), the radiation pattern is clearly more directional, and we obtain a good matching between simulations and experiments. Simulation where obtained by propagating only the first order lateral mode inside the ridge cavity.

Another improvement is given by the THz power emitted in a solid angle of ~50 deg in front of the laser facet (corresponding to f/1 optics), that we calculate to be 2 times higher compared to the QCL without antenna. Other topologies are presently under study to increase the directivity of this QCL-TEM-HA system and will be illustrated in the presentation.

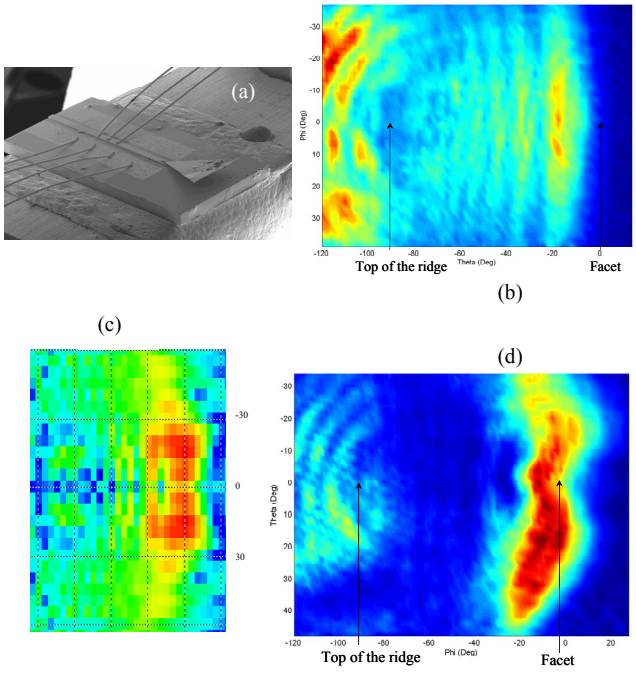

Fig.1: (a) SEM picture of a THz QCL-TEM-HA device. (b) Radiation pattern of a QCL alone. Radiation pattern of a QCL combined with a TEM-HA: Simulated far field (c) and Measurements (d).

III. Conclusion

We have shown a directive THz radiation source based on a double metal Quantum Cascade Laser (QCL) working at f=2.9THz and a TEM-Horn Antenna (TEM-HA). The collected power is increased by a factor 2. The radiation pattern is highly improved with the use of this TEM-HA especially in the vertical plane. However the shape of the antenna is a way to reach higher directivity in both vertical and horizontal planes. The advantages of this approach is that you

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do not need any Silicon lens and it can be monolithically fabricated.

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