Waveguide Embedding of a Double Metal 1.9THz QCL into a Split Block with Diagonal Horn Antenna

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Abstract— **A 70 μm wide, dry etched, double metal waveguide quantum cascade laser, operating at about 1.9THz is embedded into a full-height, 120μm wide, rectangular waveguide. We use a diagonal horn to convert the TE01 waveguide mode into a clean Gaussian beam. The coupling structure, the waveguide and the horn antenna are fabricated in split block technology by ultra-precision -milling and -stamping into a CuTe block. Measurements reveal single mode operation, 80μW output power and confirm the predicted beam shape and beam waist.**

I. Introduction

Quantum Cascade Lasers (QCLs) [1] are promising sources of coherent, CW, THz radiation for the use as local oscillators in astronomical heterodyne receivers. Although these lasers typically emit high output powers up to the mW-range [2], [3], [4], the coupling to the Gaussian telescope optics is generally quite weak due to the poor beam quality of the lasers.

In order to overcome this major obstacle, we embed a double metal QCL into a rectangular waveguide. Because of ease of fabrication, we use a diagonal horn to subsequently convert the guided wave to a Gaussian beam in free space. A diagonal horn reaches a maximum coupling efficiency (Gaussicity) of 84% [5].

II. Microstrip to Waveguide Coupler Design

To achieve a good coupling of the laser radiation to the waveguide mode it is imperative to introduce an impedance matching structure to overcome the high intrinsic reflectivity of the laser facet. We designed, simulated, manufactured and tested a resonant embedding structure, which extracts a fair fraction of the laser power into the waveguide. Small variations of the structure dimensions modify the matching quality and allow fine tuning of the out coupling of laser radiation.

Fig. 1 shows the simulated S-parameters of the first incarnation of the embedding circuit that we manufactured for our tests.

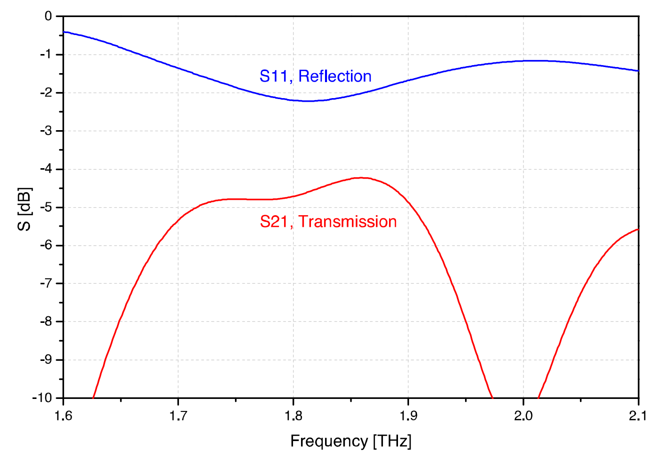

Fig. 1 Reflection and transmission of the microstrip to waveguide coupler, calculated with CST Microwave Studio [6]. About 30% of the power is coupled to the waveguide in the 1.7 … 1.9THz range.

III. Realization of the Waveguide Block

The waveguide structure together with a diagonal feed horn were created in a copper (CuTe) split block by means of advanced ultra-precision machining on a KERN Evo milling machine [7].

The laser chip is maneuvered into the coupling structure with a 6DOF micromanipulation stage and gets fixed with a leaf spring.

Fig. 2 shows the waveguide block with the QCL chip on the top side, hidden under the leaf clamp.

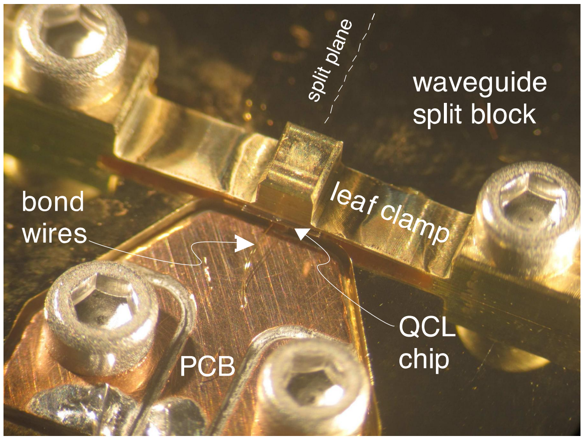

Fig. 2 Photo of the top side of the waveguide block. The QCL chip is hidden underneath a leaf spring which presses it into the coupling structure with a force of about 1N. In the centre of the image, the bond wires leave the recess clearance in the block and establish the connection to the PCB. The diagonal horn leaves the structure on the back side of the block and is not visible here.

IV. Setup and Measurements

We refocus the beam of the diagonal horn antenna by means of an elliptic mirror to produce a beam waist immediately outside the cryostat window. This allows an easy characterisation of the beam parameters. All power measurements are done with a pyroelectric detector.

The beam pattern and beam expansion match the beam shape, predicted from the horn geometry and confirm that the radiation pattern is fully defined by the horn antenna. We measure an output power of 80μW @1.9THz at a coupling factor described in Fig. 1.

V. Outlook

We are testing different coupler geometries with higher coupling factors. A test of the laser in a heterodyne receiver setup is under way.

VI. Conclusions

We report on the first time, a double-metal QCL has been successfully embedded into a rectangular waveguide in split block design. The coupling structure allows a wide range of coupling factors. Thus medium to high output powers can be extracted from the QCL facet. A high quality Gaussian beam is produced by means of a waveguide diagonal horn antenna.

Acknowledgment

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