Integration of Terahertz Quantum Cascade Lasers with Lithographically Micromachined Rectangular Waveguides

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The quantum cascade laser (QCL) is currently the only solid-state source of coherent THz radiation capable of delivering more than 1 mW of average power at frequencies above ~ 2 THz. This power level combined with very good intrinsic frequency definition characteristics make QCLs an extremely appealing solid-state solution as compact sources for THz transmission and illumination and for local oscillators in THz heterodyne receiver systems. However, several challenges to the implementation of QCLs as practical THz sources remain. Among these challenges are to shape the highly divergent and non-Gaussian output beam patterns observed from QCLs into a more useful and predictable beam shape, and to integrate QCLs into the existing, broadly used THz technical infrastructure.

One attractive approach to solving both the beam shaping problem and the integration issue is to integrate QCLs into appropriate rectangular waveguides. If the output from a QCL can be efficiently coupled into single-mode rectangular waveguide, then the radiation mode structure will be known, and the propagation, manipulation, and broadcast of the QCL radiation can then be entirely controlled by well-established rectangular waveguide techniques. Because typical QCL frequencies are > 2 THz, the dimensions of single-mode rectangular waveguide at these wavelengths are on the order of tens of microns. While such small THz waveguides can be made by traditional metal machining, this method is typically expensive, slow, and difficult to reconcile with the electrical connections needed to support high DC bias currents (order 1 A) required to operate a QCL embedded in such waveguide.

We will report on our efforts to use semiconductor lithographic methods to micromachine small, single-mode rectangular waveguide structures compatible with integration of QCLs into a waveguide circuit. Such a micromachining approach has the advantage of being amenable to large-scale production and can be tailored to suit the unique demands of a QCL source.

We have designed, fabricated, and performed preliminary tests on micromachined waveguide structures 75 μm wide by 37 μm tall, designed to operate single-mode at frequencies around 3 THz. These waveguides were fabricated using a modified LIGA (German acronym for **Li**thographie, **G**alvanoformung and **A**bformung) process and were plated with gold. These waveguides are coupled to free space via 2-dimensional horn flares (see Fig. 1) Initial quasi-optical transmission measurements at 3.1 THz using a molecular gas laser demonstrate that these waveguides couple to and guide a THz beam. The dominant loss appears to arise from the fact that the 2-D horn aperture is much smaller than the focused incident beam spot, not from losses in the waveguide itself. We will also discuss designs, simulations, and possibly test results of waveguide structures designed to integrate efficiently with metal-metal guided QCL devices.

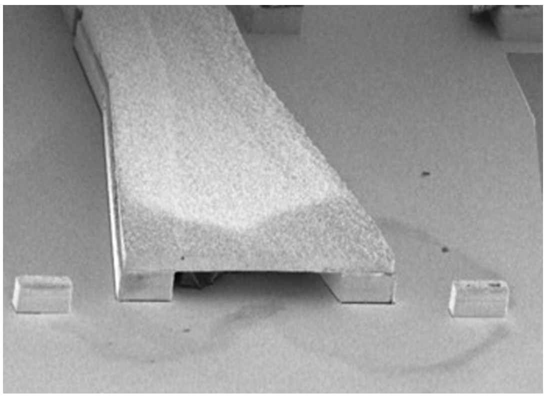

Fig. 1. SEM image of a micromachined 2-D horn antenna flare at the end of a rectangular waveguide. Horn opening dimension is approximately 200 μm wide by 37 μm high.

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