Integration of Terahertz Quantum Cascade Lasers with Lithographically Micromachined Waveguides

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***Abstract*—Gold rectangular waveguides suitable for single mode operation at frequencies near 3 THz have been micromachined using silicon microfabrication methods. The design, fabrication, and loss characteristics of these waveguides will be presented. On-chip integration of these waveguide structures with THz quantum cascade laser (QCL) sources has been achieved and the characteristics of QCL beams guided by waveguide will be discussed.**

I. Introduction And Background

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.[1] However, several challenges to the implementation of QCLs as practical THz sources remain. Among these difficulties are to shape the highly divergent and non-Gaussian free space output beam patterns observed from the edge emitting QCLs [2] into a more useful and predictable beam shape, and to integrate QCL sources into the existing and 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 rather than depend on the properties of the QCL itself. Because QCL frequencies are > 2 THz, the dimensions of single-mode rectangular waveguide are on the order of tens of microns. While such small THz waveguides can be made by traditional metal machining [3], this method is typically expensive, difficult to reconcile with required high DC bias currents (order 1 Amp) connections, and increasingly impractical at higher frequencies.

II. Results

We have designed, fabricated, and tested gold micromachined waveguide structures 75 μm wide by 37 μm tall, designed to operate single-mode at frequencies around 3 THz, where a variety of proven QCL designs exist. These waveguides were fabricated using a modified LIGA process and are coupled to free space via 2-dimensional horn flares (Fig. 1). Quasi-optical transmission measurements at 3.1 THz (using a far-infrared molecular gas laser) indicate that the dominant loss in waveguides a few mm in length arises from the fact that the 2-D horn aperture is very small relative to the incoming beam spot size, not from losses in the waveguide itself.

We have also integrated onto a single chip simple circuits of metal-metal guided QCLs butt coupled to such waveguides. In this process it was necessary to essentially construct the waveguide around an existing mounted QCL. We will present measurements on propagation and output beam shape characteristics of these integrated QCL-waveguide structures.

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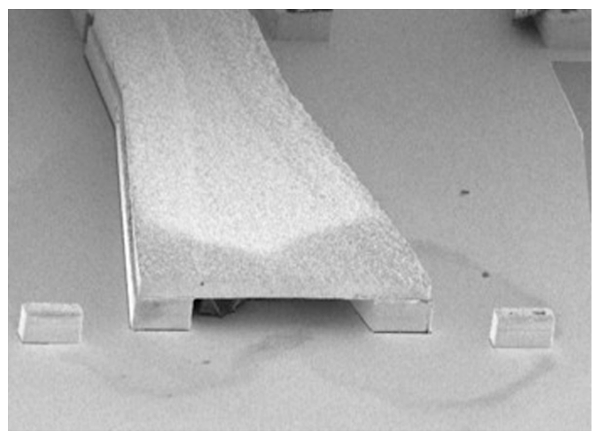

Fig. 1. SEM image of a micromachined 2-D horn antenna flare at the end of a rectangular waveguide. Horn opening dimension is approximately 200 μm wide by 37 μm high.

References

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