Micromachined Terahertz Waveguides with Embedded Metal Rods

Andrew Gallant[a], Adam Baragwanath[b], Peter Swift[b], David Wood[a] and Martyn Chamberlain[b]
[a]School of Engineering, Durham University, South Rd, Durham, DH1 3LE UK
[b]Department of Physics, Durham University, South Rd, Durham, DH1 3LE UK

***Abstract*—In this paper we report on a novel fabrication approach for the manufacture of terahertz waveguides with embedded metal rods. It is anticipated that this type of structure could be used for sub-wavelength imaging or as a method to effectively couple radiation into biological samples.**

I. Introduction And Background

THE field of terahertz spectroscopy and imaging has blossomed in recent years. As the technology has developed, so has the interest in looking at ever smaller objects. One of the common methods to achieve sub-wavelength resolution is via the use of a waveguide tip. The waveguide is used to direct the THz radiation onto a sample in the near field. After interaction with the sample, the radiation can be detected by a measurement of the transmitted signal. Keilmann [1] reported that by inserting a small diameter wire through the waveguide, he could dramatically increase the output transmission due to the wire acting as a transmitting antenna. Fig. 1 shows the effect of including a double wire transmission line in a waveguide cavity. The beam confinement appears to be improved with the double wire transmission line present.

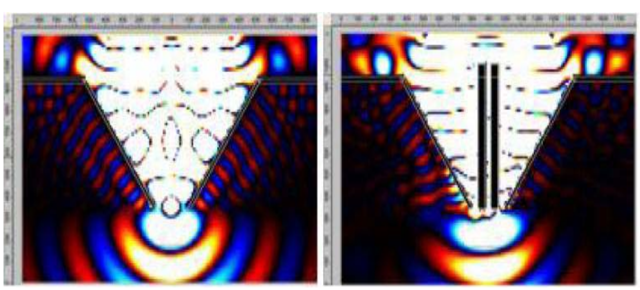

Fig. 1: FDTD simulation of a wavefront passing through a waveguide without (left) and with (right) a double wire transmission line.

In practice however, the fabrication of small and three dimensional elements using traditional techniques is highly demanding [2]. We have reported previously a UV based technique for the fabrication of extremely high aspect ratio gold-coated polymer pillars [3]. In this paper we have used this technique along with bulk micromachining to produce sub-wavelength apertures which contain lithographically aligned 'double wire' elements.

II. Fabrication

First, KOH-based bulk micromachining is used to etch pyramidal cavities through (100) oriented silicon wafers. Second, we fabricate the high aspect ratio pillars on a glass substrate (see [3]) and sputter coat this with gold. Then the aperture and pillar substrates are aligned, brought into hard contact and Sylgard 184 polydimethylsiloxane, PDMS is poured into the apertures and left at room temperature to cure for 12 hrs. Finally, the substrates are separated, causing the pillars to detach from the glass and remain in the PDMS. This completes the structure. Fig. 2 shows a fabricated waveguide.

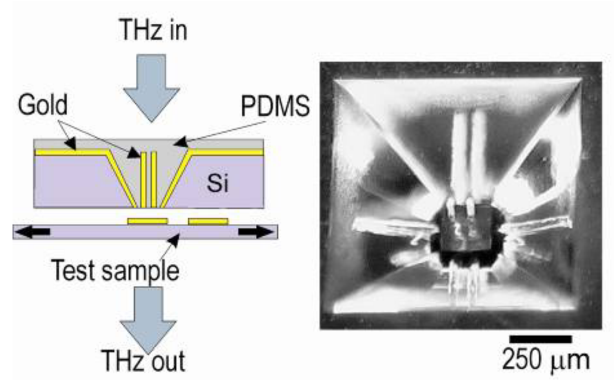

Fig. 2: (left) Schematic of the waveguide (right) A photograph of a fabricated waveguide structure with 40 μm diameter rods (and their reflections).

III. Results

The waveguides were tested in a conventional broadband terahertz time domain spectroscopy system with a bandwidth of 3 THz. A silicon wafer was prepared with patterned gold lines of various widths. This was moved under the apertures and the peak to peak transmission of the THz time domain signal recorded.

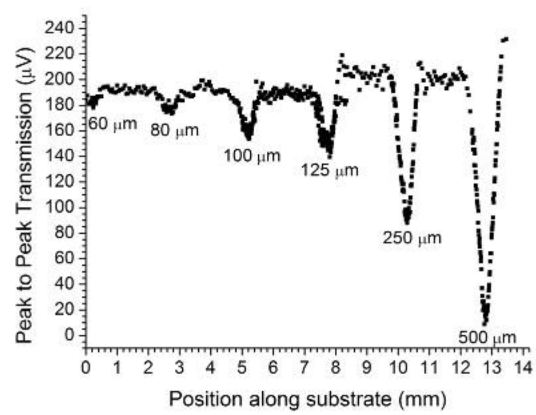

Fig. 3: Variation of the peak to peak THz time domain E-field signal as the test features (width as indicated) are scanned under the waveguide aperture.

Fig. 3 shows the variation of this transmission with feature

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size for a 172 µm output aperture containing a pair of 600 µm high, 40 µm diameter rods separated by 40 µm. It clearly shows detection of features below 100 µm. However, it should be noted that these initial trials were performed with a relatively large aperture to sample spacing of approximately 0.5 mm. Our FDTD simulations indicate that the resolution will be much higher for a reduced spacing.

The fabrication process used for this device enables it to be readily included in other micromachined systems and provide a good means of coupling the terahertz into, for example, biological samples for sensing applications.

IV. ACKNOWLEDGEMENTS

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