A Micromachined 1.37 THz Waveguide-based 2×2 Beam Divider for HEB Detectors

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***Abstract*— A 2 × 2 local oscillator (LO) beam divider for pumping a hot electron bolometer (HEB) based heterodyne array is designed at 1.37 THz. The WR0.65 rectangular waveguide-based H-plane and E-plane junctions are used to construct the feeding network. The divider comprises two 400-µm thick silicon wafers with multilayer deep reactive-ion etching (DRIE) micromachined circuits, and a Pickett-Potter horn array manufactured in copper by computer numerical control (CNC) machining. The two silicon plates and the copper plate were assembled with a special process using multilayer stacking technology to ensure an assembling misalignment lower than 10 μm. The radiation patterns of the beam divider are measured 1.37 THz.**

***Index Terms*—Beam divider, deep reactive-ion etching (DRIE), micromachining technology, multi-pixel heterodyne receiver, radio astronomy, terahertz (THz).**

I. Introduction

To achieve more scientific outputs, the next generation of sub-millimeter heterodyne receivers for both space and ground-based telescopes requires higher frequency bands, higher wide-field mapping speed and wider RF and IF bandwidth. To further improve the observing speed, multi-pixel radio astronomy receivers are favored. The observation speed will be increased by a factor of the pixel number of the receiver (as long as there is no degradation in the sensitivity of the individual pixel.). Therefore, high science throughput can be produced. For example, the observing speed of a 16-pixel focal plane array (FPA) is 16 times faster than a single pixel receiver.

II. Results

This work is focused on the design, fabrication, assembly, and measurement of a 2 × 2 beam divider to couple a LO source to a 1.37 THz heterodyne array receiver using HEB, an extremely sensitive THz mixer. The beam divider consists of a waveguide-based feeding network and four Pickett-Potter horns [1]. The feeding network contains two silicon plates and was fabricated by deep silicon etching [2]. The details of the fabrication process of one of the plates are shown in Fig. 1. The SEM images of the fabricated plates (plate1 and 2) are shown in Fig. 5(b)-(d) and Fig. 5 (e), respectively. Fig. 5 (f) is the fabricated 3D vernier sturcture of plate 2. The vernier will be used in the assembly process.

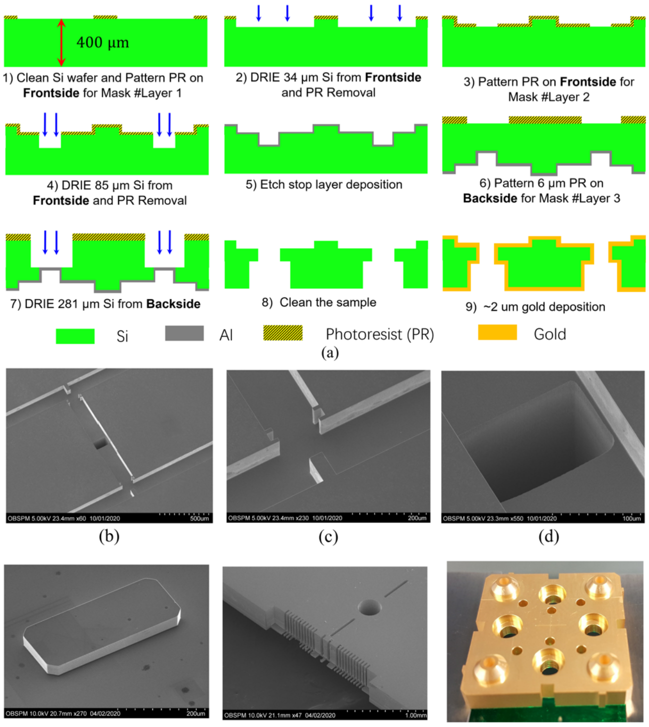

Fig. 1 (a) Fabrication process flow of plate 2. (b)-(d) Detailed SEM images of plate 1, (e)-(f) Detailed SEM images of plate 2 [note the SEM were captured before step (9)]. (g) Fabricated plate 3.

The assembly process of the beam divider was carefully studied and implemented to obtain an accuracy of a few micrometers. The fabricated beam divider is shown in Fig. 2(a). Final, the beam divider was characterized by a LERMA ABmm Vector Network Analyzer in the band of 1.3-1.4 THz. The measured normalized radiation pattern of the beam divider at 1.37 THz is shown in Fig. 2(b). A HDPE lens was set between the beam divider and the measurement plane.

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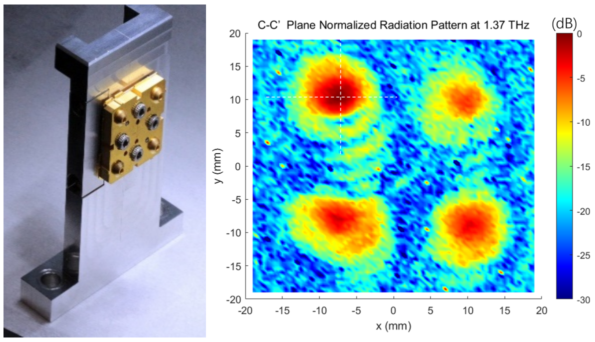
NOTES:

The distance between the beam divider and the HDPE lens is 32 mm, while the distance between the HDPE lens and the measurement plane is 190 mm. For more information about this work, please refer [3].



(a) (b)

Fig. 2 (a) Assembled beam divider, (b) Measured normalized radiation patterns of the beam divider at 1.37 THz.

CONCLUSION

This work provides a solution to couple a single LO source to a multi-pixel heterodyne array receiver for the next generation of terahertz instruments for astronomy. This paper presents a relatively new approach in which the complex E- and H-plane junction-based feeding network is engraved on two pieces of silicon by DRIE technology. The silicon stacked architecture is compatible with the standard micromachining fabrication. A third plate was realized using CNC machining. This work presents the first prototype of a multilayer stacked waveguide-based beam divider at 1.37 THz. The future work is to improve the transmission of the beam divider with the aim of pumping efficiently the 2×2 HEB heterodyne array.

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