Integratable 3D Printed Terahertz Horn Coupler

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Terahertz (THz) band (0.1 – 10 THz) has the potential to fulfill the future demands for 6G communications [1]. A major challenge for THz waveguides with air guiding channels is the poor coupling efficiency from free space. The coupling efficiency achieved utilising plastic lenses are for exmple 11% and 30% for air core hybrid photonic crystal (HPC) waveguide [2] and metamaterial cladded THz fiber [3], respectively. One solution is to use adiabatic metallic horn couplers. However, commercial metallic horn couplers (generally fabricated using CNC milling) are expensive and limited to rectangular standard waveguides dimensions. 3D additive manufacturing promises a potential solution to address these challenges with advantages such as flexibility and less cost [4]. In this work, we experimentally demonstrate an bespoke designed and fabricated THz horn coupler using 3D printing and gold sputtering, which can enhance the coupling efficiency from/to free space and as a result improving the transmittance by more than 20 dB.

We design the horn aperture and apex dimensions by maximizing the field overlap integral of rectangular waveguide with respectively Gaussian beam and a HPC waveguide [5]. Utilizing horn coupler enhances the coupling efficiency form 11% to 84.5% at 0.377 THz (center of the bandgap). We choose 10 mm as the length of the horn, which is much longer than the required adiabatic criterion 3.3 mm [6]. CST simulation of the adiabatic coupling from free space to HPC waveguide is shown in Fig. 1 (a).

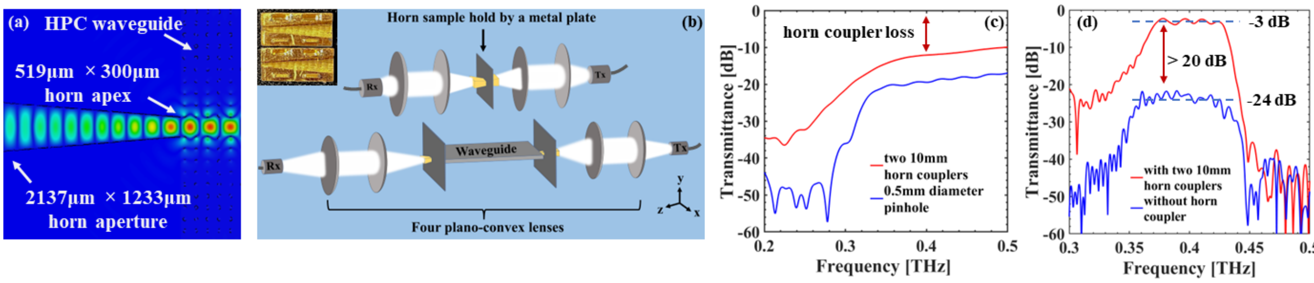

Figure 1: (a) CST simulation: coupling from free space to HPC waveguide. (b) Schematic of experimental setup. The insert is a photograph of the 3D printed and gold sputtered horn coupler before assembling. (c) Transmittance of the horn coupler and a pinhole with diameter similar to the horn apex. (d) Transmittance of the HPC waveguide with and without horn couplers.

We use a fiber coupled compact THz time-domain spectrometer for experiments, Fig. 1 (b). The insert is a photograph of the half parts of the horn coupler before assembling. Figure 1(c) confirms higher transmittance through horn couplers compared to a similar size aperture, where the loss for horn coupler is due to alignment and surface roughness (25 μm) from 3D printing. Despite of the alignment and fabrication losses, the horn coupler improves the transmittance of the HPC waveguide by more than 20 dB, Fig. 1 (d).

In conclusion, we design, fabricate and demonstrate a 3D printed horn coupler which improves the transmittance of a HPC waveguide by more than 20 dB. This work provides a fast, convenient and economical fabircation approach for coupling into air core waveguides with only 5% of the cost of commercial horn couplers.

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