Design and Simulation of a Compact Terahertz Cavity for Reflection Geometry TDS

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Abstract

The gap between the optical and microwave in the far infrared region of Electro Magnetic (EM) spectrum with frequencies ranging 0.1THz to 10THz is popularly known as Terahertz (THz). The research in THz started quite late among its other counterparts in the EM spectrum due to unavailability of suitable sources and detectors. THz Time Domain Spectroscopy (TDS) for transmission geometry has progressed to a well-established position over the last decade through extensive research. But in case of the reflection geometry THz TDS there is still lot of scope for improvement, mainly because the alignment of THz beam, which is invisible to human eye, is extremely difficult for reflection geometry. In this article we have designed and simulated a four mirror cavity for reflection geometry with practical conditions in RF Module of COMSOL Multiphysics software. This simulation gives a good insight about how a THz Gaussian beam propagates within a cavity. We have designed a compact cavity with all the four parabolic mirrors aligned only along two axes and the incident angle on the substrate is 45°. The compactness of the cavity is extreme importance due the fact that THz has to pass through an OH- less ambiance (for practical purpose minimizing OH- molecules from the THz path). Therefore, we purge the path with N2. So lower the cavity length smaller will be the time for purging.

The RF and Wave Optics modules of COMSOL Multiphysics provided a good platform to study the THz wave propagation within the cavity. With inserting exact parameters of the Gaussian THz wave from a point source we have modeled the cavity with exact experimental conditions. We can also see the interaction effects of THz when THz falls on the surface of the substrate. We have optimized the optics with diffraction for lower frequencies from our operating frequency range. All the simulations were performed in frequency domain. We have also tried unsuccessfully time domain analysis, which failed due to unavailability of computational resources. We have used 2 inch focal length (parent focal length) off-axis parabolic mirrors and the final size of the cavity was optimized to 12inch×8inch. Our optimization is done considering the lower bound of frequency is 0.3THz (limited by the emitter response). The Gaussian beam for THz is launched with horizontal polarization, 1mm beam waist and variable wavelength.

The Figure 1 shows loss in electric field for wavelengths lower than the lowest wavelength that proves our set up is optimized. Figure 2, 3 and 4 shows different components of electric filed for 4 mirror cavity at 0.3THz.

Reference

1. M. Tonouchi, "Cutting-edge terahertz technology" Nature Photonics, Volume 1, 97-105 (2007)
2. A. Pashkin et.al. ," Phase-sensitive time-domain terahertz reflection spectroscopy", Review of Scientific Instruments, Volume 74 NO.11, 4711-4717 (2003)
3. N. Hiromoto et.al. ,"Precise and Convenient Reflection THz-Time Domain Spectroscopy with a Movable Transparent Sample Holder", Infrared, Millimeter, and Terahertz Waves (IRMMW-THz), (2013)
4. D. Hashimshony et.al. ,"Characterization of the electrical properties and thickness of thin epitaxial
semiconductor layers by THz reflection spectroscopy", Journal of Applied Physics, VOLUME 90, NUMBER 11, 5778-5781, (2001)

Figures used in the abstract

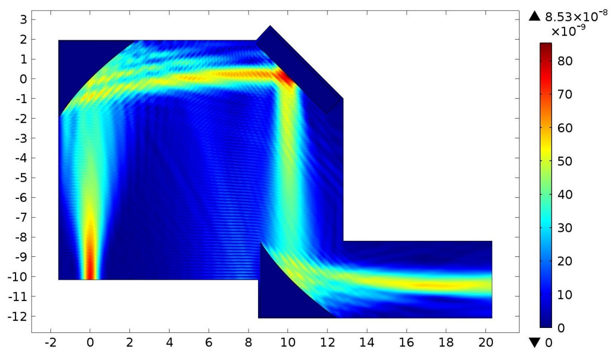

Figure 1: Normalized Electric field of 0.1THz Gaussian Wave in the cavity showing loss from reflector edges for a 2 mirror cavity.

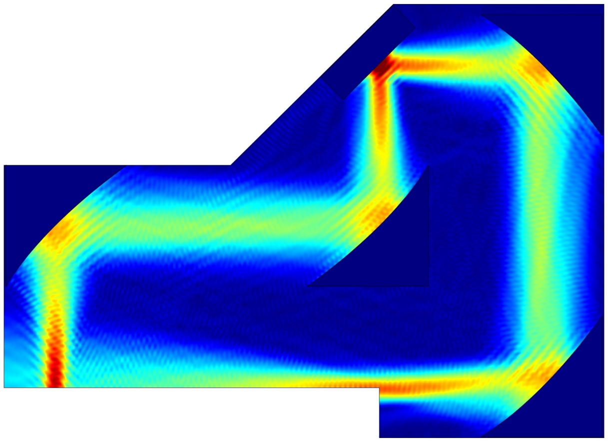

Figure 2: Normalized Electric field of 0.3THz Gaussian Wave in the cavity

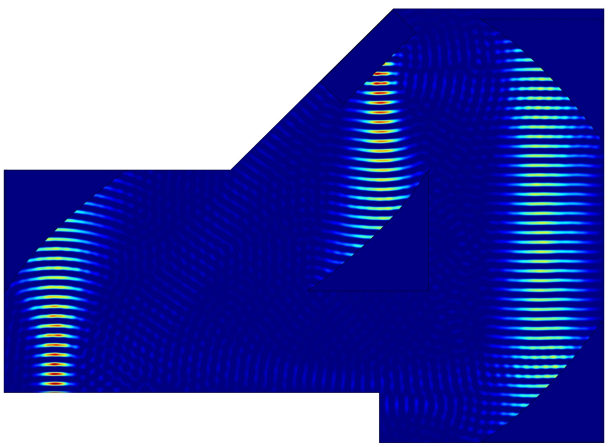

Figure 3: x component of Electric field of 0.3THz Gaussian Wave in the cavity

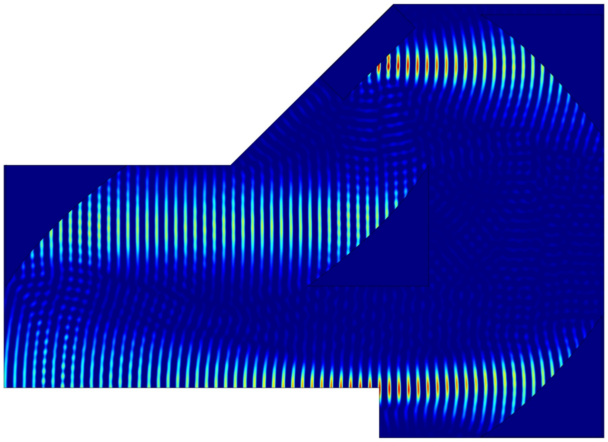

Figure 4: y component of Electric field of 0.3THz Gaussian Wave in the cavity