Low-Loss Metallic Waveguide for Terahertz Applications

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Abstract

Introduction: Terahertz waves (THz), also known as T-rays, range from 0.3 THz to 10 THz and hence positioned between Microwaves and Infrared radiations on the Electromagnetic spectrum. T-rays exhibit several distinctive properties which make these suitable for applications such as security screening, imaging, remote sensing, etc. In recent years, T-rays gained much attention in the field of security screening. The reasons behind the interest are (i) T-rays are transparent to most of the dry dielectrics allowing concealed weapons detection; (ii) different explosives have their own THz spectral signature. However, many limitations restrict proper utilization of this frequency range. One of these challenges is that T-rays suffer from high loss when propagating in free space due to atmospheric absorptions. Hence, require a guided media for low loss propagation. Hollow-core metallic waveguides play prominent role in low-loss guided propagation of T-rays.
Simulation of proposed waveguide structure: In present work, a metallic hollow-core waveguide is simulated using COMSOL multiphysics for the low-loss THz propagation. COMSOL enables low-cost, reliable and high speed model analysis considering the limitation of actual fabrication of such guided structures. This tool facilitates with ease ways to optimize the model for a specific target range of frequencies to be guided. RF module is used for simulating THz waveguide. In THz region, metals have high reflectivity because of large values of complex refractive index giving rise to high ohmic losses as well. In the proposed model, two interface layers have been introduced between core and cladding to increase the reflectivity by means of interference effect and reduce ohmic losses. Copper is used as cladding and Indium Tin Oxide (ITO) and Gallium-doped Zinc Oxide (GZO) are used as interface layers. The cladding thickness is kept 1μm which is much larger than its skin depth that is 65.2 nm at 1THz. The structure is optimized by 2D simulation using following steps: (i) selecting physics and study. For this model, physics and study used are Electromagnetic waves, Frequency Domain and Modal Analysis respectively (ii) defining parameters, creating geometry and assigning material to domains with proper value of refractive index (n) and absorption coefficient (k), (iii) creating mesh to divide the model into discrete and simple elements. Here we choose extremely fine element size so that mesh is created for the entire structure (iv) computation.
Results: The thickness of ITO and GZO layers are optimized to 8 μm and 5 μm respectively which are suitable from fabrication point of view. Fig.1 shows the 2D plot of core confining mode of waveguide at different operating frequencies. From the 2D plot it is clear that at 2.5 THz, the electric field escapes the core. Hence, the structure produces core-confining mode up to 2 THz.

Further studies: The THz waveguide demonstrated here has minimal fabrication complexity and can be utilized for application like security screening. The operating frequency range can be improved by increasing the number of interface layers and by using different material as the interface layers which we shall model using Wave Optics module in future

Figures used in the abstract

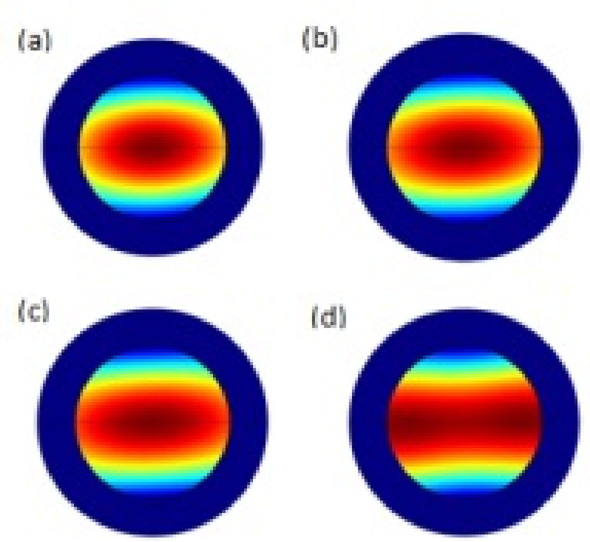

Figure 1: Fig.1 2D plot of low loss mode in THz waveguide at (a) 0.5 THz (b) 1 THz (c) 2 THz and (d) 2.5 THz