Low-Loss Metallic Waveguide for Terahertz Applications

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Introduction:

- Terahertz (THz) region is located between microwave and infrared range on the EM wave spectrum, with frequencies between 0.3 - 10 THz.
- THz waves are also known as T-rays or Sub-millimeter waves.

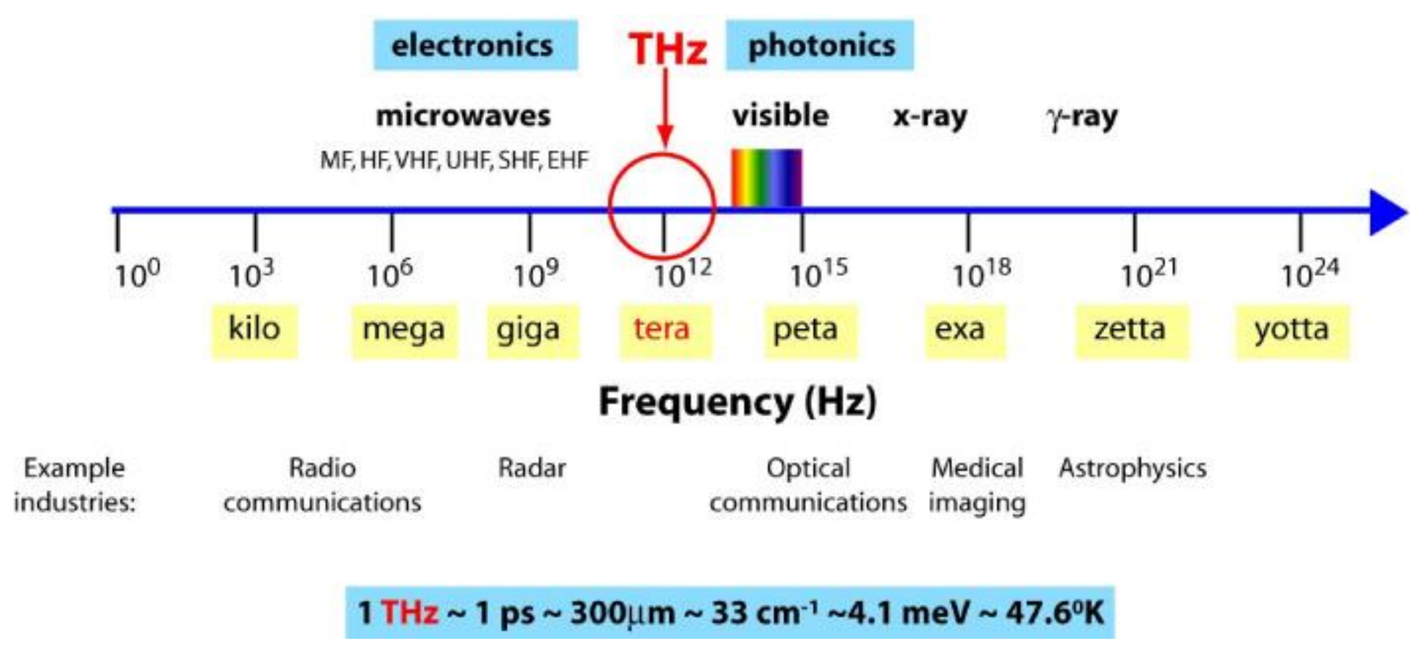


Figure 1. Terahertz region on EM spectrum

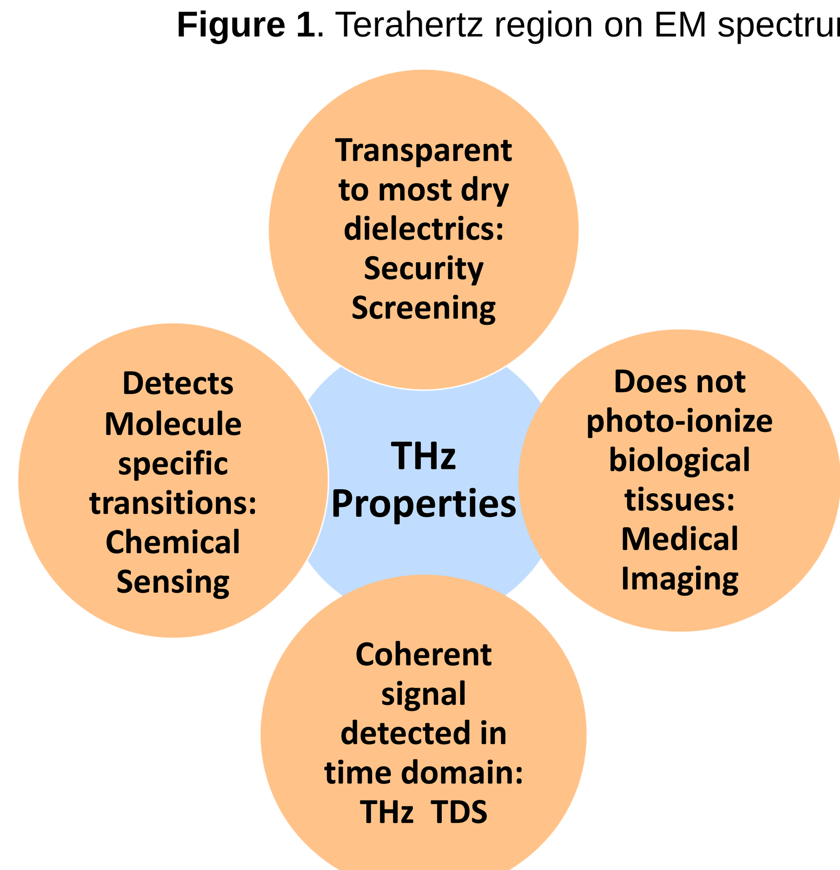


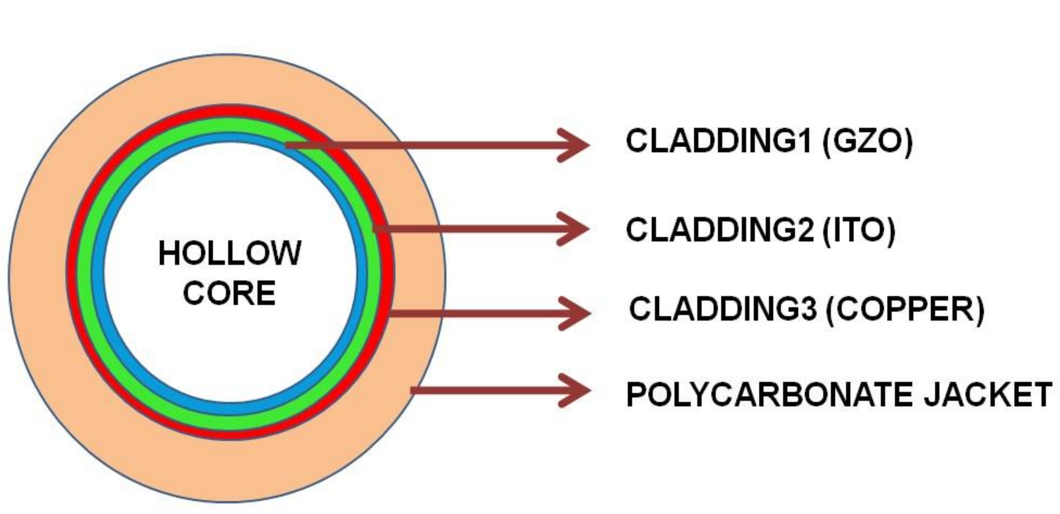
Figure 2. THz properties and applications

Proposed model:

- T-rays suffer high loss while propagating in free space, hence, needs guided media to propagate large distance.
- A hybrid cladding metallic hollow core waveguide has been proposed for low-loss THz propagation.
- Two interface layers have been added in between the core and the cladding.
- The added layers are of Indium doped Tin Oxide (ITO) and Gallium doped Zinc Oxide (GZO).
- Core confined mode loss has been calculated using formula:

$$\alpha = \left(\frac{u_{nm}}{2\pi}\right)^2 \left(\frac{\lambda^2}{a^3}\right) \mathrm{Re}\left(\frac{1}{\sqrt{n^2-1}}\right)$$

where, u_{nm} is the m^{th} root of n^{th} order Bessel function, λ is the operating wavelength, a is the radius of core and n is the complex effective mode index.

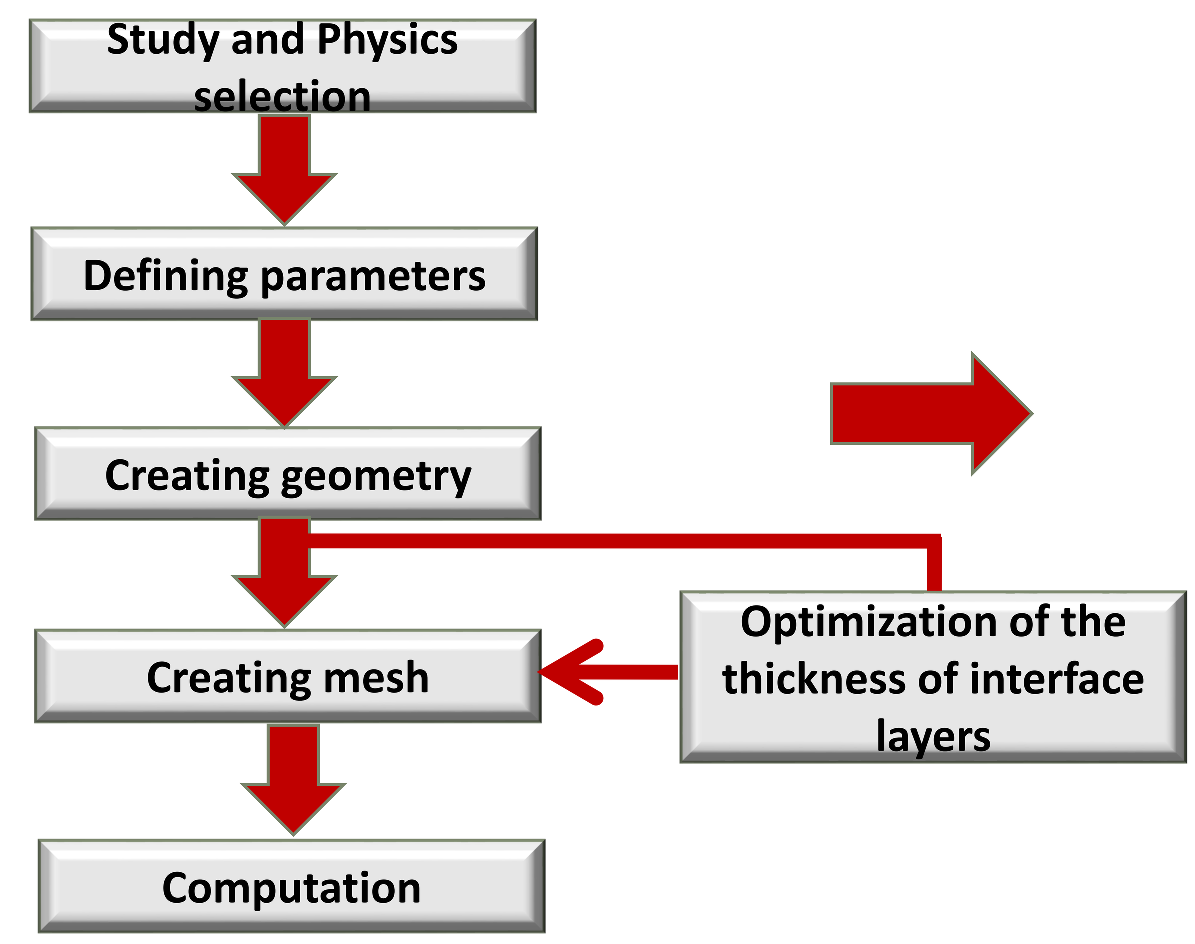


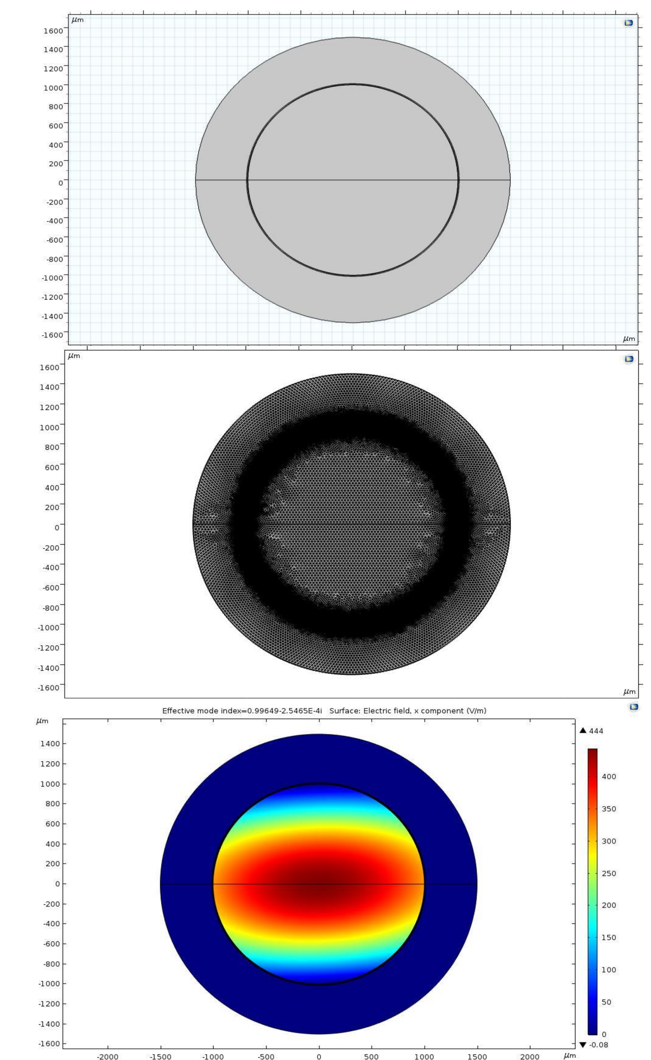
Layer	Material	Optimized thickness (μm)
Cladding-1	GZO	5
Cladding-2	ITO	8
Cladding-3	COPPER	1

Figure 3. 2D structure of proposed waveguide structure

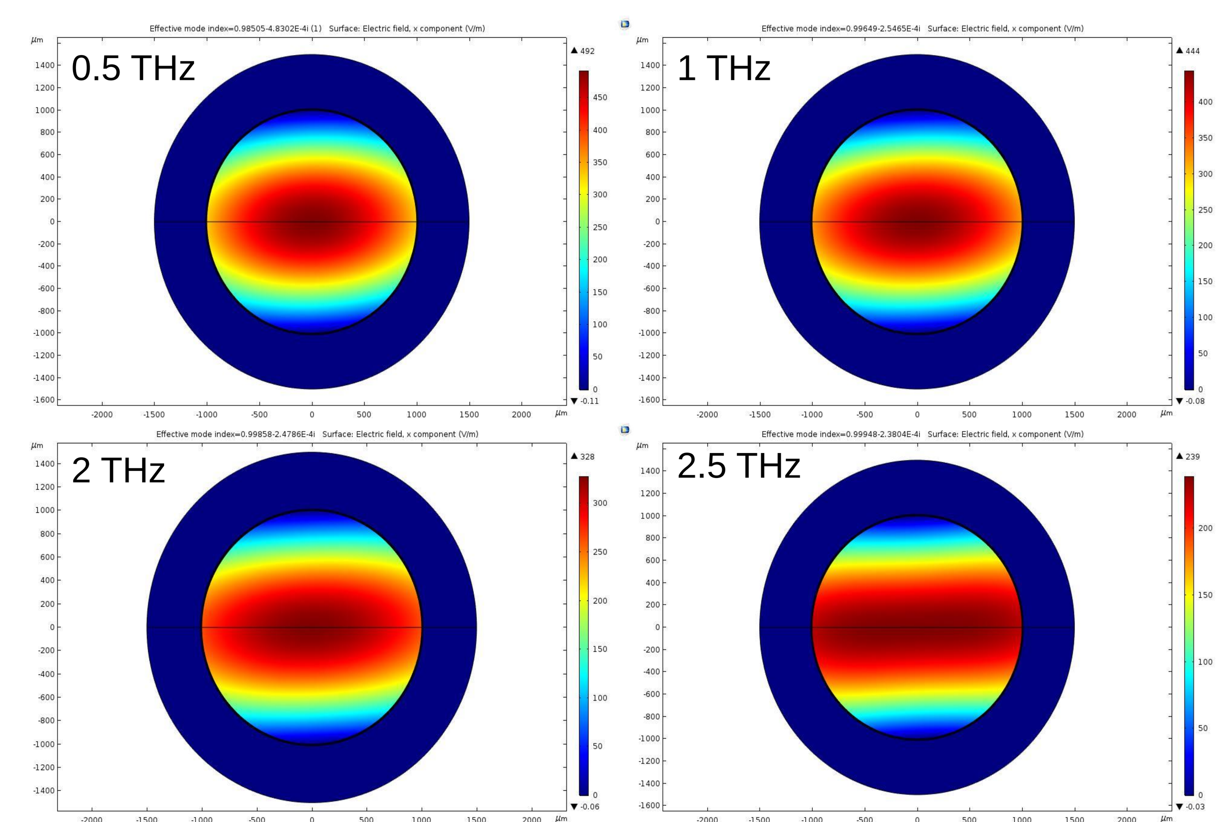
Simulation Method:

- The proposed structure was simulated in 2D using RF module.
- The study selected for this model is Electromagnetic Wave, Frequency Domain and physics selected is Modal Analysis.
- The steps involved in the simulation of this structure is given in the flow chart .





Results:



- The thickness of the interface layers and copper cladding is optimized.
- The structure produces core confined mode up to 2.25 THz.
- At 2.5 THz the structure does not produce core confined mode.

Figure 4. 2D surface plot of core confined mode at (a) 0.5 THz (b) 1 THz (c) 2 THz and (d) 2.5 THz

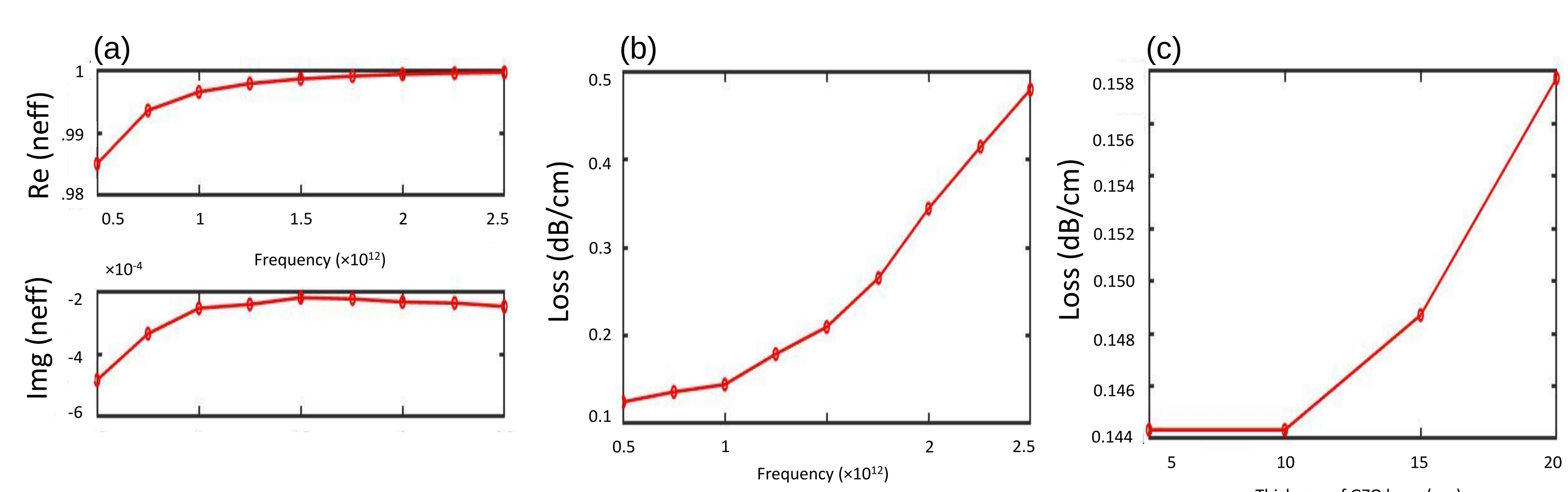


Figure 5. (a)Variation of effective mode index with operating frequency (b) Plot of core-confined mode loss at different frequencies (c) Plot of loss for different thickness of GZO layer at 1 THz

- The core confined mode loss increases with operating frequency which shows agreement with the result obtained from surface plot.
- Plot (c) demonstrates that the loss is maximum at 20 μm thickness.
- While optimizing the thickness, the loss gradually decreased and saturated after 10 μm.

Conclusion and Future Scope:

- The simulated structure has been found to be a good candidate for THz propagation with low loss up to 2.25 THz.
- The waveguide demonstrated here has minimal fabrication complexity and can be utilized for THz applications.
- In future, we are looking forward to fabricate this waveguide, and subsequently calculate the corresponding losses experimentally.

References:

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