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A Hyperbolic Metamaterial based Interaction Structure for THz Source

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***Abstract-* The THz Gap which lies between the microwave and infrared regions of the electromagnetic spectrum continues to exist, due to the unavailability of a compact and tunable THz source. This work discusses a novel concept for a THz - Vacuum electronic device (T-VED) based on Hyperbolic Metamaterial (HMM) , that shows tunability from 40 - 80 THz .**

I. INTRODUCTION

The Terahertz (THz) band lies between the microwave and infrared regions of the electromagnetic spectrum. The first journal predicting the span of THz applications and its potential to impact the society was published in the year 1980s. Since then the field of THz has witnessed an unbalanced expansion in terms of THz Science and THz Technology. THz science, since inception, has promised to serve numerous significant societal applications. The lagging THz technology, however, has limited the outreach of THz Science, mostly due to the unavailability of a source i.e. Compact, tunable and can operate at room temperature.

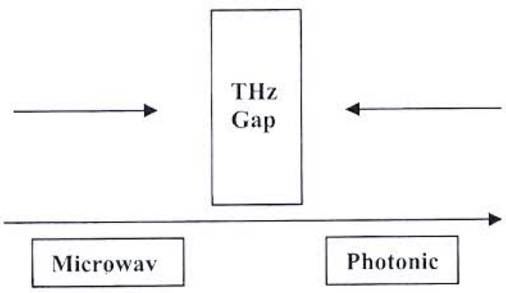

Figure 1: The approach to overcome THz Gap.

The existing THz sources are large, multi-component systems that sometimes require complex vacuum systems, external pump lasers and even cryogenic cooling. Moreover, the devices are heavy, expensive, and hard to transport, operate, and maintain. A single-component solution capable of room temperature, widely frequency tunable operation is highly desirable to enable next generation terahertz systems. In recent years the free electron induced sources with the development of artificial photonic materials and the study of the interaction between electrons and surrounding media has reached a new level. Moreover, the recent advancements in Terahertz Metamaterial [1] Terahertz plasmonic and Graphene [2]based devices have resulted in a combination of the two fields of microwave and photonics technology, depicted in figure 1. Here we propose an HMM based interaction structure for a T-VED, which can overcome the bottleneck of the existing THz source.

II. GRAPHENE HMM BASED INTEARCTION STRUCTURE

Figure 2: The geometry of the interaction structure. The arrow shows the direction of the beam bunch.

An HMM based interaction can enhance the evanescent waves and does not require to satisfy the minimum threshold of electron velocity for Cherenkov interaction to take place in the visible range [3].In this work we have analyzed graphene based HMM as the interaction region, where the evanescent waves supported by the electron bunch generates Cerenkov radiation in the HMM structure. The Graphene layer brings down the operating point of the source to THz range and also makes it an active tunable device [4].

III RESULTS AND DISCUSSION

The proposed structure was simulated using CST PIC [5] solver. The structure simulated, has a filling ratio $f_g = \frac{t_g}{t_g+t_d} = 0.5$ where t_g is the thickness of the graphene layer and t_d is the thickness of the dielectric layer. The overall structure thickness is 150 nm. A gaussian electron bunch was launched over the interaction structure with energy 20keV.

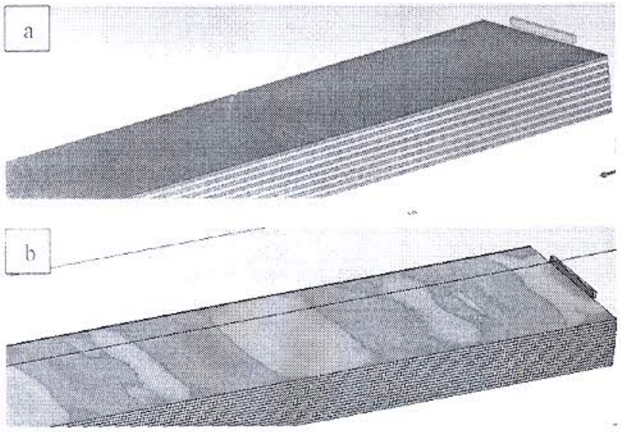

Figure 2: a) The modelled HMM structure b) The field pattern generated as the surface plasmonic gets induced due to the propagating electron beam

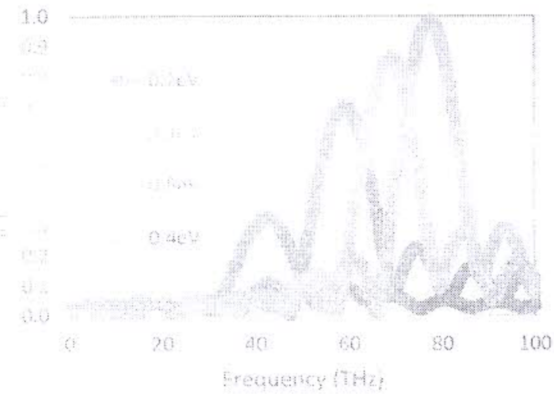

Figure 3: Frequency Spectrum of the radiation for different chemical potential applied to Graphene layer

The frequency spectrum, given in figure 3, shows the intensity peak at different frequency, as the chemical potential of graphene is varied from 0.2eV to 0.5eV.

IV CONCLUSION

The proposed interaction structure is able to give radiations that can be tuned by changing the chemical potential applied to the Graphene layer. The designed structure is able to give radiation between 40-80THz. The overall structure dimensions are much smaller than the existing THz source. The analysis carried out thus establishes a method to build next generation T-VED devices.

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