Seminar

Institute for Plasma Research

Title : Terahertz Emission Using Laser Plasma Interaction

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Date : 17th December 2021 (Friday)

Time : 10.30 AM

Venue : Online - Join the talk: https://meet.ipr.res.in/DrPrateekExtension

Abstract :

Terahertz (THz) radiation lies in between microwave and infrared range of electromagnetic (EM) wave spectrum. It has a number of applications in various areas e.g. medical imaging, terahertz spectroscopy, materials characterization and telecommunications. Conventional sources for THz radiation e.g. optical rectification, photoconductive antenna, dielectrics, quantum cascade laser and semiconductors are not efficient enough as emitted radiations are of narrow bandwidth and low efficiency. Laser-plasma based methods have been used for high power THz emission in past few years as plasmas have no damage threshold limit. As laser technology progresses for higher peak intensities, THz peak power can be increased by increase the laser intensity

Out of various schemes based on laser plasma interaction, THz radiation generation by beating of two lasers of different frequencies and wave numbers in plasmas has shown tremendous potential in terms of amplitude, tunability, efficiency and directionality. Laser with plane, Gaussian, super-Gaussian, spatial triangular and cosh-Gaussian spatial profiles (envelopes) are utilized to generate efficient THz radiation. Plasma density ripples with different types of plasma (semiconductor, cluster plasma and nanoparticle plasma) are proposed to introduce extra momentum (in propagation direction) to achieve exact phase matching condition for maximum energy transfer between nonlinear ponderomotive force (at difference frequency) and nonlinear current which is responsible for the excitation of THz.

In last one year we have carried out three analytical models of terahertz (THz) emission using laser plasma interactions which are listed below:

1. **Laser Intensity Profile Based Terahertz Field Enhancement from a Mixture of Nanoparticles Embedded in a Gas:**

   Nano-particle embedded system plays an importance in developing future THz radiation sources for real-world applications. Laser interactions with nanoparticle embedded system can produce a wide range of THz radiation due to plasma oscillation’s excitation. We investigate THz field generation from the laser-beat wave interaction with a mixture of spherical and cylindrical graphite nanoparticles (NPs) in an ambient argon gas. Different laser intensity distributions such as Gaussian, cosh-Gaussian, flat-top and ring shape laser pulses have been studied in this work. The relevant plasmon resonance conditions with appropriate symmetry of spherical nanoparticles (SNPs) and

cylindrical nanoparticles (CNPs) are discussed. THz field is shown to be enhanced upto the order of 102 when the laser intensity redistributes along the polarization direction for a ring shape field envelope. (in communication)

2. **Effect of Damping on Terahertz Radiation Generation from Laser Interaction with Nano-Particles:**

Terahertz field generation has been reported here in the presence and absence of damping mechanism when laser beat wave interact with spherical graphite nanoparticles (NPs). Clouds of electrons and ions form during interaction of laser beat wave with spherical NPs. Strong nonlinear current at the laser beat-wave frequency allows emission of fields in THz regime. Damping factor has been introduced in dynamics of electrons to include the electron-electron scattering. Beam decentred (BDC) parameter is introduced in the laser field profile that redistribute the laser intensity spatially. THz amplitude enhances significantly with increasing BDC parameter when damping is considered. Effects of damping can be controlled or tuned using the BDC parameter, laser intensity and with the enhancement of density modulation. (in communication)

3. **Effect of laser intensity redistribution on semiconductor plasma based THz emission:**

THz emission has been investigated using laser beat wave interaction with density rippled semiconductor plasmas. Two lasers with frequency and co-propagate through density rippled semiconductor plasma having wave vector and beat laser wave imparts ponderomotive force on electrons that produce nonlinear current and allows the THz emission. Gaussian, ring shape and hollow Gaussian field envelopes have been considered introducing laser intensity distribution along the polarization direction. Redistribution of laser intensity due to varied spatial profile changes the dynamics of plasma electrons and improves the ponderomotive force. Enhancement in the doping level in semiconductor also acts as a tuning parameter for the THz emission. Combined effect of laser intensity redistribution and amplitude of density modulation ( ) enhances the amplitude of the THz field. Conversion Efficiency of the order is estimated for hollow Gaussian field envelope and density modulation of 20% in semiconductor plasma. (Published: Optik, 250, 168353, 2022)

Future work: The results obtained by analytical modeling will be verified by PIC simulation results.