



A Study of the THz Generation via Magnetized hot Plasma-Laser Interaction

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Abstract: Terahertz (THz) radiation by beating of two laser beams in a groove density and magnetized hot plasma is discussed theoretically. In this mechanism, the ponderomotive force leads to a nonlinear oscillatory current that resonantly excites THz radiation at the frequency upper hybrid. And the study in which discussed about Terahertz radiation Generation, Magnetized plasma, Detection of terahertz radiations

Keywords: Terahertz, THz

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INTRODUCTION

Terahertz (THz) radiation has piqued attention due to its potential uses in a variety of areas, including material science, biomedicine, and communication. THz radiation has been driven by ultrafast powerful lasers in recent decades. Plasma-based THz generators have received a lot of interest since plasma is devoid of optical damage. THz radiation emitted by laser-induced plasma filaments in air or other low-density gases has been widely studied. However, at a pump laser intensity greater than 10^{15} W/cm², the THz yield is shown to be saturated owing to ionization-induced laser defocusing in the filaments.

Ultra-intense laser pulses may now have a concentrated intensity of far over 10^{18} W/cm². A few organizations have explored the production of greater THz radiation in relativistic laser-plasma interactions to take use of such a high laser intensity. Leemans et al., for example, produced THz radiation with energy in the sub-J range via strong laser-gas interactions. THz radiation produced by solid targets was three orders of magnitude greater than that generated by gas targets, according to Hamster et al. Sagisaka et al. and Gao et al. used an antenna model to study THz production. Tokita et al. and Poyé et al., for example, looked at the THz radiation produced by transient charge separation along the target. The production processes of THz radiation from laser-solid interactions are complex, as Gopal et al. recently produced extremely strong THz radiation with energy of 700 J from the back of a foil target, which was ascribed to the target normal sheath acceleration (TNSA). To further understand them, we looked studied THz radiation from the front or back of solid objects irradiated by relativistic femto-second and pico-second laser pulses. An electromagnetic (EM) radiation is a form of energy which travels in space without any material medium. The variation in electric and magnetic fields are at right angle to each other and the wave move in transverse direction to both the electric vector E and magnetic vector B . The electromagnetic wave propagate through empty space with speed of light $c = 3 \times 10^8$ m / s. If electromagnetic radiation are

arranged according to their wavelength or frequency, it forms the electromagnetic spectrum. The wavelength λ is defined as the distance between two consecutive crests or troughs.

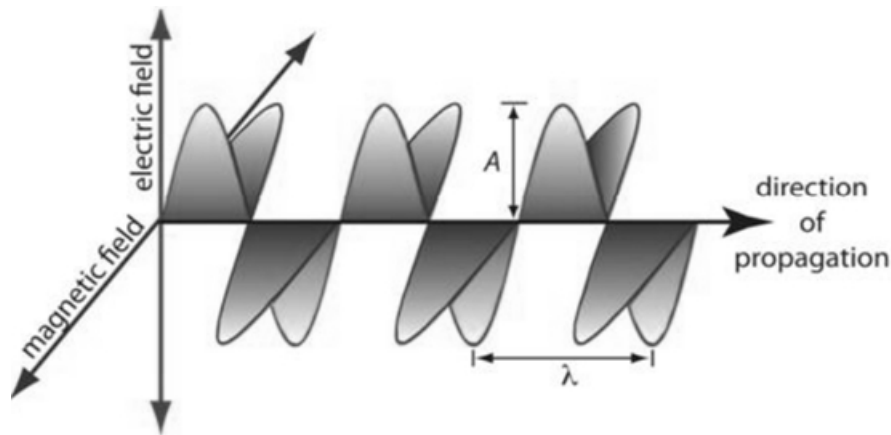


Figure 1: Representation of an Electromagnetic wave

Another important parameter frequency is the reciprocal of the wavelength (the number of oscillations per second). Radio waves, microwaves, infrared rays, X-rays, UV rays and gamma rays form the electromagnetic spectrum. This spectrum goes from the lower frequency (higher wavelength) used for commercial FM radio to the higher frequency (lower wavelength) used in the treatment of cancer and tumors. Since 1920, the electromagnetic terahertz (THz) frequency domain remains one of the least tapped regions of the EM spectrum. Over the last 30 years, this region however becomes the source of great interest for theoretical and practical research. The terahertz radiation is known as sub-millimeter radiation or far-infrared wave which occupies the region in between electronics and photonics. The terahertz frequency range (0.1-0.3 THz) is defined as sub-THz and the range lies between 0.3 to 10 THz is known as THz range. The defined wavelength range of THz radiation is from 1mm to 100 μ m corresponds to photon energy 1.2-12.4 meV

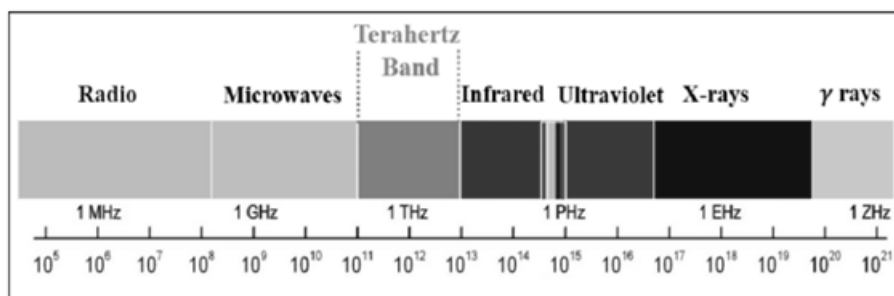


Figure 2: Representation of EM spectrum showing the terahertz spectral region (40 GHz to 4THz or 7.5mm to 75 μ m)

Microwaves (10¹⁰ Hz) and infra-red waves (10¹³ Hz) are widely studied and utilized but, the mid part of these frequencies remained untapped for a long time, generally known as terahertz gap due to generation and detection difficulties. The growth and development of photoconductive emitter with an optical pulse gating began the progress towards bridging this gap. It has attracted the scientific community due to its

ever expanding properties: (i) Due to small energy of terahertz wave, non-destructive measurements can be done on archaeological or geological samples. It causes minor damage to the biological tissues. (ii) The information about the formation of bond at a molecular scale can be easily provided. (iii) The terahertz range corresponds to molecular rotational and vibrational levels of many chemical substances. (iv) THz wave is transparent to the commonly used packaging materials such as woods, fabrics, and plastics etc. (v) They are non-ionizing and used for non-invasive detection of tumors or cancers. Other fields of application involve: information and communication technology, basic science, material characterization, heritage conservation, explosive detection.

Terahertz radiation Generation

The terahertz (THz) region of the electromagnetic spectrum has expanded considerably in recent years. Terahertz radiation may be produced in a variety of ways. Traditional methods such as quantum cascade lasers, accelerator-based sources, and optical rectification in non linear crystals are used to produce terahertz waves. Solid state electronic devices may produce THz radiation with a frequency of less than or equal to 1 THz. The development of electronic-based devices operating at frequencies more than a few hundred GHz in the low frequency microwave domain has been hampered by the inherent need for very short carrier transit times in the active areas. The output power (10.9W) is the highest value recorded from a low temperature produced GaAs photoconductive switch at approximately 0.99 THz frequency, and it is the maximum value that can be obtained by a photodiode in the terahertz domain. It is not feasible to create the fundamentals of interband diode lasers (which operate on visible and near-infrared frequencies) to work in the mid-infrared region due to a lack of high quality semiconductor.

One technique for generating terahertz radiation is using quantum cascade lasers (QCL). These lasers are made up of a semiconductor heterostructure in which the conduction band splits into many different subbands owing to quantum confinement. The electrons in the linked quantum wells travel via the potential staircase. Many studies have been conducted in this area, but it is still insufficient for the production of high-power THz devices. Cryogenic temperatures are required for their functioning. Barbieri et al. presented a GaAs-AlGaAs heterostructure with tens of mW output power in continuous wave mode. The injector states are utilised at a lower point in QCL. Instead of just one state, two are used. The higher laser state is closely linked with these two lower injector states. The wavelength of the QCL is 7-9 μ m. The transition between three linked states allows for a wide gain spectrum breadth. The coupling in injector state and higher laser state has been selected for effective optical gain and carrier transport. With the aid of an analogue locking circuit, a nonlinear signal was stabilised between a 2.408 THz quantum cascade laser (QCL) and a CH₂DOH THz CO₂ optically pumped laser (OPL) to establish a 3-4 kHz frequency at full width at half maximum (FWHM). This method's stability should be sufficient to use THz wave quantum cascade lasers as transmitters in low-range coherent transceivers and a variety of other applications.

In optics, terahertz wave production is split into two categories: (i) Terahertz wave generation in nonlinear media; (ii) Terahertz wave generation via accelerating electrons. In the first category, incoming electromagnetic (EM) waves undergo nonlinear frequency conversion, which is based on the materials' second-order nonlinear characteristics. By using optical stimulation, nonlinear media such as GaAs, GaSe, GaP, ZnTe, CdTe, DAST, and LiNbO₃ may produce terahertz radiation. Two kinds of second order

nonlinear processes are utilised in these mediums to generate THz waves. Optical rectification is one method that can only be utilised for femtosecond (fs) laser stimulation. A method for producing THz electromagnetic waves using LiNbO₃ has been suggested. Femtosecond (fs) optical laser pulses pass through the lithium niobate (LiNbO₃) crystal in this method. The domain length of optical laser and electromagnetic terahertz pulses is in appropriate order with the walk-off length. The bandwidth of the terahertz wave forms produced at 1.7 THz is 0.11, which is superior for experimental and modelling work. The periodic poled lithium niobate domain structure is in phase with the terahertz wave form produced by the optical rectification process. The optical pulse envelope THz radiation may be produced by femtosecond (fs) laser beams with a wide range. Optical rectification methods have been investigated utilising a variety of nonlinear materials. Electro-optic sampling is also used for the production of THz waves. This system achieves a sensitivity of more than 3THz. In both electro-optic sampling and optical rectification, this technique is effectively proven by obtaining phase matching conditions. Another nonlinear process is the production of difference frequencies via the laser beating process. In a nonlinear medium, two laser beams with a terahertz frequency difference may generate THz waves. Accelerating electrons may also be used to create terahertz waves. The accelerated electrons produce a time-varying current, which causes the electromagnetic terahertz wave to be generated. The production of terahertz waves may also be done using photoconductive antennas. They operate on the basis of electron acceleration. The laser beam illuminates the space between the two electrodes on the photoconductive antenna surface. In this space, picture carriers are created. The photo carriers are subsequently accelerated by the dc bias field, which produces the photocurrent. The photocurrent produced changes with time. The photocurrent produced scales the laser beam intensity. Femtosecond (fs) laser beams are used in the production of terahertz waves. Two laser pulses at different frequencies may be used as a beat wave to generate a continuous terahertz wave.

Magnetized plasma

Like plasmas, magnetic fields exist everywhere throughout the Universe and play a key role in the formation of astrophysical settings. The emulation by properly characterized experiments of these settings in the laboratory may supplement traditional astrophysical observations in a useful way. These investigations are facilitated by generating scale-equivalent plasma conditions using self-generated or external magnetic fields, or directly by moving magnetic field interactions via laser plasma. In any case, laser-plasma contact changes the magnetic fields profoundly. The presence of extremely strong quasi-static magnetic fields changes the microscopic kinetics by turning, containing or undulating electrons, by making the cyclotron resonances accessible to optical arousal, and by six laser propagations by means of specific dispersive effects, including polarization, slow light, and induced transparency.

It only recently discovered that powerful magnetic fields with lasers are able to conduct controlled, concentrated tests. The present method utilizes a lengthy, high intensity pulse to generate a current using induction spools, based on existing laser technology. These platforms enable studies of magnetized high-density physics linked to high energy particle transport and high-gain ICF methods such as rapid-ignition, as well as fundamental laboratory astrophysics. The projected intensities produced by laser systems of future generation may directly generate volumetric magnetic fields that match those on neutron (~MT) star surfaces. These extremes, created by highly nonlinear currents driven by an intense laser pulse spread by a

relative transparent plasma with high density, would lead to a number of immediate breakthroughs; they would considerably enhance the transfer of energy from a laser pulse to electrons and facilitate gamma rays emission from relative electrons through the provision of energy. For the development of nuclear and radiological detection systems, the creation of such a gamma source would be essential. The source of gammatory rays would also enable us to uncover information connected to our knowledge of the Early Universe and high energy astrophysics, including the direct production of matter and antimatter by light.

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Detection of terahertz radiations

Another significant area where research is ongoing is the detection of terahertz wave frequency transmissions. The method of time domain spectroscopy (TDS) is crucial in the detection of terahertz radiation. In comparison to the TDS method, photo thermoelectric and bolometers (power sensitive detectors) have disadvantages. The absorption and emission spectra are obtained using the Fourier transform. It may also be used to get information about the phase of terahertz radiation. Photoconductive antennas, electro-optical sampling, and frequency shifted second harmonic in optical breakdown plasma are among the methods used to detect T rays. All of these techniques are detected in the same direction. For detection, electro-optic crystals with a large aperture are also used. However, crystal size and large aperture are two major issues; manufacturing and appropriate crystal size are both challenging and costly. These challenges have prompted the scientific community to develop novel methods for producing coherent THz detectors at a low cost and on a large scale. For photoconductive (PC) detection and emission, a combination of "optically gated black phosphorus and a periodic antenna" was developed. The action of the active medium of the sensor must have high mobility of photoexcited charge carriers and appropriate absorptivity, including ultrashort lifetime, for effective PC detection of THz. Graphene can meet these

requirements since its charge carriers have mobility of up to $180000 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$ at normal temperature. The process is further aided by the relaxation of carriers (excited) in graphene.

CONCLUSION

Our analytical calculations show that the generated THz radiation can be affected by the electron temperature. The field amplitude could be increased with decreasing of electron temperature and this affection depends on the other parameter such as beating frequency, transverse distance from lasers beam center and strength of the static magnetic field. Reduction of the electron temperature is associated with an increase in plasma density, therefore more numbers of electrons take part in the oscillating current is responsible for the emission of THz radiation.

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