Full wave analysis of THz wave propagation and realization of a novel robotic-THz imaging system for arbitrary shaped materials

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Full wave analysis is a reliable tool for propagation characteristics of electromagnetic (EM) waves in plasmas and matter. The method is particularly useful for evanescent waves or mode conversion due to coinciding cutoff positions of two propagating modes in the same medium [1]. This scenario is commonly found in radio-frequency (RF) waves in a tokamak plasma. Full wave analysis of RF waves in electron cyclotron, ion cyclotron and hybrid ranges of frequencies provides sufficiently accurate estimate of the deposition profile and optimization of absorbed power by solving the integrodifferential Maxwell's equation [2-3]. Since THz waves are EM in nature, the method is equally suitable for analysis of THz wave propagation and interaction in matter.

THz waves have emerged as a new method for spectroscopy and imaging of certain materials like dielectrics and semiconductors. Advantages of THz waves over competing EM wave based methods include their better spatial resolution than microwaves, better penetration than IR, and better depth resolution than X-rays. However, the accuracy of THz imaging is limited by the system's constraints in maintaining the focal plane and the proper angle of wave-incidence during the scanning process [4]. This has been a serious challenge in practical applications when the specimen under study is fragile or has arbitrary shape and size like the archeological artefacts [5]. Autonomous control over the sample's position, angular motion and field-of-view of the transceiver by a robotic system provide solution.

In this study, in the first case, we have performed a two-dimensional full wave analysis of THz wave propagation and interaction with matter for arbitrary parameters starting in the 1 THz frequency range by developing a numerical code. The preliminary results are shown and extension to higher frequency range is proposed.

In the second case, we have presented a novel prototype robotic-THz time domain spectroscopy (TDS) and imaging system in reflection geometry. The proposed system with full control over the wave incidence angles and device's field of view should allow the acquisition of reflection THz tomography images of selected surfaces of arbitrary shapes and sizes, and extraction of the information of complex refractive index of the materials.
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