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Research on a dielectric silicon lens antenna and an attenuator in the THz region

メタデータ	言語: en 出版者: Shizuoka University 公開日: 2015-12-16 キーワード (Ja): キーワード (En): 作成者: Catur, Apriono メールアドレス: 所属:
URL	https://doi.org/10.14945/00009271

（課程博士・様式７）(Doctoral qualification by coursework,Form 7)

学 位 論 文 要 旨

Abstract of Doctoral Thesis

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論文題目：

Title of Thesis：

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論文要旨：

Abstract：

Terahertz (THz) wave radiation has attracted many researchers to explore its potentials and to develop the THz technology. Various studies have shown applications of the THz wave to solve some issues, such as inspection of concealed weapons, food examination, pharmaceutical examination, and DNA analysis. However, source and detector performance, speed of measurement and cost are some issues for extending the utilization of the THz waves. Among those issues, we study two optical elements to improve performance of THz systems, which are dielectric silicon lens antenna for focusing and collimating beams of THz wave radiation and a glass for attenuating THz wave radiation.

An extended hemispherical silicon lens antenna is an attractive and a practical element to focus and collimate beams of THz wave radiation. By adjusting the extension to the focal point and placing a detector or an emitter at around the focus, coupling efficiency of the THz system can be improved. Because linearly polarized radiation is ordinary in a THz system, a practical method to calculate a precise profile of power-flow density distribution of the polarized THz wave radiation is important to design a silicon lens antenna. In optics, the ray-tracing is widely used to design lenses and to analyze optical systems. However, if we calculate the power-flow density distribution, the regular ray-tracing method is not enough to evaluate a correct power-flow density distribution because it does not take into account transmittances depending on angles of incidence at different positions on the boundary. In this research, we propose a ray-tracing method combined with Fresnel's transmission to calculate the power-flow density distribution in a silicon lens antenna irradiated with linearly polarized THz wave. Fresnel's transmission is included to cover accurate transmittance and polarization. Because a high resistivity silicon has a very low dispersion of refractive index and low absorption in the THz range, the proposed method is applicable for calculating power-flow density distribution in the wide range of THz region.

We consider radius of the hemisphere and length of the extension are two millimeters and

one millimeter, respectively. A parallel beam of THz waves are travelling to the Si-lens antenna. When the rays pass through the hemisphere boundary, transmittance and refractive angle of every ray are calculated by using Fresnel's law and Snell's law, respectively. Power-flow density distributions are calculated by considering the rays' path and the transmittance of the transmitted rays. We execute an electromagnetic (EM) simulation by using CST Microwave studio with a linear polarization to compare with and confirm the results of the proposed method. We also compare our method with a regular ray-tracing of an optical simulator of Zemax to clarify the difference between them.

The power-flow-density distribution calculated by the proposed method has a good agreement with the result obtained by the electromagnetic wave simulator. The result was consistent with each other, though the EM simulation has effect of interference and diffraction, which are not considered in our proposed method. The power transmittance estimated by the proposed method is 68.3% of the input radiation power; on the other hand the one estimated by the regular ray-tracing is 70.0% of the value for normal incidence. This shows the proposed method is necessary for executing the precise calculations. Our proposed method is so simple and reliable that it is useful for designing and evaluating THz optical systems using dielectric lens antennas. The evaluation of the power-flow density distribution by the proposed method will contribute to designing optical elements like dielectric lens antennas in THz quasi-optical systems.

After the discussion of the proposed method to calculate the power-flow density distribution, we study attenuation characteristics of soda-lime glass at frequency 250 GHz. In this research, we propose a low cost material of an ordinary glass or also known as soda-lime glass to effectively attenuate power of THz waves. Measurements are conducted by using a pyro detector and a body scanner system. Some samples with different thickness are used in analysis. Statistical analysis is conducted to calculate the attenuation. To include Fresnel's transmission and refraction affected by polarization, refractive index is measured by using a transmission THz time domain spectroscopy.

The results show that the glass is a potential material to attenuate the THz wave. The refractive index of the glass has low dispersion between 0.2 – 1 THz, therefore, the glass can provide an attenuation element for a wide range frequency. The glass attenuation analyzed from the pyro detector measurement data are around 0.556 mm^{-1} and 0.4988 mm^{-1} when the analysis conducted without and with consider the Fresnel's factor, respectively. The attenuation analyzed from the body scanner measurement without consider the Fresnel's factor is around 0.574 mm^{-1}, which is close to the pyro detector result. The results show that the glass is a potential and low cost material to reduce around half of THz wave power for every 1 mm.