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Geometrical Optic and Electromagnetic Wave Analysis on Sperical Lens Antenna for THz Detector

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Spherical dielectric lenses were utilized to increase antenna directivity performance in THz region [1]. In [2], hemispherical dielectric lenses can be used to focus the incoming THz wave. This method is adopted to increase the performance of antenna-coupled bolometer for THz detector. The detector measures the power incident of electromagnetic radiation via the heat of the energy absorbed by the bolometer's material. In order to increase the energy absorbed by THz detector, the incoming wave power needs to be increased. Higher wave power can be obtained by converging the incoming wave into antenna-coupled bolometer as shown in Figure 1.

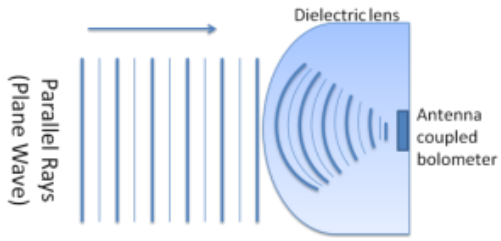

Figure 1. Parallel rays / plane wave propagation

This study focuses on the investigation of power density comparison between geometrical optics and electromagnetic wave analysis of hemispherical dielectric lens using Silicon (Si) material with ε_r=11.7 at 1 THz. The lens has radius of 2 mm. The extended length is added at the plane surface to observe the most focusing plane. We use two analysis tools: ZEMAX with ray tracing technique for geometrical optics analysis and CST Microwave studio with finite integration technique for electromagnetic wave analysis.

It is not enough to evaluate focused power density only by spot diagram of ray tracing because rays inputting onto diffetent position of a spherical lens have different incident angle, which bring different transmitivity according to Fresnel equations as shown equation 1 and 2. Figure 2 shows the result of the power density ratio calculation between power density of the incoming wave and that at extended length value (d).

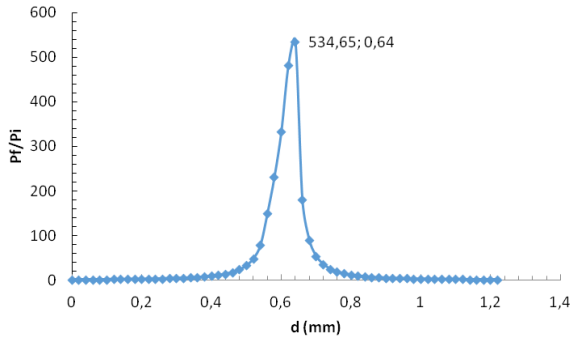

Figure 2. Power density enhancement around the focus as a function of extended length calculated including Fresnel transmission compared with the incoming wave

$$t_{\perp} = \left(\frac{E_{0t}}{E_{0i}}\right)_{\perp} = \frac{2.n_i.\cos\theta_i}{n_i.\cos\theta_i + n_t.\cos\theta_t} \quad (1)$$

$$t_{\parallel} = \frac{2.n_i.\cos\theta_i}{n_i.\cos\theta_t + n_t.\cos\theta_i} \quad (2)$$

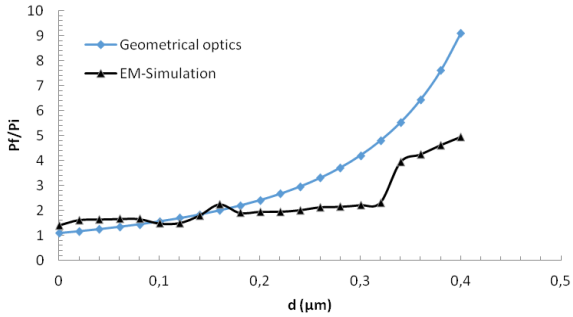

Figure 3. Power density comparison between geometrical optic including Fresnel transmission and electromagnetic simulation

Figure 3 compares the power density obtained from geometrical optic calculation and electromagnetic calculation in the extended length range between 0 μm and 0,4 μm. In the geometrical optics, it ignores Fraunhofer and Fresnel diffraction. Moreover, the electromagnetic simulation shows the diffraction factors are considered if the wavelength becomes comparable to the object size.

References

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