Analysis of a Terahertz Polarizer Using the Three-Dimensional Semi-Implicit FDTD Method

Hiroto Miyao*, Jun Shibayama, Junji Yamauchi, Hisamatsu Nakano
Faculty of Science and Engineering
Hosei University
Kajino-cho, Koganei, Tokyo 184-8584, Japan
Email: hiroto.miyao.9@stu.hosei.ac.jp

A terahertz waveguide polarizer has been efficiently analyzed using the semi-implicit finite-difference time-domain (FDTD) method [1]. However, the analysis has been limited only to two-dimensional problems. Therefore, we here extend the semi-implicit FDTD method to three-dimensional (3-D) problems and analyze a TE-pass terahertz waveguide polarizer [2].

First, we formulate the 3-D frequency-dependent semi-implicit FDTD method based on the trapezoidal recursive convolution (TRC) technique [3]. We introduce the implicit scheme only to a specific direction for which small spatial meshes are required.

Next, we analyze a TE-pass terahertz waveguide polarizer shown in Fig. 1, in which the core is buried and an InSb layer is placed on the waveguide. The core and cladding are made of Si and SiO_2, respectively. The structural parameters are as follow: $d_w = d = 50\ \mu$m, $t_b = 7.0\ \mu$m, $t_I = 50\ \mu$m, $w = 200\ \mu$m. The length of the polarizer is defined as l. The refractive indices of Si and SiO_2 are 3.40 and 1.94, respectively. The dispersion characteristic of InSb is expressed by the Drude model [4]. The spatial sampling meshes are $\Delta x = 2.5\ \mu$m, $\Delta y = 0.125\ \mu$m, and $\Delta z = 2.5\ \mu$m, so that the implicit scheme is adopted only in the z direction. We define the time step size as Courant-Friedrichs-Lewy number (CFLN) = $\Delta t / \Delta t_{CFL}$, in which Δt_{CFL} is the upper time step size of the explicit FDTD method. The maximum CFLN is calculated to be 14 for the present analysis.

We compare the field distribution, guided mode power, and extinction ratio with those of the explicit FDTD method for $T = 300$ K at 1.4 THz. As one example, the extinction ratio is shown in Fig. 2. It is found that the result of the present method with CFLN = 14 agrees well with that of the explicit FDTD method. It is worth mentioning that the calculation time is reduced to 25% of the explicit FDTD method.

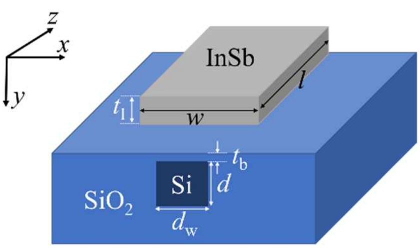

Figure 1. TE-pass terahertz waveguide polarizer

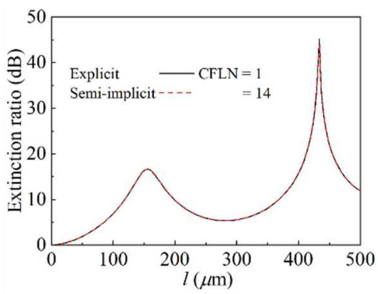

Figure 2. Extinction ratio

References

[1] J. Shibayama, S. Gomi, J. Yamauchi, and H. Nakano, "Analysis of a TM-Pass/TE-Stop Terahertz Waveguide Polarizer Using Implicit and Semi-Implicit FDTD Methods," *IEICE Trans.*, vol. J105-C, no. 5, pp. 185-192, May. 2022 (in Japanese).

[2] S. Takahashi, J. Shibayama, J. Yamauchi, and H. Nakano, "Analysis of a TE-Pass/TM-Stop Waveguide Polarizer in the THz Region," *IEICE Tech. Rep.*, vol. 119, no. 407, pp. 97-102, Jan. 2020 (in Japanese).

[3] J. Shibayama, R. Ando, A. Nomura, J. Yamauchi, and H. Nakano, "Simple Trapezoidal Recursive Convolution Technique for the Frequency-Dependent FDTD Analysis of a Drude-Lorentz Model," *IEEE Photon. Technol. Lett.*, vol. 21, no. 2, pp. 100-102, Jan. 2009.

[4] Q. Wang, Q. Tang, D. Zhang, Z. Wang, and Y. Huang, "Tunable Terahertz Spectral Filter Based on Temperature Controlled Subwavelength InSb Grating," *Superlattices Microstruct.*, vol. 75, pp. 955-961. 2014.