Analysis and Design of Planar Dipole Array for Terahertz Magnetic Surface Wave Propagation

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***Abstract*—A planar dipole array on low-temperature (LT) growth gallium arsenide (GaAs) or cyclo olefin polymer film is analyzed for magnetic terahertz surface wave, TE wave propagation. A laser pulse excites the dipole gap in order to generate photo carriers on the surface of a LT-GaAs photoconductive substrate. A dipole array on the LT-GaAs substrate is designed for a surface wave around 0.40 THz. The analysis also derives the dispersion diagram and transmission loss. The dispersion diagram indicates that propagation of the surface wave is confined around the dipole elements. The dipole array on a cyclo olefin polymer film can be also designed at around 0.45 THz.**

I. Introduction and Background

THE performance of transmission lines as well as antennas and lenses requires improved designs for the terahertz frequency band. For the spoof surface plasmon polaritons in the terahertz wave band, the work in [1] presents transmission lines composed of split ring resonators, that in [2] presents corrugated structures and that in [3] presents quasi-three dimensional post array on a LT-GaAs substrate. The works in [4], [5] present magneto-inductive waves. This paper analyzes and designs a planar dipole array for magnetic terahertz surface wave, TE wave propagation. The planar structure with subwavelength dimensions is a candidate for on-chip applications and those on films can realize flexible devices.

II. Analysis

Fig. 1 shows the analysis model for a planar dipole array on a LT-GaAs substrate. A laser pulse, which generates photo carriers on the surface of the photoconductive substrate, excites the dipole gap. Low-temperature growth or semi-insulating GaAs substrates are frequently used as the photoconductive substrate. The voltage bias accelerates the laser-excited carriers to produce a transient current in the dipole. In the analysis model, a current source excites a transient current on the first dipole. Furthermore, all boundary walls are terminated with absorbing boundary conditions in order to reduce the reflection. The dipole array on low-temperature growth GaAs substrate or cyclo olefin polymer film is designed by ANSYS HFSS Transient.

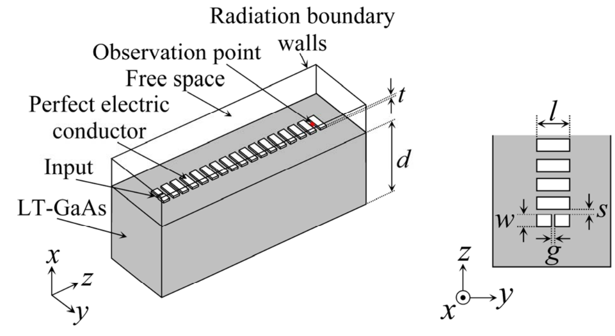

Fig. 1 Analysis model for planar dipole array on LT-GaAs for terahertz surface wave

Table 1 Design parameters for model on LT-GaAs.

l	102 μm	t	0.5 μm	s	21 μm	n	3.5
w	38 μm	g	3.0 μm	d	400 μm		

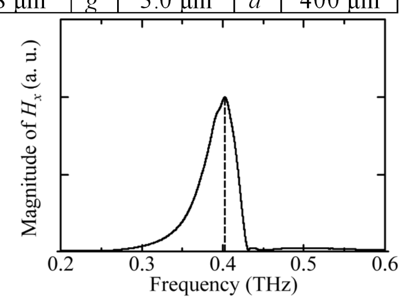

Fig. 2 Magnetic field H_x characteristics.

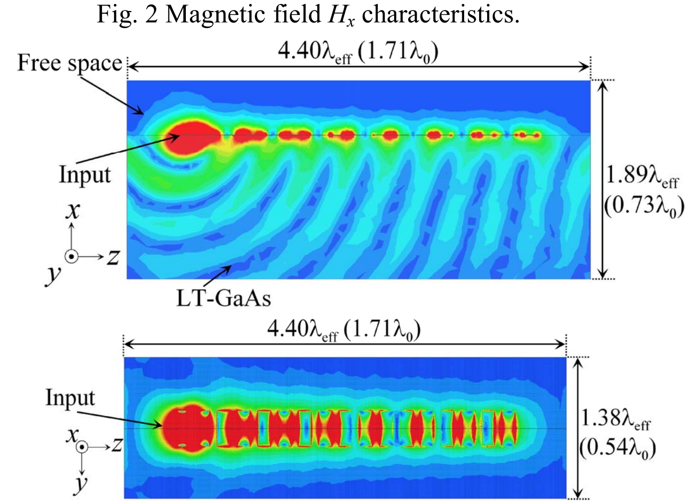

Fig. 3 Magnetic field distribution at 0.4 THz for planar dipole array on LT-GaAs

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III. ANALYSIS RESULTS

Table 1 shows the design parameters for LT-GaAs substrate planar array. The full width at half maximum of the laser pulse is 120 fs, and the carrier lifetime for the LT-GaAs substrate is 500 fs. The time waveform of the magnetic field between the terminal dipole and the adjacent one is Fourier transformed and the spectral distribution is plotted in Fig. 2. The magnetic surface wave at 0.40 THz is confirmed as shown in Fig. 3. The free space wavelength at 0.40 THz is 750 μm and the effective wavelength at 0.40 THz is 291 μm. The surface wave is observed to propagate while it is confined around the dipole elements. Fig. 4 shows the dispersion diagram of the dipole array from the transient analysis results. The light line includes the effect of the LT-GaAs. The dispersion curve asymptotically coincides with the light line at lower frequencies. That the wavevector becomes larger with higher frequency indicates the slow-light effect and the propagation confined around the dipole. The wavevector goes to infinity and the group velocity goes to zero at about 0.42 THz. Fig. 5 shows that the transmission loss and the radiation loss of the dipole array.

The surface wave on flexible cyclo olefin polymer film is also designed, and Table 2 lists the design parameters. The spectral distribution is plotted in Fig. 6. The magnetic surface wave at 0.45 THz is confirmed as shown in Fig. 7. The free space wavelength at 0.45 THz is 667 μm. Again, the surface wave is confined around the dipole elements. The effective wavelength at 0.45 THz is 436 μm. Impedance matching should be taken into account for connecting the array on film with that on LT-GaAs substrate.

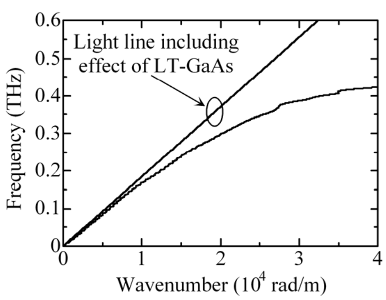

Fig. 4 Dispersion of dipole array

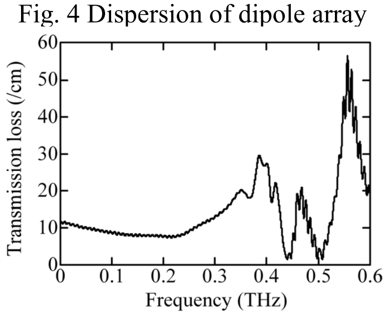

Fig. 5 Propagation loss of dipole array

Table 2 Design parameters for model on cyclo olefin polymer film.

l	203 μm	t	1.0 μm	s	41 μm	n	1.53
w	75 μm	g	3.0 μm	d	271 μm		

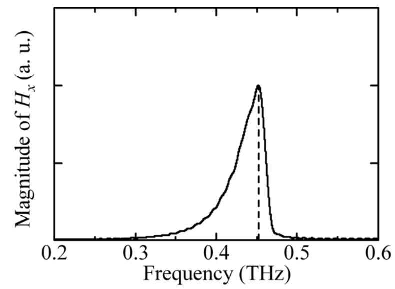

Fig. 6 Magnetic field H_x characteristics.

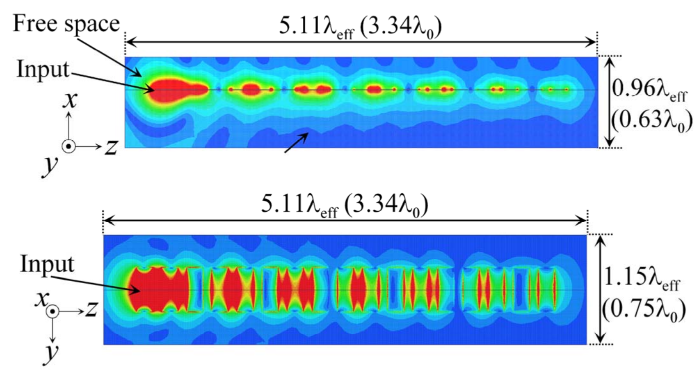

Fig. 7 Magnetic field distribution at 0.45 THz.

IV. CONCLUSIONS

A planar dipole array on LT-GaAs is designed for a magnetic terahertz surface wave. The dispersion diagram and transmission loss for LT-GaAs are calculated from the analysis. The dispersion curve indicates the slow-light effect and confinement of the surface wave around the dipole elements. The dipole array on flexible cyclo olefin polymer film is also designed for a surface wave. We are planning to fabricate the array and measure the surface wave propagation.

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