Analysis of an Edge-Coupled Terahertz Photomixer Source Integrated with a Coplanar Stripline

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***Abstract*-A transmission line representation with distributed source elements has been used to analyze an edge-coupled terahertz photomixer integrated with a coplanar stripline (CPS) waveguide. The multilayer spectral domain method has been applied to calculate the distributed source elements in the transmission line representation. To find the coupled terahertz signal along the CPS, the transmission line equations are solved. This technique can be applied to other quasi-TEM structures.**

I. MODELING

Fig. 1 shows the schematic of an edge-coupled terahertz photomixer integrated with a coplanar stripline (CPS) waveguide consisting of two metal strips of width *w*. The strips are placed in a distance *s* from each other, and are embedded in a multilayer dielectric waveguide structure. The terahertz photocurrent is generated inside the ultra-fast photoabsorbing active layer by mixing two frequency detuned laser beams guided by multilayer dielectric waveguide structure. The generated traveling-wave photocurrent acts as an impressed source to excite CPS modes.

$$\boldsymbol{J}(\boldsymbol{r}) = J(\mathrm{x})\delta(\mathrm{z}+h)\exp(-\mathrm{j}\beta_{\mathrm{i}}\mathrm{y})\hat{\mathrm{x}} \tag{1}$$

Where $\boldsymbol{J}(\mathbf{r})$ is the THz traveling-wave photocurrent inside the active layer, β_i denotes its phase constant [1], and $J(x)$ describes the x-variation of the current in the active layer. Due to the small thickness of the active layer in terms of the terahertz wavelength, the z-variation in (1) is modeled by a Dirac delta function.

To study the induced voltage and current along the CPS, the distributed-source transmission-line (TL) equations can be derived from Maxwell's equations as

$$\frac{d}{dy}V(y) = -\gamma_0 Z_0 I(y) - v_s(y) \tag{2}$$

$$\frac{d}{dy}I(y) = -\gamma_0 Y_0 V(y) \tag{3}$$

Where Z_0 and Y_0 are the characteristic impedance and admittance of the CPS, respectively. γ_0 denotes propagation constant of quasi-TEM mode of CPS, and $v_s(y)$ corresponds to the distributed voltage source along the CPS which can be expressed in terms of the traveling-wave current and the layered media Green's function as

$$v_s(y) = \left[-\frac{j\omega\mu s}{4\pi^2} \int_{-\infty}^{+\infty} \tilde{G}_H^{zx}(k_x, k_y = \beta_i)\tilde{J}(k_x)\mathrm{sinc}\left(\frac{k_x s}{2}\right)dk_x \right] \exp(-j\beta_i y) \tag{4}$$

Where $\tilde{G}_H^{zx}(k_x, k_y)$ is the layered Green's function in the spectral domain [2], $\tilde{J}(k_x)$ represents the Fourier transform of $J(x)$ in (1), μ is the permeability of the layer where the strips are buried, and ω is the terahertz angular frequency.

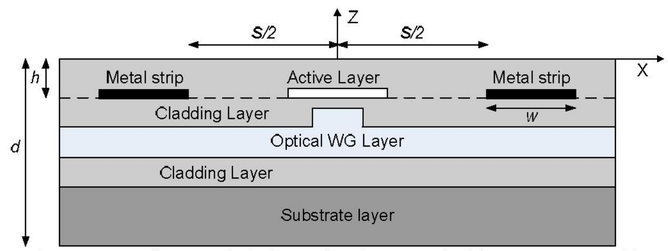

Figure 1. An edge-coupled photomixer integrated with a CPS waveguide.

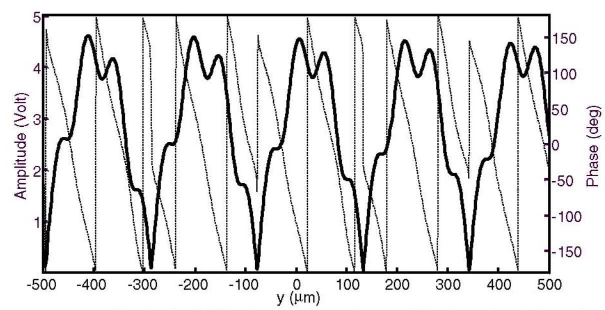

Figure 2. Amplitude (solid line) and phase (dotted line) of the induced voltage along a CPS (w=1 µm, s=2 µm) with GaAs substrate.

Solving the set of TL differential equations given by (2) and (3) with the excitation term given by (4) results in the induced voltage and current along the CPS waveguide.

II. NUMERICAL RESULTS

Applying the technique described in section I, the amplitude and phase of the induced voltage along a CPS (w=1 µm, s=2 µm) with GaAs substrate is shown in Fig. 2. At the operating frequency of 1 THz, the CPS waveguide is designed to be single mode. Also it is assumed that the CPS is terminated to its characteristic impedance (Z_0=139 Ω) at both ends. From the induced voltage shown in Fig. 2, one can calculate the coupled THz power to the CPS waveguide and the efficiency of the device.

REFERENCES

[1] D. Saeedkia, R. R. Mansour, and S. Safavi-Naeini, "The Interaction of Laser and Photoconductor in a Continuous-Wave Terahertz Photomixer", *IEEE J. Quantum Electron.* , Vol. 41, No. 9, pp. 1188-1196, Sep. 2005.

[2] L. B. Felsen and N. Marcuvitz, *Radiation and Scattering of Waves,* IEEE Press, 1994.