Scattering of Surface-Plasmon-Polariton Wave by an Abrupt Discontinuity

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Surface plasmonics for communication has recently acquired research interest because of the promise of high data-transfer rate along with miniaturization. Electronic interconnects in solid-state circuitry are slow and cause significant transmission delays. Conventional optical interconnects are faster but their sizes ($\gtrsim$ 500 nm) makes it difficult to integrate them with dense arrays of the much smaller electronic devices (10–50 nm). As the electromagnetic (EM) fields of surface-plasmon-polariton (SPP) waves are highly localized to dielectric/metal interfaces, SPP-wave-based optical interconnects hold promise.

SPP-wave propagation along continuous planar dielectric/metal interfaces is heavily investigated for sensing and imaging, but information transmission by an SPP wave across discontinuities remains unexplored. With this motivation, we studied the scattering of a pulse-modulated SPP wave guided by an air/silver interface due to an abrupt discontinuity caused by the replacement of silver by air, as shown in Fig. 1(a). A custom finite-difference-time-domain algorithm was used to compute the temporal evolution of the EM fields everywhere in the computational domain, the SPP wave assumed to be launched from the leftmost end ($x = -a$) of that two-dimensional (xz) domain.

In order to analyze scattering due to the abrupt replacement of silver by air, we calculated the time-dependent EM fields at point R, ($x = -d_R, z = 0^+$), in Fig. 1(a) as well as at several points in air after the abrupt discontinuity ($x > 0$). As examples, plots of $P_x(x, z, t) = \hat{\mathbf{x}} \bullet [\mathbf{E}(x, z, t) \times \mathbf{H}(x, z, t)]$ vs. time t at points R and S, ($x = d_S, z = 0$), are shown in Figs. 1(b) and 1(c), respectively. As an example, for $d_R = 30\lambda_c$ and $d_S = 1\lambda_c$, where λ_c is the free-space wavelength of the carrier SPP wave, the shape and duration of the pulse received at S are approximately the same as that of the pulse at R, thereby indicating that SPP waves are suitable for information transmission in integrated circuitry.

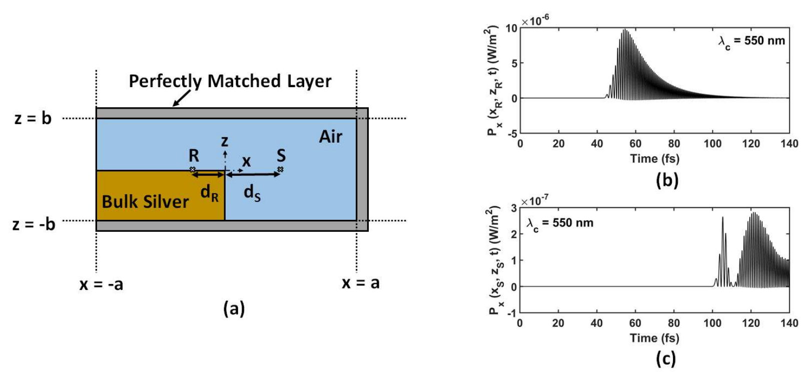

Figure 1: (a) Computational domain. (b) $P_x(-d_R, 0^+, t)$ vs. t and (c) $P_x(d_S, 0, t)$ vs. t for $d_R = 30\lambda_c$ and $d_S = 1\lambda_c$, when the carrier wavelength $\lambda_c = 550$ nm.