

Imitating a Material Response through DC-biased Spatiotemporal Modulation

Grigori A. Ptitsyn¹, Diego M. Solís^{2,3}, Mohammad S. Mirmoosa⁴, and Nader Engheta¹

¹Department of Electrical and Systems Engineering, University of Pennsylvania
Philadelphia, PA 19104, USA

²Departamento de Ingeniería Audiovisual y Comunicaciones, Polytechnic University of Madrid
Madrid 28031, Spain

³Departamento de Teoría de la Señal y Comunicaciones, University of Vigo
Vigo 36301, Spain

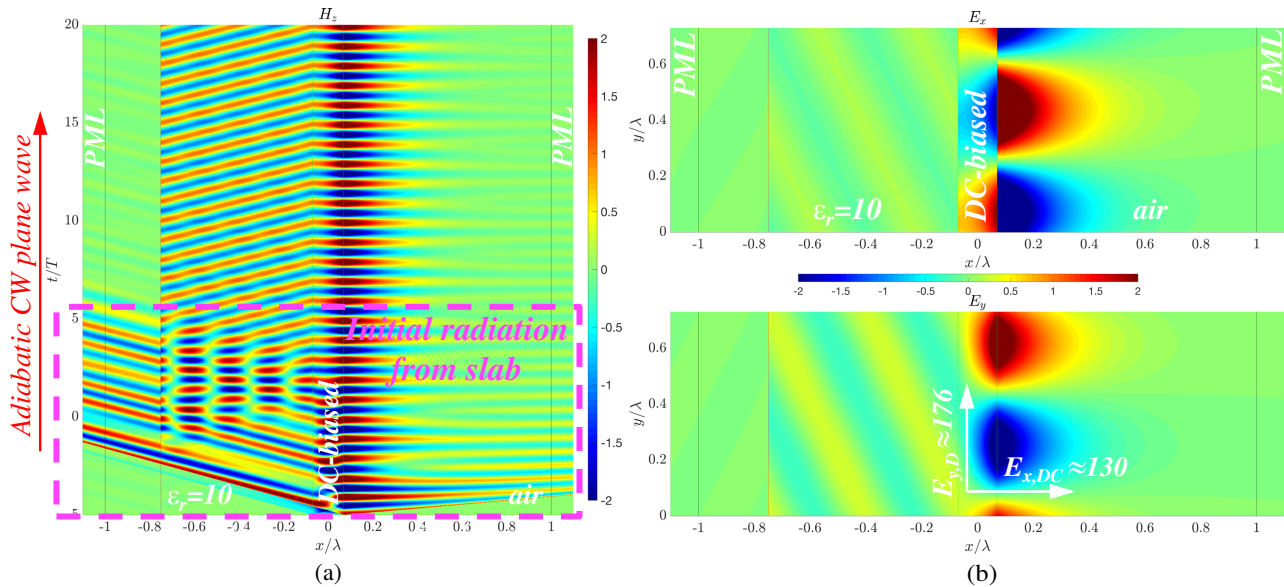
⁴Department of Physics and Mathematics, University of Eastern Finland
Joensuu 80101, Finland

Abstract— Inspired by the concept of dynamic (time-varying) modulations as a means to mimic arbitrary transfer functions, e.g., in the context of impedances of one-port passive electronic circuit elements [1] (capacitors, inductors, etc.), in this work we explore the possibility of taking this idea one step forward and apply it to wave-matter interactions. We are thus tailoring a polarization response in the presence of retardation and, accordingly, the modulation needed is now not only a function of time but of space also. Particularly, we will herein sculpt the (effective) response of a Drude material with an (actual) nondispersive spacetime-varying permittivity, and one key ingredient of our proposed approach is the presence of a DC-bias electric field, which controls that the actual dielectric function stays — at every point in space and time — within a desired, physically reasonable range.

In order to illustrate this idea, we excite a surface plasmon polariton (SPP) in the Kretschmann configuration (see Fig. 1) with a slab whose instantaneous response is parameterized with the following expression for the susceptibility:

$$\chi_{ll,\omega_o}(\mathbf{r},t) = \frac{A_l}{E_{l,DC} + E_l(\omega_o, \mathbf{r}, t)} + \chi_{eff}(\omega_o), \quad l \equiv x, y \quad (1)$$

In short, if we would like our slab to *identically* reproduce, both inside and outside, the fields scattered by the polarization current of a plasma slab at a given operating frequency ω_o , following $\chi_{eff}(\omega_o)$, we can do so by modulating our spacetime-inhomogeneous slab with those very same electric fields inside plus the incidence, whose total we denote as $E_l(\omega_o, \mathbf{r}, t)$ for each component l . The DC bias $E_{l,DC}$ and the arbitrary constant A_l (which in principle could also be allowed to have certain space dependencies) act as (i) degrees of freedom and (ii) constraints ensuring that the tensorial components $\chi_{ll,\omega_o}(\mathbf{r}, t)$ are both bounded and strictly larger than zero in order to prevent instabilities.



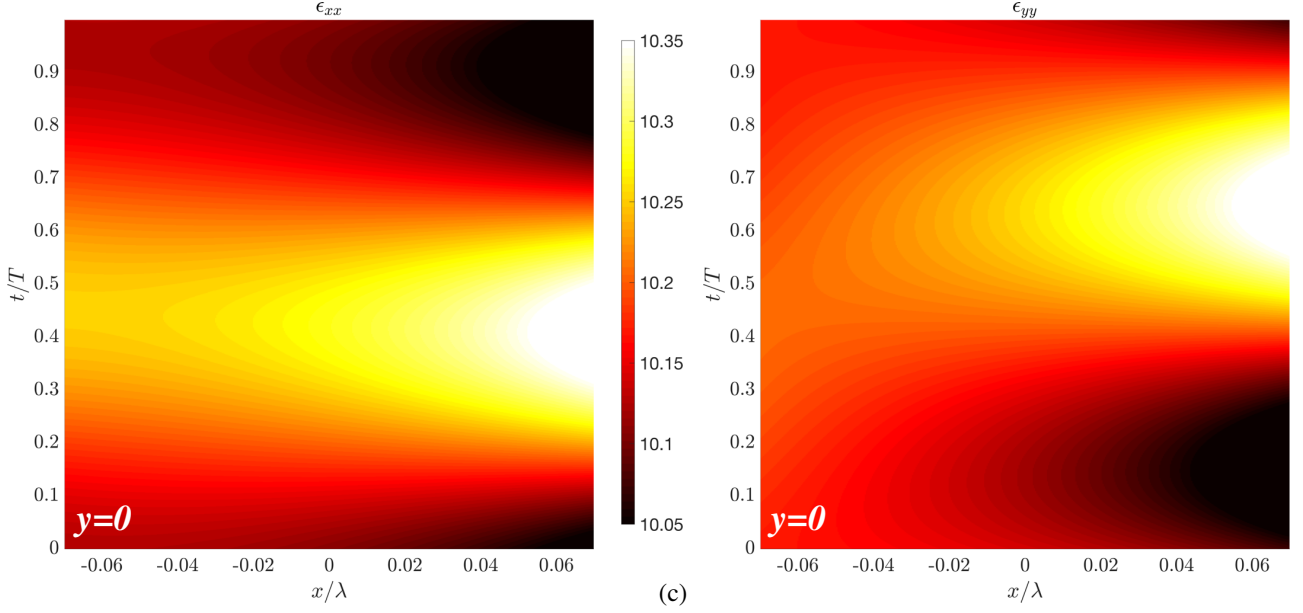


Figure 1: Numerically-simulated SPP excitation with an instantaneous spacetime-modulated slab that imitates a plasmonic response with real part $\chi_{eff}(\omega_o) = -2$ (some conduction loss has been added in order to increase both frequency and angular bandwidth). The susceptibility of the preceding slab is 9. Adiabatic plane-wave illumination is considered, and yet there is initial radiation from the slab modulation itself. (a) Temporal evolution of the out-of-plane (normalized) magnetic field vs. the normal direction x (e^{-iky} dependence is assumed for the transverse direction y). (b) Snapshot of the electric field components of the steady-state SPP. (c) Inhomogeneous dielectric tensor inside the slab over one modulation period, for $y = 0$.

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REFERENCES

1. Ptitsyn, G. A., M. S. Mirmoosa, S. Hrabar, and S. A. Tretyakov, "Time-modulated circuits and metasurfaces for emulating arbitrary transfer functions," *Phys. Rev. Applied*, Vol. 20, 014041, 2023.