URSI-B EMTS 2025, Bologna, 23–27 June

Wave Scattering from Time-Varying Dispersive Interfaces

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In this study [1], we investigate wave scattering at time-varying dispersive interfaces with Lorentz-type dispersion that undergo abrupt temporal changes. We uncover a novel frequency generation process occurring at the natural resonances of these systems. Unlike traditional methods that require spatial gratings or prisms, our approach demonstrates that propagating waves can directly couple to evanescent modes through the natural resonances triggered by a sudden temporal boundary.

We focus on a time-varying, dispersive dielectric layer placed between two homogeneous, stationary half-spaces. Our findings reveal that the abrupt change in electromagnetic parameters leads to the excitation of either radiative or bound modes, depending on the configuration. This discovery opens up new possibilities for designing compact and ultrafast photonic devices, removing the need for subwavelength spatial structuring or extended temporal modulations.

Using a semi-analytical framework, we validate our theoretical predictions with rigorous full-wave numerical simulations. Our analysis covers both normal and oblique wave incidences, highlighting the versatility of our approach in manipulating electromagnetic fields across a wide frequency range. These results have significant implications for advanced field manipulations and practical applications in metamaterials and optoelectronic technologies, particularly in the terahertz frequency range.

We also discuss the potential for real-world applications, noting that the parameters we explore are consistent with realistic values for semiconductor platforms operating at terahertz frequencies. With experimental validation within reach, we believe our findings pave the way for further research in quantum scenarios and other wave systems, such as acoustics.

References

[1] C. Rizza, M. A. Vincenti, G. Castaldi, A. Contestabile, V. Galdi, and M. Scalora, "Harnessing the natural resonances of time-varying dispersive interfaces," *Physical Review Letters*, **133**, 18, Nov. 2024, 186902, doi: 10.1103/PhysRevLett.133.186902.