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Graphene-strip-loaded cylindrical Luneburg lens: effects of plasmon resonances on lens performance

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The Luneburg lens (LL) focuses incident electromagnetic waves onto its surface through a radially graded permittivity profile that decreases from 2 at the center to 1 at the outer boundary [1]. Due to their quasi-optical properties, LL antennas are widely employed in radar, satellite communications, beamforming, and related electromagnetic systems. Since practical LLs are finite and discretized, they must be approximated by multiple concentric layers—typically about ten—to reproduce geometrical-optics performance. For electrically small lenses, the ideal focal point broadens into a finite focal region. Graphene strips placed within this region function as tunable plasmonic resonators that support quasi-surface-wave modes, leading to enhanced field localization through plasmon resonances and the electromagnetic-jet effect, similarly to the graphene-decorated dielectric rod studied in [2].

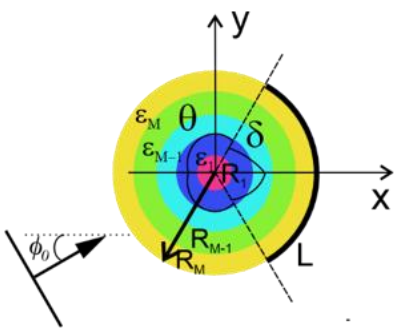

Fig. 1 Cross-section of an M-layer cylindrical Luneburg lens decorated with a conformal graphene strip of angular width 2δ. The black arrow shows the propagation direction of the incident plane wave, ϕ_0 is the incidence angle; R_p is the external radius and $\varepsilon_p = 2-(p-1/2)^2/M^2$ is the dielectric permittivity of the p-th layer, for $p = 1,\dots,M$.

In this study, A hyper-singular integral equation (HSIE) formulation [3], discretized through a Nyström-type method [4], is considered to analyze a discretized Luneburg lens loaded with a conformal graphene strip. This approach ensures mathematically rigorous convergence while maintaining a relatively low discretization requirement, even for electrically large structures [5]. The graphene layer is represented as an infinitely thin conductive surface whose impedance is the reciprocal of the Kubo-based surface conductivity, determined by the frequency f, chemical potential μ_c, temperature T, and relaxation time τ [6].

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