Interface Effects in Flatland Optics

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Controlling surface-wave propagation at the nanoscale remains a key challenge in modern photonics and nanotechnology. A particularly intriguing class of surface waves, *line waves*, propagate along the junction between surfaces with different impedances, exhibiting strong energy confinement in both in-plane and out-of-plane directions [1,2]. Unlike conventional surface waves, which spread across a two-dimensional (2D) interface, line waves confine electromagnetic energy to a one-dimensional (1D) path, making them highly attractive for applications in integrated waveguides, optical sensing, and sub-diffraction imaging.

This work explores how engineered planar impedance discontinuities can give rise to novel wave phenomena inspired by their higher-dimensional counterparts. Specifically, we introduce ghost line waves, flat leaky waves, and scale-invariant flat waveguiding, each offering unique mechanisms for manipulating light at the nanoscale.

Ghost line waves emerge at isotropic-anisotropic interfaces with a tilted optical axis, exhibiting oscillatory decay both in-plane and out-of-plane, unlike conventional line waves that decay monotonically. This behavior is reminiscent of ghost waves and ghost surface polaritons observed in anisotropic media [3]. Flat leaky waves, on the other hand, extend the properties of standard line waves by enabling in-plane leaky-wave radiation while maintaining strong out-of-plane confinement [4], akin to 2D Cherenkov radiation [5]. Finally, scale-invariant flat waveguiding provides a new mechanism for light confinement, analogous to conventional dielectric waveguides [6], where wave propagation is maintained at the transition between flatland leakage and a bound surface mode, ensuring an effective index independent of the core width.

This presentation will discuss both theoretical and computational challenges, along with experimental validations using microwave demonstrators. These results highlight the potential of impedance-engineered surfaces for advancing flat optics and wave-based nanophotonic technologies.

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