Toward Near-Field Unidirectional Excitation... and Beyond

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Summary

Similar to the effect of a waterwheel over a channel, in which the sense of rotation determines the flow direction, the circular motion of charges close to waveguiding structures may result in the unidirectional excitation of surface or guided electromagnetic modes [1]. This topological phenomenon is a clear evidence of spin-momentum locking, describing the incontrovertible relationship between the transverse spin of evanescent waves and the propagation direction of guided modes, and is generally interpreted as a manifestation of the photonic counterpart to the quantum spin Hall effect [2].

On account of this universal and robust feature, near-field directionality has been observed for circularly polarized dipolar sources in a wide variety of photonic platforms and spectral ranges. Yet, by considering linear combinations of electric and magnetic dipolar sources, the near-field directionality can be extended beyond spin-momentum locking [3]. This generalization led to the theoretical prediction of a new type of source: the Janus dipole. Together with circularly polarized and Huygens dipoles, they form a complete set of directional sources, thus simplifying the analytical description and broadening the possibilities for engineering the near-field coupling.

Beyond their scientific interest, these dipolar sources are intended to be exploited in practical applications. By means of high-index dielectric nanoparticles, in which both electric and magnetic resonances spectrally overlap with comparable strengths, Janus dipoles have been experimentally demonstrated [4]. This shows that the apparently exotic amplitude and phase relations between electric and magnetic moments required for these theoretical dipoles are indeed experimentally feasible by means of simple arrangements.

Furthermore, given the plethora of phenomena that have arisen just by adding magnetic dipoles to the playing field, we strove to explore near-field directionality beyond the dipole approximation, by considering higher order electric and magnetic multipoles and their combinations [5]. This increases the available degrees of freedom, enhances the directional contrast, the spatial frequency bandwidth, and enlarges the accessible spatial range, thus providing versatility for engineering the directional scattering and coupling.

Superposition of electric and magnetic dipoles that experimentally achieve near-field directionality, and the theoretical possibility of combining them with higher-order multipoles, promise new avenues for miniaturized light switching and nanorouting, photonic logical circuits, light polarimetry, and novel optical forces, among others.

References

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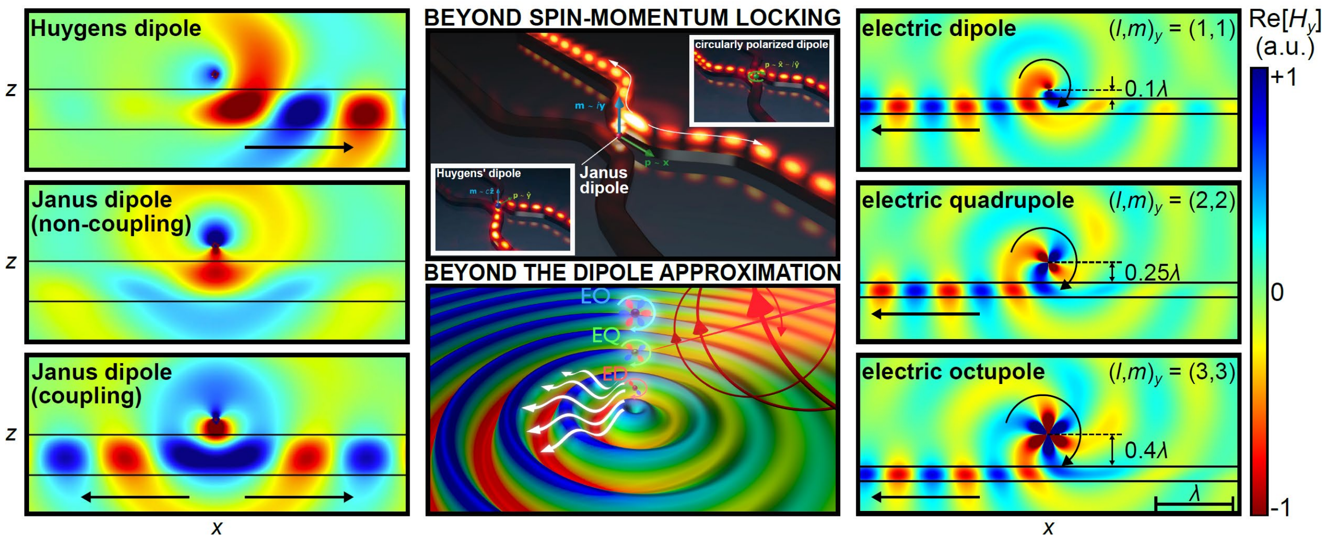
Figure



Left: Near-field behavior of Huygens and Janus sources placed over a dielectric slab waveguide. Right: Near-field directional excitation of guided modes from higher-order multipolar sources. Center: Artistic representation illustrating the main features of these sets of localized optical sources.