2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

Directional emission from dipolar sources: the Janus source

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Unidirectional scattering from nanoscale sources has been recently achieved experimentally in near-field optics based on spin-momentum locking (quantum spin-Hall effect of light [1]) involving circularly polarised electric or magnetic dipoles[2]–[4], enabling fascinating applications such as quantum spin state readout, optical nano-polarimeters and non-reciprocal optical devices.

However, spin-momentum locking is not a strict requirement for unidirectionality; here we describe how near-field directionality can be achieved beyond this effect [5]. We do so by considering the whole electromagnetic field, instead of relying solely on its electric component. This unveils the existence of a dipolar source, termed Janus dipole, whose coupling to waveguided modes is topologically protected, so that it is allowed or forbidden depending on which of its sides faces the waveguide. The near field directionality of the Huygens' dipole is also revealed, and a generalised Kerker's condition is introduced. Circular electric and magnetic dipoles, together with Huygens' and Janus sources, form the complete set of all possible directional dipolar sources in far- and near-field.

We provide a general, complete, analytical theory of dipolar near-field directionality near planar geometries [5]. The insight obtained from this simple case can be easily extended into more general three dimensional waveguides. Dipolar scatterers can be realised as strongly resonant plasmonic or high-index dielectric nanoparticles supporting electric and/or magnetic dipolar resonances, while dipole emitters can be quantum dots or atoms. With this work we show that going beyond the usual linearly polarised electric dipoles opens unexpected opportunities for electromagnetic designs.

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