MIMO Optical Wireless at the Nanoscale

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In recent years, the rise of the field of optical nanoantennas has been largely impacting the way we control and engineer light-matter interactions at the nanoscale, translating and exploiting relevant antenna concepts from radiofrequencies to the optical domain. By efficiently coupling localized, or guided, optical fields to free-space radiation, and vice versa, optical nanoantennas find application in many different scenarios, e.g., sensing, photovoltaics, enhancement of weak non-linearities and quantum effects, local scattering control for wave-shaping metasurfaces, etc. Interestingly, pairs of plasmonic nanoantennas have also been proposed to realize optical wireless broadcasting links, which may allow sending nanoscale optical signals between two points on a chip, with lower attenuation than in conventional plasmonic waveguides (A. Alù and N. Engheta, Phys. Rev. Lett. 104, 213902, 2010). In a different context, it has been shown that subwavelength plasmonic nanostructures and nanoantennas can be designed to maximize the scattering/radiation contributions from several multipolar channels at the same time (dipolar radiation, quadrupolar, etc.), realizing "superscatterers" with, in principle, unbounded scattering cross section (Z. Ruan and S. Fan, Phys. Rev. Lett., 105, 013901, 2010). Here, by combining these concepts, we will show that it is possible to increase the capacity of optical wireless interconnects by using different multipolar radiation channels (i.e., orthogonal spherical harmonics) to simultaneously carry multiple optical signals (with identical frequency and polarization), effectively realizing a multiple-input multiple-output (MIMO) optical wireless link at the nanoscale.

In our talk, we will discuss in details the design of the transmitting and receiving portions of such nanoscale MIMO link. On the transmitting side, in fact, an individual localized nanosource, such as a quantum dot, or a fluorescent molecule, would mainly radiate as a point electric dipole, as its electronic transitions are dominantly of dipolar nature. However, when such nanosource is closely coupled with a superscattering nanostructure, e.g., a suitably designed multilayered plasmonic nanoparticle, the overall radiation pattern can be drastically different from that of the individual source, as higher-order scattering harmonics can be efficiently excited, depending on the position of the nanosource relative to the plasmonic nanoparticle. Multiple optical sources located at different positions inside or around the nanoparticle will therefore "select" different multipolar radiation channels, hence allowing the independent transmission of different optical signals sharing the same physical medium. In our talk, we will show that, for the relevant case of center-symmetric nanostructures, the radiation characteristics of the system can be obtained analytically, for any position of a feeding nanosource, by using Mie theory and reciprocity considerations. Finally, on the other end of the MIMO optical wireless link, multiple nanoreceivers coupled to a superscattering nanoparticle are designed to independently pick up the different optical signals carried by orthogonal spherical harmonics. This can be done based on the principle that each multipole moment, induced in the receiving nanoparticle, responds to a different derivative of the local field, which in turn depends on the multipolar radiation pattern of the transmitter.

At the conference, we will further discuss the potential of MIMO concepts to realize high-capacity, low-attenuation optical wireless interconnects at the nanoscale.