Magnetic Nanoantennas excited by Azimuthally Polarized Beams

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Natural magnetism is usually disregarded in the optical frequency regime due to its relatively weaker response to electromagnetic excitation compared to its electrical counterpart. Therefore, the study of field-matter interactions in optics is usually limited to the interaction between electric dipole transitions and electric field. Here, in our pursuit to develop future tools to investigate optical magnetic interactions, we elaborate on the concept of magnetic nanoprobes (i.e., magnetic nanoantennas) that can be used in scanning probe microscopy. In order to enhance the magnetic field-matter interactions in the optical frequency regime, different class of magnetic nanoantennas are examined (such as a dense dielectric nanosphere, a circular cluster of plasmonic nanospheres or nanopillars, and a split-ring resonator) under different illumination beams. The goal is to generate magnetic field hot spots with high resolutions. Importantly, we require the suppression of electric field, so that an electric dipolar transition in a matter sample placed at the magnetic field hot spot becomes negligible compared to the magnetic one. This is crucial to probe the weak magnetic dipolar transitions.

We show that azimuthally polarized beam, when focused through a high numerical aperture lens, constitutes the ideal excitation type of such magnetic nanoprobes owing to its circular symmetry and strong longitudinal magnetic field on its beam axis where its electric field vanishes. Moreover from the experimental point of view the self-standing azimuthally polarized beam is a simpler and superior choice than employing a superposition of several plane waves to create a similar excitation field. Owing to the symmetries in the magnetic nanoprobe geometries and also in the azimuthally polarized beam fields, one can suppress the electric dipolar resonances while boosting the magnetic responses of the nanoantennas. The use of these magnetic nanoprobes under azimuthally polarized beam results in enhanced high resolution magnetic fields where electric field is strongly suppressed. The engineering of magnetic nanoprobes and the use of azimuthally polarized beam excitation may lead to the development of future magnetism-based microscopy and spectroscopy applications.