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Spatial isolation of femtosecond magnetic needles driven by azimuthally-polarized laser beams

Rodrigo Martín-Hernández*, Luis Sánchez-Tejerina, Enrique Conejero Jarque, Luis Plaja, Carlos Hernández-García

Grupo de Investigación en Aplicaciones del Láser y Fotónica, Departamento de Física Aplicada, Universidad de Salamanca, E-37008, Salamanca, Spain.

*e-mail: rodrigomh@usal.es

Femtosecond laser sources have great potential to trigger, control, and observe ultrafast magnetic phenomena. Since the pioneering work on ultrafast laser-induced demagnetization by Beaurepaire et al. [1], the interest on the potential applications of ultrafast laser pulses in magnetism has boosted. In particular, the development of ultrafast structured light beams has opened new perspectives in the field. Recently, it has been shown how Tesla-scale femtosecond magnetic fields, isolated from the electric field in a spatial volume, can be obtained from the interaction between azimuthally polarized vector beams and metallic nanoantennas [2]. These ultrafast isolated magnetic sources have opened a new perspective in ultrafast magnetism to study pure magnetic interactions where the key role is played by the magnetic, like magnetic switching in ferromagnetic materials [3] or oscillations in the Néel vector in antiferromagnetic materials.

In this work, we study the effect of different antenna geometries to optimize the efficiency and isolation of ultrafast magnetic fields. We have performed simulations using the Particle-In-Cell code OSIRIS [4], where circular apertured antennas generate isolated magnetic nanoprobes (fig. 1 a). However, a significant magnetic-to-electric field ratio is limited to distanced of few nanometers. Our simulations demonstrate how novel geometries enhance this contrast, allowing to keep the electric field below the sample damage threshold. As an example, the use of a double apertured antenna (Fig. 1 b), enhances the contrast ratio by a factor of three (Fig. 1 c). Further optimization of the antenna geometry could boost this contrast enhancement. Our work paves the route to employ polarization structured laser beams along metallic nanoantennas to achieve pure magnetic interactions with matter at ultrafast scales.

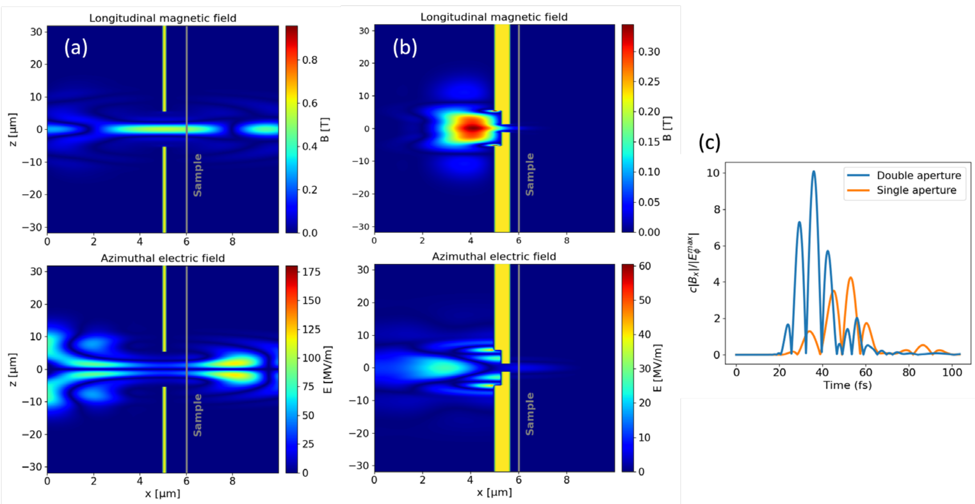

Figure 1: Spatial distribution, at *y=0,* of the longitudinal magnetic and azimuthal electric fields using (a) a single apertured antenna, as proposed in [2], and (b), a double apertured antenna. (c) Temporal evolution of the contrast at the sample for both antennas. The driving laser is a two-period 5 μm pulse, with a peak amplitude of 151 MV/m.

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