



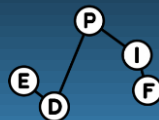
A way to improve magnetic-light and matter interactions : a plasmonic antenna

B. Reynier¹, E. Charron¹, O. Markovic¹, X. Yang¹, B. Gallas¹, A. Ferrier², S. Bidault³, M. Mivelle¹

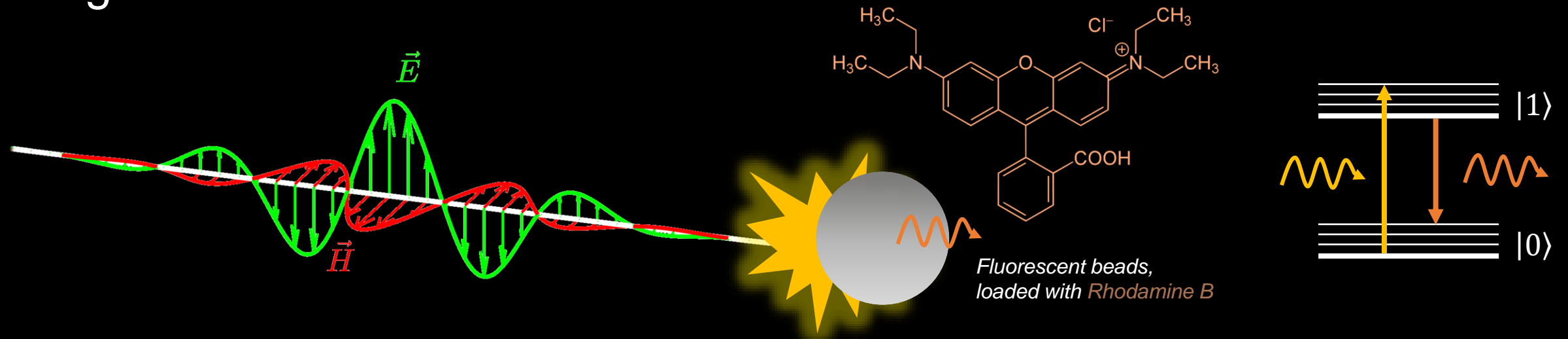
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Light and matter interactions



$$\hat{H}_{int} = \underbrace{-\mathbf{p} \cdot \mathbf{E}}_{\text{Electric Dipole (ED) energy given by } \mathbf{E}} + \underbrace{-\mathbf{m} \cdot \mathbf{H}}_{\text{Magnetic Dipole (MD) energy given by } \mathbf{H}}$$

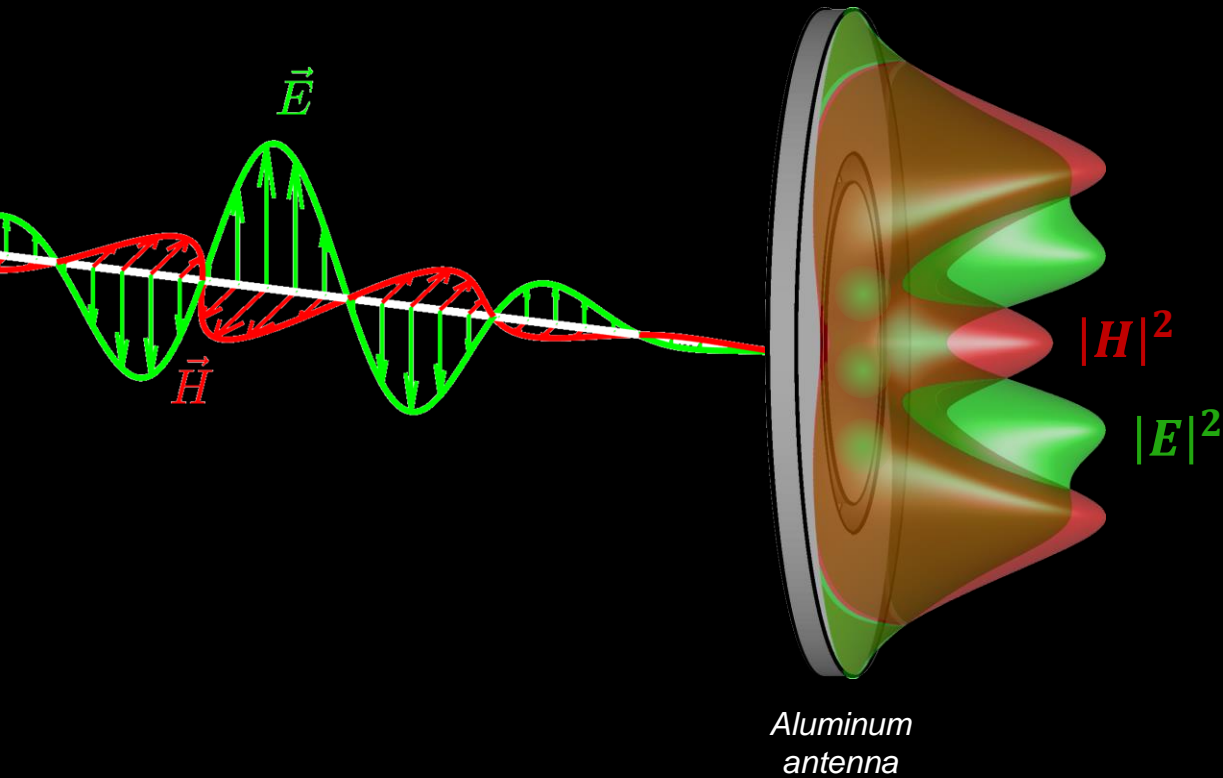
$$\frac{\mathbf{m} \cdot \mathbf{H}}{\mathbf{p} \cdot \mathbf{E}} \simeq 10^{-4}$$

ED interactions are often prevailing **BUT MD** interactions can be interesting

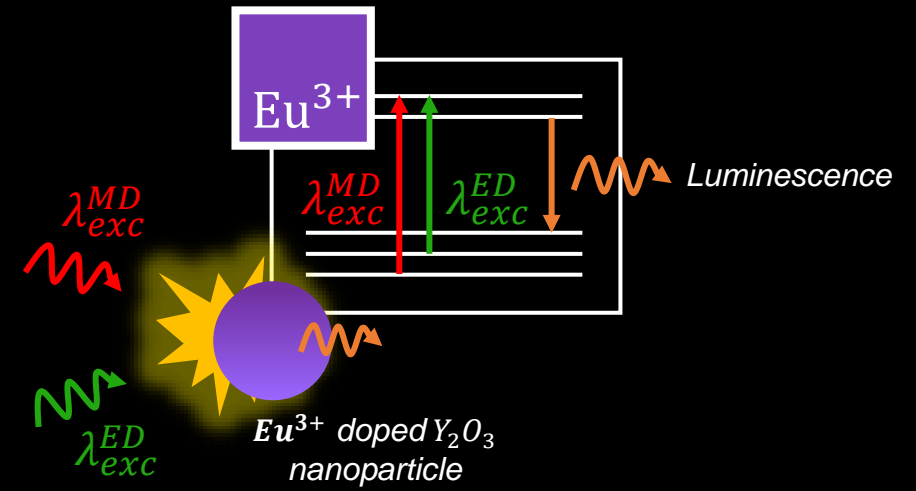
How to **enhance** the **magnetic**-light and matter coupling?

Find the two best candidates

Light : create a strong magnetic-light hot spot

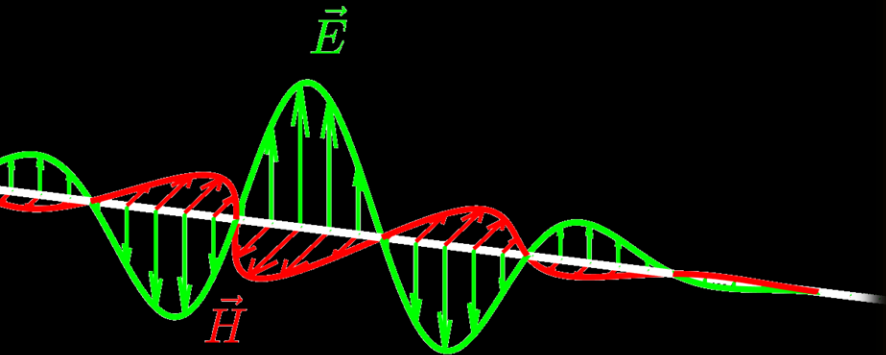


Matter : select the best magnetic-light sensor



Let's them interact !

“Excitation of a magnetic dipole transition through a plasmonic nano-antenna”



Distinguishing magnetic and electric coupling ?

Excitation of a magnetic dipole transition through a plasmonic nano-antenna

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Light-matter interactions are often considered to be mediated by the optical electric field only, discarding half of the energy stored in the optical magnetic field. Although interactions between magnetic light and matter are very weak, they can be studied in a certain class of materials, such as metal ions. For instance, it was demonstrated in Eu^{3+} ions that magnetic emission could be manipulated by tuning the local magnetic quantum environment surrounding magnetic dipoles by means of dielectric or plasmonic nanostructures. Along the same line, it is also possible to excite the electric and magnetic excitations of these ions by controlling the electric and magnetic fields distribution of the excitation light. Here, by using a plasmonic nano-antenna placed at the end of a nearfield probe, we demonstrate the localization and enhancement at sub-wavelength scales of the optical magnetic field.

Light energy is equally stored in electric and magnetic fields:

$$u = \frac{1}{2} (\epsilon_0 E^2 + \frac{1}{\mu_0} B^2)$$

Interaction of light with a quantum emitter:

$$\vec{H}_{\text{int}} = -\vec{p} \cdot \vec{E} - \vec{m} \cdot \vec{B} - \vec{Q} \cdot \vec{E} \dots \text{ and } \frac{m \cdot B}{p \cdot E} \approx 10^{-4}$$

• Very weak interactions between matter and magnetic light

Here, we demonstrate the excitation a magnetic dipole transition through a plasmonic nano-antenna

Figure 1: Schematic of the experimental setup. A plasmonic nano-antenna, designed at the end of a tapered fiber is excited through the fiber by a linear polarization. By means of a near-field setup, a Cu_2S Super Near-field probe is used to scan the XY plane the electric and magnetic intensity distributions of the localized plasmon. The fluorescence is then collected and analyzed by a spectrometer for each antenna-particle position.

$\lambda_{\text{LSPR}}^{\text{ED}} = 532 \text{ nm}$

Linecuts

$\lambda_{\text{LSPR}}^{\text{MD}} = 527 \text{ nm}$

Results and discussions:

- Imaging $|H|^2$ and $|E|^2$ nearfield distributions
- Very good agreement with simulations
- Energy transfer from magnetic optical light to matter through plasmonic antennas
- Pure and confined magnetic hot spot ($\approx 130 \text{ nm}$), below the diffraction limit

Figure 2: Simulation results in the XY plane below the plasmonic antenna (white dashed) of the (a) electric and (b) magnetic intensity distributions. (c) Linecuts along the polarization direction for the electric (blue) and magnetic (green) intensity distributions. Collected fluorescence in the XY plane below the plasmonic antenna of the (d) electric and (e) magnetic field excitation. (f) Linecuts along the polarization direction for the electric (blue) and magnetic (green) excitation.

Conclusion: By selectively exciting an electric or magnetic transition of the particle, the nanoscale scanning capabilities of our near-field system allow us to image the spatial distribution of these fields of the localized plasmons in the antenna. This research opens the way to increasing the all-magnetic light-matter coupling, with applications in quantum optics, in studying chiral phenomena, or the generation of photon avalanches.

Dealing with objects smaller than chance of finding a place in academia

Understanding why nearfield techniques are a true nightmare