All-optical generation of drift currents trough inverse Faraday effect

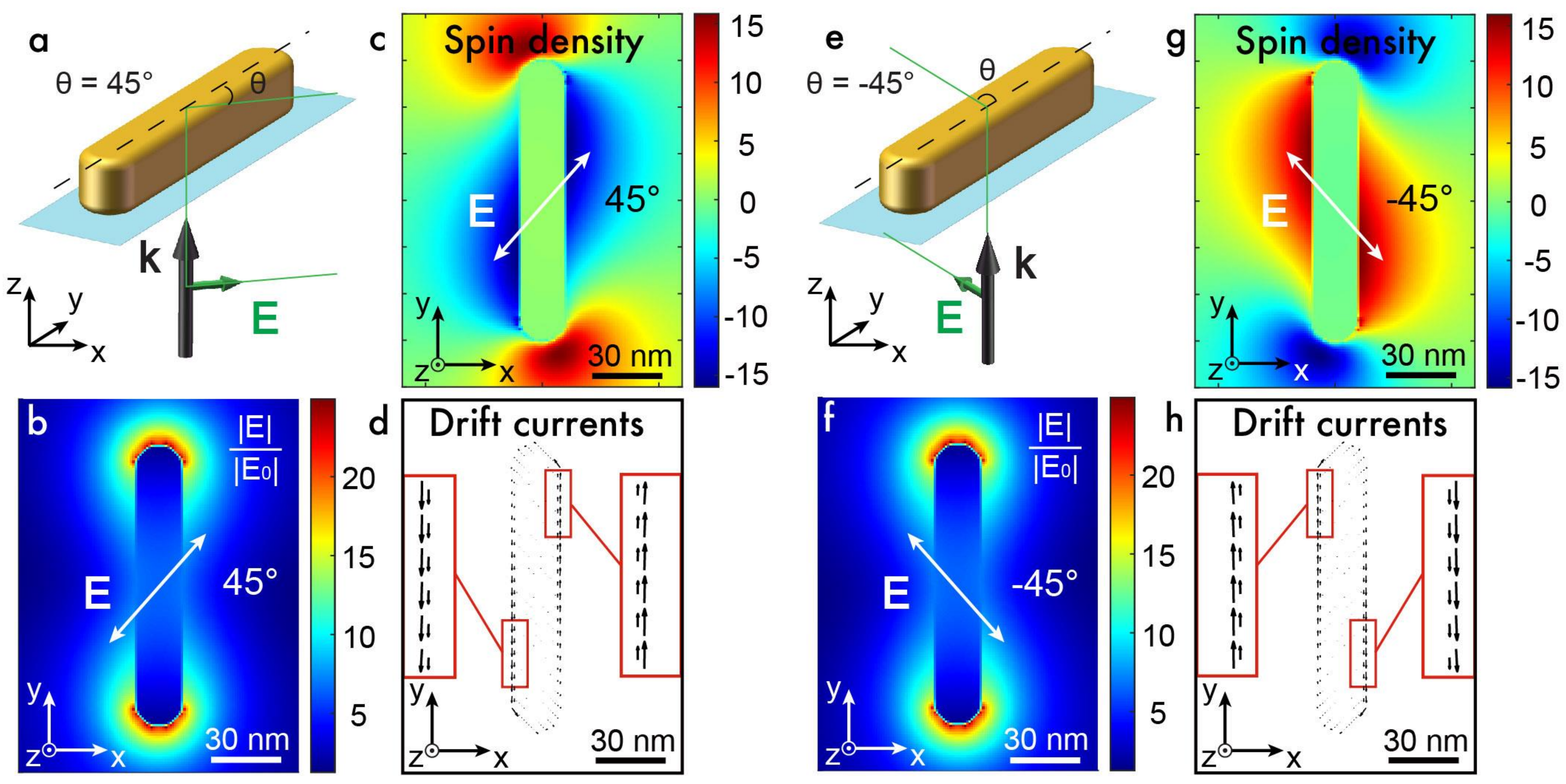
R. Zapata[1] , X. Yang [1], Y. Mou [1], Prince Gupta [2], A. Bouhelier [2], M. Mivelle[1]

[1] Institut des NanoSciences de Paris, UMR 7588, CNRS, Sorbonne Université 75005, Paris, FRANCE

[2] Laboratoire Interdisciplinaire Carnot de Bourgogne (LICB) UMR 6303, Université de Bourgogne ,9 av A Savary, BP 47870, 21078, Dijon Cedex, France

Introduction

The inverse Faraday effect allows the generation of stationary drift currents through optical excitation only. This light-matter interaction in metals results from non-linear forces that light applies to the conduction electrons of the metals. In our group, we recently described the theory underlying the generation of drift currents in metals, particularly its application to photonic nanostructures using numerical simulations. We demonstrated that a gold nano-rod allows, under linear polarization, to generate stationary drift currents when the incident polarization of the light is not parallel to the long axis of the rod. Here, by a linearly polarized optical excitation of gold nanorods aligned parallel to a gold nanowire, we manipulate the local polarization of light inside the nanometric gap between these two metallic nanostructures, allowing the generation of a local circular polarization of light that will drive drift currents with a controllable orientation along the nanowire.



Y. Xingyu, Nanophotonics, vol. 12, no. 4, 2023, https://doi.org/10.1515/nanoph-2022-0488

Figure 1 : IFE in a gold nanorod under linear polarization excitation. **Generation of drift currents** and local spin density **in a gold nanorod** excited by linear polarization at θ = +45° (A)–(D) and -45° (E)–(H) from the long axis of the nanorod.

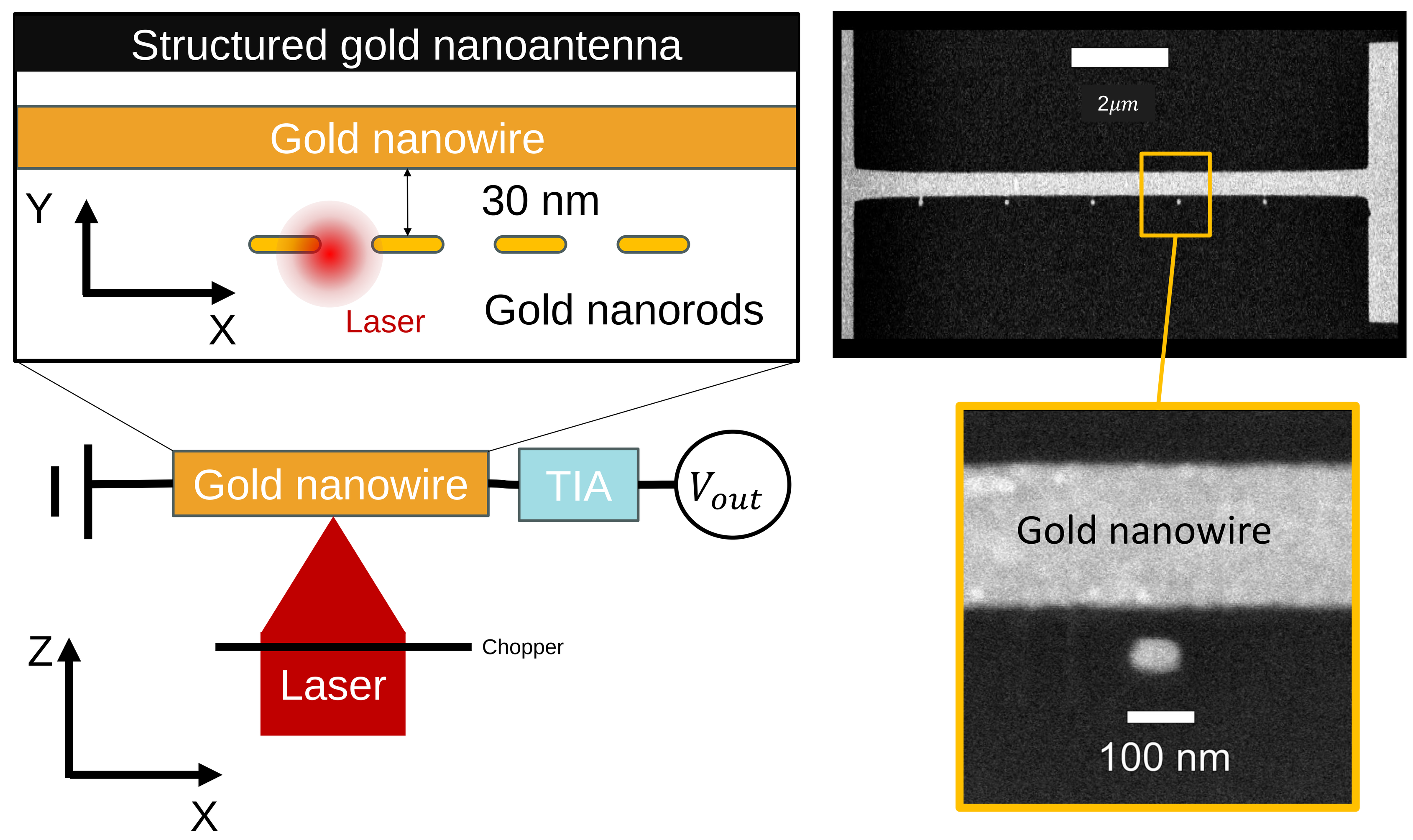


Figure 2 : Schematic of the experimental Set up. A plasmonic nanoantenna, composed of an array of nanorods placed near a gold nanowire, and optically excited by a laser. The current going through the nanowire was measured using a Transimpedance amplifier,

Spin density

$$S_z(\vec{r}) = Im(\vec{E^*} \times \vec{E}) \cdot \vec{u_z}$$

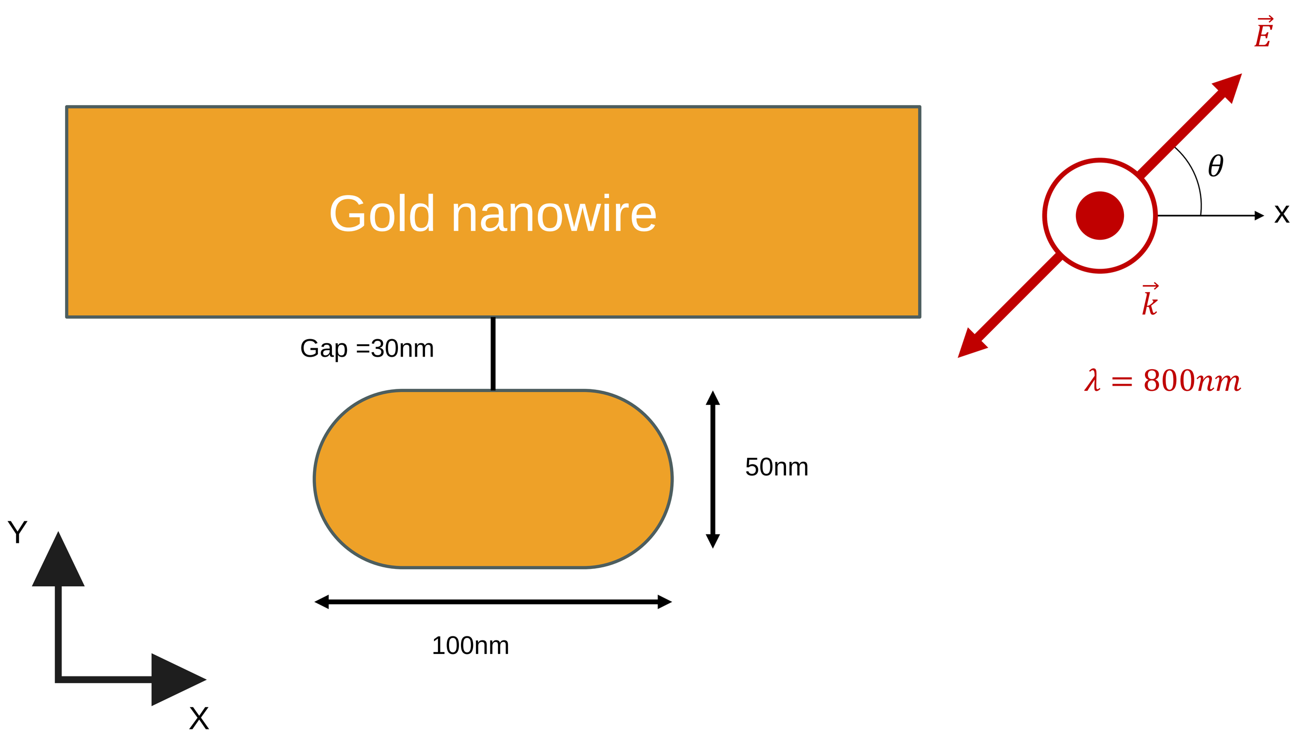
Drift currents

$$\vec{J_d} = \frac{1}{2en} Re\left\{\left(-\frac{\vec{\nabla} \cdot \vec{J_\omega}}{i\omega}\right) \cdot \vec{J_\omega^*}\right\} \text{ Where, } \vec{J_\omega} = \sigma_\omega \vec{E}$$

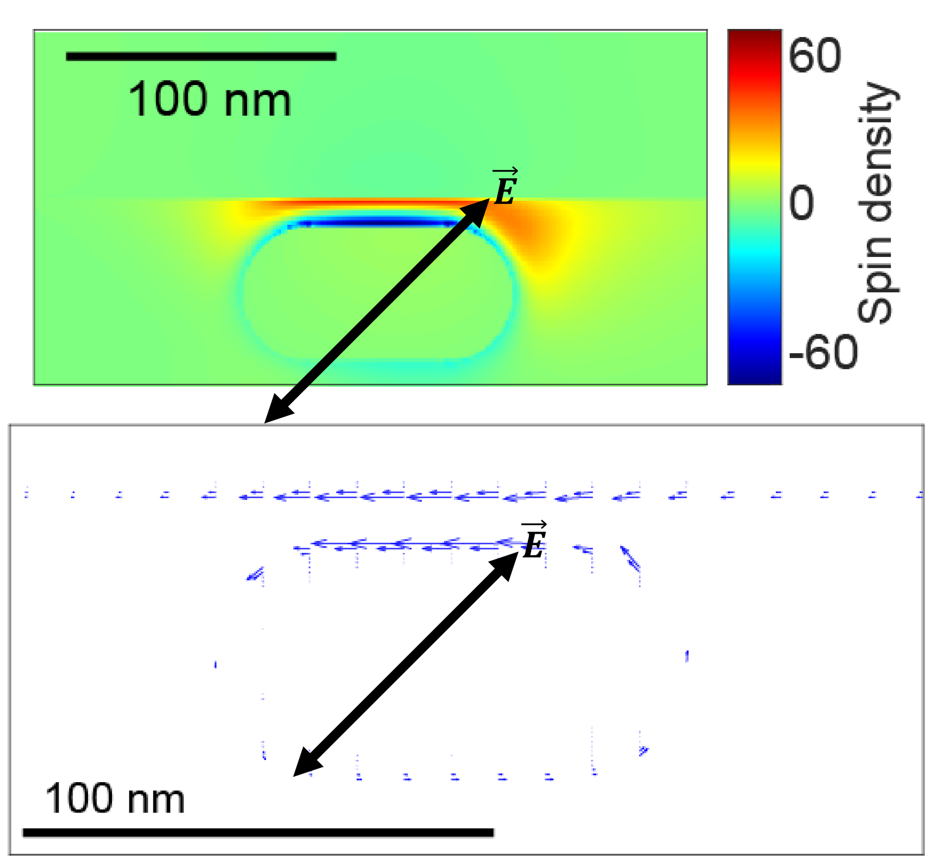
Full control of drift currents inside the gold nanowire

Theoretical response of the nano antenna

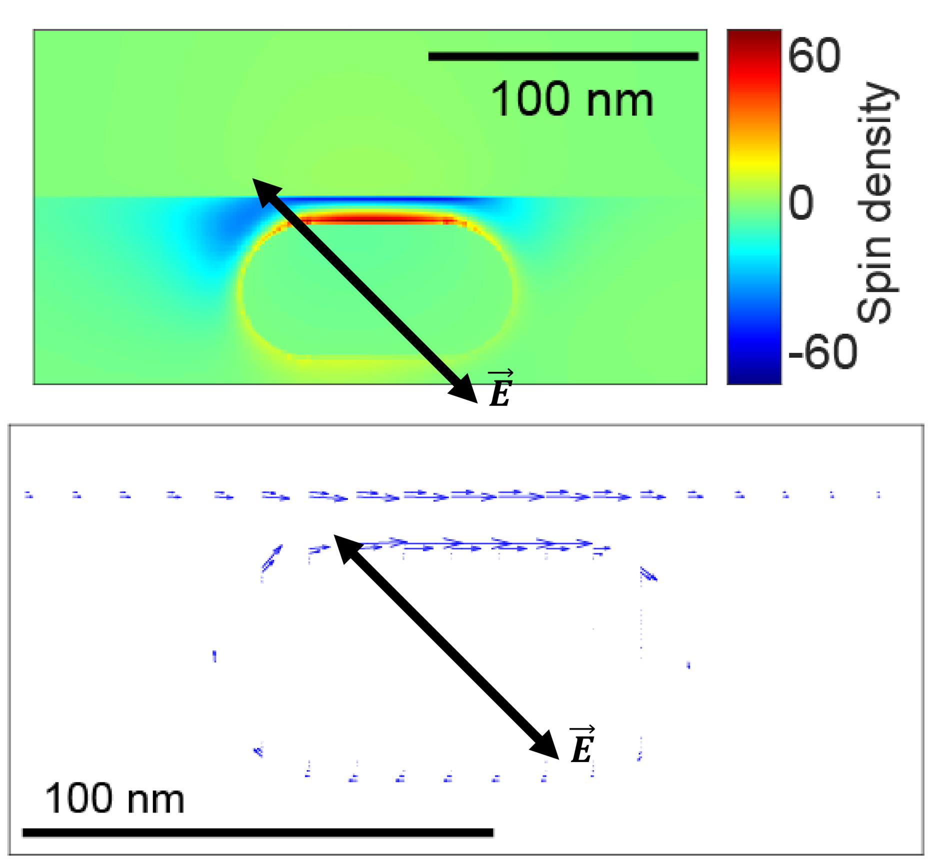
Scheme



$\theta = +45°$



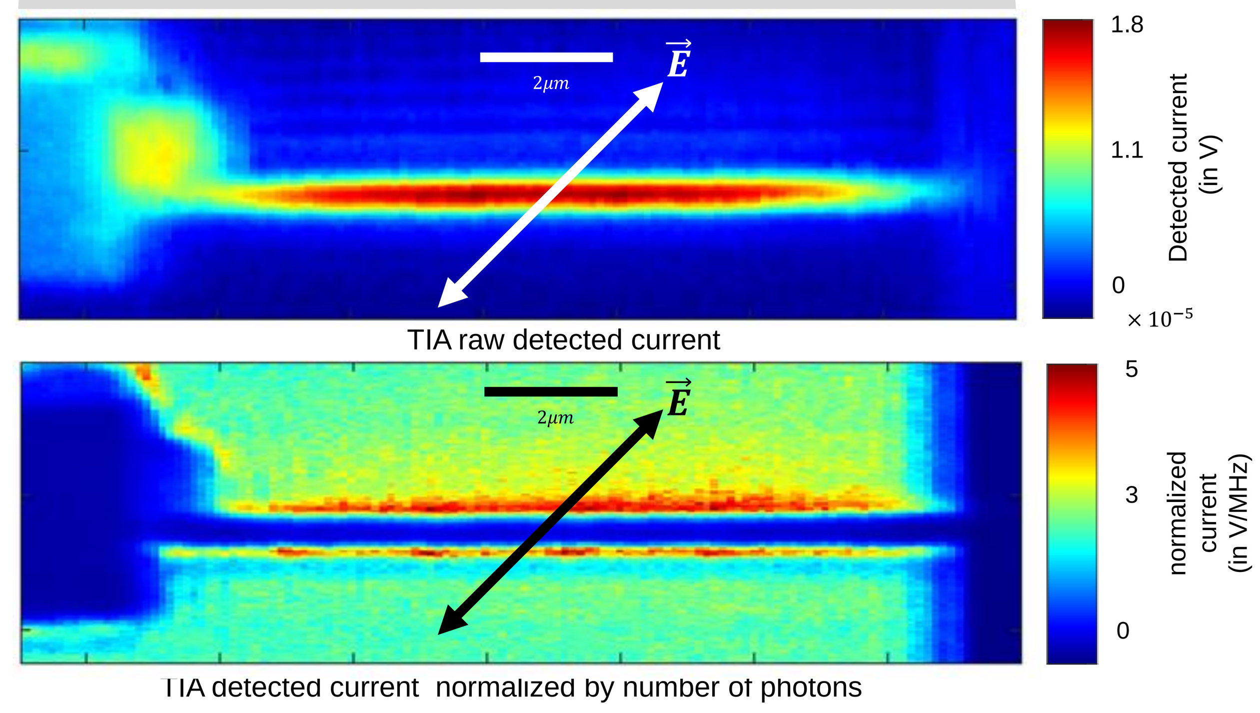
$\theta = -45°$



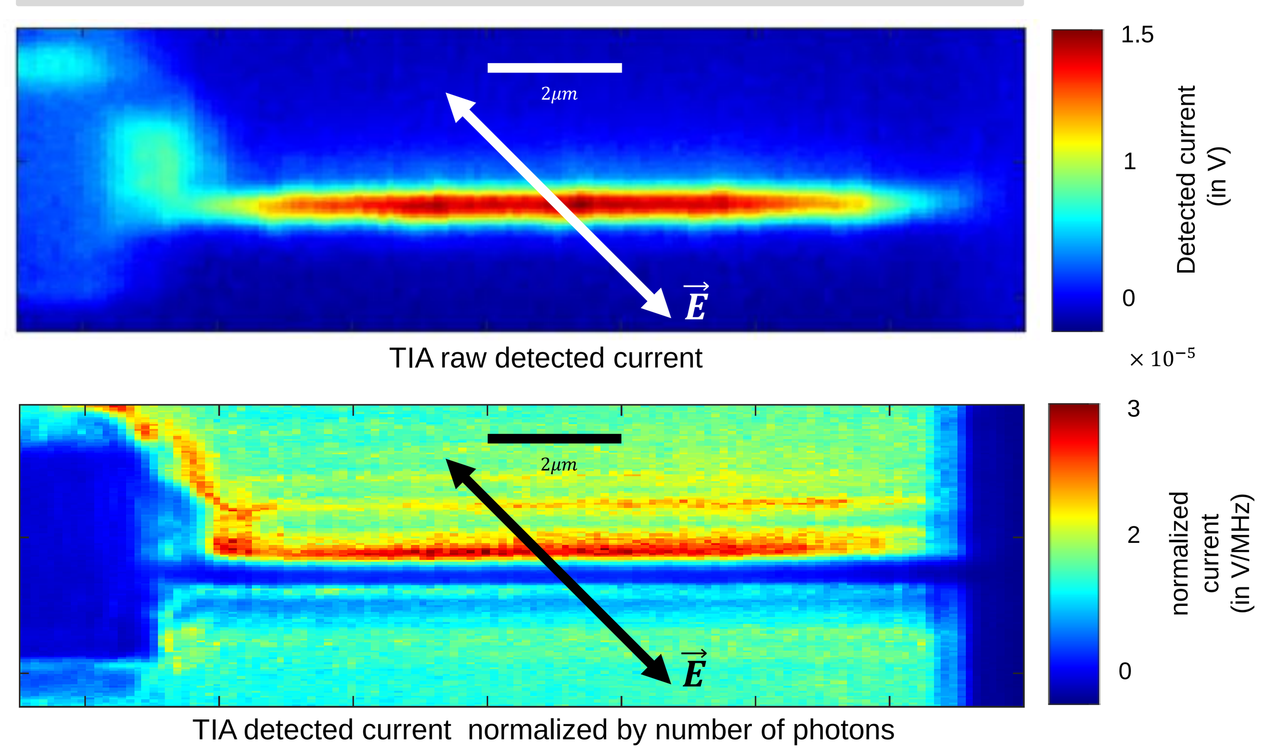
Here, the orientation of the drift currents induced inside the nano wire was reversed by changing the linear polarization of the driving light from +45° to -45° with respect to the long axis of the gold nanorods.

Experimental results

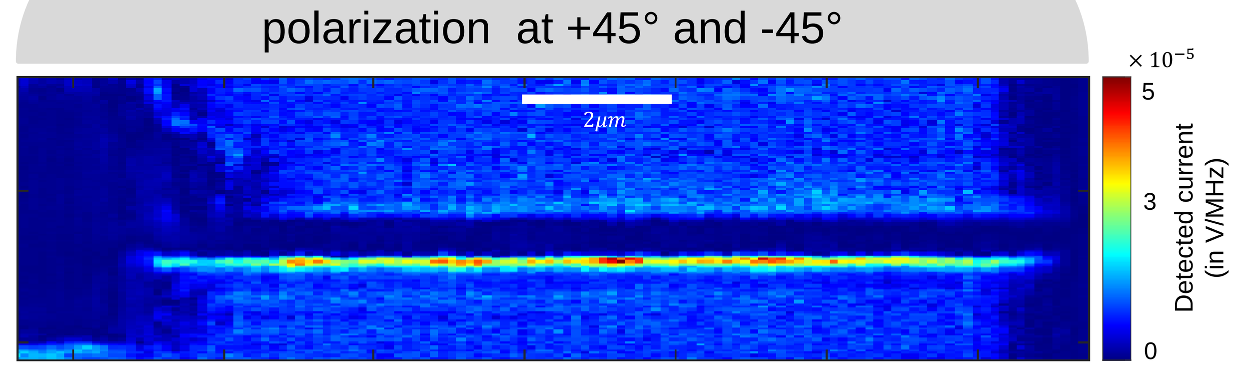
polarization of the driving light at +45°



polarization of the driving light at -45°



Absolute difference of detected currents with polarization at +45° and -45°



Drift currents detected near the nanorods