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Single Molecule Activation and Computing

SEVENTH FRAMEWORK PROGRAMME

Work Package WP n.1
Focusing Technology: Design and Fabrication

Deliverable D1.4
Report and Demonstration of nanowire in 2D geometry

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Premise

The present Deliverable provides the description and the demonstration of colloidal core-shell nanorods absorbing in the blue and emitting in the red spectral range which were positioned near a set of gold nanowires and stimulated by laser excitation. The nanorods emission was in fact converted into propagating surface plasmon polaritons in the Au nanowires and the out-coupled emission, at the opposite nanowires end, was far-field detected. We studied experimentally and theoretically both the influence of light polarization and the Au nanowires aspect ratio. The presented approach allows to decouple the nanowires light emission both spectrally and spatially from the excitation source.

Description of Work

This work has been achieved by using top-down lithography technique for the fabrication of Au nanowires (electron Beam Lithography, EBL). This top-down approach provides precise control both over the shape of the Au nanowires and on the location of the nanorods deposition, which allowed to study:

- the influence of the polarization of the excitation source on the near field coupling of the nanorods emission to the plasmons in the Au nanowires

The experimental data have been compared with the results obtained from finite elements (FEM) calculations on the propagation of SPPs in the metallic nanowires.

Results and assessment

Close image of a set of nanorods in proximity of a Au nanowire is shown in Fig. 1. The colloidal CdSe/CdS core-shell nanorods with a dot-in-a-rod architecture were used as light emitters, since this material shows very bright and stable emission and because the emission wavelength can be tuned via the size of the CdSe core. We chose the CdSe/CdS coreshell nanorod material due to the high quantum yield in optical emission (around 50%) and because of the tunability of the emission wavelength in the spectral range from 550-700 nm. The nanorods were deposited near the nanoantenna structures by a second overlayer EBL process that exposed rectangular regions.

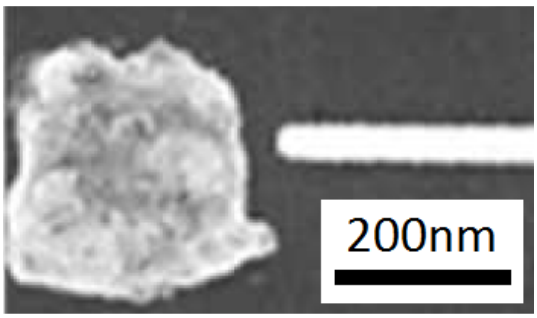

Fig. 1 Close view of nanordos-nanowires system.

Following a similar approach, we positioned "dot-in-a-rod" colloidal core-shell nanorods in the vicinity of a series of Au nanowires with 100 nm width and several microns in length fabricated by electron beam lithography (see Fig.2). The exciting laser beam was coupled off-axis into the confocal imaging optics, which allowed us to illuminate the rod-functionalized tip of the nanowires while recording the emission from the opposite end.

Spatially resolved conventional confocal luminescence mapping (Fig. 2) was used to verify the presence of nanorods solely at one side of the nanowires. The architecture of the nanorods was chosen so that their absorption was in the UV-blue spectral range and the band edge emission of the core material in the range between 620-670 nm. The nanorods were excited locally (λ=488nm) by laser light in resonance with the band gap of the shell, and the far field light emission at the opposite end of the nanowires was detected.

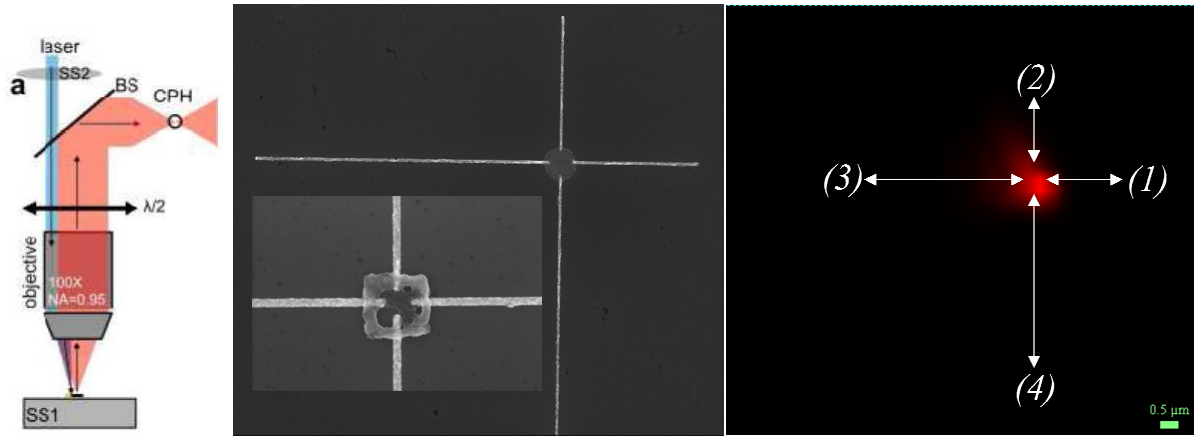

Fig.2 Left: Double scanning stage confocal microscope. Center: SEM image showing a series of 4 nanowires, with width 100nm and having different lengths (top, right: 3µm; left, bottom; 7 µm), located near to an ensemble of CdSe/CdS nanorods. Right: Confocal luminescence mapping. Inset: close view.

We observed appreciable emission at each end of the nanowires with a peak position that was slightly red-shifted with respect to the nanorods emission peak (Fig. 3). This red-shift can be explained by convolution of the nanorods emission with the transmission dispersion of the nanowires. Furthermore, we observed that in P-polarisation the intensity of the transmitted light was significantly stronger in respect to S-polarisation, which can be rationalized by the near field emission properties of the nanorods as shown in Fig. 4.

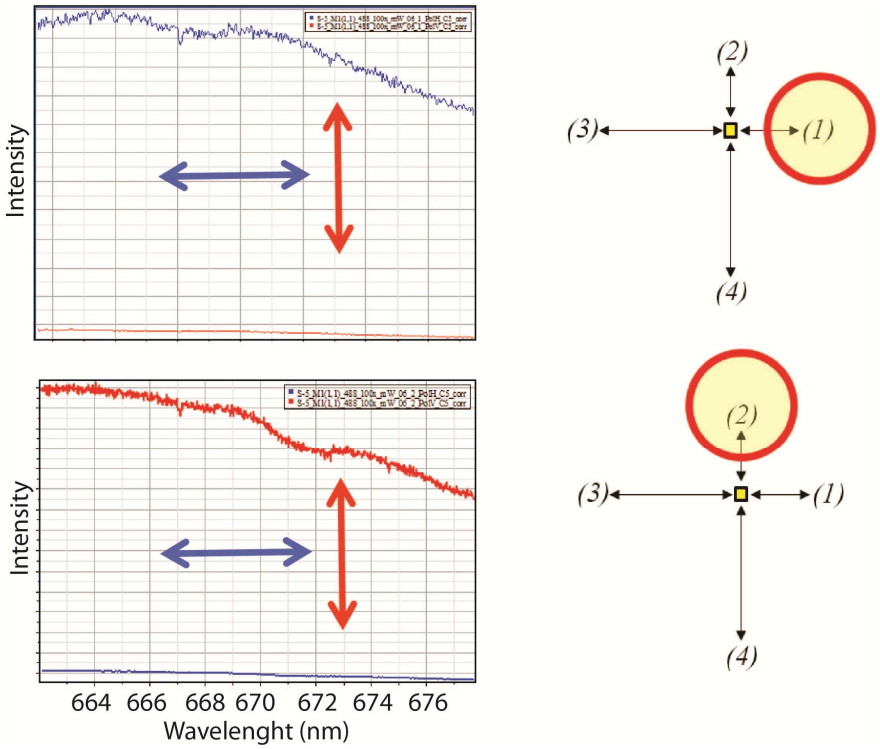

Fig.3 Emission from the nanowires under two polarizations. The strong polarization dependence is shown. The source was at λ=488nm.

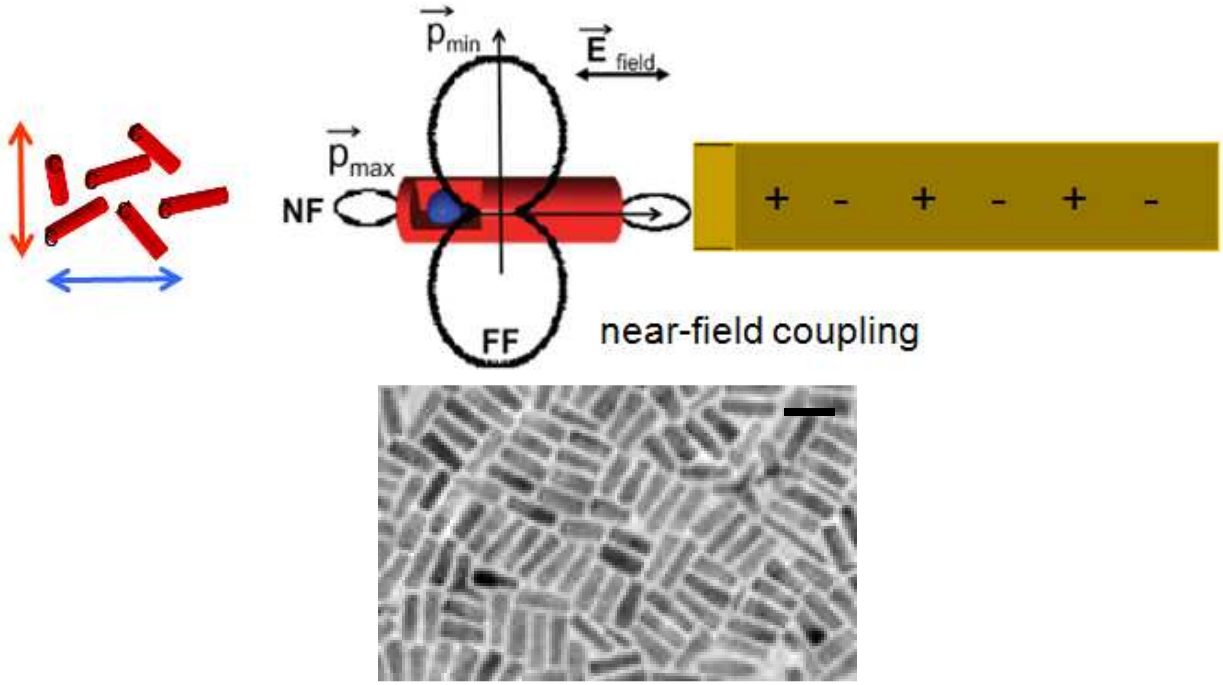

Fig. 4 Top: Near field coupling between nanorods and Au nanowires. An electric field oriented along the nanorods axis produced the maximum near-field radiation at the extremes of the nanorods. This is the ideal coupling condition to form Surface Plasmon Polaritons on the au nanowires. Bottom: SEM image of a the typical nanorods configuration. Scale bar: 50nm.

Having in mind WP3, 4 and 7, the entire system was adapted to simultaneously run a number of different signals along well defined nanowires. In particular, by following the mask design and templates of Fig. 5, the device shown in Fig. 6 was fabricated.

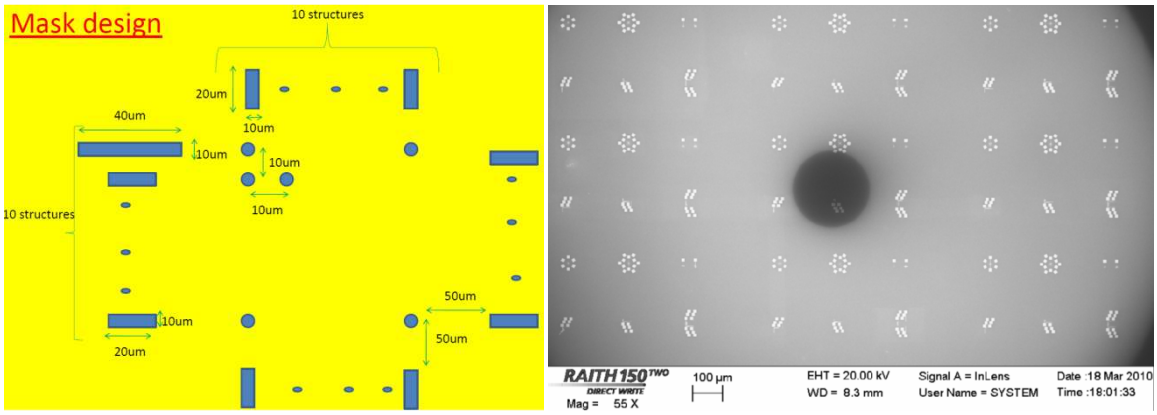

Fig. 5 Mask design and structures templates. Both nanowires and nanorods are shown.

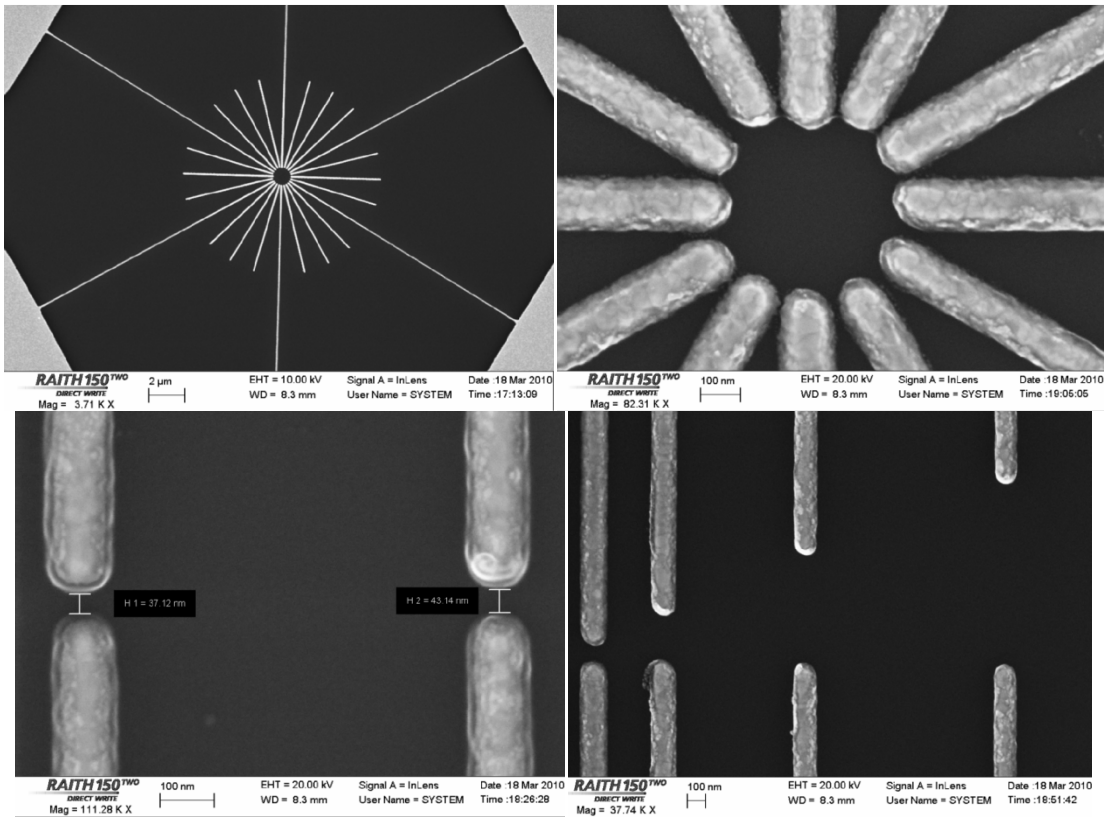

Fig. 6 Radial nanowires configurations. A series of 24 wires was fabricated (top left). The high nanowires density (top right: 12 nanowires) is possible owing to the fabrication accuracy of few tens of nm (bottom).

In conclusion we showed that a set of Au nanowires were simultaneously coupled to an ensemble of CdSe/CdS nanorods. The signal was collected, at the same time, from the opposite sides of different nanorods, hence demonstrating the parallel functionality of the device.