

Congratulations to New ICFO PhD graduate

Dr. Giorgio Volpe graduated with a thesis on Optical Nanoantennas

May 10, 2012

Before staring work on his PhD, Dr. Giorgio Volpe completed a Master?s Degree in Bioengineering at Universita degli studi di Padova (ITALY). At ICFO, he worked on a project related to Optical Nanoantennas in the group led by Romain Quidant.

Dr. Volpe presented a thesis titled ?Nanoscale Spatial Control of Light in Optical Antennas?. His thesis was supervised by ICFO Group Leader and ICREA Prof. Romain Quidant.

ABSTRACT:

The dynamic and deterministic control of light over space and time on the subwavelength scale is a key requirement in order to extend concepts and functionalities of macro-optics down to the nanometer scale. An increased level of control will also have fundamental implications in our understanding of nanoscale phenomena. One of the main problems nano-optics is aiming to tackle, therefore, is how and how well we can dynamically control the spatial distribution of light on such a length scale. Unfortunately, a fundamental limit of physics - the limit of diffraction of light - hampers our ability to selectively optically address nanoscale features separated by less than half the wavelength of light.

The field of *plasmonics* offers a unique opportunity for bridging the gap between the limit of diffraction and the nanometer scale. Plasmonic metallic nanoantennas can efficiently couple to propagating light and concentrate it into nanometer volumes, and vice versa. Additionally, these nanoantennas hold promise for enhancing the efficiency, to name but a few, of photodetection, light emission, sensing, heat transfer, and spectroscopy on the nanometer scale.

Learning how to accurately control the optical response of these nanoantennas represents a very promising approach to the control of the distribution of light fields over space and time on the nanometer scale. Traditionally, two main complementary approaches have been followed in order to control the optical response of plasmonic nanoantennas: the first, static approach aims at optimizing the design of the nanoantenna as a function of its specific application, while the second, dynamic approach aims at reversibly tuning the optical near-field response of a given nanostructure by engineering its excitation light over time and space.

The work reported in this Thesis expands on the state of the art of these two approaches, and develops new tools, both experimental and theoretical, to extend the level of control we have over the spatial distribution of light on the subwavelength scale.

After presenting an overview of the basic principle of nano-optics and surface plasmon optics, **Chapter 1** reviews the advances in the control of the optical response of metal nanostructures - either by a static or a dynamic approach - at the time this research work was initiated.

Tailoring the shape and the dimensions of metal nanoparticles is still a fundamental ingredient in order to tune plasmonic resonances and to control light fields on the nanoscale. As novel examples of static control, therefore, **Chapters 2 and 3** study new designs of plasmonic nanostructures with previously unexplored capabilities of molding light field on the nanoscale, such as a fractal design and a unidirectional Yagi-Uda nanoantenna.

Chapters 4 and 5 describe a new theoretical and experimental tool for the dynamic and deterministic control of the optical response of nanoantennas based on a spatial phase shaping of the excitation light: the optical near-field distribution resulting from the interaction between light and plasmonic nanostructures is typically determined by the geometry of the metal system and the properties of the incident light, such as its wavelength and its polarization; nonetheless, the accurate and dynamic control of the optical near field at the subwavelength scale - independently of the geometry of the nanostructure -- is also an important ingredient for the development of future nano-optical devices and to extend concepts and functionalities of macroscopic optics down to the nanometer scale.

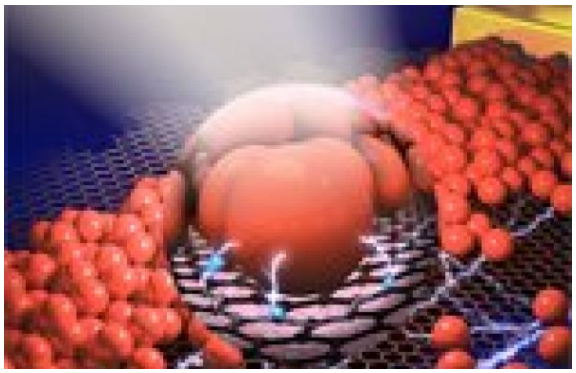
Finally, the Conclusion summarizes the results of this work and gives an overview of some parallel studies to this thesis. Some of the final remarks afford a glimpse into future perspectives and strategies to complement static and dynamic approaches in one powerful tool, which would enormously advance our ability to control the optical response of nanoantennas in space and time on a subdiffraction scale.

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Artistic representation of the device consisting of graphene with quantum dots on top



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