Project Title:	Graphene based nonlinear quantum optics (GRANQO)		
Project Manager:	Marinko Jablan		
Host institution:	ICFO – The Institute of Photonic Sciences		
Scientist in Charge:	Darrick Chang		
Return host institution:	University of Zagreb, Faculty of Science		
Fellowship scheme:	Outgoing		
Project duration:	16 months	**Project start date:**	01/07/2014

Graphene based nonlinear quantum optics

Project results:

Precise control over optical properties of materials would result in completely new paradigms in science and technology. For example, strong optical nonlinearities would enable ultra-fast data processing (optical computers), and in the extreme quantum limit, quantum information processing (quantum computers). While typical materials suffer from weak optical nonlinearities (it requires huge intensities to make two light beams to interact), in this project we have shown that graphene possesses immense nonlinear response in the terahertz spectrum, even at the quantum level [1]. Specifically we have demonstrated how the multi-plasmon absorption, as the dominant nonlinearity, leads to saturable absorption of Terahertz radiation, with low saturation intensity, in graphene nanoribbons.

Graphene is just one atom thick layer of graphite with some remarkable properties, like the ability to support plasmon-polaritons, a peculiar type of electromagnetic oscillations where the light is effectively squeezed into extremely small volume below diffraction limit. In our paper we have demonstrated how this extreme localization of plasmon fields in graphene nanodisks leads to such a strong two-plasmon absorption that it becomes nearly impossible to excite a second quantized plasmon in the system. This plasmon blockade effect is the ultimate manifestation of the nonlinear optics where one can observe interaction between just two quanta of light. Nanodisk thus behaves essentially like a quantum two-level system, which could be observable in its resonance fluorescence spectrum, see Fig. 1.

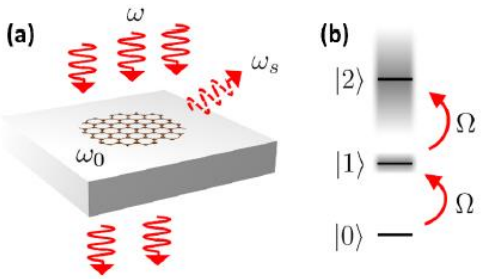

Figure 1. (a) Resonance fluorescence of a graphene nanodisk. (b) Quantized plasmon energy levels in a disk. Two-plasmon absorption induces a huge linewidth of a doubly excited state |2>, which makes it extremely difficult to populate this state and effectively turns the disk into a two-level system.

[1] M. Jablan, D.E. Chang, Multiplasmon Absorption in Graphene, Phys. Rev. Lett. **114**, 236801 (2015).

Dissemination of our results for general public

- I organized a series of popular-science lectures for general public in Zadar. For more infomation please see the web page:

  http://www.unizd.hr/uzz/Znanstveno-popularnapredavanja/tabid/7002/Default.aspx

- I gave two talks: "*New technologies based on graphene*", and "*The future of computers*".