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Study of coherent non-linear optical response of nanoparticles and application to multiphoton imaging in cell biology

Reporting

Project Information

FWMIMAGING

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Final Report Summary - FWMIMAGING (Study of coherent non-linear optical response of nanoparticles and application to multiphoton imaging in cell biology)

The main aim of this research project was to develop a novel multiphoton microscopy technique and to investigate its application to selected problems in cell biology which require sensitive three-dimensional imaging, in-vivo and real time. This novel technique is based on the detection of the resonant transient coherent non-linear optical response (four-wave mixing, FWM) of colloidal nanoparticles to explore their application as bio-labels. This method retains many of the advantages of multiphoton fluorescence microscopy, such as intrinsic sectioning capability, and offers additional advantages such as coherent detection free from fluorescence backgrounds.

A related objective of this research, beyond imaging applications, was to utilise transient FWM to study carrier population and polarisation decays in semiconductor nanocrystals. Colloidal semiconductor quantum dots have attracted great interest in the last decades for their potential application as active materials in optoelectronic devices and in quantum information.

During the two years of this Marie Curie IEF, the work performed by the researcher in line with the list of measurable objectives of the project can be summarised as follows:
1. The available set-up was implemented to be compatible with cell imaging.
2. The nonlinear properties of CdSe/ZnS and PbS colloidal quantum dots (CQDs) and gold nanoparticles (GNPs) were investigated and their application as bio-labels for FWM microscopy was assessed. The sensitivity of the technique was also.
3. The lateral and axial spatial resolution was measured by imaging structures with a size much smaller then the diffraction limit.
4. The photostability of the nanostractures investigated was evaluated as function to the excitation intensity and illumination time.
5. An important part of the work during the fellowship was to establish the applicability of the technique to cell imaging. Two cell lines were investigated (HeLa and HepG2 cells) and Golgi structures were labelled with commercial CdSe/ZnS CQDs(Invitrogen) or GNPs (BBInternational). Furthermore, beyond developing the microscopy technique, Dr Masia investigated the optical properties of colloidal nanostructures using

transient FWM spectroscopy taking advantage of the implemented three-beam geometry.
6. Zero-background imaging performances of the three-beam FWM were demonstrated.

The main results achieved so far can be grouped in three different sections:
I. The development of a novel multiphoton microscopy technique for cell imaging was achieved, based on the detection of FWM signal emitted by colloidal nanoparticles which can be used to label subcellular structures. The applicability of the technique to cell microscopy was demonstrated by imaging Golgi structures of HepG2 cells labelled with commercial functionalised GNPs of different size.
II. The generation of FWM signal from GNPs was studied, with important implications in the understanding of the thermalisation processes of the hot electron gas with the lattice in a nanometric structure.
III. The population and polarisation dynamics of carriers in semiconductor CQDs was investigated as a function of composition (CdS/CdSe, CdS/ZnS, and PbS) and size.
The results achieved during this project will impact both the physics and bioscience communities. The development of the FWM microscopy is a significant advance compared to state-of-the-art imaging techniques. This new imaging modality will enable to tackle difficult biomedical problems and is likely to be of relevance in medical applications, to improve the diagnostic and treatment of diseases. Furthermore, the studies of carrier dynamics and decoherence in CQDs is a key step in the assessment of their applicability in optoelectronic devices and for quantum computing. Scientists and companies working in this field will benefit from the results of our research.

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