UNIVERSITÀ DEGLI STUDI DI GENOVA

ISTITUTO ITALIANO DI TECNOLOGIA

Università degli Studi di Genova – Istituto Italiano di Tecnologia

Corso di Dottorato "Fisica"

Anno Accademico 2017-2018
Ciclo XXXIII

4 positions available with scholarship

Research Themes

1. Augmented Expansion Microscopy.

Expansion microscopy (ExM) is a novel method that allows super-resolution imaging with conventional optical microscopes. It consists in soaking the cells with a polymer, inducing the polymerization to form a dense meshwork throughout the cell, cross-linking the fluorophores to the polymer and, after digestion of cellular protein, rehydrating of the sample. The swelling of the polymer gel led to a four fold isotropic stretching of the sample. The proposed project consists in augmenting the increase of spatial resolution obtainable by ExM by stimulated emission depletion (STED) nanoscopy imaging (Hell, Diaspro et al., Journal of Physics D: Applied Physics 2015). With this approach one can take advantage of the use of separation of photons by lifetime tuning (SPLIT) STED as originally developed in our lab (Lanzanò, Diaspro et al., Nature communications 2015). Such an approach will offer the possibility of stretching in a controllable way the chromatin-DNA complex allowing a better understanding of the structure and function relationship of the chromatin-DNA fibers. The study will be integrated by atomic force microscopy within a global correlative approach.

IIT supervisor: Alberto Diaspro, Paolo Bianchini, Luca Lanzanò
IIT research Line: Nanoscopy and Nikon Centre@IIT
Preferred degrees: Physics, Biotechnology

2. Mueller matrix microscopy of biological macromolecules.

The project deals with the measurement and characterization of the polarization properties of a fluorescence signal using four-channel photon counting based Stokes–Mueller polarization microscopy. Lu–Chipman decomposition will be applied to extract the critical polarization properties such as depolarization, linear retardance and the optical rotation of collagen type I fiber. The spatial distribution of anisotropic and helical molecules of collagen and chromatin-DNA assemblies from the reconstructed 2D Mueller images based on the fluorescence signal in a pixel-by-pixel manner will be mapped and interpreted (Sheppard, Castello and Diaspro, JOSA A 2016). The project will include the acquisition, analysis and combined interpretation of the label free signal coming from the angular scattering Mueller matrix signature. More specifically, the main interest will be related to the element [1,4] of the Mueller matrix that can be linked to the properties of helical structures like the ones exhibited by collagen and chromatin-DNA at different stages of their spatial organization. The project will be also related to the realization and application of a Mueller matrix microscope designed in our lab (Mazumder, Diaspro et al., J.Optics 2017).

IIT supervisor: Alberto Diaspro, Colin JR Sheppard, Aymeric Le Gratiet.
IIT research Line: Nanoscopy and Nikon Centre@IIT
Preferred degrees: Physics, Bioengineering

3. Label free transient absorption, multi photon and second harmonic generation microscopy approaches towards label free investigations.

In the last decades, non-linear optical processes have captured the attention of life scientists for the development of new super-resolved microscopy techniques (Korobchevskaya, Bianchini, Diaspro et al., Nature Scientific Reports 2016). Non-linear optical microscopy goes hand-in-hand with the exploitation of the near-infrared (near-IR) part of the spectrum and was. In order to broaden the range of available targets and provide novel contrast mechanisms in weakly or non-fluorescent samples, absorption-based techniques coming from optical spectroscopy were intensely studied and coupled to with scanning microscopy.with scanning microscopy. This opens the possibility to explore saturation and differential techniques for the circumvention of the diffraction limit also in non-fluorescence-based methods (Liu, Bianchini, Diaspro et al., ACS Photonics 2016). The project proposes the development of a pump-probe (or transient absorption) microscope, where two femtosecond pulsed laser beams will be coupled with an upright microscope. Ultrafast (sub-picosecond) dynamic properties of the sample will be investigated with high spatial and temporal resolution, and high sensitivity. Moreover, the superimposition of a third beam will allow to explore super-resolution capabilities, taking advantage of spatially controlled absorption.Thus, different transient absorption mechanisms and their dynamics in biological or nanomaterial samples will be studied.
Multiphoton and Second Harmonic generation microscopy will be integrated to provide a reference within the label free context (Teodori, Diaspro et al. J.Biophotonics 2016)

IIT supervisor: Alberto Diaspro, Paolo Bianchini
IIT research Line: Nanoscopy and Nikon Centre@IIT
Preferred degree: Physics

4. Materials for spintronics, noncollinear magnets, excitations and ultrafast dynamics

Interactions between electrons in solids lead to emergent states of matter with peculiar orders, properties and excitations. The use of ordered (ferroic) materials spans virtually every area of modern technology. Magnetic materials are used for information storage, piezoelectrics are used in sensors and actuators, superconductors are needed to support maglev trains and perform MRI. Materials with multiple ferroic orders - multiferroics - combine functionalities of conventional ferroics and promise to break the ground for new devices and functionalities. For example, they could offer electric control of magnetic bits, much sought after since magnetic writing technology in hard drives is approaching its density limit.
Materials hosting non-collinear magnetic states, such as domain walls or skyrmions, hold a promise for memory devices based on topologically-protected bits, potentially offering higher information density and lower energy consumption.
We use modern analytical and numerical methods to study complex interactions between spins, leading to complex orders and interesting excitations and dynamics. The microscopic knowledge about interactions is gained from numerical simulations or fitting experimental data to phenomenological models. Analytical and numerical methods are used to solve the resulting models. The work is done in close collaboration with leading experimental groups: at Rutgers University, USA (bulk multiferroics), Los Alamos National Lab, USA (high magnetic fields), MPI-Hamburg, Germany and UCSD, USA (ultrafast dynamics of phase transitions).

IIT supervisor: Sergey Artyukhin
IIT research line: Quantum Materials Theory
Preferred degree: Physics, Nanoscience