Università degli Studi di Genova – Istituto Italiano di Tecnologia

Corso di Dottorato "Fisica e Nanoscienze"
Curriculum "Bio-Nanoscienze"

Anno Accademico 2018-2019
Ciclo XXXIV

Research Themes

4 positions available
- 3 at the "Nanoscopy and Nikon Centre@IIT" – PI Alberto Diaspro
- 1 supervised by Marti Duocastella

Temi disponibili:

1) Circular intensity differential light scattering signature of biological macromolecules.

The project deals with the measurement and characterization of the polarization properties of an optical 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 and chromatin-DNA from fluorescence and label-free signals. 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 [1]. The project will include the acquisition, analysis and combined interpretation of the label free signal coming from the angular scattering Mueller matrix signature with main focus on the S(1,4) element. This element 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 [2, 3]. The project will be also related to the optimization of a Mueller matrix microscope designed in our lab.

[1] Sheppard, Castello and Diaspro, JOSA A 2016
[2] Diaspro el IEEE transactions on biomedical engineering 1991
[3] Mazumder, Diaspro et al., J.Optics 2017.

IIT supervisor: Alberto Diaspro, Colin JR Sheppard, Aymeric Le Gratiet
Preferred degrees: Physics, Bioengineering

2) Transient absorption, multi-photon and second-harmonic generation microscopy to investigate biological macromolecules and nanomaterials.

In the last decades, non-linear optical processes have captured the attention of life scientists for the development of new super-resolved microscopy techniques [1] . 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 [2]. 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 [3]

[1] Korobchevskaya, Bianchini, Diaspro et al., Nature Scientific Reports 2016.
[2] Liu, Bianchini, Diaspro et al., ACS Photonics 2016.
[3] Teodori, Diaspro et al. J.Biophotonics 2016.

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

3) Label free imaging by means of super resolved ptychography.

The desire for new methods that can explore the function of biological systems without the need for sample modification, or the addition of fluorescent tags, is steadily emerging. The development of so called ‘label free' microscopies is important for the exploration of the natural state of biological systems, without alteration and without potentially affecting the processes being explored [1]. Label free techniques utilize contrast from novel processes to provide a means of imaging without external modification. However, the imaging of weakly interacting samples is not trivial and has required significant development or modification of current techniques to produce suitable resolution and contrast. Ptychography is a diffractive imaging technique that uses multiple diffractograms collected from spatially overlapping regions of a sample to retrieve a samples' complex transmission function, providing images of its amplitude and phase. This overlap aides not only in the unambiguous retrieval of the transmission function but can also be used to recover the quantitative phase, with great potential as a contrast mechanism for cellular imaging [2]. The project deals with the quantitative phase information from ptychography, and super-resolution techniques, that can be used to obtain high contrast images of biological molecules at high resolution, without the need for fluorescent tags or sample modification. The project also aims integrating ptychographic imaging with other optical microscopies.

Tutors: Alberto Diaspro, Nicholas Anthony
Preferred degrees: Physics, BioEngineering, Biotechnology

[1] Magidson & Khodjakov, Methods in Cell Biology, 2013
[2] Marrison et al., Scientific Reports, 2013

4) Deep sub-wavelength laser processing with advanced optical systems and engineered materials

The tight focusing of a laser beam enables the local modification of materials in common scientific and industrial applications such as patterning or additive manufacturing. However, the optical nature of lasers limit the minimum feature size, resolution and throughput of the generated structures. Indeed, diffraction normally impedes the fabrication of sub-wavelength patterns, while the requirement of point scanning in most laser systems seriously constraints fabrication speed.
This PhD project aims at breaking the above limitations and to convert lasers into high-throughput three-dimensional (3D) nanofabrication tools. The core idea of the project is to combine novel optical approaches for beam parallelization imported from microscopy, such as temporal focusing and acousto-optic beam shaping, with engineered materials that can be reconfigured after application of an external stimulus. In this way, processing beyond the limits of traditional light-matter interactions will be possible: engineered materials will shrink after laser patterning, resulting in deep sub-wavelength structures. Consisting mainly of experimental work but also including simple modeling, the project will also seek the development of 3D optical characterization tools for the in-situ, real-time inspection of the laser fabrication process.

This highly multidisciplinary project combines elements of materials science, optics and microscopy, offering a unique platform for the PhD candidate to gain an in-depth understanding of laser processing, optical system design and materials synthesis. The candidate will work on an environment that fosters interdepartmental collaborations, and will have access to state-of-the-art facilities.

IIT supervisor: Marti Duocastella

Preferred degree: Bachelor’s Degree in one of the following areas: Materials Science, Chemistry, Physics, Mechanical Engineering or Chemical Engineering