Ph.D. Program in Physics and Nanoscience
Curriculum: Bio-Nanoscience

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Student No. 4621629, XXXIV Cycle

Principal Investigator: Alberto Diaspro

Research summary:

Understanding the organization of chromatin is essential to comprehend the processes in the cell nucleus. The chromatin is a DNA complex found in the nucleus of eukaryotic cells. It helps in the packaging of long DNA into a compact form that prevents DNA damaging. It plays a role in DNA replication and regulating gene expression during the cell cycle. However, the chromatin organization during the cell cycle is still an open question. The chromatin has different levels of compaction, and different models have been reported for the chromatin during the cell cycle. The heterochromatin is the most compact form of chromatin, and in this form, it is arranged as 30 nm fiber with nucleosomes arranged in a helical array. The euchromatin or beads on a string model is the lightly compact form of chromatin. The higher-order structures of chromatin also have been reported. The overall structural organization depends on the stage of the cell cycle. We have been working to find the structural organization of chromatin fiber.

We modeled chromatin fiber with nucleosomes shaped as cylindrical units arranged as a helical array. The ellipsoidal and spherical shape has also been modeled. We calculated angle-resolved Mueller matrix elements that contain all the polarization properties of the scattering objects. The calculations of m_{00}-element and m_{03}-element are demonstrated. The m_{00} accounts for the total scattered intensity and m_{03}-element demonstrates the circular intensity differential scattering of light (CIDS). The angular scattering pattern of m_{03} is found sensitive to the chiral parameters of the chromatin fiber. By varying the chiral parameters of the chromatin fiber, we can have different compaction levels. These parameters are pitch, radius, the orientation of the fiber, number of nucleosomes, shape of nucleosomes, and orientation of nucleosomes along the helical axis. We changed these parameters, and in response to these changes, we calculated the changes in the CIDS signal. We found the CIDS contains information that is different from the information contained in the total scattered intensity of light. These calculations offer another perspective to characterize the biopolymers based on the light scattering approach at the nanoscale level.

We are also working on modeling virus particles using polarized light scattering. The virus particles have infectious nucleus acid and have spherical or ellipsoidal shape. The objective of this work is to characterize the virus from non-virus particles using light scattering calculations.

Two papers are in preparation, one on the modeling of chromatin fiber and the other on the modeling of virus, and will be submitted to peer-reviewed journals.

Courses completed:

During the second year, I have attended and passed the following two courses and have completed Ph.D. coursework requirements.

1. Advanced Crystallography, Prof. Alberto Martinelli
   Lesson location: Dept. of Physics and Nanoscience, UniGe

2. Nanotechnology: A maker's course
   Lesson location: Coursera (Online) offered by Duke University and NC State University.

Conference proceedings:

1. M. W. Ashraf, A. Le Gratiet, R. Marongiu, A. Diaspro. "Modeling of Chromatin DNA by Polarized Light Scattering" Biophysical Journal, 118(3) 136a · February 2020.
2. A. Le Gratiet, R. Marongiu, M. W. Ashraf, P. Bianchini, A. Diaspro, "Stokes-vector Resolved Multiphoton/Fluorescence Confocal Scanning Microscopy" Biophysical Journal 118 (3), 310a

Conferences attended Online:

1. OSA FiO-LS Conference 2020 ; 14 - 17 September 2020
2. SPIE Optics + Photonics Digital Forum ; 24 - 28 August 2020.