InsLight – Experimental Quantum Optics and Biophysics

InsLight is an experimental group led by Dr. Maria Bondani, Researcher of the Institute of Photonics and Nanotechnologies of CNR, and Prof. Alessia Allevi, associate professor at the University of Insubria.

The group is involved in two main research topics, nonlinear and quantum optics, and fluorescence spectroscopy applied to biomedical systems and new materials, taking place in the laboratories of Quantum Optics and Photophysics and Biomolecules, respectively. Moreover, it is strongly involved in Physics Outreach and Education.

At present, other four people enrolled at the University of Insubria belong to the group, Dr. Luca Nardo, tenure-track Researcher, Dr. Marco Lamperti, fixed-term Researcher, Silvia Cassina and Gabriele Cenedese, PhD students.

The group has several national and international collaborators.
For the quantum optics activities, we recall the group of Prof. Matteo Paris and Prof. Stefano Olivares at the University of Milan, the groups of Prof. Michela Prest and Prof. Caccia at the University of Insubria, the group of Prof. Jan Perina and Prof. Ondrej Haderka at the Joint Laboratory of Optics of the Palacky University in Olomouc (Czech Republic).
For the applied physics activities, we quote the group of Prof. Francesco Mantegazza at the University of Milano Bicocca, the group of Prof. Claudia Sissi at the University of Padua, the groups of Prof. Mauro Fasano, Prof. Andrea Penoni, Prof. Massimo Mella, Prof. Jenny Vitillo, Prof. Simona Galli, and Prof. Angelo Maspero at the University of Insubria, the group of Prof. Jean Louis Mergny at INSERM Paris, the group of Prof. Hanne Hjorth Tonnesen at the University of Oslo, and the group of Prof. Màr Masson at the University of Iceland.

The research activity in the Quantum Optics laboratory includes some relevant topics in light-matter interaction, such as nonlinear optics, quantum optics, quantum information and characterization of different classes of photodetectors. Thanks to the availability of different kinds of laser systems and detection chains, the experimental investigations are performed in different intensity regimes, ranging from the single-photon level up to the macroscopic domain, passing through the so-called mesoscopic photon-number domain, in which pulsed optical states with sizeable numbers of photons per pulse are produced and photon-number resolving detectors are employed. In particular, the research focuses on:

- generation and characterization of both classical and nonclassical states useful for applications in the field of Quantum Information and Quantum Communication
- correlated imaging protocols for fundamentals of Quantum Mechanics and applications to Quantum Information
- new detection schemes based on photon-number-resolving detectors aimed at investigating both the particle-like and wave-like properties of light and at implementing Quantum Communication protocols.

The research activity in the Photophysics and Biomolecules Lab is aimed at:

- characterizing at the single molecule level the conformational dynamics of biomolecules, particularly non-double-stranded DNA, and their relationships with metabolic regulation

- studying the aggregation of amyloidogenic proteins whose deposition in brain tissue is responsible for the onset of neurodegenerative diseases, such as Alzheimer and Parkinson
- exploiting the spectroscopic properties of metal-organic complexes for technological applications including sensing and controlled drug release
- probing the photoreactivity of drug substances, particularly β-diketones, indoles and porphyrins and deriving information to optimize their molecular structure
- evaluating pharmaceutical formulations and drug shuttles, carrier and delivery systems
- characterizing biomolecule-biomolecule and biomolecule-ligand interactions

The experimental investigations are based on advanced fluorescence techniques, such as time-correlated single-photon counting, time-resolved and single-molecule fluorescence-resonance energy transfer, fluorescence fluctuation spectroscopy and fluorescence burst analysis.

For what concerns Physics Outreach and Education, the research activities aim at finding new educational strategies and, in particular, at encouraging and supporting the experimental activity in high schools, devoted to both students and teachers. Among the other initiatives, we mention:

- the project “LuNa – La natura della Luce nella luce della Natura”,
- the annual “Physics Summer School – Optics”,
- the annual “Physics Summer School – Robotics”,
- the annual “Physics Summer School – Quantum Technologies”,
- the Workshop “Officina di didattica e divulgazione della Fisica” on different aspects of Physics and devoted to high-school students and teachers,
- the organization of PLS (Progetto Lauree Scientifiche) laboratories,
- the interdisciplinary Introduction to Forensic Science,
- the interdisciplinary activity entitled “Science shows off”,
- the international Day of Light,
- the project “Italian Quantum Weeks” devoted to the teaching of Quantum Mechanics.

Publications

[1] **A. Allevi*** and M. Bondani, “Towards underwater quantum communication in the mesoscopic intensity regime,” Opt. Express 30, 44175-44185 (2022).
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[3] G. Vesco, M. Lamperti, D. Salerno, C. A. Marrano, V. Cassina, R. Rigo, E. Buglione, M. Bondani, G. Nicoletto, F. Mantegazza, C. Sissi, and **L. Nardo*** “Double-stranded flanking ends affect the folding kinetics and conformational equilibrium of G-quadruplex forming sequences within the promoter of KIT oncogene”, Nucleic Acids Res. 49, 9724-9737 (2021).
[4] M. Moroni, **Luca Nardo***, A. Maspero, G. Vesco, M. Lamperti, L. Scapinello, R. Vismara, J.A.R. Navarro, D. Monticelli, A. Penoni, M. Mella, and S. Galli “Mercury Clathration-Driven Phase Transition in a Luminescent Bipyrazolate Metal–Organic Framework: A Multitechnique Investigation”, Chem. Mater. 35, 2892-2903 (2023).
[5] **M. Bondani***, M.L. Chiofalo, E. Ercolessi, C. Macchiavello, M. Maugeri, M. Michelini, O. Mishina, P. Onorato, F. Pallotta, S. Satanassi, A. Stefanel, and C. Sutrini, “Introducing Quantum Technologies at Secondary School Level: Challenges and Potential Impact of an Online Extracurricular Course”, Physics 4, 1150-1167 (2022).

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