Second Year Report

PhD course in Physics and Nanosciences

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supervised by

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Scientific activity

During the previous year, I worked in designing, building, and characterizing a novel Acousto-Optofluidic (AOF) device. This latter is a liquid-filled acoustic resonant cavity, capable of diffracting light in a controllable manner through the acousto-optic effect. Due to the already proven speed and tunability, this tool is of great interest for applications such as material processing and imaging.

During the second year of the Ph.D. course, I kept working on the AOF device from different perspectives. Experimentally, I contributed to the optimization of the cavity by applying a thermal stabilization and by characterizing its efficiency and its transfer function when filled with different liquids. However, my major contributions are on the theoretical side: I solved the acoustic damped wave equation that describes the cavity at different boundary conditions and in the non-resonant case. I used the solutions to calculate the diffraction and interference patterns that can be obtained with a Gaussian or any generic input beam. Therefore, I obtained a complete predictive model of the AOF device and of the structured illumination that is able to generate. My theoretical findings are strengthened by detailed numerical simulations.

This year, I also started working with a similar acousto-optic device, namely the Tunable Acoustic Gradient (TAG) lens. This latter, similarly to the AOF device, is a liquid-filled resonant acoustic cavity. However, the cavity has a cylindrical shape. As a consequence, the acoustic wave is described by a 0^{th} order Bessel function, whose central lobe can be used as a varifocal lens. This tool has been already successfully used in imaging systems to extend the depth of field (DOF) of the detection objective lens. More in detail, it has been used in a Light-Sheet Microscope in order to overcome the speed limitations of volumetric imaging: by extending the DOF, the image always appears in focus, and the translation of the light sheet suffices to acquire a z-stack, without the need of sample movement. However, this method typically results in a reduced signal-to-noise ratio (SNR). In order to compensate for this issue, I started working on a parallelization strategy. I utilize two Acousto-Optic Deflectors (AODs) to illuminate the sample with a predetermined set of simultaneous light sheets. By applying a decoding algorithm, the images of each individual plane can be retrieved, with an enhancement in SNR. I customized and aligned the Light-Sheet Microscope, designed and coded the software used to generate the parallel beams and to acquire the images, performed the experiments, and I designed an algorithm for data analysis. Moreover, I calculated the expected gain in SNR and performed numerical simulations.

Lastly, this year I participated in writing a review paper about acousto-optic systems for advanced microscopy. My main contributions lie in the explanation of the acousto-optic effect and in the description of the most important acousto-optic devices and their working principle.

Courses and Exams

- **Applied Optics**

  Prof. Repetto (exam passed)

- **Machine Learning Crash Course**

  Prof. Ferrando (exam passed)

Publications

- S. Surdo, A. Zunino, A. Diaspro, and M. Duocastella. Acoustically-shaped laser: a machining tool for industry 4.0. *Acta Imeko*, 2020 (Accepted – In publication)

- M. Duocastella, S. Surdo, A. Zunino, A. Diaspro, and P. Saggau. Acousto-optic systems for advanced microscopy. *Journal of Physics: Photonics*, 2020 (Accepted – In publication)

Other activities

- **Didactic Tutor:** General Physics 1

  From October 2019 to July 2020