Lab project M1 PPN & QuanTEEM

12/05/2025 – 20/06/2025

Title of the project: generation of vortex N_2^+ lasing

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Laboratory / Department / Team : CB/ Photonic / PFL
Collaborations:

Summary:

It is known for a long time (from Poynting in 1909) that polarized light carries a spin angular momentum (SAM), associated with circular polarization that takes value ± ħ for right/left circularly polarized field. The evidence of light carrying orbital angular momentum (OAM) came much later, in 1992, when a group at Leiden University showed that light beams with helical phase-fronts, namely with an azimuthal phase dependence $\exp(i\ell\varphi)$ with φ the azimuthal coordinate, carries an angular momentum independent of the polarization state. The orbital angular momentum is $L = \ell\hbar$, where ℓ called topological charge can take any integer values positives or negatives. The most common form of beam with helical phase-fronts (also called vortex beams) is the so-called Laguerre–Gaussian laser mode. The possibility of producing OAM fields led to new understandings and various applications [1] that range from optical manipulation, nonlinear optics, nano-optics, imaging and quantum optics, to optical communications…

The goal of this internship is to investigate the generation of OAM beams through superfluorescence, specifically focusing on cavity-free lasing in nitrogen (N_2) molecules. It is well established that, when excited by an ultrashort and intense infrared (IR) femtosecond laser pulse, N_2 molecules can act as gain media and produce coherent optical emission in the ultraviolet range. The IR laser beam ionizes the molecules, leading to coherent emission between the excited state $B^2\Sigma^+_u$ ($\nu' = 0$) and the ground state $X^2\Sigma^+g$ ($\nu = 0$) of nitrogen ions. Recent studies [2] have demonstrated that a lasing emission carrying an OAM can be generated when excited by a strong vortex IR driving field. This suggests that the spatial phase information of the driving field may be transferred to the gain medium and subsequently to the amplified radiation. However, the underlying mechanism remains unclear, with existing studies yielding contradictory results. The objective of this study is to provide an alternative and complementary experimental analysis of vortex N_2^+ lasing generation, contributing to a deeper understanding of the process.

[1] M. J. Padgett Opt. Exp. Vol. 25, 11265 (2017)
[2] see for instance Gao et al Comm Phys. (2023) 6; 97 https://doi.org/10.1038/s42005-023-01226-9

Type of project (theory/experiment): Experimental

Required skills: