Lab project M1 PPN & QuanTEEM

04/05/2026 – 19/06/2026

Title of the project: Manipulation of vortex beams through molecular alignment

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Laboratory / Department / Team : ICB / Photonic / PFL

Collaborations:

Summary:

This project aims to investigate interactions between molecular systems and ultrashort structured light beams carrying orbital angular momentum (OAM). Since Poynting's seminal work in 1909, it has been known that polarized light carries angular momentum, referred to as spin angular momentum (SAM), associated with circular polarization ($\sigma = \pm\hbar$ for right- and left-handed circular polarizations). The existence of OAM in light was demonstrated much later, in 1992, with the discovery that "vortex" beams exhibiting an azimuthal phase dependence of the form $\exp(i\ell\varphi)$ carry an orbital angular momentum $\ell\hbar$, where ℓ is called topological charge. Over the past decades, light beams carrying OAM have attracted considerable interest due to their wide-ranging applications in optical communications, super-resolution imaging, optical manipulation, and quantum information processing [1]. Recently, we have demonstrated [2] that gas-phase molecules can serve as a quantum interface capable of storing the OAM carried by an ultrashort laser pulse. Using a specific excitation scheme, analogous to holographic imaging, a rotational wave packet was generated in the vibronic ground state of molecules, encoding the OAM information. This information was retrieved through the periodic rephasing of the wave packet, which leads to field-free molecular alignment. This approach has been successfully applied to the storage of both pure OAM states [2] and coherent superpositions of multiple OAM modes [3]. Recently, we have demonstrated precise control over the readout timing of vortex beams by extending the concept of molecular alignment echoes to vortex beams [4]. By employing a pulse sequence rather than a single excitation, we were able to generate a molecular alignment echo at a tunable delay, enabling the retrieval of the OAM encoded in the molecular ensemble. The objective of this internship is to further advance the use of molecules for the development of control strategies for ultrashort OAM fields. By employing sequences of pump pulses with tailored polarization patterns, we aim to dynamically reconfigure the molecular medium—specifically, the spatial distribution of aligned molecules and thus the stored OAM—on a picosecond timescale. This approach will provide a powerful and unprecedented platform for ultrafast OAM processing.

[1] M. J. Padgett Opt. Exp. Vol. 25, 11265 (2017)
[2] F. Trawi , F. Billard, O. Faucher, P. Béjot, and E. Hertz, Laser & Photonics Review, 17, 10.1002 / lpor.202200525 (2022).
[3] A. Voisine, F. Billard, O. Faucher, P. Béjot, and E. Hertz, Holographic storage of ultrafast photonic qubit in molecules, Advanced Photonics Research 10.1002/adpr.202400008 (2024).
[4] A. Voisine, F. Billard, O. Faucher, P. Béjot, and E. Hertz, Molecular alignment echo for controlling the readout time of vortex beams, accepted to Phys. Rev. Letter. 136, 023202 (2026)

Type of project (theory/experiment): mainly experimental

Required skills: optical alignment