Interplay between atoms and optical vortices through a Raman transition

Aurélien Chopinaud[1], Marion Jacquey[1], Bruno Viaris de Lesegno[1] and Laurence Pruvost*[1]

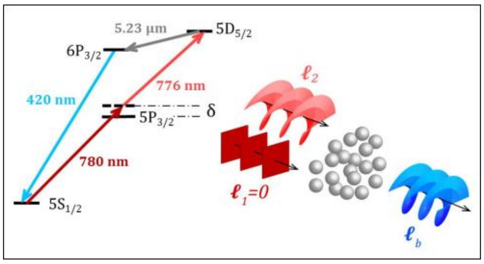
[1]*Laboratoire Aimé Cotton, CNRS, Université Paris-Sud, ENS Paris-Saclay, Université Paris-Saclay, bat 505, 91405 Orsay, France*

The orbital angular momentum of light (OAM) is a quantized variable, which is explored for quantum technology, its key strength being a wide set of values offering a large basis for encoding, entanglement, etc. In this context we study the interplay between vortices and atoms to realize quantum memories, vortex-pairs, OAM-conversion or OAM mathematical operations.

Using a Raman two-photon transition experienced in a rubidium vapour, namely the $5S_{1/2}$-$5D_{5/2}$ one (see Fig.1), we have studied the vortex conversion from a red input vortex (at 776 nm) to a blue output one (at 420 nm) for large OAMs (ℓ from -30 to 30) and we have examined the efficiency and the selection rules associated to the orbital angular momentum exchange [1].

The atomic vapour is excited by two co-propagating input lasers (780 and 776 nm) which produce a photon pair (5.23 µm and 420 nm) via the decay of the 5D level. In this four-wave mixing process we analyse the blue output wave (its shape, OAM and power) when the input laser at 776 nm is an optical vortex with ℓ varying from -30 to 30. We show that the output blue vortex respects the azimuthal phase matching, has a size determined by the product of the input beam intensities, a power decreasing with ℓ in agreement with their overlap. Finally the propagation indicates that the generated blue wave is a nearly pure mode. In addition, we explain why the input OAM is mainly transferred to the blue wave, with at large OAM input the possibility of sharing the OAM between the IR and blue wave: it relies on a combined azimuthal and Gouy phase matching conditions.

This work opens to new interplays between atoms and optical vortices, for example involving many input vortices [2], or processes for OAM storage [3] or schemes with more excited levels.



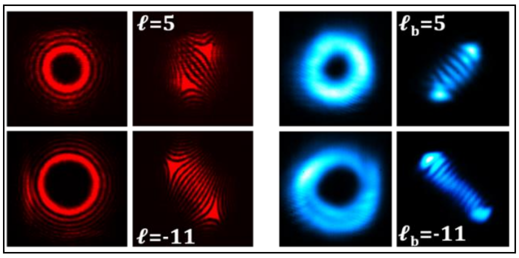


Fig. 1: on the left : principle of vortex conversion based on the two-photon Raman transition in rubidium. On the right : input red vortices and corresponding output blue vortices for ℓ=5 and ℓ=-11. The rings are the intensity profiles, the fringes pattern are the OAM characterisation.

References

[1] A. Chopinaud, M. Jacquey, B. Viaris de Lesegno and L. Pruvost, *High Helicity Vortex Conversion in a Rubidium Vapor*, Phys Rev A 2018, to appear

[2] see G. Walker, A. S. Arnold, and S. Franke-Arnold, Phys. Rev. Lett. **108**, 243601 (2012). A. M. Akulshin, et al., Opt. Lett. **40**, 1109 (2015). And references therein.

[3] see A. Nicolas et al, Nat. photonics **8**, 234 (2014). A. J. F. de Almeida et al. Opt. Lett. **40**, 2545 (2015). And references therein.

*Corresponding author: laurence.pruvost@u-psud.fr