Master 2: ***International Centre for Fundamental Physics***

INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: Laboratoire Charles Fabry
CNRS identification code: UMR 8501
Internship director'surname: Boiron
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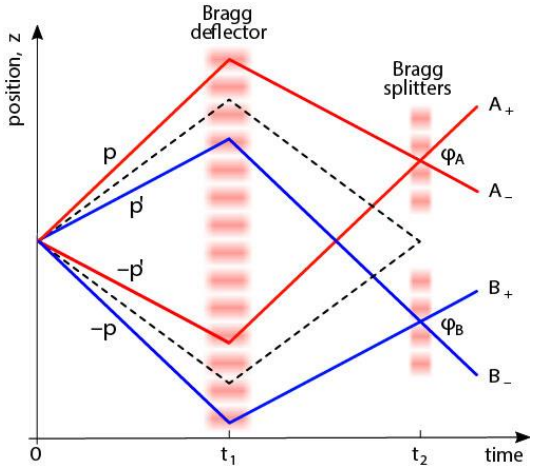
Web page: https://www.lcf.institutoptique.fr/groupes/gaz-quantiques/experiences/quantum-atom-optics
Internship location: Institut d'Optique, Palaiseau

Thesis possibility after internship: YES
Funding: demand to be done

Violation of Bell's inequality of momentum-entangled atoms

Our group has perfected methods to detect cold atom clouds released from a trap in three dimensions and with single atom sensitivity. We have been using this method to perform fundamental experiments on entanglement produced by non-linear processes in Bose-Einstein condensates. An example is our observation of the Hong-Ou-Mandel effect [1].

We have developed a two-particle interferometer in momentum space [2], see figure. Starting from a two-particle entangled state prop. to |p,-p> + |p',-p'>, such a set-up is suited to observe a violation of a Bell's inequality. This would be the first time that such inequalities have been tested for the motional degrees of freedom of freely falling, massive particles.



Compared to Ref [2], we have now a control of the interferometric phase difference ϕ_A-ϕ_B , a pre-requisite to perform a Bell experiment. The intern will participate to the experiment i.e. acquisition of the data and its analysis. An independent control of each phase has still to be done and is part of the internship. It will consist in a servo-loop using an optical interferometer to measure the phases and acousto-optical modulators for counter-reaction. He.she will implement this tool on the experiment and run the experiment with it.

We use a particular type of non-linear process in a Bose-Einstein condensate to produce entangled atom pairs reminiscent of four-wave mixing in optics [3]. This process being slightly multi-mode and coherent the state produced is multi-particle entangled. An extension of the proposed scheme to look at entanglement on a larger set of modes and/or for larger mode population is also envisioned.

[1] R. Lopes et al., Nature 520, 66-68 (2015), arXiv:1501.03065.
[2] P. Dussarrat et al., Phys. Rev. Lett. 119, 173202 (2017), arXiv:1707.01279.
[3] M. Bonneau et al., Phys. Rev. A 87, 061603 (2013), arXiv:1212.6315

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: NO