PhD project

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Laboratoire Kastler Brossel
Physique quantique et applications

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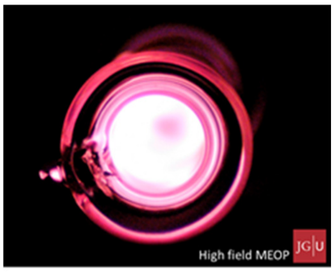
Pompage optique laser de l'^{3}He : de nouveaux défis pour de nouvelles applications

Laser optical pumping of ^{3}He: new challenges for new applications

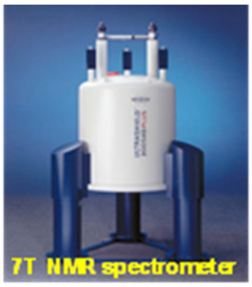
Context: Nuclear spin-polarised ^{3}He gas, currently produced (in situ or remotely) by laser optical pumping, has extensive scientific or practical applications. These include pre-clinical lung MRI, spin filters for neutron beams, targets for high energy physics, nuclear magnetometry, etc. (https://arxiv.org/abs/1612.04178) The growing needs of end-users constantly drive the physicists' efforts to boost up nuclear polarisation, gas density, or production rate, and to extend the range of operating conditions.



Metastability exchange optical pumping, MEOP, yields very high ^{3}He nuclear spin polarisation (up to 90%) in "standard" conditions: room temperature, low gas pressure, low magnetic field. The high efficiency of MEOP (typically, 1 polarised nucleus per absorbed photon) relies on two processes that involve a minority of atoms promoted in the metastable 2^3S level by a weak rf discharge: laser-driven OP cycles on the closed 2^3S-2^3P optical transition at 1083 nm (selective excitation by circularly polarised light / de-excitation by spontaneous emission) and polarisation transfer by metastability exchange collisions between 2^3S and ground state atoms (a quick binary exchange of electronic excitation, with no change of nuclear spin orientations).

Our recent investigations have focused on the fundamental limits of conventional MEOP, as well as on operation in non-standard conditions (high pressure and high field).

PhD project: Now, the challenge is to explain (and, if possible, to circumvent) the large increase in angular momentum loss which has been systematically observed during OP at strong pump light power. The first step will be a search for the underlying physical process(es) , based on the latest findings. The PhD work will aim at a quantitative description of its (their) deleterious contribution(s) to optical pumping dynamics, in order to improve the predictive models developed so far for MEOP. Experimental investigations with ^{3}He in standard optical pumping conditions will make use of new and complementary optical diagnoses, with visible and infrared lasers (light polarisation analysis, absorption and line shape measurements). They will also involve comparative studies for various gas pressures, at high and low magnetic field, in pure ^{3}He or in isotopic ^{3}He-^{4}He mixtures.



Besides, a new collaborative project (WideNMR, 2016–2019) will provide the challenging opportunity to extend the investigations of high field MEOP up to higher field strength (7 T) and down to cryogenic temperatures (77 K – 1 K), with potential application to high-sensitivity ^{3}He magnetometry (for high resolution mass spectrometry in ion traps, for instance). The planned investigations, launched with improved experimental and theoretical tools, will revisit some pioneering work on ^{3}He MEOP at low temperature previously performed at LKB.

Read more: http://www.lkb.upmc.fr/polarisedhelium/polarised-helium-and-quantum-fluids/meop/

Financement de thèse envisagé : via l'ED ou par contrat (demandé)