M2 internship – PhD

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Laboratoire Kastler Brossel
Physique quantique et applications

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

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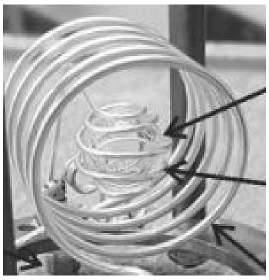
Unveiling the mechanism for nuclear spin self-orientation in ^{3}He gas discharges



Topic: Spontaneous orientation of ^{3}He nuclear spin (I=1/2) has recently been observed in strong radiofrequency gas discharges at high magnetic field strength (B > 1 T) [1]. Nuclear polarisation is fairly large (up to 10%, so far) and quick tests performed in a variety of operating conditions show that this is apparently a straightforward and robust way to "hyperpolarise" ^{3}He nuclei. The new method, called PAMP (Polarisation of Atoms in a Magnetised Plasma), is thus an attractive alternative to the laser optical pumping methods available for production of polarised ^{3}He gas in science and applications (see [2] for a review).

We have proposed a physical mechanism for PAMP that qualitatively explains the observation of discharge-induced ^{3}He nuclear polarisation that exceeds the thermal equilibrium (Boltzmann) spin polarisation of the free electrons due to the applied magnetic field. In our scenario, anisotropic excitation of ^{3}He to the 2^3P level by electron-atom collisions and radiative decay through the 2^3P-2^3S transition à 1083 nm is responsible for an unbalanced steady-state distribution of atomic populations in the metastable 2^3S hyperfine Zeeman magnetic sublevels, which enforces nuclear polarisation in the ground state level. If this is correct, optical spectroscopy measurements must provide strong evidence of hyperfine orientation in the excited states and allow absolute measurements of ^{3}He nuclear polarisation. Furthermore, we expect PAMP to be extremally efficient when hyperfine energy level anti-crossings occur and, in particular, to culminate near 0.2 T field strength.

Objective: Internship will aim at validation (or exclusion) of the above-mentioned scenario through measurements of resonant light absorption by the gas discharge. Single frequency laser diodes will be used for excitation of selected Zeeman sublevels and optical polarimetry for a detailed analysis of the transmitted light, from which population ratios can be inferred. Steady-state atom distributions in 2^3S (and 2^3P state, if needed) will be investigated in sealed low-pressure He gas cells (millibar range) up to 0.1 T, for various cell contents and rf excitation levels. Quantitative comparison will be made with numerical simulations, based on suitable rate equation models, to complete this pioneering investigation at moderate field.

Opening for PhD work: In-depth study of PAMP at high field (7 T, at CEA-Saclay) is planned in pure ^{3}He gas. Further tests will be carried out in isotopic (^{4}He-^{3}He) mixtures, as well as down to a few kelvins. The dual objective is a comprehensive description of PAMP for strong hyperfine decoupling (Paschen-Back regime) and an assessment of its actual potential for production of polarised gas. Work will also include investigations of new frontiers in metastability exchange optical pumping of ^{3}He.

References: [1] Maul et al, *Phys. Rev. A 98 (2018) 063405*; [2] *Rev. Mod. Phys. 89 (2017) 045004*.

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