Spin noise spectroscopy in gas cells

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In magnetic systems, the spectroscopy of fundamental noise due to random spin fluctuations, called Spin Noise Spectroscopy (SNS), can be optically performed, by measuring the associated fluctuations of the Faraday-like rotation experienced by a linearly polarized probe beam, which propagates through the sample [1]. Although a first experimental effort was initially reported in the early 1980s [2], only recently this method has seen a renewed interest due to advances in narrow line-width lasers and development in low noise electronics required for spectrum analysis [3]. It was then used to probe different properties of various media such as thermal atomic vapours, semi-conductors or quantum wells [1]. The perspective of possible measurements of correlations beyond the second order also raises a lot of interest, as it can be used to probe the limits of the linear response and fluctuation-dissipation theory and thus give an access to new phenomena [4]. Taking advantage of the collaboration of two teams of Paris-Saclay having different expertises, this PhD subject proposes to investigate the spin noise spectra obtained in a metastable helium vapour cell (LuMIn side) and in micro and nanocells filled with cesium and rubidium atoms (LCF side).

Rubidium, cesium or potassium atoms are usually used for this kind of experiments, but metastable helium has the advantage of not exhibiting hyperfine levels, which already allowed us to probe phenomena usually hidden with alkali atoms [5],[6]. Preliminary spin noise spectroscopy experiments were already performed in metastable helium at room temperature, and the first results demonstrated unexpected behaviours of the detected resonances. These resonances should be studied in detail both theoretically and experimentally, and the technique might then be used to probe the system in squeezed or even non-gaussian states generation conditions. On the LCF side, nano-cells will be used to study atom-atom and atom-wall interaction effects. Indeed, such cells are routine tools for high pressure transmission spectroscopy simply because the probe optical beam crosses an ultra-thin atomic vapour. A recent experimental and theoretical study of the collective Lamb shift in a Rb nanocell revealed an unexpected oscillation in the measurement of the recorded parameters, which might be attributed to a non-local response of the gas [7], and atom-surface van des Waals interaction could be measured by transmission spectroscopy [8]. We expect to get some signature of these effects in spin noise spectra recorded in such very thin cells.

This PhD subject, which has thus both experimental and theoretical aspects, will benefit from the strong collaboration of the LuMIn and LCF groups, which are located very closeby. This research work is also part of collaborations in India (S. Chaudhuri, A. Narayanan and H. Ramachandran, Raman Research Institute, Bangalore) and in UK (Ch. Adams and I. Hughes, University of Durham), the PhD student is expected to interact with.

The PhD student can also be part of another project on Rydberg atom based sensors, in collaboration with Thales Research and Technology (see the PhD subject *Rydberg atom based sensors* proposed by the same group).

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