Title: ***Laser spectroscopy of the Rydberg-surface interaction***

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The SAI group of Paris13 has pioneered atom-surface interaction experiments using selective reflection measurements that probe atoms at distances comparable to the wavelength of optical excitation (typically λ/2π~100nm). The SAI group has extensively studied the coupling of atomic dipole transitions with evanescent surface waves (polaritons), recently demonstrating that thermally excited polariton modes can strongly modify atom-surface forces [1].

The study of Rydberg-surface interactions is of fundamental importance, in particular when the spread of the atomic wavefunction (proportional to n^{*2}, where n^* is the effective quantum number) becomes comparable to the atom surface distance, defined by the probing depth of selective reflection. In this case, the dipole-dipole interaction approximation is no longer valid and higher-order (quadrupole) interactions need to be considered [3]. Higher-order effects in atom-surface interactions remain so far without experimental verification. Additionally, probing Rydberg atoms in compact platforms [2] is recently gaining considerable attention for quantum technology related applications.

Methodology

Evidence of the Rydberg surface interaction were reported in thin glass cells [2] and porous media [4]. However, these experiments are in disagreement with the predictions of quantum electrodynamics. We propose the use the sensitive selective reflection spectroscopic methods inside a sapphire cell [1]. Selective reflection is a well-established method for measuring Casimir-Polder interactions of excited state atoms, whereas sapphire surfaces are shown to be robust and chemically stable. A major scientific goal is to investigate higher order phenomena in the Rydberg-surface interaction. This can be achieved by a detailed analysis of the atomic selective reflection spectra.

1) Theory of Rydberg surface interactions

Detailed theoretical calculations of the Rydberg-surface interactions will be performed for the Rydberg states that will be experimentally probed. The calculations need to go beyond the dipole-dipole approximation (as described in [3]) and should take into account real data for the dielectric constant of the sapphire surface. We will collaborate with the theory group of S. Scheel in U. Rostock,.

2) Spectroscopic measurements of the Rydberg-surface interaction

We will use an intense laser at 894nm to pump cesium atoms to the $6P_{1/2}$ level. Subsequently, a probe selective reflection experiment will be performed on the $6P_{1/2}$→nS, nD lines. We will start by probing relatively low lying Rydberg atoms of $n^* = 15 - 20$, with a probe laser ~510nm. We will then probe high lying Rydberg sates $n^* = 30 - 50$. This will be achieved by initially pumping the atoms to the $6P_{3/2}$ level with an 852nm laser (D2 line of caesium). The experimental spectra, will be compared with the theoretical predictions to extract the exact nature of the atom-surface interaction. The SAI group has extensively developed technics to increase the signal to noise ratio of these measurements and has extensive experience in tackling systematic errors in atom-surface experiments [5]. The group has already the equipment to perform these experiments.

Perspectives

The SAI group is also developing a project that aims at probing molecular gases next to surfaces using selective reflection and thin cell spectroscopy. The major scientific goal of this experiment is to measure molecule-surface interactions and fabricate compact frequency references based on molecular rovibrational transitions. Depending on the available time and the evolution of the experiments, the student may also be involved in this project.

References

[1] A. Laliotis et al., “Casimir–Polder interactions in the presence of thermally excited surface modes,” *Nat. Commun.*, vol. 5, Jul. 2014.
[2] H. Kübler et al., “Coherent excitation of Rydberg atoms in thin vapour cells,” *Nat. Photonics*, vol. 4, no. 2, pp. 112–116, Feb. 2010.
[3] J. A. Crosse et al., “Thermal Casimir-Polder shifts in Rydberg atoms near metallic surfaces,” *Phys. Rev. A*, vol. 82, no. 1, Jul. 2010.
[4] H. Failache et al., “Spectroscopy of Atoms Confined to Micrometric Pores in Glass,” 2016, p. LTu2B.5.