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Poster

Measuring the Casimir-Polder interaction of Rydberg atoms by vapour cell spectroscopy

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The modification of quantum fluctuations by a surface of finite reflectivity shifts the energy levels of atoms and changes their radiative properties (Casimir-Polder effect). At nanometric distances away from a surface (near field), the Casimir-Polder energy shift is given by $-C_3/z^3$ (where C_3 is the van der Waals coefficient and z is the atom-surface distance) corresponding to the interaction of the fluctuating atomic dipole with its surface induced image. Near field Rydberg-surface interactions are of fundamental interest because the atomic size, scaling as n^2 (where n^* is the principle quantum number corrected by the quantum defect), is no longer negligible compared to the atom-surface separation, z . In this case, the dipole approximation, ($-C_3/z^3$ law of interaction), is no longer valid and higher-order terms, corresponding to the interaction of the fluctuation quadrupole with its own image, need to be taken into account. Quadrupole interaction terms in the atom-surface interaction manifest themselves with a novel distance dependence of z^5 that has not been experimentally investigated yet¹. Casimir-Polder experiments were first performed with low-lying Rydberg states ($n=10-14$), demonstrating the $-C_3/z^3$ law of interaction². Nevertheless, more recent experiments with high-lying rubidium Rydbergs ($n=32-43$)³ were not in agreement with Casimir-Polder theory thus highlighting the need for further experimental studies.

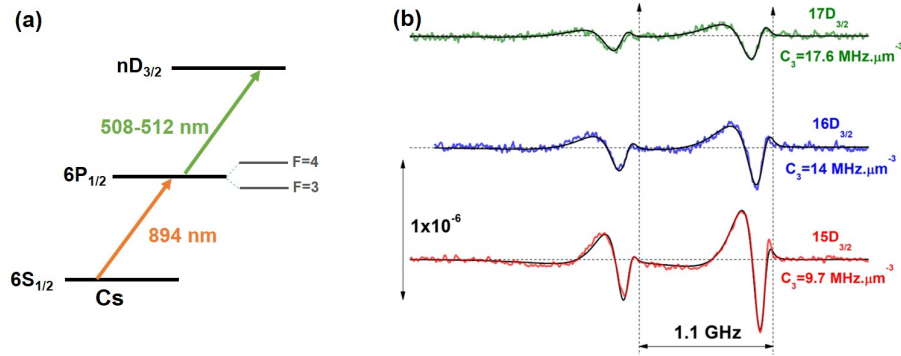


Figure 1: (a) Relevant cesium energy levels. (b) Selective reflection spectra normalized by the off-resonant reflection for the $6P_{1/2} \rightarrow nD_{3/2}$ transitions (where $n=15,16,17$). Experimental data are represented with black lines and theoretical fits with coloured lines. The cesium pressure is 25mTorr. The two peaks correspond to the $6P_{1/2}$ hyperfine manifold (both levels are populated due to collisions), separated by 1.1 GHz.

In the SAI group, we use the well-developed technique of selective reflection spectroscopy that probes atoms at a distance of about $\lambda/2\pi$ (where λ is the excitation wavelength) and allows us to measure the Casimir-Polder interaction between $\text{Cs}(nD_{3/2}, nS_{1/2})$ (where $n=15-18$) atoms and a sapphire surface. The experiments are performed in a vapour cell with sapphire windows using a set-up similar to the one reported in previous experiments⁴. The cesium atoms are excited by a strong pump laser to the first cesium resonance ($6P_{1/2}$) and subsequently selective reflection is performed on $6P_{1/2} \rightarrow nD_{3/2}, nS_{1/2}$ transition with a tunable laser at $\lambda = 512\text{nm} - 508\text{nm}$ (see Fig.1a). In Fig.1b we show selective reflection spectra for the $6P_{1/2} \rightarrow nD_{3/2}$ transitions (colored lines), along with the best theoretical predictions (black lines) assuming an interaction energy of $-C_3/z^3$ and considering motionless atoms (an assumption justified when the van der Waals shift is much larger than the Doppler shift). Our theoretical model describes well the experimental data but provides C_3 coefficients larger than the theoretically predicted values. However, the experimentally extracted values of the van der Waals coefficients scale with the principle quantum number as n^4 faithful to basic theoretical considerations.

We are currently working on improving our theoretical models to include the effects of atomic motion. This could lead to more accurate measurements of the C_3 coefficient. In addition, we are also planning to conduct experiments on a thin cell⁵ which allows us to probe atoms at distances from 50 nm up to 1 μm from the surface and can prove to be an excellent way to test the limits of the dipole approximation and probe quadrupole interactions.

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