# Vacuum-field level shifts in a single atom mediated by a single distant mirror

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A single $Ba^+$ ion is confined in a minature Paul trap and Doppler cooled with green laser light at 493 nm and red light at 650 nm. Part of the green resonance fluorescence is collimated by a lens and then retro-reflected by a mirror. The reflected light is detected by a photomultiplier (PMT1) together with the light emitted directly into that direction, see Figure 1. Varying the mirror-ion distance leads to high-visibility interference fringes in the green fluorescence (~60%) whilst the red fluorescence, that is transmitted by the mirror and detected by PMT2, is seen to be modulated with the same period but with lower visibility (~1-2%) [1]. The modulation of the red light indicates a modified decay rate on the green transition, showing that the mirror changes the vacuum field at the green wavelength and leads to enhancement and inhibition of spontaneous decay from the upper state.

A theoretical description of the experiment [2] predicts that a level shift of the upper ($P_{1/2}$) state is associated with the modified decay. We observe this level shift in the following way: as the frequency detuning of the red laser is scanned across resonance, the phase between green and red fringes is recorded. Experimental data are shown in Figure 2 together with the predicted phase. The green and red fringes are anti-correlated near zero detuning but approach the correlated case as the red laser is tuned away from resonance. The theoretical curve is calculated from optical Bloch equations taking into account the predicted level shift, whereas a model without the level shift would lead to anti-correlation or correlation at all detunings. Thus the experimental data clearly demonstrate that the single mirror, some 25 cm away from the trapped ion, creates a level shift of the $P_{1/2}$ state.

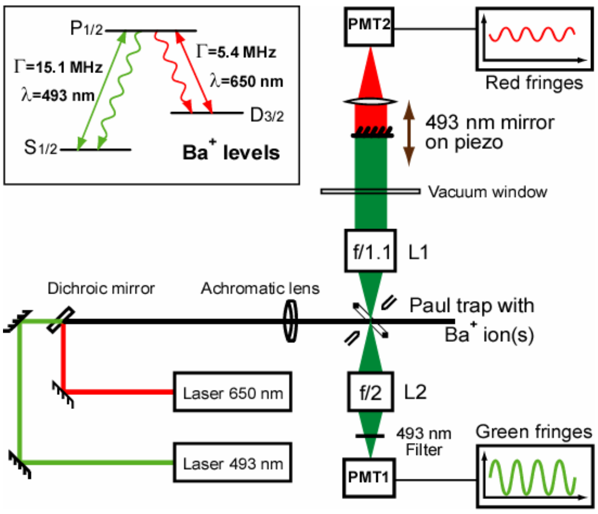


Figure 1: Experimental setup.

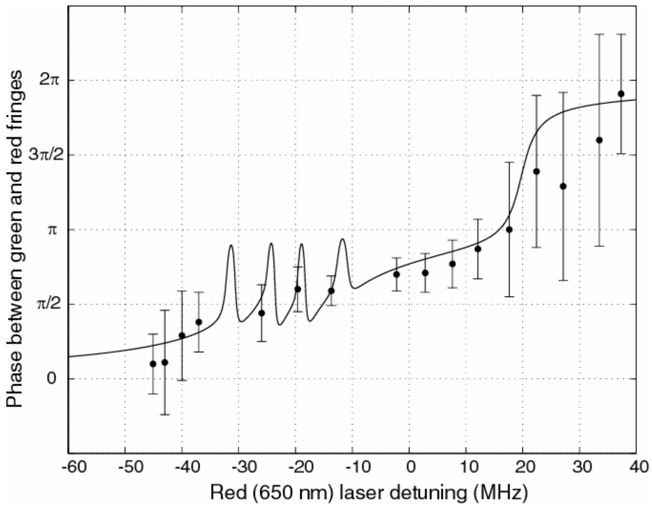


Figure 2: Measured and predicted phase between the green and red fringes vs. detuning of the red laser. The green detuning is –21.5 MHz. The four peaks are associated with dark resonances between Zeeman-split sublevels of the $S_{1/2}$ and $D_{3/2}$ states.

[1] J. Eschner, Ch. Raab, F. Schmidt-Kaler, and R. Blatt, *Light interference from single atoms and their mirror images*, Nature **413**, 495 (2001).
[2] U. Dorner and P. Zoller, *Laser-driven atoms in half-cavities*, Phys. Rev. A **66**, 023816 (2002).