Model-Independent Measurement of the Excited Fraction in a Magneto-Optical Trap

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In many experiments involving a magneto-optical trap (MOT) it is of great importance to know the fraction of atoms placed in an excited state due to the trapping process. Generally speaking, researchers have had to use untested models to estimate this fraction. In this work, the excited fractions of ^{87}Rb atoms in a MOT are directly measured using a charge transfer technique, for a range of MOT parameters. Simple models are then fit to the measured fractions. Using the results of this work, the excited fraction of ^{87}Rb atoms trapped in a MOT can be accurately estimated with knowledge of only the trapping laser intensity and detuning. The results are, at most, only weakly dependent on other MOT parameters.

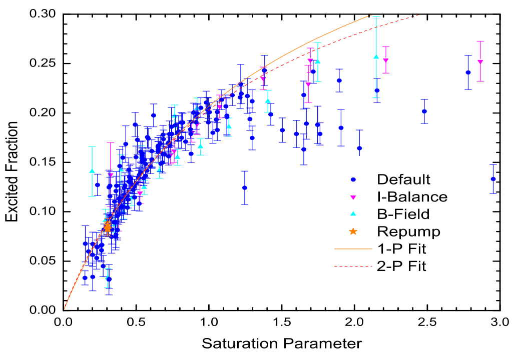

Fig. 1. Excited state fraction versus the saturation parameter. The different types of points are for different MOT parameters. The curves are fits to simple theoretical models.

The excited fractions are measured using the MOTRIMS methodology [1]. In this approach, a beam of projectile ions, in this case 7 keV Na^+, is directed toward a target of cold, trapped ^{87}Rb, and the relative count rates for capture from the ground and first excited states, Rb(5s) and Rb(5p), respectively, are measured. Because the capture rates are proportional to the product of the capture cross sections and the number of atoms in the states, and because the relative capture cross sections are already known, these measurements directly yield the relative populations in those two states. In Fig. 1 we show the measured excited fraction, f_m as a function of the so-called saturation parameter, s.

The saturation parameter, which is a function of trapping laser intensity I and detuning δ from resonance, is given by:

$$s = \frac{I/I_s}{1 + (2\delta/\Gamma)^2}\,, \tag{1}$$

where Γ is the full line width of the transition; for Rb($5s_{1/2} \rightarrow 5p_{3/2}$), $\Gamma/2\pi = 5.98$ MHz. Also, I is the measured total trapping laser intensity, and I_s is the so-called saturation intensity. In the work presented here, we find that a commonly used expression for the excited fraction in a simple two-level system fit the data extremely well over a wide range of MOT parameters, including not only trapping laser intensity and detuning, which enter the simple formula via the saturation parameter, but also for a range of magnetic field gradients, repump laser intensities, and balance between the three pairs of counter-propagating trap laser beams. This simple formula is given by

$$f = \frac{s}{1 + 2s}\,, \tag{2}$$

where the single fitted parameter is I_s from Eq. (1). The best fit is given by $I_s = 9.2 \pm 1.7$ mW/cm^2. We have also determined that one can estimate the excited fraction in one's MOT with an error given approximately by

$$\frac{\Delta f}{f(1-2f)} = \frac{\Delta I_s}{I_s} = 0.18. \tag{3}$$

References

[1] H. Nguyen, X. Fléchard, R. Brédy, H. A. Camp, and B. D. DePaola, Rev. Sci. Instrum., **75**, 2638 (2004).