

Hyperfine splitting

Mahadevan Subramanian & Drishti Baruah

March 2021

Value of Intensity for $\Omega=100$ MHz

$$\Omega^2 = \frac{d^2 2c\mu_0 I}{\hbar^2}$$

where d is the transition dipole moment.

An alternate formula is

$$\Omega^2 = \frac{\gamma^2 I}{2I_{sat}}$$

Putting $I_{sat} = 1.67$ mW/cm² and $\gamma = 6$ MHz we get

$I = 0.928$ W/cm² for $\Omega = 100$ MHz.

Since Ω^2 is proportional to I , so for $\Omega = 200$ MHz we get $I = \sqrt{20.927}$ W/cm² = 1.312 W/cm².

What intensity is used for a microwave transition of 6.85 GHz in the D2 line of Rubidium?

Saturation intensity of D2 line of ⁸⁵Rb is $I_{sat} = 1.66932$ mW/cm²

Hyperfine splitting of 6.85 GHz is obtained using Zeeman splitting on 5s level of ⁸⁷Rb. In low field limit for hyperfine splitting dominates the Zeeman interaction ($\Delta E_Z \ll \Delta E^{hfs}$) the interaction hamiltonian is written as

$$H_Z = \frac{1}{\hbar} \mu_B g_F F_z B_z$$

Here g_F is the Landé factor which would be -0.5 for $F = 1$ and 0.5 for $F = 2$ approximately. For the hyperfine levels we have $\Delta^{HFS} = 2\pi \times 6.834$ GHz. For Rubidium D2 line we have that $\gamma = 2\pi \times 6.1$ MHz.

$$\Omega_{F_g, m_g, F_e, m_e} = \gamma \sqrt{\frac{I}{2I_{sat}}} d_{F_g, F_e} \langle F_e, m_e, 1, q | F_g m_g \rangle$$

In experimental apparatus two lasers (a master and slave) are used which have a difference in frequency by Δ^{HFS} . The magnetic field at the trap bottom is approximately set to 3.2 Gauss (see [1]).

The laser intensities are defined by the peak intensities

$$I = \frac{2P}{\pi w^2}$$

Here w is the $1/e^2$ Raman beam waist at the atomic cloud which approximately comes as $140\mu\text{m}$, and P is the laser power which has been varied 0 to $75\mu\text{W}$. In [1] the values which were experimentally tested were for slave intensity of $I_S = 92 \pm 18$ mW/cm² with master intensity being $I_P = 0.42I_S$. On fitting the experimental data with a lorentzian distribution for the power we get a FWHM of 1.7 ± 0.1 kHz.

Referecneces

- [1] [Stimulated Raman Transitions Between Hyperfine Ground States of Magnetically Trapped Rubidium-87 Atoms](#)
- [2] [Two-Photon spectroscopy of rubidium in the vicinity of silicon devices](#)