laser polarization effect on the tune-out wavelength of He

Li-Yan Tang[1]

[1]*State Key Laboratory of Magnetic Resonance and Atomic and Molecular Physics,
Wuhan Institute of Physics and Mathematics,
Chinese Academy of Sciences, Wuhan 430071, P. R. China*

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I. THE DYNAMIC POLARIZABILITY

Considering an atom in a uniform static electron field, the dynamic dipole polarizability can be written as

$$\alpha_1(\omega) = \alpha_1^S(\omega) + A\cos\theta_k \frac{M_{J_0}}{2J_0}\alpha_1^V(\omega) + [\frac{3\cos^2\theta_p - 1}{2}]\frac{3M_{J_0}^2 - J_0(J_0+1)}{2J_0(2J_0-1)}\alpha_1^T(\omega) \tag{1}$$

where $\alpha_1^S(\omega)$, $\alpha_1^V(\omega)$, and $\alpha_1^T(\omega)$ present the scalar, vector and tensor polarizabilities,

$$\alpha_1^S(\omega) = \frac{2}{3(2J_0+1)}\sum_k \frac{\Delta E_{k0}|\langle\Psi_0\|T_1\|\Psi_k\rangle|^2}{\Delta E_{k0}^2 - \omega^2} \tag{2}$$

$$\alpha_1^V(\omega) = \sqrt{\frac{24J_0}{(J_0+1)(2J_0+1)}}\sum_k (-1)^{(J_0+J_k+1)} \begin{Bmatrix} J_0 & 1 & J_0 \\ 1 & J_k & 1 \end{Bmatrix} \frac{\omega|\langle\Psi_0\|T_1\|\Psi_k\rangle|^2}{\Delta E_{k0}^2 - \omega^2} \tag{3}$$

$$\alpha_1^T(\omega) = \sqrt{\frac{40J_0(2J_0-1)}{3(J_0+1)(2J_0+1)(2J_0+3)}}\sum_k (-1)^{(J_0+J_k)} \begin{Bmatrix} J_0 & 2 & J_0 \\ 1 & J_k & 1 \end{Bmatrix} \frac{\Delta E_{k0}|\langle\Psi_0\|T_1\|\Psi_k\rangle|^2}{\Delta E_{k0}^2 - \omega^2} \tag{4}$$

Since laser polarization is impossible to achieve 100% linear polarization, we set a parameter η in the Eq.(1) to represent the degree of linear polarization,

$$\alpha_1(\omega) = \alpha_1^S(\omega) + (1-\eta)A\cos\theta_k \frac{M_{J_0}}{2J_0}\alpha_1^V(\omega) + \eta[\frac{3\cos^2\theta_p - 1}{2}]\frac{3M_{J_0}^2 - J_0(J_0+1)}{2J_0(2J_0-1)}\alpha_1^T(\omega) \tag{5}$$

In Eq.(1), when the A is adjusted from –1 to +1, then we find this adjustment will produce 0.4pm-6pm correction on the 413 nm tune-out wavelength.

In Eq.(5), if we fix $A = 1$, adjusting the η from 95%-99.8%, then we find that the laser polarization has 0.11-0.27pm correction on the 413 nm tune-wavelength.