Effect of tensor shift from linear polarization

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Tensor shift hamiltonian

$$H \propto \frac{3}{2}\left\{\vec{u}^* \cdot \vec{F}, \vec{u} \cdot \vec{F}\right\} - \vec{F}^2 \tag{1}$$

For linear polarization $\vec{u} = \vec{u}^*$

$$H \propto 3\left(\vec{u} \cdot \vec{F}\right)^2 - \vec{F}^2 \tag{2}$$

If the polarization is very closed to π but off by a small angle θ in the x direction (can also be any other direction in the x-y plane without loss of generality)

$$\vec{u} = \cos\theta\hat{z} + \sin\theta\hat{x} \tag{3}$$

$$\begin{aligned} H \propto& 3(\cos\theta F_z + \sin\theta F_x)^2 - \vec{F}^2 \\ =& 3\left(\cos^2\theta F_z^2 + \sin\theta\cos\theta(F_zF_x + F_xF_z) + \sin^2\theta F_x^2\right) - \vec{F}^2 \\ \approx& 3\left(\cos^2\theta F_z^2 + \frac{1}{2}\sin\theta\cos\theta(F_zF_+ + F_zF_- + F_+F_z + F_-F_z)\right) - \vec{F}^2 \\ =& 3\left(\cos^2\theta m_F^2 + \frac{1}{2}\sin\theta\cos\theta((2m_F+1)F_+ + (2m_F-1)F_-)\right) - F(F+1)^2 \\ =& 3\cos^2\theta m_F^2 - F(F+1)^2 + \frac{3}{2}\sin\theta\cos\theta((2m_F+1)F_+ + (2m_F-1)F_-) \end{aligned} \tag{4}$$

Here we've ignored the second order term (in θ) and calculated the matrix element in the z basis.

The result shows that the tensor light shift can cause a first order coupling between the neighboring m_F state when the polarization is not π even if it remains linear. This is different from vector light shift which only have non-trivial effect for circular polarization.