Characteristics of SHG by Circularly Polarized Fundamental Beam

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1. Motivation of the study

Initially, second harmonic generation (SHG) microscopy was introduced predominantly under linearly polarized light as fundamental frequency source. Recent years, we and several groups [1,2] have reported polarization modulation as a useful and cost-efficient add-on modality to SHG to offer structural information. Briefly speaking, there are two ways of implementing it, one is by changing the orientation of the plane of polarization, whereas the beam is linearly polarized; the other is by altering the mode of polarization from linear to circular.

In the latter case, we found in experiment that the SH generated by collagen fibres, one of most well-known biological SH generators, comprise polar orientations of all angles. This interested us because high-nonlinearity molecules are not likely to generate circularly polarized harmonics, even when so excited.

2. Numerical treatment and result

We start from breaking the CP electric field into two linear components:

$$E=\mathbf{x}Ex(z,t) + \mathbf{y}Ey(z,t), \quad (1)$$

Where *Ex* and *Ey* oscillate at same amplitude with $\pi/2$ phase difference.

By plugging the above expressions to the second order nonlinearity equation containing the $\chi^{(2)}$ tensor, we get,

$$P_x = \frac{1}{2}\left(d_{iii}+d_{jij}\right)\left|E_{ox}\right|^2 + \frac{1}{2}\left(d_{iii}-d_{jij}\right)\left|E_{ox}\right|^2 Cos(2kz-2\omega t) + \frac{1}{2}\left(d_{iij}+d_{jii}\right)\left|E_{ox}\right|^2 Sin(2kz-2\omega t)$$

$$P_y = \frac{1}{2}\left(d_{iji}+d_{jjj}\right)\left|E_{ox}\right|^2 + \frac{1}{2}\left(d_{iji}-d_{jjj}\right)\left|E_{ox}\right|^2 Cos(2kz-2\omega t) + \frac{1}{2}\left(d_{ijj}+d_{jji}\right)\left|E_{ox}\right|^2 Sin(2kz-2\omega t) \quad (2)$$

Now when we revisit our crystal model of collagen as taking it as a $\bar{6}$m2 crystal, we get,

$$P_x = \frac{1}{2}d_{iii}\left|E_{ox}\right|^2 + \frac{1}{2}d_{iii}\left|E_{ox}\right|^2 Cos(2kz-2\omega t)$$

$$P_y = \frac{1}{2}d_{iii}\left|E_{ox}\right|^2 Sin(2kz-2\omega t) \quad (3)$$

It is obvious then, apart from a DC component in *Px, Px* and *Py* are oscillating in exactly the same amplitude with a phase lag of $\pi/2$, in other words, the lateral polarization of SHG is elliptical.

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