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Spectral Width of Reflection from a Cholesteric Liquid Crystal.

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The aim of this note is to rectify an error in the expression for the spectral width of reflection $\Delta\lambda$ from a cholesteric liquid crystal derived in a previous paper.¹ The correct derivation presented here leads to a value of $\Delta\lambda$ in agreement with the de Vries theory.²

We first write down the formulae for reflection when light is incident normally on the surface of a non-absorbing anisotropic crystal.³ Let μ_0 be the refractive index of the first medium from which light is incident and μ_1, μ_2 the principal indices of the anisotropic crystal. If the incident light is of unit amplitude and linearly polarized at an angle θ with respect to the principal axis for which the refractive index is μ_1 , the reflected light will consist of two vibrations linearly polarized along the two principal axes:

$$\left. \begin{aligned} E_1 &= -\frac{\mu_1 - \mu_0}{\mu_1 + \mu_0} \cos \theta \\ E_2 &= -\frac{\mu_2 - \mu_0}{\mu_2 + \mu_0} \sin \theta \end{aligned} \right\} \quad (1)$$

Now, the cholesteric structure is regarded as a pile of thin birefringent layers, the principal axes of the successive layers turned through a small angle β . Let the principal axes of the first layer be along OX, OY . If the structure is right-handed, i.e., β is positive, it can be shown⁴ that right circular light incident normal to the layers is reflected without change of sense of circular polarization when $\lambda_0 = \mu P$, where P is the pitch, μ the refractive index and λ_0 the wavelength in

vacuum. To calculate the reflection coefficient at the boundary between the $(\nu+1)$ th and $(\nu+2)$ th layers, we resolve the incident light vector along the principal axes of the $(\nu+1)$ th layer which are inclined at an angle $(\nu+1)\beta$ with respect to OX, OY . The resolved components are⁴

$$\begin{bmatrix} \xi \\ \eta \end{bmatrix} = \begin{bmatrix} 1 \\ i \end{bmatrix} \exp[i\{(\nu+1)\beta - \phi_{\nu+1}\}],$$

where $\phi_{\nu+1} = 2\pi\mu(\nu+1)p/\lambda$, where p is the thickness of each layer. At the boundary, the ξ vibration emerges from a medium of refractive index μ_1 and the η vibration from a medium of refractive index μ_2 . If ξ' and η' refer to the principal axes of the $(\nu+2)$ th layer, then using Eq. (1) the reflected components are

$$\begin{aligned} \begin{bmatrix} \xi' \\ \eta' \end{bmatrix} &= -\frac{\beta\Delta\mu}{2\mu} \begin{bmatrix} i \\ 1 \end{bmatrix} \exp[i\{(\nu+1)\beta - \phi_{\nu+1}\}] \\ &= -iq \begin{bmatrix} 1 \\ -i \end{bmatrix} \exp[i\{(\nu+1)\beta - \phi_{\nu+1}\}], \end{aligned}$$

where $\Delta\mu = \mu_1 - \mu_2$, $2\mu = \mu_1 + \mu_2$ and $|q| = \beta\Delta\mu/2\mu$. We make the approximation here that $\sin\beta \approx \beta$, since β is assumed to be very small. Transforming back to OX, OY , the reflected wave on reaching the surface of the liquid crystal will be

$$\begin{bmatrix} X \\ Y \end{bmatrix} = -iq \begin{bmatrix} 1 \\ -i \end{bmatrix} \exp[i\{(2\nu+3)\beta - 2\phi_{\nu+1}\}],$$

which represents a right circular vibration travelling in the negative direction of OZ . Clearly the phase difference between this wave and the one reflected at the boundary between the first and second layers is $\exp[2i(\nu\beta - \phi_\nu)]$. When $\lambda = \mu P$, we have $2\pi\mu p/\lambda = \beta$ and $\phi_\nu = \nu\beta$ (since $n p = P$ and $n\beta = 2\pi$, where n is the number of layers per turn of the helix). Hence the phase factor $\exp[2i(\nu\beta - \phi_\nu)]$ becomes unity irrespective of the value of ν , and there results a strong interference maximum. On the other hand, for a left-handed structure, β is negative and $(\nu\beta - \phi_\nu)$ does not vanish.

The reflection coefficient $-iQ$ per turn of the helix (neglecting multiple reflections within the n layers) is then $-inq$ and the spectral width of reflection from a thick specimen^{1,4}

$$\frac{Q\lambda_0}{\pi} = \frac{n\beta\Delta\mu\lambda_0}{2\pi\mu} = P\Delta\mu$$

in agreement with the de Vries theory.

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