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A SIMPLE TECHNIQUE FOR MAKING MICA RETARDATION PLATES

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Mica, usually in the form of muscovite, has long been used for quarter-wave or half-wave plates in the visible and near infrared wavelengths. Since the fast and slow crystals axes are almost exactly parallel to the cleavage planes, large aperture retardation plates can be made without resorting to expensive grinding and polishing. In addition, thin, unsupported sheets give little beam deviation or wavefront distortion. However, since the difference in the fast and slow indices of refraction for mica varies from sample to sample by as much as 20%, an accurate retardation plate cannot be made by measuring the thickness of the plate, and an optical check has to be made. We describe an easy method for cleaving and optically measuring the phase retardation that is especially useful at infrared wavelengths of a few microns where commercial suppliers of mica wave plates cannot usually measure the optical retardation directly.

We measure the phase retardation of a $\lambda/4$ plate as shown in Fig. 1. The electric field amplitude at point (a) of Fig. 1 can be written as

$$\underset{\sim}{E} = E_0(\hat{\varepsilon}_s t_s e^{2i(\pi/2 + \delta\phi)} \cos\Theta + \hat{\varepsilon}_f t_f \sin\Theta \quad , \qquad (1)$$

where $\hat{\varepsilon}_s$, $\hat{\varepsilon}_f$ are unit vectors in the direction of the slow, fast axes respectively, $\delta\phi$ measures the departure of the retardation from $\pi/2$

and t_s, t_f are the transmission coefficients for the components of E along $\hat{\varepsilon}_s$ and $\hat{\varepsilon}_f$. The difference in transmission due to the difference in Fresnel reflectivities along the two axes is typically 0.001 or less per surface. However, the linear dichroism in mica can be large in the near infrared, and in our work at 2.18 μm, we measure

$$\delta\ell = \frac{t_s - t_f}{t_s + t_f} \cong 0.1.$$

A straightforward expansion of equation (1) gives

$$\underset{\sim}{E} = E_o t_s \left\{ \hat{x} \left[-\cos^2\Theta \, (\cos 2\delta\phi + i\sin 2\delta\phi + \sin^2\Theta \left(\frac{1 - \delta\ell}{1 + \delta\ell}\right)\right] + \hat{y} \left[\cos\Theta \, \sin\Theta \left(\frac{1 - \delta\ell}{1 + \delta\ell} + \cos 2\delta\phi + i\sin 2\delta\phi\right)\right]\right\} \tag{2}$$

The measurement requires that we minimize

$$|E_x|^2 = \left(\sin^2\Theta \left(\frac{1 - \delta\ell}{1 + \delta\ell}\right) - \cos^2\Theta \cos 2\delta\phi\right)^2 + (\cos^2\Theta \sin 2\delta\phi)^2, \tag{3}$$

and since $\delta\Theta = \pi/4 - \Theta$ is a small number, it means that we have the condition

$$\tan^2\Theta \left(\frac{1 - \delta\ell}{1 + \delta\ell}\right) \cong \cos 2\delta\ell.$$

Thus, we can compensate for the linear dichroism $\delta\ell$ with a suitable choice of $\delta\Theta$, in which case only the second term of equation (3) survives.

$$|E_x|^2 \simeq (\cos^2\Theta \sin 2\delta\phi)^2 \simeq (2\delta\phi)^2.$$

For $\delta\ell \sim 0.1$, $\delta\Theta$ is approximately 3^o.

The method used for splitting the mica sheets is an improvement over hit and miss cleaving with a razor blade. We found that a piece of adhesive tape tacked gently near an edge of the mica can lift off a layer of mica 5 μm thick or less. Quite often layers that thin will not tear evenly, and high or low spots will form as shown in Fig. 2. The tape can then be used to "dress-up" the surface since a tear in central region of the mica will only remove a local plateau. Thus, large aperture quarter wave plates are easily made. By starting with a slightly thicker piece of mica (at 2.18 μm, a 90^o phase retardation corresponds to a mica thickness of roughly 130 μm), and pulling off thin layers, a retardation accuracy of better than 1^o can be obtained. Using this technique we could easily get extinction ratios $|E_x|^2/|E_y|^2$ of better than 1/900. This corresponds to an admixture of "wrong" circular polarization of less than one part in 1800.

We wish to thank John Conway for originally suggesting that we try to manufacture our own quarter wave plates from mica and Bob Maier for helpful comments. This work was supported by the U. S. Department of Energy.

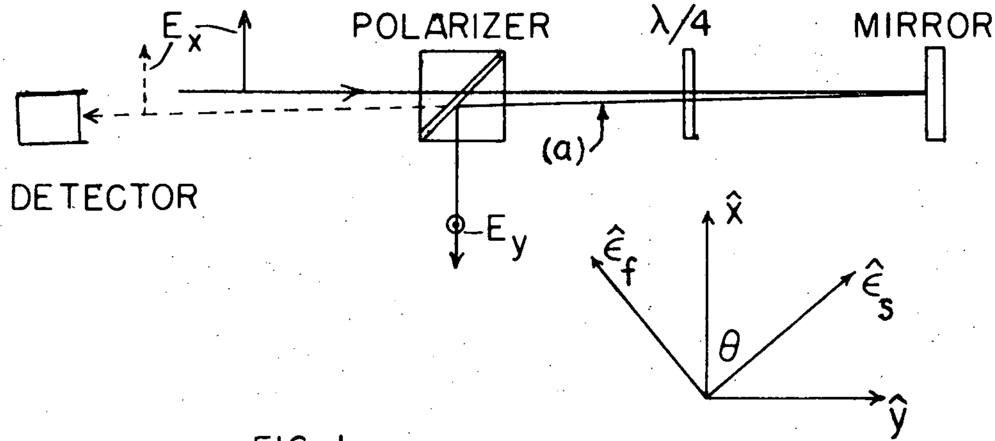

FIG. 1

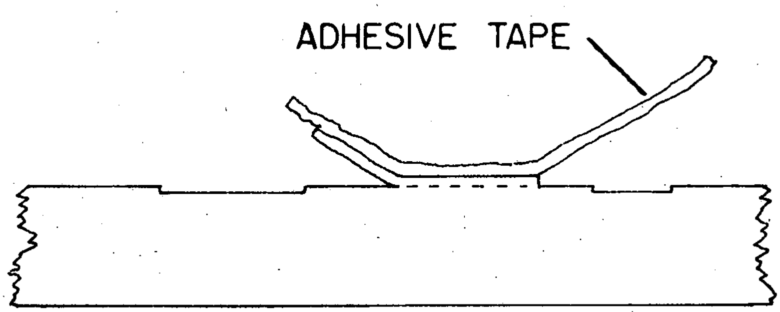

FIG. 2 REMOVING A LOCAL PLATEAU

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