Acta Cryst. (1971). A**27**, 680

A new method to demonstrate and measure birefringence. By G. Busch and R. Verreault,* *Laboratorium für Festkörperphysik ETH, Zürich, Switzerland*

(*Received* 30 *April* 1971)

The polarization properties of the light scattered in the bulk of an anisotropic solid are used to measure circular and linear birefringence. Recently, the extension of the method to scattering at an air–solid interface has increased the precision significantly and the range of measurement by three orders of magnitude. Moreover, the brightness handicap of Rayleigh scattering is surmounted by designing the roughness of the scattering surface adequately and by using an analyser in the scattered beam.

Rayleigh (Strutt, 1919) and Chandrasekharan (1947*a*, *b*) have recognized that the light scattered from a linearly polarized beam in a solid can be used to demonstrate optical activity and weak linear birefringence ($\Delta n \lesssim 0{\cdot}0005$), due to the toroidal intensity pattern of Rayleigh scattering (scattering-centre size: $a \ll \lambda$). The intensity vanishes along the direction of vibration of the incident wave and is maximal at 90° to it. Those authors utilized bulk scattering and photographic recording with exposure times ranging from a few minutes in the ultraviolet region of the spectrum up to many days in the visible region, according to the a^6/λ^4 intensity law for Rayleigh scattering. Circular or linear birefringence produces a fringe pattern in the trace of the transmitted beam. The fringe width Λ is related to the birefringence Δn and to the vacuum wavelength λ of the radiation by the relation $\Delta n = \lambda/\Lambda$. The limit to the measurable Δn in bulk scatttering arises from the finite depth d of the scattering region along the direction of observation. The contrast decreases rapidly when $d \gtrsim \Lambda$.

Fig. 1(*a*) shows an application of bulk scattering ($a \ll \lambda$) in a crystal of cubic EuTe to demonstrate the huge Faraday effect of that paramagnetic red-transparent semi-conductor at room temperature. A laser beam from the left is linearly vibrating in the plane of the paper. With the applied magnetic field of 28·5 kOe, the first dark fringe indicates a 90° rotation and the other ones subsequent 180° rotations of the plane of vibration. The measured fringe width yields the Verdet constant $(V)^{632.8nm}_{300^\circ K} = -3{\cdot}79 \pm 0{\cdot}04$ min. $Oe^{-1}.cm^{-1}$.

The present contribution to the measurement of birefringence in the light-scattering configuration introduces the technique of surface scattering and extends the method to scattering-centre sizes $a \simeq \lambda$. For measurements in surface scattering, the crystal facet through which the trace of the beam is observed is cut at a small angle to the intended beam direction and hence is met at grazing incidence from the inside. To produce Rayleigh scattering at the observation facet, this one must be polished or very finely ground. The surface roughness can be adjusted to take advantage of the a^6 intensity law and the use of a 2 mW laser makes total darkness unnecessary. The scattering due to the spatial refractive-index fluctuations at the crystal–air interface shows the same fringe system as bulk scattering, thus giving information about the polarization state of the transmitted beam immediately below each point of the observation facet. One essential difference from bulk scattering is that the depth of the scattering region is now vanishingly small, so that high-power, low-depth-of-field microscope objectives can be used for observing the fringe system. The lowest measurable Λ values ($\sim 2\ \mu$) increase the range of measurement up to $\Delta n \simeq 0{\cdot}2$ (calcite). Fig. 1(*b*) shows a part of an optically polished facet of monoclinic (biaxial) Eu_2SiO_4 for a direction of propagation normal to the optic plane. The value $\Lambda = 18{\cdot}80\ \mu$ gives the maximum linear birefringence $(n_\gamma - n_\alpha)^{632.8\ nm}_{27^\circ C} = 0{\cdot}0337$ of that substance.

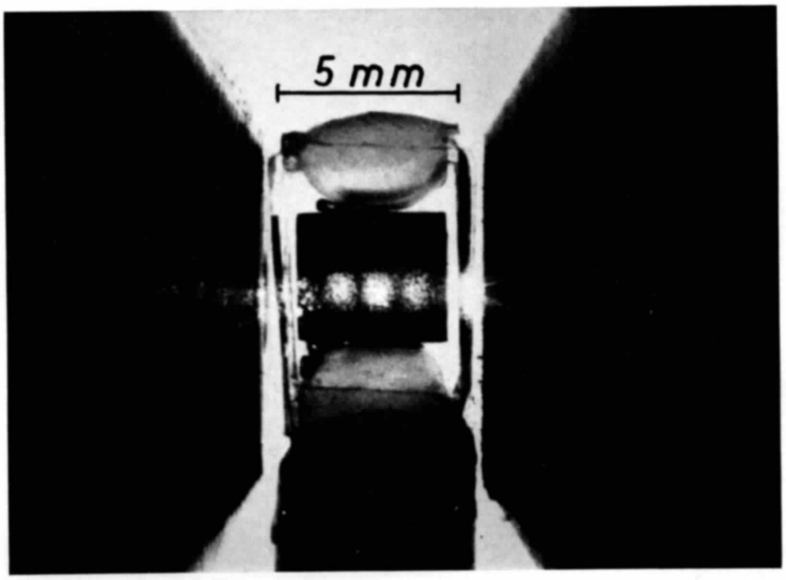
The brightness handicap of Rayleigh scattering (a^6/λ^4 law) can be surmounted at leisure in the surface-scattering method by designing a facet with $a \simeq \lambda$. The intensity is then only weakly wavelength dependent and the fringe system can, in subdued ambient lighting, be observed with ordinary low-power incandescent lamps or, in total darkness, with a $\frac{1}{2}$ watt pocket flashlight. Although the intensity of the scattered beam is no longer dependent on the polarization state below the surface, its own polarization state varies spatially with the same period as that of the transmitted beam. It suffices to introduce an analyser into the scattered beam to obtain a fringe system as before. This is illustrated with the optical activity of quartz along the optic axis in Fig. 1(*c*) (note the polaroid filter lying on the observation facet). On illuminating that sample with a 60 watt tungsten lamp, the sequence of vivid interference colours given in the Michel–Lévy chart could be seen at once.

A more comprehensive work presenting a general theory of the phenemenon and a more detailed experimental evidence will appear elsewhere (Verreault, 1971).

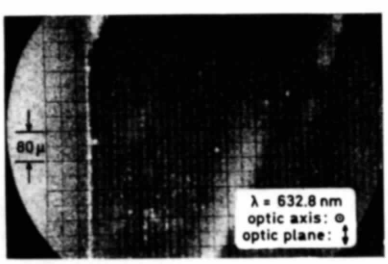
* Present address: Université du Québec, Chicoutimi, Qué., Canada.

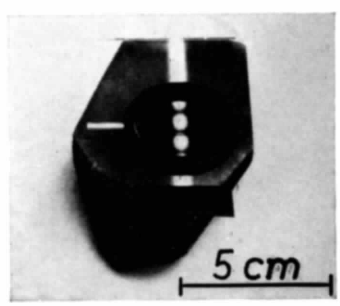
References

Chandrasekharan, V. (1947*a*). *Proc. Indian Acad. Sci.* A**25**, 256.
Chandrasekharan, V. (1947*b*). *Proc. Indian Acad. Sci.* A**26**, 110.
Strutt, R. J. (1919). *Proc. Roy. Soc.* A**95**, 476.
Verreault, R. (1971). *Z. Kristallogr.* To be published.



(*a*)





(*b*) (*c*)

Fig. 1. Circular and linear birefringence in the light-scattering configuration: (*a*) room-temperature Faraday effect in EuTe; (*b*) linear birefringence of Eu_2SiO_4 normally to the optic plane (laser beam from the left); (*c*) optical activity of quartz along the optic axis.