

A Polarizer, Using Sodium Nitrate Single Crystal, Designed as Part of an Optical Pumping Light Source

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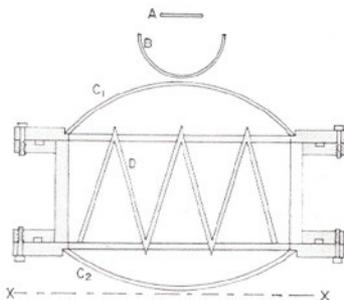
THERE is a need, for optical pumping experiments, for intense sources of polarized light. Whatever the state of polarization desired, the first step is usually to make the light plane polarized, and this is most conveniently achieved using a "Polaroid" type polarizer. Such a polarizer, however, typically absorbs 50% of the incident light intensity because it has the wrong polarization to pass through and also about 30% of the intensity which remains. Where it is important to have as intense a light source as possible, an alternative polarizer which does not absorb so much light would be very desirable. Polarizers using the principle of the Nicol prism typically pass about 46% of the incident light. The 4% loss, being due to reflection at the end windows, could be eliminated by anti-reflecting coatings. Unfortunately, a Nicol prism with a diameter of 7.5 cm or more is very expensive.

We have built a polarizer for an optical pumping light source using a birefringent crystal. The principle on which this polarizer is based is exactly that of the Nicol prism, except that the birefringent material is in the form of a thin plate placed obliquely across a cell containing a liquid whose refractive index is equal to the higher refractive index of the birefringent material. (Such a polarizer was first constructed by Jamin; an account of the principles

of such polarizers has been given by Feussner.¹) The birefringent material used was sodium nitrate, for which $\mu_o = 1.585$ and $\mu_e = 1.336$ for Na-D light at 20°C; the liquid used was 2,4-dimethyl benzophenone, refractive index $n_D^{20} = 1.591$. The plane of the crystal makes an angle of 16.25° with the direction of the central ray passing through the polarizer, and the optic axis of the crystal is perpendicular to the plane of the plate. An ordinary Nicol type polarizer built to these specifications, with flat end windows, will accept, and polarize, light in a cone of total angle approximately 53°. We have built such a polarizer and have verified that it does indeed polarize light as completely as could be ascertained. The intensity of the light passed was 49% of the intensity passed when the sodium nitrate crystal was removed. However, the transmission of the cell was only 42% of the incident intensity. This is rather less than the 46% expected, and we believe this is due to the absorption by the liquid of ir radiation which is emitted by the lamp, and to which the photodiode detector is sensitive. The cell body was made of brass, the end windows were made of glass stuck on with "Stycast 2850 GT" epoxy,² and the interior of the cell was blackened by sticking matte black photographic wrapping paper on to the walls with the same epoxy cement.

The sodium nitrate single crystal plates were grown epitaxially on mica in the manner described by West.³ Briefly, sodium nitrate (mp 308°C) is melted in a shallow dish in an oven heated to 325°C, with a freshly cloven mica sheet on the bottom of the dish. The oven is then closed and the temperature is reduced slowly at about 5°C/h. Sodium nitrate grows in a single crystal on the mica with its optic axis perpendicular to the surface. After cooling, the crystal is roughly shaped with sand paper and polished on wet blotting paper. Single crystal plates 15×15×0.16 cm can be so obtained without too much difficulty.

FIG. 1. Section of the polarizer and discharge lamp. A—Discharge; B—cooling jacket, filled with coolant of refractive index 1.33; C₁, C₂—entrance and exit windows, shaped to focus the light; D—plates of sodium nitrate; X—reference plane for Fig. 2.



We have designed the polarizer as an integral part of the optical system for use with a discharge light source in

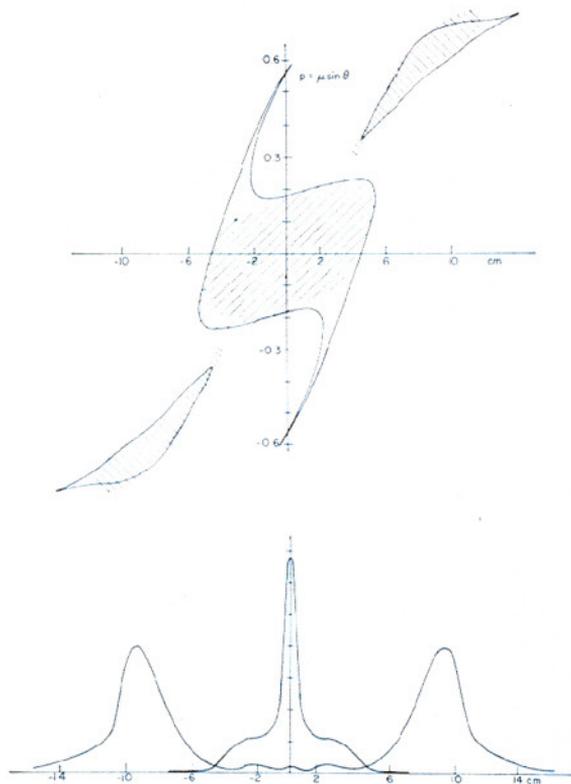


FIG. 2. (Upper) phase space of light transmitted by the polarizing system, determined along the line X-X in Fig. 1. The calculated phase space is outlined, the observed phase space is hatched, and the two polarizations are oppositely hatched. θ is the angle between a light ray and the axis of the instrument. (Lower) plot of the intensity of light of the two polarizations along the line X-X in Fig. 1.

the form of a disk of 2 cm diam (see Fig. 1). In order to keep the length of the polarizer small, and hence to prevent inconvenient divergence of the light passing through, we used six pieces of sodium nitrate. This has the disadvantage that light of the wrong polarization, reflected from the four central pieces of sodium nitrate, does pass through the cell. However, when the polarizer is used with a small fixed source, as in this application, the light of the wrong polarization is spatially separated a few centimeters beyond the exit window and can be blocked off with a screen. The entrance and exit windows are spherical to assist the focusing of the light. In an application like this, image forming properties of the system are of little interest, and the transmission of the light is best described by a phase space, as is common in particle beam optics. Phase spaces, both measured and calculated, on the line X-X (Fig. 1) are shown in Fig. 2. This figure also shows the measured intensities along X-X of light of each polarization. It should be noted that the light of the desired polarization, which appears in the central peak, is symmetrically distributed around the axis of the polarizer, but that the light of the undesired polarization appears only off the axis in the directions perpendicular to the planes of the sodium nitrate crystals. The appearance of light of the wrong polarization near the axis, which is very weak, seems to be due to multiple reflections between the entrance and exit windows. Financial support of the National Research Council of Canada and the University of Toronto is gratefully acknowledged.

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¹ S. Feussner, *Z. Instrumentk.* 4, 41 (1884).

² Obtainable from Emerson & Cuming Inc., 59, Walpole St., Canton, Mass. 02021.

³ C. D. West, *J. Opt. Soc. Amer.* 35, 26 (1945).