

No. 57 MODULAR OPTICAL TEST INSTRUMENT FOR 1700–11,000 Å*†

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December 28, 1964

ABSTRACT

A laboratory instrument is described which is capable of precise measurements of refraction, transmission, polarization, and reflection from 1700 to 11,000 Å. The instrument consists of eight modular units that can be bolted together in various serial arrangements as required for the particular test. A goniometer specimen chamber and specimen carriage of unusual design are described. The specimen chamber utilizes a transit dial and is readable to 20".

1. Introduction

THE nature of the measurements to be made with the balloon-borne telescope of Project Polariscope¹ demands a versatile type of laboratory test instrument which is not commercially available. It is necessary to measure the transmission, polarization, and depolarization properties of filters, mirrors, and new materials in the ultraviolet. In addition, the instrumental polarization and total response of the Polariscope system have to be determined.

The instrument described here is capable of refraction, transmission, polarization, and reflection measurements from 1700 to 11 000 Å. The spectral response of detectors below 3200 Å can be determined.

2. Description of the Optical System

The light source (Fig. 1) used below 3400 Å is a deuterium concentrated-arc lamp, with a fused silica window, giving a continuous spectrum output (Sylvania DE-350). A mercury-vapor lamp is used as a line source for refraction studies (Ultra-Violet Products 11-SC-1A).

Monochromatization of the light beam is achieved by a 600 lines/mm reflection grating, blazed at 2500 Å, and

overcoated for use below 2000 Å. The monochromator (Diffraction Products, Inc.) has a focal length of 250 mm and is normally used with the slits set for a 9 Å bandwidth.

Collimation of the $f/4$ exit beam of the monochromator is done with a 60 mm focal length plano-convex lens made of Suprasil (Englehard Industries, Inc.). An adjustable iris follows the lens. The lens is moved along its optical axis, without rotation, for focusing (Fig. 2).

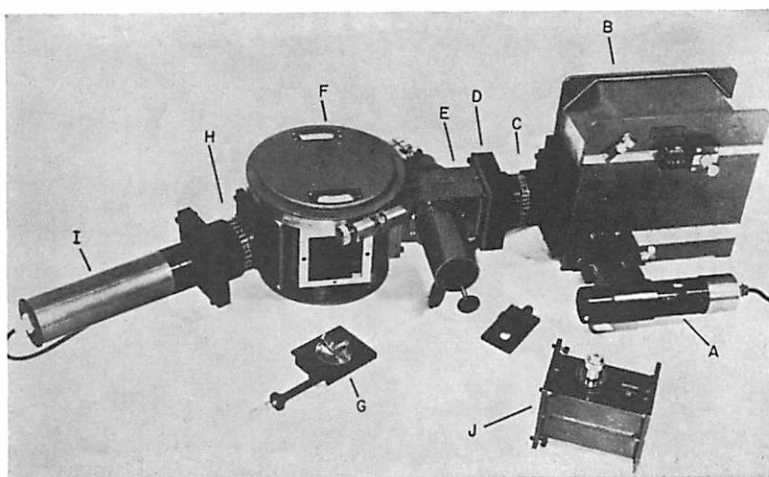
A second such lens module is used as a telescope in front of the detector. The focal plane aperture for this lens is circular, with a diameter of 0.165 mm. The Suprasil lenses will be replaced by lithium fluoride lenses to extend the range in the uv to the limit set by the window on the source.

The modules described below are constructed of 4×8 cm aluminum channel welded together to form rigid boxes. These boxes are provided with 10 cm square flanges on their ends so that they can be bolted together. The flanges are machined parallel and lapped, and can be provided with pins for exact mating with flanges of successive units.

A thin filter-slide follows the collimator. Filters can be inserted into the beam at this point if desired.

Following the filter-slide a reference detector or a polariz-

FIG. 1. General view of instrument. (A) Hydrogen lamp, (B) grating monochromator, (C) collimator, (D) filter and dark slides, (E) reference detector, (F) specimen chamber, (G) specimen carriage, (H) telescope, (I) photomultiplier housing, (J) ADP polarizer.



*This work is supported by the National Science Foundation as a part of Project Polariscope, and by the National Aeronautics and Space Administration (NASr-138).

†Reprinted from *The Review of Scientific Instruments*, Vol. 36, No. 5, pp. 611–614, May 1965, with permission.

¹T. Gehrels and T. M. Teska, *Appl. Opt.* 2, 67 (1963).

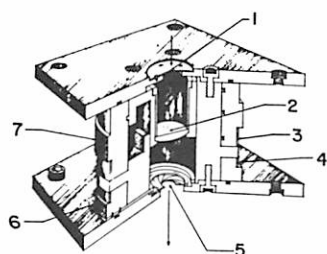


FIG. 2. Collimator-telescope module. (1) aperture, (2) lens, (3) calibrated focusing scale, (4) calibrated iris scale, (5) iris, (6) iris adjustment ring, (7) lens focusing ring.

ing prism module can be inserted. The polarizer consists of a rotatable single-beam ammonium dihydrogen phosphate prism whose position angle can be read to $6'$. The prism is contacted with Dow Corning 200 fluid and can be used down to 2000 \AA . The reference detector module is constructed of a cylindrical tube mounted at a right angle to the light beam, as shown in Fig. 1. In the tube is a piston on which is mounted the reference detector which can be slid into or out of the beam. The detector is a 1P21 photomultiplier tube preceded by a blue filter on whose front surface is coated a thin film of sodium salicylate. This film has a constant quantum efficiency for conversion of ultraviolet radiation, from 3200 down to 900 \AA , into blue light of constant wavelength. This detector can thus be used to measure the spectral energy distribution in the beam emergent from the monochromator-collimator system.

A specimen chamber and specimen carriage follow next. They will be discussed at length below.

Several photomultiplier tubes are used as detectors. For work below 6500 \AA an EMI 6255S is used. For measure-

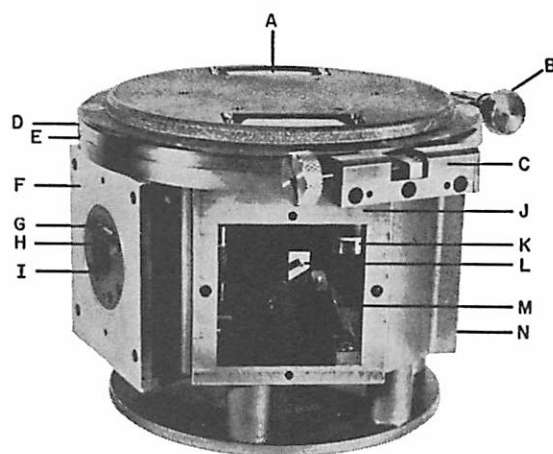


FIG. 3. Specimen chamber. (A) Transit dial, (B) clamping screw, (C) tangent screw, (D) clamping ring, (E) thrust ring for rotating plate, (F) rotating plate, (G) dial arm load spring, (H) dial arm load lever, (I) dial arm tube, (J) chamber door mounting surface, (K) Negator spring roll, (L) carriage stop, (M) carriage rail, (N) mounting surface for reference detector or collimator.

ments above 6000 \AA an RCA 7102 can be inserted in its place. Dark current can be "bucked out" with a constant current source.

The entire instrument can be flushed with dry nitrogen when used below 2200 \AA and is then usable down to 1700 \AA .

3. Specimen Chamber

The specimen chamber utilizes a 16.5 cm diam transit dial that is readable to $20''$ (Figs. 3 and 4). The dial hous-

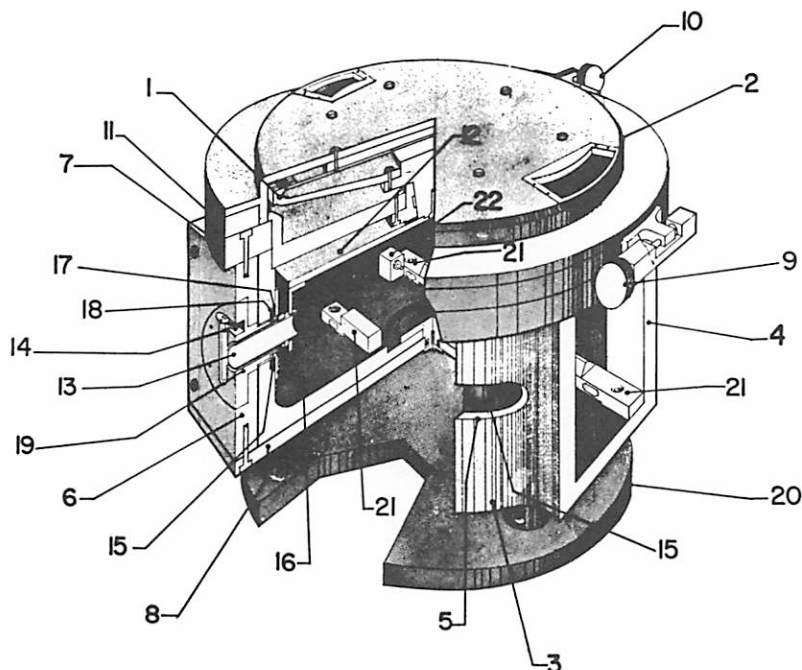


FIG. 4. Construction of the specimen chamber. (1) Transit dial, (2) dial housing, (3) body, (4) chamber door mounting surface, (5) slot for exiting beam, (6) rotating plate, (7) thrust ring for rotating plate, (8) plate radial support axis, (9) tangent screw, (10) clamping screw, (11) clamping ring, (12) dial arm, (13) dial arm tube, (14) dial arm load spring, (15) Negator spring slot closure, (16) slot closure guides, (17) Teflon tape, (18) felt strip, (19) slot closure drive tube, (20) base, (21) carriage rail, (22) carriage stop.

ing is fitted into one end of a cast-aluminum body of cylindrical shape. The other end of the body is closed, and the whole forms a light-tight chamber in which the test specimen is mounted.

A door for introducing the specimen into the chamber is provided on one side of the body. A machined flat surface for attaching the instrument to the collimator is located at 90° spacing from the door. The collimated monochromatic beam passes into the interior of the chamber through an aperture in this surface. After leaving the test specimen, the beam passes from the chamber via a slot in the wall.

The detector is carried on a plate that is rotatable about the axis of the specimen chamber. This plate is supported at its upper end by a thrust ring which fits closely the outside diameter of the dial housing and which bears upon the machined upper surface of the instrument body. The lower end of the rotating plate is supported radially by an arm pivoted at the bottom of the body. Fine adjustment of the angular position of the rotating plate is obtained by means of a tangent screw and a clamping ring assembly.

The position angle of the rotary plate is determined from a reading of the transit dial. The plate can be rotated through approximately 150°. The dial is connected to the plate by means of a radial arm attached to the dial hub. The plane of arm rotation is located at the top of the specimen chamber. The end of the arm carries a small right angle plate into which a stainless steel tube is threaded. The tube projects through the slotted wall of the chamber and is held in spring-loaded contact with a steel pin fitted into the rotating plate. Motion of the plate is transmitted to the dial through this tube-arm connection. The emergent beam passes out through the tube. A spring-loaded arm is used to prevent undesirable stresses in the dial drive members and bearings in the event any slight misalignment of the dial and plate axes should exist.

As the rotary plate is moved, the dial drive tube moves along the slot in the side of the body. Since the body forms the specimen chamber, a light-tight and moderately gas-

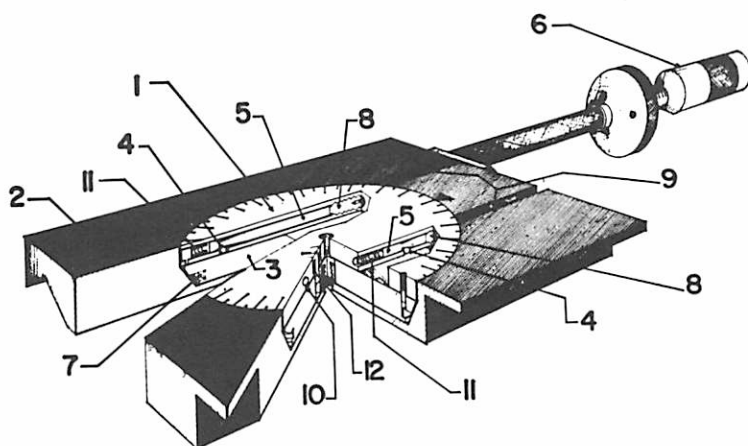
tight slot closure had to be devised. A Negator spring (Hunter Spring Division, Ametek, Inc.), is used as such a closure. The Negator spring is held in a groove that runs along the inside wall of the chamber by means of metal guides. Teflon tape reduces sliding friction between guides and spring. Strip felt is used as a seal between Negator spring and chamber wall. The spring is used without take-up spools as the natural tendency of the material to recur is sufficient to cause the spring to roll up at the end of the guide in a satisfactory manner for this application. A steel tube rigidly attached to the rotating plate fits into a hole in the Negator spring and causes it to be driven along as the plate is rotated. The dial drive tube passes through this larger diameter tube but is not in contact with it. In this way, the force required to move the spring closure is transmitted directly from the rotary plate and does not have to be provided by the dial arm spring.

4. Specimen Carriage

The instrument is provided with a sliding specimen carriage. The carriage can be moved along a pair of guide rails by means of a handle that passes through a seal in the chamber door. In this way, the specimen can be inserted into or withdrawn from the monochromator beam without opening the chamber. The carriage contains a table that permits rotation of the specimen about an axis coinciding with the rotating plate axis of the specimen chamber (Fig. 5). The carriage guide rails are adjustable for precise alignment of these axes. The carriage table is driven by means of a micrometer screw and a spring-loaded strap arrangement. The table may be slipped with respect to the drive strap for rapid adjustment, which initially is coarse. The micrometer is carried by the carriage-positioning handle that projects through the chamber door. Each division of the micrometer head (0.002 cm) corresponds to a rotation of 5' of the table.

The carriage table is provided with a plate that is tapped

FIG. 5. Specimen carriage. (1) Specimen mounting plate, (2) carriage body, (3) rotary table, (4) adjustable balls, (5) cones, (6) micrometer screw, (7) drive strap, (8) cone adjustment screw, (9) adjustment screw access slot, (10) fixed ball, (11) cone load spring, (12) mounting plate load spring.



for attachment of the samples to be tested. This mounting plate is supported at three points by means of steel balls that project from its lower surface and that bear upon the top of the rotary table. One of the three balls is fixed. The remaining two balls fit into holes drilled in the under side of the plate, perpendicular to the specimen mounting surface. These two balls engage a pair of hardened steel cones that slide into holes drilled in the edge of the plate. Each cone is spring loaded to keep it against an adjustment screw accessible in the edge of the plate. Rotation of an adjustment screw causes the cone to move along its axis of symmetry and thereby change the amount by which the ball projects beyond the lower surface of the plate. The balls are located in a right-angled triangular pattern so that such movement of a cone causes rotation of the plate about one of a pair of orthogonal axes. The range of rotation is limited to $\pm 0.5^\circ$ about one of these axes and to $\pm 0.3^\circ$ about the other. The mounting plate is spring loaded to keep it and the steel balls in firm engagement with the carriage table. The cone adjustment screws are accessible by means of a special wrench that can be inserted through holes in the chamber door.

The test specimen can be precisely oriented with respect to the incident beam by means of the carriage adjustments described above. A telescope can be bolted to the rotary plate to allow autocollimation of the specimen. In this way the surface of the specimen can be set perpendicular to the beam to within $\pm 1'$.

5. Experimental Results

Teska has done a study of the refractive indices of ammonium dihydrogen phosphate (ADP) from 6563 to 1810 Å, and of magnesium fluoride to 1780 Å.² The probable error in the measurements above 1850 Å for magnesium

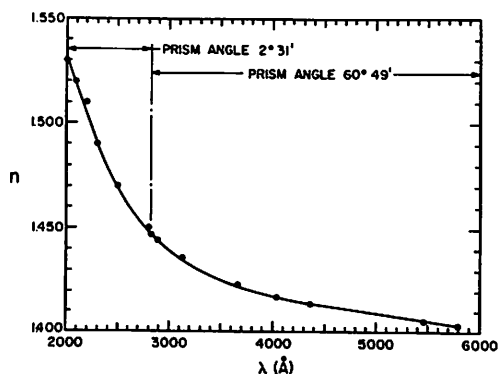


FIG. 6. Refractive indices of Dow-Corning fluid 200, 60 000 cS.

² T. M. Teska, *Appl. Opt.* (to be published).

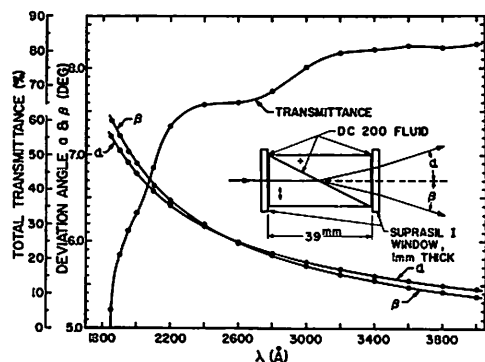


FIG. 7. Total transmittances and deviation angles of ADP Wollaston prism.

fluoride is ± 0.00004 . A comparison made for magnesium fluoride with the more precise measures made in the visible by Duncanson and Stevenson³ shows our data to be high by 0.00022. This difference might be due to an actual scatter in the indices of different samples. More probably it is due to a $30''$ error in the portion of our transit dial used to measure the deviation of the refracted beams. This degree of error is consistent with the ± 0.013 mm machining tolerance used in the construction of the instrument.

A 60° prism for liquid refraction studies was made. An epoxy jacket was molded around a glass tube which was fitted with Suprasil end windows. A space was allowed in the epoxy jacket for the circulation of liquid for the heating or the cooling of the fluid under test. Figure 6 gives the refractive index of Dow-Corning 200 fluid, which is used as the contacting agent in uv prisms down to 2000 Å.⁴ Different batches of Dow-Corning 200 fluid will have slightly different indices.

With proper elimination of stray light and dark current, it is possible to measure transmittances $\leq 0.005\%$ throughout the spectral range.

The instrument has been regularly used to measure the transmissions of filters and ADP Wollaston prisms, and the responses of ultraviolet phototubes. Figure 7 shows the transmission and deviations for a typical ADP Wollaston type polarizing prism made for the Polariscopes program.

Acknowledgments

The precise work of the machinists of the Physics Shop of the University of Arizona and of M. Sivilli is greatly appreciated. The illustrations for this article were done by T. J. Posedly and A. T. Cross.

³ A. Duncanson and R. W. H. Stevenson, *Proc. Phys. Soc. (London)* 72, 1001 (1958).

⁴ S. F. Pellicori, *Appl. Opt.* 3, 361 (1964).

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