Program of the 1959 Annual Meeting of the Optical Society of America

Chateau Laurier, Ottawa, Canada, October 8, 9, and 10, 1959

(Titles and Abstracts of Papers)

Leslie E. Howlett, *Chairman*

Invited Paper

T1. N.P.L. Symposium on Interferometry. K. M. Baird, *National Research Council of Canada, Ottawa, Canada.*—This talk will report on the Symposium on Interferometry held at the National Physical Laboratory of Great Britain on the 9th, 10th, and 11th of June, 1959. This symposium was concerned with interferometry in general including such aspects as length and wavelength measurement, moire-fringe interferometry, radio and microwave interferometry, photoelectric techniques, and optical testing. A number of exhibits were on display which demonstrated new work being done at N.P.L. as well as some work reported by guests at the symposium.

F. Dow Smith, *Chairman*

Contributed Papers

TA11. Improved Woodson Interferometer. Robert A. Woodson, *Link Aviation, Inc., Binghamton, New York.*—This paper is a sequel to the one that presented the Woodson interferometer,[1] an instrument that was specifically designed to measure the distance of a test point from a reference plane. The improved optical system retains the advantages of the original system while adding other important characteristics. The fringes may be reversibly counted[2] by a pair of photomultipliers and a counting circuit in the usual manner. The fringe count is directly proportional to the normal component of the motion of the test point regardless of the possible presence of other components in its motion. The test point may be located on a movable member in such a way that the fringe count is independent of the orientation of the movable member about any axis. The sensitivity is inherently twice that of the Michelson-type interferometer. The principal improvement consists of lengthening the fixed path so that the range of the order of interference is greatly increased. Both positive and negative orders may be encountered. Another improvement makes the dispersing prism integral with the reference path prism.

[1] Robert A. Woodson, J. Opt. Soc. Am. 48, 872(A) (1958).
[2] Edson R. Peck and S. Wendell Obetz, J. Opt. Soc. Am. 43, 505 (1953).

TA12. Phase Shift Effects in Fabry-Perot Interferometry. Charles J. Koester,* *National Bureau of Standards, Washington, D. C.*—A method is proposed and demonstrated for utilizing in Fabry-Perot interferometry the data on reflection-shift dispersion obtained from fringes of equal chromatic order. From the wavelengths of the fringes, the phase-shift dispersion can be measured to an accuracy of about 10 A. The data are then combined with the method of exact fractions to obtain the correct orders of interference for large spacers and to determine unknown wavelengths. The method is especially useful for reflectors with large dispersion of phase shift, such as multilayers. Results are reported for aluminum films and a pair of dielectric 15-layer broad-band reflectors.[1]

* Now with American Optical Company, Southbridge, Massachusetts. Work performed under a National Research Council Postdoctoral Research Associateship.
[1] P. W. Baumeister and J. M. Stone, J. Opt. Soc. Am. 46, 228 (1956).

TA13. Interference with Mercury-198 and a Path Difference of 2000 mm. Irvine C. Gardner and Karl F. Nefflen, *National Bureau of Standards, Washington, D. C.*—A Fabry-Perot spherical interferometer, as developed and described by Connes[1] has been constructed with a separation of 10 cm. It has been used as a monochromator and it is estimated that the width of the transmitted band is approximately 0.003 cm^{-1}. The maximum path difference available with the National Bureau of Standards' Michelson-type interferometer is 2000 mm, and with this difference interference was readily obtained. The fringes were photographed with exposures of one to four minutes and with fast film 15 to 45 sec. The experimental procedure will be described in some detail and possible applications to length measurement will be discussed.

[1] Pierre Connes, Rev. opt. 35, 37 (1956); J. phys. radium 19, 262 (1958); Colloq. intern., Les Progres Recents en Spectroscopie Interferentielle, (Editions du Centre National de la Recherche Scientifique, 13 Quai Anatole-France, Paris, France, 1958).

TA14. Rapid Precision Wave Number Measurements from Fabry-Perot Interferograms.* David W. Steinhaus, *University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico.*—In order to obtain the more accurate wave numbers needed for studies of the very rich heavy-element spectra, a new measuring and calculating procedure has been developed. A modern sharp-line source, like a hollow cathode tube or an electrodeless metal-halide lamp, is used to illuminate a vacuum interferometer (5-, 10-, or 20-mm spacer) which is crossed with a spectrograph resolving the free spectral range of the interferometer. The resulting interferogram is measured with a two-coordinate photoelectric comparator. IBM cards are punched with the measurements, and vacuum wave numbers are directly calculated with an IBM 704 computer. A mercury-198 line is the only standard needed and the index of refraction of air correction is used only to obtain air wavelengths. The dispersion of phase-change correction is obtained from measurements with two different spacers. Only a few minutes of reading time are needed for each line. This procedure is being used for a further study of the uranium spectrum with sources containing separated uranium isotopes.

Over 4000 measurements on lines near 4100 A have been made with a precision which seems to be better than 0.006 cm^{-1}.

* Work done under the auspices of the U. S. Atomic Energy Commission.

TA15. Applications of Interferometry to Astronomy. JAMES B. SAUNDERS, *National Bureau of Standards, Washington, D. C.*—An interferometer for measuring the aberrations of telescope objectives of all sizes and types has been developed and tested. It is quite applicable to the testing of astronomical refractors and reflectors *in situ*, concave mirrors (spherical or aspherical), and camera objectives. To test an astronomical objective the eyepiece of the telescope is replaced with a modified Kösters' double-image prism and the telescope is directed toward a bright star. Two symmetrically located pairs of coherent light beams emerge from the prism, one of which is received by a camera and the other by the operator's eye for maintaining adjustments of the interference fringes. The width of the fringes may have any chosen value and the contrast in the neighborhood of the zero order fringe approaches infinity. Owing to polarization effects in the prism, a Polaroid screen is used just back of it for obtaining contrast in the fringe pattern. Other important applications of this interferometer are: (1) for measuring the angular separation of binary stars, (2) for studying the turbidity of the atmosphere through which light travels to a telescope, and (3) in combination with photoelectric cells; the automatic control of telescope pointing.

TA16. Far-Field Diffraction Properties of a Plane Parallel Plate When Placed in Front of a Rectangular Diffracting Aperture.* A. I. MAHAN AND L. P. BONE, *Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland.*—Some rather unusual far-field diffraction effects can be found when a semi-infinite plane-parallel plate is partially inserted in front of a rectangular aperture. Two interferometer plates of different thicknesses have been used to observe these diffraction phenomena. Each interferometer plate was placed with its surfaces parallel to the plane of the rectangular aperture and its edges parallel to the edges of the rectangular aperture and then slowly moved across in front of the rectangular aperture from the "all out" position to the "all in" position. The conventional Fraunhofer pattern at the "all out" position is modified in an interesting manner and returns to a Fraunhofer pattern at the "all in" position. The changes which one sees are a function of the thickness of the interferometer plate. Another sequence of diffraction patterns has also been photographed when one of the interferometer plates is rotated about an axis in the plane of the rectangular aperture which is parallel to the long dimension of the aperture. These diffraction patterns differ in form and behavior from the previous ones. To explore the differences in these two phenomena, two moving pictures have been prepared consisting of about eight hundred three-minute exposures taken frame by frame when the displacements and angular rotations are decreased by a factor of ten. These pictures show in quite a striking way the differences between the two phenomena.

* This work supported by Bureau of Ordnance, Department of the Navy under contract NOrd 7386.

TA17. Spectroscopic and Photometric Studies of the Aurora during the IGY. M. H. REES, *Geophysical Institute at the University of Alaska, Box 938, College, Alaska.*—A report of the results which have been obtained from preliminary and selected analyses of the IGY data is given. The problems of auroral spectroscopy and spectrophotometry are briefly discussed with specific reference to the various instruments employed in auroral research at College, Alaska. New evidence has been obtained to clarify the relative importance of protons and electrons in the excitation of the auroral spectrum, both from a study of the normal polar aurora and a great red aurora which occurred on February 10–11, 1958. The observational results indicate that in a polar aurora protons are responsible primarily for the initial phase of a display while electron excitation accounts for the later and brighter stages in the auroral development. On the other hand, a great red aurora is associated with an unusually high proton flux. Preliminary results on the total energy involved in an auroral display are given.

TA18. Theory of Reflectance of Inhomogeneous Layer Structures and the Iridescence of Hummingbird Feathers. CRAWFORD H. GREENEWALT AND WERNER BRANDT, *E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware.*—The reflected interference spectra of iridescent hummingbird feathers have been measured spectrophotometrically for many species, and the surface structure of such feathers investigated by electron microscopy.[1] The structure was found to be periodic in optical dimensions. It consists of stacks of 5–8 pancake-shaped platelets of a material with refractive index ~ 2, each containing a structurally reinforced air gap. To interpret the interference spectra in terms of the surface structures, a theory is given of reflection coefficients of stacks of optically inhomogeneous films with alternatingly high- and low-mean refractive indices such that the films are joined by "optically continuous interfaces"; that is, the refractive index varies continuously and monotonically across the film interfaces. It is shown that such structures behave as reflectance filters for which the reflectance and band width vary as the optical density gradient at the film interfaces. The theory is applied to the iridescence of hummingbird feathers with satisfactory results.

[1] Greenewalt, Friel, and Brandt (to be published).

W. LEWIS HYDE, *Chairman*

Contributed Papers

TB31. Automatic Recording Spectropolarimeter. HELLMUTH RUDOLPH AND ROBERT BRUCE, *Rudolph Instruments Engineering Company, Little Falls, New Jersey.*—An automatic recording spectropolarimeter has been developed whereby rotary dispersion curves may be recorded in 20 to 30 min over an effective wavelength region extending from 210 $\mathrm{m}\mu$ to 680 $\mathrm{m}\mu$. Continuous monochromatic light is obtained over this region from an 165-w xenon lamp and monochromator of the Littrow type with fused silica dispersion prism. The polarimeter proper contains quartz polarizer and analyzer prisms of 6 mm effective aperture, an RCA No. 7200 photomultiplier, 20 cy preamplifier, two 60 cy servo-amplifiers with motors to turn the polarizer prism and to monitor the photomultiplier anode voltage. The analyzer prism is mounted in a rotary bearing with 10 cy mechanical oscillating means and electrical commutator to convert the photoelectric current to a null-sensing 60 cy signal for operation of the polarizer servo. The recorder is connected directly to the polarizer gearing to provide three linear optical rotation ranges of ±2°, ±20°, and ±200° along its 1000 mm vertical axis and both wavelength and time-base drives along its 500 mm horizontal axis. The basic sensitivity of the polarimeter is 0.001°. However, the actual sensitivity and accuracy vary with operating conditions and ranges. An over-all error of 1.1% was obtained in recording a quartz control plate whose calibrated rotation varied from $-10.73°$ at 680 mμ to $-167.73°$ at 210 mμ.

TB32. Two New Lightweight Military Binoculars. P. R. YODER, JR., *U. S. Army Ordnance, Frankford Arsenal, Philadelphia, Pennsylvania.*—Requirements exist within the military for improved binoculars providing the optical performance of existing standard instruments but with significantly reduced weight and bulk. Prototypes of a 6×20 minimum size binocular and of a 7×50 lightweight binocular developed by U. S. Army Ordnance in response to the foregoing requirements are now being evaluated by the U. S. Army to determine their suitability for field use. In this paper, the optical performance and physical characteristics of these new binoculars will be described.

TB33. Simple Periscope for Rear Vision from Automobiles. W. LEWIS HYDE, *American Optical Company, Southbridge, Massachusetts.*—A unit power telescope made of cylindrical lenses can be utilized in a simple periscope for tanks and airplanes.[1] This paper describes how the system can be adapted as a rear-view periscope for automobiles and similar vehicles. The objective lens is appropriately about 2 ft long and 2 in. high, set into a step in the roof of the vehicle. It throws light onto a long inverting mirror at a high angle of incidence and then onto a concave cylindrical mirror which constitutes the eyepiece of the periscope. This mirror can be located above the windshield like a conventional rear-view mirror, or below the windshield on the dashboard cowling. In cases where the eye of the driver does not conveniently fall in the exit pupil of the simple system a field lens may be added. An experimental model of this periscope has been built into a hardtop car, and this model contains such a field lens. Pictures will be shown of the experimental car.

[1] W. L. Hyde, J. Opt. Soc. Am. **49**, 506(A) (1959).

TB34. Ultra-High Speed Photographic Objective Utilizing Fiber Optics.* WALTER P. SIEGMUND, *American Optical Company, Southbridge, Massachusetts,* AND RALPH WIGHT, *J. W. Fecker, Inc., Pittsburgh, Pennsylvania.*—The use of a a convergent conical rod of glass to condense light is well known. A bundle of small conical rods or fibers will similarly condense light and also transmit an image. This principle has been applied in the design of a phtographic objective of high optical speed. The objective consists of a concentric catadioptric optical system having a pair of meniscus correcting lenses and a spherical mirror which forms a primary image on the larger face of a tapered bundle of optical fibers. This image is transmitted to the smaller face of the fiber bundle at an effective increase in optical speed. The design and performance of a system having a focal length of about 1 in., a field of 25° and an optical speed approaching $f/0.50$ will be described.

* The work described in this abstract was supported by the U. S. Air Force under Contract AF 33(616)-6171.

TB35. Properties of Optical Fibers.* ROBERT J. POTTER AND ROBERT E. HOPKINS, *Institute of Optics, University of Rochester, Rochester, New York.*—Many applications of fiber optics have been suggested, but it has been difficult to evaluate their feasibility because of the lack of sufficient data on the performance of optical fibers. Some of the practical properties (attenuation, decollimation, and angular distribution) of plastic scintillating fibers and glass fibers have been measured. Also the formal equations[1] for some of these properties have been numerically evaluated for various choices of the optical and geometrical parameters. The experiments will be described and the data compared with the calculated results.

* Supported in part by Air Force Contract AF 33(616)-6171 with American Optical Company and in part by the U. S. Atomic Energy Commission Contract AT (30-1)-375.

[1] R. J. Potter and J. W. Hicks, J. Opt. Soc. Am. **49**, 507 (1959).

TB36. Optical Wave-Guide Modes in Small Glass Fibers. I. Theoretical. E. SNITZER, *American Optical Company, Southbridge, Massachusetts,* AND J. W. HICKS, *Mosaic Fabrications, Inc., Southbridge, Massachusetts.*—The light transmission in fibers with diameters comparable to the wavelength of light is treated as a dielectric wave guide. Two sets of solutions are obtained, one of which is the same as that given by Schelkunoff.[1] The other solutions are also hybrid modes with the cutoffs given by the roots of $J_n(u_{nm})=0$. The radiation patterns for light leaving the end of a fiber is calculated by a modified vector Kirchhoff integral due to Stratton and Chu.[2] The results indicate that only the modes of the first set mentioned in the foregoing and with $n=1$ have forward radiation lobes.

[1] S. A. Schelkunoff, *Electromagnetic Waves* (D. Van Nostrand Company, Inc., Princeton, New Jersey, 1943), p. 425.

[2] J. A. Stratton and L. J. Chu, Phys. Rev. **56**, 99 (1939).

TB37. Optical Wave-Guide Modes in Small Glass Fibers. II. Experimental. H. OSTERBERG, E. SNITZER, M. POLANYI, R. HILBERG, *American Optical Company, Southbridge, Massachusetts,* AND J. W. HICKS, *Mosaic Fabrications, Inc., Southbridge, Massachusetts.*—Observations of dielectric wave-guide modes have been made on clad fibers with core diam from 0.2 to 8 μ. The index of refraction of the cladding was 1.52 and that of the core 1.53, 1.62, and 1.75. The different modes were excited by changing the angle of incidence of plane parallel light falling on the end of the fiber, or by changing the position of an Airy disk projected onto the end of the fiber. Both the direct image and the radiation pattern of the light leaving the fiber were observed by means of a 1.8-mm oil immersion objective. The observed cutoffs for the modes with nm combinations given by 11, 21, 31, 41, and 12 showed general agreement with calculated values. Photographic slides of the modes will be shown.

TB38. Optical Coupling Between Two Parallel Dielectric Wave Guides. E. SNITZER, *American Optical Company, Southbridge, Massachusetts.*—Because of the field penetration into the cladding of a dielectric wave guide, energy can be transferred between closely spaced fibers. The strength of the coupling and the shift in phase velocity is calculated by considering the z component of the electric field, E_z. For z and time dependences given by $e^{i(hz-\omega t)}$, it satisfies the inhomogeneous wave equation, $\nabla_t^2 E_z-(h^2-\omega^2\mu\epsilon)E_z+ih\nabla\epsilon\cdot\mathbf{E}/\epsilon=0$. ∇_t^2 is the two-dimensional Laplacian operator in the plane transverse to the guide axis and ϵ is the dielectric constant. An approximate solution can be obtained by expressing the electric field as a linear combination of the known fields for modes of a single fiber. The result is an oscillation of the energy between the two fibers with the oscillation frequency for loose coupling given roughly by an exponential of the fiber spacing.

TB39. Fiber Optics—Some Recent Techniques.* N. S. KAPANY AND D. F. CAPELLARO, *Armour Research Foundation, Physics Division, Chicago, Illinois.*—In the past, the major