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PROCEEDINGS

of the

Fifteenth Annual Meeting

UNIVERSITY OF VIRGINIA
CHARLOTTESVILLE, VIRGINIA

October 30, 31, and November 1, 1930

MINUTES OF THE MEETING

The fifteenth annual meeting of the Optical Society of America was held at the University of Virginia, October 30, 31, and November 1, 1930.

The meeting convened Thursday morning, October 30, the Society being welcomed by Dr. Edwin Anderson Alderman, President of the University.

THOMAS JEFFERSON

Thursday afternoon, October 30, the Society listened to an invited paper.

Some Aspects of the Scientific Work of Thomas Jefferson, by Prof. Walter S. Rodman, which gave a clear picture of Jefferson's varied scientific activities.

SESSION DEVOTED TO THE EXTREMES OF THE SPECTRUM

The session Friday afternoon, October 30, was devoted to papers on the extremes of the spectrum. The following papers were presented by invitation.

Optics of X-rays, by Prof. Arthur H. Compton.

Grating Measurements of X-ray Wave lengths and their Significance, by Dr. J. A. Bearden.

Optics of Radio-Transmission, by Prof. Ernest Merritt.

PUBLIC LECTURE ON RELIEF PICTURES AND PROJECTION IN RELIEF

On Thursday evening, October 30, Dr. Herbert E. Ives gave, by invitation, a lecture on *Relief Pictures and Projection in Relief*. The lecture was illustrated by special demonstrations of relief pictures including the stereoscope, the various stages of development of the parallax stereogram, the parallax panoramogram, and ending with demonstrations of two new types of projected pictures with stereoscopic relief.

BUSINESS SESSION

A brief business session of the society was held Saturday morning, November 1, President Jones presiding.

Informal reports of the secretary, the treasurer and the business manager of the journal were presented by the secretary. (Note: The society's fiscal year being identical with the civil calendar year, the officers' *formal* reports are made as of December 31 each year.)

In presenting the treasurer's report, the secretary read a telegram from Mr. Lomb regretting his inability to be present.

On a motion by Dr. Herbert E. Ives, the society directed the secretary to write a letter to Mr. Lomb expressing their regrets that he was unable to be present and their best wishes for his complete recovery.

FUTURE MEETINGS

The President announced the decision of the Council to hold a meeting in New York City in February and the annual meeting in Rochester, N. Y. in October.

On the President's invitation Dr. I. H. Godlove of the Museums of the Peaceful Arts, New York City, gave a short outline of the plan of their Exhibition on Color in connection with which sessions of the February meeting are planned.

VOTE OF THANKS TO THE UNIVERSITY OF VIRGINIA AND THE LOCAL COMMITTEE ON ARRANGEMENTS

Dr. W. E. Forsythe moved a vote of thanks to the University of Virginia and the local committee and all others who by their many courtesies and hospitality had contributed to a highly successful and enjoyable meeting. The motion was carried unanimously, and the secretary was instructed to communicate it to the President of the University and the local committee.

There being no other business, the business session was adjourned, and the reading of contributed papers taken up.

ATTENDANCE

The total registration was:

Members	53
Guests	29
Total	82

SESSIONS FOR THE READING AND DISCUSSION OF CONTRIBUTED PAPERS

Sessions for the reading and discussion of contributed papers were held as follows:

October 30, 9:15 A.M.	Television, Theory of Vision and Optical Instruments
October 30, 3:00 P.M.	Electro-optical Measurements
October 31, 9:00 A.M.	Photometry, Colorimetry, Polarimetry and Kerr Effect
November 1, 9:30 A.M.	Radiation, etc.

The authors' abstracts of these papers are appended.

MEETING OF THE COUNCIL

Sessions of the executive council were held as follows:

Wednesday, October 29, 3:15 P.M.
Wednesday, October 29, 8:20 P.M.
Thursday, October 30, 4:05 P.M.
Friday, October 31, 9:30 P.M.

(*Signed*) L. B. TUCKERMAN, *Secretary*

PROGRAM OF SESSIONS FOR CONTRIBUTED PAPERS

(TITLES AND ABSTRACTS OF PAPERS)

The abstracts were preprinted in the program subject to correction by the authors. Corrections that have been communicated to the secretary have been made in the abstracts reprinted below.

Thursday, October 30
9:15 A.M.

CONTRIBUTED PAPERS ON TELEVISION, THEORY OF VISION AND OPTICAL INSTRUMENTS

Herbert E. Ives **Bell Telephone Laboratories**

A MULTI-CHANNEL TELEVISION APPARATUS

A bar to the attainment of television images having a large amount of detail is set by the practical difficulty of generating and transmitting wide frequency bands. An alternative to a single wide frequency band is to divide it among several narrow bands, separately transmitted. A three channel apparatus has been constructed in which prisms placed over the holes in a scanning disc direct the incident light into three photoelectric cells. The three sets of signals are transmitted over three channels to a triple electrode neon lamp placed behind a viewing disc also provided with prisms over its apertures so that each electrode is visible only through every third aperture. An image of 13,000 elements is thus produced. For the successful operation of the multi-channel system, it is imperative to have very accurate matching of the characteristics in the several channels.

The present paper will appear in full in J.O.S.A.

Herbert E. Ives **Bell Telephone Laboratories**

SOME OPTICAL FEATURES IN TWO-WAY TELEVISION

The two-way television apparatus has been modified in several details, chiefly optical, since first demonstrated.[1] In place of scanning by blue light, light from both ends of the spectrum is employed, whereby more correct tone values of faces are obtained. Incandescent electric lamps are used instead of arc lamps to produce the scanning beams, and their large proportion of long wave energy is utilized effectively by a pair of caesium oxide, red-sensitive, cells added to the blue sensitive potassium cells previously used. At the receiving end, the discs have been furnished with condensing lenses over each hole, utilizing rays from a single large collimating lens focused on a small electrode glow lamp. A new general illumination of the booths has been provided of a yellow-green color to which neither the potassium or caesium cells are sensitive.

Bibliography:

[1] Bell System Technical Journal, July, 1930, p. 448.

The present paper will appear in full in J.O.S.A.

Herbert E. Ives **Bell Telephone Laboratories**

TELEVISION IN COLOR FROM MOTION PICTURE FILM

If a television scanning disc is placed close to the ridged film in a Kodacolor projector, and three photelectric cells are placed side by side in front of the projection lens, three sets of

photoelectric signals will be produced, each corresponding to one of the primary colors. It is not necessary to use the color filters ordinarily placed before the lens or color sensitive photoelectric cells, since the black and white strip images on the film contain the complete record of the characteristics of each colored image. The three sets of signals are transmitted over three communication channels and actuate a free color receiving apparatus previously described.[1]

Bibliography:
[1] Journal of the Optical Society of America, January, 1930, p. 11.
The present paper will appear in full in J.O.S.A.

Deane B. Judd **Bureau of Standards**

THE MIXTURE DATA EMBODIED IN THE TENTATIVE CURVES OF HECHT'S THEORY OF VISION

Dr. Selig Hecht[1] has recently proposed a modification of Thomas Young's theory of vision which has attracted considerable interest. To make his views specific he has put forward in a tentative way a set of response curves which he states possess the property of describing the facts experimentally determined by means of the mixture of color stimuli. In substantiation of this belief Dr. Hecht demonstrates that his curves are almost exactly duplicated by a transformation of the O. S. A. "excitation" curves which have been adopted widely as the standard description of the mixture relations characteristic of the normal visual mechanism.

If it could be shown that Dr. Hecht's curves duplicate exactly a transformation of the O. S. A. "excitaton" curves, the conclusion that his curves describe normal mixture data would be indisputable. Whether this conclusion is correct, however, cannot be judged from his own comparison because we cannot be sure that the apparently unimportant discrepancies are really negligible.

In the present paper a comparison of these two sets of curves is presented by a method which permits of the determination of the importance of the discrepancies found. It is shown that, in spite of the apparent agreement, Dr. Hecht's theoretical curves really embody mixture relations essentially different from those of the O. S. A. "excitation" curves; and, hence, his curves fail to describe the known facts arising from the mixture of color stimuli.

It is concluded that Dr. Hecht's methods of comparison are inadequate. But it should be stressed that Dr. Hecht's theory is not disproved by the findings of this paper; merely the first tentative set of curves has been shown to be unacceptable.

Bibliography:
[1] Selig Hecht, *The Development of Thomas Young's Theory of Color Vision*, J. O. S. A., *20*, 231–270; May, 1930.
The present paper will appear in full in J.O.S.A.

I. C. Gardner **Bureau of Standards**

THE CHROMATIC ABERRATION OF APOCHROMATIC MAGNIFYING SYSTEMS

The results of a series of tests on 17 apochromatic microscope objectives from 4 manufacturers and 10 compensating eyepieces from two manufacturers will be presented. The objectives were sensibly free from distortion and the average values of the lateral chromatic aberration for the objectives of the different manufacturers showed no important differences. The variation in the amount of compensation introduced by the different eyepieces was more significant than the variation found in the objectives. For the eyepieces the chromatic variation in distortion is an important factor in introducing the necessary compensation of the aberration of the objective.

Harold F. Bennett Bureau of Standards

THE RECIPROCAL SPHERICAL ABERRATION OF A LENS INCLUDING FIFTH AND HIGHER ORDERS

In this paper the reciprocal of the distance between the intersection of a ray with the axis and a fixed point on the axis is expressed as a power series in h, where h is the perpendicular distance from the ray to the fixed point. This fixed point of reference is ordinarily either the vertex or the center of curvature of the appropriate lens surface. Expressions are developed by which the coefficients of the series in the image space of any given plane or spherical surface may be computed if the corresponding series in the object space is given.

Supplementary formulas are then developed by which the aberrations may be referred to a different point such as the vertex or center of curvature of the succeeding surface. By means of these transfer formulas the computation may be carried through a lens system and a series expression for the aberrations obtained. Numerical applications and results are given and comparisons drawn with trigonometric ray tracing. Some relations to diffraction theory are also pointed out.

The present paper will appear in full in B. S. Journal of Research.

A. P. H. Trivelli and L. V. Foster Research Lab. Eastman Kodak Co. & Scientific Bureau, Bausch & Lomb Optical Co.

PHOTOMICROGRAPHY WITH WAVE LENGTH 365 mμ

By using a mercury arc lamp and Wratten filter No. 18-A we are able to isolate the mercury line 365 mμ for photomicrography. The microscope objectives were so built that both the mercury green line (546 mμ) and the ultraviolet line (365 mμ) are brought into the same focus. This makes focusing possible with Wratten filter No. 77, which isolates the mercury green line. By these means photomicrographs can be made by 365 *mμ* light by merely changing the filters. Examples of the results will be projected.

The present paper will appear in full in J.O.S.A.

David W. Mann Jefferson Physical Laboratory, Harvard University, and Mann Instrument Co.

MECHANICAL ACCESSORIES TO THE VACUUM SPECTROGRAPH

Methods of moving internal elements of the spectrograph while under vacuum are discussed from the viewpoint of the instrument designer and mechanician. It is the intention of the author to exhibit details of the spectrograph and related apparatus.

Thursday, October 30
3:00 P.M.

CONTRIBUTED PAPERS ON ELECTRO-OPTICAL MEASUREMENTS

Frederick Bedell Cornell University

REFINEMENTS IN LINEAR TIME-SCALE FOR CATHODE RAY OSCILLOGRAPH

In using a linear time-scale for a cathode-ray oscillograph, as in the stabilized oscilloscope[1] developed by Bedell and Reich, any tendency for the time-scale to be distorted, shown by a pinching together of successive wave lengths at left or right, is corrected by a biasing or equalizing voltage applied to the amplifying tube for the time-scale, so that successive wave lengths are equal. This correction, readily made by an equalizer on the control panel of the instrument, is for most purposes sufficient. When highest accuracy is desired, a remaining error due to a cloud of ions between the plates of the oscillograph tube (affecting the vertical as well as the horizontal scale) may be avoided by applying a bias[2] to the plates of the oscillograph tube itself. A linear relation is thus obtained between the deflecting potential and the displacement of the cathode beam.

Bibliography:

[1] *Stabilized Oscilloscope with Amplified Stabilization*, F. Bedell and J. G. Kuhn, Rev. Sc. Instr., I, 227, Apr., 1930.

[2] *Linear Correction for Cathode Ray Oscillograph*, F. Bedell and J. G. Kuhn, Phys. Rev., 36, 993, Sept. 1, 1930.

John A. Tiedeman **University of Virginia**

(Introduced by J. W. Beams)

THE EFFECT OF FIELD STRENGTH AND FREE ELECTRONS ON THE BREAKDOWN TIME OF SPARK GAPS

The Lichtenberg Figure Method [1,2] has been used to study the time required for electrical breakdown in gases, or the time lag of the spark, as a function of the applied field strength and the number of free electrons present. The discharge of a spark gap impresses an electric field across the spark gap under investigation, and at the same time permits a measurable number of electrons to be photoelectrically ejected from the cathode. The time between the application of the potential and the initiation of the discharge is measured by the position of the dividing line between two Lichtenberg figures formed around similar electrodes placed upon a photographic plate and attached to lead wires in the ground side of the gaps. The spark gap under investigation is contained in a charged metal casing which serves to sweep out residual ions. The cathode is of zinc and the anode of steel. A biasing potential on the cathode prevents electrons from escaping in the gap until the impressed potential exceeds the biasing potential, at which time the electrons begin to be released photoelectrically. The source of ultraviolet light was a properly time condensed discharge in air. The intensity of the ultraviolet light could be varied by moving it various distances from the spark gap under investigation. An iron arc was also used in this way. The number of electrons liberated per second from the cathode was measured by an electroscope. Some of the data are given below:

Field applied to gap volts/cm.	Time necessary for breakdown		
	Intensity 15 $\times 10^{-8}$ sec	Intensity 1 $\times 10^{-8}$ sec	Intensity 0 $\times 10^{-8}$ sec
150,000	1.3	1.4	2.0
75,000	1.8	2.3	>100
50,000	4.2	4.8	
42,700	6.2	7.0	
40,000	7.1	>100	
37,500	>100		

The data show that there is a definite limiting time lag of the gap that is approached asymptotically at a definite field strength as the number of electrons in the gap is increased.

Bibliography:

[1] Pederson, Ann. d. Physik., *71*, 317; 1923.

[2] Tiedeman, Phys. Rev., *36*, 376; 1930.

Friday, October 31
9:00 A.M.

CONTRIBUTED PAPERS ON PHOTOMETRY, COLORIMETRY, POLARIMETRY AND KERR EFFECT

Harlan T. Stetson Perkins Observatory, Ohio Wesleyan University

ON THE USE OF THE MACBETH ILLUMINOMETER IN THE MEASUREMENT OF THE BRIGHTNESS OF THE SOLAR CORONA

At the eclipse of 1925, the Macbeth Illuminometer was employed by a number of scientific observers for measuring the total illumination at the time of the eclipse on January 24th. From the discordant results published,[1] it was inferred that much of the difficulty lay in the indefiniteness with which the illuminometer was directed at the sun during the time of the eclipse.

During subsequent eclipse expeditions, 1926, 1927 and 1929, the apparatus was used by Stetson, Coblentz and Arnold,[2] in a fixed position directed to the sun at mid-totality. The right angled horn with diffusing screen added greatly to the convenience of operation and eliminated the difficulty of following the sun's motion. An important change in the design for eclipse purposes incorporates the arrangement of the several absorbing screens on two slides, one for the sky and one for the working standard. The new form was first put into operation in 1927, in Norway, but unfavorable weather prevented important results.

Measures of coronal brightness in Malaya, in 1929, have been recently reduced, the light curve being shown herewith. The measured brightness during mid-totality at the 1926 eclipse was 0.14 foot candles, and in 1929, 0.15 foot candles. There is some evidence that the illumination increases with increasing solar activity.

The apparatus is being used at the eclipse of October 22, 1930, in Niaufou, by Mr. Josef Johnson, Research Assistant of the Perkins Observatory.

The value of continued measurements of the brightness of the corona at times of total solar eclipses is enhanced by every addition of data, for it is by means of an accumulated series of such observations that we may hope to learn of the varying intensity of the coronal light with changing solar activity throughout the sun spot cycle.

Bibliography:

1 Transactions of the Illuminating Society, *20*, No. 6, 1925.

2 Astrophysical Journal, *66*, 65.

K. S. Gibson Bureau of Standards

AN ILLUMINATION SPHERE FOR REFLECTOMETRY AND PHOTOELECTRIC SPECTROPHOTOMETRY

Plans for a new photoelectric spectrophotometer were briefly outlined at a previous meeting.[1] The design of the illumination sphere there noted has been completed. This design is such that the sphere may be used with the Martens photometer, not only with the photoelectric cell as originally planned, but also visually with undispersed light (with or without filters). The sphere is of the general type proposed by Sharp and Little, by Karrer, and by McNicholas, but differs in details of design and of the resulting manipulation and observation. The following quanities can be measured with the present sphere:

(1) Apparent normal reflectance for diffuse illumination. By virtue of the Helmholtz reciprocal relations (as developed by McNicholas),[2] this quantity is numerically equal to the absolute reflectance for undirectional normal illumination.

(2) Apparent 60° reflectance for diffuse illumination. This quantity closely approximates for most materials[2] the absolute reflectance for diffuse illumination. Reciprocally, the quantity measured numerically equals the absolute reflectance for unidirectional 60° illumination.

(3) The analogous quantities for transmitted light.

For both (1) and (2) the sphere as a whole is rotated, carrying the sample from one beam to the other in accordance with the best method of use of the Martens photometer, and enabling the comparison beam to originate in turn from two different regions of the sphere wall. This last feature should assist in making the brightness of the comparison beam equal to the average for the whole sphere, which is necessary if correct values are to be obtained.

Bibliography:

[1] Gibson, J.O.S.A. and R.S.I., *18*, 166; March, 1929.

[2] McNicholas, B. S., Res. Pap., No. 3, July, 1928.

E. M. Lowry **Research Lab. Eastman Kodak Co.**

THE PHOTOMETRIC SENSIBILITY OF THE EYE AND THE PRECISION OF PHOTOMETRIC MEASUREMENTS

In this paper data are presented to show that for maximum photometric sensibility the brightness of the photometric field should be adjusted so that a brightness level of from 20 to 30 millilamberts is secured. At this brightness the difference fraction b/B has a value of 1.37 percent. Further the precision of photometric observations as expressed by the average percentage deviation, from the mean, of a single observation is 0.19 percent at the above mentioned optimum brightness level. At this same field brightness the maximum percentage deviation from the mean of a single observation was found to be 0.41 percent.

Bibliography:

[1] Nutting, P. G.: *Retinal Sensibilities Related to Illuminating Engineering.* Trans. Ill. Eng. Soc., *11*, 1, 1916.

[2] Blanchard, J.: *Brightness Sensibility of the Retina*, Phys. Rev., *11*, 81, 1918.

[3] Holladay, L. L.: *Fundamentals of Glare and Visibility*, J. O. S. A., *12*, 276, 1926.

[4] Uppenborn, F.: Lehrbuch d. Photometrie, p. 212.

[5] Dauber, J.: *Psychophysische Untersuchungen zur Photometrie.* Marbe's Fortschr. d. Psychol., *3*, 102, 1914.

[6] Wild, L. W.: *Electrician, 60*, 122, 1907–08.

The present paper will appear in full in J.O.S.A.

Deane B. Judd **Bureau of Standards**

PRECISION OF COLOR TEMPERATURE MEASUREMENTS UNDER VARIOUS OBSERVING CONDITIONS; A NEW COLOR COMPARATOR FOR INCANDESCENT LAMPS

The determination of the color temperature of incandescent lamps by visual comparison with a standard lamp previously calibrated radiometrically has heretofore been carried out at the Bureau of Standards either by mean of the 3° circular field of the rotatory dispersion colorimeter or by means of the 6° circular field of the Martens photometer. Preliminary to the construction of a color comparator which was to be designed to permit color temperature determinations with a maximum of precision, an investigation was made of the effect on precision of various observing conditions. It was discovered for one observer, corroborated to some extent by another observer, that: (1) The larger the fields to be compared as to color, the greater the precision of determination of color temperature; (2) the closer together the fields to be compared as to color, the greater the precision of determination of color temperature, but if the space separating the areas be black, observation is considerably more disturbed than if the space be of about the same color as the areas, themselves; and (3) use of both eyes gives no greater precision than the use of one eye, but if the one eye has to be held close to an artificial pupil, the precision is lowered.

It was also discovered that the retina of an apparently normal observer may be seriously asymmetrical in sensitivity; that is, a serious discrepancy in color temperature may result simply from interchanging the areas to be compared or from changing the shape or size of the field; this finding serves to emphasize the importance of using a strict substitution method in comparing lamps as to color temperature. The new color comparator which was constructed during the course of these preliminary measurements permits the visual determination of color temperature with a precision two or three times as great as that by the instruments previously used for this purpose at the Bureau of Standards.

The present paper will appear in full in B. S. Journal of Research.

William G. Exton **Prudential Insurance Co. of America**

ELECTRO-SCOPOMETRY

The present paper deals with an attempt to apply photo-electricity to measuring devices designed for the colorimetry and turbidimetry of laboratory medicine which were shown the Society on former occasions.[1,2,3,4] The instrument consists of two photo-electric cells, a rugged short period galvanometer and two fixed resistances in a simple Wheatstone bridge circuit. All connections are permanent. There are no electrical adjustments and the balanced circuit avoids the need of batteries, etc., for maintaining constancy of illumination and plate voltage.

Besides advantages in the way of unusual sensitivity, freedom from personal equations of observers, and avoidance of standardizing troubles, the Electro-Scopometer has proven remarkably stable in use and capable of reproducing calibrations. Its operation is so simple and rapid that routine and untrained workers can measure color and turbidity with an accuracy equal to or exceeding that now characteristic of research in this field.

After touching on some of the conditions peculiar to laboratory medicine the Electro-Scopometer and some of its applications are described.

Bibliography:

1 Exton, Wm. G.: *Turbidimeter*, J.O.S.A. & R.S.I., 6, 414; 1922.

2 Exton, Wm. G.: *A New and Direct Method of Measuring the Cloudiness of Liquids* (Scopometry), J.O.S.A. & R.S.I., *11*, 126; 1925.

3 Exton, Wm. G.: *A New Method of Colorimetry*, J.O.S.A. & R.S.I., *14*, 134; 1927.

4 Exton, Wm. G.: *Scopometry, Archives of Pathology and Laboratory Medicine*, *5*, fol. 49, 1928.

R. V. Baud **The Westinghouse Electric & Mfg. Co.**

CONTRIBUTION TO STUDY OF EFFECT OF ELLIPTICAL POLARIZATION UPON ENERGY TRANSMISSION

This paper contains the equation for the energy transmission in a polarized light equipment that is composed of lenses, two crossed polarizing prisms, two crossed mica plates in 45° position with respect to the prisms, and a light source that produces "white" light. This equation is as follows:

$$E = \left[\cos^2 2\beta + \sin^2 2\beta \cos^2 \left\{ \frac{(n_1' - n_2')\lambda}{(n_1 - n_2)\lambda'} - 1 \right\} \frac{\pi}{2} \right] \sin^2 \frac{\phi'}{2} E_o$$

where E_0 is the energy incident on a small area of the specimen, E the final energy as transmitted through the instrument for the same area of the specimen, ϕ' the phase shift in the specimen for a wave length λ', n_1' and n_2' the indices of refraction for the mica plates for a wave length (λ', n_1 and n_2 the indices of refraction for the mica plates for a wave length) λ corresponding to circular polarization, and β the angle between the axes of refraction of the specimen and the axes of the mica plates.

The present study of the energy transmission is primarily a continuation of previous photoelastic researches, see references below. However, it is believed that the equation given will be of interest and practical use not only for workers in the field of optical stress analysis, but also for investigators working with the same equipment along other lines.

Bibliography:
[1] *Further Development in Photoelasticity*, R. V. Baud, J.O.S.A. & R.S.I., *18*, 5, 1929.
[2] *The Analysis of the Colors Observed in Photoelastic Experiments*, R. V. Baud and W. D. Wright, *J.O.S.A.*, *20*, 7; 1930.
The present paper will appear in full in J.O.S.A.

E. C. Stevenson and J. W. Beams **University of Virginia**

A PRECISE METHOD FOR DETERMINING THE KERR ELECTRO-OPTICAL EFFECT IN GASES

The method[1] used for determining the Kerr electro-optical effect or electric double refraction in gases has been extended and made to yield greater precision. Light from a mercury arc or incandescent strip filament lamp passes through filters or a monochromator, is made parallel by a lens, and plane polarized by a polarizing prism. It then passes between two oppositely charged parallel metal plates (Kerr cell) the lines of force making an angle of 45° with the plane of vibration of the entering light, then a second or analyzing prism, and is brought to focus by a lens on the surface of a vacuum photoelectric cell, previously tested for linearity. The analyzing prism is oriented at any desired angle and, from ratios of light intensities measured with the photoelectric cell and an electrometer for particular settings of this prism, the amount of double refraction can be calculated. This method of measuring the double refraction gives better precision than the well known Brace half shade method. The intensity of the source is maintained constant by the use of a second photoelectric cell in series with a galvanometer. The polarizing and analyzing prisms together with the Kerr cell are enclosed in a heavy steel tube with glass windows in the ends to permit the passage of the light. The metal plates of the Kerr cell are insulated from each other and from the tube by bakelite. The connections are made through ordinary spark plugs. Placing the two prisms inside the tube makes it possible to study gases at a few hundred atmospheres pressure, without introducing errors due to strains in the windows. It gives the advantage of increased density and dielectric strength of the gas. Gas pressures are measured on a special spring gauge calibrated by a piston gauge, and electric potentials are obtained from a 5 kw x-ray transformer feeding a condenser through two kenotrons in parallel. The potentials are measured by the use of a long continuous flow water resistance. Any desired temperature between 0° and 80° C is obtained and kept constant to 0.05° C by immersing the steel tube in a suitable liquid, thermostatically controlled.

Bibliography:
[1] Beams and Stevenson, Phys. Rev. A, *35*, 1440, 1930.

J. W. Beams **University of Virginia**

SOME IMPROVEMENTS IN THE KERR CELL METHOD AND ITS APPLICATION TO THE STUDY OF THE TIME OF APPEARANCE OF THE SPECTRUM LINES OF HELIUM

Experimental methods are given by which the proper constants of the apparatus used in the Kerr Cell arrangement for measuring short time intervals[1] can easily be determined. Impulsive surges are impressed upon the wires leading to the Kerr Cell, and the potential across the cell measured by a spark gap intensely irradiated with ultraviolet light. From the value of this potential, determined with various lengths of lead wires, different amounts of resistance and various sizes of Kerr Cells, the shortest time of optical cut off can be obtained. The methods of testing for potential reflections and oscillations in the Kerr Cell, including a rotating mirror arrangement, Lichtenberg figure method, and a procedure based upon the rapid diffusion of luminous metallic vapor from the electrode surface toward the center of the spark gap, are described.

Utilizing constants that give the minimum time of optical cut off, the method has been applied to the study of the order of appearance of the visible spectrum in the initial stages of a condensed discharge through helium. The previous results[2] have been extended and a study made of the effect of pressure on the time of appearance of the lines. At the higher pressures (0.1 to 0.5 atmospheres) the lines appear very broad. A strong continuous spectrum appears in the very initial stages. The parahelium lines 5016 and 4922 appear before the orthohelium lines 4472, 5876 and 4713. The time between the appearance of 5016 (2^1S-3^1P) and 5876 (2^3P-3^3D) was found to decrease with increasing pressure which supports the conclusion of Ornstein[3] that the singlet levels are more readily excited by electron impacts than the triplet levels. Further that the orthohelium lines may result from secondary processes.

Bibliography:

1 Beams, Phys. Rev., *35*, 24, 1930.

2 Beams and Rhodes, Phys. Rev., *28*, 1147, 1926.

3 Ornstein, Jour. Franklin Inst., *208*, 589, 1929.

Arthur Bramley **Bartol Research Foundation**

MODULATION OF LIGHT WAVES IN WATER

In investigating the effect of radio waves on the frequency of the light passing through a Kerr cell, a change in frequency of certain of the lines of the mercury and iron arc towards the red was found.[1] Further investigation showed that the light passing through the cell was highly scattered and that this scattered light showed the wave-length change of 0.06A towards the red. In the original experiments, where the light was examined with a spectrograph, the spectrogram showed either a displacement of the position of the line towards the red or an unsymmetrical broadening without a change in the position of the maximum density, depending on the intensity of the scattered and unscattered light and on the form of the line emitted by the source.[2] These displacements are too large to be accounted for by the modulation of the light by the radio waves. These displacements are independent of the frequency of the radio waves and of the plane of polarization of the light. Both are contradictory to theory of electromagnetic modulation.

The broadening of spectral lines towards the red by 0.05A through scattering in liquids[3] and the symmetrical displacement of the lines of scattered light towards the red and the blue[4] both arise possibly from perturbing effect of neighboring molecules on the frequency of the vertical oscillators producing the scattering.[5] The results obtained by the writer for the magnitude of the change in frequency of scattered light agree with the results obtained by Cabannes and Gross for 90° scattering as we should expect if they were the same phenomena since the construction of the cell makes it possible for light scattered at various angles to leave the cell at a small angle with the primary beam.

The origin of the scattered light is probably the metallic ions brought into solution from the electrodes by the high frequency field which also is shown by the absorption bands of the liquid for high frequency radio waves.

Bibliography:

1 J. of F. I., *207*, p. 316, March, 1929; Phys. Rev. (A), *33*, 279.

2 Phys. Rev. (L), *34*, 1061.

3 Cabannes C. R., *188*, 907.

4 Gross, Nature, *126*, 201.

5 Schutz-Mensing, ZS. f. Physik., *61*, 655.

Saturday, November 1

9:30 A.M.

CONTRIBUTED PAPERS ON RADIATION

A. H. Taylor **Lighting Research Laboratory, Nela Park**

ULTRAVIOLET RADIATION FROM THE SUNLIGHT (TYPE S-1) LAMP

The Sunlight (Type S-1) lamp, which made its debut about a year ago, furnishes light of a color appreciably whiter than that from an ordinary gas-filled tungsten lamp, together with biologically-important ultraviolet radiation. Physically, it is a lamp combining incandescent tungsten with a mercury arc, enclosed in a special bulb having a high transmission in the region of 3000 Angstroms (λ3000), and a rapidly decreasing transmission for shorter wave lengths, becoming negligible below λ2700. It operates on a special transformer, and starts automatically when the current is turned on.

The distribution of energy in the spectrum of a Sunlight (Type S-1) lamp, chosen as representative of a group of 15 new lamps, has been carefully measured from the shortest wavelength emitted to λ7400. Energy values for each of the important spectral lines from the arc have been evaluated, also the continuous spectrum component in bands 100A wide. The measurements were made at rated voltage under two different conditions as follows: (A) in open air, axis vertical; (B) in open air, axis vertical, with temperature artificially altered to reproduce the electrical conditions existing in the lamp when operated in a Sunlamp reflector. The measurements were made for energy radiated in a direction normal to the plane of filament and electrodes, and energy values are expressed in percentages of the *total energy radiated in this direction.* The table below summarizes the results for important spectral regions.

	Per cent of total energy	
Wave-length region	Operated in open air	At temperature of operation in sunlamp
Shortest to λ2800	0.03	0.05
λ2800 to λ3200*	1.65	2.45
λ3200 to λ4000	1.56	2.55
λ4000 to λ7400†	9.50	7.8
Total, shortest λ to λ7400	12.74	12.85

* Biologically-important ultraviolet region.

† Visible spectrum.

The present paper will appear in full in J.O.S.A.

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ENERGY FLUX OF WAVE LENGTHS SHORTER THAN 3150A FROM THE GENERAL ELECTRIC SUNLAMP UNIT

The spectral distribution of energy flux from the Type S-1 lamp, the source of radiation in the General Electric Sunlamp, has been determined by means of a quartz monochromator and thermopile. The experimental method and detailed results will appear in an article by the author in the Physical Review. The ratio of the amount of ultraviolet radiation below 3200A received from the Sunlamp unit to that from the lamp without reflector has been determined in this laboratory by Miss Easley.[1] She has also measured the average temperature of the mercury pool with the lamp in and out of the reflector. The changes in the relative intensity of the principal ultraviolet lines with varying mercury pool temperature have also been determined.[1] Luckiesh[2] has published curves for the reflectance of polished aluminum and aluminum oxide powder. By taking the average of data from these two curves approximate values for the relative reflectance at different wave lengths of the oxidized aluminum reflector are obtained. Correlating all these data, the energy flux in each of the principal ultraviolet bands below 3200A may be computed. The results indicate that the energy flux per cm^2 at one meter distance directly below the Sunlamp unit is 67 microwatts for the group of lines at 3130A, 23 for the lines at 3024A, 12 for the line at 2967A, 3 each for the 2894 and 2804A lines, 2 for 2650A, and 0.3 for 2537A. The figures refer to normal operation with 115 volts on the primary of the transformer. These data are not directly comparable with those given by Coblentz[3] since he measured the radiation from the Sunlamp without the screen. However, measurements made in this laboratory show that without the screen the energy flux density of wave lengths shorter than 3200A averages 126μw (microwatts) per cm^2 at 1 meter distance. From Coblentz's data a corresponding figure of 96μw per cm^2 at 36″ distance is obtained. The agreement is satisfactory since the output of individual lamps may differ from the average by 20 percent. Data published by Gordon and Benford[4] is in apparent disagreement with ours because their reflector gave a broader less concentrated beam than the ones measured by Miss Easley.[1] Taking this into account the agreement is very satisfactory.

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THE ABSORPTION OF RADIATION FROM DIFFERENT SOURCES BY WATER AND BY BODY TISSUE

There are a number of infrared or total radiation devices on the market intended for therapeutic purposes which use as the source of the radiation, heaters that vary from low temperature blackened iron surfaces to high temperature tungsten lamps. In the use of these infrared radiators it is important to know whether the radiation is to be absorbed in a very thin layer near the surface of the body or whether it is desired to have the radiant energy penetrate deep into the tissue, because as shown in what follows, it is possible by the selection of the source of radiation to determine whether the radiation that is not reflected from the surface shall be absorbed in a very thin layer near the surface or whether a considerable portion of it shall penetrate deep into the tissue of the body. Since the body is made up of a very large percentage of water, radiation that will not go through water will not penetrate very deep into the body tissue. The transmission of different thicknesses of water has been calculated for the radiation from four different sources: iron heater at 1000° K., carbon lamp at 2150°K., tungsten lamp at 2970°K., and radiation from the sun. Cartwright[1] has presented some data on the spectral transmission of the human cheek. Making use of these data the amount of radiation from the four above sources transmitted through different thickness of body tissue has been calculated and the results given in the table. From these results it can be seen that if it is desired to have the radiation penetrate deep into the body tissue the high temperature source should be used.

Transmission of radiation from different sources through different thickness of water and body tissue

Flesh	Iron heater 1000°K.	Carbon lamp 2150°K.	Tungsten lamp 2970°K.	Sun
1 mm.............:	0.58%	15.0%	30.0%	29.0%
1 cm..............	.02	.9	1.9	2.3
Water				
1 mm..............	3.1	35.	66.	85.
2 mm..............	1.4	28.	59.	81.
5 mm..............	.5	20.	51.	76.
1 cm..............	.25	15.	43.	71.
2 cm..............	.10	11.	36.	65.
1 cm water and 1 mm flesh			19.	
1 cm water and 1 cm flesh			1.2	

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The present paper will appear in full in J.O.S.A.

F. L. Mohler **Bureau of Standards**

INTENSITY DISTRIBUTION IN THE EMISSION SPECTRUM OF CÆSIUM

The spectrum was excited in a thermionic discharge between an axial cathode and a cylindrical anode with vapor pressures usually between .08 and .8 mm and discharge current of the order of .5 amp at 6 volts. Under these conditions, the continuous spectrum from recombination of cæsium ions and electrons as well as the line spectrum of neutral cæsium is emitted. Intensity measurements were made by direct visual and photographic matching of the discharge spectrum with the spectrum of a calibrated tungsten strip lamp. Results on line intensities have been plotted with the log of the intensity in quanta per second as ordinates and the log of the effective total quantum number, n (square root of the Rydberg denominator), as abscissæ. Then the line intensities in each series fall in a curve which is closely linear for n greater than 5 and the linear portions of the curves are parallel for different series. In the range of discharge conditions specified the slopes remained between 5.5 and 6.0 but at low pressure the slope becomes much greater. That is, the intensity varies inversely as the 5.5 power of n or faster.

In so far as the plots for different series approximate parallel lines the intervals between these lines measure the intensity ratios between series. These ratios remained nearly 1 to 10 to 25 for the sharp, diffuse and fundamental series.

C. Boeckner **Bureau of Standards**

PROBABILITIES OF RECOMBINATION INTO THE 1S STATE OF CÆSIUM

Measurements were made of the intensity distribution in the continuous emission band, appearing at the 1S series limit of cæsium using a low voltage thermionic discharge in the vapor as a source. The wave length range covered lay between the series limit at 3184A and about 2750A. The methods of photographic densitometry were employed and a tungsten strip lamp in quartz was used as a comparison source.

From the variation of intensity with wave length and the velocity distribution of the discharge electrons (obtained from probe wire measurements) were computed the relative probabilities of recombination of free electrons into the 1S state as a function of their initial velocities. The method is that given by Mohler and Boeckner.[1] Previous work has shown that the probability of recombination into the 2P and 3D state of cæsium varies approximately inversely as the square of the velocity of the free electron, a relation which is also predicted by quantum mechanics for recombination into any level of a hydrogen atom. The present measurements show that the probability of recombination into the 1S cæsium level falls off much more rapidly with the velocity; for electron speeds greater than .15 volts more nearly as the inverse fourth power.

From the probability of recombination with emission of light a thermodynamical relation given by Milne enables one to deduce the probability of the inverse process, namely, the absorption of light and the ejection of a photoelectron. This latter probability has been measured directly as a function of wave length by Mohler and Boeckner and by Lawrence and Edlefsen. There are some discrepancies between the measurements of these different workers. It is found, however, that the absorption wave length curve deduced from recombination probabilities lies between the two curves obtained by direct measurement and agrees with either within the experimental error.

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FINE STRUCTURE OF COPPER LINES IN THE VISIBLE

The brighter lines given by a copper vacuum arc were examined with a Fabry-Perot Interferometer using separators of 2.7, 5.4, and 10.8 mm. Three lines 5782 ($m^2D_2-2^2P_1$), 5700 ($m^2D_2-2^2P_2$), and 4705 ($a^4F_4-c^4D_4$) appear to be double. The separation of the components is about 0.20 wave number units in each case. For 5782 and 5700 the component of longer wave length appears to be sharper than the other and about three times as intense. For 4705 the components are more nearly equal, but one of them must be more hazy or complex than the other for with the 10.8 separation only one set of rings is observed against a darkened background. The notation is that of Shenstone.[1] Burns and Walters[2] suspect the 3^2P_2 level of being double, and state that the c^4D levels present some difficulties as D_4 appeared to be single and D_1 multiple.

The other bright lines in the visible appeared to remain sharp except that 5106($m^2D_3-2^2P_2$) is widening at 10.8 mm, but the separation is less than for the three lines measured. The measurements are more or less in agreement with Wali-Mohammad.[3]

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(Introduced by J. W. Beams)

THE DARK CURRENT TIME IN CONDENSED DISCHARGES IN AIR AT ATMOSPHERIC PRESSURE

In order to measure the time during which current flows in condensed discharges prior to the appearance of luminosity it is necessary to determine the time at which the discharge is initiated as well as the interval between the initiation and the appearance of luminosity. In this experiment the discharge is initiated by ultraviolet light from another spark gap. The light from this tripping gap is focused by a quartz lens on the cathode of the second gap. The combined light from the two gaps after reflection by a rotating mirror is focused by another lens on a photographic plate. The separation of the images on the plate gives a measure of the dark current time. By using the high speed rotating mirror developed by Henriot[1] and Hunguenard and improved by Beams,[2] a resolving power of 1.7×10^{-7} second was obtained. The dark current time was found to be a function of the electrode geometry. For symmetrical hemispherical electrodes 4 mm apart the time is not greater than 1.7×10^{-7} second. This time increases to approximately 3×10^{-5} second for a gap with two spherical electrodes, the positive 25.7 mm in diameter and the negative 1 mm in diameter. As near as this method is capable of determining, in all cases the luminosity appears at the same time throughout the gap.

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A PLATE REFRACTOMETER FOR DEMONSTRATIONS

The instrument consists of a piece of plane-parallel glass (plate glass) about 5 cm square and of about 3 mm thickness. The lower side of the glass is painted white. Illumination is effected by means of an auto headlight lamp whose filament-image is projected downward on the glass-paint interface by means of a short-focus convex lens. This image ought to be less than 0.5 mm in diameter but of great sharpness and brilliancy. When viewed in a darkened room, the plate reveals a central brilliant spot surrounded by a black disc. The boundaries of this disc are defined by the critical angle between glass and air. If, now, the upper glass surface be moistened with water, a second and larger ring also appears. This ring is due to total reflection at the water-glass interface. By using a piece of glass on which a millimeter scale is ruled and by covering this with white paint, it is possible to read off circle-diameters to 0.1 mm with a reading glass. If the thickness of this plate be about 5 mm, refractive indices may be measured to the third decimal place. By making use of multiple reflections it is possible to construct a precision instrument whose performance rivals that of the best of present-day refractometers.