9. COMMISSION DES INSTRUMENTS ASTRONOMIQUES

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9a. SOUS-COMMISSION DES CONVERTISSEURS D'IMAGES

PRÉSIDENT: W. A. Baum.

MEMBRES: MM. Duchesne, Fellgett, J. S. Hall, Hiltner, Krassovsky, Lallemand, Leighton, McGee, Morton, A. G. Wilson.

PROGRESS IN INSTRUMENTATION

Rösch reports that the new dome described at the Dublin meeting is being built at the Pic-du-Midi. Two wide-field monochromators after the design by Lyot have been built. One now in use is for $\lambda 5303$ and $\lambda 6374$; one in the course of adjustment is for $\lambda 5694$. Dolfuss is testing a photo-electric polarimeter of his design for the white corona. Michard has designed and is using a spectrograph for the study of solar flares from the ultra-violet to the infra-red with an average dispersion of 1 Å/mm. Rösch has designed for Earth-light measurements for the I.G.Y. a new type of visual photometer, of which eight are being built in their workshops.

Hiltner reports that a new 36-inch reflector, designed primarily for photo-electric photometry, is now in use at the McDonald Observatory. Van den Bos has found the telescope, which is used at its Cassegrain focus, excellent for double star measurements. The telescope has an ellipsoidal primary mirror and a spherical secondary. Photo-electric equipment, including an offset guiding arrangement, has been constructed for photometric work on faint objects with the 82-inch telescope. Magnitude 21·5 has been reached so far. Errors of observation, larger than expected, are attributed to variable background. Steps are being taken to reduce this source of error by measuring background simultaneously with a second photomultiplier. Efforts are being made at Yerkes-McDonald to secure multipliers with unusually sensitive cathodes by the statistical process of investigating many samples. Hiltner emphasizes the importance of highly efficient cathodes for critical photo-electric work. An eight-colour photometer is being tested, and a lead sulphide cell photometer employing an Eastman cell is now in use.

McMath reports the completion and routine use of the 15·24 m focal length vacuum spectrograph, which has performed without trouble since being placed into operation [1, 2, 3]. An auxiliary direct recording instrument plots automatically on paper tape loci of constant density of astronomical photographs. Experiments were made without success to increase the speed of the vacuum spectrograph by means of a Bendix-Friex Lumicon (see report of Sub-Commission). A radio flare recorder is in operation for the I.G.Y., and a receiver for 226 Mc/s direct recording of solar radiation has been installed. A Wadsworth type 1½ m concave grating spectrograph is in use for flares in the 50 ft solar tower. The Stone radial-velocity spectroheliograph in the 50 ft tower has been changed to photograph a short section of the solar spectrum in the Hα region at moderate dispersion.

H. W. Babcock reports that an improved magnetograph [4, 5], incorporating an image slicer and functioning in two spectral lines, has been installed in the 150 ft tower at Mount Wilson, and is in regular use. The newer grating ruling machine at the Mount

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Wilson Observatory [6] is still producing limited quantities of ultra-precise gratings. The quality and size of these gratings are still being improved. An improved Babcock guider [7] has been in use at the coudé focus of the 200-inch telescope for two years. Also, an exposure meter [8] is in operation at the 200-inch, where it has been of great practical value in obtaining well-exposed spectra. Experimental work is being done with 'template spectroscopy', for determining radial velocities and evaluating Zeeman effect. A photographic template of a spectrum is traversed over the real spectrum, and a photomultiplier senses coincidence. Zeeman effect can be measured by adding analysing equipment. Experiments are being conducted on 'pneumatic mirrors', thin, aluminized films of organic materials, stretched into a plane and stabilized by the viscosity of a thin layer of air trapped between the film and a closely spaced backing-plate. This principle could form the basis for making paraboloidal mirrors by changing the pressure between the film and the backing-plate. Even lenses of low power could possibly be built by containing a high-density gas between two transparent films. An immediate application for plane mirrors appears to be for the flats for solar telescopes. Three- and ten-inch mirrors tested at Mount Wilson have shown encouraging results. Baum reports that infra-red photo-electric photometry is now being done at the Mount Wilson and Palomar Observatories with an infra-red multiplier kindly furnished by Lallemand, and with a small-cathode multiplier supplied by the Farnsworth Electronics Company. Experiments are also being made with multi-alkali photo-surfaces supplied by R.C.A. The cathode sensitivities of these surfaces have been found to be high, but they yield low secondary multiplication. Two complete new photometers have been built for the 60- and 100-inch telescopes. They will ultimately be operated with chopper-type amplifiers and charge integrating systems.

G. M. Sisson reports the completion by Sir Howard Grubb, Parsons and Co., Ltd, of a 75-inch reflecting telescope [9] for the Saint Michel Observatory. This telescope has a ventilated tube which, according to experiments made at Saint Michel, improves the local seeing.

Väisälä reports that the recently founded Institute for Astronomical and Optical Research, belonging to the Turku University, is being built at a site about 12 km from Turku [10]. A 400 mm zenith tube is being constructed. With this instrument observations can be made either photographically or visually. The great speed of the tube enables some stars near the zenith to be observed throughout the year. A field-flattening telescope is being constructed in the underground laboratory of the Institute for observations of minor planets and comets. Mirror and meniscus-correcting plate are 70 cm in diameter, focal length is 172 cm [11].

Evans reports that the microphotometer at the Sacramento Peak Observatory is now in the final stages of development. This microphotometer yields an output directly in either intensity or log intensity. The basic electronic circuit is similar to that described by Sweet [12]. The output is recorded by a Brown recording potentiometer. An 'Autograph' curve follower [13] will convert the output signal into intensity or log intensity. A digitizer attached to the Brown recorder will record the output as a column of numbers. In a year and a half of operation, the microphotometer has proved itself to be accurate, reliable, and efficient.

A 40-inch general purpose reflecting telescope for the Dominion Astrophysical Observatory is ready for bids from prospective manufacturers.

The 36-inch reflector for the new observatory at the University of Wisconsin is under construction. Buildings for the new observatory are under construction at a site west of Madison, beyond the influence of the city lights.

At the Lick Observatory, the final figuring of the mirror for the 120-inch telescope is being conducted by Hendrix. Mayall and Vasilevskis are making Hartmann tests on stars, to monitor the progress of the figuring. Bidelman and Herbig have placed into successful operation on the 36-inch refractor a grating spectrograph of their design. The 22-inch Tauchmann reflector is in service as a photo-electric telescope. The rehabilitation and modernization of the old and worn original telescopic equipment of the observatory, begun about 1948, is about complete. A two-storey laboratory building is expected to be finished about spring, 1958. All infra-red and six-colour photometry, as well as much photometry in the blue and yellow, is being done with photo-multipliers kindly supplied by Lallemand.

At the Royal Greenwich Observatory the 20-inch (Isaac Roberts) and 30-inch reflectors are both in service for photo-electric photometry and a visual double star programme has been started with the 28-inch refractor. The 26-inch parallax refractor and the 13-inch astrographic should both be ready soon after the beginning of 1958. The 36-inch Yapp reflector will be put in service sometime during 1958. Both the PZT and the Cooke transit circle have been put into operation since the Dublin meeting. The new office and laboratory building is partially occupied and will be fully occupied by February 1958.

The following report on progress in observatories in U.S.S.R. has been communicated by O. A. Melnikov.

Pulkovo. A new high-power 18-cm zenith-telescope (one from a series completed in connexion with the I.G.Y. programme) ($f=240$ cm) and a 25-cm photographic zenith tube ($f=400$ cm) have been installed at the Pulkovo Observatory. Besides the standard transit instrument, another based on the original, N. N. Pavlov system with hidden pivots was constructed. A photo-electric device and a mirror transit instrument (Yu. P. Platonov and V. B. Sukhov) were built.

A new zenith telescope (one of a series) was installed in Blagovetschensk on Amur (the new department of the Pulkovo Observatory).

The work connected with the application of pendulums as height precision levels (L. A. Sukharev) is progressing successfully.

The Pulkovo meridian circle was transported to the Nikolaev department.

New meniscus systems of telescopes with very small field aberrations and screening of the pencil of light by secondary mirror are proposed and designed by D. D. Maksutov. D. D. Maksutov also worked out a compensation method for the control of primary mirrors of large telescopes (ellipsoids, paraboloids and hyperboloids) and the methods of independent control of the form of a secondary convex mirror. Methods for the manufacturing of cellular (ribbed) metal mirrors with diameters up to 70 cm ($f/3$), the edge effect of which is reduced ten times below that of glass, are being mastered. A 50/50-cm meniscus telescope with coudé focus was also installed.

The coronograph, heliograph and spectroheliograph were installed at the mountain station of the Pulkovo Observatory.

Radio telescopes (notably one at the Pulkovo Observatory with 120×3 m reflector) were installed.

Sternberg Astronomical Institute (Moscow). A new meridian circle is being completed at present. The following instruments have been installed: a 25-cm Pulkovo type zenith-tube; a 23-cm wide-angle astrograph with a field of $6° \times 6°$ for photographic astrometry ($f/10$); a 70-cm classical type reflecting telescope ($f/4{\cdot}5$) with accessories (a similar instrument is installed at the Observatory of the Academy of Sciences of the Ukrainian S.S.R. at Goloseevo, near Kiev); 50/70-cm and 25/30-cm meniscus telescopes with objective prisms. Numerous solar instruments were also installed.

A 40-cm Zeiss astrograph with a large field and other smaller instruments were installed at the Kutchino station.

Crimea. The classical-type 122-cm Zeiss reflecting telescope with spectrographs was mounted and tested after its full repair. A double 40-cm Zeiss astrograph of the Moscow type, a 64-cm ($f/1{\cdot}4$) and 50-cm meniscus telescopes and others have been built.

The group of solar instruments consists of the tower telescope with a spectrograph and a spectroheliograph (coelostat mirror—70 cm and a supplementary mirror of 60 cm), a Lyot-type coronograph and others.

The nebular Struve-type spectrograph is successfully working at the Simeis department; there is a similar instrument at Burakan.

Burakan. A 50/50-cm Schmidt telescope and a number of radio telescopes, interferometric ones in particular, have been installed. The work connected with the building of a radio telescope with four cylindrical mirror-reflectors (total area of 4500 m^2), installed according to the Cross-type radio-interferometer principle, is nearing completion.

Alma-Ata. A 50-cm meniscus telescope ($f/2{\cdot}4$), a 50-cm reflecting telescope, a 20-cm refractor and others are successfully operating. A Lyot-type coronagraph was installed at the Mountain station on the altitude of 2600 m.

Abastumani. The semi-automatic meniscus 70/98-cm telescope ($f/3$) with a 72-cm objective prism and slit spectrograph have been installed and are now working successfully.

A standard chromosphere-photospheric telescope giving solar images of 20 mm and 50 mm in diameter at a band-width of 0·5 and 1·2 Å through the interference-polarization filter was also installed. A mounting for solar radio-observations on 209 Mc/sec frequency, an electrophotometer for observations of the twilight glow, a spectrograph for the night sky and a three-channel photo-electric ozonograph have also been installed; the latter in connexion with the I.G.Y. programme.

Kiev (*Goloseevo near Kiev*). A 40-cm astrograph ($f/13{\cdot}7$) for photographic astrometry, a 19-cm vertical circle, chromosphere-photospheric telescope and other instruments have been installed. An automatic lunar plate-holder, a compact blink-microscope and a six-camera astrograph (A. A. Jakovkin) have been designed. (*Bull. Central Astr. Obs. Acad. Sci. Ukr. S.S.R.* **1**, 20, 1956).

Standard transit time-service instruments, an 18-cm zenith-telescope, meteor patrol-cameras were installed in the Kiev, Odessa, Ashkhabad, Stalinabad and other observatories in accordance with the I.G.Y. programme. E. N. Kramer designed a three-blade obscurator of variable cross-section.

It should be mentioned that V. E. Stepanov and A. A. Kapustiansky (Lvov observatory) developed a solar diffraction spectrograph with double reflection and of a high resolving power (*Bull. of Solar Commission*, 10/24, 1954).

Kharkov. L. I. Kassel published a number of papers including: (1) Hydraulic engine for the Kharkov Observatory spectroheliοscope (*Kharkov Obs. Circ.* no. 7, 1951); this mechanism provides uniform motion of the plate in front of the spectrograph slit. (2) An instrument for the photographic recording of meridian-circle divisions (*Kharkov Obs. Circ.* no. 7, 1951); circle divisions are photographed on a film.

Engelhardt. N. D. Kalinenkov has designed an oscillographic microphotometer for the study of spectra obtained with a prism camera. The results are registered on the oscillograph screen of 32 mm diameter.

Odessa. A series of meteor patrol-cameras, a part of which with obscurators of variable cross-section have been manufactured in Odessa under the direction of V. P. Tsesevich. A 7-camera astrograph for a sky region of 120° × 40° has been designed (V. P. Tsesevich); a panoramic arrangement of object glasses is used.

Other instruments, for example for two-colour sky service, have also been constructed.

PHOTOGRAPHY

Fellgett has computed some quantum efficiencies for some photographic emulsions from homogeneous granularity and sensitometric data recently made available by Eastman Kodak. He finds quantum efficiencies as high as 1%, some ten times greater than has been thought. Proper techniques may bring into service the full effects of this efficiency, and the margin of expected superiority for the electronic image tube may be considerably reduced.

PROPOSALS

Rösch suggests that Commission 9 may be a more suitable commission under which to handle problems of 'seeing' than Commission 25. He points out that Commission 25 would naturally emphasize the photometric aspects of seeing, which is only about one-third of the whole problem.

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Dimitroff would like to undertake a survey of existing astronomical instrumentation, including instrumentation for radio astronomy. He has already made a partial survey of this kind, and would be able to complete it with little further trouble. He would like the official backing of the I.A.U. Dimitroff would also like to have an agreement to define and standardize the technical terms used to describe the instrumentation in radio astronomy.

As president of Commission 9, I am aware of the weak contact with radio astronomy that is indicated by the contents of this Draft Report. With the expansion of the activities and facilities of radio astronomy, it may be well to consider lightening the load of Commission 40 by treating instrumentation under Commission 9.

G. E. KRON

President of the Commission

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9*a*. SOUS COMMISSION DES CONVERTISSEURS D'IMAGES

Photo-electric image tubes and their astronomical applications were reviewed in 1955 at a Joint Discussion held in connexion with the General Assembly of the I.A.U. at Dublin (*Trans. I.A.U.* **9**, 673, 1955). This is a field of rapidly growing activity, and much work has been done since the Dublin meeting.

Most of the activities in this field fall into two general categories: (*a*) experiments involving image-converter tubes, and (*b*) experiments involving signal-generating (television-type) image tubes. In systems of the first type, an optical image incident upon the photocathode of a converter tube is directly reproduced in a recordable form elsewhere in the same tube. In systems of the second type, the image is transformed into a modulated electrical current which can be fed into an amplifier and then be transformed back into an image.

IMAGE-CONVERTER TUBES EMPLOYING ELECTRONOGRAPHY

A. Lallemand and M. Duchesne of the Paris Observatory have achieved new successes with the method described in 1955 [1]. At a symposium at Philadelphia [2] in 1956 Lallemand exhibited some very impressive spectra of faint stars obtained with his device attached to the spectrograph of the 120-cm telescope at Haute Provence. The dispersion of the spectrograph was 170 Å/mm, the electronic images were recorded on Ilford G 5 emulsions, and a resolution of 15μ was obtained at an accelerating potential of 30 kV.

Exposures of 3 min were sufficient to reach 12th magnitude M stars. This represents a substantial gain over ordinary photography. Lallemand remarks, however, that two practical problems are encountered when faint objects are observed with long exposure times: (i) visual identification and guiding become difficult, and (ii) the motion of the telescope with respect to the Earth's magnetic field tends to cause a smearing of the electronic image.

During the past year Lallemand has altered his converter system to make it more convenient and efficient to operate. Each time the tube is used, the procedure includes evaporating the getter, breaking the glass capsule containing the photocathode, and later letting air into the chamber before reloading. The various parts must consequently be cleaned very thoroughly prior to reassembly for the next use. Since this cleaning process is hard on the parts, he has tried to redesign the system to use simple interchangeable parts of low cost and to keep replacement parts in stock. Lallemand's apparatus has recently been used by several astronomers at Haute Provence and Meudon, including Ch. Fehrenbach and G. Wlérick.

Lallemand reports that the preservation of antimony-caesium photocathodes is essentially perfect for more than the length of time required in normal operation. For infra-red-sensitive photocathodes of the silver-caesium-oxide type, the present system of refrigeration is not sufficient to prevent a rapid decay of sensitivity, but in spite of this he has been able to excel the sensitivity of conventional infra-red photography.

In Lallemand's system the photocathode and the photographic emulsion reside in the same vacuum with no barrier between them. Electrons travel directly from the photocathode to the photographic emulsion. The problem is to prevent gas molecules exuded by the emulsion from reaching the photocathode and destroying its sensitivity. Although Lallemand has achieved remarkable success in this respect, the problem is a difficult one and some alternative procedures have been explored. One of these alternatives consists in placing a very thin membrane (usually less than 1000 Å thick) just in front of the photographic emulsion to prevent contamination introduced by the emulsion from reaching the photocathode. The two investigations of this technique reported in 1955 have both been carried forward, the one by W. A. Hiltner and collaborators at the Yerkes Observatory and the University of Chicago [3], and the other jointly by J. S. Hall of the U.S. Naval Observatory, W. K. Ford of the Carnegie Institution, and W. A. Baum of the Mount Wilson and Palomar Observatories [4]. This latter group functions as the Carnegie Image-Tube Committee under the chairmanship of M. A. Tuve.

Hiltner reports that he has done considerable work on barrier membranes made of aluminium oxide, which he finds to be much stronger than most other materials suitable for this purpose, and which can be baked in air at 400° C. These membranes reduce the transfer of gas by a factor of 10^8 but it is hoped that the leakage can be reduced still further. The cause of the leakage or diffusion is uncertain, because electron diffraction tests indicate that the membranes are amorphous and electron microscope inspections reveal no holes.

Hiltner also reports that he has been making a careful investigation of field emission. The evidence appears strong that it will be necessary to have a caesium-free tube in order to reduce the field emission to the level that is needed. He feels that some information might be gained by means of a commercial image converter of modified design which would permit an evaluation of the minimum level of field emission in the presence of caesium, but commercial firms have been reluctant to do this. Hiltner reports that he now has a good design for a caesium-free tube but that he does not plan to proceed until a completely satisfactory barrier membrane can be made.

The attention of the Carnegie Image-Tube Committee has been confined to designs which might eventually be commercially producible in quantity. Contracts have been written with the Radio Corporation of America and with the Farnsworth Electronics Company, and several image converters with barrier membranes have been made experimentally by each. These tubes have been operated and tested on the 26-inch refractor of the Naval Observatory at Washington and on the 40-inch reflector of the

Naval Observatory Station at Flagstaff, Arizona. During the past two years these tubes have incorporated various successive minor improvements, but they all have consisted basically of standard commercial parts.

In August 1957, November 1957, and February 1958 Hall, Ford, and Baum were successful in obtaining a number of electron photographs with barrier membrane converter tubes attached to the Cassegrain focus of the 40-inch reflector at Flagstaff. Test images used were mainly double stars and star clusters. Estimates of resolution, efficiency, and background are in progress, and attempts at improving these are contemplated in further forthcoming tests. From the images thus far obtained it is evident that a cathode of average sensitivity will offer some gain over ordinary direct photography if the gain is reckoned in terms of the number of image grains blackened in equal exposure times. This gain is difficult to estimate accurately because of the small grain size of the Ilford G5 emulsion used for recording the electron images.

The tubes presently under test have infra-red-sensitive cathodes and a useful field about 18 mm in diameter, corresponding at the 40-inch telescope to a sky field about 9′ in diameter. In order to avoid excessive field emission, accelerating potentials of 10 kV or less have generally been used. It is estimated that approximately 3kV are lost by the photo-electrons in passing through the barrier membrane. It is important that the gap between the membrane and the photographic emulsion be very small so that the scattering of the photo-electrons in the membrane will not result in a serious loss of image resolution. A spacing of 0·04 mm has been successfully employed at the telescope, and the possibility of bringing the membrane into actual contact with the emulsion has been explored in the laboratory by means of electrostatic deflexion.

During the past four years, Ford [5] has made an extensive study of the physical properties of very thin self-supported membranes of the type needed in this application. He has succeeded in producing membranes which have sufficiently low gas leakage, which will withstand the high temperatures required in image-tube processing, and which are strong, flat, uniform, and free of holes.

IMAGE CONVERTERS PRODUCING AN OPTICAL OUTPUT

Image-converter tubes employing direct electronography, such as those described in the preceding section, have produced some impressive results, but they also introduce some practical complications if one is seeking a system suitable for replacing photography in routine astronomical observations. There are several alternative image-converter schemes which do not require manipulating photographic plates in a vacuum.

At the Imperial College of Science in London, J. D. McGee, S. Dowden, and B. Zacharov have carried out laboratory experiments with an image converter having a thin mica window (25 mm in diameter) which will withstand atmospheric pressure and upon the inner surface of which a phosphor screen is deposited. The electron image is formed on this screen and a 'contact' photograph is made by pressing a photographic film snugly against the outside of the mica window. This procedure makes efficient use of the fluorescent light from the screen. Focusing is provided by a magnetic field. Resolution is limited by the granularity of the phosphor and by the thickness of the mica window. Both of these can be kept to about 15 μ. A problem with tubes of this type, as with other high-voltage converters, is the spurious background, and efforts are being made to reduce this by activating the photocathode in an isolated antechamber which prevents excess caesium from reaching the main chamber of the tube.

Recent observations with image converters in the U.S.S.R. have been reported by V. I. Krassovsky, and are summarized in the next few paragraphs. The Russian tubes have caesium-oxide-on-silver photocathodes which are sensitive in the infra-red. Electrostatic focusing is used, and the photocathodes are curved. Some of the tubes have mica exit windows, like those described above, reported to be about 25 μ thick and 10 mm in diameter.

Using an infra-red-sensitive converter at the Sternberg State Astronomical Institute, P. B. Shcheglov has obtained very sharp images of the region of the galactic centre where a large number of new infra-red objects have been discovered. Among them apparently are several new globular clusters. By the same method a large area in Cassiopeia has been photo-electrically photographed and several thousands of infra-red indices have been derived, some of which are quite large. Infra-red images were also obtained of the Crab Nebula, of Comet Arend-Roland, and of the nuclei of M 31 and its companions.

At the Sternberg State Astronomical Institute and the Mountain Observatory in Kislovodsk, V. G. Kurt and M. N. Gnevyshev have used an infra-red sensitive converter on a solar coronagraph. Using exposures of tens of seconds, they have obtained, for the first time since Lyot, spectra of the corona showing the lines Fe XIII at 10747 and 10798 Å. It was established that the relative intensity of these lines is not constant. Regular observations of the solar corona are being carried on by this method. The Sternberg Institute in collaboration with the Pulkovo Observatory (V. F. Yesipov, O. L. Weissberg, and I. A. Prokofyev) have arranged for similar coronagraph observations at sea level near Leningrad; these observations will help yield the profiles of the coronal lines mentioned above. Observations of solar prominences in the line He 10830 Å have been continued by E. V. Kononovich.

Similar methods have been applied with great success by V. I. Krassovsky at the Institute of Atmospheric Physics of the Academy of Sciences of the U.S.S.R. in connexion with infra-red spectrography of night-sky radiation. It would be impossible to obtain such spectra with reasonable exposure times by ordinary photography. In the same fashion, the spectra of aurorae can be obtained with considerably shorter exposures than otherwise required.

A variation of the phosphor-coated mica-window technique would be to use a 'storage' phosphor which is capable of integrating an electronic image and releasing it later when irradiated with infra-red light or when heated. Krassovsky points out that the advantage of storing an electronic image on a phosphor of this type, instead of on a photographic emulsion as in direct electronography, is that the phosphor is chemically stable and does not exude gases which poison a photocathode. Phosphors are known which will store an image for as long as several months. There is of course still the problem that the final record of the image must somehow be extracted, perhaps by placing a photographic emulsion in direct contact with (or at least very close to) the phosphor screen so as to avoid the loss of light which would be encountered if a lens system were used. Storage phosphors might provide a solution to the problem of obtaining a large usable image area if, as suggested by Krassovsky, magnetic focusing were used between a large flat photocathode and a flat phosphor, each tube being used for only one picture and then being broken to obtain a photographic contact print of the image stored on the phosphor.

Another general approach to the image converter problem is to try amplifying the brightness of the image inside the converter tube so that one can afford the inefficiency of photographing the intensified image on the phosphor screen. When an ordinary image converter without internal amplification is used with an ordinary camera photographing the phosphor screen, the combination provides virtually no gain over unaided direct photography. However, if an internal gain of 100-fold can be incorporated into an image converter, the image on the phosphor screen will be bright enough that it can be photographed with an ordinary camera without any loss in the information contained in the original photo-electron image. This is to say that each photo-electron can be made to result in one or more blackened grains in the final camera photograph.

Two methods of internal intensification are being explored. One of these methods involves a series of thin membranes, each having a phosphor on one side and a photocathode on the other side. The other method involves a similar series of thin membranes which function as secondary-electron multipliers. In both cases, the electrons must be focused from the photocathode to the first membrane, from each membrane to the next, and from the last membrane to the phosphor screen.

At the Imperial College of Science in London, J. D. McGee, L. Mandel, and E. J. Davis have been experimenting with an intensifier converter having two internal stages of amplification of the phosphor-photocathode type. McGee reports that this tube has given fairly encouraging results, and that the main effort at present is being directed towards overcoming the technical difficulties of fabrication of tubes of this type. Elimination of spurious background is found to be a major problem but he is hopeful that it can be substantially reduced.

Intensifier converters of the same kind are being produced by R. G. Stoudenheimer and R. W. Engstrom of the Radio Corporation of America. These R.C.A. tubes have tri-alkali photocathodes and one stage of internal intensification. They are made in two sizes, the usable cathode area of the larger being nearly 5 cm in diameter. Electrostatic focusing is used and the cathode surfaces are curved. Overall light gains as high as 1000 have been obtained in the laboratory.

Membranes of the secondary-electron multiplier type have been the subject of an extensive study at the Westinghouse Research Laboratories by E. J. Sternglass, A. E. Anderson, M. M. Wachtel, and H. Kanter [7]. In addition to being efficient secondary-electron multipliers, the membranes of this type must also have the property of slowing the secondaries down to energies of release which are low in comparison with the accelerating potential between stages. If the secondaries coming out of one of the membranes were to have a broad range of energies, they could not be brought to a sharp focus on the next membrane. The workers at Westinghouse have been quite successful in producing membranes which perform these essential functions, and their present efforts are concerned with incorporating these membranes in image converters of good over-all performance. Wachtel has recently been able to find a way of preparing the dynode membranes in such a manner that they retain high secondary yields after they have been baked at the temperatures required during the tube fabrication (at least 250° C). Sternglass and Kanter have set up equipment for comparing the secondary-emission yields of various possible membrane materials. Yields of six per stage have been achieved with self-supported dynode membranes. Mesh-supported membranes are less delicate but have yields of only three or four per stage, as one might expect from the obscuration factor of the mesh. Anderson reports that a six-stage multiplier converter using mesh-supported membranes and a gold photocathode has recently been assembled for laboratory tests. This tube has an over-all multiplication greater than 1500 and a resolution of about 6 line pairs per mm.

One of the problems encountered by the Westinghouse group is that membrane materials now in use have a limited charge-transfer life, and it is hoped that other materials which are superior in this respect can be found. At present the effective lifetimes are several thousands of hours at a current density of 10^{-11} amp./cm^2, which is approximately what one might expect from a typical patch of the night sky if the multiplication of the tube were roughly 1000 and if the focal ratio of the telescope were in the neighbourhood of $f/5$ or $f/6$. This limitation would not in itself be serious, but fatigued spots due to moderately bright images would be troublesome.

McGee and W. L. Wilcock at the Imperial College of Science in London report that they are undertaking an exploratory investigation of the multiplier-membrane problem. Both they and Morton point out that this problem is basically an old one which may now be amenable to a solution.

J. Burns and M. J. Neumann at the Midway Laboratories of the University of Chicago report that a cellular electron-image multiplier is under development. Several dynode screens are placed very close together to form a sandwich, and the holes in successive screens are aligned so that electrons are channelled through the resulting cellular multiplier without the need for inter-stage focusing.

McGee, in collaboration with H. D. Evans and E. A. Flinn, also reports that work is being done on a cellular type of electron-image multiplier. Efforts to date have been directed towards constructing, assembling, and activating the cellular dynodes with adequate accuracy. Experiments have also been carried out on the tracing of electron paths through scaled-up models of such structures. This method has the attractive feature that inter-stage voltages are low and spurious background effects are consequently less troublesome.

Optical feed-back schemes for obtaining a useful gain from ordinary image converters without internal intensification have been suggested by A. Roberts of the University of Rochester and by M. L. Perl of the University of Michigan.

SIGNAL-GENERATING IMAGE TUBES

During the past few years several astronomical experiments have been made with standard or nearly standard closed-circuit television systems. One of these, which was reported by Morgan, Sturm and Wilson in 1955 [8], was repeated with some improvements in 1956. The system tested was manufactured by the Bendix-Friez Corporation under the trade name 'Lumicon'. It was attached to the 24-inch Lowell refractor at Flagstaff, Arizona, and used for experimental observations of Mars. The pick-up tube was a selected image orthicon. The system scanned thirty frames per second with 1029 interlaced lines. The best results were obtained when a relay lens was used to produce an image of Mars approximately 10 mm in diameter on the photocathode, corresponding to 250 scan lines in width. The kinescope image, which was about 60 mm in diameter, was photographed with an $f/1{\cdot}5$ Leica camera producing a final photographic image of Mars about 14 mm in diameter. The photocathode was of the antimony-caesium type, having its highest sensitivity in the blue region, but a red-transmitting filter was inserted to optimize the contrast of surface features on Mars. Although recordable images of Mars could thus be obtained with exposure times shorter than those required for conventional photography, the images were not as good. No further experiments are at present contemplated with the same equipment.

A very similar series of experiments was made by B. V. Somes-Charlton and A. A. Bargh of Pye Ltd., Cambridge, England. Somes-Charlton reports that observations at the telescope were preceded by sensitometric tests in the laboratory carried out in co-operation with Fellgett. The image orthicons used were of a special type developed by Cathodeon Ltd. for low light-levels. It was found that improved faint-light performance resulted from increasing the target-mesh spacing to 8 or 12 mils, but that further increases did not help. A test pattern of the type developed by A. Rose of R.C.A. was used for comparing the equivalent quantum efficiencies of these special orthicons with photographic emulsions, and the orthicons appeared to be superior to the best available emulsions by a factor of 3 at the lowest light-levels.

It seemed accordingly that these tubes might detect surface features on Mars in shorter effective exposure times than would be required by unaided photography. An expedition to observe Mars at Bloemfontein, South Africa, during the favourable opposition in 1956 was organized in co-operation with E. C. Slipher of the Lowell Observatory with the support of the National Geographic Society and of Pye Ltd. On about twenty nights in September and October the Pye television system was operated on the 27·5-inch refractor of the Lamont-Hussey Observatory; in early November it was used on two nights at the coudé focus of the 74-inch Radcliffe reflector. The portion of the equipment attached to the telescope weighed about 100 lb.

The Pye system operated on 625 vertical sequential lines in a frame time of 1/75th sec, and the resolution at the photocathode was approximately 20 line pairs per mm. Somes-Charlton stresses the importance of controlling the lateral leakage of the orthicon target by controlling its operating temperature. When a suitable relay lens was used, the image of Mars was about 9 mm in diameter on the photocathode and the kinescope image was 45 mm in diameter. The scanning structure was smaller than the smallest detail visible on the planet's surface. A 35-mm camera fitted with an $f/1{\cdot}9$ lens was used for photographing the kinescope screen.

Altogether, about 1500 photographs of Mars were obtained with the Pye system, most of them through a Wratten 8 filter. Exposures ranged from 1/10th to 1/75th sec. Slipher found that in general these television photographs did not show quite as much detail as the best direct photographs obtained on Eastman 103-type emulsions. They did, however, have the advantage of contrast enhancement which tended to bring out small brightness differences between extended areas not limited by resolution.

Somes-Charlton suggests that some departures from the present television techniques should be explored to seek a better signal-to-noise ratio than now available with image orthicons. One possibility might be the image isocon developed by Weimar at R.C.A. Another might be an orthicon-like tube in which the scan signal is collected directly at the target instead of via a return beam. He also thinks that photo-conductive tubes offer some possibilities.

Some tests of a Bendix-Friez Lumicon system were carried out by O. C. Mohler of the McMath-Hulbert Observatory of the University of Michgan in co-operation with the Vision Research Laboratory of the University of Michigan and with the help of R. H. Lee of Bendix-Friez. The pick-up tube (R.C.A. 5820 image orthicon) was mounted at the focus of a large solar spectrograph to evaluate the usefulness of the system in observing variations of certain features. It was used both with and without relay lenses. The raster on the photocathode was 25×25 mm. When in proper adjustment, the system was capable of resolving at least 20 line pairs per mm in both directions. A Speed Graphic camera with a between-the-lens shutter was used for photographing the kinescope screen on Eastman Royal Pan film. The illumination was adequate for single-scan photographs. Since the shutter was not synchronized with the scan, however, not all of the photographs caught full scans.

Mohler found that the Lumicon did not give any gain in speed for a constant degree of resolution. Although it was possible to obtain recordable pictures of single scans with 1/30th-sec exposures, instead of with the usual exposures of several seconds required for direct unaided photography, the results were inferior due to the large amount of electrical noise evident in the single-frame pictures. When longer exposure times were used for averaging out the electrical noise of the Lumicon, the results were still not as good as unaided photography. Moreover, when the spectrograph slit was widened to permit 1/30th-sec exposures by unaided photography, the Lumicon was surpassed again.

The instrument did have one rather interesting use in the ultra-violet part of the spectrum, where it provided a visible display of what was going on. Mohler mentions that it was very interesting, for instance, to be able to look at the strong iron lines in the 3300 Å region and to watch their changes in various solar features.

One of the major difficulties with present television-type systems is the very short grey scale that can be recorded at any given setting. Mohler found that one could make the slightest intensity difference appear as a black-and-white feature but that it was not possible to show the centre and wings of an absorption line simultaneously. Additional experiments with a special image orthicon which was said to have an unusually long grey scale did not result in an adequate improvement in this respect. No further experiments with instruments of the Lumicon type are presently contemplated at Michigan.

Another Lumicon system was tested by E. W. Dennison at the Sacramento Peak Observatory, Sunspot, New Mexico. The image orthicon was mounted at the focus of a large solar spectrograph having a dispersion of 0·6 Å/mm. Recordable single-frame pictures (1/30th-sec) were obtained as compared with exposure times of one or two seconds ordinarily required for unaided photography with Eastman 103-type emulsions. Just as at Michigan, however, the resolving power and the signal-to-noise ratio were found to be inferior to unaided photography. The resolution was approximately 300 line pairs over a total photocathode raster area 30×30 mm, i.e. about 10 line pairs/mm.

Instead of trying to use the Lumicon merely as an image intensifier, Dennison has added a device developed for the Sacramento Peak Observatory by the Eberline Instrument Company. This device transforms the light-intensity signal from the image orthicon into a series of quantized steps. Between the intermediate and final amplifiers of the Lumicon system, the signal is converted from a half-tone picture to a contour diagram consisting of isophotes. Basically this is accomplished by feeding the output of the image orthicon to the vertical drive of a monoscope which is crossed by a series of horizontal black-and-white lines; thus, the output of the monoscope is either an on or off signal

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depending upon the amplitude of the orthicon output. Dennison is optimistic that the results thus obtained will be useful, particularly as improvements in image orthicons become available.

At the University of California at Berkeley, William Livingston has made some interesting experiments with a closed-circuit television system largely of his own design, his aim being to investigate the integration and storage properties of the target of an image orthicon. The system is arranged to permit integration and storage times limited only by leakage at the orthicon target, and to accommodate reading rates from 0·01 sec to 5 min. The output can be displayed either on an x, y-plotting oscilloscope, or at the slower speeds, on a pen recorder. The image section is operated in two different modes. In the first mode, the photocathode is 500 V negative with respect to the target so that photo-electrons striking the target eject secondaries and leave a positive charge pattern corresponding to the optical image. In the second mode, the cathode-target potential is reduced to 45 V and the photocathode is uniformly illuminated to produce a flood of low-velocity photo-electrons which stick to the target without ejecting secondaries. This may be thought of as a method for arithmetically subtracting the sky background and thereby circumventing the limited charge-storage capacity of the target. Local non-uniformities in photocathode sensitivity tend to cancel out.

Livingston has used refrigeration with dry ice to increase the integration time of the orthicon target. Target leakage may be considered as due both to surface and volume effects, the volume conductivity being an exponential function of temperature. He reports that storage times up to 40 min have been realized with only slight deterioration of the image. J. D. McGee and R. P. Randall have made similar experiments with a C.P.S. Emitron.

At the Imperial College of Science in London, J. D. McGee, R. L. Beurle, and N. Slark report that work has continued on a television-type tube of special design suitable for charge integration during exposures of substantial duration. Exclusion of caesium from the operational section of the tube results in low dark-emission and good insulation of the mosaic. By making the target of a high capacity dielectric, storage and integration times of 15–30 min have been reached. Efforts are now being directed toward making such a tube with as near perfect characteristics as possible. This will be necessary before a realistic assessment of efficiency can be established. Tubes having targets suitable for long exposures have also been made and tested by W. Heimann at Wiesbaden.

A system designed to circumvent the limitations introduced by beam noise was described in 1955 by G. A. Morton [9] of the R.C.A. Laboratories, Princeton, New Jersey. The advantage in quantum efficiency of a photocathode over a photographic emulsion cannot be fully utilized unless extraneous sources of noise such as the scanning beam can be reduced below the fundamental threshold set by the statistical fluctuation in the flow of photo-electrons. For a tube of the image-orthicon type Morton states that the primary photo-electron current must be amplified in a relatively noise-free fashion by at least a hundredfold before it reaches the target if beam noise is to play a secondary role. Morton's method for providing the required amplification between the photocathode and the target is illustrated in Fig. 3 of the 1955 report. Some preliminary astronomical experiments with an intensifier orthicon have been made by R. K. H. Gobel and L. Devol on a 10-inch refractor at Wittenberg College in Ohio. Images of a few bright objects have been obtained, but no quantitative tests have been applied.

Fellgett [12] has investigated the mechanism of charge evaluation by a low-velocity scanning beam and has concluded that, independent of amplifier developments, simple orthicons offer no advantages over image orthicons for very faint light. He has also suggested [10] that it should be possible to design a simple signal-generating tube whose target consists of a storage phosphor for integrating the electronic image; the image could later be read off by scanning the phosphor with a tiny infra-red spot. The fluorescent output thereby extracted from the storage phosphor would provide a time-based signal which could be received by a photo-multiplier and fed into television-like circuits. One advantage of this scheme would be that the cathode of the photo-multiplier could be arranged to catch most of the fluorescent output of the phosphor, because no imaging between them is required. Another suggestion by Fellgett is that an alternative to secondary-emission multiplication is provided by the type of tube in which the charge-image is stored on a grid and is evaluated by passing a reading beam through the grid in such a way that it is modulated by the charge-pattern without erasing it. The reading, either by a flood beam for a converter or a scanning-beam for signal-generation, can be continued, until the noise in the reading process is small compared with that in the charge-pattern itself. Several such tubes have been demonstrated by manufacturers.

An interesting and slightly different astronomical application of television techniques is reported by J. H. DeWitt, R. H. Hardie, and C. K. Seyfert of the Dyer Observatory at Nashville, Tennessee. They have combined a conventional closed-circuit television system with a photo-electric guider to produce a fast-acting image tranquillizer. The system has been used at the Cassegrain focus of a 24-inch reflector for observation of Venus, Jupiter, and Mars. Just ahead of the focus, the beam is split by a dichroic filter into two images, one falling on the photocathode of an image orthicon (R.C.A. 5820) and the other on a pair of slits with photo-multipliers behind them. Since the slits are at right angles to one another, the outputs of the photo-multipliers provide x and y error signals whenever the image of the planet shifts its position. These error signals are amplified and fed to x and y deflexion coils mounted around the image orthicon. Any deflexion of the optical image from a normal mean position is thereby compensated by a counter-deflexion of the photo-electron paths inside the image orthicon. Thus the electronic image arriving at the orthicon target is stabilized against any errors in guiding and against jumping of the image due to atmospheric 'seeing'. The improvement achieved by tranquillizing the image in this manner is clearly illustrated by some sample photographs of Jupiter recently published [11]. Various details of DeWitt, Hardie, and Seyfert's system will be found in the same publication.

Krassovsky reports that N. F. Kuprevich has begun experiments with television-type systems at the Pulkovo Observatory. Images of the Moon and planets have been obtained, but no details are given.

COMMENTS

Most views and ideas associated with specific experiments have been included in the preceding sections. A few comments of a more general nature, however, should be added.

From the long-range point of view it seems generally agreed that the main astronomical aim in the development of image tubes should be to find a system which can eventually be put into routine use at observatories everywhere. In other words, our task includes more than merely demonstrating that the quantum efficiency of a photocathode is capable of yielding a gain over conventional direct photography; we must seek a practical technique involving tubes which can be mass-produced and which do not require an image-tube specialist to operate them. Clearly this will require assistance from organizations outside astronomy. It will be important to have the help of electronic experts, the co-operation of industry, and the support of adequate funds. It will accordingly be desirable to agree among ourselves what we really want, and such considerations are very much to the point of the present Sub-Commission.

Following are a few of the individual views that have been expressed. Fellgett believes that a good secondary-emission multiplier of the type under investigation by Sternglass and his colleagues at Westinghouse would solve the image-converter problem. He points out that signal-generating systems have the advantage of being able to avoid the intermediate steps of photography and microphotometry. Hiltner believes that astronomers themselves, although they have been able to make some headway on image converters, can do relatively little on the development of signal-generating tubes. He hopes that devices of that sort will be pursued by the commercial laboratories, because he thinks that they would be a more desirable ultimate solution than image converters. The Carnegie Committee feels that commercial firms must be called upon sooner or later in either case, and that commercial interest should be encouraged at the beginning. The Committee has valued the co-operation of Farnsworth, R.C.A., and Westinghouse.

Krassovsky feels that there are currently too few investigators with too much diversity in their apparatus to make efficient progress toward a final solution. He points out that the smallness of the sensitive area of present image tubes and the unfamiliar complications of image-tube systems are factors preventing a wider acceptance among astronomers, and that the popularization of image-tube techniques among astronomers should be one of our first objectives. From the technological point of view, Krassovsky believes that more attention should be given to external effects resulting in loss of resolution, such as thermal deformation due to cooling and electronic de-focusing due to stray magnetic fields.

Somes-Charlton calls attention to the need for unlimited telescope time if real progress is to be made with experimental systems. He suggests that it would be worth while to have telescopes which are allocated entirely to experiments being conducted in this new field.

Fellgett [12] has investigated what might be accomplished with unaided photography, particularly if the same care were taken in optimizing the conditions of photography as is so often used in photo-electric work. For example, one can refrigerate plates to very low temperatures during exposure to reduce reciprocity failure. He is of the opinion that the quantum efficiencies of photographic emulsions are not always so far below those of photo-electric cathodes as usually assumed. On the basis of granularity and sensitometry data recently made available by the Eastman Kodak Company, he quotes peak monochromatic quantum efficiencies ranging from 0·1 to 1·3%. The equivalent number of photons stored is in the range from 0·06 to 0·40 per square micron at optimum exposure.

W. A. BAUM
President of the Sub-Commission

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INSTRUMENTS

Report of Meetings. 15 and 19 August 1958

PRESIDENT: G. E. Kron.

SECRETARY: W. A. Hiltner.

First Meeting. 15 August

This meeting had been preceded by a meeting of Sub-Commission 9*a* under the chairmanship of W. A. Baum. The *Draft Report* was discussed. Nikonov said the term 'Moscow type' should be deleted from p. 58, line 47. Fehrenbach expressed an opinion that the emphasis on telescope ventilation might have been misplaced in the *Draft Report*, and he pointed out that Couder was the first to ventilate telescope and dome at the Observatory of Marseilles. With consideration given to the above remarks, the *Draft Report* was approved.

Rösch proposed that problems concerning the study of 'seeing' phenomena should be handled by Commission 9. After some discussion, it was decided to recommend that Sub-Commission 25*b* be transferred to Commission 9 as 9*b*. Dimitroff brought up a proposal that he handle the preparation of an interim tabulation of existing radio and optical astronomical instrumentation, as he has access to material that would make such a duty easy for him. After some discussion, Dimitroff was encouraged to proceed with his proposal.

After a discussion no formal action was taken regarding the relationship of instrumentation in radio-astronomy to Commission 9.

Gottlieb gave a report on the present state of development of the Mount Stromlo Observatory. The 74-inch telescope is in use with the original mirror. Dunham is preparing a design for a modern coudé spectrograph to be used with the 74-inch reflector.

Couder reported on the new 193 cm reflector of the Haute-Provence Observatory, with special attention to the execution of the mirror, the characteristics of the mounting, and the results of the first trials.

Second Meeting. 19 August

The Commission considered item 13*c* of the agenda of the General Assembly, that problems concerning the selection of sites for astronomical observatories be given active consideration by some part of the International Astronomical Union. The Commission voted to support this concept, and submitted a resolution to this effect.

Sukharev gave a report on the horizontal meridian instrument of the Pulkovo Observatory. The design of the instrument is so unusual that a model was constructed and tested first, and the full-sized instrument is now being constructed following the success of the model.

A report on the new Belgian telescope was given by E. Vanderkerkhove. Edmondson gave a report on the progress of the National Observatory at Kitt Peak, Arizona.

F. Link reported on a method for absolute photometry of sources differing by a very large amount in intensity.

G. Courtès described an improved method for using a Fabry-Perot etalon with aperture ratios of the order of $f/1$.

It was resolved (1) to recommend to the Executive Committee that Commission 25*b* on astronomical 'seeing' be transferred to Commission 9 as 9*b* (Resolution no. 20).

(2) That Commission 9 will support item 13*c* of the agenda of the General Assembly, that the I.A.U. act to promote a study of the problems concerned in the testing of sites for astronomical observatories (Resolution no. 19).

COMMISSION 9

Report of Meetings of Sub-Commission 9a. 14 and 15 August 1958

PRESIDENT: W. A. Baum.

SECRETARY: J. D. McGee.

The Sub-Commission held two sessions at the Moscow General Assembly, the first being on 14 August in the Conference Hall of the Sternberg Astronomical Institute and the second being on 15 August in the main building of Moscow University. Following a brief discussion of the *Draft Report*, there were fourteen reports of work done since the 1955 meeting. These were presented by the following investigators:

Prof. V. I. Krassovsky, Geophysical Institute, Leningrad.
Prof. A. Lallemand, Observatoire de Paris.
Prof. Ch. Fehrenbach, Observatoire de Marseille.
Dr G. Wlérick, Observatoire de Meudon.
Prof. J. D. McGee, Imperial College of Science, London.
Dr J. S. Hall, Lowell Observatory, Flagstaff.
Dr W. A. Hiltner, Yerkes Observatory, University of Chicago.
Dr N. F. Kuprevich, Pulkovo Observatory, Leningrad.
Mr Jay Burns, Midway Laboratories, Chicago (via McGee).
Mr M. Wachtel, Westinghouse Laboratories, Pittsburgh (via Hall).
Prof. V. B. Nikonov, Crimean Astrophysical Observatory, Simeis.
Dr E. Dennison, Sacramento Peak Observatory, Sunspot.
Dr P. B. Shcheglov, Sternberg Astronomical Institute, Moscow.
Dr G. A. Morton, Radio Corporation of America, Princeton (via Baum).

In general, these reports amplified the material contained in the *Draft Report*, and the main points have been incorporated into the version printed herewith. No supplementary manuscripts were submitted.

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