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L. *Multiple Transmission Fixed-Arm Spectroscopes.* By W. CASSIE, M.A., *Professor of Physics in the Royal Holloway College* *.

VARIOUS forms of spectroscope have been devised to diminish the number of prisms required for great dispersion by using each prism more than once. Contrivances for reflecting the beam of light back through a prism or train of prisms a second time by means of a mirror or a reflecting prism have been used by many observers. An instrument has been devised by Prof. Wadsworth in which the beam is sent six times through one prism by the use of seven mirrors.

The spectroscopes described in the present paper secure many transmissions of the beam through one or two prisms by the use of a principle which will be best explained by describing the instruments themselves.

I.

The first form of instrument I have to describe, which is in some respects the most satisfactory of the first three, is made with two half-prisms each silvered on one side. Figs. 1 and 2 (p. 450) show the essentials of the instrument, fig. 1 in plan and fig. 2 in elevation.

A is the collimator, B the telescope. abc and def are two equal half-prisms silvered on the faces ac and df and placed with their faces vertical. The beam of light, after emerging from the collimator A, passes under the prism abc and strikes the prism def near the lower edge of the face de . This prism is so placed that the beam entering at de is reflected almost normally at the silvered face df , and comes out again at the face de . Now this beam is not horizontal in direction, but is slightly inclined upwards. The consequence is that the beam returning after emergence from de can be caused to strike the prism abc on the lower part of the face ab . This prism also is placed so that the beam is reflected almost normally at the silvered face ac , and after emerging from ab again strikes de at a place higher than at first; and so travels backwards and forwards between the two prisms, gradually climbing upwards until at last the beam from ab passes over the top of the prism def and enters the telescope B. Each reflexion through a half-prism is equivalent to transmission with minimum deviation through a prism whose refracting angle is twice that of the half-prism. So that this arrangement is equivalent to a train of as many prisms as there are

* Communicated by the Physical Society : read November 22, 1901.

reflexions of the beam. The loss of light can be reduced to a minimum by choosing the angles of the prisms so that the light is incident at the angle of polarization.

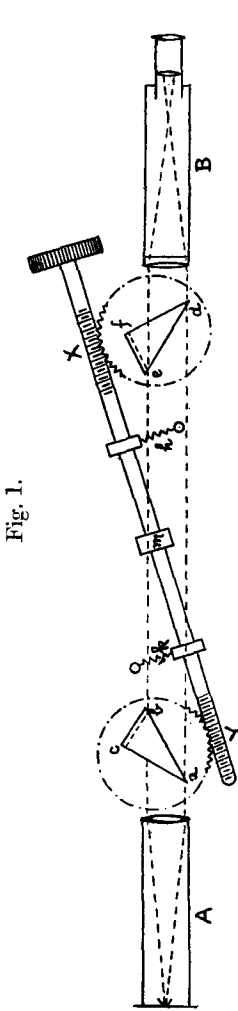


Fig. 1.

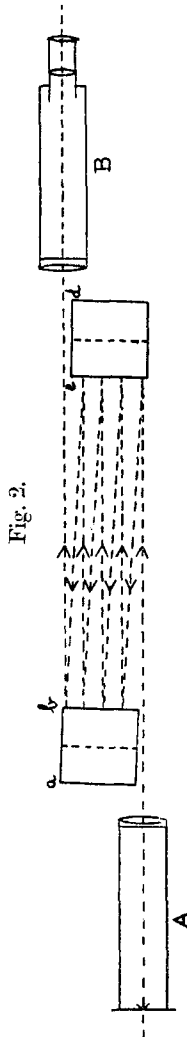


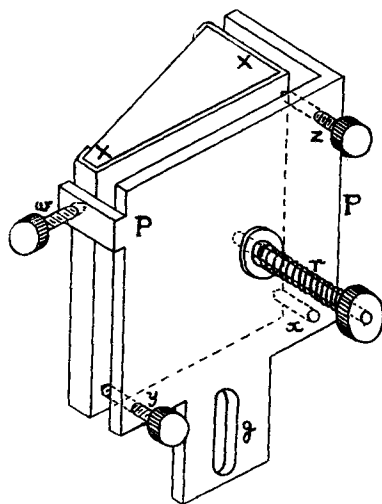
Fig. 2.

The adjustment for light of different refrangibilities is secured by turning the prisms in opposite directions so that they are always inclined to the beam of light at equal angles.

This is done by supporting the prisms on disks with cogged edges, represented by the circles surrounding them in fig. 1, and having a rod XY with tangent-screws pressed against these disks by springs h, k . The rod XY can be turned about the point m so as to remove the tangent-screws from the disks for a quick motion of the prisms. The prisms are attached to the disks by mountings which admit of their accurate adjustment. When the instrument has been adjusted for light of one refrangibility, it is adjusted for all refrangibilities; and the whole spectrum can be made to cross the field of view by turning the head of the tangent-screws.

The mounting of a prism is shown in fig. 3. The prism is

Fig. 3.



fixed in a brass cell X which is attached by springs and screws to the upright plate P . From the back of the prism-cell a rod r passes freely through a hole in the plate P , and is surrounded by a spiral spring which presses the cell against the fixed point x (which enters a slight depression in the back of the cell) and the points of the screws y and z . The cell is pressed against the point of the screw w by a spring on the opposite side. The plate P is supported with freedom for adjustment by a bolt and nut passing through the slot g .

The breadth of the beam which can be used is limited

horizontally only by the breadth of the face of the prism ; but vertically the beam must be narrow if a number of reflexions are required. Thus the resolving power of the instrument depending, as it does, on the horizontal breadth of the beam, is not affected by this restriction. The resolving power is that of a train of as many complete prisms as there are reflexions in the half-prisms.

The beam does not traverse the prisms exactly in a principal plane. But the smallness of this obliquity and the narrowness of the beam in a vertical direction make any such effect of small consequence. Moreover, the obliquity can be indefinitely diminished by increasing the distance between the prisms.

II.

Another form of instrument is illustrated in plan in fig. 4 and in elevation in fig. 5. In this case one prism and two plane mirrors are used.

A is the collimator and B the telescope. C is the prism mounted on a levelling-table which rests on and turns with the arm Cf. *d* is a plane mirror fixed above the object-glass of the collimator and facing towards the prism. *e* is a plane mirror supported on the extremity of the arm Ce, and also facing towards the prism. The arm Ce is free to turn round the centre of the table of the instrument. To the arm Cf is attached a screw carrying a block Z, which is free to move along the arm, and is linked to a pin X fixed on the table of the instrument and to a pin Y on the arm Ce. To use the prism with minimum deviation ZX and ZY are made equal, and the prism and the mirror *e* are moved simultaneously by turning the screw.

The beam of light emerging from the collimator A passes under the mirror *d* and is deviated by the prism. The mirror *e* is so placed that the light strikes it near its lower edge and goes back through the prism. The beam being inclined slightly upwards, now strikes the mirror *d*, and so is reflected backwards and forwards between the mirrors traversing the prism at each journey and gradually climbing upwards until finally it passes from the mirror *d* over the top of the prism into the telescope B. If the prism and mirrors are once properly adjusted for minimum deviation for light of one refrangibility, they are brought in adjustment into the position for any other refrangibility simply by turning the head of the screw Cf.

III.

A third form of instrument which may be convenient when it is desired to have the reversed beam in a separate position

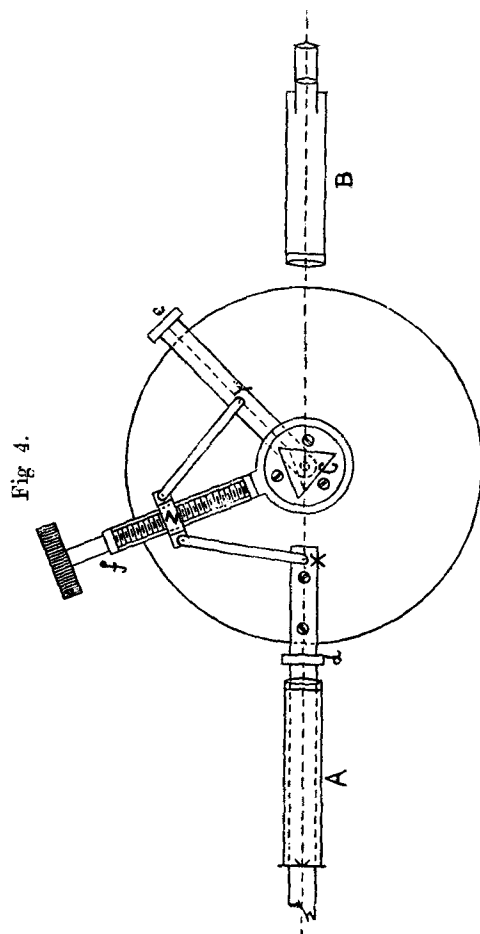


Fig. 4.

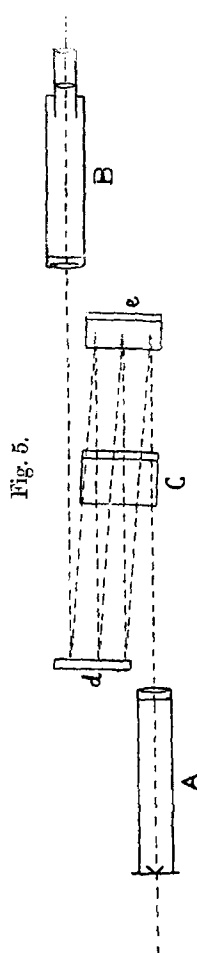


Fig. 5.

from the direct one, is shown in plan in fig. 6 and in elevation in fig. 7 (p. 454).

A and B are the collimator and telescope as before. The refracting prisms are cde and fgh . k is a right-angled reflecting prism above the object-glass of the collimator. The beam from the collimator inclined slightly upwards as before is refracted at the face cd of one prism, is totally reflected at the face de , and emerging at the face ec enters

Fig. 6.

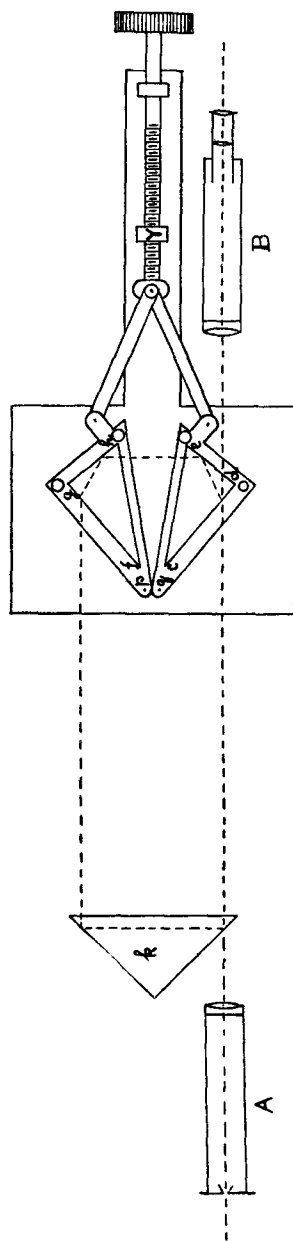
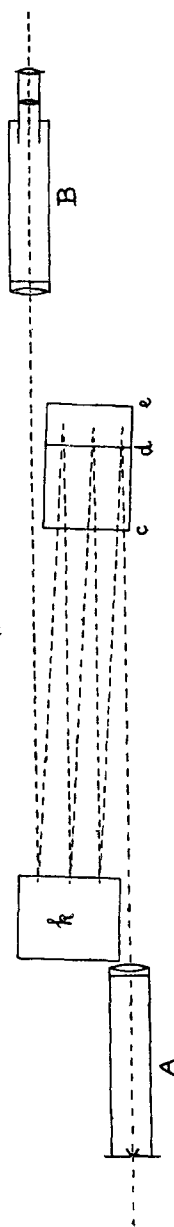


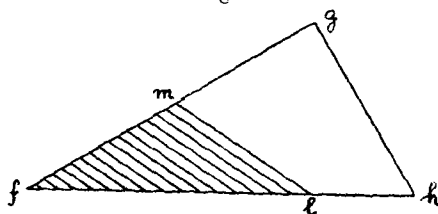
Fig. 7.



the face hf of the next prism, is totally reflected at the face gh , and refracted out at the face fg . The angles and positions of the prisms are made such that the beam emerging from fg is parallel to that entering at cd (except for a slight inclination upwards). After leaving the two refracting prisms the beam enters k , which returns it after two reflexions to the face cd in a direction parallel to that in which it first entered that face. Thus the beam circulates round the system of three prisms, gradually rising until it finally passes over the top of the prism cde into the telescope B. For adjustment of the refracting prisms they are mounted on levelling-tables which are free to turn about centres at p and q , and are linked as shown in fig. 6 to a screw working in a fixed block Y, so that by turning the screw the angle between the faces ce and fh can be altered while the positions of the prisms are kept symmetrical with respect to the central line of the system. Thus when the instrument is adjusted for one wave-length, the whole spectrum can be brought into view by simply turning the adjusting screws.

It is not necessary that the refracting prisms be complete, because a ray entering near c strikes the face ec after refraction, and is for present purposes lost; consequently the portion shaded in fig. 8 may be cut from the prisms at the

Fig. 8.



corners c and f . If hgm is the actual form of prism used, it is necessary to cut it so that the beam in passing between the refracting prisms meets the faces ce and fh as nearly as possible at normal incidence; because if, for instance, the prism were made triangular of the form hmg , the refraction at the face mh would produce dispersion opposite to that due to mg .

This instrument is much inferior to the others in resolving power. To get the internal reflexions in the refracting prisms total, it is necessary to make the refractions at a large obliquity. That gives, no doubt, considerable dispersion. But the difference between the longest and shortest paths of rays through the refracting prisms is comparatively small.

For flint-glass the angles at d and g do not differ much from 90° ; so that if $de = a = gh$ and the angles at e and h are about 60° , the difference of the paths for the pair of prisms is about $\frac{a}{2}$. Whereas the same two prisms with the corners at c and f not cut off, used as reflecting half-prisms in the arrangement first described, would give a difference of path about $4a$ for rays traversing each once. That is to say, the resolving power of such an instrument of type I. would be about eight times that of one of type III.

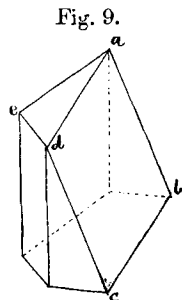
Other combinations involving similar principles will readily suggest themselves. But the three described are sufficient to illustrate the method. The number of transmissions may be increased by lengthening the prisms or mirrors. The length of slit that can be used may be increased in the same way. In the instruments I have had made for trial the prisms and mirrors were 5 centimetres high and gave very good results. They are simple in construction, and the adjustments are easy compared with those of a train of prisms. Moreover, by a few turns of an adjusting-screw one can change the number of transmissions, and with them the degree of dispersion, step by step through a wide range.

IV.

[*Addition made Dec. 6, 1901, after the reading of the paper.*]

Another arrangement in which the reflectors are totally reflecting prisms is shown in figs. 10 and 11.

The back of the half-prism instead of being silvered is formed into a right-angled totally-reflecting prism with its edge at right angles to the refracting edge of the half-prism,



as shown in fig. 9. The beam is reflected back to this combined half-prism and reflector by two right-angled prisms fh and lm , as shown in figs. 10 and 11. The prism fh is exactly

half the breadth of the refracting prism, and is exactly opposite to the full upper half of it. The prism lm is of the

Fig. 10.

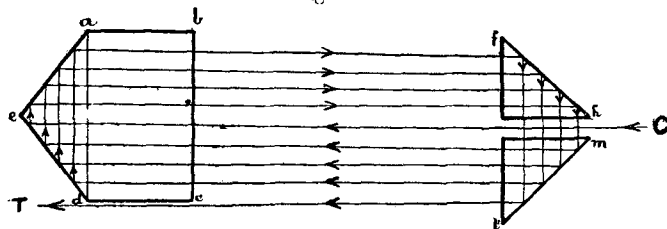
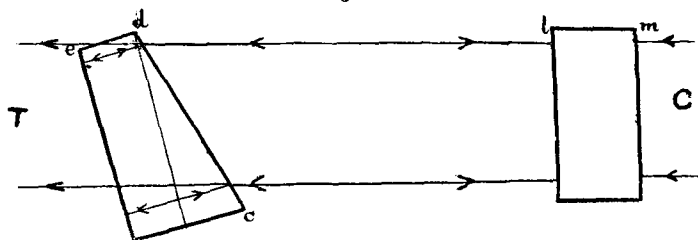


Fig. 11.



same size as fh , but has its lower edge at a lower level than the bottom of the refracting prism, so that a space is left between the reflecting prisms. A beam of light from the collimator passes from C between the reflecting prisms, is refracted and reflected at the half-prism, and so passes to and fro, taking the course indicated by the arrows in figs. 10 and 11, and finally passes from the reflector lm under the refracting prism into the observing-telescope at T. The result in dispersing and resolving power is equivalent to passage through a train of as many complete prisms as there are to-and-fro journeys of the beam.

This arrangement is better than I. and II., because less light is lost by reflexion; and it is better than III. because it gives full resolving power. Moreover, the beam passes through the refracting prism in a principal plane, so that all the prisms may be placed quite close together, and the apparatus thus made more compact. The number of transmissions possible depends upon the width of the opening left between the reflecting prisms fh and lm . A very large number of transmissions may be used if this opening is made small. Another possible form would be to make the prisms fh and lm also refract, by giving them the form produced by cutting the prism of fig. 9 by a plane through e at right angles to the face $a b c d$.