A SPECTROSCOPE OF FIXED DEVIATION.[1]

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It is well known that when a ray of light has traversed a prism at minimum deviation its direction, after reflection on a mirror attached to the prism, is independent of its color. This is readily understood when it is remembered that the direction of a ray which has traversed a prism at minimum deviation is the same as if it were reflected from its base. If it is then made to undergo reflection the result will be the same as if the ray were reflected on two mirrors making an angle with each other. The final ray will make with the incident ray an angle double that between the two mirrors.

This principle has frequently been employed in bolometric researches where a definite dispersion and a fixed receiving apparatus were required. To realize these conditions it is only necessary to rotate a system composed of a prism and an attached mirror in order to cause the dispersed radiations, at minimum deviation, to pass in succession over the bolometer.

In this form the apparatus is not suitable for practical use in a spectroscope, for silvered glass mirrors give a bad image and metallic mirrors are soon unfit for use. It is therefore necessary to devise a prism giving total reflection on one of its interior surfaces in such a manner as to realize a fixed deviation without the use of a perishable mirror. It must be shown at the outset that under these conditions the property of fixed deviation for a ray twice refracted at the desired angle is preserved.

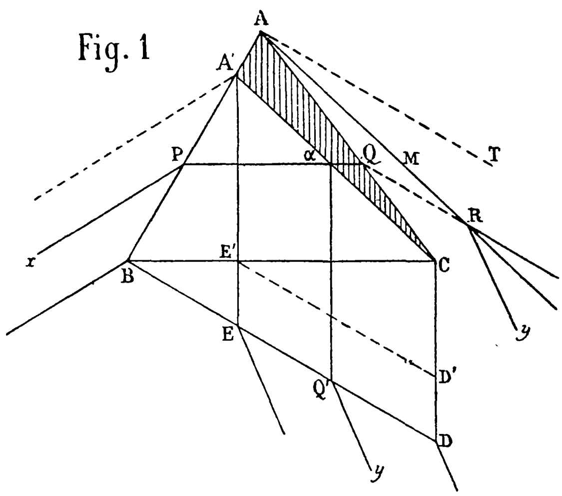
Imagine a prism of 60°, ABC, and a mirror M (Fig. 1). Consider the ray $xPQRy$, and let us endeavor to replace the external reflection M by a total reflection. The emergent ray must take the direction Ry; since we may replace QR by its symmetrical with respect to M, and since we wish to preserve

[1] *Séances de la Société Française de Physique*, No. 1, 1899.

the same angle of refraction Q, we must take as the surface of emergence a surface symmetrical to $A\ C$ with respect to the mirror M. We must therefore take a face parallel to $A\ T$. Under these conditions it is evident that the ray which is twice refracted at the same angle at P and Q' will have precisely the same properties as if it had been refracted at P and Q in the prism $B\ A\ C$.

Let us now consider a 60° prism to be cut by a plane $A'\ C$, such that the angle $B\ C\ A'$ shall be 45°, which gives $B\ A'\ C = 75°$;

Fig. 1



let us join to it a rectangular prism $B\ C\ D$, having acute angles of 30° and 60°, and we shall obtain a prism having an internal reflection and a fixed deviation of 90° which is equivalent to a prism of 60°. It is moreover evident, since the angles $D\ Q'\ y$, $x\ P\ B$ are equal, that the faces $A'B$, $B\ D$, must be at right angles.

In the actual construction the faces may be limited to the parts actually used. If we assume an aperture $B\ A'$, we shall obtain a useful prism by joining to $B\ A'\ C$ the prism $E'\ C\ D'$. But this requires the use of cement, which should be avoided if possible. We are thus led to the solution which consists in cutting a single block $B\ A\ C\ D$. This requires a slight increase in the thickness of glass to be traversed, but it avoids the necessity of cementing the surfaces, which is far more important.

Such a prism renders possible the construction of a very convenient spectroscope. The collimator and observing telescope may be fixed at an angle of 90°. When the prism is rotated the spectral lines will always be at the position of minimum deviation at the moment of crossing the reticule in the telescope. They will thus always be of maximum sharpness.

The operation of setting for minimum deviation of a line is accomplished by a single motion and the fixed position of the telescope simplifies the construction and the use of the instrument. It is only necessary to have a good achromatic objective in order to be able to focus the photographic camera, for example, on the D line, and then, by simply rotating the prism, to bring a given region of the ultra-violet at minimum deviation to the point previously occupied by the D line.

It is evident that the prism just described causes the ray which has traversed it at minimum deviation to turn through an angle of 90° to the right. We will call this prism right-handed. If the same prism worked in the opposite direction, receiving the light on its large face and at a suitable angle, it would be left-handed. Or such a prism may be considered to be reversed top for bottom, in which case the new prism is right-handed when it receives the light on its large face and left-handed in the inverse direction.

The condition of fixed deviation may be met with the greatest simplicity in the construction of a spectroscope having several prisms. It is evident that if we wish to obtain dispersion we must join in pairs prisms which are opposite in character.

Each of these prisms will produce a deviation of 90°, either in one direction or the other, depending upon whether it is made to work in this or that direction. Let us consider the possible solutions for various numbers of prisms.

For a one prism spectroscope either position of the prism may be employed. With two prisms we may obtain either direct vision with displaced path (Fig. 2), or parallelism of the collimator and telescope, as shown in Figs. 3 and 4. With this arrangement the observer is distant only some 20 cm from the slit and source of light. When a telescope of longer focus than

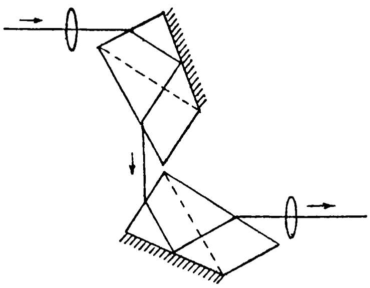


Fig. 2

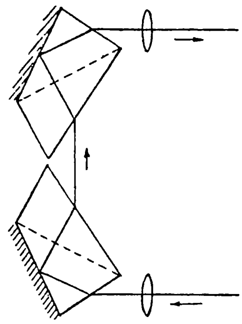


Fig. 3

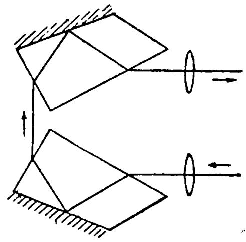


Fig. 4

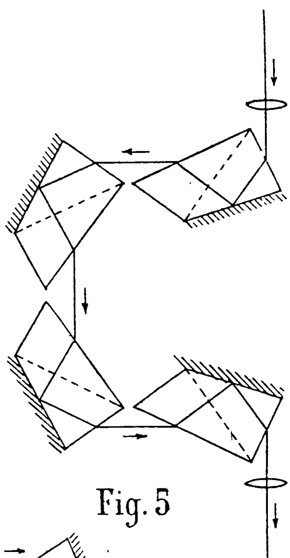


Fig. 5

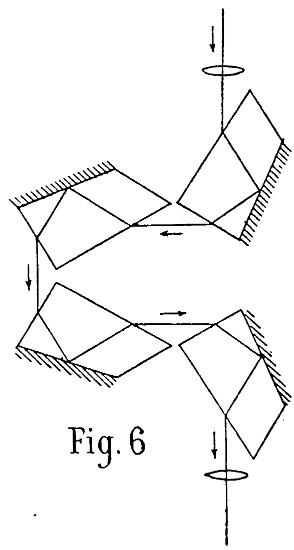


Fig. 6

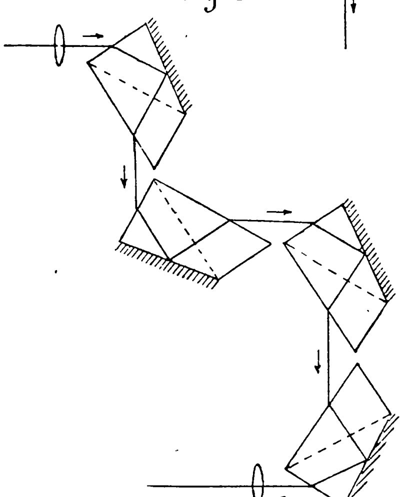


Fig. 7

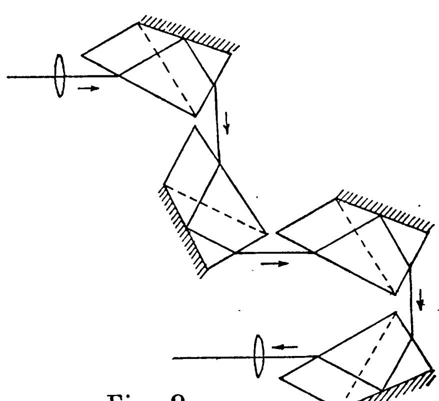


Fig. 8

the collimator is employed, the light source and slit may be placed at any desired distance. In both cases the motions of the prisms are effected by causing them to turn about fixed centers lying upon a perpendicular to the direction of the telescope, by means of two rods moved by a single fixed screw.

If three prisms are used, the collimator and telescope will lie at right angles, either to the right or left. The three prism spectroscope may be of the form (2), (3) or (4). Form (4) is most convenient.

Finally, four prisms may be used, in which case we may have either direct vision (5), or an arrangement like that shown in Fig. 3, with the slit close at hand. For each of these forms there are two solutions, shown in (5), (6), (7), (8).

In all of these solutions, in order to keep the prisms in the required position, it is only necessary to arrange them in such a manner that alternate prisms will rotate in opposite directions. This is easily accomplished by means of a tangent screw having right and left threads, or, in the case where the slit and eyepiece closely adjoin, two right and two left threads. It is evident that the faces of the prisms are always completely utilized.

It is further evident that by setting the telescope in position determined in advance by the aid of a scale, it is possible to observe with $(p-1)$ prisms, if that of order p is removed.

In this instrument a spectral line is defined by the position of the prisms at which it crosses the reticle. The angle through which the spectrum is moved by a rotation a of the prisms is $8a$. The amount of this rotation may be determined with a precision equal to the sensitiveness by means of the image of a micrometer reflected once on each of the refracting prisms. We have realized this by means of total reflection prisms placed above each of the first three refracting prisms. A double total reflection prism brings down the ray so as to utilize as a reflecting surface the last refracting face of the last prism. Thus the observing telescope may be used to measure the rotation. If, moreover, there is any error in the motion of the prism, the readings will be affected in exactly the same way as the displacement of the spectrum, and a line will always be defined by that division of the micrometer with which it coincides at the desired point.

In arrangements (5) or (7) we may have a motion of the micrometer in the direction of the spectrum, if the rectangular prism giving double total reflection is fixed. If it partakes of the motion of the fourth dispersing prism the motion of the micrometer will be in the opposite direction to that of the spectrum. The pointing of the micrometer wire will not be affected by this; but the system having direct motion is preferable.

Of these instruments we have constructed type (5), which performs perfectly. With the instrument it is possible to make a general examination of a region of the spectrum with a single prism and then to study it in detail with the four prisms. In order to realize the dispersion of eight prisms it is only necessary to employ the principle of auto-collimation, by placing a mirror in the position previously occupied by the collimator.

These instruments seem to be well suited for the use of chemists, as they will permit the use of greater dispersions than are now employed, on account of the possibility of determining positions with a precision of the same order as the dispersion.