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Recent advances in spectroscopy

Nobel Lecture, December 12,1907

The fame of Newton rests chiefly on his epoch-making discovery of the laws of gravitational astronomy - by means of which the position of the moons, the planets, and the comets, and other members of our solar system can be calculated and verified with the utmost precision - and in many cases such calculation and verification may be extended to systems of suns and planets outside our own.

But in no less degree are we indebted to this monumental genius for that equally important branch of Astrophysics - in which the spectroscope plays so fundamental a role - by means of which we are enabled to discover the physical and chemical constitution of the heavenly bodies, as well as their positions and motions. As the number and intricacy of the wonderful systems of stellar worlds which the telescope can reveal increase with its power, so also do the evidences of the innermost molecular structure of matter increase with the power of the spectroscope. If Newton's fundamental experiment of separating the colors of sunlight had been made under conditions so slightly different from those in his actual experiment that in the present stage of experimental science, they would at once suggest themselves to the veriest tyro - the science of spectroscopy would have been founded.

So simple a matter as the narrowing of the aperture through which the sunlight streamed before it fell upon the prism which separates it into its constituent colors - would have sufficed to show that the spectrum was crossed by dark lines, named after their discoverer, the Fraunhofer lines of the Solar Spectrum. These may be readily enough observed, with no other appliances than a slit in a shutter which is observed through an ordinary prism of glass. Fraunhofer increased the power of the combination enormously by observing with a telescope - and this simple combination, omitting minor details, constitutes that wonder of modern science, the Spectroscope. As the power of a telescope is measured by the closeness of the double stars which it can "resolve", so that of the Spectroscope may be estimated by the closeness of the spectral lines which it can separate. In order to form an idea of the advance in the power of spectroscopes

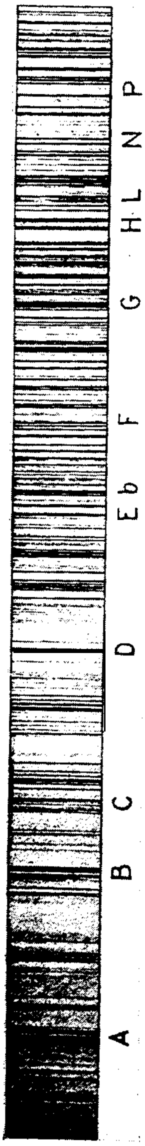

Fig.1.

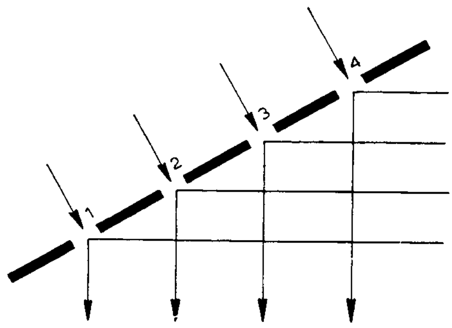

Fig.2.

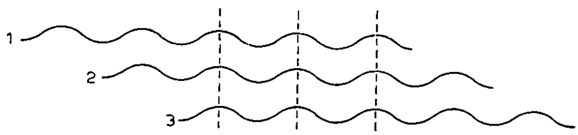

Fig. 3.

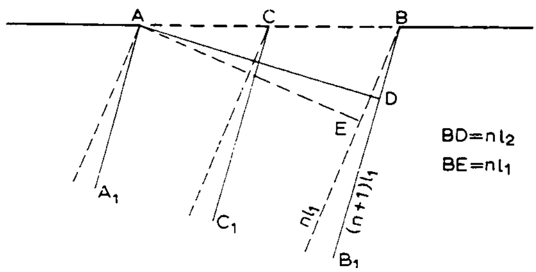

Fig. 4.

ference fringes are still visible when the difference of path is of the order of five hundred millimeters, corresponding to over a million light-waves; and the corresponding width of spectral line would be less than a thousandth part of that which separates the sodium lines.

Fig. 5 illustrates the arrangement of the apparatus as it is actually used. An ordinary prism spectroscope gives a preliminary analysis of the light from the source. This is necessary because the spectra of most substances consist of numerous lines. For example, the spectrum of mercury contains two yellow lines, a very brilliant green line, and a less brilliant violet line, so that if we pass all the light together into the interferometer, we have a combination of all four. It is usually better to separate the various radiations before they enter the interferometer. Accordingly, the light from the vacuum tube at *a* passes through an ordinary spectroscope *b c*, and the light from only one of the lines in the spectrum thus formed is allowed to pass through the slit *d* into the interferometer.

As explained above, the light divides at the plate *e*, part going to the mirror *f*, which is movable, and part passing through, to the mirror *g*. The first ray returns on the path *f e h*. The second returns to e, is reflected, and passes into the telescope *h*.

The resolving power of the interferometer is measured by the number of light-waves in the difference of path of the two interfering pencils, and as this is unlimited, the interferometer furnishes the most powerful means for investigating the structure of spectral lines or groups. Its use is, however, somewhat handicapped by the fact that the examination of a single group of lines may require a considerable number of observations which take some time and during which it may be difficult to prevent changes in the light source. Nevertheless it was found possible by its means to investigate the wonderful discovery of Zeeman - of the effect of a magnetic field on the character of the radiation from a source subjected to its influence; and the results thus obtained have been since confirmed by methods which have been subsequently devised.

One of these is the application of the echelon. This is in effect a diffraction grating in which high resolving power is obtained by using a very high order of spectrum into which practically all, the light is concentrated. The number of elements may be quite moderate - since the resolving power is the product of the two. The order of the spectrum is the number of wave-lengths in the retardation at each step. This retardation (which must be very accurately constant) is secured by allowing the incident light to fall upon a

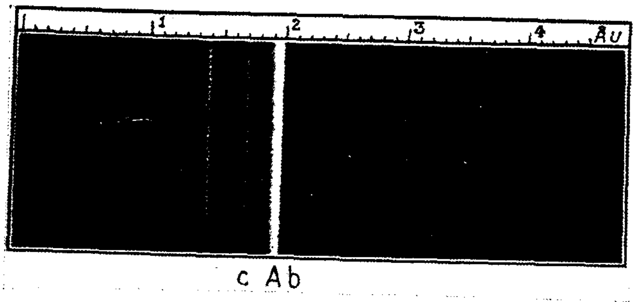

Fig.7.

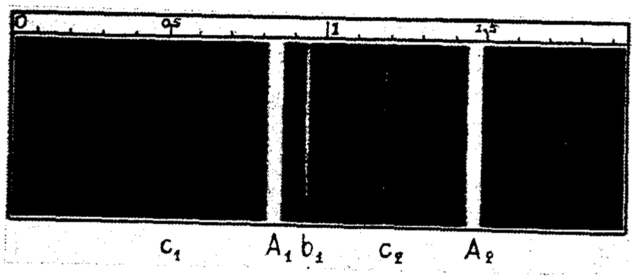

Fig.8.

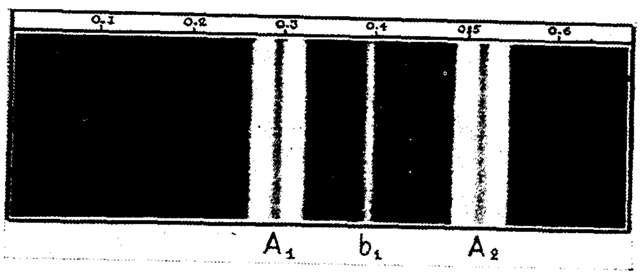

Fig.9.

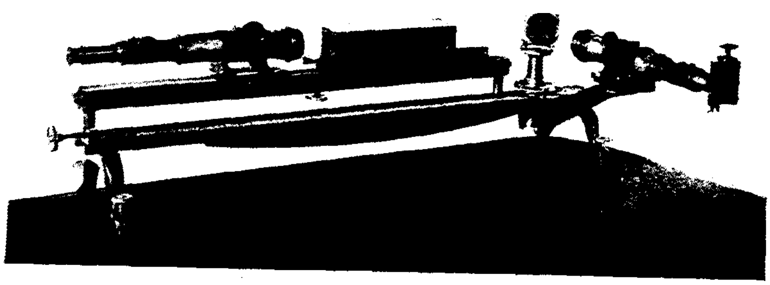

Fig.10.

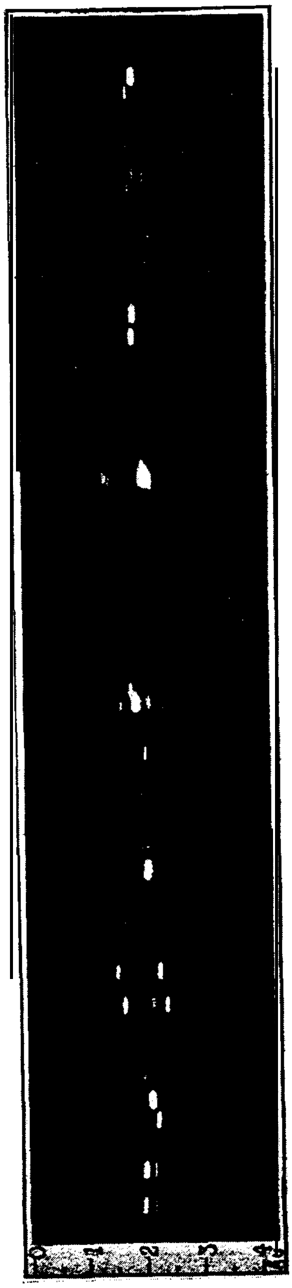

Fig.11.

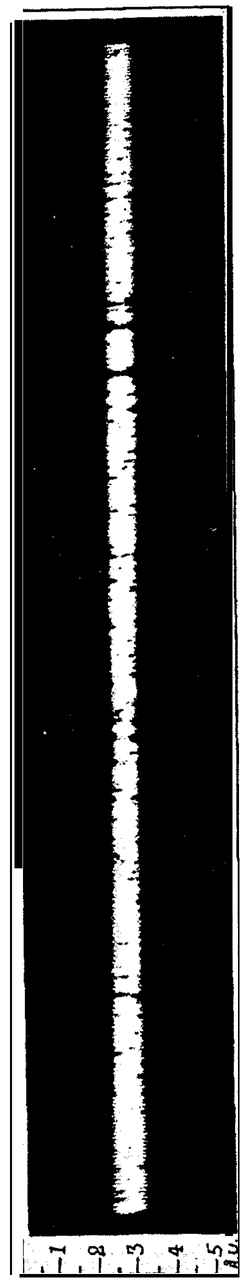

Fig.12.