Optical Experiments with Electrons.*

IT is now seven years since L. de Broglie brought forward the view of the duality between waves and particles which is now almost universally accepted under the name of wave mechanics, and represents one of the greatest advances in physics of this or any other century. The original treatment was a development of the theory of relativity, but this side of his theory can no longer be kept in its original form. It appears, in fact, that the requirements of relativity are closely connected with the magnetic properties of the electron which gave rise on the older theory to the idea of a 'spinning electron' and were not considered by de Broglie. I do not propose to deal with these, and shall give the theory in the approximate form, which is sufficient to explain the experiments I propose to describe.

The basis of the whole is a duality between waves and particles which is common both to matter and radiation. Maxwell made optics a branch of electricity; if de Broglie has not reversed the relation, he has at least shown both as different cases of a common principle, which is more like old-fashioned optics than old-fashioned electricity. The duality takes this form: any observable atomic event is representable as the arrival or departure of a particle at or from a small region of space, but the laws which govern this event involve a quantity which is best thought of as the amplitude of a wave (possibly in multidimensional space). In the case of light, this quantity is indeed the electric or magnetic vector of the Maxwell wave (it is indifferent which).

In the case of electrons, it is the more elusive ψ which obeys also an equation of the type known to mathematicians as a wave equation. In general, ψ is complex, for the equation is complex, so no direct physical meaning can be assigned to it. Its modulus $|\psi|$ is real, and de Broglie gives as his 'principle of interference' the statement that the chance of the presence of an electron at a given place and time is proportional to $|\psi|^2$. The analogous statement in optics is that the chance of a quantum of light appearing at a given place and time is proportional to the square of the amplitude of the Maxwell wave.

According to de Broglie's theory, the wave-length associated with a free electron is $\lambda = h/mv$ where h is Planck's constant and mv the momentum. He enunciates, therefore, a 'law of spectral distribution', according to which the chance of the presence of an electron with a given momentum is proportional to the square of the modulus of the Fourier component of the wave, the wave-length of which corresponds to the given momentum. In optics, the chance of the appearance of a quantum of energy W is proportional to the square of the Fourier component of the Maxwell wave of wave-length hc/W.

This simple correspondence between electron and quantum—ψ wave and Maxwell wave—in the case of the free electron, prepares us for a close experimental analogy. In fact, we can repeat many optical experiments with electrons and get strikingly similar results. The chief differences are due to the smaller wave-length, which is usually less than that of X-rays, and the much smaller penetrating power. Davisson and Germer made experiments with electrons which are analogous to the diffraction of X-rays by a single crystal, as in the Bragg method.

Other experiments have reproduced with cathode rays the diffraction of X-rays by a crystalline powder, and have verified de Broglie's law of wave-length with considerable accuracy. Some recent work with cathode rays and single crystals of copper and silver provides the electron analogy to the optical experiment in which two transmission diffraction gratings are superposed with their rulings inclined to each other (Fig. 1). The etched surface of the single crystal is apparently covered with a number of small lumps, probably the material left between etching pits. The cathode rays strike the crystal at a small glancing angle to the main surface, and pass through the lumps, being diffracted by the atoms in them. If the thickness of the lump, in the direction in which the rays traverse it, is less than a certain amount, which for the angles of diffraction and electronic wave-lengths used is of the order 10^{-6} cm., the thickness has no influence on the pattern. The diffracting system is then equivalent to an arrangement of atoms in the plane normal to the rays, and this two-dimensional array is mathematically equivalent to the crossed gratings of the optical experiment, giving rise to an array of spectra which is reciprocally connected with the atomic array producing it.

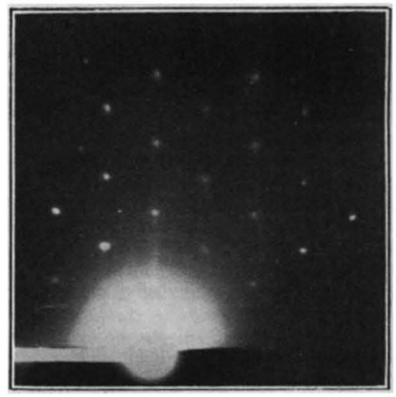

FIG. 1.—Diffraction pattern of cathode rays incident on a cube face of a single crystal of silver.

The spectra, when received on a fluorescent screen, are bright enough to be shown to a small audience.

* From a lecture delivered by Prof. G. P. Thomson, F.R.S., before the Optical Society on May 14.

Indian Fossil Plants.

IN 1928, Prof. Sahni produced the first part of an important work on Indian fossil plants. It dealt with the fossil coniferous plant remains found in the form of impressions and incrustations in rocks of the Gondwana System in India. The majority of the fossils described were of Mesozoic age, but there were also a few Palæozoic species of a doubtful nature.

In the second part of the work, which has recently been published,* Prof. Sahni extends his researches to petrified coniferous plants, providing descriptions of much that is new and interesting, as well as revising earlier work on this subject. The material with which

* Memoirs of the Geological Survey of India. *Palæontologia Indica*, New Series, vol. 11: "Revision of Indian Fossil Plants". Part 2: Coniferales (b. Petrifactions), by Dr. B. Sahni. Pp. 47-124+plates 7-15. (Calcutta: Government of India Central Publication Branch, 1931.) 7.6 rupees; 12*s*.