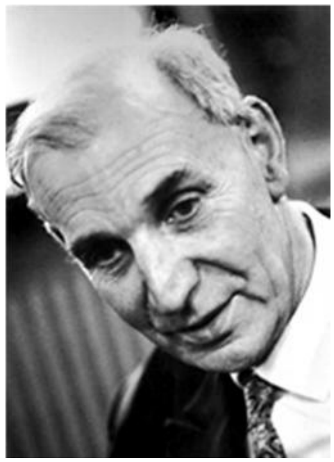
ISSN:2249-5347

IJSID

International Journal of Science Innovations and Discoveries

An International peer Review Journal for Science

Nobel Prize in Physics 1966



Alfred Kastler

The Nobel Prize in Physics 1966 was awarded to Alfred Kastler *"for the discovery and development of optical methods for studying Hertzian resonances in atoms"*.

RESEARCH INFORMATION:

When, shortly after 1930, Alfred Kastler embarked upon a scientific career, he concentrated his attention on problems connected with light scattering. He used novel methods to analyse this phenomenon, which had already been studied by projecting light emitted by certain atoms into a chamber containing the same kind of atoms. The illuminated atoms are thus excited by the light to a higher energy level. When a resonance effect of this kind is produced, strong fluorescence is emitted by the excited atoms as they return to the ground state.

The phenomenon received close attention a little earlier, particularly after it was found that the fluorescence is strongly polarized by placing a polarizer between the lamp and the resonance chamber. Another observation was that this polarization was considerably influenced by a magnetic field acting on the illuminated atoms.

Kastler made an important contribution to our understanding of these phenomena. He studied the relationships between the spatial orientation of the atoms and the

ISSN:2249-5347
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polarization of their radiation, and thus laid the foundations of the work that is today honoured with the Nobel Physics prize.

The starting point of the work was research into Hertzian resonances. These are produced when atoms interact with radio waves or microwaves, i. e. with electromagnetic radiation having a frequency at least a thousand times lower than visible light. Such waves are therefore well suited to the study of fine details in spectra, which, though observable by optical spectroscopy, could not be measured with satisfactory precision by this method. Hertzian resonances were first used for this purpose - and with success - in 1938, by Rabi following Gorter's suggestion. Rabi was able to measure, with high precision, the splitting of energy levels into a number of sublevels, a phenomenon that is produced in the presence of a magnetic field and that is due to the orientation of the atoms in space. The hyperfine structure is another kind of small subdivisions, associated with the magnetic and electric moments of magnetic nuclei. On the basis of his exact measurements, Rabi was in a position to calculate these nuclear moments with great precision.

Aided by Jean Brossel, first his pupil and later close co-worker, Kastler was the first to propose a method of investigating Hertzian resonances by optical methods, indicating the possibility of exciting selectively magnetic sublevels from excited states by polarized light having the resonance frequency. If a high-frequency oscillating magnetic field is applied, Hertzian resonance will be induced when the ratio of this frequency to an applied constant magnetic field is suitably chosen. Hertzian resonances tend to equalize the population of the magnetic sublevels, and inconsequence influence the observed polarization of the fluorescence. In practice, the resonance chamber in the process described earlier is surrounded by a coil carrying a current of radio or microwave frequency.

The experiment was carried out some years later by Brossel in collaboration with the American physicist Bitter. To extend the use of Hertzian resonances to excited states Bitter had already suggested combining optical and Hertzian resonances, but he did not propose a method of accomplishing this aim. He called the Brossel-Kastler method double optical resonance.

New profound analysis of the atomic processes connected with the scattering of resonance radiation led Kastler to the method of optical pumping, which he proposed in 1950. In this method the atoms are illuminated with resonance radiation, which is as a rule circularly polarized. According to Kastler, the atoms returning to the ground state concentrate in certain sublevels and assume preferential orientations in space if the experiment is conducted under appropriate conditions. The use of this method should allow orientation of both atoms and atomic nuclei. The experiment was actually performed two years later by Brossel, Kastler and Winter.

Double resonance and optical pumping permit very sensitive detection of Hertzian resonances, because such resonances provoke easily observable optical effects. These methods are therefore based on a different principle than ESR or NMR spectroscopy; in contrast to the latter methods, they can be applied to materials having very low density. The methods were systematically developed by Kastler in collaboration with Brossel and with a large number of young and brilliant researchers, and the investigations bear witness to the extraordinary fertility and the numerous possibilities of application of this approach.

As an important example of the phenomena involving excited states studied by double resonance in Kastler's laboratory, I shall mention the narrowing of spectral lines with increasing gas pressure within the resonance chamber.

Experiments on optical pumping were at first done with atomic beams. They led to extensive experimental and theoretical investigations of the simultaneous interactions of several quanta of an oscillating magnetic field with atoms. An important improvement in the method of pumping was obtained when the attempts to conduct these experiments on the vapour in the resonance chamber proved successful. Some very interesting work was done on the relaxation of atoms back to the disordered state after pumping, which provided information on the mechanism acting in interatomic collisions and in collisions between atoms and the walls of the container.

In the last few years, Cohen-Tannoudji has conducted research of extreme general importance, again in Kastler's laboratory, by studying the broadening and displacement of energy levels in pumped atoms, caused by their interactions with an electromagnetic field.

A large number of nuclear moments have been determined with high precision. Kastler's ideas about optical pumping played an important part in the development of the laser. Optical pumping has permitted the construction of easy to use and very sensitive magnetometers as well as atomic clocks

Professor Alfred Kastler. Through your discoveries, made partly in collaboration with your erstwhile pupil Jean Brossel, you have set a seal upon the great French tradition in optical science. Your methods have been perfected and have been successfully applied to a large number of fundamental problems by yourself and by the team of eminent young scientists attracted by the illustrious reputation of your laboratory. You have consistently acknowledged the research of your colleagues with characteristic generosity and personal modesty.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1966/press.html