Present State of Physics in the People's Republic of Bulgaria

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We shall not retrace the development of physics in Bulgaria, which is remarkable in its growth and rich in achievements, although this could be useful and instructive in outlining the future. We shall only mention that as both a fundamental science and a source of innumerable applications, physics has attracted government attention and support. At the last congress of the Bulgarian Communist Party the present state of physics was reviewed and the main objectives of its future development were set out. Here we shall restrict ourselves to the picture of the present state.

The principal institutions in Bulgaria, engaged in physics research are the following:

1) The Institute for Nuclear Research and Nuclear Energy with a research reactor and a cosmic ray station on the peak of Mussala at an altitude of 2924 m.

2) The Institute of Solid State Physics with sections for spectroscopy, low temperatures and quantum electronics.

3) The Institute of Electronics with a division of vacuum techniques.

4) The Department for Astronomy with an observatory under construction on the Rhodope Mts., centred on a 200 cm Ritchey-Chretien telescope.

5, 6, 7) The Institutes of Geophysics, of Cosmic Research and of Meteorology and Hydrology, whose activity is closely concerned with the physical sciences.

All these units belong to the Bulgarian Academy of Sciences.

8, 9, 10) The Faculty of Physics at Sofia University, which is the oldest centre of physics in the country and whose programme includes the following specialities: physics for research and engineering; physics of the earth, the atmosphere and the cosmos; physics for teachers ; in addition the physics departments at the University in Plovdiv and at the Higher Pedagogical Institute in Shumen.

There are also physics divisions in all engineering, medical and agricultural higher schools.

Physicists are employed in many laboratories concerned with electronics, chemistry, metallurgy, agriculture, medicine, biophysics, etc. and their number is continually growing. A large number of physicists are engaged as well in primary and secondary education.

All Bulgarian physicists — from the research, training and application fields — are organized in the Bulgarian Physical Society. It sponsors all scientific and public initiatives and is the chief organizer of a series of conferences, symposia and assemblies.

An interesting change that has been initiated in the past few years has been to combine the activities of all specialists in a given branch at the Academy and Sofia University. Ten general centres have been established, each of which comprises one faculty of the University and three-five institutes of the Academy. These are for: mathematics, physics, chemistry, biology, sciences of the earth, literature, history, law, philosophy and sociology, and sciences of the arts. (The general centre for literature comprises two faculties—for Slav and Occidental literature, but the General centre for sciences of the arts is not connected with any faculty). As regards the scientific programme, the centres are responsible to the Academy, but for training and education, to the University. The final aim is to create more powerful research teams and integrated facilities engaged on each problem and at the same time train the whole academic staff in teaching. This is a significant and long-term project, very important for a country that is comparatively small and at this time when scientific research, especially physics research, is becoming more and more expensive.

Other aims of the centres are to act as information organs and also to apply all results of scientific research. For this reason, they maintain and develop close relations with other institutes and different enterprises. It is clearly desirable to limit the number of areas in which research is undertaken, but applications raise problems over the whole realm of physical phenomena. This is why it is difficult to neglect any particular large field.

It is generally agreed that the main emphasis of physics research today is in nuclear physics, physics of condensed matter and electronics. These are the main areas of our work as well.

Investigations in nuclear physics proceed in six fields — two theoretical: theory of nuclei and of elementary particles; two experimental: low and high energies; and two applied: nuclear methods and instruments and reactor physics.

We should mention especially a very strong group in quantum field theory — fundamental questions, axiomatics, algebraic approach, conformal invariance, quasipotential approach, etc. There are groups studying the theory of nuclear interactions of different kinds and the microscopic description of the rotations and the vibrations of nuclei. Efforts in high energy physics are concentrated on scattering at small angles and multiple production of pions. Low energy research has several branches: spectroscopy of neutron deficient nuclei, ultracold neutrons, nuclear reactions with accelerated ions, non-stationary diffusion of neutrons in non-homogenous media, Mössbauer effect, etc.

Several applications of the Mössbauer effect have been developed in metallurgy, chemistry, solid state physics and biology. New apparatus for measuring humidity and density, various radiometers and dosimeters of high sensitivity as well as different nuclear electronic devices have been constructed. The scientific work in reactor physics is directed mainly in support of our nuclear energy programme. In Bulgaria there are two power reactors in operation and several under construction. Studies are concerned with the improvement of water cycles, assessing fission product yields, process modelling, etc. Thanks to our connections with different nuclear centres, mainly in the USSR, we are able to participate also in more complicated studies of very big reactors, breeder projects, etc.

The work in semiconductors and solid state physics traditionally has priority, because of the research in ferroelectrics and the photoelectric effect carried out by Professor Nadjykov and his school since the 1930's. Current research has several directions, which can be divided into properties, phenomena and systems.

In the first category are the fundamental properties of different substances — magnetic properties and magnetic structure of crystals; photoelectric properties of ferroelectrics; piezo-electric and optical properties of liquid crystals, etc. In the second we can cite: memory in semiconductors, crystals and amorphous layers; photoelectric phenomena in dielectrics and semiconductors; plasma spectroscopy of new gaseous sources of coherent light; Raman effect in crystals and organic molecules by laser excitation; molecular spectroscopy of semiconductors, etc. In the third, where we have grouped devices and integral systems, there are: physics of metal-dielectric-semiconductor structures and their applications in integral microelectronics; physical problems in acoustic electronics; construction of photodiodes, Gunn-diodes, etc.

In addition, as auxiliary methods and instruments, we should mention electron microscope structural investigations; techniques of low temperatures and thermodynamical properties of superconductors, etc.

Physical electronics is, in practice, closely connected with the physics of condensed matter and nuclear physics. The following specific trends in its development can be noted:

Emission and modulation of electron and ion beams: photoelectron and secondary electron emission; electron and ion methods for the formation and treatment of thin films: electron and ion methods for the creation and measuring of high and superhigh vacuum.

Plasma physics: transport phenomena, instability phenomena, interactions with electromagnetic waves, plasma chemistry, voltaic arc, etc.

At superhigh frequences, investigations are being made into gyromagnetic phenomena in radiotranslation elements and sets; applications of semiconducting elements in the creation, amplification and transformation of oscillations ; construction of devices and systems for the transformation of information, etc.

In the domain of quantum electronics, different types of laser (gaseous, metal vapours, dyed liquid) have been constructed, by means of which some questions concerning holography and different non-linear effects have been solved.

Several more general problems such as metrology, methodology, new trends in teaching, etc. are also examined, mainly at the University.

Most of the research work in all branches of physics is carried out in close cooperation with the Joint Institute for Nuclear Research in Dubna, the Centre for Magnetic Phenomena in Wroclaw and other research centres of the socialist countries, as well as in collaboration with Trieste, CERN, Batavia, etc.

We do not consider it necessary to describe here the activities in meteorology, astrophysics, geophysics, biophysics and in other more practical domains of physics or in any border areas with other sciences. It seems to us that the research fields, mentioned above, give an idea of the level, scope and development of physics in Bulgaria. We are carrying out theoretical and experimental research, which is mainly directed at national needs.

We are able to state that physics in Bulgaria is developing well, and results are on a high level, even if research has a relatively limited scope, i.e. of interest for the technical and cultural development of our country. The trend now is to push forward the process of concentration of manpower and material facilities in order to achieve a better connection between the different scientific disciplines and further raise the level of research, training, and application.

Scattering of Thermal Atoms from Crystal Surfaces

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The scattering of neutrals from surfaces is not a new subject. Soon after the first experiments by Dunoyer in 1911, molecular beams were systematically applied by Stern and coworkers in Hamburg to study different phenomena (1919-1933) including scattering from crystal surfaces. The best known result is the first observation of atom diffraction in 1929 — a brilliant confirmation of the wave nature of material particles. We must, however, recall that Stern and coworkers carried out a complete and very accurate study of the diffraction of He and H_2 beams from alkali halide surfaces under different physical conditions. At the same time, Johnson in 1930-31, made similar experiments with a beam of hydrogen atoms. Some of the experimental apparatus used by these workers was so sophisticated, that about forty years elapsed before significantly new experiments in the area of atom scattering from surfaces were carried out.

In the sixties some revival of interest for gas-solid collisions was stimulated by studies in rarefied gas dynamics connected with the launch of satellites. A particular emphasis was given to the collision of molecules in the classical limit, together with problems like the accommodation coefficient and the mean momentum transfer.

An important breakthrough in experimental techniques came from the discovery of supersonic nozzle sources, which provided the means for producing very intense and well collimated quasi-monochromatic beams of atoms and molecules at thermal energies. In the meantime, the whole field of surface physics had started a big expansion, encouraged by the advancing knowledge in solid state science and by the development of more and more refined experimental techniques.

Also the quantum theory of scattering of atoms from surfaces, after the pioneer work of Lennard-Jones and Devonshire in the thirties, made several improvements, starting with the non-perturbative approach suggested by Cabrera, Celli, Goodman and Manson.

Advances in Experimentation

Starting around 1969-70, several groups in Europe, the USA and Canada, developed new scattering apparatus for a more careful study of the interaction of atoms and molecules with surfaces. Particular emphasis was given to the understanding of the *coherent scattering* from well characterized crystal surfaces; this method of investigation appeared to be complementary to the low energy electron diffraction (LEED) technique for the study of surface structure, and was rich in information about the atom-surface interaction and the surface excitations.

Coherent scattering may be naturally classified into elastic and inelastic diffraction, two subjects which will be briefly reviewed in this article.

In order to observe coherent scattering, several conditions must be fulfilled. To begin with, the de Broglie wave length $\lambda = h\,(2mE)^{-1/2}$ must be of the same order of magnitude as the surface lattice parameter *a*. Furthermore, the surface should be ordered over regions of the order of the coherence length of the beam, and thermal motions of the atoms must not be too large. Diffraction is easily observed when beams of light atoms or molecules, e.g. He, Ne, H, H_2, and clean cleaved surfaces are used. The