Drawing on his experience as director of the International Centre for Theoretical Physics in Trieste, Abdus Salam, who gave the banquet address, emphasized the potentially key role to be played by the United Nations in fostering international collaboration in science. Interestingly enough, the center at Trieste marks the first important step taken by the United Nations in the direction of the support of pure as opposed to applied science. It also serves as a perhaps unique meeting ground between physicists from the East and the West, which can also help in large measure to solve the problem of the isolation of physicists from developing countries who must otherwise exile themselves abroad if they are to remain active in science. Salam expressed the fervent hope that the natural extension of this activity by the United Nations would consist ultimately in the founding of one or several United Nations Universities.

The proceedings of this conference will be published shortly, and the next such conference will be held at Vanderbilt University in the fall.

* * *

The authors thank T. T. Wu (Harvard) for discussions and suggestions. They feel that David Feldman (Brown) is to be congratulated for his efforts as chairman in organizing this conference.

H. Y. Chiu
Institute for Space Studies and State University of New York, Stony Brook
S. F. Tuan
University of Hawaii

Kyoto: the Physics of Semiconductors

In reporting on the highlights of the 7th International Conference on the Physics of Semiconductors (Kyoto, Japan, 8-13 Sept. 1966) we are amazed at the breadth and depth of the subject matter—basic phenomena of lattice dynamics, electromagnetic theory, quantum theory in connection with band structure, many-body effects dealing with plasmons, phonons and interactions between them, quantitative effects in transport, magneto-öptical and magnetoacoustic effects and scattering.

Band structure studies. Theoretical and experimental investigations of band structure have been one of the

central themes of the semiconductor conferences that have been traditionally held every two years since 1952. Techniques and computer calculations from the embryonic beginnings, reported in 1954 at Amsterdam, have been advanced significantly. In particular, perturbation and pseudopotential calculations, correlated with experimental data, principally those obtained by optical reflectivity techniques, have now given a fairly complete picture of the band structure throughout the Brillouin zone of not only elemental materials, such as germanium and silicon, but also the more complex 3-5 and 2-6 compounds.

Optical investigations. Although optical and infrared experiments have been traditionally important tools for the study of fundamental semiconductor properties, sophistication of methods and elegance of results reported at the Kyoto conference indicated the maturity of this field of physics. The use of high-resolution spectrometers, combined with low temperature, has made possible measurements in new crystals of complex structure such as the layer compounds of the gallium-selenide family. An interesting investigation of amorphous germanium, in which the short-range order is approximately the same as in single crystals but the long range order is absent, revealed spectral structure in the infrared region, analogous to that of crystalline material.

Another significant class of problems to be studied by optical means has been lattice vibrations in crystalline material. In particular, observation of higher-order Raman and multiphonon processes is currently of great interest in semiconductors. Such spectral studies of phonon processes are pertinent because of the current and future work in the area of Raman scattering with laser beams.

In a session devoted to impurities, such topics as impurity-band tails in degenerate semi-conductors were discussed. This subject is important in the infrared emission from diodes and lasers. Sophisticated theoretical and experimental studies of the complicated energy-level structure of neutral and singly and doubly ionized impurity levels in host crystals such as germanium and silicon were carried out by means of piezospectroscopic techniques. Results were also reported on the Zeeman effect of acceptor states in type II diamond.

Magnetoöptics. New crossed-electric- and magnetic-field effects at very high magnetic fields, of the order of 100kG or more, were presented; there is great theoretical interest here, not only in magnetoabsorption but also in photon-assisted magnetotunneling. Some interesting work concerned recent experiments and theory of nonlinear magnetoöptics, in which multiphoton-induced interband transitions have been observed with a Q-spoiled carbon-dioxide laser. Resonance nonlinearities that were indicated show great promise for future study of semiconductors and semimetals. From results obtained by combination of piezoreflectance and high magnetic fields it was apparent that there is a new future for the quantitative study of band structure in semiconductors, semimetals and metals as well.

The study of solids with lasers combined with high magnetic fields was not restricted to the near infrared with sources such as the carbon-dioxide laser; for example, the cyanide laser has been used to observe cyclotron resonance in p-type germanium at 0.337 nm in fields up to 150 kG. Cyclotron resonance has also been studied in the submillimeter region near 0.7 nm using well known carcinotron sources. Thus it appears that these two techniques of generating coherent radiation have converged in this region of the spectrum and, in conjunction with superconducting magnets, should provide very effective tools for resonance studies in semiconductors and semimetals.

Transport investigations. One of the striking features in investigating transport phenomena in semiconductors is the more extensive use of high magnetic fields. In the study of one new phenomenon, oscillatory magnetoconductance in silicon surfaces, dc fields up to 93 kG were employed. A relatively new quantum transport effect, magnetophonon resonance, was studied in indium antimonide and indium arsenide by sweeping a pulsed magnetic field up to 500 000 G and observing oscillations in the magnetoresistance arising from resonant scattering of electrons when the Landau level or spin spacings coincide with the energy of the optical phonon.

The natural extension of microwave and millimeter semiconductor techniques to semimetals was quite evident throughout the conference. Not only traditional dc techniques but also cyclotron resonance, which was first reported in 1954 in germanium and silicon, have now been found extremely useful in studying semimetals such as arsenic, which are in many ways similar to semiconductors. An interpretation of magnetothermoelectric and galvanothermoelectric effects observed in bismuth, which has anisotropic and complicated energy surfaces, was considered.

A paper on bismuth-antimony alloys also illustrated the close relation between semimetals and semiconductors. The quantum transport Shubnikov-de Haas technique indicated that this alloy indeed does become a semiconductor in the vicinity of 12% concentration of antimony in bismuth as had been predicted earlier. In related work it was demonstrated that for sufficient doping with tin, bismuth conducts primarily by holes in a manner analogous to an extrinsic p-type semiconductor.

Proceeding from linear transport theory it is natural to consider the behavior of electrons under the action of high electronic fields—that is, the hot electrons. The invited paper in this session emphasized the role of optical phonons, which are excited by the hot electrons, in determining the energy distribution of these energetic carriers. In turn, particularly in piezoelectric crystals, the effect on phonon distribution of energy transfer between electrons and phonons was pointed out. Hot electrons are of considerable interest because of their role in the amplification of acoustical waves by fast moving charges, avalanche breakdown in low-energy-gap semiconductors, and the well known Gunn effect. In discussing the current instabilities involved in the latter effect in gallium arsenide, experimental evidence was presented for the creation of high-field domains of electrons in the higher band and for the drift of these domains, which are responsible for the microwave oscillations.

Electron-phonon interactions that occur naturally in the context of hot electrons can be examined from another viewpoint, namely, the "acoustoelectric" effect; this phenomenon has been widely studied in cadmium sulfide. In particular, the physics of high-frequency sound amplification and the mechanisms of the nonlinear electron-phonon interaction were examined not only in cadmium sulfide but also in tellurium and many-valley semiconductors as well. A unique presentation concerned the observation of polarons (mobile charge in polar crystals that drag along excited phonons) in indium antimonide. The most significant aspect of this work was the behavior of polarons in a magnetic field, examined by the interband magnetoöptical phenomenon.

Impurity conduction is a phenomenon that was observed some time ago; only recently with more advanced theoretical techniques and better experiments, however, has this subject become susceptible to quantitative theoretical analysis. One of the papers presented the thesis that *s-d* scattering due to spin interactions may be important. The resistance minimum as a function of temperature (in this case with magnetic field), which is well known in magnetic alloys, is thought to resemble the Kondo effect of spin scattering. The role of localized spins in impurity scattering has also been proposed in a different form by Toyozawa and appears to be in qualitative accord with experiment. In another approach to understanding the phenomenon of impurity conduction it was studied as a function of frequency.

Superconducting and magnetic semiconductors. Among the relatively new aspects of semiconductor physics that were introduced at this conference were semiconductors that exhibit magnetic properties and those that become superconductors at very low temperatures. What is significant about these semiconductors is that since the carrier concentration can be controlled, new information can be obtained regarding the mechanism of superconductivity. This remarkable phenomenon has been extensively studied in strontium titanate and germanium telluride, below 1°K.

The conference was held under the joint auspices of the International Union of Pure and Applied Physics and the Science Council and Ministry of Education of Japan. It was organized by T. Muto, chairman, and G.M. Hatoyama, secretary. The proceedings have been published as a supplement to volume 21 of the Journal of the Physical Society of Japan.

B. Lax
National Magnet Laboratory, MIT
J. G. Mavroides
Lincoln Laboratory, MIT

Magnetizers Discuss Their Ways and Whys at Grenoble

The magnetic-field parameter is now recognized as one of the most important in modern and future science and technology. This is the reason for world-wide interest in production and application of high magnetic fields and the importance of the 1966 International Conference on High Magnetic Fields (University of Grenoble, France, 12–14 Sept.). It was sponsored by the Centre National de la Recherche Scientifique, with the blessing of the International Union of Pure and Applied Physics and had more than 250 participants.

High-field production. The following is a list, from the conference, of laboratories that produce intense magnetic fields by conventional, superconducting, combined, quasi-continuous cryogenic, pulsed and explosive techniques:

Conventional continuous fields (using some megawatts of power) in the 100-kG range and above were reported from

France:

Laboratoire d'Electrostatique et de Physique du Métal, University of Grenoble, 103 kG, 3-cm diameter.

Centre d'Etudes Nucléaires, 100 kG.

United States:

Low Temperature Laboratory, University of California, Berkeley, 100 kG, 12-cm diameter, 50-cm length.

National Magnet Laboratory, Cambridge, Mass., 225 kG, 3-cm diameter (240 kG for a short time).

Holland:

Kamerlingh Onnes Laboratorium, Leiden, 80 kG, 8.6-cm diameter.

England: