Yu. N. Denisyuk and V. I. Sukhanov. Holography in Two-dimensional and Three-dimensional Media.

Holography can be defined as a photographic method of recording and reproducing wave fields. There are now two essentially different varieties of the hologram—two-dimensional holograms and holograms in which the wave field is recorded in a three-dimensional medium.

In registration of a two-dimensional hologram, the result of interference between the radiation scattered by the object and the radiation propagated directly from the source is recorded on the surface of a photographic plate. The plate becomes transparent where the phases of these two waves coincide. When such a hologram is illuminated with radiation from the source used in the exposure, it transmits this radiation only where its phase coincides with that of the wave scattered by the object, and, as a result, the object wave field is reproduced on approximately half of the hologram area. In accordance with the Huygens principle, the wave field of the object is also reconstructed throughout the space behind the hologram. An observer registering this field cannot distinguish it from a real field and sees a three-dimensional image of the object that is indistinguishable from the original. The fact that the two-dimensional hologram reproduces the field on only half of its surface results in phase-reproduction ambiguity and ultimately in the appearance of a spurious additional image.

When three-dimensional holograms are registered, a fragment of the three-dimensional interference pattern surrounding the object is impressed into the volume of the photosensitive layer. Each surface of antinodes of this pattern is a geometric locus of points at which the phase of the object wave coincides with the phase of the source wave. Accordingly, on illumination of each such surface by source radiation, the phase of the wave reflected by this surface coincides with the phase of the object wave over the entire surface of the hologram. As a result, this hologram reproduces the exact value of the object wave field and, accordingly, a unique three-dimensional image of the object appears. But a whole ensemble of antinode surfaces is recorded in the volume of the hologram. Like an interference filter, this complex structure exhibits spectral selectivity, with the result that three-dimensional holograms admit of reconstruction of the radiation with a continuous spectrum. The fact that the three-dimensional hologram reflects radiation in the same way as the object makes it possible to regard it as a kind of optical equivalent of this object. It is natural to assume that this property of the three-dimensional hologram results from the fact that its structure tends to reproduce the structure of the object. It is not possible to prove this in the general case, since the method to be used in describing an arbitrary three-dimensional object is still unclear. In order to define the general tendencies that determine the structure of a three-dimensional hologram and the relation of its structure to that of the object, the authors investigated a particular case in which a transparent phase object was registered on the hologram. It was shown as a result that the space-frequency spectrum of the three-dimensional hologram equals the product of the space-frequency spectrum of the object by a certain transfer function that depends exclusively on the parameters of the wave illuminating the object. Thus, just as in the case of formation of an image by an optical system, formation of a hologram is attended by filtration of the object's space frequencies; it can be shown that for a specified propagation direction of the radiation, the space-frequency spectra of the object and its hologram are identical, with the result that their optical properties are also identical in this case. Effects related to the limits on the volume of the registering system were then examined, and the limit transition to the case of the two-dimensional hologram was carried out. It was shown that the hologram spectrum then shows spatial frequencies that did not exist in the object spectrum. The presence of the additional frequencies in the two-dimensional hologram leads to the appearance of three additional spurious images and to loss of the spectral-selectivity property. On the whole, the relation between the two- and three-dimensional holograms can be described as follows. The most complete set of information on the image of the object is included in the entire limitless three-dimensional standing-wave pattern surrounding it. One of the remarkable properties of this pattern consists in the fact that each fragment of it also creates a complete image of the object as a whole. Division of the primary pattern into fragments merely results in gradual impoverishment of the reconstructed image, which retains its integrity. For example, a plane section through such a pattern—the two-dimensional hologram—reconstructs spurious images in addition to the true image; moreover, it becomes impossible to accomplish the reconstruction with white light when the plane section is used.

M. I. D'yakonov, B. P. Zakharchenya, V. I. Perel', S. I. Safarov, and V. G. Fleĭsher. Orientation of Electron Spins in Semiconductors.

The phenomenon of optical orientation of atoms in gases is well known and offers a powerful tool for study of atomic processes. Kastler and his school had a major role in the development of this field. The first experiments that indicated the possibility of optical orientation of free electrons in semiconductors were also performed in France by Lampel[1] and Parsons[2].

The present report is devoted to results obtained in this field at the A. F. Ioffe-Physico-technical Institute of the USSR Academy of Sciences. It appears to us that this trend, which is a novelty for semiconductor physics, will be found effective in the investigation of the properties of semiconductors and will also find practical applications.

In the optical-orientation method, nonequilibrium electrons are produced in the conduction band by interband absorption of circularly polarized light. The momentum M of a circularly polarized photon is transferred to the electron-hole system. In crystals with the GaAs band structure, the hole momentum relaxes rapidly, and the electron spins are found to be oriented. The selection rules indicate that in an interband transition $\Gamma_8 \to \Gamma_6$, three times as many electrons are ejected into a state with spin opposed to the momentum of the photon than are ejected into a state with spin of the same direction as the photon momentum. This corresponds to a degree of orientation $P_0 = 50\%$ of the electrons at their production.

Under stationary excitation, the degree of orientation P depends on the relation between the electron lifetime τ and the spin relaxation time τ_S:

A magnetic field perpendicular to the direction of the exciting beam of light disturbs the orientation (Hanle effect):

$$P(H) = P\frac{1}{1+(\mu_0 g H T_s/h)^2}, \tag{2}$$

where P(H) is the degree of orientation in a magnetic field H, μ_0 is the Bohr magneton, g is the g factor, h is Planck's constant, and the time T_S is defined in terms of τ and τ_S as follows:

$$T_s^{-1} = \tau^{-1} + \tau_s^{-1}. \tag{3}$$

The presence of spin orientation can be registered from the polarization of the recombination emission.

For the $\Gamma_6 \to \Gamma_8$ transition, the degree of polarization ρ of the radiation is 0.5P (for observation with or against the direction of the spin). Then the maximum degree of polarization is 25%. According to[1], it is reached at $\tau_S \gg \tau$.

Study of ρ as a function of the energy $E_{h\nu}$ of the photon of circularly polarized exciting light makes it possi-