Scientific session of the Division of General Physics and Astronomy and of the Division of Nuclear Physics of the Academy of Sciences of the USSR (21–22 October 1987)

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A joint scientific session of the Division of General Physics and Astronomy and of the Division of Nuclear Physics of the Academy of Sciences of the USSR was held on 21 and 22 October 1987 at the S. I. Vavilov Institute of Physics Problems. The following reports were presented at the session:

October 21

1. I. N. Sisakyan and A. B. Shvartsburg. Adaptive radiooptics.

2. I. I. Tsukkerman. Information principles and methods for image processing for automating scientific research.

3. V. L. Afanas'ev. Experience in the use of the "Kvant" complex for producing and processing images.

October 22

4. V. I. Panov. Scanning tunneling microscopy and surface spectroscopy.

5. M. S. Khaĭkin. Scanning tunneling microscopy and spectroscopy.

6. V. I. Anisimov, V. P. Antropov, V. A. Guvanov, M. I. Katsnel'son, and A. I. Likhtenshteĭn. Band theory of the magnetism of metals and alloys.

7. V. G. Vaks, S. P. Kravchuk, and A. V. Trefilov. Microscopic theory of anharmonic effects in alkali and bcc alkaline earth metals.

Summaries of four of these reports are given below.

I. N. Sisakyan and A. B. Shvartsburg. *Adaptive radiooptics.* Adaptive radiooptics arose from a convergence of traditional radiooptics, which studies wave processes in the millimeter and submillimeter ranges, and adaptive optics, which involves the flexible adjustment of the parameters of radiation in the visible and near-IR parts of the spectrum. A current problem in adaptive radiooptics is the development of elements of wave systems for the submillimeter and far-IR ranges, bordering the optical range, which are analogous to optical modulators, polarizers, filters, and deflectors. Such problems are currently attracting interest because of the problems of long-range communications, signal processing, and the programmable shaping of fields of a given space-time structure. In order to achieve flexible control of the wave fluxes in these ranges it is necessary to find effective nonlinear mechanisms. This report calls attention to the promising outlook for the use of thermal and magnetic effects in thin slabs of a semiconductor plasma for the modulation of submillimeter waves reflected from such slabs. In other words, this report discusses the properties of a "mirror" whose reflection coefficient (both its amplitude and its phase) is controlled by the heating of carriers and by an external magnetic field.

This report discusses the temperature-induced changes in the reflection coefficients in examples of n-type III-V semiconductors (GaAs and InSb) at low temperatures ($T_e \approx 10$–30 K). In this temperature region, the carrier collision rate ν_e is affected significantly by the scattering of carriers by ionized impurities, in accordance with $\nu_e \approx \nu_{e0} T_e^{-3/2}$. If, as a result of doping, the frequency of the incident wave, ω, the carrier plasma frequency Ω, and the collision rate before heating, $\nu_{e'}$ are related by

$$\omega \approx \Omega \approx \nu_{e0},$$

then the thermal change in the collision rate ν_e during heating by an external field will lead—in contrast with the result in the case of traditional cross modulation—to a significant perturbation of both the real and imaginary parts of the di-

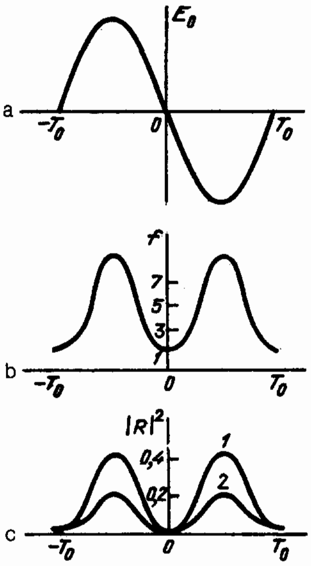

FIG. 1. a—Envelope of the heating field; b—of a pulse of the carrier temperature; c—and of pulses of the reflected field of radiation with $\lambda = 120\,\mu$m which is incident at an angle of 45° on the surface of n-GaAs with a carrier density $N = 4.5 \cdot 10^{16}$ cm^{-3}. Lines 1 and 2 refer to the s and p polarizations, respectively.

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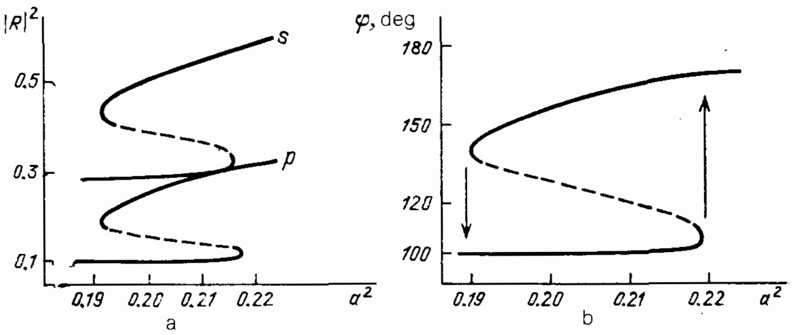

FIG. 2. Bistability of the reflection coefficient for a wave with $\lambda = 380\ \mu$m (a) in terms of the intensity and (b) in terms of the phase for the case of s polarization and incidence at an angle of $\alpha = 45°$ on the surface of n-InSb (the magnetic field is $H = 150$ G).

electric permittivity of the medium and thus to significant perturbations of the amplitude R and phase φ of the complex reflection coefficient.

During periodic heating of the carriers of a semiconductor by an external electric field whose period T_0 is related to the relaxation time of the carrier temperature, τ, by $T_0 \gg \tau$, the oscillations in the carrier temperature will lead to oscillations in the reflection coefficient under condition (1). When a continuous flux of submillimeter radiation is incident on the surface of such a semiconductor, the reflected wave will be amplitude-modulated (Fig. 1). During rf heating of the carriers, a bistable reflection regime can arise. The jumps in the temperature which cause the bistability of the amplitude and phase of the reflected signal can be controlled by an external magnetic field (Fig. 2). Flexible thermal control of radiation is based on the following theoretically predicted effects:

1. This tuning of the radiation occurs over a wide frequency range of the heating electric field and is characterized by a low energy expenditure (a power $W \lesssim 10$ W in films of thickness $d \approx 20$–$30\ \mu$m), since the thermal changes in ε do not require the generation of new carriers, in contrast with the situation in the traditional laser effects.

2. The depth of the amplitude modulation, which differs for the s and p polarizations, can reach 95–99%.

3. The phase shift of the reflected wave during heating can be 90–150°.

4. The appearance of bistable regimes in both the amplitude and phase of the reflected signal leads to hysteretic jumps in these parameters in the range 200–400 μm.

5. The imposition of a magnetic field $H \lesssim 300$ G prevents bistable regimes and leads to the formation of a continuous dependence of the level of the reflected signal on the amplitude of the heating field. Raising the magnetic field to $H \approx 800$ G can lead to doubling the number of reflected signals.

6. The speed of this nonlinear system is characterized by a time $t \lesssim 10^{-8}$ s.

7. Nonuniform magnetic fields in the heated plasma slab lead to deformations of the reflected wavefront, in a manner analogous to the effect of tunable deflectors, lenses, and polarizers.

The wide range over which the amplitudes, phases, and polarizations of the modulated signals can be varied; the speed; and the possibility of a "soft" control of the space-time characteristics of radiation with a low energy expenditure make these effects candidates for a physical foundation of adaptive radiooptics.