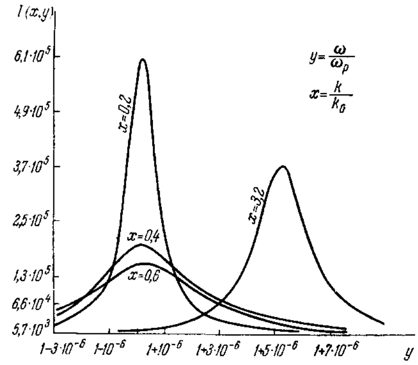

FIG. 2

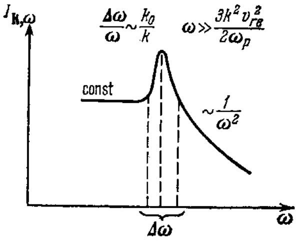

FIG. 3

and the linear increments, owing to their cancellation by the nonlinear processes under conditions of stationary turbulence. Far from the resonance $\omega = \omega(k)$ (on the "tails") there arise oscillations in which there is no unique relation between ω and k. Their spectrum can be obtained if one knows the turbulence spectrum (Fig. 3). It is interesting that the maximum frequency of these oscillations is equal to the difference between the frequencies of the high-frequency excitations. Exactly such an effect was observed experimentally by exciting stochastic oscillations under conditions of plasma-beam interaction (Ya. B. Fainberg). These low-frequency pulsations lead to stochastic heating of the particles. If the particle distribution function is resolved in regular and stochastic components, $f = f^R + f^S$, then the equation for f^R described diffusion in momentum space, and the diffusion on the "tail" of the correlation curve, which is proportional to $I_{k,\omega}$, has the same order as the $I^2_{k,\omega}$ effects, and their sum describes exactly the induced scattering of plasmons with allowance for two scattering processes—scattering by the main charge and by its surrounding "jacket" of charges of opposite sign. The presence of such a "jacket" alters appreciably the scattering processes, leading, for example, to an intense scattering for plasma ions. Thus, a closed physical picture is obtained, in which f^R describes the electronic and ionic excitations (charge + "jacket"), and W_k describes plasmons interacting with one another via the induced radiation and the induced scattering. Such a picture is correct so long as the correlation broadenings γ^N_k are much smaller than $\omega(k)$, i.e., when $W/nT \ll 1$. The smallness of $1/N_D$ leads to a very wide range of applicability of these concepts. In addition to plasmons, photons should be included in this scheme. The point is that their appearance is inevitable in a system of sufficiently large dimensions. It is possible to subdivide the types of plasma turbulence into the following classes, depending on whether the turbulence is dissipated into a) thermal energy, b) electromagnetic radiation, c) energy of the accelerated particles. It can be shown that if the system is optically thick relative to electromagnetic dissipation processes, then its main energy goes to the fast particles, which are accelerated quite effectively to ultrarelativistic energies, and consequently start to emit high frequencies when scattered by the plasmons. These photons have a spectrum $\sim \omega^{5/2}$ in the frequency regions that are optically thick, and their action on the relativistic particles causes the latter to have a power-law spectrum $1/\epsilon^{\gamma}$. Figure 4 shows the results of a numerical solution of the equation for γ as a function of $-\log \kappa = \log(W/nmc^2)$ and $(eH/mc)/\omega_p$, which yields $0.9 < \gamma < 3$. The spectral indices $\nu = (\gamma - 1)/2$ of most radio sources lie in this interval, and the value $\gamma = 2.7$, for which, according to Fig. 3, large changes of κ and ξ produce practically no change of γ, correspond to the cosmic-ray spectrum. We emphasize that this conclusion is a necessary consequence of the developed theory of a plasma as a system of interacting elementary excitations.

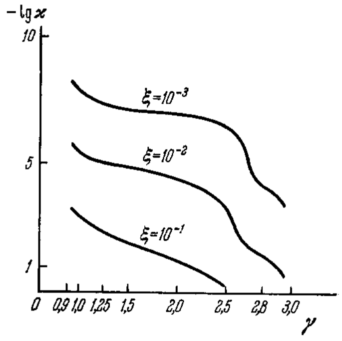

FIG. 4

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[2] V. N. Tsytovich, JINR Preprint (1969).

[3] V. N. Tsytovich and B. M. Chikhachev, Astron. zh. 46, 486 (1969) [Sov. Astron. AJ 13, 385 (1969)].

Yu. B. Denisyuk, V. I. Sukhanov, Hologram Recorded in a Three-dimensional Medium as the Most Perfect Form of Image

The ability of light to depict material bodies and the associate concept of "image" are fundamental in optics. Essentially, these concepts play the role of axioms and cannot be defined in terms of categories of higher order. In this connection, the fact of representing the optical properties of an object by means of its three-dimensional hologram assumes particular importance for optics, for it is precisely the three-dimensional hologram which is the most perfect of all the presently known images[1].

Investigations performed at the State Optical Institute from 1958 through 1962 have shown that a three-dimensional hologram, by duplicating the amplitude, phase, and spectral composition of the radiation, is the optical equivalent of an object that acts on a given radiation in the same manner as the object itself (for example, a three-dimensional hologram of a convex mirror selects from the white spectrum the radiation that has exposed it, and focuses it in the same manner as the original mirror)[2].

A more perfect image can obviously be provided only by a duplicate of the object, which acts in the same manner as the object itself on any radiation.

As a further development of these concepts, the connection between the space-frequency spectrum of a three-dimensional hologram and the space-frequency spectrum of a phase object was recently investigated. It turned out that the spectrum of a three-dimensional hologram is part of the spectrum of such an object. When the radiation band used to expose the hologram is broadened, the region over which these spectra coincide broadens and the distribution of matter in the three-dimensional hologram approaches the distribution of matter in the original object[3].

Thus, a three-dimensional hologram indeed tends to copy the object. This property of light may be very useful for the development of the theory of an image, and should possibly be taken into account in the elementary acts of interaction between light and matter.

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[2] Yu. N. Denisyuk, Opt spektrosk. **15**, 522 (1963).

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E. S. Voronin, Nonlinear Transformation of Images and Infrared Holography

The infrared band plays an important part in optical technology. This is connected with the greater transparency of the atmosphere in the IR band, with the lower level of fluctuation noise, and with a number of other specific features. At the same time, reception of radiation in this band is a much more complicated matter than, for example, in the visible, and the problem of reception hinders in many respects the development of IR technology.

The situation is particularly difficult with image receivers, since electron-optical image converters operate only up to 1.2 μ, and thermal systems have definite shortcomings. The use of frequency conversion by methods of nonlinear optics uncover great prospects in this direction. Indeed, using a plane pumping wave of frequency ω_1, then each plane IR wave of frequency ω_2 having a wave vector lying within a certain solid angle will correspond to a plane wave generated in the crystal, with a frequency $\omega_3 = \omega_1 + \omega_2$ and a wave vector whose direction is determined uniquely by the direction of the wave vector of the signal wave. This makes it possible to obtain an image at the summary frequency, if the information is contained in the angle spectrum, i.e., if the field with frequency ω_2 corresponds to radiation from an object located at infinity. This is precisely the possibility employed by Midwinter[1] and by Warner[3] to obtain a visible image of objects illuminated with IR radiation. The image of the object was obtained at infinity with the aid of ordinary lens or mirror systems. Such a procedure, however, yields results that are far from the ultimately attainable ones, and information concerning the longitudinal dimensions of the object is completely lost.

At the Moscow University, M. I. Divlikeev, Yu. A. Il'inskiĭ, V. S. Solomatin, R. V. Khokhlov, and the author have carried out a cycle of investigations in this direction. As a result we developed a new scheme (Fig. 1) for obtaining images at a summary frequency, wherein the object (or its image constructed by means of an ordinary optical system) is located at a finite distance from a nonlinear crystal. This reduces greatly the requirements concerning the divergence of the pump signal, and also concerning the monochromaticity of the radiation, and lifts the limitations on the maximum resolution. The developed procedure yielded, for the first time, diffraction resolution of the image. Inasmuch as in this scheme the information on the object is contained more readily in the spatial structure of the field than in the angular structure, the information on the longitudinal scales of the object is preserved. This makes it possible to transform the three-dimensional image and to obtain holograms of three-dimensional objects illuminated by IR radiation, with subsequent reconstruction in visible light. The reference beam for the recording of the holograms can be obtained either in the same crystal (see Fig. 1) or in another crystal, in which a summary frequency is likewise obtained. The former method has the advantage that the inhomogeneities of the crystal and the distortions of the pump wave front are cancelled out to some degree, since they are the same in the main and in the reference beams. The second method makes it possible to obtain larger angles between the main and the reference beams and to raise them to values determined by the resolution of the available photographic material. When the hologram is reconstructed with the aid of the frequency ω_3, the reconstructed image has the same properties as the image at the frequency ω_2. The angle field of view can be increased by successively photographing the hologram on a single film while varying the refractive indices of the crystals with the aid of an external field or by varying the temperature.

Experiments aimed at converting an image from 1.06 μ to 0.53 μ with a KDP crystal, using two-dimensional interaction of the signal and pump waves, gave the largest resolution. The scheme shown in Fig. 1 yielded, for the first time, ordinary and three-dimensional holograms of objects illuminated with IR. An

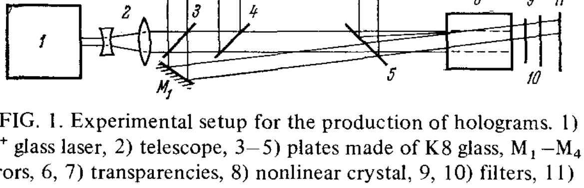

FIG. 1. Experimental setup for the production of holograms. 1) Nd^{3+} glass laser, 2) telescope, 3–5) plates made of K8 glass, M_1–M_4) mirrors, 6, 7) transparencies, 8) nonlinear crystal, 9, 10) filters, 11) film.