Lapidus, and V. M. Shekhter for valuable discussions, and to the entire staff for taking part in exposing the chamber and in the processing of the photographs.

[1] Yu. A. Budagov, Yu. F. Lomakin, and A. V. Bogomolov, et al., PTE No. 1, 61 (1964).
[2] V. S. Kladnitskii and V. B. Flyagin, PTE No. 1, 24 (1965).
[3] Wang Yu Ch'ang, Kim Hi In, and E. N. Kladnitskaya, et al., Proc. XII Int. Conf. on High Energy Physics 1, 615 (1964); E. G. Bubelev, B. Chadchaa, and I. V. Chuvilo, Phys. Lett. 24, 246 (1967).
[4] G. I. Kopylov, JINR Preprint R1-3048, Dubna, 1966.
[5] A. G. Volod'ko, V. B. Vinogradov, and S. V. Klimenko et al. JINR Preprint R1-3351, Dubna, 1967.
[6] D. Berley, P. L. Connolly, and E. L. Hart et al., Phys. Rev. Lett. 15, 641 (1965).
[7] Birmingham-Glasgow-London-Oxford-Rutherford Collaboration, Phys. Rev. 152, 1148 (1966).
[8] M. Gell-Mann and Y. Neeman, The Eightfold Way, p. 43, n N=Y-Amsterdam, 1964.
[9] I. Schwinger, Phys. Rev. Lett. 12, 237 (1965).

INFRARED HOLOGRAPHY BY METHODS OF NONLINEAR OPTICS

E. S. Voronin, N. I. Divlekeev, Yu. A. Il'inskii, V. S. Solomatin, and R. V. Khokhlov
Moscow State University
Submitted 2 July 1969
ZhETF Pis. Red. 10, No. 4, 172 - 174 (20 August 1969)

Holography in the infrared cannot be obtained by usual methods, since the photographic emulsions are not sensitive to infrared.

Nonlinear optics makes it possible to transform, with the aid of an auxillary pump beam of frequency ω_1, infrared radiation of frequency ω_2 into radiation of visible frequency $\omega_3 = \omega_1 + \omega_2$ [1 - 3]. In this paper we propose a new image-conversion scheme, which unlike the published ones makes it possible to transform a three-dimensional image, and also obtain holograms of three-dimensional objects illuminated with infrared.

If the object is located at a distance z_1 from the nonlinear crystal then, as can be shown, the image at the summary frequency is located at the distance

$$z_2 = z_1(\omega_3/\omega_2) - \ell[1 - (1/2n_3) - (\omega_3/2n_2\omega_2)] \quad (1)$$

from the crystal. Here ℓ is the length of the crystal, and n_1, n_2, and n_3 are the refractive indices for the corresponding waves. As seen from (1), the longitudinal dimensions of the image at the summary frequency change, compared with the object, by a factor equal to the frequency ratio. The transverse dimensions remain unchanged.

The transverse resolution is in this case of the order of

$$\Delta x = \Delta y = 1{,}4\sqrt{n_1\omega_1 c\ell/n_2 n_3\omega_2\omega_3}\ , \quad (2)$$

where c is the velocity of light, and the longitudinal resolution (in object space) is

$$\Delta z \approx \ell/n_2\ . \quad (3)$$

These formulas are valid when $z_1 < d/\Delta\phi$, where d is the effective transverse dimension of the crystal (the diameter of the pump beam) and $\Delta\phi$ is the permissible angular deviation of the wave of frequency ω_2 from exact synchronism. When the system is properly adjusted, $\Delta\phi$ is of the order of $\pi(n_2 n_3\omega_3 c/\ell n_1\omega_1\omega_2)^{1/2}$ and amounts to several degrees when ℓ is of the order

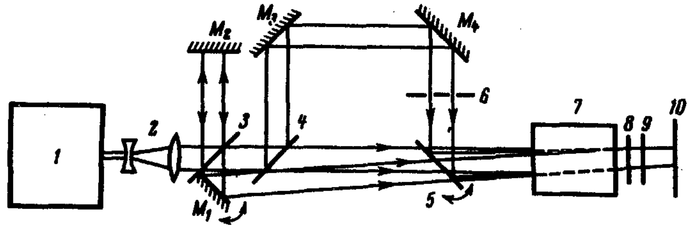

Fig. 1

Fig. 1. Experimental setup: 1 - neodymium glass laser, 2 - telescope, 3, 4, 5 - plates of K8 glass, M_1, M_2, M_3, M_4 - mirrors, 6 - pattern, 7 - KDP crystal, 8 - filter SzS-24, 9 - filter NS-2, 10 - film.

Fig. 2. Photograph of pattern image reconstructed from hologram.

Fig. 3. Photograph of pattern.

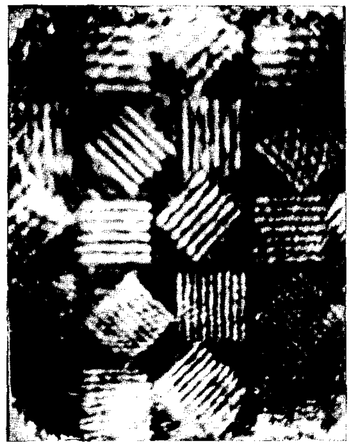

Fig.2

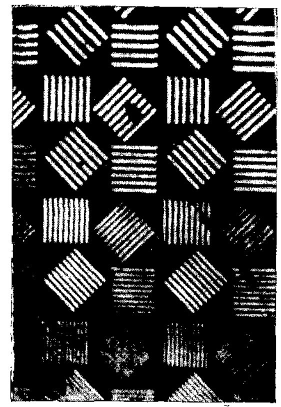

Fig. 3

of one centimeter.

If $z_1 \geq d/\Delta\phi$, then $\Delta x = \Delta y \approx z_1(\lambda_2/d)$ and $\Delta z \approx 4\lambda_2(z_1/d)^2$, where $\lambda_2 = 2\pi c/\omega_2$.

The hologram can be obtained by placing a photographic film behind the crystal. The reference beam can be obtained either in the same crystal or in another, in which the summary frequency is likewise obtained. The first method has the advantage that the inhomogeneities of the crystal and the distortions of the pump wave front cancel each other to a certain 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 reference and the main beam. The image reconstructed with the aid of light of frequency ω_3 has the same properties (listed above) as the image obtained at ω_2. Reconstruction with light of frequency ω_3' produces a change of the longitudinal scales in a ratio ω_3'/ω_3 ($\omega_3' < \omega_3$) than when $\omega_3' = \omega_3$.

The angular field of view is determined by the angle $\Delta\phi$. It can be increased by successive photography of the holograms on a single film while the refractive indices of the crystal are varied by an external field or by slight rotations of the crystal.

We obtained experimentally a hologram in the light of a neodymium laser (1.06μ). The pump wavelength was also 1.06μ and had more power than the light from the object. The hologram was recorded at 0.53μ. The reference beam was obtained in the same crystal as the main beam. We used a KDP crystal 3 cm long. The object was a pattern used to test lenses without a ground glass. The distance from the crystal to the pattern was 50 cm, and the pump beam diameter and the image diameter were 8 mm each.

The experimental setup is shown in Fig. 1. The reconstructed image of the pattern is shown in Fig. 3, while Fig. 3 shows an ordinary photograph of the pattern. We observed and registered both virtual and real reconstructed images. The virtual image was photographed with a camera, and the real one was produced on a screen behind the hologram and photographed with a camera without a lens.

Since the angle between the signal and reference beams was small, the hologram was photographed on an ordinary film of type MZ-2.

[1] Midwinter, Appl. Phys. Lett. 12, 68 (1968).
[2] L. Campel and F. Johnson, JEE J. Quantum Electronics, QE-4, 354 (1968).
[3] J. Warner, Appl. Phys. Lett. 13, 360 (1968).

MAGNETOSTRICTION OF ANTIFERROMAGNETIC COBALT FLUORIDE

A. S. Prokhorov and E. G. Rudashevskii
P. N. Lebedev Physics Institute, USSR Academy of Sciences

Submitted 3 July 1969
ZhETF Pis. Red. 10, No. 4, 175 - 179 (20 August 1969)

Odd magnetostriction (linear in the magnetic field) is a thermodynamically reversible effect relative to piezomagnetism [1]. The piezomagnetic effect, which is linear in the applied stress, was first observed experimentally in the antiferromagnetic fluorides of cobalt and manganese [2, 3]. An experimental investigation of antiferromagnetic CoF_2 in magnetic fields up to 1.5 kOe [4] has revealed a linear dependence of the magnetostriction on the applied magnetic field. An experimental study of hematite (α-Fe_2O_3), in which the piezomagnetic effect also exists, has shown that the magnetostriction deviates from linearity at $H > 1.5$ kOe [5].

We have investigated the magnetostriction of antiferromagnetic CoF_2 using a capacitive dilatometer of 5 Å sensitivity, in magnetic fields up to 20 kOe at a temperature 4.2°K. The CoF_2 crystal was grown at the Physics Problems Institute of the USSR Academy of Sciences.

Figures 1 and 2 show the experimental curves, plotted with an automatic x-y recorder, corresponding to magnetic-field orientations along the [001] and [$\bar{1}$10] axes of the CoF_2 single crystal; the deformation was measured in both cases in the [110] direction. The experimental curves for the linear (Fig. 1) and quadratic (Fig. 2) magnetostriction are described by the respective relations

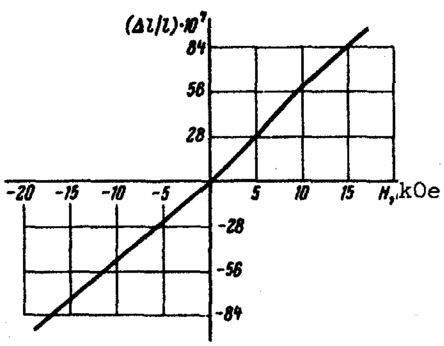

Fig. 1. Dependence of relative deformation of CoF_2 along the [110] axis on a magnetic field parallel to the [001] axis.

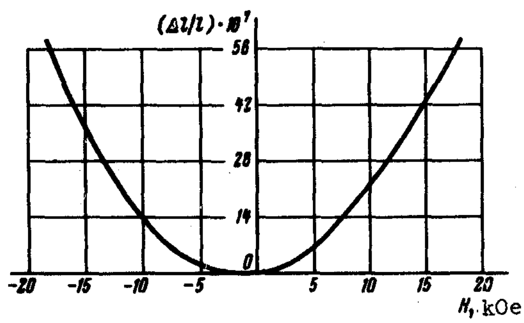

Fig. 2. Dependence of relative deformation of CoF_2 along the [110] axis on a magnetic field parallel to the [1$\bar{1}$0] axis.