For standard high-resistivity samples of n-germanium doped with gold ($\rho = 10^8$ ohm-cm, μ (77°K) = 10^4 cm^2/V-sec, $N_{Au} = 5 \times 10^{14}$ cm^{-3}, $\tau = 2 \times 10^{-5}$ sec) at an anode-cathode voltage $V = 4 \times 10^3$ V the quantum yield for the wavelength $\lambda = 2\mu$ ($\sigma_{ph} = 1 \times 10^{-16}$ cm^2) calculated by formula (2) is $\gamma = 0.12$ electron/photon. The experimentally obtained value of the quantum yield for this wavelength is $\gamma_{exp} = 0.06$ electron/photon. This corresponds to a cathode photosensitivity ≅ 2.5 A/W.

Formula (2) discloses the operating peculiarities of this cathode: the need for an initial dark current (in the example described above this current was $I_0 = 4.5 \times 10^{-8}$ A), and the decrease in photosensitivity at large light intensity incident on the sample.

In conclusion we note that the method described here, subject to a suitable choice of semiconductor and doping impurity, can be used to construct a field-emission cathode which is sensitive to practically any region of the infrared spectrum.

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SELF-FOCUSING OF LIGHT. ROLE OF KERR EFFECT AND STRICTION

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Self-focusing of light, predicted in general form in [1] and considered in detail in [2,3], can be attributed to different physical causes (see [4] for the first information on experimental observations of the phenomenon).

According to [3], the most important may be the Kerr effect, i.e., the orientation of molecules by a high-frequency light field, and striction (change in the density of the medium).

The present note contains an analysis of the difference in the observable phenomena in these two cases. An appropriate experiment could decide which of the effects actually plays the principal role.

In the case of the Kerr effect, inasmuch as the light field has a high frequency, the effect depends not on the dipole moment of the molecule, but on the anisotropy of its polarizability, since the corresponding moment of the force is proportional to E^2 and does not reverse sign.

It follows therefore that the high-frequency Kerr effect should be large for such symmetrical molecules as p-dibromobenzene or p-dinitrobenzene.

In the case of light propagating along the z axis and linearly polarized with the electric vector directed along the x axis, the molecules become oriented (more accurately, "aligned") in the x direction.

The substance becomes birefringent with a dielectric tensor ϵ such that

$$\epsilon_{xx} = \epsilon_0 + \beta E_x^2, \quad \epsilon_{yy} = \epsilon_{xx} = \epsilon_0 - \frac{1}{2}\beta E_x^2.$$

This results in the focusing of the very same linearly polarized light E_x which caused the molecule alignment, but the additional light with E_y becomes defocused.

As noted in [5] without reference to self-focusing, in this situation the axes of the elliptic polarization will systematically rotate. Let us examine circularly polarized or unpolarized light [1)].

Let $E_x^2 = E_y^2 = E_0^2/2$.

We obtain

$$\epsilon_{xx} = \epsilon_0 + \beta E_x^2 - \frac{1}{2}\beta E_y^2 = \epsilon_0 + \frac{1}{4}\beta E_0^2$$

and analogously for ϵ_{yy}. This means that the critical energy necessary for self-focusing is four times larger for circularly polarized light than for linearly polarized light (in the case of the Kerr effect). It is obvious that the two types of polarization are on par in the case of striction.

An experimental comparison of the threshold would serve as a method of determining the predominant mechanism.

We have considered above a gaseous or liquid substance with anisotropic molecules. An investigation of the same substance in the crystalline state, with molecules aligned by the lattice field, yields direct experimental data on the limiting values of $\epsilon_{xx}^{(m)}$, $\epsilon_{yy}^{(m)}$, and $\epsilon_{zz}^{(m)}$ when the effect is totally saturated. Knowing these limiting values, we can approximately account for the saturation effect, using formulas of the type

$$\epsilon_{xx} = \epsilon_0 + \frac{\beta E_x^2}{1 + \beta E_x^2/(\epsilon_{xx}^{(m)} - \epsilon_0)}.$$

Self-focusing in optical anisotropic crystals should have interesting features, depending on the orientation of the optical axes.

It is curious that there exist crystalline substances with a refractive index that decreases upon compression (these include diamond and MgO). In such crystals the change in density under the influence of the field also leads to self-focusing: although the sign of the change in density is itself opposite the usual sign, expansion takes place under the influence of the light wave.

The Kerr effect and striction lead to essentially different estimates for the rate of growth of the self-focusing channel D.

We shall analyze approximately the growth of the channel by assuming that it has a sharp boundary at $z_1 = z_0 + Dt$. When $z < z_1$ the light beam has a constant radius R, and when $z > z_1$ the light propagates in a homogeneous medium.

From the diffraction-theory formulas we find that the beam radius R has, on entering the homogeneous medium, a divergence angle $\theta \sim \lambda/R$, so that the intensity is incident on a characteristic length $L = R/\theta \sim R^2/\lambda$. It is precisely the region $z_1 < z < z_1 + L$ which determines the growth dynamics, for in this region the nonlinear addition to the dielectric constant has not yet been established, but there is already a field of the same order of magnitude as in the self-focused beam. This field is sufficient to produce under static conditions the required increase in the refractive index n.

However, this change in the refractive index requires a definite time τ (relaxation time). After the lapse of a time τ the boundary of the region of variation of n and ϵ is displaced by an amount L, so that the linear velocity is

$$D \sim L/\tau \sim R^2/\tau\lambda.$$

The relaxation time τ of n and ϵ is in the case of the Kerr effect of the order of $\tau_K \sim 10^{-11} - 10^{-12}$ sec (cf. [3]). In the case of striction τ_s is of the order of R/a, where a is the speed of sound. When $R \sim \lambda \sim 10^{-4}$ cm and $a \sim 10^5$ cm/sec this yields $\tau_s \sim 10^{-9}$ sec.

Thus, the speed D should be much lower in the case of striction than in the case of the Kerr effect: $D_s \sim 10^5$ cm/sec and $D_K \sim 10^7 - 10^8$ cm/sec. The fact that channels of noticeable length are obtained with short pulses apparently points to the leading role of the Kerr effect. This does not exclude, however, the fact that the primary focusing of the beam by the Kerr effect is followed, at a constant distance of the order of $D_K\tau_s \sim R^2/a\tau_K$, by a zone in which striction is realized.

The dependence of D on R is also different: $D_s \sim R$ and $D_K \sim R^2$. Special note must be taken of the fact that the increase of D with increasing R necessitates a very thorough analysis of the growth mechanism. It is not clear whether such a dependence of D on R can lead to a situation similar to a centered rarefaction wave in hydrodynamics (unlike the shock-wave situation, which we used above as the basis of the approximate analysis), wherein zones with different R propagate with different velocities, and there is no mode of the type $z = z_1 + Dt$. We note that when account is taken of the finite velocity of light in the medium ($c' = c/\sqrt{\epsilon}$), we get $L \sim R(1 - D/c')/\theta$ in lieu of $L \sim R/\theta$, so that $D/(1 - D/c') \sim R^2/\tau\lambda$ and $D \leq c'$ as $R \to \infty$.

We note finally a curious consequence of the systematic variation of the optical length during the course of self-focusing: An observer looking at the end of the channel should see light of changed frequency, i.e., should observe a Doppler shift that depends on the speed D and on the change in the focusing exponent.

A detailed theoretical analysis and experimental study of the problems touched upon above is now under way. We take the opportunity to thank B. Ya. Zel'dovich and N. F. Pilipetskii who took part in this project, for valuable discussions.

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PHASE TRANSITION IN SUPERCONDUCTORS OF SMALL SIZE

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Large fluctuations in the ordering parameter, which lead to the "smearing" of the second-order phase transition over a certain temperature interval, should occur near the critical temperature T_c. In the case of a superconductor, these are fluctuations of the "effective wave function" of the Ginzburg-Landau theory [1] or, from the point of view of the microscopic theory, fluctuations of the energy gap $2\Delta(T)$.

The question of density fluctuations of the superconducting electrons that should be present when $T > T_c$ and, as it were, anticipate the superconducting transition, was raised already in [2], where the possible effect of the fluctuations about T_c on certain characteristics of the superconductor were discussed.

It is known, however, that in pure homogeneous superconductors the transition to the normal state is very abrupt. The temperature region ΔT near T_c, in which $\overline{|\Delta\Psi|^2}$ is comparable with $|\Psi|^2$, amounts in accord with [3] to $\Delta T \sim 10^{-14} - 10^{-15}$ °K. A similar estimate of the width ΔT of the region of the logarithmic singularity in the temperature variation of the specific heat near the transition point was arrived at by the authors of [4].

So narrow a phase-transition region is attributed to the fact that the fluctuations of Ψ in pure superconductors are strongly "suppressed." Actually the fluctuation probability increases exponentially with decreasing volume, but to realize the fluctuation in a small volume of a large superconductor it is necessary to have a large gradient of Ψ. This reduces greatly the fluctuation probability, which decreases exponentially with increasing $(\Delta\Psi)^2$. Thus, fluctuations with small gradients should encompass large volumes of matter and have therefore low probability, while fluctuations in small volumes are accompanied by large gradients and have therefore likewise low probability.

The purpose of this investigation was to show that there exists an object for which the fluctuations of Ψ may turn out to be appreciable. These are superconducting particles of a size small compared with ξ_0 (the dimension of the Cooer pair). If, starting from physical considerations, we cut off the Fourier-integral expansion at a wave number ξ_0^{-1}, then it is easy to show that when $|\Psi|^2$ is calculated for such particles it is possible to neglect the gradient term, and the expression for the free-energy density in the absence of a magnetic field takes the form [1]

$$\Delta F = F_{s0} - F_{n0} = \alpha|\Psi|^2 + \frac{\beta}{2}|\Psi|^4 \quad (1)$$

Since this expression has been written out without the kinetic-energy term $(\hbar^2/2m)|\Delta\Psi|^2$, the states Ψ and Ψ^* are physically indistinguishable and therefore we shall regard Ψ as real.