$$1/R_{nn} = 4\pi e^2 N_1(0) N_2(0) \iint \frac{d\Omega_1 d\Omega_2}{(4\pi)^2} |T_{kq}|^2 = 4\pi e^2 N_1(0) N_2(0) t_0,$$

we get ultimately

$$I_1 = \frac{\pi}{2} \frac{\Delta(\ell)}{eR_{nn}} \frac{t_e}{t_0} \sin(\varphi_1 - \varphi_2). \quad (10)$$

Equation (10) shows that experiment cannot identify the state of the superconductors.

In our opinion, to find superconductors with different $\ell$ it is necessary to start with "transition element - principal-group element" structures. The samples, of course, must be of sufficiently large size so that no Larkin effect [6] appears in any of the cases.

In conclusion we note that in this experiment $\ell$ is not a sufficiently good quantum number. It is therefore more likely that we will be able to distinguish between superconductors with different pair multiplicities.


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1) In the more general case, putting $\vec{k} \to -\vec{k}$ and $\vec{q} \to -\vec{q}$ and recognizing that $\Delta(-\vec{k}) = \Delta(\vec{k})$ and $\Delta(-\vec{q}) = -\Delta(\vec{q})$, we find that the Josephson current equals zero for superconductors with different pair multiplicities.

## SPECTRUM OF ELECTROMAGNETOLUMINESCENCE IN InSb


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We obtain in this paper the spectral distribution of recombination radiation caused by the magnetoconcentration effect (electromagnetoluminescence - EML) in InSb at room temperature [1]. It has been observed that the character of the spectral distribution of EML differs from the spectra of recombination radiation excited by other known means, and the maximum of the spectral emission of EML depends on the intensities of the electric and magnetic fields.

Recombination radiation was excited by applying a pulsed electric field to a sample of

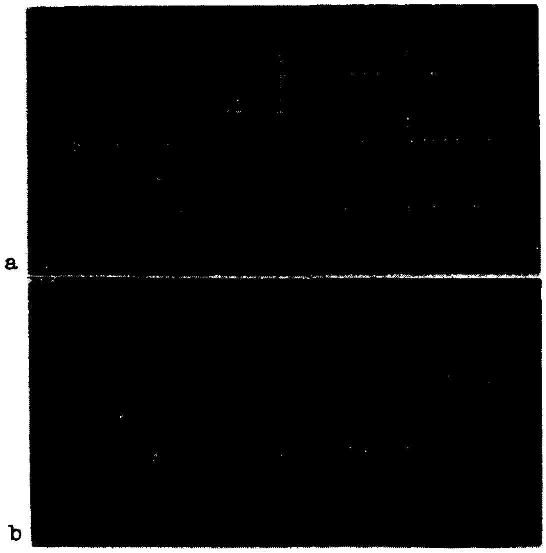


Fig. 1. Pulse oscillograms: a - current through sample, b - photoreceiver signal. Each major horizontal division represents 1 μsec.

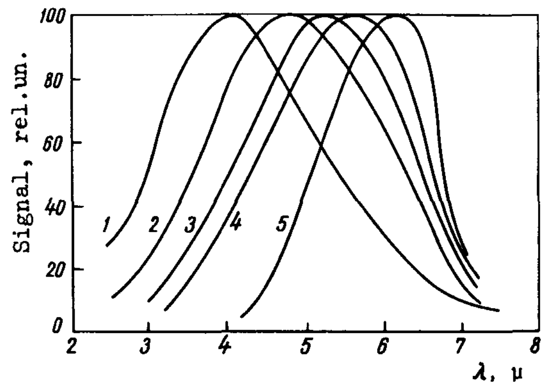


Fig. 2. EML spectra:

1 - E = 520 V/cm, H = 5 kOe;
2 - E = 200 V/cm, H = 8 kOe;
3 - E = 90 V/cm, H = 8 kOe;
4 - E = 60 V/cm, H = 5 kOe;
5 - E = 45 V/cm, H = 5 kOe.

almost intrinsic p-InSb placed in a magnetic field perpendicular to the electric one. The radiation was gathered in a third mutually-perpendicular direction, guided to a monochromator, and recorded with a photoreceiver of gold-doped germanium. The pulse duration was 2 - 3 μsec at a repetition frequency 2 - 3 cps. A pulsed synchronous detector was used to increase the signal/noise ratio at the output of the broadband amplifier. The spectral width of the monochromator slit was 0.3 μ at a wavelength of 6 μ.

Figure 1 shows oscillograms of the sample-current and photoreceiver signal pulses. We see that the time necessary for the signal to rise to the 0.7 level is of the order of 0.2 - 0.3 μsec, corresponding to the time constant of the amplifier employed, and consequently the signal time constant is equal to or smaller than this value. So low an inertia of the observed signal allows us to assume that the thermal effects are negligible and credit the observed signal to electromagnetoluminescence. The stretching of the trailing front of the signal pulse is determined by the characteristics of the measuring circuit.

Figure 2 shows the EML spectra of p-InSb with acceptor density $5 \times 10^{16}$ $cm^{-3}$ for different intensities of the electric and magnetic fields $\vec{E}$ and $\vec{H}$. We see that with increasing product $\vec{E} \times \vec{H}$ the maximum of the emission intensity shifts markedly toward the short-wave part of the spectrum, and the spectral-band shape and width are simultaneously changed.

It can be shown that the value of the product $\vec{E} \times \vec{H}$ determines the concentration of the excess carriers on the crystal face from which the radiation is observed. Indeed, the theory of magnetoconcentration effect [2], in the limiting case of a thick sample with intrinsic conductivity ($n_i$), yields the following expression for the carrier density ($n_{(0)}$) on one of the crystal faces on which the carrier pumping is effected:

$$n_{(0)} = n_i \frac{A \mu_n (\vec{E} \times \vec{H})}{kT} \frac{(b + 1)}{\left(\frac{\sqrt{\lambda^2 + l^2}}{l\lambda_0} + \frac{S_1}{D}\right)} , \qquad (1)$$

where A is a certain constant, $\lambda_0 = \sqrt{D\tau}$, D is the diffusion coefficient, $\tau$ the lifetime, $S_1$ the rate of surface recombination on the face Y = 0,

$$l = \frac{2}{A} \frac{kT}{\mu_n(\vec{E} \times \vec{H})(b + 1)} ,$$

$\mu_n$ the electron mobility, and b the ratio of the electron mobility to hole mobility.

Thus, the shift of the maximum on Fig. 2 can be connected with the appreciable increase of the concentration of the excess carriers, which fill noticeably the bottom of the conduction band, and we are dealing with a unique Moss-Burstein effect.

The shift of the maximum and the broadening of the spectral band may be due, in addition, to heating of the electron gas under the influence of the electric field.

Since recombination of the non-equilibrium carriers occurs in the case of EML in the direct vicinity of the crystal surface, and consequently the absorption of the high-frequency photons plays no considerable role, the heating of the electron gas cannot influence noticeably the spectral distribution of the radiation.

It should also be noted that in the analysis of EML spectra it is apparently necessary to take into account the principal inhomogeneity in the distribution of the carriers, which causes the observed EML spectrum to be a summary one, consisting of the spectra of the corresponding layers with equal carrier density.

The difficulties entailed in taking simultaneous account of all the foregoing circumstances does not permit at present an exact estimate of the density of the excess carriers near the surface from which the radiation is observed. A rough order-of-magnitude estimate without account of heating of the electron gas shows that at maximum electric and magnetic field there are $\sim 10^{-8}$ carriers per $cm^3$ in the immediate vicinity of the crystal face.

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