$$2(\cosh \kappa L - 1) - \gamma \kappa L \sinh \kappa L + \gamma \frac{L\omega}{V} [\kappa L \sinh \kappa L - 2(\cosh \kappa L - 1)] = 0, \tag{8}$$

where $\kappa = (\omega_e/c_e^2 - \omega_1^2/V^2)^{1/2}$ is a real positive quantity, and $\gamma = mc_e^2/MV^2 < 1$. We see from (8) that if $\kappa L = (\kappa L)^*$ satisfies the equation

$$2(\cosh \kappa L - 1) - \gamma \kappa L \sinh \kappa L = 0, \tag{9}$$

then the only solution of (2) - (7) is the solution with $\omega = 0$. If $\kappa L > (\kappa L)^*$ a solution is possible only for real $\omega > 0$, and if $\kappa L < (\kappa L)^*$ - only with real $\omega < 0$. If $\gamma < 0.5$, then a highly accurate solution of (9) is

$$(\kappa L)^* \approx 2/\gamma \tag{10}$$

and the critical current density is

$$j^* \approx \{1/[\gamma(1 - \gamma)]\}(2/\pi)(2e/M)^{1/2}(\varphi_0^{3/2}/L^2). \tag{11}$$

Putting $\gamma = mc_e^2/MV^2 = T_e/2\varphi_0$, where $T_e$ is the electron temperature and $e\varphi_0$ is the beam-ion energy, we find for

$$T_e \ll \varphi_0 < (M/2m)T_e$$

that

$$j^* \approx (\varphi_0/T_e)(4/\pi)(2e/M)^{1/2}(\varphi_0^{3/2}/L^2). \tag{12}$$

The increment on the instability threshold at $\gamma \ll 1$ is

$$\omega \approx \alpha \frac{V}{L}, \tag{13}$$

where $\alpha = [\kappa L - (\kappa L)^*]/(\kappa L)^*$. We can therefore expect that when $j \approx 2j^*$ the growth time is of the same order as the time of flight.

The author thanks A. V. Zharinov for suggesting the problem and for a useful discussion.

[1]   A. A. Vedenov, E. P. Velikhov, and R. Z. Sagdeev, UFN 73, 701 (1961), Soviet Phys. Uspekhi 4, 332 (1961).

[2]   J. R. Pierce, J. Appl. Phys. 15, 721 (1944).

POLARIZATION OF ANTHRACENE FLUORESCENCE EXCITED BY TWO PHOTONS

V. Stefanov, P. Simova, and P. Kircheva

Peticolas, Goldsborough, and Rieckhoff [1] and Singh and Stoicheff [2] were the first to observe two-photon absorption in anthracene. Later, several workers investigated two-photon-excited fluorescence of anthracene in the crystalline state and in solutions, in order to determine the mechanism of fluorescence excitation with the aid of a laser [3-7].

In this communication we present some new results of an investigation of the polarization of fluorescence of anthracene single crystals excited with red light from a ruby laser.

Figure 1 shows the experimental setup. The fluorescence excitation source is a ruby laser with output energy 0.04 J. The laser light passes through a interference filter, which transmits only the 6943 Å laser line and absorbs the light from the xenon lamp, after which it is focused sharply, with the aid of a short-focus lens, into a point on the anthracene single crystal. The crystal fluorescence light is focused by a second lens on a photomultiplier (FEU-17), the signal from which is registered with an oscilloscope after amplification. For complete elimination of the exciting laser light, a filter is placed between the second lens and the photomultiplier. This filter consists of a 12.5-cm layer of an aqueous solution of $CuSO_4$ which is saturated at room temperature. The anthracene single crystals were produced by sublimating pure anthracene in air.
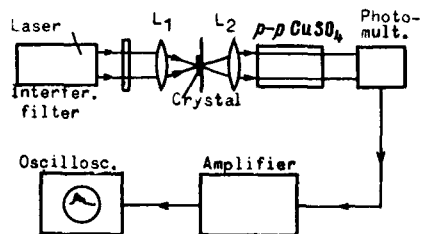


Fig. 1

Figure 2 shows an oscillogram of a laser pulse of 350 μsec duration and of the fluorescence of the anthracene single crystal, which lasts another 500 μsec following the termination of the pulse. The present polarization investigation pertains to "fast" fluorescence of the anthracene single crystals.
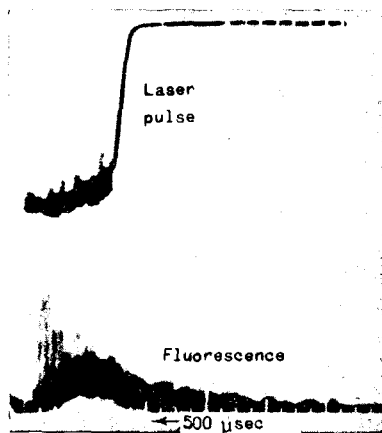
Investigations of the polarization of single-photon absorption and excited fluorescence of anthracene single crystals have shown that the single crystal absorbs more strongly along the b axis and that the fluorescence light is polarized predominantly along the b axis. Thus, Craig [8] has found that the absorption is 1.5 times larger when the direction of the oscillation of the incident light coincides with the b axis than with the a axis. In addition, as a result of polarization measurements of the fluorescence, Craig has established that the fluorescence intensity along the b axis is double that polarized along the a axis of the crystal.



Fig. 2

| | Room temperature | | -196°C | |
|---|---|---|---|---|
| | Single-photon process | | Two-photon process | |
| | [8] | [9] | | |
| Polarized absorption | 1.5 | - | 1.8 | 1.3 |
| Polarized fluorescence | 2.0 | 1.54 | 2.5 | 1.6 |

We investigated the polarization of the two-photon absorption by placing a polarizer

in the path of the laser beam. The single crystal, whose optical axes (a and b) were determined beforehand, was placed in a special holder, which made it possible to align one of its optical axes with the oscillation direction of the laser beam by rotating the crystal. To investigate the influence of the temperature, the crystal was placed in a cryostat. Measurements at room temperature (see the table) have shown that the fluorescence intensity is 1.8 times larger when the b axis of the crystal coincides with the laser beam oscillation direction. From this we conclude indirectly that the anthracene crystal absorbs more strongly in the b direction in the case of the two-photon mechanism, too.

In order to investigate the polarization of the fluorescence excited by two-photon absorption, we used a second polarizer placed in the path of the fluorescence light. The measurements have shown that at room temperature the flourescence polarized along the b axis was 2.5 times more intense than the fluorescence polarized along the a axis.

What is striking is the change in the relative intensities $I^b/I^a$ at -196°C (see the table). Singh and Stoicheff [7] found, by investigating the influence of the temperature of the "fast" and delayed fluorescence of anthracene single crystals, that as the temperature is lowered the intensity of the delayed fluorescence is greatly reduced, while that of the "fast" fluorescence is markedly increased. They attribute the presence of two types of fluorescence and the temperature dependence to two different excitation mechanisms: the "fast" fluorescence is excited by the two-photon transition $^1A_g - {}^1B_{2u}$, and increases when the temperature is lowered; the delayed fluorescence is the result of the one-photon transition $^1A_g - {}^3B_{2u}$ with formation of triplet excitons and their annihilation, and is strongly decreased by a lowering of the temperature.

The present investigations have shown that as the temperature decreases to -196°C the fluorescence of different anthracene single crystals obtained by sublimation in air can exhibit different variations. Thus, for example, some samples exhibit an increase in the "fast" fluorescence, and others a decrease. According to investigations by Zima and Faidysh [11], this can be attributed to the presence in the anthracene crystals of 0-centers obtained by photooxidation of the anthracene as the latter is sublimated in air. Since the defect-impurity fluorescence vanishes at room temperature, the results obtained with different crystals at room temperature are comparable, whereas at low temperatures this is difficult to do because of the possible existence of photo-oxides and their uncertain concentration. We are continuing the investigation of the temperature dependence of two-photon fluorescence of anthracene.

[1]    W. L. Peticolas, J. P. Goldsborough, and K. E. Rieckhoff, Phys. Rev. Lett. 10, 43 (1963).
[2]    S. Singh and B. P. Stoicheff, J. Chem. Phys. 38, 2032 (1963).
[3]    R. G. Kepler, J. C. Caris, P. Avakian, and E. Abramson, Pys. Rev. Lett. 10, 400 (1963).
[4]    M. Jannuzzi and E. Polacco, Phys. Rev. Lett. 13, 371 (1964).
[5]    M. Jannuzzi and E. Polacco, Phys. Rev. 138, A806 (1965).
[6]    D. H. McMahon, R. A. Soref, and A. R. Franklin, Phys. Rev. Lett. 14, 1060 (1965).

[7]   S. Singh, W. J. Jones, W. Sierband, B. P. Stoicheff, and W. G. Schneider, J. Chem. Phys.
      42, 330 (1965).

[8]   D. P. Craig, Rev. Pure Appl. Chem. (Australia) 3, 207 (1953).

[9]   S. C. Ganguly and N. R. Chaudhuri, J. Chem. Phys. 19, 617 (1951).

[10]  J. W. Sidman, Phys. Rev. 102, 96 (1956).

[11]  V. L. Zima and A. N. Faidysh, Optika i spektroskopiya 19, 356 (1956).

EFFECT OF DELAY ON THE FORM OF THE TUNNEL CHARACTERISTICS OF SUPERCONDUCTORS

Yu. M. Ivanchenko
Donets Physico-technical Institute, Ukrainian Academy of Sciences
Submitted 21 July 1966
ZhETF Pis'ma 4, No. 9, 358-361, 1 November 1966

Yanson, Svistunov, and Dmitrenko [1] observed in an Sn - Sn tunnel structure current
peaks at a barrier voltage v = $2\Delta/n$ (n - integer, $\Delta$ - energy gap). A similar phenomenon was
observed recently by Marcus in a Pb - Pb structure [2]. In tunnel junctions of the same type
as in [2], Rochlin and Douglass [3] observed a more complicated dependence of the current on
the voltage. The authors of [1,2] relate the appearance of peaks with tunneling of certain
particles [4]. Such processes, however, have low probability and lead to a very rapid decrease
of the intensity with increasing peak number, in disagreement with the data of [1,2]. In [3]
the complicated dependence of the current on the voltage was attributed to the anisotropy of
the electric gap.

We propose in this note another mechanism, which is apparently in good agreement with
both the results of [1,2] and the data of [3].

As shown by the author earlier [6], the tunnel current through the junction is

$$I(\vec{r}, t) = \int_0^\infty dr\{K_s(r) \sin[\varphi(t) + \varphi(t - r)] + K_n(r) \sin[\varphi(t) - \varphi(t - r)]\}. \qquad (1)$$

The concrete form of the kernels $K_s$ and $K_n$ is immaterial in what follows, and $\varphi$ satisfies the
relations

$$\frac{\partial \varphi}{\partial t} = ev(\vec{r}, t), \qquad (2)$$

$$\frac{\partial \varphi}{\partial r} = \frac{8\pi e}{c^2} \lambda_L \vec{j}(\vec{r}, t). \qquad (3)$$

Here $\vec{r}$ are the coordinates in the junction plane, $\lambda_L$ the London depth of penetration ($\lambda_L \gg d$,
where d is the thickness of the oxide), and $\vec{j}$ is the current along the surface of the super-
conductor.

Relations (1), (2), and (3), together with Maxwell's equations, form a closed system.
We could therefore, as in [7-9], obtain one equation for $\varphi$. As shown in [6], for a point con-
tact this equation has no solutions with $\partial \varphi/\partial t$ = const. This statement holds true also for