v statisticheskoi fizike (Methods of Quantum Field Theory in Statistical Physics), 1962.

1) The explanation proposed in [3] has been refuted in [4].

2) By substituting the experimental data in (4) (see Sec. 1), we obtain the reasonable estimate $k_0/p_0 \sim 0.1 - 0.2$.

ON THE USE OF AN ELECTRON SYNCHROTRON AS A MASER

A. A. Sokolov and I. M. Ternov
Physics Department, Moscow State University
Submitted 23 May 1966
ZhETF Pis'ma 4, No. 3, 90-92, 1 August 1966

The question of obtaining stimulated emission from electrons moving in a magnetic field [1,2] or crossed (magnetic and electrostatic) fields [3] has been discussed many times recently. The papers cited, however, consider the nonrelativistic or weakly-relativistic case, involving emission at the fundamental harmonic, which can be used to obtain radiation at a wavelength of the order of the orbit radius. We wish to show that in the relativistic case it is possible, with an electron moving in a magnetic field only, to make the stimulated emission prevail over absorption in a definite band of high harmonics corresponding to a certain resonance.

If the incident electromagnetic wave of frequency ω is linearly polarized (the vector of electric intensity $\mathcal{E}$ lies in the plane of the orbit) and propagates perpendicular to a constant magnetic field $\vec{H}$, causing cyclic motion of the electron, then we obtain for the total power of the stimulated emission and absorption of a harmonic ν the following formula [4]:

$$W_\nu = -\frac{4e^2\mathcal{E}^2\tau}{m_0}\frac{m_0c^2}{E}\nu J_\nu'^2(\nu\beta)\left(\frac{1-\beta^2}{\beta}\frac{J_\nu(\nu\beta)}{J_\nu'(\nu\beta)} - \frac{3}{2\nu}\beta^2\right), \tag{1}$$

where e is the electron charge, τ the average lifetime, E the energy, m_0c^2 the rest energy, $c\beta$ the velocity of motion, and J_ν a Bessel function of order ν.

Formula (1) has been derived for resonance, when

$$\omega = \nu\Omega = \nu\frac{eHc}{E}. \tag{2}$$

In the case when

$$\frac{1-\beta^2}{\beta}\frac{J_\nu(\nu\beta)}{J_\nu'(\nu\beta)} > \frac{3}{2\nu}\beta^2 \tag{3}$$

we obtain ultimately stimulated absorption ($W_\nu < 0$), which takes place, for example, in the nonrelativistic case ($\beta \ll 1$). As shown by Schneider [1], emission in the nonrelativistic approximation is possible for motion in a magnetic field only if resonance is violated.

In the case when

$$\frac{1-\beta^2}{\beta}\frac{J_\nu(\nu\beta)}{J'_\nu(\nu\beta)} < \frac{3}{2\nu}\beta^2, \tag{4}$$

we have as a net result stimulated emission ($W_\nu > 1$). The stimulated emission can prevail over absorption in the ultrarelativistic case $\beta \to 1$, starting with the fundamental harmonic. Using for this case the known asymptotic formulas for the Bessel function and its derivative [5], we obtain

$$W_\nu = 1.013\nu^{-4/3}\frac{e^2\mathcal{E}^2\tau}{m_0}\frac{m_0c^2}{E}\left(1 - 0.726\nu^{4/3}\left(\frac{m_0c^2}{E}\right)^2\right). \tag{5}$$

We see therefore that stimulated emission will prevail over absorption up to the harmonics

$$\nu < \sqrt{\nu_{max}}, \tag{6}$$

and that the harmonic

$$\nu_{max} \sim (E/m_0c^2)^3$$

gives a maximum intensity of spontaneous emission.

In particular, for an accelerator with $E \sim 50$ MeV the intensification of the emission is possible up to harmonics $\nu < \sqrt{\nu_{max}} \sim 1000$. When $\nu > \sqrt{\nu_{max}}$, to the contrary, the absorption energy begins to exceed the emission energy. This method (in the case of absorption) can also be used to accelerate relativistic electrons in cyclic accelerators.

[1] J. Schneider, Phys. Rev. Lett. 2, 504 (1959).

[2] A. V. Gaponov, A. L. Gol'denberg, D. P. Grigor'ev, I. M. Orlova, T. B. Pankratova, and M. I. Petelin, JETP Letters 2, 430 (1965), transl. p. 267.

[3] A. A. Sokolov and Yu. M. Pavlenko, ibid. 2, 449 (1965), transl. p. 279.

[4] A. A. Sokolov and I. M. Ternov, DAN SSSR 166, 1332 (1966), Soviet Phys. Doklady 11, 156 (1966).

[5] G. N. Watson, A Treatise on the Theory of Bessel Functions, Russ. Transl. IIL., 1949, p. 288 [Cambridge, 1944].

THE PHOTOREDUCTION $TR^{3+} \to TR^{2+}$ IN FLUORITE CRYSTALS

A. A. Kaminskii, V. V. Osiko, and M. M. Fursikov
Crystallography Institute, USSR Academy of Sciences

Submitted 24 May 1966
ZhETF Pis'ma 4, No. 3, 92-96, 1 August 1966

The effect of reduction of trivalent rare-earth ions (TR^{3+}) serving as activators in CaF_2 to the divalent state has been observed so far only under the influence of hard radiation (γ, neutrons, deuterons, fast electrons), in chemical reactions, or in electrolysis. The valent transition $TR^{3+} \to TR^{2+}$ is accompanied by a crystal coloration characteristic of