STIMULATED SYNCHROTRON RADIATION OF ELECTRONS IN A PIECEWISE-HOMOGENEOUS MAG-
NETIC FIELD

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Stimulated synchronous emission of electrons in a hollow system imbedded
in a homogeneous magnetic field were investigated in [1, 2] and elsewhere. In
this paper we consider the case of an inhomogeneous magnetic field. We demon-
strate theoretically the feasibility of almost complete conversion of the
energy of the rotational motion of the electrons into radiation energy, i.e.,
of the case in which the conversion coefficient $G_{opt} = (P_{rad}/P_{e\perp})_{opt}$ approaches
unity.

Figure 1 shows schematically an
axially-symmetrical model of a bounded-
volume system with a tubular stream of
rotating oscillator electrons. The in-
homogeneous magnetic field subdivides
the entire volume into qualitatively
different sections. In the sections
ΔT_1, ΔT_2, ΔT_3, and ΔT_4 the magnetic
field is homogeneous and its induction
B_z has a synchronous value B_s at which
the gyromagnetic frequency of the elec-
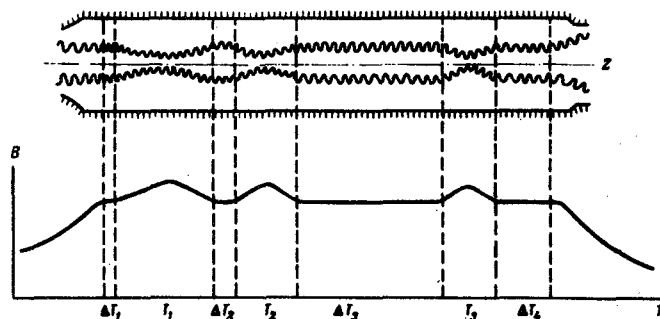trons $(e/m)B_s$ is close to the frequency
of the external field (the synchronism
condition). In these sections the
electron oscillators interact cumula-

Fig. 1

tively (resonantly) with the radiated field (active sections). In sections T_1,
T_2, and T_3 the interaction ceases, since the electron oscillators go out of
synchronism as a result of the change of the gyromagnetic frequency.

Arriving at the short active section ΔT_1 is a homogeneous stream of oscil-
lator electrons, which experience in this section a short-duration synchronous
action of a transverse electric field of amplitude $E_\perp$. This results in modula-
tion of the transverse electron velocity. In the inhomogeneous magnetic field
of section T_1, as a result of the conservation of the transverse adiabatic in-
variant $I = 3p_t^2/2eB$ and of the total electron momentum $p = (p_\ell^2 + p_t^2)^{1/2}$, the
values of p_t and p_ℓ change with changing B. Thus, the modulation of the trans-
verse velocity is transformed into modulation of the longitudinal velocity v_ℓ
(relative to the force line B). The phase bunching in the region of the in-
homogeneity is therefore determined by the difference between the longitudinal
(spatial) bunching and the transverse (relativistic) bunching, the longitudinal
bunching being more effective. The bunching induced by the field in the sec-
tion ΔT_1 is improved as a result of the introduction of the second (also short)
modulating section ΔT_1 and the bunching section T_2 that follows it. Conse-
quently, at the entrance into the active section ΔT_3 the electron current is a
near-δ-like periodic sequence of bunches of phased electron oscillators. In
the extended active section ΔT_3, these oscillators produce coherent intense
radiation until the electron-oscillators begin to absorb the field energy as a
result of rebunching; from that instant on, the electrons enter the region of
the inhomogeneous field T_3 and the interaction ceases. After rebunching in
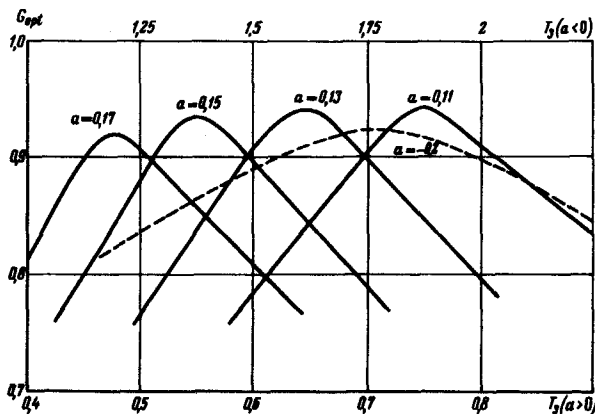section T_3 and formation of a favorable phase distribution of the electron

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Fig. 2

oscillators with residual energy, the current again interacts with the field in the last active section ΔT_4. The length of the latter is chosen such as to optimize the conversion coefficient G.

The described model was analyzed by solving numerically, with a computer, the nonlinear equations of weakly-relativistic motion of charged oscillators in a piecewise homogeneous field of the type shown in Fig. 1. All the parameters of the problem were chosen such as to obtain the optimal value of G. The inhomogeneity of the magnetic field separating the active sections was specified in the form

$$\phi(T) = \frac{B(T)}{B_s} - 1 = a \sin^2\left(\frac{\pi T}{T_l}\right), \qquad T = \frac{e}{m_0} E_\perp \frac{1}{v_{t_0}} \frac{z}{v_{\ell_0}},$$

where v_{t_0} and v_{ℓ_0} are the transverse and longitudinal velocities of the electron at the start of the section ΔT_1.

The calculation results are shown in Fig. 2 in the form of plots of $G(T_3)$ at the optimal values of all other parameters (E, ΔT_1, ΔT_2, ΔT_3, ΔT_4, T_1, T_2, etc.). $G_{opt} \to 1$ for both $a > 0$ and $a < 0$ (lowering of the field induction) in the optimal variants. This conclusion, on the one hand, demonstrates qualitatively the feasibility of coherent synchrotron radiation under natural conditions [3], and on the other hand is of interest for practical utilization (generation of microwaves with high efficiency).

[1] A.V. Gaponov, A.L. Gol'denberg, D.P. Grigor'ev, et al. ZhETF Pis. Red. 2, 430 (1965) [JETP Lett. 2, 267 (1965)].
[2] V.P. Grigor'ev and A.P. Privezentsev, Izv. Vuzov Fizika 11, 154 (1968).
[3] J.L. Hirshfield and G. Bekefi, Nature 198, 20 (1963).

NONLINEAR PHENOMENA IN THE PASSAGE OF BROAD-SPECTRUM LASER EMISSION THROUGH ATOMIC POTASSIUM VAPOR

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We observed a change in the angular distribution of the intensity of light with spectral components near the lines D_1 ($\lambda = 7699$ Å) and D_2 ($\lambda = 7665$ Å) of the principal doublet of potassium following the passage of an intense light beam through vapor of this metal.

The source of the intense radiation was a dye-solution (DS) laser with intensity $I_0 = 10^7$ W/cm^2 ($\Delta t = 20$ nsec, beam divergence angle $\alpha = 10^{-3} - 10^{-2}$ rad). The radiation was linearly polarized, and its spectrum was located in the 7600 - 8000 Å band that includes the potassium absorption D lines (transitions $4S_{1/2} - 4P_{1/2, 3/2}$). The STE-1 spectrograph (dispersion 13 Å/mm) was