Experimental observation of a linear growth of b'(E) with increasing ln E would be direct evidence of curvature of the P trajectory, i.e., of $\alpha''_P > 0$.

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YIELD COEFFICIENT OF CYCLOTRON RADIATION FROM A "THERMONUCLEAR" PLASMA

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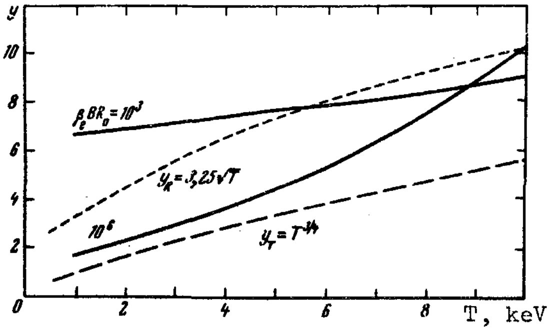
An important role will be played in the energy balance of thermonuclear reactors by cyclotron radiation, which can be calculated only by numerical methods, owing to the complexity of the formulas for the absorption coefficient. The results are usually represented in graphical form. It may be very useful however, to have very simple approximation formulas for these graphs.

An analysis of three examples [1 - 3] of numerical calculations shows that the radiation yield coefficient can be approximated, with 50% accuracy, by a "universal" formula suitable for a plasma layer, cylinder, and torus:

$$\Phi \simeq 60\frac{t^{3/2}}{\sqrt{p_a}}\sqrt{1-r}\sqrt{1+\chi_T}. \tag{1}$$

Here $t = T/mc^2$ is the temperature in units of $mc^2 = 511$ keV, $p_a = a\omega^2/c\omega_B$ is the dimensionless "opacity parameter," in which a is the radius of the cylinder, the thickness of the flat layer, or the minor radius of the torus, $\omega_0^2 = 4\pi n_e e^2/m$ is the square of the plasma frequency, $\omega_B \simeq eB/mc$ is the cyclotron frequency of the electron, c is the speed of light, r is the reflection coefficient of the mirrors located at the plasma boundary, and $\chi_T = a/R\sqrt{t}$ is the parameter of the



Plot analogous to Fig. 2 of [3], but taking formula (2) into account. Two plots of $y = 5\pi\sqrt{\beta_e BR}\ \phi/T$ keV for $\beta_e BR_0 = 10^3$ and 10^6, and two approximations (Rosenbluth's y_R [3] and ours, corresponding to formula (1)), are shown.

inhomogeneity of the magnetic field in a torus with minor and major radii a and R.

Rosenbluth's case [3] corresponds to $\chi_T \gg 1$, but formula (1), which describes satisfactorily the results of [1 - 2], yields under the conditions of [3] approximately half of the radiation obtained in [3], where no account was taken at all of the Doppler broadening of the cyclotron spectrum lines. The main discrepancy, however, is apparently due to the fact that Rosenbluth used in the calculation of the absorption coefficients only the first term of the expansion of the bessel functions $J_n(x) \simeq (x/2)^n/n!$ where $x = n\beta \sin\theta$ and θ is the angle between $\vec{k}$ and $\vec{B}$. This yielded after averaging over the nonrelativistic Maxwellian distribution $\langle J_n^2(x)\rangle = (\xi/2)^n/n!$, where $\xi = n^2 t \sin^2\theta$, and led to the appearance of divergent series in the sums over n. Yet the use of the exact formula

$$\langle J_n^2(x)\rangle = e^{-\xi} I_n(\xi) \tag{2}$$

shows that the quantities $z\Lambda^1$ used in [3] should be multiplied by approximately $\exp(-n^2 t)$, which leads (at $T \simeq 5 - 10$ keV) to a faster convergence of the series and to a better agreement of the results with the approximation formula (1) (see the figure).

The total cyclotron radiation of a layer, cylinder, or torus (tokamak) is calculated from the formula (v is the plasma volume)

$$w = N_e \frac{2e^2}{3c^3} \langle \dot{v}^2 \rangle\ \Phi, \text{where } N_e = n_e V,\ \langle \dot{v}^2 \rangle = \omega_B^2 \frac{2T}{m} \tag{3}$$

and will be smaller than the thermonuclear energy released in a reactor using a 1:1 mixture of deterium and tritium approximately (for T = 15 keV) under the condition $\Phi < 8\beta_e$, where $\beta_e = 8\pi n_e T/B^2$.

For the tokamak designs discussed in [4], with $\beta_e \simeq 0.1$, the radiation is not dangerous even in the absence of reflector. Devices with small β_e and using pure deuterium are less promising, since they require reflectors with $r \gtrsim 0.99$.

A detailed article will be submitted for publication in the journal "Nuclear Fusion."

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EFFECTIVE PULSED COPPER-VAPOR LASER WITH HIGH AVERAGE GENERATION POWER

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At the present time there are no visible-band lasers with high efficiency and appreciable average generation power. The most widely used lasers for this region of the spectrum (helium-neon and neon) have efficiencies of about 0.1% or worse, and their applications are thus sharply limited. The problem of developing an effective laser for the visible band is therefore very acute.

We present here the results of investigations of a pulsed copper-vapor laser, which have made possible, for the first time, generation in the green and yellow regions of the spectrum with a high average power (15 W) and with a practical efficiency of 1%. Heretofore, copper-vapor lasers delivered an average power of 0.5 W [1, 2]. The efficiency in terms of the discharge was about 1%, but the practical efficiency was apparently much lower, since additional energy was needed to heat the working tube in the oven.

We used in our experiments alundum discharge tubes of volume 35 cm^3 (8 mm diameter and 70 cm length) and 125 cm^3 (15 mm diameter and 70 cm length). The copper was placed in pieces along the entire tube. The pulsed discharge was excited in the tube by discharging a capacitor through a thyratron. Inert buffer gases were used at a pressure of several dozen Torr. The tubes were heated to the working temperature (about 1500°C) without an oven, by the heat released in the discharge. The resonator consisted of a spherical mirror with a multilayer dielectric coating and a flat glass plate. The generation pulses were registered with an FEK-16 coaxial photocell and an I2-7 oscilloscope with a time resolution 0.5 nsec. The average power was measured with a KIM-1 meter.

Under the indicated experimental conditions, generation was observed in both tubes without a noticeable decrease of the peak power, both on the green (5105 Å) and on the yellow line (5782 Å) up to a pulse repetition frequency 20 kHz. Further increase of the frequency was limited by the available power supply. The largest average generation power on both lines in the 35 cm^3 tube was obtained at 18 kHz and amounted to 6 W at an efficiency 0.35%. An increase of the tube volume led to an increase of the power and of the efficiency. The maximum average power in the 125-cm^3 tube reached 15 W and was obtained under two conditions: 1) At a pulse repetition frequency 15 kHz and a capacitor voltage 21 kV. In this case the generation pulse duration was 5 nsec, and the peak power (on both lines, with the green line much stronger) reached its maximum value 200 kW at an efficiency of 0.8%. The specific peak power was 1.6 kW/cm^3. 2) At a pulse repetition frequency 18 kHz and 18 kV on the capacitor. In this case the peak power was 170 kW and the efficiency 1.0%. These efficiency values were calculated in both cases from the ratio of the generation energy to the energy stored in the working capacitor.