The use of the approximation $r_0 << \ell$, when the main nonlinear effect is the radial compression of the beam, leads to the following limitation on the parameters of the beam and of the plasma:

$$\frac{v_T^2}{v_0^2} |\epsilon| << \frac{\omega_b^2}{\omega_p^2}. \qquad (10)$$

At a specified plasma density, this inequality can be readily satisfied for strong-current beams with a small thermal transverse-velocity scatter.

We note in conclusion that inasmuch of the effect of self-compression of the beam can greatly reduce its radius at large beam-current density, the growth increment γ of the oscillations generated by such a beam in the plasma also decreases in comparison with the case of an unbounded beam: $\gamma \sim (r_0/\ell)^{2/3}(\omega_b/\omega_p)^{2/3}\,\omega_p$. It is obvious that this effect has time to develop if the beam compression time $\sim 1/\omega_b$ turns out to be shorter than the instability-development time $\sim 1/\gamma$, i.e., if

$$\omega_b \gtrsim \omega_p \left(\frac{v_T}{v_0}\right)^{2/3} |\epsilon|^{1/3}$$

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REGION OF POSITIVE EXISTENCE OF 2S POSITRONIUM IN A MEDIUM

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It was already noted in [1] that searches for excited states of positronium (primarily 2^3S_1 with a self-annihilation lifetime $\tau_{3\gamma} = 1.1 \times 10^{-6}$ sec are now among the most vital problems of positronium (Ps). It was also indicated [2] that the probability of formation of excited positronium states is ~ 0.5.

The possible existence of 2S positronium in vacuum was considered in [4]. In [4] it was assumed that approximately 1/30 of all the Ps atoms in a medium stay in 2S states. The existence of 2S positronium in water was proposed in [5]. The possible existence of 2S positronium is mentioned also in [6, 7].

However, the region of possible existence of the 2^3S_1 and 2^1S_0 states of positronium and the condition of their stability against the process competing with self-annihilation remain unclear. We have attempted in this work to find the upper limit of certain parameters of the indicated region.

Let us consider 2S positronium with account taken of the internal fields of the medium. We assume that the electric field $\mathcal{E}$ of the medium is parallel to the z axis and is sufficiently small compared with the internal field of the positronium itself.

The interaction energy of positronium with such a perturbing field E equals

$$H = e\mathcal{E}z, \tag{1}$$

where e is the electron charge. Taking into account the wave functions ψ_{2s} and ψ_{2p} of the Ps atom, we obtain the matrix element

$$< 2s|z|2p > = -6\,a, \tag{2}$$

where 2a is the radius of the first Bohr orbit of positronium.

In this case the first-approximation perturbation-theory correction to the unperturbed energy levels is

$$\delta E = 6e\mathcal{E}a. \tag{3}$$

In the presence of a field, the time-dependent wave function $\psi(t)$ of the positronium is a linear combination of the wave functions of the stationary state [8]. On the basis of perturbation theory, with allowance for the initial conditions, $\psi(t)$ is given by

$$\psi(t) = \{ \psi_{2s} \cos \frac{\delta E t}{\hbar} + i\psi_{2p} \sin \frac{\delta E t}{\hbar} \} \exp \{ -\frac{i}{\hbar} Et \} . \tag{4}$$

The positronium state described by the wave function $\psi(t)$ returns, with a time period $h/\delta E$, to the state described by the function ψ_{2s}. Let us estimate the field $\mathcal{E}$ under the condition that $h/\delta E = \tau_{3\gamma}$. Using (3) we get

$$\mathcal{E} = \frac{h}{6\,ea\tau_{3\gamma}} \approx 0{,}1 \text{ V/cm} \tag{5}$$

When $H/\delta E = \tau_2 = 10^{-10}$ sec (τ_2 is the lifetime of the 2^1S_0 state of the positronium with respect to self-annihilation), we have $\mathcal{E} \geq 130$ V/cm.

It is usually assumed that self-annihilation predominates only for the n^1S_0 singlet states, whereas radiative transitions to the ground state prevail for singlet states with $\ell \neq 0$. Since the lifetime of the 2^1P_1 state relative to the radiative processes (dipole electric) is 3.2×10^{-9} sec [9], the predominant process, even in weak fields of the medium, $\mathcal{E} > 130$ V/cm, is the 2^1S_0 of positronium in the 2^1P_1 state.

The influence of the collisions on the transitions from the 2S states of positronium in molecular crystals was considered in [10]. The lifetime of the 2S positronium with respect to collisions, according to [10], amounts to $\sim 10^{-14}$ sec. It i- possible to verify, by means of a direct estimate of the probability for decreasing the population of the positronium 2S states by collisions with neutral molecules, in accordance with [9], that at pressures $p < 10^{-3}$ Torr the probability of the self-annihilation of the 2^3S_1 state of positronium will exceed the probability of de-excitation at $p < 1$ Torr; the same holds true also for 2^1S_0.

Consequently, "pure" 2^3S_1 positronium can exist in principle when $p < 10^{-3}$ Torr and

$\mathcal{E}$ < 0.1 V/cm. Experimental studies of the shift of the energy levels of atomic positronium in gases (so far there are experimental data only for argon at pressures somewhat higher than atmospheric and at a temperature 300°K [11]) can answer the question concerning the concrete substances in which the indicated value of $\mathcal{E}$ is realized.

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STRUCTURE OF LAMB DIP FOR LONG-LIVED SYSTEMS IN SPATIALLY BOUNDED FIELDS

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The most promising method of stabilizing the frequency of laser radiation is based on the use of an absorbing gas cell [1 - 3]. The spectral width of the output-power peak, against which the stabilization is effected, is determined by the time of coherent interaction of the atomic system with the field. In this connection, particular interest attaches to the long-lived systems, i.e., with small level width Γ. Molecule-beam lasers have been analyzed in a number of papers (cf., e.g., [4, 5]). The spectral width of the power peak is determined here only by the time of flight $\bar{\tau}$ of the light wave for the average thermal velocity $\bar{v}$, if $\Gamma \ll 1/\tau$. This raises naturally the question whether this result is general or whether it is possible to construct lasers in which the parameters of the spectral structures are determined by the value of Γ in spite of the fact that $\Gamma \ll 1/\tau$. It will be shown below that in ordinary (not beam) systems, at a certain field configuration, the decisive role is played not by the mean-thermal atoms but by the slow ones, for which the time of flight is larger than or of the order of $1/\Gamma$. Consequently, such lasers can be constructed.

The stationary equations for the density matrix, in the case of a standing monochromatic wave, are given by

$$\left(\Gamma_j + v\frac{\partial}{\partial z} + u\frac{\partial}{\partial x}\right)\rho_j = q_j(u,\, v) \pm 2\,\mathrm{Re}\,\{i\,G(x)\,\rho_{mn}\cos kz\};\quad j = m, n$$