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HIGH PRESSURE GAS LASER WITH PRE-IONIZATION WITH A REACTOR

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Realization of combined pumping of CO_2 lasers has been reported in a number of recent publications [1 - 4]. An advantage of this pumping method is the possibility of igniting a homogeneous gas discharge in a large volume. Preliminary uniform ionization by an external ionizing source creates discharge conditions such that neither current filaments nor contraction takes place during the initial discharge stage. The use of powerful ionization sources (high-current accelerators [3, 4], pulsed reactors [5]) permits the excitation of lasing in large volumes at high pressure.

A nuclear reactor was already used as a source of gas ionization in an appreciable volume ($\sim$750 cm^3) at near-atmospheric pressure in experiment on direct excitation of lasing in an Hg + He^3 mixture [5]. We describe here experiments on combined excitation of a CO_2 laser, effected with the same reactor (the thermal-neutron flux density in the central channel was $\Pi \sim 5 \times 10^{16}$ neut/cm^2sec, the pulse duration was $\sim$1 msec).

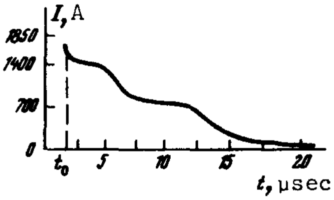
The laser was construction in the form of a cylindrical tube of organic glass with inside diameter 37 mm and length 550 mm. Two parallel duraluminum electrodes were placed inside the tube. Their polished surfaces, which faced each other, measured S = 500 × 20 mm, and the distance ℓ between them was 15 mm. The resonator was made of spherical metallic mirrors (gold sputtered on brass substrates, $R_{\text{opaque}} = 15$ m, $R_{\text{out}} = 3$ m). The output mirror had a central opening of 4 mm diameter, and heat-sensitive paper, used as the radiation indicator, was placed 15 mm above the mirror on the internal side of the sealing flange.

The laser was placed in the central channel of the reactor and filled with a $CO_2 + N_2 + He^3$ mixture at a pressure of several atmospheres. The high conductivity of the interelectrode gap during the operation of the reactor was due to the ionization loss of the charged products of the nuclear reaction $He^3(n, p)H^3 + 0.8$ meV.

The laser was fed from a high-voltage capacitor through a low-inductance circuit and a controllable discharge gap. Control of the electric discharge is necessary to be able to synchronize the instant of the discharge, whose duration is much shorter than that of the neutron pulse, with the instant when the chosen neutron flux level is attained.

The neutron-pickup signal and the discharge current and voltage, which were synchronized with this signal, were registered with S1-51 oscilloscopes.

The oscillograms of the idle discharges differed greatly from those obtained from the discharges produced with the reactor in operation. In the former case the current oscillogram has the form of periodic oscillations with a period equal to the period of the electric circuit with the electrodes short circuited. No lasing was observed. A typical oscillogram of the discharge current with the reactor in operation is shown in the figure.



Oscillogram of discharge current with reactor in operation. The oscilloscope speed is incapable of registering the current maximum in the time interval between 0 and t_0.

The laser operating conditions were in this case as follows: total pressure of all mixture components 2.5 atm (P_{CO_2} = 0.8 atm, P_{N_2} = 0.7 atm, P_{He^3} = 1 atm), voltage U = 36 kV, capacitor rating C = 0.7 μF, inductance and active resistance of electric circuit with the electrodes short circuited L_0 = 1.5 μH and R_0 = 0.05 ohm.

The laser radiation energy per pulse, estimated by comparing the exposed heat sensor with calibrated samples, was about 1 Joule.

The capacitor voltage was chosen to obtain the optimal discharge for the excitation of the lasing ($E/p \sim 10$ V/cm-mm Hg [1]). Such a regime is established across the discharge gap within a time $\tau_L \approx L/R$, where L is the inductance of the electric circuit and R is the active resistance of the gas-discharge gap, with $R \gg R_0$. On the other hand, the gas medium can be optically active only until the gas is heated. The characteristic time of this heating is $\tau_T \approx w/\sigma E^2$, where σ is the conductivity of the gas-discharge plasma and w is the specific enthalpy of the gas. It is therefore necessary to satisfy the inequality $\tau_L \ll \tau_T$. The conductivity of the gas-discharge plasma can be obtained from the balance equation for the electrons produced in the gas when the protons are slowed down, the proton range being small under the experimental conditions compared with the transverse dimension of the laser tube. Such a calculation of the electron density n_e is apparently justified, since estimates using the known values of the Townsend coefficient [6] show that the rate of ionization by the electric field does not exceed the ionization rate provided by the reactor.

From the balance equation for the electrons, $\Pi QN(\varepsilon/I) = \alpha n_e^2$, it follows therefore that $n_e \approx 10^{13}$ cm^{-3}.

Here $A = 5 \times 10^{-21}$ cm^2 is the cross section of the reaction $He^3(n, p)H^2$, $\varepsilon = 0.8$ meV is the energy of the reaction products, $I \approx 40$ eV is the average energy consumed in producing an ion-electron pair by a high-energy proton, N is the concentration of the He^3 atoms, and $\alpha \approx 10^{-7}$ cm^3/sec is the coefficient of dissociative recombination of the electrons.

The plasma conductivity in this case is $\sigma \approx 10^9$ cgs esu, and the total resistance of the gas-discharge gap is $R = \ell/S\sigma = 15$ ohm $\gg R_0$.

We see thus that τ_T is of the order of several microseconds and $\tau_1 \sim 10^{-7}$ sec, so that the condition $\tau_L \ll \tau_T$ is satisfied under the experimental conditions. It can be assumed that the lasing was realized during the heating time τ_T, since the capacitor discharge time was $\tau_C \sim RC \sim 10^{-5}$ sec and $\tau_C \gg \tau_T$. The foregoing estimates are in satisfactory agreement with the experimental time dependence of the current, and testify in favor of the assumption that the discharge develops through the volume during the lasing process.

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TWO-PARTICLE PRECESSION OF MUONIUM IN STRONG MAGNETIC FIELDS

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We consider here the change of the polarization P(t) of the μ^+ meson of muonium in a transverse magnetic field B (perpendicular to the μ^+-meson spin). Under these conditions the state of the muonium is not stationary, but is a superposition of states with different energies. The general form of the time dependence of P(t) was obtained for such a case in [1]. In the present article we point out several peculiarities of P(t) in strong transverse magnetic fields. These peculiarities can be used to determine the frequency ω_0 of the hyperfine splitting of the muonium atom in matter.

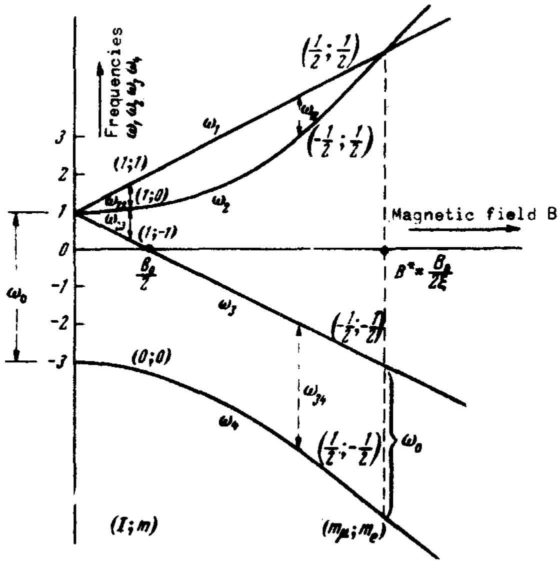

Fig. 1. Breit-Rabi diagram for the muonium terms in a magnetic field. The arrows designate the frequencies ω_{12}, ω_{23} and ω_{12}, ω_{34}, which determine the two-frequency precession for weak ($B << B_0$) and strong ($B >> B_0$) fields, respectively. The figure shows the quantum numbers that determine the state of the muonium atom in weak and strong fields. The good quantum numbers are the total angular momentum I of the muonium and its projection m on the direction of the field B in a field $B << B_0$. The good numbers and the projections of the separate spins μ^+ meson and the electron in the region $B >> B_0$.

Figure 1 shows schematically plots of the frequencies $\omega = E/\hbar$ of the eigenstates of the muonium atom against the external magnetic field B. The