trary spin $J \geq 5/2$. The method of calculation is similar to that already described in [2], with the sole difference that in this case it is necessary to change to the energy representation in which the Hamiltonian H_Q is diagonal.

The results of calculating the amplitudes of the induction and spin echo signals for an arbitrary spin J ($\geq 5/2$) are given in Table 1. In Table 2 there are analytical expressions for the frequencies and matrix elements of the corresponding transitions obtained for the spins $J = 5/2$ and $7/2$ taking into account second-order perturbation theory for the asymmetry parameter $\eta \leq 0.20$. Generally speaking, the matrix elements of the operator I_x in the energy representation can be calculated for any η by a numerical method.

It can be seen from Table 1 that for all spins in the case of $\eta \neq 0$ the position of the basic echo with $t = 2t$ does not depend on η. Additional echos should arise for $t = (1 + \omega_2^0/\omega_1^0)\tau$ and $t = (2 + \omega_2^0/\omega_1^0)\tau$ at the frequency of the lower of the two adjacent excited frequencies ω_1^0. For example, in the case of $J = 5/2$ and low η the phase coherence of the spins as well as echo signals arise with $t = (3 - 70\eta^2/27)\tau$ and $t = (4 - 70\eta^2/27)\tau$. Similarly, at the frequency of the upper transition ω_2^0 the position of the additional echos is determined by the times $t = (1 + \omega_1^0/\omega_2^0)\tau$ and $t = (2 + \omega_1^0/\omega_2^0)\tau$, and for the special case referred to above $t = (3/2 + 35\eta^2/54)\tau$ and $t = (5/2 + 35\eta^2/54)\tau$. Thus the asymmetry parameter has four times less effect on the position of the echo for the upper transition than for the lower.

In the case of $J = 7/2$, when the double-frequency excitation is carried out for the transitions ($1/2 \rightarrow 3/2$) and ($3/2 \rightarrow 5/2$) an echo signal occurs at the frequency ω_1^0 for $t = 2\tau$, $(3 - 42\eta^2/5)\tau$ and $(4 - 42\eta^2/5)$, and at the frequency ω_2^0 for $t = 2\tau$, $(3/2 + 21\eta^2/10)\tau$ and $(5/2 + 21\eta^2/10)\tau$.

Thus, it is possible to estimate the magnitude of the asymmetry parameter η according to the position of the additional echos. In addition, it is clear that the spread in the values of this parameter at different places in the crystal lattice should lead to a broadening of the additional echo signals. However, a theoretical calculation of these broadenings from which useful information might be derived for the study of lattice defects does not appear feasible at the present time.

Figure 1 gives the results of an actual calculation of the amplitudes of the echo for the case of a $BiCl_3$ crystal (resonance of the Bi^{209} nucleus, $J = 9/2$, $\eta = 0.58$) which was the subject of experiment [3]. The agreement obtained between experiment and theory is good. Actually, if the second pulse is taken at 90° the amplitude of the additional echo for $t = 1.7\tau$ (transition $7/2 \rightarrow 9/2$) is very small, whereas the echo signal for $t = 2.7\tau$ is easily detected. A knowledge of the analytical form of the amplitudes and positions of the double-frequency echos makes it possible to find the optimal conditions of observing them in various suitable crystalline compounds.

The method of a double-frequency echo is also of interest in view of the fact that it opens up possibilities of studying irreversible processes in multilevel systems. It is shown in [1] that with double-frequency action in the case when $\gamma = 0.1$ ($\gamma = w_2/w_1$, w_1 and w_2 are relaxation probabilities) the process of approximation to equilibrium in subsystems of spins has a nonmonotonic character.

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A SEALED SUBMILLIMETER $H_2O + H_2$ LASER

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An important role in opening the submillimeter waveband is played by the lasers recently developed for this range, operating with molecular gases [1, 2]. The present submillimeter lasers are continuous systems in which there is constant displacement of the working medium, and this complicates the equipment and makes it difficult to operate. The advantages of systems widely employed in the visible and infrared regions of the spectrum are well known. However, the attempt to produce submillimeter lasers in sealed form has not yet met with success.

It is pointed out in [2] that when the pumping of the working medium is stopped, a water-vapor laser ($\lambda \simeq 119\ \mu$) would generate for only a few minutes; after generation has ceased it cannot be restored even with prolonged rest without discharge of the consumed working medium. Flesher and Muller [2] suggest that this occurs because of the dissociation of the water vapor in the discharge, while the reverse process is greatly impeded for a variety of reasons. We have assumed that in a sealed laser the hydrogen/oxygen relationship needed for laser action is disturbed and this causes laser operation to cease. For example, the hydrogen formed in the discharge can be absorbed by the walls of the vacuum space [3]. It should be noted that till now the group of atoms or molecules responsible for laser action remains unknown. Furthermore, if the presence of specific quantities of hydrogen and oxygen alone is essential for laser operation, it may be that their ratio in water is not optimal for laser operation. To check these assumptions we carried out certain experiments on the submillimeter laser installation described below.

The laser was of the usual design (see, for example [2]). The laser tube was two meters long and 7.5 cm in diameter. The mirrors at the ends of the tube were glass, spherical in form with a curvature radius of 2.5 m, and coated with a vacuum-sputtered layer of aluminum which is covered with silver. The aluminum substrate increases mirror stability in the discharge, and the silver layer has a higher reflection coefficient in the submillimeter range than aluminum. The discharge took place between one anode in the center of the tube and two water-cooled hollow cathodes at the ends. The working conditions of the discharge corresponded to voltages on the order of 1–1.5 kV, and currents of 200-600 mA in each arm. The tube was forced-cooled when in operation. The laser emitted its radiation through a 2mm opening in the center of one of the mirrors. Since the equipment is intended as a rule to operate under conditions, it was sealed vacuum-tight with rubber and the window for the radiation output was sealed with a thin plastic film which, when the pumping was stopped, led to the rather rapid deterioration of the vacuum in the system (the accumulation in the system under static conditions amounted to $3-8 \cdot 10^2$ mm Hg per hour).

With this equipment we were able to achieve uninterrupted generation under continuous conditions in water vapor at the previously known wavelengths of 28 and 119 μ. The radiation was received in a Golay cell with KBr (for $\lambda = 28\ \mu$) or crystalline quartz (for $\lambda = 119\ \mu$) windows. The 28μ wavelength was determined by means of an echellette. At a wavelength of 119μ the laser would generate only with the cavity formed by the mirrors appropriately tuned. When the length of the laser resonator is changed by displacing one of the mirrors, the radiation maxima appear within $\lambda/2$, which is used to measure the wavelength emitted by the laser.

We then started the laser in a continuous regime with a mixture of gaseous hydrogen and oxygen; in this way we obtained generation at the same wavelengths and approximately the same power as in water vapor. The laser would not work on hydrogen or oxygen alone. We then carried out experiments on adding oxygen and hydrogen separately to the discharge in water vapor during laser generation. The addition of oxygen at 0.2 mm Hg led to a several-fold reduction in the generated power at both 28 and 119 μ. The addition of the same quantity of hydrogen approximately doubled the power at both wavelengths (see Correction).

These results, which confirmed our assumptions, enabled us to pass on to the study of the possibility of operating the laser under sealed conditions. First of all, the experiments in [2] were repeated. In agreement with this paper, laser generation in water vapor ceased under sealed conditions after 3–4 minutes and could not be restored. However, the addition of hydrogen to the consumed working medium renewed the generation. This result also confirmed our assumptions. Following this, the laser, filled with an $H_2O + H_2$ mixture in approximately equal quantities (at 0.2 mm Hg), was started and it operated in the sealed regime for more than four hours at wavelengths of 28 and 119 μ. It was established that the laser will allow the discharge to be stopped and then to be started again. At the end of operation under sealed conditions the color of the discharge was reminiscent of that of a discharge in air, and the generated power was considerably reduced. A control experiment with the addition of ordinary air to the working laser in quantities on the order of a fraction of a millimeter of Hg showed extinction of generation by the air. This fact was in accordance with the limited working life of our equipment under sealed conditions, and was apparently due to the accumulation of air in the vacuum space. A further increase in the period of continuous operation of a sealed submillimeter laser employing $H_2O + H_2$ appears to be possible provided a suitable vacuum system is designed, which will prevent both the build-up of foreign gases and the loss of the working medium. We note that when necessary the addition of hydrogen to the discharge can be achieved, for example, by evaporation from the corresponding adsorber.

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Correction.

Studies of D_2O lasers $\lambda \sim 172\mu$) showed similar behavior on the part of H_2O and D_2O lasers with respect to chemical additives of corresponding isotope composition, which may be evidence of the chemical nature of the excitation processes in these lasers.

THE RESONANCES OF A GAS-DISCHARGE PLASMA IN A MAGNETIC FIELD*

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Longitudinal waves set up in plasmas having very diffuse boundaries (on the Debye-radius scale) owing to the high Landau attenuation at the periphery of a plasma must satisfy the radiation condition which makes it impossible for longitudinal-wave resonances to arise in objects with smooth and monotonically decreasing densities from the center to the periphery. As shown in [1] these resonances are absent in spherically and cylindrically symmetrical structures, even when the escape of longitudinal waves to the region of strong damping is made difficult by the presence of discontinuities in the derived density.

The possibility of formulating an analogous condition for radiation in the presence of a constant magnetic field perpendicular to the direction of propagation of the longitudinal wave set up in the plasma is a much more complicated matter. Since Cerenkov losses are absent in the case of purely transverse propagation, and cyclotron absorption in a uniform field takes place only in a limited range of harmonics of the gyrofrequency ($\omega = n\omega_H$, n = 1, 2, 3), the bases for imposing radiation conditions on longitudinal waves at intermediate frequencies $\omega \neq n\omega_H$ in a plasma without collisions (even assuming a very diffuse boundary) would seem to be lacking.

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