METASTABLE STATE OF ROTATING HELIUM II WHEN ITS ROTARY SPEED IS SUDDENLY CHANGED

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Relaxation phenomena in rotating helium II, connected either with a phase transition occurring in the liquid (see [1 - 3]) or with a change in the regime of its motion (see, e.g., [4 - 6]), have been under study for quite a while. These studies have shown that helium II rotating in a transcritical regime can remain in a metastable state for a long time.

Unlike in [5], where it is shown that the vortices vanish or are formed in groups when the rotary speed is varied smoothly and slowly, we report here results of experiments in which the rotary speed of the apparatus was decreased almost instantaneously. We used the method first employed in [7] to damp the free oscillations of the disk. The brass disk was 30 mm in diameter and 1 mm thick. To decrease the slippage coefficient of the vortices, both faces of the disk were covered with sand grains with dimensions $\ell \sim 50\ \mu$. The disk was suspended by a phosphor-bronze wire of 30 μ diameter and 120 mm length in a rotating vessel with liquid helium. In addition to rotating jointly with the vessel, the disk could also execute axial-torsional oscillations. The logarithmic oscillation-damping decrement was measured by a chronometric method [8] using a fully-automatized setup in which the measurement results were processed with an M-220M computer.

At different helium-II temperatures, we measured the time between the instantaneous decrease (within $\sim$ 1 - 2 sec) of the rotary speed of the instrument from $\omega = 0.029\ \text{sec}^{-1}$ to $\omega = 0.012\ \text{sec}^{-1}$ and the instant when new equilibrium damping of the disk oscillations was established for the new speed. The period of the disk oscillations was constant at 19.99 sec for all temperatures and rotary speeds.

It was found that when a liquid-helium-filled vessel initially rotating at a speed $\omega = 0.029\ \text{sec}^{-1}$ or $\omega = 0.012\ \text{sec}^{-1}$ is suddenly stopped, the decrease of the damping of the disk immersed in the helium begins immediately and terminates within $\sim$150 - 300 sec (at T = 2.15°K and T = 1.47°K, respectively). This indicates that the decay of the vortices begins simultaneously with the stopping of the motion.

To the contrary, when the rotary speed is decreased by a factor of almost 2.5, the damping remains constant for a long time at the value corresponding to the initial rotary speed. Only after the lapse of a certain time does the damping decrease jumpwise and assumes after 30 - 50 sec the value corresponding to the new rotary speed (see Fig. 1).

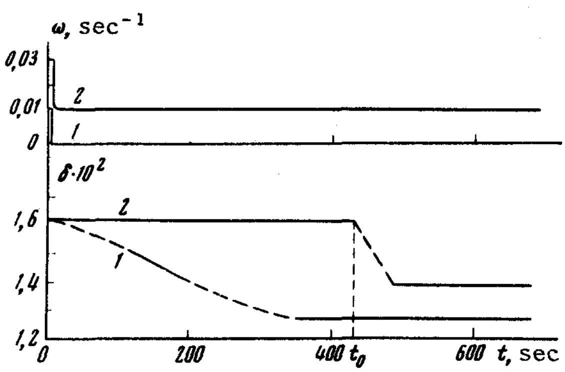

Fig. 1. Time variation of the rotary speed of the vessel and ensuing change in the damping decrement of the oscillating disk: 1) vessel stopped; 2) vessel slowed down.

Figure 2 shows the dependence of t on the temperature of the helium II.

It should be noted that the establishment of a new equilibrium state in helium II following a rapid and appreciable change of its rotary speed is very similar to the vanishing of the vortices when the rotating helium II is heated above T_λ; in that case, too, the damping of the disk oscillations retains its initial value for a long time,

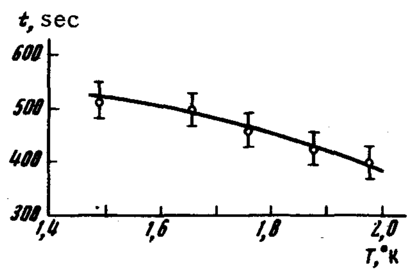

Fig. 2. Relaxation time t vs the temperature T of He-II when the rotary speed of the vessel is decreased from $\omega = 0.029$ sec^{-1} to $\omega = 0.012$ sec^{-1}.

and then assumes the new equilibrium value relatively rapidly [1, 2].

It follows from these observations that the decay of the vortex system when the rotation of the helium II stops differs strongly from the decay of the excess vortices following a sudden decrease of the rotary speed. Whereas in the former case the system responds instantaneously to the change of the conditions and starts immediately to go over to the new equilibrium state, in the latter case the system stays for a long time in a metastable state.

We note finally that our results, like the results of [1, 2, 7], serve as an additional argument favoring a new hypothesis recently advanced by Packard [9], that the acceleration (starquake) of pulsars is connected with the metastability of the vortex lattice of superfluid neutron liquid.

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[1] E. L. Andronikashvili, K. B. Mesoed, and Dzh. S. Tsakadze, Zh. Eksp. Teor. Fiz. 46, 157 (1964) [Sov. Phys.-JETP 19, 113 (1964)].
[2] E. L. Andronikashvili, G. V. Gudzhabidze, and Dzh. S. Tsakadze, Proc. 9th Internat. Conf. on Low Temp. Phys., Columbus, Ohio, 1965.
[3] E. L. Andronikashvili, R. A. Bablidze, and Dzh. S. Tsakadze, Zh. Eksp. Teor. Fiz. 50, 46 (1966) [Sov. Phys.-JETP 23, 31 (1966)].
[4] G. V. Gudzhabidze and Dzh. S. Tsakadze, ibid. 50, 55 (1966) [23, 37 (1966)].
[5] R. E. Packard and T. M. Sanders, Phys. Rev. Lett. 22, 823 (1962).
[6] Z. Sh. Nadirashvili and Dzh. S. Tsakadze, Zh. Eksp. Teor. Fiz. 64, 1672 (1973) [Sov. Phys.-JETP 37, No. 5 (1973)].
[7] E. L. Andronikashvili and Dzh. S. Tsakadze, Proc. 5th All-Union Conf. on Low Temp. Phys., Tbilisi, 1968.
[8] E. L. Andronikashvili, Yu. G. Mamaladze, and Dzh. S. Tsakadze, Trudy Inst. Fiz. AN GSSR 7, 59 (1960).
[9] R. E. Packard, Phys. Lett. 28, 1080 (1972).

GAS LASER USING IONIZED EUROPIUM

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A high-power pulsed and quasicontinuous lasing was obtained using singly-ionized europium in the near infrared. The laser has high efficiency. New promising conditions for gas-laser excitation are found.

The use of metal vapors as active media in gas lasers has led to the development of high-efficiency and high-power lasers in the visible band [1]. A large group of metals, however, has not yet been investigated or used in gas lasers, including the series of rare-earth elements. At the same time, the diversity of energy-level structures of the atoms and ions of rare earth make them promising for the development of new highly efficient active media.

In the present study, by investigating electric discharges in mixtures of rare-earth metal vapors with inert gases, we obtained for the first time lasing on a number of lines of singly-ionized europium. The upper levels of the new laser belong to the configurations $4f^76p\,^9p$, ^7P, and the lower ones to $4f^75d\,^7D^0$ of Eu II. Under near-optimal excitation conditions we observed simultaneous lasing on three powerful lines with wavelengths $\lambda = 1.002\ \mu$ ($^7P_4 - {}^7D_0$), $\lambda = 1.0166\ \mu$ ($^7P_4 - {}^7D_4^0$), and $\lambda = 1.361\ \mu$ ($^9P_4 - {}^7D_5^0$) (we used the energy-level