corded by the electronic equipment.

Thus, the number of γ rays which can be identified as scattered from electrons is 0.42 ± 0.08 per acceleration cycle and per laser pulse.

On the basis of the experimental result obtained, we can state that we have detected the Compton scattering of 1.79 eV laser photons on 550 MeV relativistic electrons in a head-on collision of the beams.

Increase in the number of scattered γ rays by tens or hundreds of times by use of a more powerful laser (up to 20-30 joules), transfer of the interaction region to a straight section of the electron orbit, and incorporation of the interaction region in the resonant optical path of the laser[2] promises to diminish the main experimental difficulty - adjustment of the apparatus to achieve proper collision of the beams - and to make possible measurement of the energy and angular characteristics of the beam.

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[1] A. I. Akhiezer and V. B. Berestetskiĭ, Kvantovaya elektrodinamika (Quantum Electrodynamics), 2d. ed., Gostekhizdat, 1959, Sec. 28.

[2] R. H. Milburn, Phys. Rev. Letters 10, 75 (1963).

[3] F. R. Arutyunyan and V. A. Tumanyan, JETP 44, 2100 (1963). Soviet Phys. JETP 17, 1412 (1963).

[4] Arutyunyan, Gol'dman, and Tumanyan, JETP 45, 312 (1963), Soviet Phys. JETP 18, 218 (1964).

[5] Korolev, Ershov, and Kulikov, JETP 40, 1644 (1961), Soviet Phys. JETP 13, 1158 (1961).

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ION THRESHOLD ENERGY FOR A TWO-STREAM ION INSTABILITY

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THE relative motion of an ion beam and a plasma or plasma streams can lead to a two-stream ion instability [1,2] if certain relations are satisfied between the electron thermal energy and the energy of the directed ion motion. This instability has been observed experimentally in a number of investigations.[3-5]

An ion beam with ion energies greater than the thermal energy of the ions in the plasma through which it passes can excite oscillations. As the beam energy increases further the system becomes stable. According to the hydrodynamic theory the threshold energy is a weak function of the ratio of the ion density in the beam to the ion density in the plasma and is given by $\epsilon_{th} = 2\gamma kT_e$ when these two quantities are equal. The kinetic analysis [2] yields the relation $\epsilon_{th} \approx 3kT_e$.

By transmitting an ion beam (with a current of order 1 ma) through a plasma formed in various gases one can observe the excitation of oscillations by the ion beam at various electron temperatures and verify this prediction of the theory over a relatively wide range of electron temperature.

The curve showing the dependence of oscillation amplitude on ion energy goes through a maximum value. The threshold energy is determined by the maximum of these curves, which precedes a more or less sharp reduction in oscillation amplitude. The function $\epsilon_{th}(T_e)$ obtained in this way is shown in the figure. It is evident that there is a proportionality between the ion threshold energy and the electron temperature, as follows from the theory. The quantitative agreement between theory and experiment that is obtained with

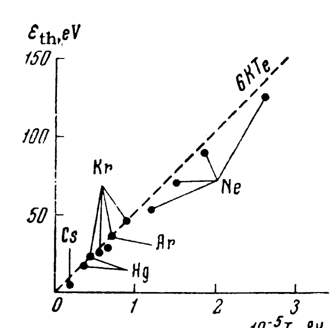

FIG. 1

$\gamma = 3$ should be taken with caution because in these experiments it was not always possible to avoid an energy spread in the ion beam or other complicating circumstances.

The observed oscillation frequency is found to be approximately proportional to the ion velocity (cf. [6]). This is also in agreement with the solution ($w = kv/2$) of the appropriate dispersion equation if one assumes that K is determined by the transverse dimensions of the ion beam.

The experimental verification of the dependence of the threshold energy of the ion beam on electron temperature, predicted by theory, indicates the possibility of using the two-stream ion instabilitiy for thermalization of powerful ion beams in a plasma with high electron temperatures or for plasma diagnostic applications.

[1] Vedenov, Velikhov, and Sagdeev, UFN **73**, 701 (1961), Soviet Phys. Uspekhi **4**, 332 (1961).

[2] Nexsen, Cummins, Coensgen, and Sherman, Phys. Rev. **119**, 1457 (1960).

[3] Babykin, Zavoĭskiĭ, Rudakov and Skoryupin, JETP **43**, 1976 (1962), Soviet Phys. JETP **16**, 1391 (1963).

[4] M. D. Gabovich and G. S. Kirichenko, JETP **42**, 1478 (1962), Soviet Phys. JETP **15**, 1026 (1962); Ukranian Physics Journal 8, 624 (1963).

[5] Gabovich, Kirichenko and Koĭdan, Sb. Diagnostika plazmy, (Coll. Plasma Diagnostics) Gosatomizdat, 1963.

[6] Gabovich, Kirichenko and Koĭdan, Sb. FTI AN Uk. S.S.R., Fizika plazmy i problema upravlyaemogo termoyadernogo sinteza [Plasma Physics and the Problem of a Controlled Thermonucleuar Fusion] (in press).

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A Q-SWITCHED OPTICAL MASER

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THE instantaneous output power of an optical maser can be increased by using the well known method of Q-switching [1]. We have used an electro-optic shutter for controlling the Q. The laser

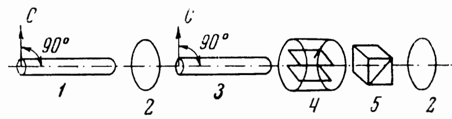

FIG. 1

is shown schematically in Fig. 1. The numbers in the figure have the following meaning: 1- a 90° oriented ruby crystal, 12 cm long, 0.9 cm in diameter, with a chromium ion concentration of 0.06%; 2- mirrors, the left hand one is a plane parallel glass plate without any coatings, the right hand one has a 98% reflectivity; 3- the laser crystal; 4- the Kerr cell; 5- a specially constructed polarizing prism. The ruby, the Kerr cell and the prism are oriented so that, in the absence of voltage on the Kerr cell, laser action in the ordinary ray is impossible (laser action was not observed in our experiments in the extraordinary ray).

The Kerr cell was operated by a voltage pulse which produced a phase difference of $\lambda/2$. The pulse duration was 0.5 μsec and its rise time was 5 nanoseconds. A delay line generator was used to produce the pulse [2].

The crystal was pumped with a helical flash lamp through which a 300 μf condenser bank at up to 8kV was discharged. Under these conditions the flash lamp took about 700 microseconds to rise to the 0.3 intensity level. At this excitation the crystal lased due to the Fresnel reflection from the uncoated ends of the ruby, provided the side wall of the crystal was rough ground. The occurrence of laser oscillation indicates that the negative absorption coefficient was not less than 0.22 cm^{-1}. It should be noted that, in the same crystal with a polished side wall, the coefficient of negative absorption could not be made greater than 0.16 cm^{-1}.

It is clear from Fig. 1 that when the shutter is closed the laser can oscillate using the reflections from the end wall of the laser crystal and the parallel plate which acts as a mirror. The plane parallel plate and the end face of the ruby opposite it form a compound interferometer with a maximum reflectivity of about 30%. During oscillation under these conditions the coefficient of negative absorption attains a value of 0.16 cm^{-1}. In order to attain maximum inversion the end faces of the crystal and the Kerr cell were anti-reflection coated to 1% at each surface. The polarizing prism was not coated and therefore its surfaces were canted at a 0.5° angle to the plane of the mirrors.

The voltage pulse was applied to the Kerr cell 550 μsec after the firing of the flash lamp. At this