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SEARCH FOR RAMAN SCATTERING OF ELECTROMAGNETIC WAVES IN THE MICROWAVE BAND WITH THE AID OF A TURBULENT PLASMA

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It is shown in the theory of Raman scattering of electromagnetic waves by the electronic oscillations of a bounded plasma [1] that the Raman-scattering signal can yield very valuable information on the level of the turbulent oscillations 1). In this connection, we have undertaken, using the toroidal plasma installation described in [6], a search for the scattering of electromagnetic waves from an external source, accompanied by a change in frequency.

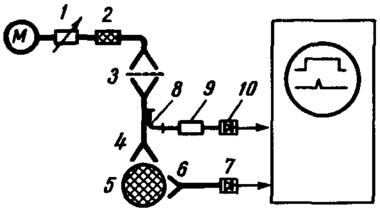

Fig. 1. Diagram of installation

A diagram of the experiment is shown in Fig. 1. Here 1 - attenuator, 2 - ferrite decoupler, 3 - filter to attenuate a signal with $\lambda = 1.5$ cm by 30 dB, 4 - transmitting antenna, 5 - plasma, 6 - receiving antenna, 6-7 - waveguide operating beyond cutoff, 7 - receiving detector head, 8 - directional coupler, 9 - attenuator, 10 - control detector head. Radio signals at wavelength $\lambda = 3$ cm, generated by magnetron M, are beamed at the plasma pinch by the transmitting antenna. The antenna, which is so oriented that the electric vector of the wave is parallel to the magnetic field confining the plasma, produces a pulse of ~10 kW power and 4 μsec duration. The waveform of the pulse generated by the magnetron is determined with the aid of the control detector head, the signal from which is fed to one of the beams of the oscilloscope (OK-17).

The scattered radiation is received by a horn antenna and is fed through a waveguide with cutoff wavelength 2.2 cm to a detector head tuned to 1.6 cm wavelength. The signal from the detector head is fed to the second oscilloscope beam.

A plasma with density $n \sim 10^{11} - 10^{12}$ cm^{-3} was heated to $T_e = 10^2 - 10^3$ eV [6] by a current that experienced an anomalous active resistance and was accompanied by intense microwave noise with $\lambda > 3.5$ cm.

Under these conditions the detector head recorded a signal of 10^{-5} W power, correlated in time with the current. When the magnetron was turned on the signal increased 3 - 4 times (see Fig. 2), and in some cases 10 times. The experiments made it possible to establish the following:

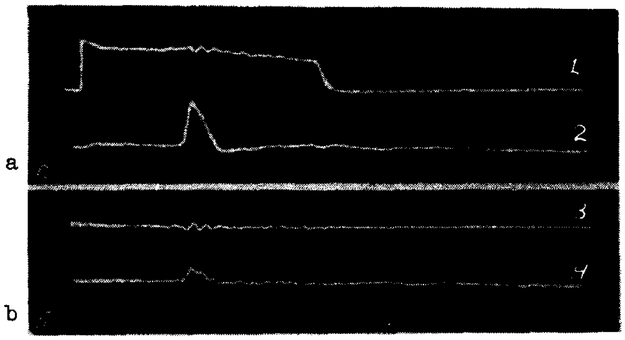

Fig. 2. Oscillograms of signals: a - plasma irradiated by a pulse from the magnetron, b - magnetron turned off, 1, 3 - envelope of pulse generated by the magnetron at 3 cm wavelength. 2, 4 - signal from receiving detector head. The noise in oscillograms 1 and 3 characterizes the duration of the current in the plasma (see Fig. 4 of [5]).

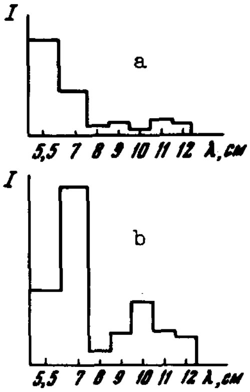

Fig. 3. Spectrum of intrinsic microwave radiation of a plasma with $n \sim 10^{12}$ cm^{-3}, H = 2 kOe, and longitudinal electric field intensity E_θ = 75 V/cm. In diagram b the value of n is reduced by a factor 3 - 5.

1. The signal is observed only under the discharge conditions indicated above, when the anomalous resistance and the plasma noise offer evidence of plasma turbulence.

2. The signal is not connected with the registration of radio emission at $\lambda_0 = 3$ cm.

3. The signal cannot be attributed to plasma scattering of the second harmonic (λ = 1.5 cm) generated by the magnetron. A diffraction-grating filter making use of the properties of H-polarized waves [7], introduced in the transmission channel, completely suppressed the second-harmonic noise of 4 μsec duration, but caused no noticeable change in the amplitude of the current-correlated signal shown in Fig. 2.

This apparently shows that the signal observed when the magnetron is turned off is due to noise radiation from the plasma near λ = 1.5 - 2 cm, and the signal with the magnetron turned on is due to the sought-for Raman scattering effect. The ratio of the power of the latter signal to the power of the radio signal beamed at the plasma was of the order of 10^{-8} - 10^{-9}, in agreement with the theoretical estimate for Raman scattering at frequency ω_{pe} [1].

It is of interest to compare these results with data on the spectrum of the plasma microwave noise previously observed in the region $\lambda > 3.5$ cm. The measurements were made with a resonator tunable from 5.5 to 12 cm. Several maxima were noticed in the emission spectrum. The shift in the maxima with changing <u>n</u> (Fig. 3) indicates that they correspond to frequencies proportional to ω_{pe}.

Theory predicts for a bounded plasma emission maxima at frequencies $\omega_{pe}(1 - 1/\sqrt{2})$, $\omega_{pe}/\sqrt{2}$, ω_{pe}, $\omega_{pe}(1 + 1/\sqrt{2})$, and $2\omega_{pe}$.

All the results obtained can be summarized as follows: When radio emission with $\lambda_0 = 3$ cm from an external source is incident on a turbulent plasma, Raman scattering in which the frequency change is of the order of ω_{pe} is apparently observed, in accord with the estimate in [1], thus offering evidence of the high level of the electronic oscillations. Intense maxima were observed in the intrinsic radiation of the plasma in the region $\lambda > 3.5$ cm at frequencies close to ω_{pe}, and a much weaker maximum in the interval $\lambda = 1.5 - 2$ cm where the frequency $2\omega_{pe}$ is situated.

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1) The theory of Raman scattering for an unbounded plasma [2,3] was confirmed experimentally on a laminar plasma of a "Q machine," where the Raman scattering was from slow space-charge oscillations excited by an external generator [4]. Combination frequencies were observed in [5] upon interaction of an external high-frequency field with low-frequency ionic plasma oscillations in a magnetic field.

QUANTUM OSCILLATIONS OF THE THERMOELECTRIC POWER IN n-InAs

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It is shown in this paper that quantization of the electron energy spectrum of degenerate ($\mu/k_1T \gg 1$) indium arsenide placed in a strong magnetic field ($uH/c \gg 1$) is manifest at low temperatures ($k_0T \ll \hbar\Omega$) in an oscillatory dependence of the thermoelectric power on the magnetic field intensity H (u is the mobility, μ the chemical potential, and $\Omega = eH/m^*c$ the cyclotron frequency). We also explain in this paper some additional details of the quantum oscillations of the Hall effect, which take place at the same time. So far n-InSb is the only semiconductor exhibiting quantum oscillation of the thermoelectric power [1].

An oscillatory field dependence was observed earlier in several investigations of the magnetoresistance and of the Hall coefficient of n-InAs. A detailed discussion of these results is given in [2]. According to theory, the physical conditions which determine the oscillation of the magnetoresistance differ noticeably from the conditions determining the os-