We note finally that energywise pairproduction is always much less (by at least a factor α) than the bremsstrahlung. The unique role of pair production lies in the fact that in the presence of a magnetic field the positrons remain within the limits of the considered region of space, whereas the photons go off from the optically thin region ($\tau < 1$ with respect to Compton scattering). At an ultrarelativistic temperature, the bremsstrahlung photons cause pair photoproduction with a cross section smaller by a factor α than the photon-scattering cross section.

This factor α cancels out the ratio α^{-1} of the bremsstrahlung to pair production in collisions. The condition $\tau < 1$ suffices therefore for our results to be valid. When $\tau > 1$, so long as the bremsstrahlung absorption is small and there is no thermodynamic equilibrium, there also exists a temperature at which the stationarity vanishes; it is lower than $40mc^2$ and is close to mc^2 when $\tau \sim 10$.

Under astrophysical conditions, a relativistic plasma can consist for a long time of the same particles, and the energy loss is offset by pumping by radiation, shock waves, or alternating magnetic fields. In particular, such a situation can take place near radio-emitting regions of quasars and pulsars [3]. Another case is also possible, wherein fast particles are injected in the given region of space, and leave the region simultaneously with the energy loss.

Our calculations pertain only to a plasma with a lifetime larger than the time required to establish equilibrium. Observation of a plasma having an electron temperature (or effective energy) much higher than critical indicates that the plasma has stayed in such a state for a short time. A detailed article will be published in "Astronomicheskii zhurnal."

We are grateful to A. Z. Dolginov for a remark that stimultaed this research.

[1] L. D. Landau and E. M. Lifshitz, Statisticheskaya fizika (Statistical Physics), Nauka, 1964 [Addison-Wesley].
[2] A. I. Akhiezer and V. B. Berestetskii, Kvantovaya elektrodinamika (Quantum Electrodynamics), Fizmatgiz, 1959 [Wiley, 1965].
[3] E. V. Levich and R. A. Syunyaev, Radiofizika 13, No. 9 (1970)].

ATTENUATION OF LIGHT ABSORPTION IN ANTIFERROMAGNETIC $FeCO_3$ BY A MAGNETIC FIELD

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It was shown recently that the main electric-dipole absorption of light in antiferromagnetic crystals is due to exciton-magnon optical transitions [1 - 4]. These transitions constitute a particular case of "double" transitions, the general theory of which was constructed by Dexter [5].

In an antiferromagnetic crystal, the "double" exciton-magnon transition is much less intense than the "single" pure-exciton transition. Inasmuch as exciton-magnon electric-dipole absorption is peculiar to antiferromagnets, one can expect light absorption in the crystal to weaken when the antiferromagnetic structure is destroyed. The present paper is devoted to an experimental observation of this effect.

We chose for the investigation siderite - $FeCO_3$. This crystal has a rhombohedral structure and a magnetic anisotropy of the "easy axis" type. Below the temperature $T_N = 32°K$, siderite goes over into an antiferromagnetic state , with the magnetic moments of the sublattices directed along the threefold axis C_3. In a magnetic field H parallel to C_3 with intensity $H \geq 180$ kOe, the magnetic moments of both sublattices of siderite become practically parallel to each other and to the external magnetic field H. In any case, the measured magnetic moment of the crystal in so strong a field is close to the calculated summary magnetic moment of both sublattices when the latter are parallel [6]. It was precisely this circumstance that governed the choice of siderite as the object of the investigation.

The experimental procedure was described earlier [7]. The linear dispersion of the spectral instrument (DFS-13) is sufficiently large, 4 Å/mm. The sample temperature was 20.4 or

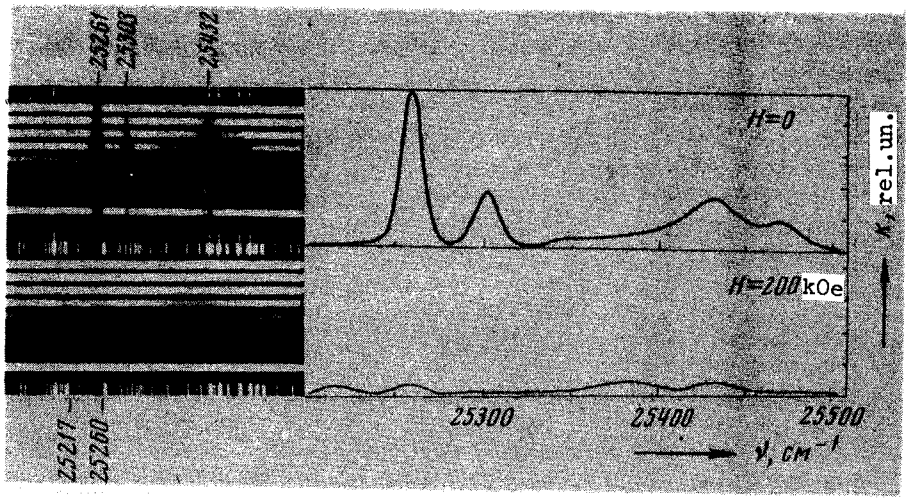

Fig. 1

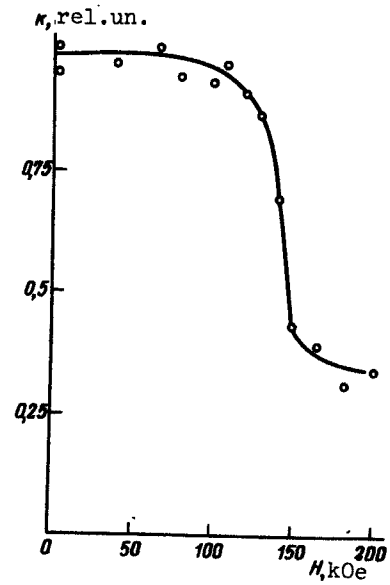

Fig. 2

Fig. 1. Spectrograms and spectral distributions of optical density of a siderite crystal without a magnetic field and in a field H = 200 kOe at T = 20.4°K.

Fig. 2. Integral absorption coefficient vs. magnetic field intensity.

4.2°K. The spectra were photographed on RF-3 film and then reduced by photographic photometry.

The experimental results are illustrated in Figs. 1 and 2. Figure 1 shows the spectrograms and the curves of spectral distribution of the optical density of single-crystal siderite at 20.4°K without a magnetic field and in a field H || C_3 of intensity H = 200 kOe. One can clearly see an appreciable attenuation of the intensity of the absorption bands in the spectral region 25 200 - 25 400 cm^{-1}. Figure 2 shows the dependence of the integral absorption coefficient on the intensity of the external magnetic field. The character of this dependence, and a comparison withe the magnetization curve m(H) [6] allow us to state that the integral absorption coefficient decreases with increasing summary magnetic moment m of the crystal.

Light absorption in antiferromagnetic siderite was investigated earlier by McClure et al. [8] These authors did not succeed in identifying uniquely the observed bands, since the frequency region under consideration can contain components of Bethe splitting of the different terms ^5D, ^3H, ... of the iron ion Fe^{2+}. However, independently of the concrete identification, the bands 25 261, 25 303 and 25 432 cm^{-1} were attributed by them to "double" exciton-magnon transitions. This is evidenced by the electric-dipole character of the polarization of the absorption bands and the peculiarity of the dependence of their frequencies on the external magnetic field [8].

If we assume the exciton-magnon identification of the considered absorption bands in the antiferromagnetic siderite, then we can explain, at least qualitatively, the observed decrease of the band intensity upon magnetization of the crystal. So long as the antiferromagnetic crystal has a collinear structure, the summary change of the spin projection on the magnetic-ordering axis is equal to zero in the case of an exciton-magnon optical transition, when the exciton is produced in one sublattice and the magnon in the opposite one. This is true of the spin changes by -1 in the purely exciton transition, as is the case for the majority of the optical transitions in the 3d shell of transition-metal ions. When the collinearity of the magnetic structure is violated, the exciton-magnon light-absorption mechanism should become weaker. This circumstance is easiest to understand by turning to the limiting case. Let the external-field intensity be sufficient to align the magnetic moments of both sublattices parallel to each other. In this case the mechanism of the exciton-magnon light-absorption can not be realized, since the change of the spin projection upon creation of the exciton can now no longer be compensated by the change of the spin projection upon excitation of the spin wave.

In a weaker field, the intensity of the exciton-magnon absorption should decrease gradually with increasing intensity of the external magnetic field, as is indeed observed in experiment.

In conclusion we note that the exciton-magnon mechanism is the main mechanism of absorption in antiferromagnetic crystals. Thus, the observed effect of attenuation of the absorption of light in a strong magnetic field has a general character for antiferromagnets. A similar behavior should obviously be observed also for all other "double" transitions (two-magnon or two-exciton) in an antiferromagnet.

A weakening of light absorption by means of a magnetic field was observed by us also in antiferromagnetic CoF_2.

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[1] R. L. Greene, D. D. Sell, W.H. Yen, A.L. Shawlow, R.M. White, Phys. Rev. Lett. 15 656 (1965).
[2] D.D. Sell, R.L. Greene, R.M. White, Phys. Rev. 158, 489 (1967).
[3] R. S. Meltzer, M. Lowe, and D.S. McClure, Phys. Rev. 180, 561 (1969).
[4] V. V. Eremenko andA.I. Belyaeva, Usp. Fiz. Nauk 98,27 (1969) [Sov. Phys.-Usp. 12, 320 (1969)].
[5] D.L. Dexter, Phys. Rev. 126, 1962 (1962).
[6] V.I. Ozhogin, Zh. Eksp. Teor. Fiz. 45, 1687 (1963) [Sov. Phys.-JETP 18, 1156 (1964)].
[7] V. V. Eremenko and Yu.A. Popkov, Ukr. Fiz. zh. 8, 88 (1963).
[8] D.S. McClure, R. Meltzer, S.A. Reed, Ph. Russel, and J. W. Stout, Optical Properties of Ions in Crystals, Johns Hopkins University (Proc. Conf. in Baltimore), 1967, p. 257.

EXCITATION OF ION-ACOUSTIC WAVES BY LANGMUIR WAVES AND STATIONARY REGIMES IN A BEAM-PLASMA SYSTEM

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We investigated the threshold excitation of ion-acoustic waves by Langmuir waves and the behavior of the amplitudes of these waves beyond threshold in a beam-plasma system.

As is well known, the electronic and ionic plasma oscillations interact effectively with each other and this interaction gives rise to a number of nonlinear phenomena, viz., energy exchange between waves [1, 2], control of the oscillation spectra with the aid of external modulation [3], threshold excitation of ion-acoustic waves by Langmuir waves [4], and others. The gist of the last of these phenomena is that in the presence of an intense Langmuir wave (frequency ω_0, initial amplitude a_0) an initially small amplitude of an ion-acoustic wave of frequency Ω and the amplitudes $a_{\pm n}$ of the Langmuir waves with combined frequencies $\omega_0 \pm n\Omega$ increase exponentially in time if a_0 exceeds a certain critical (threshold) value that depends on the values of the wave interaction and damping coefficients. The exponential growth of the initially small amplitudes takes place only during the initial state. In the course of time, a stationary regime is establish and constitutes an assembly of oscillations having the aforementioned frequencies and constant amplitudes. Naturally, a regime with nonzero stationary amplitudes is realized only if there exist forces (such as an external field or a beam) that compensate for the energy dissipation in the system of interacting waves.

The interaction between the electronic and ionic oscillations should become manifest effectively and play an important role in the beam-plasma system under conditions when the beam excites intense electronic oscillations. The excitation of ionic excitations by electronic ones leads to an effective heating of not only the electrons but also the ions, and exerts a noticeable influence on the character of the process of excitation of the oscillations by the beam.

The purpose of the work was twofold: 1) to investigate the interaction of Langmuir and ion-acoustic oscillations in a beam-plasma system, and 2) to study the near-threshold stationary regimes in the system of interacting waves. This makes it possible to study the dynamics of wave interaction in the beam-plasma system and to ascertain the possibility of two-stream heating of a plasma.