

²) A similar type of equation for a phonon system is considered in Ref. 3.

³) The terms with the second derivatives drop out in going from Eq. (26) to the equations, (25), for the correlators, since there is not a single pair of indices among the indices p, q, r, s that differ only in sign.

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The permittivity tensor and increase in the transmittance of the spinel ferrites upon their conversion into single-sublattice structures

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Investigations of the optical properties of substituted spinel ferrites have indicated a significant increase in the transmittance of these compounds upon their conversion into a structure with a single Fe^{3+} -ion magnetic sublattice. The off-diagonal components of the permittivity tensor are determined from the optical and magneto-optical spectra, and some of the transitions that occur in the hexagonal ferrites are identified. It is suggested that the two-ion optical transitions with charge transfer between neighboring magnetically active ions play the decisive role, and a selection rule for such transitions is proposed.

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INTRODUCTION

In ferromagnets with two magnetic iron sublattices intense allowed transitions in the visible and near-ultraviolet regions of the spectrum are observed only in the case when they are due to pair excitation of the Fe^{3+} ions.¹⁻⁷ This follows from the fact that, in the indicated spectral region, the electric dipole transitions of the Fe^{3+} ion in the internal crystal field are spin and parity forbidden, as well as from the quadratic dependence of the intensity of these transitions on the iron-ion concentration.¹ The first intense single-ion optical transitions of the type of a charge transfer from the $2p$ orbitals of oxygen to the $3d$ orbitals of iron⁸ lie, according to Ref. 4, in the shorter-wavelength region of the spectrum.

The two-exciton mechanism of simultaneous excitation of two Fe^{3+} ions located on different sublattices, and coupled by a strong exchange interaction, has been considered in investigations of the garnet ferrites⁵ and substituted spinel ferrites.^{6,7} In particular, in Ref. 6, where chromium-substituted spinel ferrites are considered, the conclusion that the two-ion optical-transition mechanism plays the decisive role is based on the fact that the magnitude of the magneto-optical effect has been found in investigations of the magneto-optical spectra of the spinel ferrites of cobalt and nickel to decrease sharply when the iron ions on one of the sublattices are replaced by Cr^{3+} ions. Another possible mechanism for the pair excitation of the iron ions is the transfer of charge between Fe^{3+} ions on different

sublattices with the formation of Fe^{4+} - and Fe^{2+} -ion pairs.^{2,4} Analysis of the splitting of the energy levels of the Fe^{3+} ion in tetrahedral and octahedral crystal fields and the computation of the energies of the possible transitions both in the case of two-exciton excitation and in the case of charge transfer between sublattices lead to good agreement with the experimental data.^{4,6}

Thus, if we consider the pair mechanism of transition excitation in iron ions located on different sublattices to have been reliably established, then we should expect to observe not only the above-indicated decrease in the magnitude of the magneto-optical effect, but also a decrease in the absorption coefficient of such ferromagnets when the iron ions on the tetrahedral or octahedral sublattices are replaced. With the object of verifying this assertion, we carried out optical investigations of the aluminate ferrites and chromite ferrites of cobalt and nickel, in which we replaced in turn the iron ions on the octahedral or tetrahedral sublattice respectively by Al^{3+} and Cr^{3+} ions. On the basis of the optical and the earlier-performed magneto-optical measurements, we computed the permittivity-tensor components, which were used for a more reliable identification of the optical transitions and the determination of the nature of their splitting.

By qualitatively comparing the magneto-optical spectra of the spinel ferrites with those of the hexagonal ferrites with the M , W , Z , Y , and X structures, we have identified some of the optical transitions in the

hexaferrites. The basis for this is the fact that all these structures consist, in the main, of spinel blocks separated by blocks with hexagonal packing. The various combinations in the sequence of such blocks lead to a number of possible magnetic structures for the hexaferrites and to a wide range of possible exchange couplings both within, and between, individual blocks, and this determines the unique magnetic properties of the indicated compounds. It is of interest to track down any manifestation of a structural difference, or, conversely, any manifestation of a similarity between the hexaferrites and the spinels in a comparison of their magneto-optical spectra.

THE EXPERIMENTAL PART

To determine the optical constants—the refractive index n and the absorption coefficient k —we measured, using a single-reflection reflectometer with a mobile detector having a GS-5 goniometer as its basic unit, the reflection-coefficient ratio R_p/R_s for light linearly polarized in a direction parallel (p component), and perpendicular (s component), to the incidence plane. The measurements were performed in the spectral range from 1.6 to 5 eV with the use of a DMR-4 monochromator and an FÉU-39A photomultiplier. As the polarizer, we used a Glan-Thompson prism (ensuring a 99.98% degree of polarization). The error in the incidence-angle setting did not exceed 5'. The divergence of the light beam (half the aperture angle) was not more than 30'. The spectral width of the slit did not exceed 0.05 eV.

The optical constants were calculated from the measured R_p/R_s values for two angles of incidence of the light on the sample by the methods described in Refs. 9 and 10. Following Ref. 9, we computed n and k by means of geometrical constructions, which allowed us to determine the optical constants fairly quickly and accurately without recourse to the use of a computer, which is important for the n - and k -measurement-region determination, aimed at choosing the optimum angles of incidence. Then, using a previously-de-

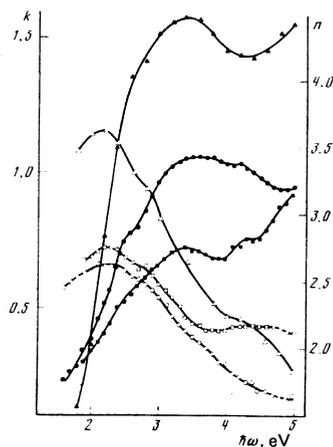


FIG. 2. Spectral dependence of the refractive index n and the absorption coefficient k for the spinels NiFe_2O_4 (n —○, k —●), NiCrFeO_4 (n —□, k —■), and CdCr_2S_4 (n —△, k —▲).

scribed procedure,¹⁰ we computed n and k by the method of successive approximations with the aid of a computer.

The chromite ferrite and aluminate ferrite samples used were prepared by the conventional ceramic technology. An x-ray phase analysis showed that all of them were single-phase crystals with lattice constants that corresponded with the data available in the literature.¹¹ Prior to the measurements, the samples were subjected to mechanical polishing, followed by etching in orthophosphoric acid at a temperature of about 200 °C. The samples were etched until the reflectivity value and the magnitude of the equatorial Kerr effect ceased to vary and the polished surface was still specular. The etching time for the various samples ranged from 10 to 120 sec.

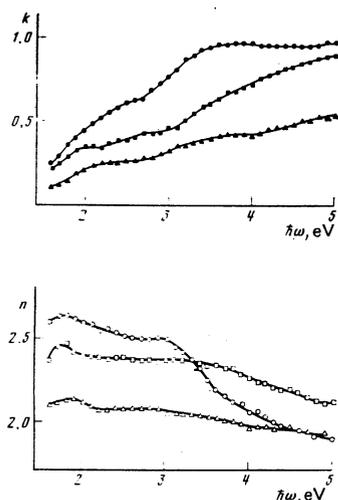


FIG. 1. Spectral dependence of the refractive index n and the absorption coefficient k for the spinels CoFe_2O_4 (n —○, k —●), CoCrFeO_4 (n —□, k —■), and CoAlFeO_4 (n —△, k —▲).

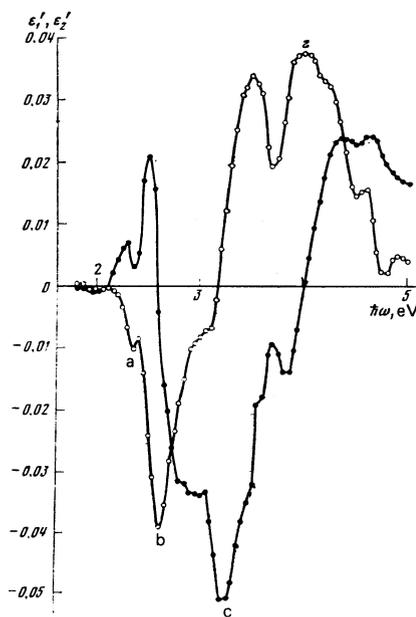


FIG. 3. Spectral dependences of the real, ϵ_1' (○), and imaginary, ϵ_2' (●), parts of the off-diagonal component of the permittivity tensor of a $\text{Li}_{0.5}\text{Fe}_{2.5}\text{O}_4$ single crystal. The peaks a), b), c), and d) correspond to the energies 2.3, 2.6, 3.27, and 4 eV.

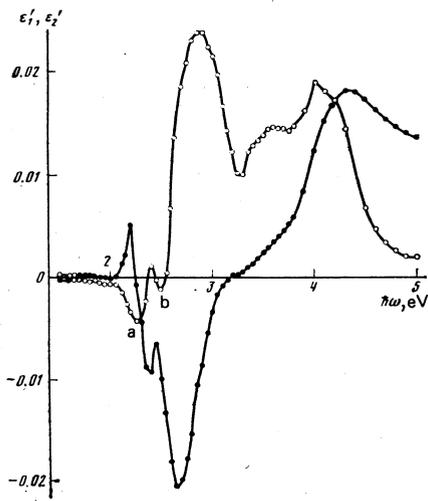


FIG. 4. Spectral dependence of the off-diagonal permittivity-tensor component $\epsilon' = \epsilon_1' - i\epsilon_2'$ for a NiFe_2O_4 polycrystal (ϵ_1' —○, ϵ_2' —●). The peaks a) and b) correspond to the energies 2.24 and 2.5 eV.

The optical constants n and k for the compounds CoFe_2O_4 , CoCrFeO_4 , CoAlFeO_4 , NiFe_2O_4 , and NiCrFeO_4 are shown in Figs. 1 and 2 as functions of the light-radiation energy $\hbar\omega$. As the Fe^{3+} ions in all the three systems $\text{CoCr}_x\text{Fe}_{2-x}\text{O}_4$, $\text{CoAl}_x\text{Fe}_{2-x}\text{O}_4$, and $\text{NiCr}_x\text{Fe}_{2-x}\text{O}_4$ are replaced, the quantity k decreases. Figure 2 also shows the optical constants of the normal chalcospinel CdCr_2S_4 , in which the chromium ions are located at the octahedral sites only.¹²

From the experimentally obtained optical constants and the magnitudes, δ , of the equatorial Kerr effect⁶ for two angles of incidence of the light, $\varphi_1 = 60^\circ$, $\varphi_2 = 70^\circ$, we computed the off-diagonal permittivity-tensor $\epsilon' = \epsilon_1' - i\epsilon_2'$ with the aid of the formulas given in Ref. 13.

In Figs. 3, 4, and 5 we show the real, ϵ_1' , the imaginary, ϵ_2' , parts of the off-diagonal component of the permittivity tensor for the spinel ferrites $\text{Li}_{0.5}\text{Fe}_{2.5}\text{O}_4$,

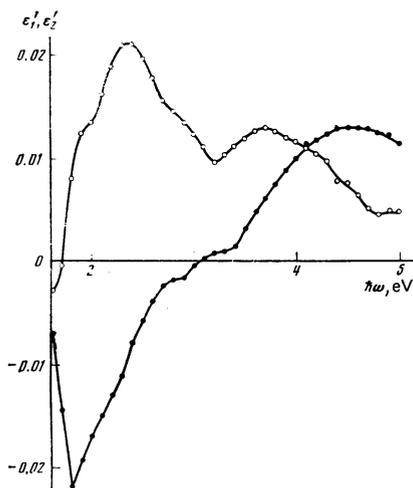


FIG. 5. Spectral dependence of the off-diagonal permittivity-tensor component $\epsilon' = \epsilon_1' - i\epsilon_2'$ for a polycrystalline sample of the spinel CoFe_2O_4 (ϵ_1' —○, ϵ_2' —●).

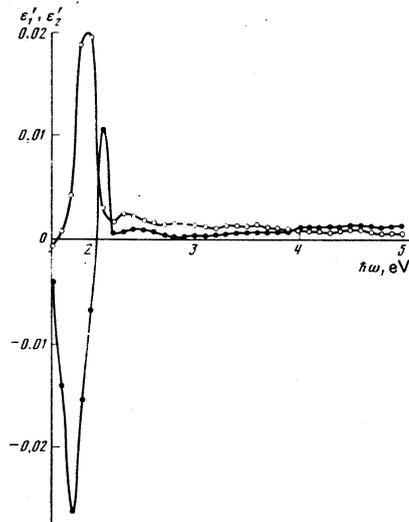


FIG. 6. Spectral dependence of the real, ϵ_1' (○), and imaginary, ϵ_2' (●), parts of the off-diagonal component of the permittivity tensor for a polycrystalline sample of the spinel CoCrFeO_4 .

NiFe_2O_4 , and CoFe_2O_4 . The quite different behavior of ϵ_1' and ϵ_2' for these ferrites at energies of 2–4 eV is, in all probability, due to the influence of the divalent, magnetically active Ni^{2+} and Co^{2+} ions.

The real and imaginary parts of the off-diagonal component of the permittivity tensor of cobalt chromite ferrite, CoCrFeO_4 , are shown in Fig. 6.

With the object of verifying the accuracy of the determination of the off-diagonal components of the permittivity tensor from the obtained data, we computed the polar Kerr effect for the ferrites NiFe_2O_4 and

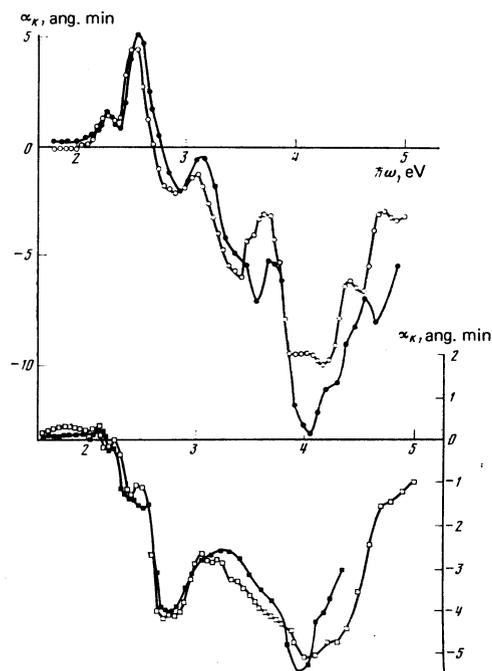


FIG. 7. Spectral dependence of the polar Kerr effect α_K for a $\text{Li}_{0.5}\text{Fe}_{2.5}\text{O}_4$ single crystal (experimental curve—●, calculated—○) and a NiFe_2O_4 polycrystal (experimental curve—■, calculated—□).

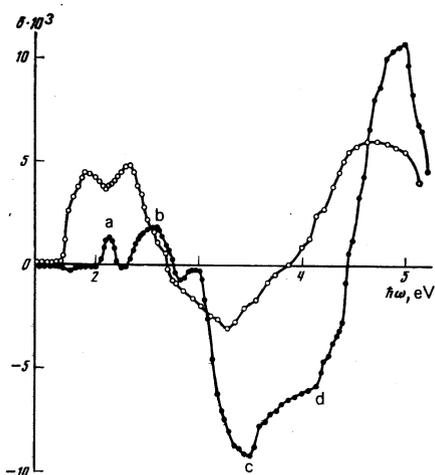


FIG. 8. The equatorial Kerr effect for single crystals of the hexaferrites $\text{SrFe}_{12}\text{O}_{19}$ (●) and $\text{Ba}_3\text{Co}_2\text{Fe}_{24}\text{O}_{41}$ (○) for angle of incidence of the light $\varphi = 65^\circ$. The peaks a), b), c), and d) correspond to the energies 2.1, 2.5, 3.45, and 4.0 eV.

$\text{Li}_{0.5}\text{Fe}_{2.5}\text{O}_4$ and then experimentally determined the effect in these same samples. The polar Kerr effect was measured at an angle of incidence of the light equal to $\varphi = 4^\circ$; the sample was magnetized by a magnetic field perpendicular to the surface. The measurements were performed on the p and s components of light with the analyzer oriented at an angle of 45° to the polarizer. The resulting value of α_K for normal incidence of the light was defined as the arithmetic mean of the two indicated measurements on the p and s components. The amplitude of the variable field of the electro-magnet in the gap of which the sample was placed was 6 kOe. As can be seen from Fig. 7, there is satisfactory agreement between the theory and experiment for the case of $\text{Li}_{0.5}\text{Fe}_{2.5}\text{O}_4$ and NiFe_2O_4 . On the magneto-optical spectra, $\delta(\omega)$, of the hexagonal ferrites $\text{SrFe}_{12}\text{O}_{19}$ (M structure) and $\text{Ba}_3\text{Co}_2\text{Fe}_{24}\text{O}_{41}$ (Z structure), measured by the method described in Ref. 6, and shown in Fig. 8, we can distinguish positive peaks at the energies 2.1 and 2.5 eV, a wide negative peak in the 3.5-eV region, and a positive peak at 4.9 eV for the M structure. On the $\delta(\omega)$ spectrum for the Z structure we can clearly see two positive peaks at 1.9 and 2.3 eV, a negative peak at 3.3 eV, and a positive peak at 4.7 eV.

DISCUSSION OF THE RESULTS

As can be seen from Figs. 1 and 2, when the Fe^{3+} ions in the spinel ferrites CoFe_2O_4 and NiFe_2O_4 are replaced by Cr^{3+} ions and, especially, by Al^{3+} ions, the absorption coefficient in the visible and near-ultraviolet regions of the spectrum decreases. Such a behavior of the absorption coefficient cannot be explained by the normal single-ion transitions in magnetically active ions. If only such transitions occurred, then the absorption coefficient for the substituted spinel CoCrFeO_4 would be approximately equal to half the sum of the absorption coefficients for the spinels CoFe_2O_4 and CdCr_2S_4 . But, as can be seen from Figs. 1 and 2, the absorption coefficient of CoCrFeO_4 has a considerably smaller value, and this fact again confirms the two-ion mechanism of excitation of Fe^{3+} ions located on different sublattices. An even more drastic reduction in

the absorption coefficient is observed for the compound CoAlFeO_4 (Fig. 1). The absorption coefficient for this sample becomes comparable to, and in the region $\hbar\omega > 3$ eV even smaller than, the absorption coefficient of yttrium iron garnet.³ Thus, we have, in going over to the state with a single iron sublattice, obtained an increase in the transmittance in the visible and near-ultraviolet regions of the spectrum. This fact may acquire practical significance in the development of new transparent ferromagnetic crystals.

The simplest classification of the optical transitions in the magneto-optical spectra $\varepsilon'_1(\omega)$ and $\varepsilon'_2(\omega)$ consists in the delimitation of the paramagnetic and diamagnetic transitions.^{3,8} The paramagnetic transitions are due to the difference in the oscillator strengths f_+ and f_- for clockwise and counterclockwise polarized light; the diamagnetic transitions, to the difference between the natural frequencies ω_0^+ and ω_0^- for these components. In the case of the paramagnetic mechanism, the transition frequencies should correspond to the peaks on the $\varepsilon'_2(\omega)$ curves and the zero points on the $\varepsilon'_1(\omega)$ curves. In the case of the diamagnetic mechanism there should be a peak on the $\varepsilon'_1(\omega)$ curve and, correspondingly, a zero point on the $\varepsilon'_2(\omega)$ curve. The diamagnetic character of the behavior of the off-diagonal components of the tensor corresponds to transitions from the ground singlet level to an excited level split by the spin-orbit interaction. The paramagnetic behavior of the off-diagonal components of the permittivity tensor is customarily ascribed to transitions to an unsplit excited level.

A qualitative investigation of the spectrum of the off-diagonal component of the permittivity tensor for the lithium, nickel, and cobalt spinels $(\text{Fe})[\text{Li}_{0.5}\text{Fe}_{1.5}]_2\text{O}_4$, $(\text{Fe})[\text{NiFe}]_2\text{O}_4$, and $(\text{Fe})[\text{CoFe}]_2\text{O}_4$ ¹ immediately reveals a sharp difference in the behavior of the real and imaginary parts of the off-diagonal components. The spectra $\varepsilon'_1(\omega)$ and $\varepsilon'_2(\omega)$ for NiFe_2O_4 (Fig. 4) in the 3-eV region turn out to be very different from the spectra of $\text{Li}_{0.5}\text{Fe}_{2.5}\text{O}_4$ (Fig. 3), which is naturally explained by the presence in the composition of this spinel of the divalent, magnetically active Ni^{2+} ions. It is pointed out in Ref. 6 that the spin-allowed transition ${}^3A_{2g}({}^3F) \rightarrow {}^3T_{1g}({}^3P)$ occurs in the absorption spectrum of the Ni^{2+} ion in an octahedral coordination at an energy of 2.9–3.0 eV, and that, what is more, this transition in the magneto-optical spectrum should exhibit the diamagnetic character as a result of the spin-orbit splitting of the excited level of the Ni^{2+} ion. Thus, the frequency of this transition, determined from the peak on the $\varepsilon'_1(\omega)$ curve, is located at $\hbar\omega = 2.95$ eV. A rapid variation of the spectra $\varepsilon'_1(\omega)$ and $\varepsilon'_2(\omega)$ is observed also in the case of the cobalt spinel (Fig. 5). We can distinguish on the $\varepsilon'_1(\omega)$ spectrum in the 2–3-eV region one broad peak located at the energy 2.4 eV. In the investigation⁶ of the magneto-optical spectrum of CoFe_2O_4 , the singularity in the 2.4-eV region was identified with the transition ${}^4T_{1g}({}^4F) \rightarrow {}^4A_{2g}$, ${}^4T_{1g}({}^4P)$ in the Co^{2+} ions in octahedral coordination. A similar interpretation does not contradict the diamagnetic shape of the $\varepsilon'_1(\omega)$ curve in Fig. 5.

The substitution of the iron ions in the systems

$\text{CoCr}_x\text{Fe}_{2-x}\text{O}_4$ and $\text{CoAl}_x\text{Fe}_{2-x}\text{O}_4$ leads to a sharp decrease in both the real and imaginary parts of the off-diagonal component of the tensor in the region above 2.5 eV and to the appearance of a strong diamagnetic transition in the 1.9-eV region. As the iron ions are replaced by Cr^{3+} or Al^{3+} ions, the cation distribution changes in such a way that at $x=1$ for $\text{CoCr}_x\text{Fe}_{2-x}\text{O}_4$ and $x=2$ for $\text{CoAl}_x\text{Fe}_{2-x}\text{O}_4$ these compounds become normal spinels, $(\text{Co})[\text{FeCr}]\text{O}_4$ and $(\text{Co})[\text{Fe}_{0.8}\text{Al}_{1.2}]\text{O}_4$, with one iron sublattice,¹³ which causes the decrease of ϵ'_1 and ϵ'_2 in the region above 2.5 eV. Since during the transition to the normal spinel structure the Co^{2+} ions are displaced from the octahedral to the tetrahedral sites, the decrease of the peak at 2.3 eV and the growth of the peak at 1.9 eV can be related to the cation redistribution. The transition at 1.9 eV should be referred to the ${}^4A_2({}^4F) \rightarrow {}^4T_1({}^4P)$ transition in Co^{2+} ions, which is allowed in the electric-dipole approximation.¹⁴ The spectral dependences $\epsilon'_1(\omega)$ and $\epsilon'_2(\omega)$ for the systems $\text{CoAl}_x\text{Fe}_{2-x}\text{O}_4$ and $\text{CoCr}_x\text{Fe}_{2-x}\text{O}_4$ have a similar character. It follows from this that the introducible $3d$ ions Cr^{3+} do not participate in the determination of the magneto-optical properties of the chromium-substituted cobalt spinel.

The cation distribution in the system $\text{NiCr}_x\text{Fe}_{2-x}\text{O}_4$ does not change during the substitution process,¹³ but the octahedral iron sublattice is completely substituted at $x=1$: $(\text{Fe})[\text{NiCr}]\text{O}_4$. This is the cause of the sharp decrease in both parts of the off-diagonal component of the tensor in the entire investigated region. However, the case of the disappearance of the spin-allowed transition in Ni^{2+} ions in the 2.9-eV region remains obscure.

The presence of the Co^{2+} ion in the composition of $\text{Ba}_3\text{Co}_2\text{Fe}_{24}\text{O}_{41}$ leads to the appearance of two peaks in the magneto-optical spectrum of the equatorial Kerr effect at 1.9 and 2.3 eV, which, as in the case of the spinels CoFe_2O_4 and CoCrFeO_4 , we ascribe respectively to the transitions ${}^4A_2({}^4F) \rightarrow {}^4T_1({}^4P)$ in tetrahedral Co^{2+} ions and ${}^4T_2({}^4F) \rightarrow {}^4A_2g$, ${}^4T_1g({}^4P)$ in octahedral Co^{2+} ions. The simultaneous appearance of the two peaks is connected with the fact that, in contrast to the spinels CoFe_2O_4 and CoCrFeO_4 , in which the Co^{2+} ions are located either only on the octahedral, or only on the tetrahedral, sublattices, in a Z -structure hexaferrite these ions occupy both types of sites at the same time.

If we use the Fe^{3+} -ion transition energies obtained in Ref. 6 for the spinel ferrites, then the transitions a), b), and d) in $\text{Li}_{0.5}\text{Fe}_{2.5}\text{O}_4$ (Fig. 3) can be classified with transitions of the diamagnetic type, whereas the transition c) exhibits the paramagnetic character. The a) and b) peaks in the $\epsilon'_1(\omega)$ spectrum for NiFe_2O_4 (Fig. 4) are similar to the a) and b) transitions in $\text{Li}_{0.5}\text{Fe}_{2.5}\text{O}_4$.

The compound $\text{SrFe}_{12}\text{O}_{19}$ contains only one kind of magnetic ions (Fe^{3+}), and we can also distinguish the peaks a), b), c), and d) (Fig. 8) in the magneto-optical spectrum of this single crystal. Notice that the diamagnetic character of the a), b), and d) transitions and the paramagnetic character of the c) transition should be preserved, since the presence in the M structure of a spinel block with two magnetic iron sublattices causes the same Fe^{3+} -ion excitation mechanisms that operate

in the case of the spinel to operate in the case of $\text{SrFe}_{12}\text{O}_{19}$ as well.

In the Introduction we discuss the two most probable mechanisms for the pair excitation of optical transitions in ferrimagnets: two-exciton excitations and charge transfer between magnetically active ions on different sublattices. The two mechanisms are used by different authors, and lead to reasonable values for the transition energies. So far two-exciton transitions have been observed in the weak ferromagnets FeBO_3 (Ref. 15) and Fe_3BO_6 (Ref. 16). However, the available experimental data, including the data obtained in the present investigation, are, on the whole, more easily explained on the basis of the mechanism of charge transfer between magnetically active ions. In this, a significant role should, in our opinion, be played by the following selection rule for the charge transfer: the greater oscillator strength should be possessed by those transitions in which the electron is transferred to the neighboring excited ion without a spin flip, and without violating the Hund rules for the excited ion in the process. From this standpoint, the major role in yttrium iron garnet and in the lithium and magnesium spinels should be played by the intersublattice charge-transfer processes

$$[\text{Fe}^{3+}] + (\text{Fe}^{3+}) + \hbar\omega \rightarrow [\text{Fe}^{4+}] + (\text{Fe}^{2+})$$

or

$$(\text{Fe}^{3+}) + [\text{Fe}^{3+}] + \hbar\omega \rightarrow (\text{Fe}^{4+}) + [\text{Fe}^{2+}].$$

On the other hand, in the case when the octahedral Fe^{3+} ions in $\text{NiCr}_x\text{Fe}_{2-x}\text{O}_4$ are replaced by chromium ions, the intensity of the transitions $(\text{Fe}^{3+}) \rightarrow [\text{Cr}^{3+}]$ should, for the reason indicated above, decrease considerably. The stated selection rule automatically excludes charge transfer between iron ions located on the same garnet or spinel sublattice. At the same time, electron transitions between the $[\text{Cr}^{3+}]$ ions in the chalcospinel CdCr_2S_4 can occur (see Fig. 2), since the d shell of the Cr^{3+} ion is less than half-filled. This may explain the relatively high value of the absorption coefficient of CdCr_2S_4 in the visible and ultraviolet regions of the spectrum.

The role of the mechanism in question in optical transitions can be directly verified by experimentally investigating the dependence of the intensity of these transitions on the angle between the directions of the magnetic moments of neighboring ions as this angle is varied under the action of a strong external magnetic field, or on the sample temperature.

The authors thank \hat{E} . L. Nagaev for a useful discussion of the problem of charge transfer in magnetically ordered crystals.

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Dynamic electroacoustic echo and the recording in piezoelectric powders

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The dependence of the amplitudes and phases of two- and three-pulse electroacoustic echo on the amplitudes and phases of the applied pulses is investigated. Two methods of erasing the electroacoustic recording are proposed and used to discern the three-pulse dynamic echo in the recording. Some features of the recording and erasing processes are revealed which confirm the plastic deformation mechanism.

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INTRODUCTION

The electroacoustic echo (EAE), discovered in 1970,^{1,2} manifests itself in the formation of a series of signals at the instants of time $t = (n+1)\tau$ and $t = T + n\tau$ ($n = 1, 2, 3, \dots$) upon excitation of a piezoelectric specimen by three electromagnetic radio pulses at the instants of time $t = 0, \tau, T$.³⁻⁵ The signals at $t = (n+1)\tau$ are called the two-pulse echo, and those at $t = T + n\tau$ are called the three-pulse echo. The EAE is one of the most interesting and intensely studied echo phenomena at the present time. It has been observed in a large class of different physical systems. The essential condition for the formation of the echo is the presence of nonlinearity. This nonlinearity can be an internal property of the system or can manifest itself in the interaction of the system with external fields.^{6,7} Some properties of the echo signals are common to both types of nonlinearities, while others are characteristic only of one or the other. Thus, from the character of the dependence of the echo amplitude on the interval between the exciting pulses, we can distinguish the dominant role of one of the mentioned types of nonlinearity.^{6,7} In the case of EAE in piezoelectric powders, the study of the dependence of the echo amplitude on the interval between the pulses has led to the assumption that the dominant mechanism in echo formation is the mechanism based on the nonlinearity of the system

of piezoelectric oscillators itself.³⁻⁵

Of special interest for investigation is the long memory of the three-pulse echo, which was first discovered in single crystals at low temperatures,⁹ and later in piezoelectric powders at room temperature.^{10,11} It was noted that, upon increase in the interval of time between the first and third pulses T , the amplitude of the three-pulse echo of the signal falls off rapidly with a characteristic time $T_1 \sim T_2$, reaches some definite value, and is then independent of the time of application of the third pulse. Such a dependence of the amplitude of the three-pulse echo on T is explained by the fact that the three-pulse echo is the sum of two signals: one falls exponentially to zero upon increase of T (the dynamic three-pulse echo), the other does not depend on T (the recording).¹⁰ Thus, it is possible to record the signal for a rather long period (days, weeks). In this case, the first two exciting pulses can be called the recording pulses and the third, the reading pulse.

This paper is devoted to the study of the dependence of the amplitude and phase of the EAE on the amplitudes and phases of the exciting pulses. On the basis of the results, two methods of erasing the recordings are proposed, an experimental proof is given of the compound character of the three-pulse echo, and a method is proposed for separation of the dynamic echo and the record-