Self-oscillation regime of domain-wall generation in a ferrimagnet

V. K. Vlasko-Vlasov and L. S. Uspenskaya

Institute of Solid State Physics, USSR Academy of Sciences
(Submitted 24 March 1986)
Zh. Eksp. Teor. Fiz. **91**, 1483–1495 (October 1986)

Periodic generation and directed motion of domains in single-crystal ferrimagnet slabs under the influence of a high-amplitude ac field, at frequencies much lower than the FMR frequency, was observed and investigated. The features of the stochastization of the dynamic behavior of the domain structure with increasing field amplitude were studied. The periodic domain generation is attributed to excitation of a self-oscillating process in the nonlinear magnetic subsystem in the presence of intense pumping by an external field.

INTRODUCTION

Interest in the dynamic behavior of magnetics has noticeably increased of late. Besides the importance of the basic problem of magnetization dynamics and its practical significance, this is due also to the generation rise of activity in the investigation of the dynamics of nonlinear systems, which include the overwhelming majority of physical, chemical, and other objects. The lack of sophisticated methods of solving nonlinear equations has long hindered progress in the description of the dynamics of these systems, restricting it to the linear approximation, which can be used to analyze their state only near an equilibrium position, and to small external perturbations. Recent progress of mathematical physics (in particular, advances in soliton theory), and also extensive use of computers to solve nonlinear problems, have revealed a number of common laws in the complicated behavior of nonlinear systems. These laws are no less common to various physical phenomena than the results of the harmonic approximation, but take many more forms.

Many nonlinear systems, in particular, have natural modes in the form of solitary waves (or trains of such waves), and also of periodic nonsinusoidal waves of large amplitude.[1] Appreciable external forces can cause self-oscillations (in lumped systems) or autowaves (in distributed systems)[2]; this is treated directly in certain cases as parametric generation of solitons.[2] Other structures stable in space and time can also be formed.[1,4] With increase of the external action, dynamic stochasticity sets in, etc.[1]

These conclusions are valid to a considerable degree for the nonlinear dynamics of magnetics. Thus, the Landau-Lifshitz equation, which describes the dynamics, has (in the absence of damping) exact soliton solutions.[5] Self-oscillations manifested by periodic changes of microwave power have been observed in magnetics[6–8] and become randomized[7,8] when the pump amplitude is increased. Motion of one-dimensional domain walls, faster than the Walker velocity, are also subject to self-oscillations: the azimuthal angle of the magnetization in the wall varies periodically and causes vibrational instability of its displacement in a dc field.[9] The same situation is realized in two-dimensional walls, in which generation of Bloch lines sets in[10] when the Slonczewski velocity is exceeded. It was recently established that continuous illumination of a magnet can lead to a spontaneous-wave process characterized by periodic generation of domains.[11,12] Generation of domains (bubble and annular) can be caused also at FMR frequencies by an alternating field of high amplitude.[13,14] It corresponds to jumps of the magnetization into a new dynamic equilibrium position as a result of microwave pumping.[15] Investigations of the behavior of the domain structure of single-crystal plates of ferrimagnetic YIG in alternating magnetic fields[16,17] have shown that even much below the FMR frequencies one can observe effects connected with excitation of nonlinear oscillations. Onset of continuous generation of domains[16] and of Bloch lines in the domain boundaries[17] was observed at sufficiently large field amplitudes. There has been yet no rigorous explanation of these phenomena.

We report here an experimental study of continuous creation and undirectional motion of domains. It is established that the process sets in at critical field amplitudes, is strictly periodic in definite frequency (f) and amplitude (h_0) intervals, and becomes randomized with increase of h_0. These results indicate that an intense alternating field produces in the magnetic a self-oscillation regime (or possibly an autowave regime, as proposed for generation and displacement of Bloch lines[11]).

EXPERIMENT

We investigated the dynamic behavior of the domain structure in thin ($\sim 50\,\mu$m) {110} and {112} plates of yttrium iron garnet containing 180° neighborhood domains and magnetized in the planes of the plates. The transverse dimensions of the samples, which were irregular in shape, amounted to several millimeters. The domain structure was made visible and analyzed in a polarization microscope based on the Faraday and Cotton-Mouton effects. The magnetization changes in different sections of the crystal were determined by measuring the intensities of the images of these sections with a photomultiplier. A slit diaphragm was placed in front of the photomultiplier photocathode and framed in the image field a strip parallel to the domain wall. This strip was the image of a sample region (10–20 μm wide and 100–200 μm long, depending on the microscope magnification and on the slit aperture) several times narrower

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than the domain width. Passage of domains magnetized in opposite directions and having different image intensities in polarized light through the region bordered by the diaphragm was accompanied by photomultiplier-signal changes recorded by a storage oscilloscope. In addition, the magneto-optic response measured by the photomultiplier was fed to a multichannel analyzer, and a computer was used to smooth it, to calculate the front duration (τ) and the period T, and also to average τ and T over several periods. The obtained τ and T were used to determine the velocities and the rates of formation of the domain walls (i.e., the number of domains undergoing photometry per unit time). The illumination used to measure the magneto-optical signal was a focused helium-neon laser beam. To determine the direction of the domain-wall displacement, this beam was split in two with a glass wedge, so that two spots of unequal intensity, separated by a dark band, were focused side by side in the section bordered by the diaphragm. Successive passage of a domain wall through both spots is accompanied by a stepwise increase (or conversely, decrease) of the magneto-optic signal level. The height of the signal front ahead of the step identifies the spot through which the wall passes first (i.e., the wall-displacement direction). In addition, the dynamic state of the domain structure was photographed by pulses ($\tau_p \sim 20$ ns) from an LTI-PCh neodymium laser.

The ac field was produced by solenoids double the size of the samples and fed from an alternator. The field amplitude was determined from the current in the coils, which were calibrated with direct current. The alternating field was oriented along the easy axis by orienting the domain-wall image parallel to the coil axis.

RESULTS

As previously reported,[16] an alternating field rearranges the domain structure (DS) in a magnetic dielectric. This rearrangement, in which the dynamic behavior of the domain structure becomes successively more complicated, sets in when the field amplitude h_0 increases to threshold values that depend on the frequency. After the first critical field amplitude $H_1(f)$ is reached, generation and unidirectional motion of Bloch lines begins in the domain walls. Next, in stronger fields $h_0 > H_2(f) > H_1(f)$, where formation of new domains sets in, their number (and period of the DS) increases in the sample. The number of domains formed in the crystal by the field depends on the field frequency and amplitude[16] and the domain walls oscillate after the DS restructuring about new stable (if $h_0 > H_2$ but is not very large) equilibrium positions. At sufficiently high frequencies, when the domain-wall oscillation amplitude is small, the DS picture in constant light appears static, and only the image of the Bloch lines in the walls is blurred.

At field amplitudes higher than the third critical value $h_0 > H_3(f) > H_2(f)$, continuous formation of domains sets in; the domains move in the crystal in one direction (the critical fields for the generation of Bloch lines and domains are shown in Fig. 1[1)]). Initially, at values of f and h_0 close to the limit $H_3(f)$ of the continuous generation region, the domains are formed randomly in time and the average rate of

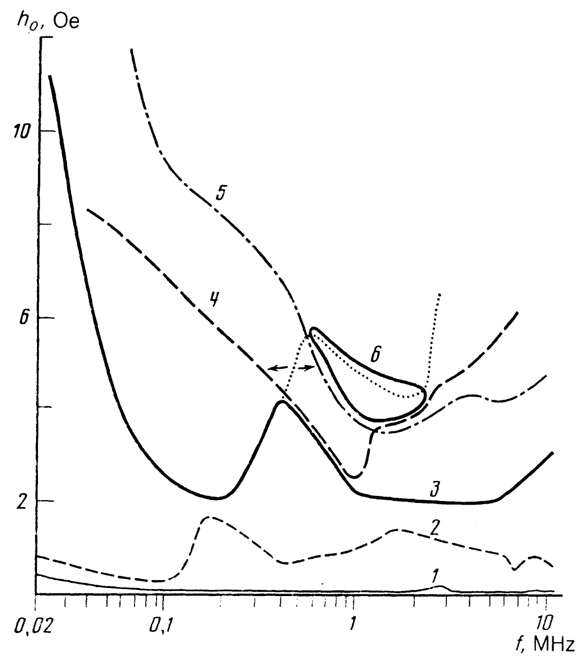

FIG. 1. Critical field amplitudes at which the dynamic states of the domain structure begin to change; 1—H_1, 2—H_2, . . . (explanation in text), 6—region of domain-structure stability. The dotted line is the boundary of reversal of domain motion.

their appearance is low. Direct observations at low formation frequencies show that the new domains appear on one crystal edge perpendicular to the easy axis. The already existing domains are then shifted towards the opposite edge, where the outermost walls are pushed out of the sample. Unidirectional wall displacement is thus produced. This process is particularly clearly pronounced if the alternating field is applied not continuously but in the form of trains. It must be noted that the points where new domains are formed are governed to a considerable degree by the presence of crystal-lattice defects. In particular, in plates with strong inhomogeneity of the growth striae the domains were produced not at the edge of the crystal but near the inhomogeneity.

Figure 2a shows the variation of the magneto-optic signal under condition when continuous formation sets in. The changes of the signal level correspond to passage of light and dark domains through the photometry region bordered by the diaphragm. It follows from Fig. 2a, in accordance with the direct observations, that new domains are infrequently produced, and the remaining domains shift rapidly, so that the ensuing domain configuration is equivalent to the initial one (a shift by one period of the DS). Situations can occur, when a domain at a given place is replaced by one having reversed polarization (shift by one-half the DS period).

With increasing distance from the boundary $[H_3(f)]$ of the continuous-formation region to its interior (when the field amplitude is increased or the frequency is changed), the rate of domain generation increases and the process changes from disordered to regular (Fig. 2, b–d). The image of the

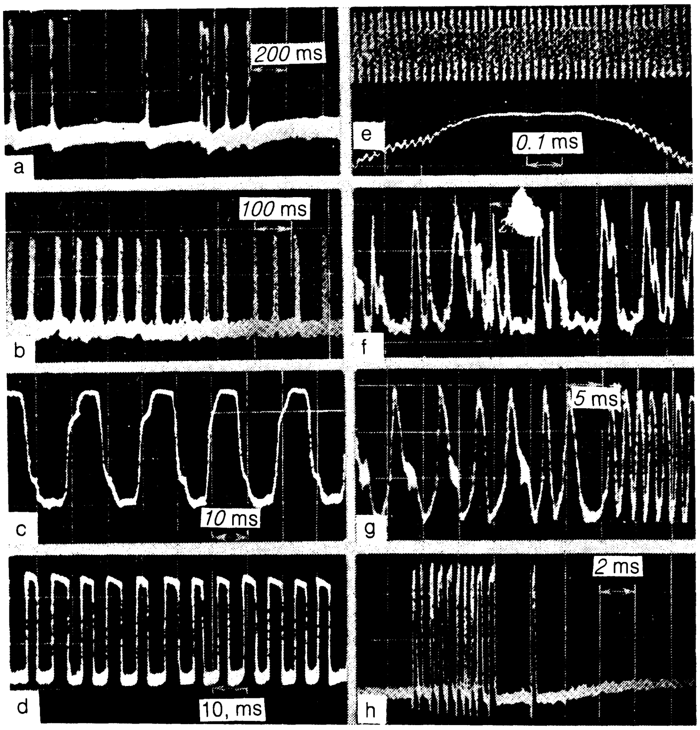

FIG. 2. Magneto-optic signal changes due to generation and directed motion of domain: a)–d) $f = 150$ kHz, a) $h_0 = 2$ Oe; b) 2.1 Oe; c) 2.5 Oe; d) 4.2 Oe, e) $f = 50$ kHz, $h_0 = 8.4$ Oe, the oscillations on the fronts correspond to wall oscillations in synchronism with the field (upper sinusoid—current in the field-producing coil); f) 150 kHz, 8 Oe; g) 800 kHz, 5.25 Oe, h) 600 kHz, 5.7 Oe.

visually observed domain structure is then completely washed out. It can be seen from Fig. 2, curves b–d, that a stationary regime of continuous generation is characterized by a constant period T. The velocity of ordered motion of the domains in the given section of the crystal is also preserved ($V = d/\tau$ at the front duration τ and the known distance d corresponding to the chosen slit width). It should be noted that when the period of the DS is long and the rate of formation is small, the domain motion is not smooth, viz., the domains are shifted jumpwise after each formation act ($\tau \ll T$). In this case the velocity V introduced above determines only the time of transition of the walls to a new equilibrium position. Such a domain displacement is perfectly natural in view of the limited dimensions of the crystal and the discrete character of the DS. When, however, the number of domains increases and the rate of their generation becomes quite large, so that $\tau \sim T$, the velocity characterizes already a quasicontinuous wall motion.

The directed velocity of the domains can vary substantially over the crystal. First, it decreases somewhat with increasing distance from the formation point. Second, the crystal may contain defects that delay the walls (V decreases), which are, however, again accelerated after passing through the defect. These variations of V over the crystal decreases with increasing generation rate. Recall that in the stationary domain-generation process the velocity V in some selected section of the crystal is constant. On the other hand, the variations of V in different sections with change of amplitude and of field frequency are qualitatively similar. In contrast to the front duration τ, the period T does not vary over the crystal as long as directed displacement of the domains continues.

Analysis of the magneto-optic signal obtained upon illumination by a split laser beam, under condition when the photometry region is moved in succession through the entire sample, has shown that the walls continue to move in the same direction in a wide range of amplitudes above $H_3(f)$. Figure 2c shows a typical form of the signal corresponding to directed displacement of the domains. Each signal-rise section corresponds to passage to a bright domain first through the brighter spot, and then through the darker spot alongside. The darker spot is next "obscured" by the dark domain, which passes next through the brighter spot (the signal fall-off region). A bright domain then enters again into the photometry region, and so forth. The steps on the pulse fronts correspond to the passage of the domains through the dark strip separating the light spots. Note that the moving walls execute also small oscillations that can be revealed if the signal time is lengthened, at the external-field frequency that exceeds greatly the formation frequency (Fig. 2d).

The described directed motion of the domains might be attributed to the possible crystal structural inhomogeneity (variation of composition, density of point defects, etc.) frequently present in garnets grown from a molten solution. Such an inhomogeneity might tilt the potential relief for the wall motion in the sample, and cause the walls to drift in an alternating field. It was found, however, that the directed motion of the domains is reversed on going from $f < 400$ kHz to $f > 400$ kHz. Furthermore, small rotations of the sample in a plane, in either direction, relative to the orientation of the alternating field, cause the domain walls in the entire investigated frequency band to move in one, or respectively, the other direction. The location of the reversal of the motion direction in a field $\mathbf{h}_\sim$ parallel to the easy axis is shown by the dashed curve of Fig. 1, and the (arbitrary) directions are shown by arrows in the same figure.

Growth of the field amplitude upsets the regular directed motion of the wall. When h_0 reaches a critical value $H_4(f) > H_3(f)$, the frequency of the magneto-optic signal near one of the edges of the crystal increases abruptly compared with the signal frequency in sections far from this edge. A similar situation occurs near the other edge at $h_0 = H_5(f) > H_3(f)$. This corresponds to an increased rate of generation of domains on the edge, whereas in the interior of the crystal the domains continue their directed motion at a slower rate. If directed domain motion were to start at $h_0 < H_4(f)$ and, respectively, $h_0 < H_5(f)$ from an edge at which more frequent generation took place in a field $h_0 > H_4$ or $h_0 > H_5$, it would turn out that at the start of the generation a fraction rather than all of the generated domains move in the same direction, and the remainder collapse near the formation point. On the other hand, if the walls moved at smaller h_0 towards the edge where frequent generation sets in, all the domains generated there collapse near this edge. In both cases, sections in which the domains collapse are produced at a certain distance from the crystal edges. The collapse of the domains influences the motion of the walls of the neighboring domains, causing them to execute periodic jumplike oscillations that are superimposed on the directed motion. The appearance of this irregularity in the behavior of the domain walls can apparently be regarded as the first step towards dynamic stochastization of the domain structure. Note that the most frequent generation on the crystal edge, as well as the motion of the domains far from the edge, can still remain perfectly regular. When the field amplitude is increased above $H_4(f)$ and $H_5(f)$ the region of the most frequent signal moves away somewhat from the edge of the sample, and causes narrowing of the central region in which the signal remains periodic, i.e., a larger part of the domains goes farther towards the center of the crystal. This enlarges the region where the domains collapse, and accordingly the region of irregular wall motion.

Further increase of the field amplitude decreases the amplitude of the magneto-optic signal at the crystal edges. This corresponds (as shown also by direct observations using pulsed illumination) to a decrease of the thickness of the generated domains, which are now formed and move away from the edge in the form of surface "troughs." An ever increasing fraction of the domain walls in the crystal begins to execute asynchronous jumps and collapses in various sections. Finally, at even larger amplitude, the behavior of the domains becomes completely chaotic (Fig. 2f). They begin to be formed and collapse over the entire crystal at arbitrary times. This disrupts the spatial periodicity of the domain structure. Whereas in weaker fields the number of domains in the crystal is determined quite unambiguously by the frequency and amplitude of the field,[16] now this number varies irregularly with time.

One feature of continuous domain generation is the appearance of a domain-structure stability "window" at $h_0 > H_4$, $h_0 > H_5$, and $f > 500$ kHz. In the stability region (shown in Fig. 1), the domain walls in the main volume of the crystal oscillate with very small amplitude at the external-field frequency about stable equilibrium positions (the Bloch lines in the walls continue to be generated in this case). Domains can be formed only on the edges, where they also collapse. At field amplitudes above the upper limit of the indicated region, directed motion of the domains is resumed, but in a direction opposite to that at lower field amplitudes. Since $h_0 > H_4$ and $h_0 > H_5$, the walls move in the volume more slowly than they are generated at the crystal edges. Note that at certain values of the field amplitude the directed domain velocity is somewhat intermittent: the magneto-optic signal changes frequency alternately (Fig. 2g). A qualitatively similar effect occurs when generation sets in near $H_3(f)$ and near the upper stability limit when trains of domains are formed (Fig. 2h).

The described features of the continuous generation process are illustrated by the dependence of the reciprocal period of the magneto-optic signal on the alternating-field amplitude at $f =$ const. These dependences are sections of the constant-generation-rate lines $T =$ const on the (h_0, f) plane, which are similar to the $H_3(f)$ curve (they are left out of Fig. 1 for simplicity). Figure 3 shows $1/T$ as a function of the field amplitude at $f = 150$ kHz, measured at several points of the crystal. Similar curves are obtained for frequencies lower than 400 kHz. For higher frequencies, the plots of $1/T(h_0)$ are similar to that shown in Fig. 4 for $f = 2$ MHz. It

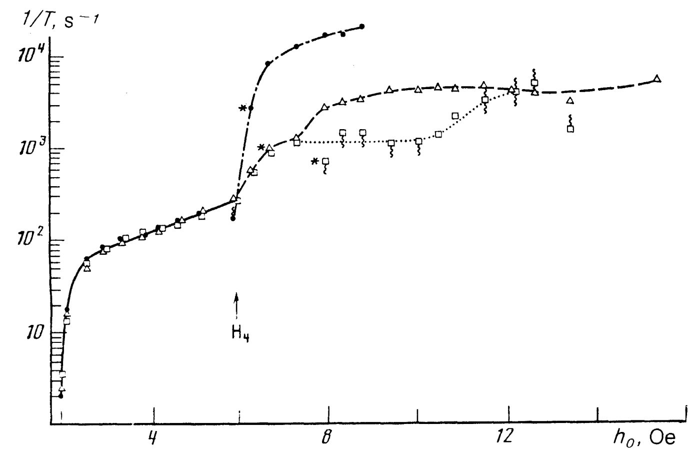

FIG. 3. Reciprocal period of magneto-optic signal, measured at the edges (●, △) and at the center (□) of the crystal, vs the field amplitude at $f = 150$ kOe. The wavy lines indicate violation of periodicity of the signal. The measurement symbol gives the average value of $1/T$), *—start of decrease of signal amplitude.

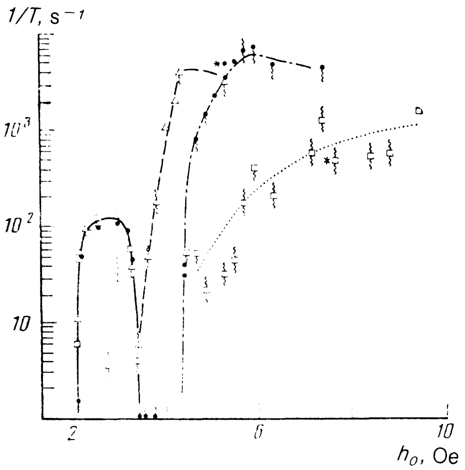

FIG. 4. Reciprocal of the magneto-optic signal period vs the field amplitude at $f = 2$ MHz. The symbols are the same as in Fig. 3. At $h_0 = 4$ Oe a periodic signal exists only near one of the edges of the crystal, while in other sections of the sample the domain structure is stable and there is no signal.

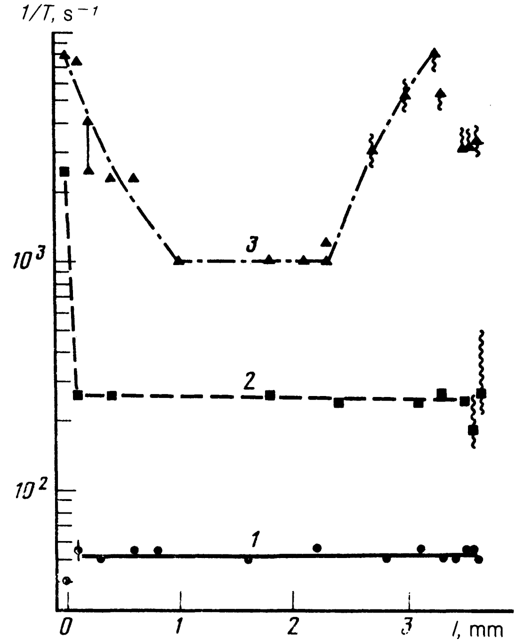

FIG. 5. Variation of reciprocal period of the magneto-optic signal over the crystal: l—distance of the measurement point from one of the sample edges, 1—$h_0 = 2.52$ Oe, 2—4.2 Oe, 3—6.3 Oe; $f = 1$ MHz.

can be seen from Fig. 3 that the generation has a field-amplitude threshold and its rate increases abruptly. This is followed by a section in which the formation frequency increases more smoothly, and at definite h_0 the generation rate again begins to increase rapidly with the field. Following the associated kink on the $1/T(h_0)$ plot (it corresponds in Fig. 3 to $h_0 = H_4$), the curves for the period of the magneto-optic signal, plotted for different points of the sample, begin to diverge, and this corresponds to the collapse, described above, of some of the domains near the edges at which they are formed. The points with wavy lines in Fig. 3 denote the average number of domains passing through the photometry region under conditions when the periodicity of their motion is disturbed. The asterisks (*) mark the instant when the signal amplitude begins to decrease noticeably (near-surface domains are generated and move). At frequencies higher than 500 kHz there appears on the $1/T(h_0)$ curves, besides the indicated singularities, a region in which the generation rate decreases (Fig. 4), due to the appearance of the domain-structure stability window. Note that the change of the generation rate can be represented by a set of constant-T lines on the (h_0, f) plane, lines similar to the $H_3(f)$ curve for regular directed displacement of the domains. The onset of spatial irregularity in the motion of the domain walls can be easily traced on the plots of the reciprocal period of the magneto-optic signal through the crystal at constant f and h_0. For example, the plots of Fig. 5 for $f = 1$ MHz show that as field amplitude increases the values of $1/T$ at different points of the crystal become unequal and the region where the domain motion is no longer directed expands away from the edges of the crystal.

To determine the connection between the rate of domain generation and their directed motion we plotted, besides the dependences above, also $1/T$ and V as functions of the field frequency and amplitude for a signal measured in the central part of the crystal. These plots are shown in Figs. 6 and 7. With allowance for the foregoing statements concerning the non-uniformity of domain motion through the crystal at large field amplitudes, it can be stated that the variation of V duplicates that of the generation rate.

DISCUSSION

Thus, periodic generation of domains, at a frequency much lower than that of the external field, is induced in a ferrimagnet by an alternating magnetic field that exceeds a

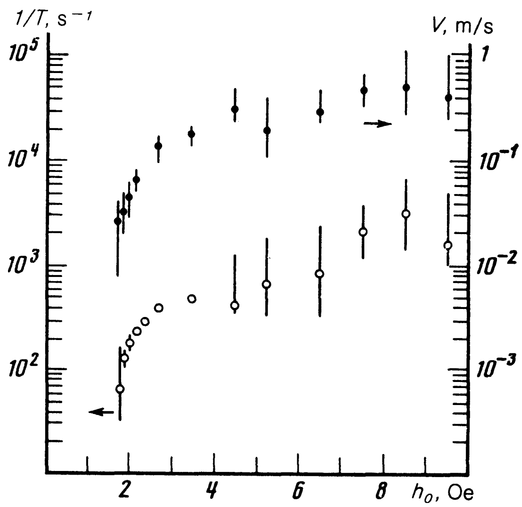

FIG. 6. Comparison of the changes of the velocities of the directed motion and of the magneto-optic signal with increase of field amplitude. The mean value (V—●, $1/T$—○) and the maximum measured scatter are shown, f—5 MHz.

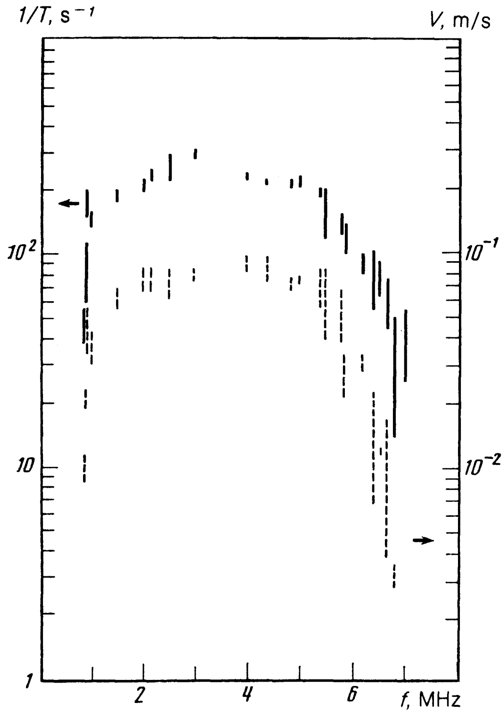

FIG. 7. Reciprocal period of magneto-optic signal and of the domain-displacement velocity vs the field frequency; $h_0 = 2.5$ Oe.

certain threshold. This phenomenon was not observed heretofore and was not predicted theoretically. A qualitatively similar picture, however, continuous formation of domains accompanied by their directed motion in an alternating field, was observed in a triangular silicon-steel plate and was attributed to domain-wall drift[2)] determined by the sample shape.[18] It can be assumed that in our case domain generation is also caused by wall drift that leads to displacement of the walls from the edges of the sample and as a result to the appearance of a non-uniform magnetostatic field that contributes to formation of new domains. The cause of the directed wall drift, in turn, can be a gyroscopic force applied by the unidirectionally moving Bloch lines. It is just such a motion of Bloch lines that takes place in the investigated crystals at relatively low alternating field amplitudes ($\sim H_1(f)$).[17] It is impossible to record experimentally regular motion of the lines at $h_0 > H_3(f)$, but it may nevertheless be that a preferred directed motion that leads to drift of the walls exists also at large field amplitudes besides the observed irregularities of the generation and displacement of the Bloch lines. A confirmation of the described mechanism capable of explaining the continuous formation of domains, at least in fields in which the wall motion through the crystal is regular, would be broadening of the domain at the sample edge prior to the appearance of new walls. We did not succeed in revealing such a broadening. On the contrary, an increase of the density of the array of 180° walls was observed near the crystal edges, where the domains were formed. In addition, as can be distinctly seen at low generation frequencies, the trailing tail of the magneto-optic signal is longer than the leading front. Finally, in strong fields the rate of domain formation at the crystal edge, as described in the preceding section, becomes lower than the rate of their motion at the center of the crystal. The foregoing facts offer evidence on favor of the assumption that domain formation is obviously initiated by pumping with the alternating field and not by the wall drift. Conversely, the subsequent growth of new domains causes displacement of the already existing walls and determines thereby their directed motion. A similar effect was observed in a uniaxial iron-garnet film, where an alternating FMR-frequency field concentrated in the gap of a microstrip line caused continuous formation (whose periodicity was not investigated) of bubble domains expanding one inside the other and pressing the produced annular domain towards the periphery.[13] Computer simulation of the behavior of the magnetization in magnet section irradiated by a microwave field has shown that the formation of new domains may be caused by reversal of the magnetic moments at sufficiently high field amplitude.[15] The response of a magnetic to application of an alternating field was investigated in Ref. 15, but it was found that the reversal of the magnetization was due neither to the transient response to the rapid increase of the microwave field amplitude h_0 nor to the jump of the magnetization-precession angle (this jump occurs when h_0 is increased and is due to foldover formation, i.e., to the fact that the dependence of θ on h_0 becomes multiple-valued). The reversal is rather the result of development of the dynamic instability related to the nonlinearity of the Landau-Lifshitz equation. The instability develops via a specific oscillatory transient process and has a characteristic time substantially longer than the period of the microwave field. The calculation of Ref. 15, carried out for frequencies in the vicinity of $f_{\rm FMR}$. It was found in addition that the field amplitude needed for the reversal reaches a minimum at a frequency approximately half that of the FMR frequency, and begins to increase with further decrease of f.

The numerical calculation of Ref. 15, carried out for specific parameters of a magnetic film in a relatively narrow frequency interval, can unfortunately not be used to analyze domain formation at $f \ll f_{\rm FMR}$ in YIG plates. Moreover, only one act of magnetization reversal is considered in Ref. 15, whereas in our experiment periodic domain generation was observed. It seems nonetheless that the situation realized in our case is similar to that described in Ref. 15. Obviously, in a continuous alternating field the formation of a domain can be followed, as a result of local reversal of the magnetization and of the sufficiently large domain broadening, by onset of instability of the "reversed" state formation of another domain, etc. The result is self-excited oscillatory domain generation.

In contrast to the theoretically considered[15] concentration of the alternating field in the case of a microstrip line, in our experiments the field is uniform over the crystal. Near the crystal edges, however, there exist non-uniform magnetostatic fields that facilitate there the magnetization rotation. It is therefore just at the edges and at sufficiently large h_0 that overturning processes should set in and lead to nucleation of reversed magnetic phase (recall that in some crystals continuous domain generation is produced by defects, which are also known to be favorable nucleation spots[19]). Subsequent relaxation of the domain structure, at which the produced wedge-shaped domain increases and all the domains in the crystals become equalized in width (duplicating the dependence of the dynamic period of the domain on the field frequency and amplitude[16]), leads to directed displacement of the walls. The more frequently new domains are formed, the faster should the domain structure build up. The latter obviously explains the observed correlation of the velocity V with the rate of domain generation.

The periodicity of the process described should be specified both by the characteristic time of magnetization reversal and by the relaxation time of the domain structure after the appearance of a new domain. It is difficult to determine which of these processes is the limiting one, since it seems that either one can become accelerated when the field amplitude is increased and can govern the generation-rate changes observed with increase of h_0.

Note that the kinks on the plots of $1/T(h_0)$ (see $h_0 \sim H_4$ in Fig. 3), at which the generation rate increases and the domain-wall motion becomes non-uniform over the crystal, are indications of a transition to a new dynamic regime. It appears that they are similar to the kink on the typical plots of the reciprocal time of pulsed magnetization reversal of thin films vs the field-pulse amplitude (see, e.g., Ref. 19), which correspond to transition to a new mode of magnetization reversal and are characterized by an abrupt increase in the number of formed domains. The question of the nature of the change of the magnetization-reversal mechanism is still open. In our case, the new dynamic regime can be regarded as the start of stochastization of the behavior of the domain structure in an alternating field. By merely observing the distinguishing features of the disruption of regular generation (the onset of breaks, intermittency of the periods and subsequent total randomization of the displacement of the domain walls at large field amplitude) it is difficult to identify the type of the transition to chaos. Probably the most likely scenario is the one suggested by Pomeau and Manneville.[20] A similar picture of transition to chaos after the onset of quasiperiodic self-excited oscillations in a high-power microwave field was revealed in a numerical simulation of the nonlinear response of a chain of spins under longitudinal-pumping conditions.[8]

In conclusion, mention must be made of the possible autowave behavior, observed periodic generation, and directed displacement of the domains (see the discussion of autowave propagation from leading centers in Ref. 2) which, as proposed in Ref. 11, can explain also the generation of Bloch lines and their motion in an alternating field.

The authors thank V. I. Nikitenko for interest in the work and for helpful discussions.

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Translated by J. G. Adashko