Observation of a parametric instability of a surface magnetostatic wave

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A method is proposed for directly observing a parametric instability of a surface magnetostatic wave—a three-magnon decay process—in a YIG film. This method has been implemented experimentally. © *1994 American Institute of Physics.*

Many studies of a parametric instability of exchange-free spin waves (more often called "magnetostatic waves") in ferrite films have been reported over the past decade.[1] Of particular interest are nonlinear phenomena associated with a surface magnetostatic wave. The reasons for this interest are 1) the single-mode nature of this wave and 2) the ease with which this wave can be excited in a film.

Surface magnetostatic waves are excited in a film by means of a stripline running along the surface of the ferrite film. Regardless of whether the microwave power is fed along a narrow or wide strip, a region of a uniform microwave magnetic wave forms below the strip. This field can serve as a parametric pump, independent of the surface magnetostatic wave which is excited. In this case one can assume that nonlinear phenomena develop without the involvement of a surface magnetostatic wave in the pump. The latter wave simply carries information about the parametric instability out of the region in which this instability occurs to a receiving antenna (a stripline on the surface of the film, at some distance from the exciting stripline). In other words, no experiment of such a design can answer the question of just what the parametric pump is: the uniform field under the stripline or the magnetostatic wave which this field excites. Both the threshold characteristics and the phenomena which occur above the threshold are identical in the two cases.

The experiment described below demonstrates unambiguously a parametric instability of a surface magnetostatic wave.

The idea of the experiment is to arrange conditions such that there is a region in the film, far from the exciting element (the stripline), in which the power density of the surface magnetostatic wave is above the threshold for three-magnon decay, but the power density in the vicinity of the exciting element is below this threshold. It was found possible to achieve these conditions during the excitation of two intersecting beams of surface magnetostatic waves in an yttrium iron garnet (YIG) film. An intersection of the beams can be achieved only in the case of noncollinear propagation of the surface magnetostatic waves (the beam velocity $\mathbf{V}_g$ is noncollinear with the phase-velocity vector $\mathbf{V}_{\text{ph}}$).

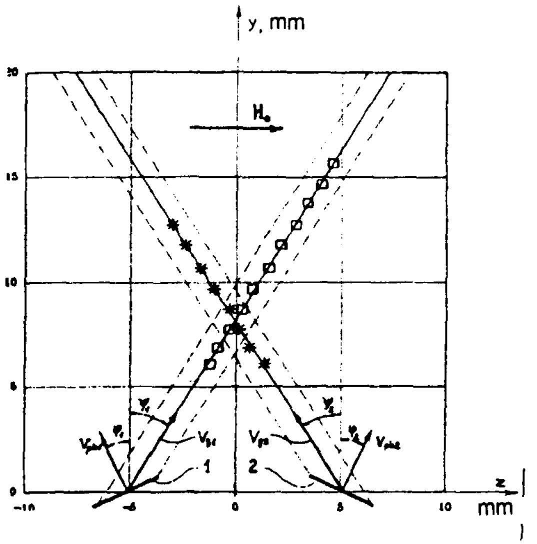

FIG. 1. Geometry of the experiment in the plane of the ferrite film. 1—First exciting element; 2—second exciting element. The points show the trajectories of the beams of surface magnetostatic waves, measured by a probe on the basis of the maximum of the received signal.

In the experiments we used a YIG film 13 μm thick and 76 mm in diameter with a saturation magnetization $4\pi M_0 = 1750$ G. On the average over the film, we have $\Delta H = 0.47$ Oe. The film is magnetized in a direction tangent with respect to the plane by a uniform and constant field of 500 Oe. Under these conditions, a surface magnetostatic wave can propagate over the frequency interval 3020–3660 MHz. A parametric instability of this wave (a three-magnon decay) is allowed over this entire interval. The wave frequency in the experiments was chosen to be 3212 MHz.

Two noncollinear beams of surface magnetostatic waves were excited by common microwave source, through a power splitter, by means of two striplines on the surface of the YIG film. The length of these exciting elements was 3.5 mm. They were 10 mm apart and oriented symmetrically with respect to the axis of collinear propagation (the direction perpendicular to the direction of the magnetizing field), at angles of $\varphi_{1,2} = \pm 25°$. The wave group velocities were in the respective directions $\psi_{1,2} = \mp 32°$. Figure 1 shows the orientation of the exciting elements and the phase and group velocities. From the dispersion relation we can easily find the magnitude of the wave vector: 110 cm^{-1}. Another advantage of a noncollinear beam is that its divergence in the plane of the film is small. It thus becomes easier to achieve the necessary power density at the point at which the beams intersect.[2] Measurements of the attenuation of the waves along the beams showed that we were able to satisfy yet another important condition for the success of this experiment: We were able to achieve an attenuation of less than 3 dB as a wave propagated from the exciting element to the beam intersection point (this is a necessary condition for the attainment of the threshold power at the beam intersection point).

The beam propagation directions, the beam profiles, and the beam power levels were monitored by a movable probe 0.5 mm long made of wire 12 μm thick. Figure 1 shows points along the trajectories of the beams corresponding to the measured maximum power in the beam. Curves 1 and 2 in Fig. 2 show the power distribution along the cross sections of the beams at the point at which they intersect. These measurements were

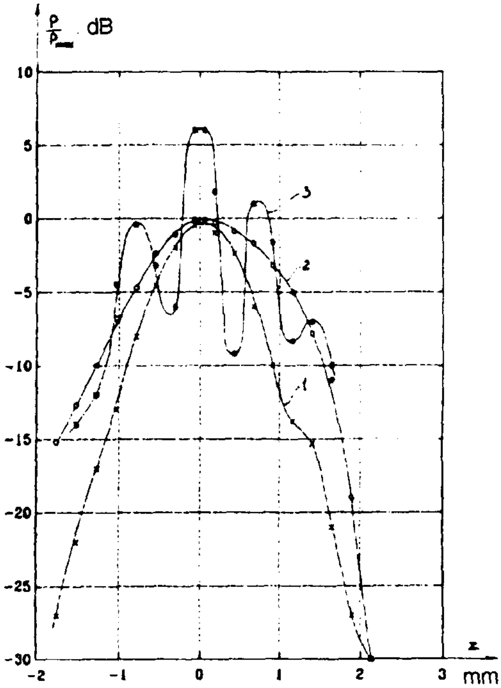

FIG. 2. Profiles of the beams of surface magnetostatic waves, normalized at their maximum, as measured by a probe (operating in the linear regime) along the straight line running parallel to the field H_0 and through the point at which the beams intersect. Curve 1—Profile of the first beam (the second beam was not excited in this case); 2—profile of the second beam (the first beam was not excited in this case); 3—interference of the two beams.

taken at a power level below the threshold. The width of a beam at the level of -3 dB in the cross section was on the order of 1.2 mm. (Figure 2 shows cross sections measured in the direction of the magnetizing field.) During the simultaneous excitation of the two beams, we observe an interference of the waves in the intersection region (curve 3 in Fig. 2). The region of in-phase interference of the waves is on the order of 0.3 mm in size. A phase shifter was placed behind the power splitter in one of the channels in order to achieve in-phase oscillations in the beam intersection region.

The experiment to observe the parametric instability was carried out in two steps.

First, microwave power modulated by a "meander" signal with a frequency of 1 kHz was fed from the source through the power splitter to the two exciting elements. One of the elements had a matched load, while the other excited a beam of surface magnetostatic waves in the film. As the probe was moved along this beam, it measured the threshold power which resulted in the parametric instability. This power level was found from the abrupt change in the height of the pulse observed on an oscilloscope. We determined that level of the power fed to the exciting element at which the wave was stable along the entire beam. The same procedure was then used with the second exciting element.

The measurements revealed some difference in the threshold power levels for the first and second exciting elements: $P_{\text{th}1}=4.90$ μW and $P_{\text{th}2}=4.95$ μW. The reasons for this difference are that the exciting elements are not perfectly identical and that there is a nonuniformity in ΔH along the beam propagation path.

In the second step of the measurements, the two exciting elements were excited

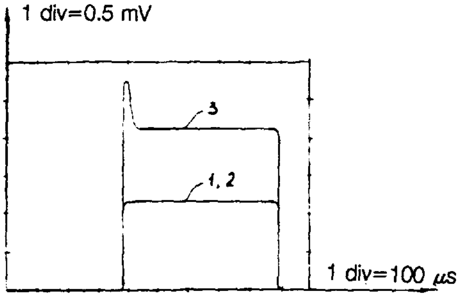

FIG. 3. Oscilloscope traces of the pulses at the point at which the beams of surface magnetostatic waves intersect. 1,2—Shape of the pulse during alternate excitation of the beams; 3—during simultaneous excitation of the beams.

simultaneously. The power fed to each of the elements was lower than the threshold for the region of the exciting element. The power along each beam was below the threshold, as was verified by a probe. However, the resultant power in the central part of the beam intersection region exceeded the threshold level, as was clearly detected from the abrupt change in the height of the pulse. Figure 3 shows oscilloscope traces of the pulses.

In summary, a parametric instability of a surface magnetostatic wave (a three-magnon decay process) has been observed directly for the first time.

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[1] A. G. Gurevich and G. A. Melkov, *Magnetic Oscillations and Waves* [in Russian] (Nauka, Moscow, 1994).
[2] A. V. Vashkovskiĭ *et al.*, Radiotekh. Elektron. **33**, 876 (1988).

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