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Detection of CO_2 laser radiation in a ferrite

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Abstract. The detection of plane polarized, amplitude modulated radiation of CO_2 laser ($\lambda \sim 10$ μm) in a transparent ferrite at room temperature is experimentally performed. It is shown that the detected signal is observed when the magnetization of the ferrite reaches the saturation value. The dependence of detected signal parameters on the external magnetic field is well correlated with the magnetization curve of the ferrite sample.

Ferromagnetism in general is widely used in modern industry and technology, underlying as a basis for many electrical and electromechanical devices such as electromagnets, electric motors, generators, transformers, and magnetic storage such as tape recorders, and hard disks. Ferromagnetic materials are widely used in electronics due to wide range of their physical properties. In addition to their usage in customer low-frequency electronics, ferrites found numerous applications in microwave and optoelectronic devices. In many studies the possibility of generation, detection, frequency conversion, and amplification of microwave radiation has been demonstrated [1].

The nonlinear behavior of the magnetic susceptibility of ferromagnets exposed to radiofrequency and microwave fields has been well investigated [1], [2]. These phenomena have a great scientific and practical value in the areas of signal detection, frequency conversion, etc.

Nevertheless, despite the fact that there is a plurality of ferrites, which are transparent in the infrared and optical domain, and are successfully used for rotation of polarization plane, for radiation control, etc., the nonlinear features of ferromagnets in this range are not well investigated. There are a series of works devoted to reorientation of the magnetic momentum in ferromagnetic materials exposed to ultrashort laser pulses (see e.g. [3]). However, it is generally considered that ferromagnetic materials cannot exhibit magnetic nonlinearity, because the magnetic permeability in said bands is equal to unity. According to [3] the ultrafast variation of the magneto-optical response taking place during an ultrashort laser pulse can be explained in terms of nonlinear optical susceptibility. However, the appearance of nonlinear optical susceptibility of a ferromagnet in an external magnetic field is not physically substantiated. This description is purely phenomenological, and interpretation of ultrafast magneto-optical response of ferromagnetic materials is still a subject for debates.

In [4] the optical detection of femtosecond laser radiation (wavelength range 0.71-0.95 μm and 200 kW peak power) by the partially transparent YIG ferromagnet was obtained. Based on the fact that the dependence of detected signal parameters on external magnetic field is well correlated with the magnetization curve of the used ferromagnet sample, the authors suggested that the detection is attributed to nonlinear interaction of laser radiation with a ferromagnet. Meanwhile, if detection is feasibly due to nonlinearity of magnetisation curve, this phenomenon will be seen for any transparent ferromagnet medium, in the case of nonlinear operating range of magnetisation curve.

The equation of motion for the magnetic momentum M in an alternating magnetic field H was proposed in [4], where excitation of the magnetic momentum appears to be caused by the induction of magnetic field, also taking into account losses in the ferromagnet:

$$\frac{d\mathbf{M}}{dt} = -\gamma\left[\mathbf{M}\times\mathbf{H}\right] - \gamma^2 I\frac{d\mathbf{H}}{dt} + \boldsymbol{R}, \qquad (1)$$

where γ= q/2mc is the gyromagnetic ratio, I - moment of inertia, and R - dissipative term.

As it follows from equation (1), the alternating magnetic field of the wave can change the magnetic momentum of ferromagnet. Ferromagnetic materials exhibit magnetic momentum saturation with the increase of external magnetic field. As a result, clearly nonlinear response for magnetic momentum is expected when the applied magnetic field changes in the proximity of the saturation level. Thus, in the case of penetration of the electromagnetic wave in a ferromagnetic material, in certain conditions one may expect nonlinear interaction of the electromagnetic wave with the ferromagnet.

In this paper we report the results of experimental investigation of possibility to detect far infrared laser radiation in a transparent ferromagnet recorded due to the excitation of magnetic momentum of a magnetized ferromagnet by induction of magnetic field of the laser radiation.

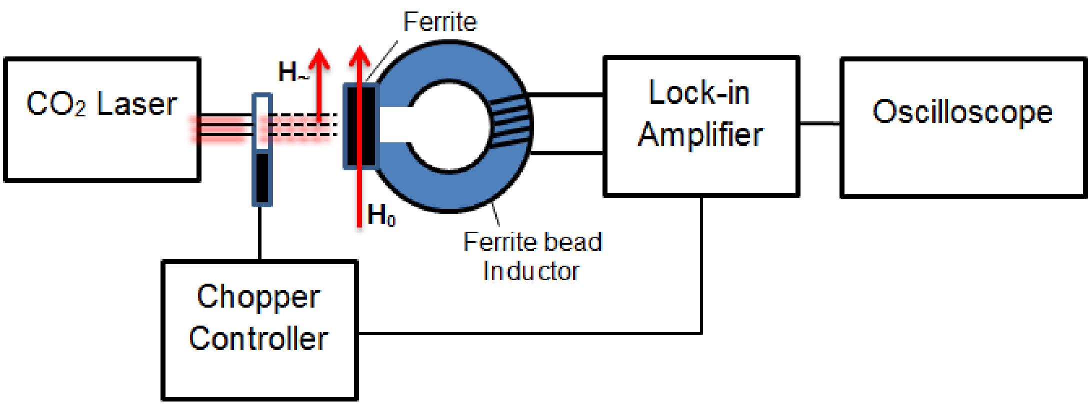

Figure 1. Schematic diagram of the experimental setup. H_0 shows direction of the external magnetic field, and $H_{\sim}$ denotes the magnetic field of laser radiation.

Schematic diagram of the experimental setup is sketched in Figure 1. The continuous-wave linearly polarized radiation of CO_2 laser (λ ~ 10 μm) with output power of about 15 W was used as an electromagnetic field. The laser radiation was modulated by a mechanical chopper in order to realize lock-in detection of the recorded signal. The sample of NM2000 ferrite widely applicable in the low-frequency electronics served as a ferromagnet. This sample was partially transparent in far infrared: the measured absorption coefficient was 16 cm^{-1} for λ ~10 μm wavelength. To record variation of the magnetic momentum in the sample, the latter was attached to a ferrite bead inductor with n = 500 turns winding (see Figure 1). The output signal of the inductor was detected by a lock-in amplifier and recorded by an oscilloscope.

In Figure 2 the magnetization curve of NM2000 ferrite and the dependence of the detected signal on magnetic field are plotted. In Figure 2b for evident demonstration of the dependence of detected signal on the non-linearity of the magnetization curve the second order derivative of the magnetization curve is shown.

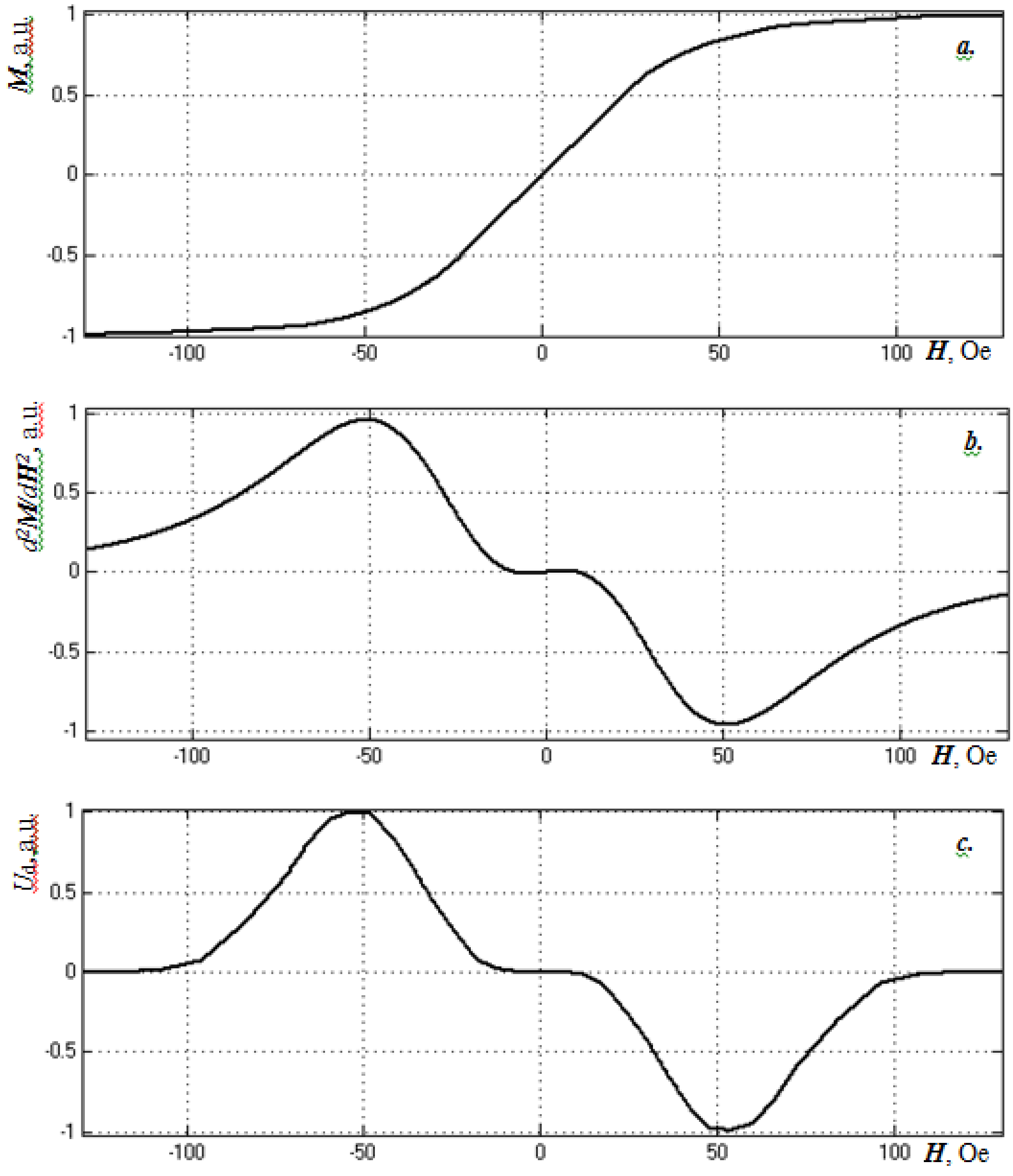

Figure 2. ***a.*** Magnetization curve; ***b.*** second order derivative of the magnetization curve, ***c.*** magnitude of the detected signal versus external magnetic field.

As is seen from Figure 2, no signal detected in the absence of an external magnetic field. Signal reaches its maximum value in the region where the change of the slope of magnetization curve for a ferrite sample is maximal. Moreover, the reversal of external magnetic field alters the polarity of the detected signal. $U_{max} \approx 150$ μV peak amplitude of the detected signal was recorded at $H_0 \approx 50$ Oe.

It should be noted that besides direct detection of far infrared radiation, nonlinear interaction of laser radiation with ferromagnets can find practical application in frequency conversion of laser radiation, recording and storage of information, etc.

References

[1] Gurevich A G 1961 *Ferrites in nonlinear microwave devices, collection of articles* (Moscow: Foreign Literature Publishing House) in Russian
[2] Yakovlev Yu M and Gendelev S Sh 1975 *Sov. Radio* Moscow (in russian)
[3] Kimel A V, Kirilyuk A, Hansteen F, Pisarev R V and Rasing Th 2007 *J. Phys.: Condens. Matter* **19** 04320
[4] Martirosian R M *et al* 2014 *JETP Letters* **99** 8 435