Ferromagnetic Detector of Infrared Radiation

D. Bagdasaryan[1], A. Hakhoumian[2], R. Martirosian[1,2], H. Julfayan[2],
A. Makaryan[1], F. Nazari[1], V. Tadevosyan[1]

[1] Microwave Radiophysics and Telecommunications Dept., Yerevan State University,
[2] Institute of Radiophysics and Electronics, Armenian National Academy of Sciences.

The detection of laser radiation in the magnetized ferromagnetic yttrium iron garnet (YIG) at room temperature was experimentally obtained. A magnetic sensor (a coil inductor wound around YIG sample) was used to register changes in the magnetic moment of the magnetized YIG sample. The bias magnetization of the ferromagnetic sample required for detection was carried out using an inductive coil wrapped on the horseshoe-shaped ferrite docked to the sample. The dependence of the detection efficiency on the magnetizing current was investigated.

It is shown, that in providing a good decoupling between current source and the magnetic bias coil, such a system can be successfully used for the registration and conversion of short laser pulses in infrared region.

I. INTRODUCTION

In recent decades it was actively investigated different magneto-optical and opto-magnetic phenomena in the ferromagnetic mediums, particularly magnetic moment inversion under the influence of ultra-short laser pulses [1-3]. In [4] and [5] works were studied the inverse Faraday and Voigt (Cotton-Mouton) effects. In the other works [6-8] the detection of visible and infrared linearly polarized laser radiation in the magnetized transparent ferromagnetic at room temperature was experimentally obtained. It was shown that the amplitude and sign of detected signal strictly depend on external magnetic field, the polarization of laser radiation and the magnetization curve of ferromagnetic medium. These phenomena cannot be explained by the inverse Faraday and Voigt effects.

The detection of electromagnetic radiation in microwave range in ferromagnetic medium was studied well [9-10]. It has resonance behavior and fully explains by ferromagnetic resonance theory. However, the mechanisms of interaction of laser radiation in the infrared and visible regions are still the subject of discussions and debates.

In the works [6-8] it was shown that in soft ferromagnetic medium at the absence of magnetic bias field the detection of electromagnetic wave does not occur for any shape of magnetization curve of ferromagnetic sample. The detected signal arises only in the magnetized sample due to the changes of magnetic moment under the influence of electromagnetic radiation.

Upon the application of a magnetizing external magnetic field, the detected signal is still zero as long as the magnetization curve remains linear. Detected signal initially increases with increasing of the external magnetic field, reaches a maximum in the range, where the magnetization curve has the maximum nonlinearity. Near of turning point of the magnetization curve the signal reaches to zero. With the increasing of the external magnetic field the detected signal changes polarity and again begins to increase to the next maximum. At full saturation, the reorientation of the magnetic moment hardly occurs under the action of laser radiation, which leads to a drop in the amplitude of the detected signal.

In [6-8], where the ferromagnetic samples (YIG 0.4 mm thick single-crystal ferrite NM2000 5 mm thick) with the magnetic sensors were used, the optimal value of the external magnetic field is in the range of 20-100G. Furthermore, in the detecting process changes in the magnetic moment occurs along the applied magnetic field. This makes it possible magnetize the sample not only by external electromagnet or a permanent magnet, but also by an induction coil wound around magnetic sensor.

In present work the detection of laser radiation was experimentally obtained, at the magnetic biasing of the ferromagnetic sample using an inductive coil wrapped on a horseshoe-shaped ferrite docked to the sample.

II. EXPERIMENTAL INVESTIGATION OF FERROMAGNETIC DETECTOR

Block diagram of the experimental setup is shown in the Fig. 1. A neodymium pulse laser with λ = 1.06 μm wavelength as a radiation source was used (the pulse power ~1 MW, repetition rate ~10 Hz). The radiationwas linearly polarized. The absorption coefficient of the monocrystalline YIG sample, applied in our experiments was $\gamma \approx 15\text{cm}^{-1}$.

A coil inductor wound around ferromagnetic sample was used as a magnetic sensor to register changes in the magnetic moment of the magnetized YIG sample. A change in the magnetic moment of the YIG crystal leads to the change in the magnetic flux, which induces a voltage in the inductor coil.

In [6-8] for the magnetic bias to the desired value for the nonlinear interaction of the external electromagnets have been used. Here an induction coil wound around the horseshoe-shaped ferrite for magnetizing of ferromagnetic sample we used (see Fig. 1).

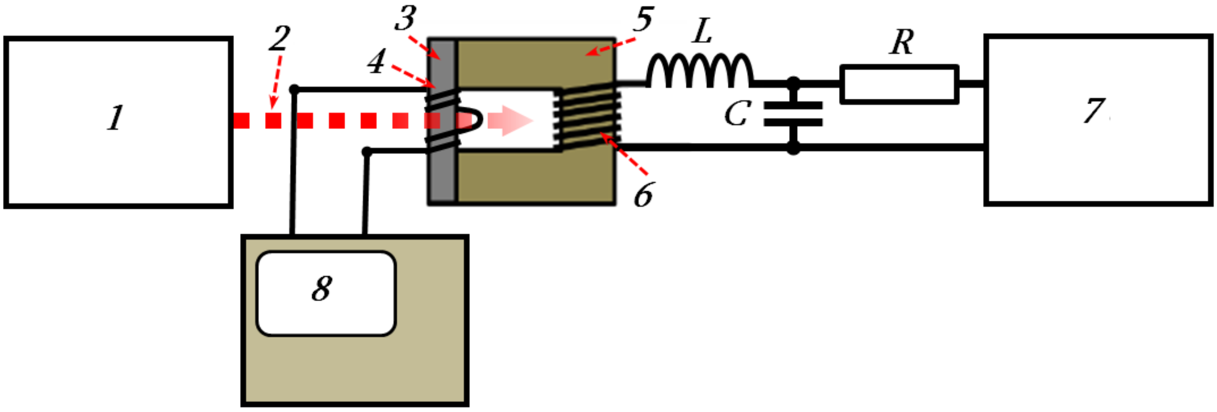

Fig. 1 The block scheme of experimental setup:
1 – Nd:YAG pulse laser, 2 – laser beam, 3 – YIG sample, 4 – registering coil, 5 – horseshoe ferrite, 6 – magnetizing coil, 7– regulated power supply, 8 – oscilloscope, L – decoupling inductor. R – ballast resistor, C – smoothing capacitance.

For decoupling of magnetizing coil 6 from the power supply 7 the voltage was applied to the coil through the RLC lowpass filter. Ballast resistor R (R=1kOm) at the same time provides the necessary magnitude of current through the magnetizing coil.

In our experiments for magnetizing of ferromagnetic sample the horseshoe-shaped ferrites with different configurations and dimensions were used. Dependence of magnetizations of YIG samples with two different ferrites on the voltage of power supply 6 applied to magnetizing coil through the RL circuit are shown in Fig. 2a and 2b. The magnitude of the output signals of corresponding ferromagnetic detectors depending on the voltage of power supply (see Fig. 1) are shown in Fig. 2 c and 2d. These experimental results are in a good agreement with the results of [2] in which a magnetic field was applied using an external electromagnet.

Particularly, the Fig. 2 shows, that when using the above method for the magnetization YIG sample, the amplitude of the detected signal reaches a maximum at the nonlinear region of the static magnetization curve. Reversing the direction of applied voltage to the magnetizing coils leads to the reversal of the sign of the detected signal.

Only one coil for the magnetization of the ferromagnetic sample and recording the detected signal can be used in the detector. However, in this case it is necessary to provide decoupling between the power source and the receiver of detected signal (Fig. 3).

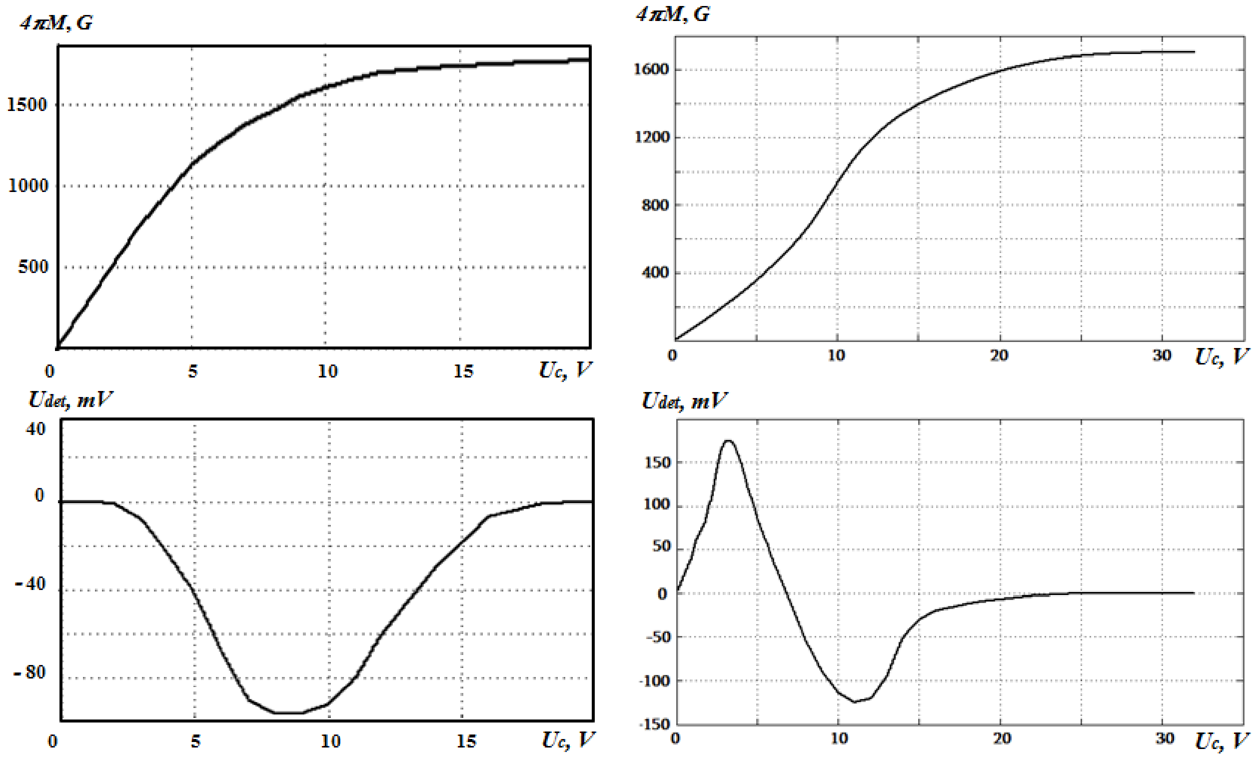

Fig. 2. Dependence of magnetization curves (a, b) and of the magnitudes of detected signals (b, c) on applied voltage to the magnetizing coils.

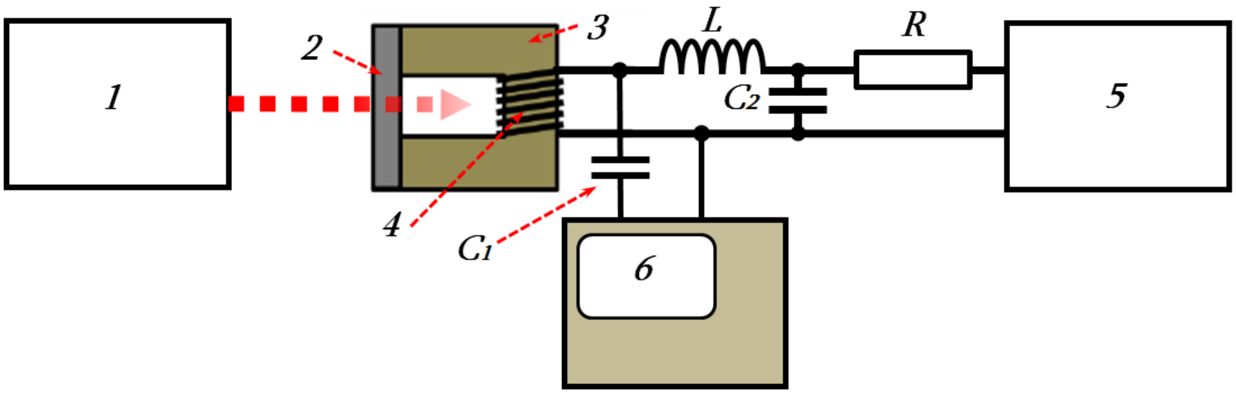

Fig. 3. The scheme of experimental setup with one inductive coil:

1 –laser, 2 – YIG sample, 3 – horseshoe ferrite, 4 – inductive coil, 5 – power source, 6 – oscilloscope, L – decoupling inductor, R – ballast resistor, C_1 – decoupling capacitance, C_2 – smoothing capacitance.

It should be noted that to the detection of short pulses should be used a high-frequency ferrite in the sensor.

III. CONCLUSION

In conclusion we mention that the results obtained can find wide practical application for the detection and conversion of frequencies of electromagnetic radiation for the optical recording, storage and processing of information, etc.

IV. REFERENCES

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