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Terahertz Magneto-optical Properties of Hexaferrite Ceramics

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***Abstract*—In this work, we performed an investigation of the terahertz magneto-optical effect in barium and strontium hexaferrite ceramics with various compositions. The Faraday rotation of the samples taking into account the insertion losses were evaluated. As a result, the most perspective sample ($BaAl_{1.4}Fe_{10.6}O_{19}$) in terms of maximum polarization rotation and minimum insertion losses has revealed.**

I. INTRODUCTION

THE terahertz (THz) spectral range is currently under extensive investigation, due to a wide range of possible applications [1]. To utilize full potential of THz radiation in relevant applications, the development of functional THz components is on demand [2, 3]. However, most of proposed devices possess reciprocal features. While nonreciprocal components are becoming of critical importance in the THz frequency range [4]. There are several approaches for achieving non-reciprocity. Among them, spatiotemporal modulation of media [5,6] and utilizing nonlinear materials [7] can be marked. A traditional way to achieve nonreciprocity is through magneto-optical effects [8]. It is characterized by broadband response in contrast with resonant systems. On the downside, usually magneto-optical materials are with high insertion losses and requiring strong bias magnetic fields. Thereby, searching for new low-loss self-biased magnetic materials which enable achieving a strong magneto-optical effect in the THz range is of great importance.

Here we investigate the terahertz magneto-optical properties of six magnetized 1-mm thick barium and strontium hexaferrite ceramics with different compositions.

II. RESULTS

The Faraday rotation spectra was measured using THz time-domain spectrometer (Menlo Systems TERA K8) by placing a polarizer after the sample in +45° and -45° positions relative to the orientation of the incident THz electric field. Two fixed polarizers were set for defining the vertical linear polarization state for generated and detected signals. Corresponding Faraday rotation measurements scheme is shown in Figure 1.

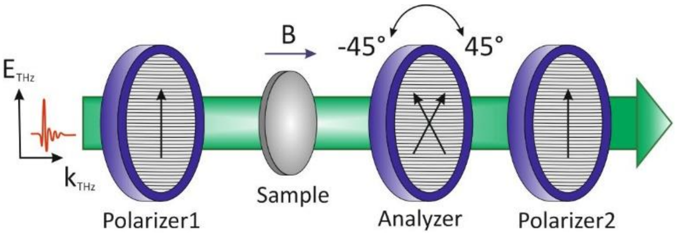

Fig. 1. The experimental THz polarimetry scheme.

The Faraday rotation angle was calculated using the following relation:

$$\theta_F = \frac{1}{2}\text{acrtan}\frac{2\text{Re}(E_x^* E_y)}{|E_x|^2 - |E_y|^2}, \quad (1)$$

where E_x and E_y are two mutually orthogonal complex components of THz electric field. That E component can be defined using the complex electric field components of Tha radiation transmitted through the system (Fig. 1) when analyzer was set at +45° and -45° position:

$$\begin{pmatrix} E_x \\ E_y \end{pmatrix} = \begin{pmatrix} E_{+45} + E_{-45} \\ -E_{+45} + E_{-45} \end{pmatrix}. \quad (2)$$

Figure 2 gives the THz Faraday rotation spectra for six investigated samples.

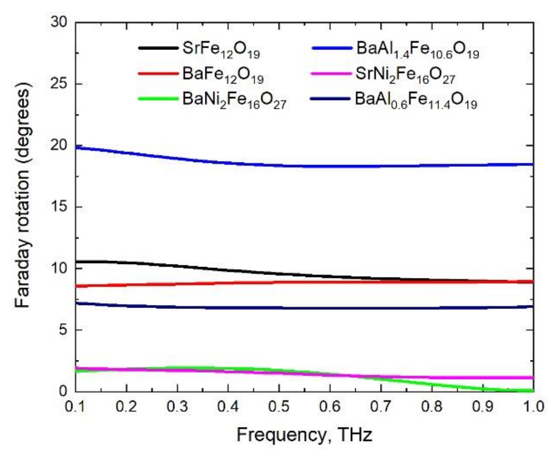

Fig. 2. Faraday rotation spectra of normally incident THz radiation on 1-mm thick barium and strontium hexaferrite ceramics.

As a result, we've obtained broadband low-dispersive Faraday rotation for all investigated hexaferrite samples. As seen in Figure 2, the maximal rotation value of 20° is observed for the $BaAl_{1.4}Fe_{10.6}O_{19}$ sample. For all other hexaferrite ceramics, the polarization plane rotation is at least two times lower. After that, the samples were set at a demagnetized state to evaluate the insertion losses. Corresponding absorption spectra are presented in Figure 3. Obtained spectra show significant increase in absorption for higher frequencies.

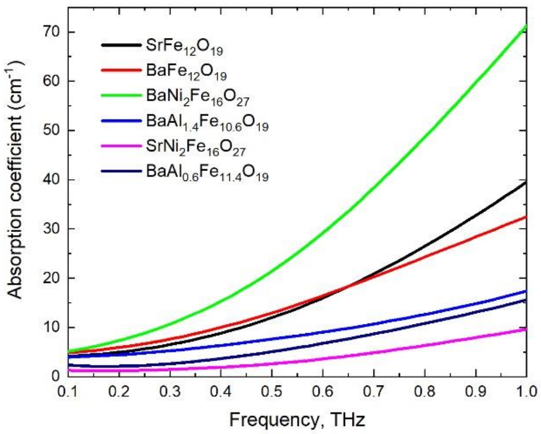

Fig. 3. Absorption spectra of 1-mm thick barium and strontium hexaferrite ceramics.

As shown in Figure 3, the absorption of two samples ($SrNi_2Fe_{16}O_{27}$ and $BaAl_{0.6}Fe_{11.4}O_{19}$) is lower than for the $BaAl_{1.4}Fe_{10.6}O_{19}$ sample within the whole exploited spectral range. However, the mentioned two low-loss samples offer quite weak rotatory power (2° and 7° correspondingly).

To evaluate the Faraday rotation of hexaferrite samples taking into account insertion losses, the figure of merit (FOM) parameter was introduced as

$$\mathrm{FOM} = \theta_F \exp(-\alpha d), \quad (3)$$

where θ_F is the Faraday rotation value (Fig. 1), α is the absorption (Fig. 2) and d = 1 mm is the thickness of the samples. Corresponding FOM spectra for different hexaferrite samples are presented in Figure 4.

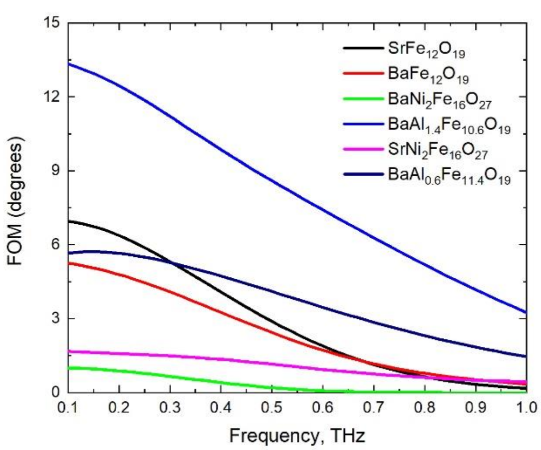

Fig. 4. The figure of merit THz spectra of 1-mm thick barium and strontium hexaferrite ceramics.

As seen from Fig. 4 the best FOM spectra corresponds to $BaAl_{1.4}Fe_{10.6}O_{19}$ in the entire investigated spectral range.

III. Summary

In summary, the magneto-optical properties of barium and strontium hexaferrites were experimentally investigated in the THz frequency range. All the samples enable self-biased broadband THz Faraday rotation. Among them the $BaAl_{1.4}Fe_{10.6}O_{19}$ sample possesses the most perspective features based on high rotatory power and low absorption. Our results may open up a pathway for the realization of nonreciprocal broadband THz devices with moderate insertion losses.

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