Title
Rare-earth Fibers for Faraday Isolator Applications Ece170A Review Paper

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Review of Paper by John Ballato and Elias Snitzer, “Fabrication of fibers with high rare-earth concentrations for Faraday isolator applications”

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1. Introduction

This paper delves into a method of developing fibers with high rare-earth concentrations. This is important for Faraday isolators because of the high Verdet constants in rare-earth glasses which allow for ideal rotation in Faraday rotators. Faraday rotators implemented in a system with light polarizers make unidirectional propagation of light possible. Unidirectional propagation is important, for example, in cases where back propagation of light could cause damage to lab instruments.

2. Faraday Effect

To start off, a section is included that describes how the Faraday effect works in the Faraday rotator. Birefringence, which is to say, different indices of refraction for polarizations in different directions, causes rotation of a light source’s polarization. The different indices of refraction mean that polarizations in different directions will experience non-uniform changes based on which indices act on them. The circular birefringence in the case of a Faraday rotator is induced by a magnetic field. Circular birefringence causes a difference in phase change for right and left circularly polarized waves to cause rotation. Simply put, a light source is passed through a polarizer, rotated 45°, passed through another polarizer, and then on the back propagation is rotated another 45° so that it can no longer pass through the first polarizer. A schematic can be seen below in Fig. 1 from the study [1].

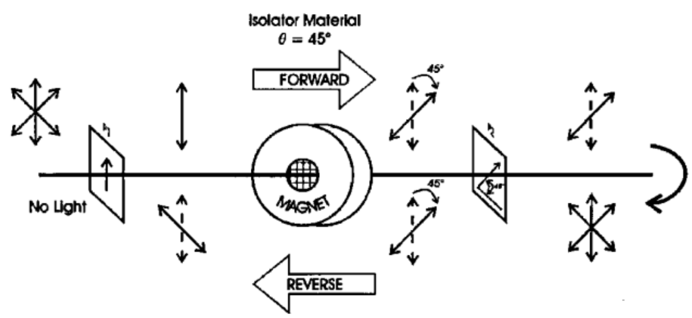

Fig. 1. Schematic of a bulk Faraday rotation isolator configuration with electromagnetic polarization states.

The equation for polarization angle change is given by $\theta = VBL$ where V is Verdet constant, B is magnetic field, and L is the length of the rotator [2]. It is desirable to have a high V so that the magnetic field and amount of material can be kept low, thus reducing costs.

3. Rare-earth glasses and fiber construction methods

The paper does a decent job explaining why rare-earth glasses are desirable because of their high rotation per ion property. It does not, however, go into much detail on the reason for rare-earth ions having this high Verdet constant. Since the focus of this paper is on a new method of constructing a rare-earth fiber the omission of going into lengthy explanation is understandable and not necessary for the paper's purpose.

Traditional fiber construction processes were outlined, which is very helpful to readers who may not be familiar with typical processes and issues that arise in fiber construction. The main issue with traditional methods is that during melting of the material in a crucible its contents can become contaminated. This is the problem that the paper says can be addressed by the powder-in-tube method. The process is similar to the traditional batch method however the melt is put in the hollow core of a silica capillary tube. The core and cladding may require specific properties for certain cases briefly outlined in the paper to minimize diffusion [1].

4. Experimental Results

The experiment was conducted using Tb_2O_3 as the rare-earth powder [1]. A potential issue that was addressed was the diffusion of silica between core and cladding. The authors acknowledged this concern and explicitly stated in their results that a slight difference in refractive index is caused by this, which is negligible in most cases. Another issue they brought up was possible unfined bubbles in the core, however they assured the reader that the concern was unfounded since no scattering cores were found. Addressing concerns is necessary in this experiment as the authors are proposing a different method of fiber construction compared to traditional methods. If the reader is not convinced that powder-in-tube is a better method, then the goal of the paper is not met. Another important parameter that the authors could have added was the effectiveness of the transmission. That is to say, how much of the power was lost as the light passed through the polarizers and the rotator. The crystal could have a high Verdet constant and be cheaply produced, however if it causes too much power loss it would not be an effective alternative. It is stated that the alternative has more impurities which cause loss, implying that powder-in-tube created fibers would have less loss, however more concrete evidence of this would be helpful. Other factors that play into the effectiveness of a material is the wavelength of light shot through it. The Verdet constant of a material is also dependent on the wavelength so the inclusion of a graph showing the Verdet constant over different wavelengths shows over which wavelengths the fiber may be most effective. As expected, the longer the wavelength, the less rotation in a Faraday rotator since rotation angle is directly proportional to the Verdet constant.

5. Conclusion

This paper has effectively shown why the powder-in-tube method of fiber formation is a valid cheaper alternative to traditional methods. The important factor in this conclusion is that the Verdet constant remains sufficiently high while reducing impurities in the fiber that are common in batching techniques.

References:

1. John Ballato and Elias Snitzer, "Fabrication of fibers with high rare-earth concentrations for Faraday isolator applications," Appl. Opt. 34, 6848-6854 (1995)
2. Liu, Jia-Ming. *Principles of Photonics*. Cambridge University Press, 2017.