Measurements of the magneto-optical properties of PbS-doped silica optical fiber

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Abstract. The Verdet constants of PbS-doped silica optical fiber and single mode fiber (SMF-28e) have been investigated based on a magneto-optical effect measurement system at wavelengths between 660 and 1550 nm. The Verdet constant of PbS-doped fiber is 3.17 rad/Tm, 31.5% larger than that of SMF at 660 nm. The PbS-doped silica optical fiber can become a promising material for Faraday rotator.

1. Introduction

Faraday rotators are important optical components widely utilized in optical isolators, optical modulators and sensors of current and magnetic fields [1-3]. Faraday rotator can be a crystal, bulk glass or optical fiber, placed inside a magnetic field. However, crystals and bulk glasses as Faraday rotator present technological disadvantages such as difficult and high-cost growth and temperature dependence [4, 5]. The optical fiber as a Faraday rotator has certain advantages, such as small size, high sensitivity, immunity to electromagnetic interference. The PbS-doped fiber is fabricated using atomic layer deposition (ALD) and modified chemical vapor deposition (MCVD) technology, whose refractive index difference (RID) is about 0.75% and the concentration of Pb element is 0.11 at%, respectively, and its photoluminescence (PL) spectra nearly cover a broad band from 800 to 1600 nm, which matches well the whole optical communication window [6, 7]. However, magneto-optical properties of PbS-doped silica optical fibers have rarely been investigated. In this paper, the wavelength dependence of Verdet constants of PbS-doped silica optical fiber has been experimentally measured by the Stokes polarimetry. The Verdet constants of PbS-doped silica optical fiber are larger than that of SMF at different wavelengths.

2. Theory and Experiment

Faraday effect as one of the most useful magneto-optical phenomena refers to the rotation of the plane of polarization of linearly polarized light due to magnetic field induced circular birefringence of a material. The rotation is given by equation (1).

\[ \theta = H \cdot L \cdot V \]  

where \( \theta \) is the angle of rotation of the plane of polarization, \( H \) is the applied magnetic field, \( L \) is the distance travelled by light through the material parallel to the magnetic field and \( V \) is Verdet constant.
The magnetic-field-induced Larmor precession of electron orbits is the simplest mechanism for Faraday effect [8]. The well-known Becquerel formula, which describes the wavelength dependence of the Verdet constant, was originally proposed by Becquerel [9], described by equation (2)

\[ V = \frac{e}{2mc} \lambda \frac{dn}{d\lambda} \]  

(2)

where \( e \) is the electron charge, \( m \) is the electron mass, \( c \) is the speed of light in vacuum and \( \frac{dn}{d\lambda} \) is the dispersion of the material. The equation (2) shows that the Verdet constant is proportional to both the wavelength of the light and its dispersion in the medium.

A magneto-optical effect measurement system, which is based on the Stokes polarization parameters method, is set up shown in figure 1. A light wave from the laser source (Fabry-Perot Benchtop Laser Source, Thorlabs) is passed through a collimating lens (F220FC-B, Thorlabs) and a polarizer (LPVIS050-MP2, Thorlabs) for a linearly polarized light. And then the polarized light is launched into the fiber, which is clamped on the bare fiber launch system (MAX350D, Thorlabs). To observe Faraday effect, the optical fiber, length about 1m, is placed in a 30.4 cm long copper-wire coil (coil diameter: 1.8 mm per turn, inner radius: 12.8 mm, outer radius: 74.8 mm, the number of layer: 38, the number of turns: 5890). The magnetic field is produced by using a solenoid with a direct-current (DC). Its direction is parallel to the axial direction of the fiber. Maximum allowable current and magnetic fields strength of on the coil axis is 6 A, 140 mT, respectively. After passing through the optical fiber, the collimated light arrives at the Stokes polarimeter. And then the states of polarization can be displayed on the Poincare sphere model.

### 3. Results and Discussion

The Verdet constant are measured at different wavelengths (660, 808, 980, 1310, 1550 nm), which are listed in Table 1.

**Table 1.** Verdet constant of PbS-doped fiber and SMF at different wavelengths.

| Wavelength(nm) | SMF  | PbS-doped fiber |
|---------------|------|-----------------|
|               | Verdet Constant (rad/Tm) |               |
| 660           | 2.41 | 3.17            |
| 808           | 1.85 | 2.42            |
| 980           | 1.28 | 1.77            |
| 1310          | 0.73 | 0.86            |
| 1550          | 0.61 | 0.65            |
According to table 1, the Verdet constant for PbS-doped fiber and SMF at different wavelengths are plotted, and then polynomial fitted to the wavelength dependent relationship, as shown in figure 2. It indicates that the Verdet constant of PbS-doped fiber is larger than that of SMF at different wavelengths.

![Figure 2. Verdet constant of PbS-doped fiber and SMF at different wavelengths.](image)

And the wavelength dependence effect of the Verdet constant has been demonstrated. Furthermore, for PbS-doped fiber, its Verdet constant at 660 nm is 3.17 rad/Tm, and that of SMF is 2.41 rad/Tm, 31.5% larger than that of SMF. In summary, the larger Verdet constant of the PbS-doped fiber than that of SMF is ascribed primarily to the PbS material doped in the optical fiber.

4. Conclusion

We have been experimentally measured the Verdet constants of the PbS-doped fiber and SMF by the Stokes polarimetry and found that the Verdet constant of the PbS-doped fiber is higher than that of SMF at different wavelengths. And the increment of Verdet constant of PbS-doped fiber can reach to about 31.5% at 660 nm.

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