Tunable fiber lasers with birefringent fiber Bragg grating mirrors

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ABSTRACT

A ring-type fiber laser with an external birefringent Bragg grating reflector is presented. The birefringent grating has a polarization-dependent transmission/reflection spectrum and by adjusting an intracavity polarization controller, a tunability range of 0.6 nm is achieved.

Keywords: tunable fiber laser, birefringent fiber Bragg grating

1. INTRODUCTION

Before photosensitivity enhancement techniques were introduced\(^1\), gratings were quite often written in elliptical core fibers\(^2\) due to their relatively high contents of germania. The observed polarization dependent behavior\(^3\) was considered undesired, since it may result in ambiguity in fiber sensor applications, or lead to polarization problems in communication systems.

In this paper we harness these polarization-dependent spectra to build a tunable fiber laser with some unique properties. The characteristics of the gratings, the laser set-up and some preliminary results are presented in the following sections.

2. BRAGG GRATINGS IN HIGH BIREFRINGENCE FIBERS

2.1 Imprinting of the gratings

A UV laser beam was used to side-illuminate the fiber through a phase mask, which efficiently split the incident beam into the +1 and -1 orders of diffraction, with the zero order being highly suppressed. The periodic pattern produced by the interfering diffraction orders, imprinted a periodic refractive index grating into the fiber core.

We used an elliptical core high germania fiber and a cw frequency-doubled Ar laser was utilized to write gratings with transmission notches as deep as 23 dB (0.5% transmission), Fig. 1, having only 0.5 dB of ringing due to radiation modes losses.
2.2 Polarization dependent spectra

Initial measurements of the transmission and reflection spectra, carried out using an edge-emitting LED and an optical spectrum analyzer have shown a double notch shape (Fig. 2).

Fig. 2: Measurements using polarization-independent setup

To resolve the polarization dependence of the spectra we used the setup in Fig 3, where an intense Erbium-doped fiber amplifier with no input served as the source, followed by the grating and a rotating analyzer.

Fig. 3: Setup for the polarization analysis of the spectrum
Measuring the transmission spectra over all angular positions of the analyzer lead to the following results: two states of linear polarizations showed a single notch transmission curve, with all other states of the polarizer manifesting a double notch shape. The single notch curves were the deepest and were associated with orthogonal polarizations (Fig. 4). We concluded they originated from polarizations parallel to the slow and fast axes of the fiber.

![Graph showing polarization dependent spectra.](image)

**Fig. 4: Polarization dependent spectra**

The wavelength differential of the two clean notches of Fig. 4 (Δλ = 0.25 nm = 1539.12 - 1538.87) can be used to calculate the fiber normalized birefringence. Since according to the Bragg condition, the center of the notch occurs at \( \lambda_{\text{fast/slow}} = 2n_{\text{fast/slow}} \Lambda \), where \( \Lambda \) is the grating period and \( n_{\text{fast/slow}} \) are the corresponding refractive indexes for polarizations parallel to the fast/slow axes of the fiber, then

\[
\frac{n_{\text{slow}} - n_{\text{fast}}}{n_{\text{ave}}} = \frac{\Delta n}{n} = \frac{\Delta \lambda}{\lambda} = 1.6 \cdot 10^{-4}
\]

This value is in good agreement with the manufacturer data (1.5 \( \cdot 10^{-4} \)).

At any other setting of the analyzer, the measured spectrum is a weighted average of the two principal spectra, see Fig. 4.

### 3 A TUNABLE RING FIBER LASER WITH A BIREFRINGENT GRATING REFLECTOR

A birefringent grating reflector was coupled to a unidirectional ring laser by means of a 3 dB coupler, see Fig. 5. The ring had an intracavity polarization controller. While quite a few schemes have been tested we hereby present one of the most promising configuration with a polarizer situated between the grating and the ring.
This configuration manifested a single lasing peak, which could be continuously tuned over 0.6 nm range, Fig. 6, through proper adjustments of the polarization controller. The operating mechanism of this laser and its relationships to other tunable fiber laser schemes, having an intracavity polarizer are under current study.\textsuperscript{4,5}

![Image](image.png)

Fig. 6: The laser output spectrum for different setting of the polarization controller

4. SUMMARY

A fiber Bragg grating as strong as 23 dB was imprinted into a high birefringent fiber, having only 0.5 dB level of radiation mode losses. The grating was found to have two polarization orthogonal Bragg resonance wavelengths, associated with the fiber fast and slow axes. A ring scheme of grating locked fiber laser with 0.6 nm tunability was also demonstrated.

5. ACKNOWLEDGMENTS

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6. REFERENCES


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