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Wavelength-switchable fiber ring laser using cascaded fiber Bragg gratings combined with amplitude modulator

Jianliang Yang [a,b,*], Swee Chuan Tjin [c], Nam Quoc Ngo [c], Ruitao Zheng [c]

[a] *SIF Universal Pte Ltd, 41 Science Park Road, #01-16 The Gemini, Singapore 117610*
[b] *Xiangtan University, Hunan 41110, People's Republic of China*
[c] *School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore 639798*

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Abstract

The wavelength-switchable fiber laser has been studied in this paper. A wavelength-switchable erbium-doped fiber ring laser constructed using cascaded five fiber Bragg gratings (FBGs) incorporated with amplitude modulator is achieved and switching over 5 separate wavelengths has been demonstrated. The output power is about −4 dB m, the 3-dB linewidth is less than 0.02 nm, and the side mode suppression ratio is more than 45 dB. The transit process of the wavelength switching from one wavelength to another is studied and the lasing competition is also investigated.

Keywords: Fiber Bragg grating (FBG); Erbium-doped fiber; Fiber ring laser; Wavelength-switchable fiber laser; Mode-locking

* Corresponding author.
E-mail address: ejlyang@yahoo.com.sg (J. Yang).

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1. Introduction

Multi-wavelength and wavelength switchable fiber lasers are of great interests, because they may serve as simple and compact sources for applications in wavelength division multiplexing (WDM) optical communications [1–6], differential absorption spectroscopy (DAS) measurements [7], and optical time domain reflectometer (OTDR) [8]. In addition, such lasers have excellent applications in sensors and characterization of systems that have wavelength dependent properties. Such kind of fiber lasers can be simply constructed with a ring configuration in which wavelength lasing can be generated by integrating FBGs in the laser cavity [9,10]. Furthermore, a unidirectional ring cavity design is well suited for attaining single longitudinal mode operation due to the lack of spatial hole-burning effect in the case of a traveling wave field in a ring cavity. In the paper, we present a wavelength switchable erbium-doped fiber ring laser source using cascaded fiber Bragg gratings combined with an amplitude modulator. The transit process of the wavelength switching from one wavelength to another is studied. The lasing competition is also investigated and the smallest wavelength separation in fiber laser is achieved at the room temperature.

2. Experimental setup

Many techniques for switchable lasers are mechanical, such as rotatable bulk gratings [8], mechanical optical switches (OCW) [5], choppers [7], and rotatable fiber-coil halfwave plate [11], or electronic, such as TE-TM converters [12], fiber filters [13], acousto-optic modulators [14], liquid crystal etalons [15], and integrated-optic arrays of DBR and DFB lasers [16]. However, in our configuration, an electro-optic modulator is incorporated in the laser cavity to achieve wavelength switching. We know that the lasing wavelength with a higher net gain will win the superiority in the oscillation process. Therefore, we can use modulator to induce a modulating cavity loss to the wavelengths that are to be suppressed and get a switchable lasing. Once the modulation frequency matches the round-trip frequency of certain wavelength, this wavelength will win the competition, switchable lasing is thus achieved. Our configuration of using an electro-optic modulator to achieve wavelength switching has overcome most disadvantages of mechanical switch such as bulk, long response times (therefore long switching times), poor repeatability, and short lifetime due to inherent mechanical abrasion. Compared with to other electric methods, the advantages of our configuration are also evident: electro-optic modulator introduces very low insert loss into the laser system; and most important, only one modulator is needed to achieve wavelength switching between multi-FBGs, and modulator is compatible with optical fiber and all these make the system compact, low-cost, and easy operating.

The switchable fiber laser configuration is shown in Fig. 1, the optical isolator is used to ensure unidirectional propagation, fused fiber coupler to direct light wave to FBGs and couple out the laser radiation, and cascaded FBGs to select the lasing wavelengths and form the resonator with multiple cavity lengths. A $LiNO_3$ amplitude modulator with an insertion loss of 4.3 dB is used for wavelength switching in the ring cavity. With the modulation frequency selected to match the round-trip frequency of the resonator, a modulation for the modulating cavity loss can be introduced into the laser cavity via the amplitude modulator.