



Contents lists available at ScienceDirect

Optics Communications

journal homepage: www.elsevier.com/locate/optcom

Wavelength-tunable passively mode-locked Erbium-doped fiber laser based on carbon nanotube and a 45° tilted fiber grating

Chuanhang Zou^a, Tianxing Wang^a, Zhijun Yan^b, Qianqian Huang^a, Mohammed AlAraimi^{c,d,e}, Aleksey Rozhin^{c,d}, Chengbo Mou^{a,*}

^a Key Laboratory of Specialty Fiber Optics and Optical Access Networks, Shanghai University, Shanghai 200072, PR China

^b School of Optical and Electronic Information, National Engineering Laboratory for Next Generation Internet Access System, Huazhong University of Science and Technology, Wuhan 430074, PR China

^c Aston Institute of Photonic Technologies (AIPIT), Aston University, Birmingham, B4 7ET, United Kingdom

^d Nanoscience Research Group, Aston University, Birmingham, B4 7ET, United Kingdom

^e Al Musanna College of Technology, Muladdah, Al Musanna, P.O.Box 191, P.C.314, Oman

ARTICLE INFO

Keywords:

Mode locked fiber laser
Erbium fiber laser
Carbon nanotube
Tilted fiber grating

ABSTRACT

A wavelength-tunable all-fiber Erbium-doped mode-locked fiber laser based on carbon nanotubes and 45° tilted fiber grating (TFG) is demonstrated. We investigated the effect of PDL of 45TFG in the tuning range of a mode locked laser. The central wavelength of the laser can be tuned continuously from 1559.85 nm to 1564.46 nm with a tuning range of 4.6 nm using a weak 45TFG and from 1553.37 nm to 1568.63 nm with a tuning range of 15.26 nm using a strong 45TFG. The laser maintains high signal to noise ratio >50 dB across all the wavelength tuning range.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Nowadays, wavelength tunable mode-locked fiber lasers have attracted significant interests because of their widespread application in biomedical research, spectroscopy, fiber-optic sensors, optical instrumentation and telecommunications [1–5]. A number of methods can be employed to realize the mode locking operation of a wavelength tunable fiber laser. To achieve passive mode locking, two major approaches can be employed including artificial saturable absorber (SA) and physical SA. The clear advantages of using fiber nonlinearity based artificial SA is its low cost and ease of implementation. Typical artificial SA consists of nonlinear polarization rotation (NPR) [6,7], nonlinear amplifying loop mirror [8,9], nonlinear loop mirror [10]. However, even wide band tuning can be achieved [11], the inherent polarization sensitivity of the lasers claims that tunability would inevitably break the mode-locking operation during wavelength tuning. Hence, a physical SA in addition to an intracavity tunable filter manifests to be a better option.

Although semiconductor saturable absorber mirror serves to be a sophisticated SA, the limited bandwidth is an inherent drawback of wavelength tuning [12]. Recently, the development of nanomaterial as advanced nonlinear photonic devices has successfully demonstrate physical SA with wide band response including carbon nanotube [13,14],

graphene [15,16], topological insulator [17,18], chalcogenide material [19]. Among these, although wavelength tuning have been demonstrated [20–23], the fabrication of 2D, topological insulator photonic device has not been shown to be highly mature. Carbon nanotubes, as a well-studied nonlinear photonic material, have exhibited excellent SA properties with comfortable performance in fiber laser applications. So far, various types of SA based on CNT have been demonstrated including filling in hollow core fiber [24], deposition on D-shaped fiber [25], deposition on tapered fiber [26], microfluidic injection [27] and sandwich structure [28]. Carbon nanotube polymer composite film offers special merits over the other methods such as well-developed fabrication procedures, ease of operation, robust, polarization insensitive thus rendering a better way of physical incorporation in the laser cavity.

The tunable filters incorporated in the mode-locked fiber laser cavity act as a key element for continuous wavelength tuning. By far, various types of tunable filters have been demonstrated for wavelength tuning in a mode-locked fiber laser including Fabry–Perot interferometer (FPI) [29], mechanical tunable filter [30], stretchable fiber Bragg grating (FBG) [31], and birefringence filter [32]. Both FPI and mechanical tunable filters are bulky therefore reduces the integrity of the fiber laser system. Although modified FBG could offer a wide tuning range,

* Corresponding author.

E-mail address: mouc1@shu.edu.cn (C. Mou).

<http://dx.doi.org/10.1016/j.optcom.2017.06.006>

Received 31 March 2017; Received in revised form 21 May 2017; Accepted 2 June 2017

Available online xxxx

0030-4018/© 2017 Elsevier B.V. All rights reserved.

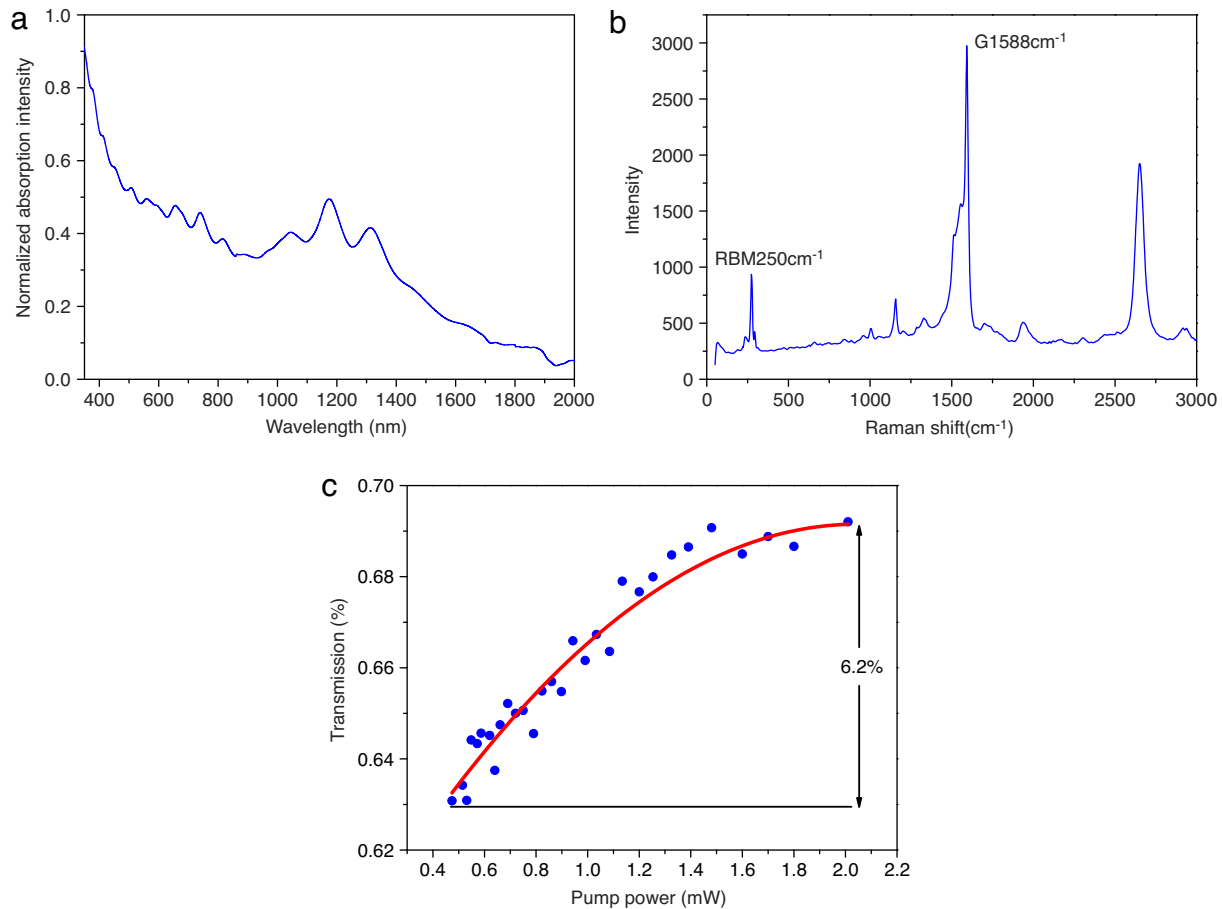


Fig. 1. (a) Measured absorption spectrum of the CNT-PVA film. (b) Measured Raman spectrum of the CNT-PVA film. (c) Measured nonlinear transmission of the CNT-PVA film.

the circulator in the laser cavity would induce extra loss. Recently, a new type of W-shape long period grating (LPG) has been developed for wide range mode-locked laser wavelength tuning [33]. However, such LPGs are difficult to fabricate and temperature sensitive. Due to the inherent fiber birefringence, the utilization of birefringence filter in a mode-locked fiber laser offers good opportunity for efficient wavelength tuning. To obtain intracavity birefringence filtering effect, a piece of high-birefringence fiber and polarizing element have always been employed [34]. The incorporation of either device would inherently introduce extra loss, complexity and cost of the laser system. It is therefore desirable to have a low loss and standard fiber compatible birefringence filter. The 45° tilted fiber grating (45TFG) inscribed in a standard single mode fiber (SMF) features huge *s*-light loss and negligible *p*-light loss is an ideal polarizing device to achieve intracavity birefringence filter. With the advantages of all-fiber structure, low fabrication cost, strong polarization dependent loss (PDL) and low insertion loss, 45TFG have been already applied in many fields such as spectrometer [35], in-fiber Lyot filter [36], single polarization fiber laser [37], mode locked fiber laser [38–40].

In this letter, we proposed and demonstrated a wavelength-tunable all-fiber Erbium-doped mode-locked fiber laser based on CNTs and 45TFG. The fiber laser is mode-locked by single wall CNTs-Polyvinyl alcohol (PVA) composite film. The polarization controller combined with the SMF based 45TFG forms an intracavity birefringence filter. When adjusting the polarization controller, the central wavelength of the laser can be tuned continuously. Two distinct 45TFGs have been examined to investigate the PDL effect on the laser tuning performance. The central wavelength of the laser can be tuned continuously from 1559.85 nm to 1564.46 nm with a tuning range of 4.6 nm using a weak 45TFG. A maximum tuning range of 15.26 nm from 1553.37 nm

to 1568.63 nm was obtained using a strong 45TFG. The demonstrated laser system features low cost, robust, all-fiber structure and compact design.

2. Characteristics of CNT SA

CNTs are fabricated through high-pressure CO conversion, which is commercially available and purified. As for the preparation of CNT-PVA composite film, firstly, 2 mg of carbon nanotubes are put into 10 mg of deionized water which mixed with 10 mg of sodium dodecylbenzene sulfonate (Sigma-Aldrich) surfactant, then ultrasonic treatment of the mixed solution for one hour using the commercial ultrasonic processor (Nanoruptor, Diagenode) under the condition of 200W. Secondly, centrifugation was (Beckman Coulter) carried out with the resulting solution for an hour under the condition of 25000RPM. The solution was then mixed with PVA powder and placed in a Petri dish. Finally, the CNT-PVA film can be obtained by placing the Petri dish containing the latest mixed solution in the dryer for several days. Fig. 1(a) shows the absorption spectrum of the CNT-PVA film with typical features of HiPCo CNTs between 1000 and 1600 nm. The absorption intensity at 1550 nm is close to 0.2. Measured Raman spectrum of the SWCNTs/PVA film under pump laser of 532 nm is shown in Fig. 1(b). From Fig. 1(b), we can see the frequency of the radial breathing mode (RBM) is 250 cm⁻¹ so the average diameter of SWCNTs can be calculated as ~0.88 nm [41]. The existence of RBM (250 cm⁻¹) and G mode (1588 cm⁻¹) proves that the carbon nanotubes are single walled. The CNT-PVA film does not show large amount of defects due to the weak D mode. We also measured the nonlinear transmission of the CNT-PVA film using the typical twin-power method as shown in Fig. 1(c). From Fig. 1(c), we can clearly see that the CNT-PVA film has 6.2% modulation depth which is ideal for laser mode locking.

Download English Version:

<https://daneshyari.com/en/article/7926656>

Download Persian Version:

<https://daneshyari.com/article/7926656>

[Daneshyari.com](https://daneshyari.com)