Erbium doped fiber lasers based on 45° tilted fiber gratings

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ABSTRACT

45° tilted fiber grating (TFG) possesses a series of merits, such as strong polarization dependant loss (PDL), low insertion loss, superior compatibility, and compactness. One of the most prominent features of such polarizing device is the all-fiber structure. This polarizing element plays an important role in all-fiber integrated systems which have been widely investigated in the last two decades. In this report, we reviewed the recent development in single wavelength, multiple wavelength, Q-switched, and mode locked fiber lasers based on the 45°TFG as in-fiber polarizer.

Keywords: *Erbium doped fiber laser, Fiber Bragg grating, mode-locked fiber laser, Q-switched fiber laser, single polarization*

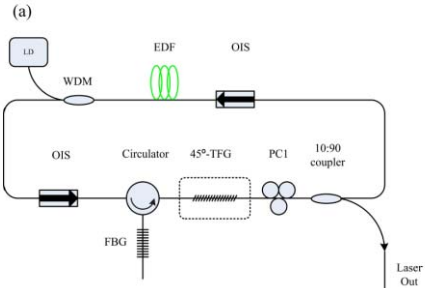
1. INTRODUCTION

Fiber lasers operating at C-band with strong emission at 1.55μm have drawn considerable attentions in different applications, such as optical communication, sensors, light source, laser manufacturing, metrology, and so on [1-4]. In contrast to the traditional solid laser sources, fiber lasers show dominant merits in many areas including compact design, low maintenance cost, great heat dissipation properties *etc*. Polarization is an important index to evaluate the quality of laser output. The 45° TFG employed in our laser cavity functions as a broadband in-fiber polarizer [5]. The TFG with asymmetric structure enhances intra-cavity birefringence to make laser oscillate in single polarization condition. Moreover, using a fiber laser cavity to generate polarized beam has raised great attractions. Covering all areas of both continuous wave (CW) and pulsed laser, single polarization plays a vital role in a resonant. In pulsed lasers, polarization induced nonlinear Kerr effect could dominate the formation regime of pulses.

In this report, both single and multiple wavelength fiber laser cavities have been demonstrated based on 45° TFG which can induce the polarization effect [6-7]. Besides, pulsed fiber lasers operating at Q-switching or mode locking regime have also been illustrated via the nonlinear polarization rotation (NPR) technique [8-9].

2. SINGLE WAVELENGTH LASER

Single wavelength, single polarization fiber laser is more desirable in both optical communication and sensing applications. Due to the very low birefringence of traditional optical fiber device, standard fiber laser configuration can not generate the polarized output. Light propagate through the 45° TFG used in our experiment can achieve single polarization oscillation based on the Brewster Law. Firstly, we constructed a standard single wavelength ring fiber laser which contains ~6 m Erbium doped fiber (EDF, Lucent Technologies), a section of single mode fiber (SMF), a 980/1550 wavelength division multiplexing (WDM), two optical independent isolators (OIS), a 10/90 output coupler, one in-fiber polarization controller (PC), a circulator and a fiber Bragg grating (FBG) with a reflectivity of ~97% and ~0.1 nm bandwidth, shown in Fig. 1(a). The typical single wavelength continuous wave (CW) is depicted in Fig. 1(b) which is recorded by the optical spectrum analyzer (OSA).



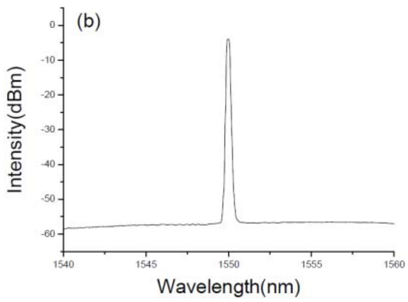


Fig. 1 single wavelength: (a) Schematic of the fiber laser with a 45° TFG. (b) Typical output optical spectrum.

3. MULTIWAVELENGTH LASER

Nowadays, with the rapid development of optical WDM communication system, optical sensing and metrology platform, multi-wavelength fiber lasers are under a wide range of surveys. The expanded experimental setup which supports quadruple wavelength lasing operation is shown in Fig. 2(a). The total cavity contains one WDM, a length of EDF, a 30/70 output coupler, one OIS, one circulator, two PCs, and three TFGs. All of the TFGs are employed as intra cavity polarizer and PDL filter. In order to vary polarization, PC1 is located between 45° TFG and 77° TFG, PC2 is placed after the 77° TFG. Four FBGs designed as seeding wavelength selectors are coupled into the laser cavity by using the circulator. Thus, we deposit the index matching gel on the end of FBG array to eliminate any background noise. A typical multi-wavelength output optical spectrum is obtained in Fig. 2(b).

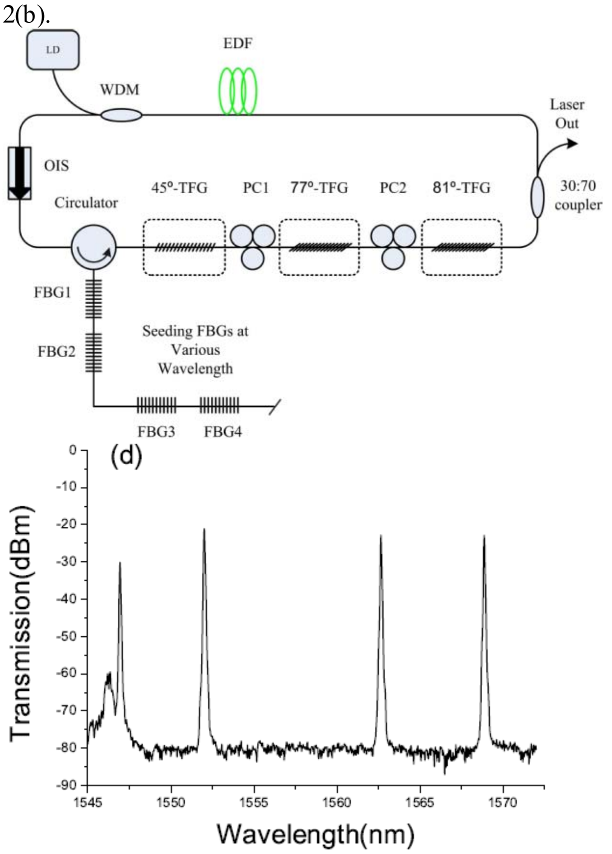
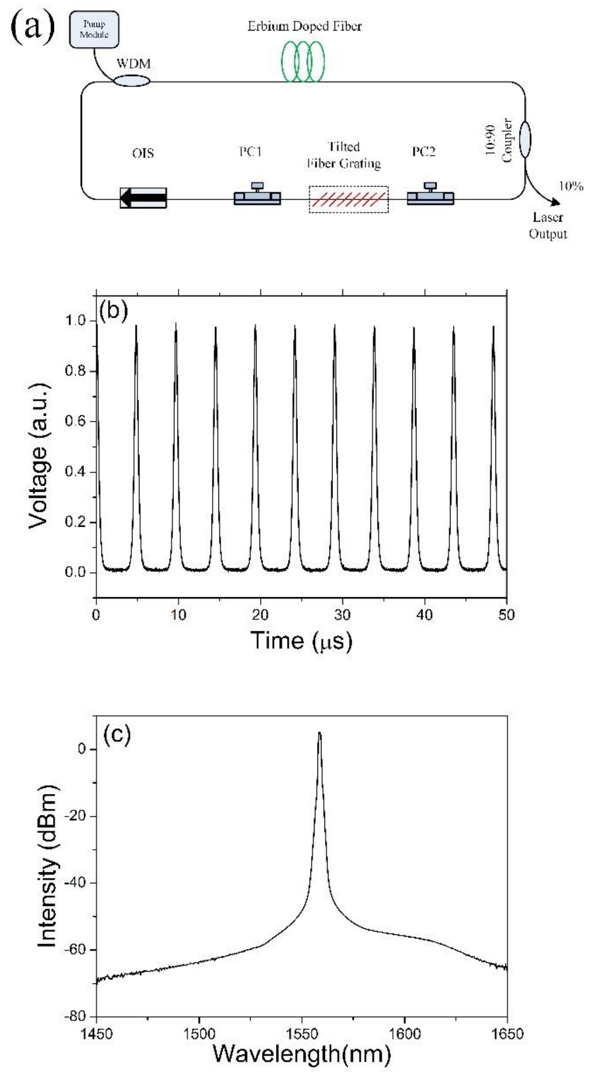


Fig. 2 Multi-wavelength: (a) Schematic of the fiber laser with TFGs. (b) Typical output optical spectrum.

4. PULSED LASERS

A large quantity of pulsed seed laser sources are needed in telecommunication, microscopy, laser manufacturing, metrology, and so on. In some areas, we need the pulsed laser source which possesses high single pulse energy. Thus, Q-switching technique is the most straightforward method to be adopted. However, in the other areas, high peak power of the single pulse is in the vital level. So, the mode locking technique is widely employed at the same time. We design the following schematic of the pulsed fiber laser with a 45° TFG shown in Fig. 3(a). The total part which contains two PCs and a 45° TFG functions as artificial saturable absorber to create pulse with the NPR technique. The traditional Q-switched pulse trains are depicted in Fig. 3(b). In opposition to the Q-switching, we can observe that much denser mode locked pulse trains as shown in Fig. 3(d). The Q-switched and mode locked optical spectrum is shown in Fig. 3(c) and Fig. 3(d), respectively, recorded by the OSA.



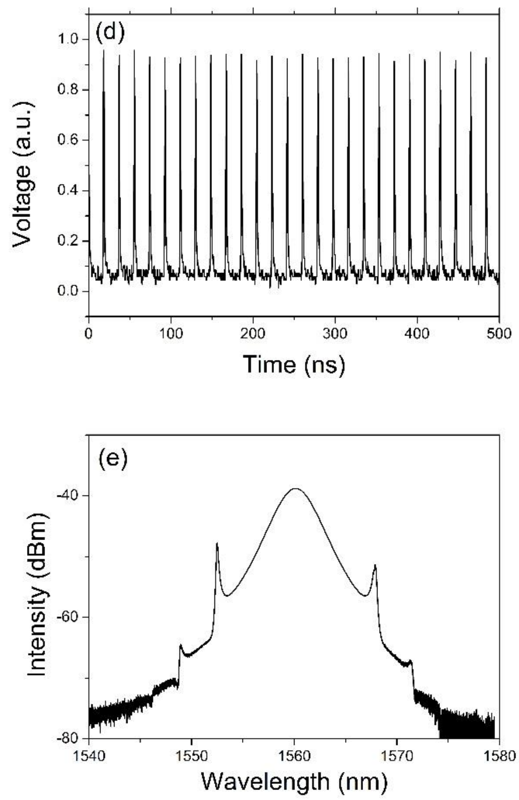


Fig. 3 (a) Schematic of the pulsed fiber laser with a 45° TFG. (b) Typical Q-switched pulse trains. (c) Typical Q-switched optical spectrum. (d) Typical mode locked pulse trains. (e) Typical mode locked optical spectrum.

5. DISCUSSION & CONCLUSION

Very recently, 45° TFG based fiber laser successfully support generation of sub 100fs generation from an Erbium doped fiber laser system. We anticipate further advancement of such novel device based laser in terms of output power, pulse energy, repetition rate, pulse width etc. Furthermore, due to the sophisticated fabrication procedure of UV grating devices, the performance of 45° TFG can be easily extended to other wavelength such as 1um, 2um which have already been demonstrated. Further enhancement of polarization properties with shorter grating length is another challenging topic in the development for compact laser systems. Least but not last, the inscription of such grating in the gain medium would offer more versatile applications in terms of both 45° TFG and fiber lasers.

In conclusion, we have investigated the different laser cavities based on the 45° TFG. Specifically, single wavelength, quadruple wavelength, Q-switched, and mode locked fiber laser is demonstrated, respectively. We expect that with the fast development of such novel polarizing grating devices, significant contributions can be obtained for the advancement of all-fiber laser systems across a broad operating wavelength regions.

6. ACKNOWLEDGMENTS

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