ULTRA-SHORT PULSES GENERATION USING A CARBON NANOTUBES SATURABLE ABSORBER

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3.0 Acknowledgements

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4.0 Report

Executive Summary

The field of fiber lasers and fiber optic devices has experienced a sustained rapid growth despite witnessing the infamous 'telecom bubble burst'. All-fiber optic devices have inherent advantages of relatively low cost, compact design, light weight, low maintenance, and increased vibration tolerances. In this research, Ultra Short Pulses Generation Using A carbon Nanotubes Saturable Absorber are investigated through experimental. At first, Q-switched Erbium-doped fiber lasers are demonstrated using a homemade passive saturable absorber (SA) based on single-walled carbon nanotubes (SWCNTs) and graphene oxide films. For instance, with the use of a SWCNTs-Polyvinyl alcohol (PVA) SA, the laser has a multi-wavelength output at 1533.5 nm region with a repetition rate of 13.1 kHz, the pulse width of 7.2 µs and pulse energy of 21 nJ at the pump power of 64 mW. Two mode-locked EDFLs are also demonstrated using a homemade SA based on SWCNTs. For instance, a stable mode-locked EDFL is demonstrated using SWCNTs-PVA SA to generate a dissipative soliton pulse train operating in 1533.6 nm region. At pump power above the threshold value of 35.2 mW, the EDFL generates a self-starting pulse train with duration of 1.8 ps and repetition rate of 15.3 MHz. Besides showing good Q-switching and mode-locking performances, the proposed new saturable absorbers are easy to fabricate and cheap. Finally, the EDFL produces a fixed pulse width of 2.8 µs and harmonic pulse repetition rate of 58 kHz. Q-

switched and mode-locked EDFLs have wide and important applications in many fields such as optical communications, laser micro-machining, optical sensors and laser ablation.

4.1 Introduction

At the heart of the fiber optics is the optical fiber, which acts as a transmission conduit for light encoded with information. Ever since the use of uncladded optical fibers in 1920, the technology of optical fibers has improved drastically. The continued improvement process has resulted in the removal of almost every single impurity in silicate glass fibers. Nowaday, a typical optical fiber has losses of the order of 0.15 dB/km at 1550 nm, which is very close to the theoretical lower limits of losses in a silicate glass (Agrawal, 2010). The concept of a fiber laser was firstly proposed and demonstrated by Snitzer in 1961 using a neodymium-doped fiber with a core diameter of around 0.3 mm (Snitzer, 1961a). The first fiber amplifier was also successfully demonstrated by Snitzer in 1964 (Koester & Snitzer, 1964). Early work on fiber lasers and fiber amplifiers were mainly focused on neodymium-doped multimode fibers which operate at 1060 nm. Since then, fiber lasers and amplifiers have always been an active research area but did not really take off or attract much attention until the laser 1980s after low loss rare-earth doped fibers were demonstrated (Poole et. al., 1986). So far, several rare-earth elements such as praseodymium (Wang et. al.,2014), neodymium (Rusu et. al., 2004), samarium (Farries et. al.,1988), holmium (Honzatko et. al.,2014), thulium (Holder et. al., 2012), erbium (Sulaiman et. al.,2012) and ytterbium (Kassim et. al., 2014) have been used as active dopants in fiber lasers. Neodymium, thulium, erbium and ytterbium are the most used active dopants in fiber laser based applications.

Recently, pulsed EDFLs have proved to be indispensable as they are useful in a variety of applications in both research and industry and their uses are expected to broaden. These applications vary depending on the wavelength, power and pulse width. For instance, short pulse duration and high peak powers are the two main characteristics of ultra-short pulses that have been useful in the analysis of materials. Pulses capable of delivering huge amounts of energy to very small areas have revolutionized manufacturing, and short duration pulses have made advances in high-speed imaging possible. Pulsed sources are generated using three basic methods: Q-switching, mode-locking and Q-switch mode-locking. The focus of this report is the generation of pulsed EDFL in Q-switched and mode-locked regime using both passive saturable absorber and nonlinear polarisation rotation (NPR) effect.

4.2 Motivation

Pulsed lasers have a broad range of applications ranging from industry to optical communication. For an instance, pulsed laser with high peak intensity and high pulse energy is suitable for micromachining and drilling which benefits the medical, electronic and automotive industry (Nikumb et. al., 2005). In the medical field, pulsed laser is used in eye and dental surgery (Plamann et. al., 2010; Serbin et. al., 2002). In eye surgery, ultra-violet (UV) laser is normally used to photo-ablate the corneal tissue rather than mechanical cutting which will somehow damage the surface layer or cornea and the surrounding cells. In the electronic semiconductor manufacturing industry, pulsed laser is used to mark information such as batch number, manufactured date and logo (Noor et. al., 1994).

There are many ways to synthesize Graphene to construct SA, such as by liquid phase exfoliation, chemical vapor deposition (CVD), carbon segregation, graphene oxide (GO), reduced graphene oxide (rGO) and micro-mechanical cleavage (Sun et al., 2012). Recently, Lin et al., 2013 produced graphene nanoparticles by electrochemical exfoliation and siphoning the graphene nano-particles into a multicore photonic crystal fiber (PCF) to develop a passive saturable absorber. This method shows that it is possible to exfoliate graphene at room temperature with minimal apparatus. In this report, electrochemical exfoliation of graphene is proposed and the graphene flakes produced is mixed with different host polymers (PVA and PEO) to develop graphene based passive saturable absorber for pulsed laser generation.

On the other hand, artificial saturable absorber such as Kerr-lens effect and nonlinear polarization rotation (NPR) absorber can also be used as passive saturable absorbers. In this report, Q-switched and mode-locked EDFLs are also demonstrated using an artificial SA based on NPR technique. This technique is simpler than the incorporation of SA since it requires less component in the cavity. In this approach, a polarization dependent isolator (PDI) is used in conjunction with a highly nonlinear Erbium-doped fiber (EDF) in a ring cavity to induce intensity dependent loss and initiate various pulse trains.