Analyses and Fabricate Saturable Absorber Film

for Q-switched Fiber Laser Application

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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ABSTRACT

In this work, the feasibility of employing graphene oxide as a saturable absorber (SA) to passive generate pluses in Q-switched at C-bands is investigated. Passive Q-switched lasers were previously manufactured utilizing semi - conductor saturable absorber mirrors with nonlinear polarization rotation. (NPR) (SESAMs). Recent research has shown that 2D materials like single-walled carbon nanotubes may also be used to create passive Q-switched lasers (SWCNT). At C-band areas, the performance of graphene saturable absorbers will be explored. A thin coating of graphene saturable absorber was created to enable for simple Incorporation into a fiber laser cavity. Graphene SA modulation depth with saturation intensity is found to be 66.5% and 0.710.61 MW/cm2, respectively. When put between fiber ferrules, Graphene SA developed self-starting passive Q-switched lasers in the C-bands. The repetition rate of the C-band Q-switched fiber laser increased as the pump power increased, from 4.25 to 47.90 kHz, while the pulse width decreased from 30.35 to 7.2 s. These discoveries demonstrated that graphene is an unique 2D material that may be utilized to create passive Q-switched devices for a range of photonic applications.

ABSTRAK

Tujuan kajian ini adalah untuk mengkaji daya maju menggunakan nanopartikel graphene sebagai penyerap tepu (SA) untuk menghasilkan denyutan bertukar-Q secara pasif dalam jalur-C. Pada masa lalu, laser Q-switched pasif dihasilkan menggunakan cermin penyerap tepu semikonduktor dan putaran polarisasi tak linear (NPR) (SESAM). Penyelidikan terkini menunjukkan bahawa bahan 2D seperti tiub nano karbon berdinding tunggal juga boleh digunakan untuk mencipta laser Q-switched pasif (SWCNT). Di kawasan jalur C, prestasi penyerap boleh tepu graphene akan diterokai. Salutan nipis penyerap boleh tepu graphene dicipta untuk membolehkan penyepaduan mudah ke dalam rongga laser gentian. Kedalaman modulasi dan keamatan tepu graphene SA diukur masing-masing 66.5% dan 0.71~0.61 MW/cm2. Graphene SA mencipta laser suis-Q pasif yang bermula sendiri dalam jalur-C apabila diletakkan di antara ferrules gentian. Apabila kuasa pam dinaikkan, kadar pengulangan laser gentian suis Q jalur-C meningkat daripada 4.25 kepada 47.90 kHz, manakala lebar nadi turun daripada 30.35 kepada 7.2 µs. Penemuan ini mendedahkan bahawa graphene ialah bahan 2D baru yang boleh digunakan untuk membina peranti Q-switched pasif yang boleh digunakan dalam pelbagai aplikasi fotonik.

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Figure 4.2 (b) shows how the pulse length and repetition frequency vary as the pump power increases from 128.4 mW to 244.6 mW.

The correlation between the output power and single pulse energy as well as the pump power is shown in Figure 4.2(c).

The projected EDFL's output spectrum while using GeO-SA is depicted in Fig. 4.2(d).

The RF spectra were measured, as depicted in Fig.4.2(e) and Fig.4.2(f).

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LIST OF SYMBOLS AND ABBREVIATIONS

EDF : Erbium-Doped Fiber

OSA : Optical Spectrum Analyzer

GO : Graphene Oxide

SA : Saturable Absorber

SESAM : Semiconductor Saturable Absorber Mirror

TI : Topological Insulator

CHAPTER 1

INTRODUCTION

1.1 Background

The fibre optics industry has grown tremendously. in the 1960s, with a significant emphasis on picture transmission via a bundle of glass fibre (Kapany, 1967). When fibre was first discovered, it produced losses that were up to 1000 dB/km below modern standards. However, after using the advice of (Kao & Hockham, 1966), silica fibre underwent significant modifications that revealed losses that were less than 20 dB/km (Kapron, Keck, & Maurer, 1970). Due to advancements in manufacturing technique, silica fibres were reduced to only 0.2 dB/km at 1.55 m wavelength region in the 1979s (Miya, Terunuma, Hosaka, & Miyashita, 1979). In addition to introducing fibre optic communications, the development of low-loss silica fibres also paves the way for novel nonlinear fibre optics applications in the future (Agrawal, 1997; L. Mollenauer, Gordon, Mamyshev, Kaminow, & Koch, 1997; Ramaswami, Sivarajan, & Sasaki, 2009), which ultimatelyearned Charles K. Kao the 2009 Nobel Prize in Physics. Researchers begin to investigate optical fibres in early 1972 that exhibit stimulated Raman and Brillouin scattering (Ippen & Stolen, 1972; Smith, 1972; R. H. Stolen, Ippen, & Tynes, 1972), optically produced parametric four-wave mixing, birefringence, and self-phase modulation (Hill, Johnson, Kawasaki, & MacDonald, 1978; R. Stolen & Ashkin, 1973; R. Stolen, Bjorkholm, & Ashkin, 1974). As a result of the 1980s discovery of the optical soliton, ultrashort optical pulses have been created (Gordon & Haus, 1986; Gouveia-Neto, Gomes, & Taylor, 1988; Islam, Simpson, Shang, Mollenauer,& Stolen, 1987; Kafka & Baer, 1987; L. F. Mollenauer & Stolen, 1984), and there has been an upsurge in research on pulse compression and optical switching (Nakatsuka, Grischkowsky, & Balant, 1981; Nikolaus & Grischkowsky, 1983; Shank, Fork, Yen, Stolen, & Tomlinson, 1982).

The nonlinear fibre optics industry has continued to grow due to the 1990s' increasing demand. Researchers have improved optical fibres by adding a rare-earth element to create amplifiers and lasers (Digonnet, 1993). Because of its effectiveness in amplifying light in 1.5 m wavelength region (C-band) and having the least loss, erbium-doped fibre amplifiers have attracted the most interest. Due to the volume of data transmitted at standard wavelengths, the S-band (1400–1530 nm) is a more recent transmission. By inhibiting an enhanced spontaneous emission (ASE) in the C-band area wavelength, its basic mode-cutoff of such depressed-cladding erbium- doped fibre (DC-EDF) is employed to create the S-band amplification (Chen, Chi, & Tseng, 2005; Yeh, Lee, & Chi, 2004).

Significant advantages of Q-switched technology include high pulse energy and small pulse width, which may be used in nonlinear optics (Geist, 1997; Stöppler, Kieleck, & Eichhorn, 2010), remote sensing, range finding, laser radar, biotechnology, spectroscopy, and communications (Kilpelä, Pennala, & Kostamovaara, 2001; Koechner, 2013; Kölbl Q-switching enables In order to employ active approaches, it is necessary to use equipment that is externally driven, such as electro-optic modulators (Delgado-Pinar, Zalvidea, Diez, Pérez-Millán, & Andrés, 2006; El-Sherif & King, 2003; Michelangeli, Giuliani, Palange, & Penco, 1986) and acoustic-optic modulators. The saturable absorber (SA), in contrast, offersadditional advantages for passive approaches due to its simplicity in integrating into laser cavity technologies, high level of reliability, and low price.

1.2 Problem Statement

I. This project will enable the improvement of the light energy source in multiple sectors.

II. Many factors are limiting our usage of the light source such as expanse material, high maintenance, and prominently is that the technology has not to be commercialized. Even a large number of experiments has been conducted yet we can’t choose the best material from a large number of Low -Dimensional (LD) material.

III. Lastly, we need to achieve controllable nonlinear optical parameters for LD material and high-performance ultrafast laser.

1.3 Research objectives and scope of research

In order to provide Q-switched operation in C-band (1530–1560 nm) wavelengths, the primary objective of this research is to employ graphene nanoparticles as a SA. The gain medium will be Erbium-Doped Fiber (EDF), that will be fed by a laser diode to achieve the necessary laser operating wavelengths.

Two nonlinear aspects of the GE thin-film that will be explored in orderto achieve the Q-switched operation are the modulation depth with saturation intensity of the graphene-nanoparticles. An oscilloscope, an optical spectrum analyzer (OSA), and an optical power metre will be used to examine the performance of Q-switched operating using trends for repetition rate and pulse width, laser spectrum, the laser output power (OPM)

- .To fabricate a material that able to achieve controllable nonlinear optical parameters for 2D material and high-performance ultrafast laser in mid-infrared waveband
- Create Q-switched laser mechanism is cheap and easy to fabricated
- Able to prepare LD materials with large size, high quality, and controllable layers while providing enhanced durability and shelf-life. With diagnosing in (EDF)

1.4 Scope

- Studies of Material.
- Fabrication of Material
- Testing Material in EDF
- Calculation and Analysis the Output of the material

CHAPTER 2

LITERATURE REVIEW

2.1 Background of laser and fiber optics

Fundamental laser ideas were identified in 1958 by Bell Telephone Laboratories' Charles Townes with Arthur Schalow (Schawlow & Townes, 1958). When Theodore Maiman, who'd been operating for Hughes Research Laboratories at the time, built the first practical laser in 1960, several types of lasers were invented from other researchers (Maiman, 1960). He accomplished this by using a ruby crystal. However, only a few of these havebeen shown to have practical uses across industrial, scientific, military, or commercial settings. Examples include air-cooled ion lasers, semiconductor diode lasers, and some helium neon laser (its first continuous-wave laser).

Light Amplification through Stimulated Emission of Radiation (LASER) is a high-power, continuous, monochromatic, collimated laser. These characteristics set a laser apart from other types of light, such as that produced by light bulbs. In comparison to a light bulb, a laser has a beam with a higher intensity. The laser beams are coherent when they have a fixed phase relationship with each other. Low divergence means the laser is well collimated. A laser may cover great distances while still emitting light with a strong intensity. Monochromatic denotes a laser's single wavelength of emission. The distinction between laser light and light from a light bulb is shown in Figure 2.1.

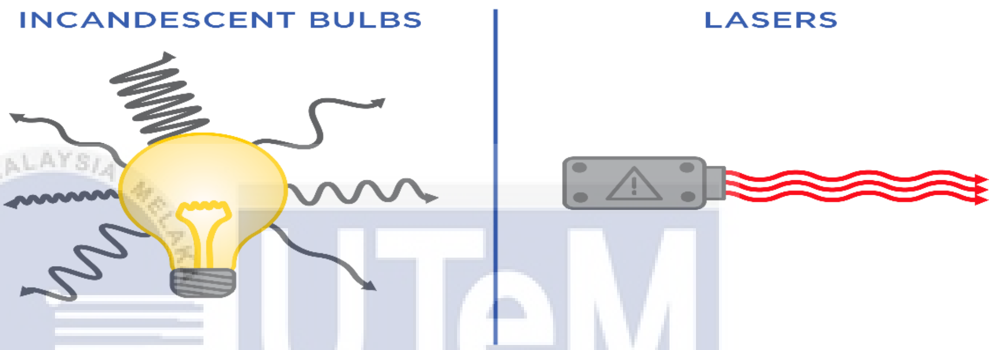

Figure 2. 1: The comparison between incoherent light bulb and coherent laser (Renk, 2012).

2.2 Fiber Optic

Transmission of light through extremely tiny glass or plastic fibres is known as fibre optics. Total internal refraction is the principle used to move light through fibre optics. Charles K. Kao and George A. Hockham from Standard Telecommunication Laboratories in the UK made a significant optical communication breakthrough in 1966. (Kao & Hockham, 1966). Prior to their groundbreaking breakthrough, fibre glass was thought to have the capability to transmit light. The unusually high signal loss from Rayleigh scattering meant that it was not appropriate. Kao and Hockham published their theories regarding the fundamental glass limitation in 1965. Their discovery enabled light attenuation to be successfully decreased to 20dB/km. In the past, fibre optics attenuated light by 1000 dB/km. Further research on the glass material revealed that the impurities contained inside it were the primary cause of the problem. In order to solve the issue, a new low-loss material was required. They tested a variety of materials and found that fused-silica (SiO_2) was a great contender.

Their astonishing finding sparked explosive growth in a wide range of photonics applications based on fibre optics. Ultimately, their finding led to them being awarded the 2009 Nobel Prize in Physics. Fiber optics has emerged as the new option to replace the existing copper connections as the demand for data transmission has increased. Compared to copper carbles, fibre optics has the following advantages:

i.) Compared to electrical conductors, fibre optics offers a high signal bandwidth (200 to 600 MHz-km for multimode (MM) fibres and more than 10 GHz for single mode (SM) fibres);

ii.) Fiber optics having low attenuation provide lengthier cable lines and lesser repeaters.

iii.) Optical fibres do not release any radiation and are not impacted by electromagnetic radiation,

iv) Optical fibres are simple to instal, lighter, and more economical than copper.

The four main components of an optical fibre are the core, cladding, buffer, and jacket. A thin core with core/cladding diameters of 8/125 m is utilized as the medium for light transmission. The cladding's refraction index must be lower than the core's refraction index in order to achieve 100% internal reflection. The purpose of the