UNIVERSITI TEKNOLOGI MARA

SHORT PULSE LASER GENERATION IN 1.5-MICRON REGION USING TRANSITION METAL-BASED SATURABLE ABSORBER

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ABSTRACT

Short-pulse fiber lasers have significant applications in many areas, including optical communication, biomedical, eye surgery, laser cutting, range finding, and spectroscopy. It outperforms bulk lasers in terms of flexibility and reliability, offering a promising platform for future fiber laser technology. The generation of these pulses, operating in a Q-switched and mode-locked regime, can be categorized as active or passive. The passive approach utilizing a saturable absorber (SA), an optical component that exhibits an intensity-dependent transmission, has gained great interest due to its simplicity of structure, low cost (without the need for expensive and complex electrically-driven modulators), and ability to achieve narrow pulse durations, high output power, and perfect beam quality. This thesis demonstrated the generation of a Q-switched and mode-locked laser through a passive approach based on a saturable absorber (SA). The newly developed SA was integrated into an erbium-doped fiber laser (EDFL) cavity to generate pulses operating in the 1.5-micron region. The proposed SAs are based on two-dimensional (2D) materials classified as transition metal oxide (TMO), transition metal dichalcogenide (TMD), and transition metal chalcogenide (TMC), whose elements are titanium dioxide (TiO_2), iron disulfide (FeS_2), and silver sulfide (Ag_2S), respectively. Their versatile properties, which are desired in photonics and optoelectronics applications, inspired this work. The SA is fabricated using the liquid phase exfoliation method. The fabricated SA, in the form of a thin film, is then physically characterized using a field emission scanning electron microscope (FESEM) and electron dispersion spectroscopy (EDS) to confirm the presence of the element in the device. The optical characterizations such as linear and nonlinear absorption measurements are also carried out. The SA device is integrated into the laser cavity to validate its performance. This is accomplished by sandwiching a piece of the SA film between two fiber ferrules. Overall, the potential of Ag_2S as a promising Q-switcher has been demonstrated through the generation of a Q-switched pulse with the highest repetition rate, highest output power, and highest pulse energy of 93.81 kHz, 5.07 mW, and 54.05 nJ, respectively. As for the mode-locked operation, the results show that FeS_2 is capable of providing a pulsed laser output with the shortest pulse width of 2.53 ps, the highest output power of 10.65 mW, and the highest pulse energy of 5.69 nJ. These findings show convincingly that the passive devices proposed in this work can generate short-pulse lasers and, in photonic applications, these materials hold great potential.

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CHAPTER ONE
INTRODUCTION

1.1 Background

Over the last two decades, photonics technology has advanced at a breakneck pace. One of the major focus areas in the development and improvement of photonic devices is the fiber laser. There has been a lot of tremendous progress in fiber laser technology since 1961 when the first demonstration of laser oscillation in glass was made [1]. Fiber lasers have evolved into an important device for laser light sources, enabling advancements in various fields such as laser processing in manufacturing [2], microscopy [3], spectroscopy [4], and medical applications [5], etc. A fiber laser uses optical fiber as the active gain medium. The optical fiber is doped with rare earth elements such as ytterbium, erbium, thulium, dysprosium, and neodymium. There are numerous advantages to utilizing doped optical fibers over their solid-state counterparts. For instance, the pump and light signal in the active gain medium is perfectly overlapping due to the optical fiber's waveguide nature. The fiber laser's construction is also completely alignment-free, as there are no free-space components in its design. The large ratio of the surface area to the volume of the fiber also eliminates the need for water cooling of the gain medium. Furthermore, optical fiber's single mode properties ascertain great beam quality [6]. In practice, fiber lasers are usually less expensive than solid-state lasers and more portable, which makes it easier for the system to be used outside of specialized laboratories.

Fiber lasers advanced dramatically in the 1980s, owing primarily to the availability of powerful and dependable laser diodes as well as the advancement of diode-pumped laser technology. The superiority of fiber lasers has outperformed other types of lasers such as dye, gas, chemical, solid-state, and semiconductor, and they are regarded as the most promising laser technology. Fiber lasers were not only efficient but also flexible and compact. Because of their high durability and excellent heat management to carry high optical powers, these lasers are capable of performing as powerful industrial high-power fiber lasers [7]. Most applications, in general, have mutual laser requirements. It necessitates the generation of optical pulses with the greatest possible amount of energy. A continuous-wave (CW) is one type of laser in