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TITANIUM ALUMINIUM CARBIDE (Ti_3AlC_2) AND LANTHANUM HEXABORIDE (LaB_6) AS SATURABLE ABSORBER FOR PULSE GENERATION IN 1.5 MICRON REGION

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ABSTRACT

Fiber laser applications are attracted to optical fibre because of its inexpensive cost, small size, and immunity to electromagnetic interference. The saturable absorber (SA) in the fibre laser cavity is essential for the passive initiation of pulses. As a result, the researchers have always been interested in SAs that can create pulse lasers with great performance and strong optical stability. The present saturable absorber has a small working bandwidth, a low damage threshold, and weak nonlinear optical properties. In this thesis, we have drawn attention to the two new materials used as SA, which are Titanium aluminium carbide (Ti_3AlC_2) and Lanthanum hexaboride (LaB_6). Titanium aluminium carbide (Ti_3AlC_2) is one of the materials which belong to the MAX phase compound. It has received great attention due to its resistance to high temperature. Next, lanthanum hexaboride (LaB_6) nanoparticles, an inorganic chemical of rare earths and refractory ceramic materials, it has attracted a lot of interest. The main goal of this research is to explore the potential of Ti_3AlC_2 and LaB_6 materials in pulse generation within the 1.5-micron region. In this work, two types of saturable absorbers (SAs) were prepared based on both materials using two approaches: thin film and deposited onto D-shape fibre. These SAs were also characterized in terms of physical property, linear, and nonlinear absorptions The SA devices with linear absorption (1.9 dB -7 dB) demonstrated the wide linear absorption, enabling the SA to produce pulses over a broad range of wavelengths. The modulation depth (0.6 % - 4.2 %) demonstrated the high saturable absorption, robust pulse shaping, and stable pulsed laser operation of the SA. To generate Q-switching pulsed laser, a small cut of SA thin film was sandwiched into two fibre ferrules and inserted into laser cavity. The mode-locked pulses were generated by adding a 100 m single mode fibre (SMF) inside the laser cavity to balance the total cavity dispersion which consequently promotes the mode locking action. The SAs produced based on D-shaped fiber and thin film structure were successfully used to generate Q-switched and mode-locked lasers in the erbium-doped fiber laser cavity, demonstrating the suitability of such SA devices in the all fiber-based cavity. This is the first demonstration of using LaB_6 material as a SA to generate pulses in the 1.5 µm range. The MAX phase Ti_3AlC_2 thin film generated a soliton mode-locked laser with a pulse width that was 5.02 ps shorter than that of other materials. Higher pulse energy for a Q-switching laser in a Ti3AlC2 thin film was 138.76 nJ. The development of a SA with strong nonlinear absorption, a high optical damage threshold, wavelength independence from bandgap, and a broad operational bandwidth was demonstrated by Ti_3AlC_2. These results indicate that sources for a variety of steady and reasonably priced pulsed laser generations, Ti_3AlC_2 and LaB_6, are equally promising. Short-pulsed lasers in the 1.55-m regime are essential for applications such optical fiber networking, remote sensing, material processing, and lasers.

Keywords: Titanium Aluminium Carbide, Lanthanum Hexaboride, D-shape fiber, Q-switched fiber laser, mode-locked fiber laser

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CHAPTER ONE

INTRODUCTION

1.1 Research Background

Optical fibre is a reliable, simple resonator, low-cost, stable, durable, and practical medium for transmitting optical signals. The use of optical fibre for communication was firstly proposed by Charles Kao in 1960s. Due to this great contribution, he was awarded the Nobel Prize in physics in year 2009 [1, 2]. As this optical fibre can confine the light propagation along a core area, the optical signals can be transmitted in a long distance with insignificant loss for communication applications. It also provides a new opportunity for the development of laser and lays a foundation for the development of fibre lasers [3-7]. Fibre 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. Fibre lasers have the advantages of small-weight, compact-structure, and no need for spatial alignment, which have been expected to be a new generation of lasers replacing solid-state lasers. They have been widely applied in plentiful of applications such as materials processing, fast diagnosis, nonlinear optics, biomedicine, communication etc. The mode operation of fibre laser can be continuous wave (CW) or pulse. A continuous wave (CW) laser light runs continuously with time. The phase and amplitude of the CW laser oscillate randomly which makes it more preferable in laser cutting, welding, and manufacturing [8].

Q-switching and mode-locking are two effective methods to produce short pulses. Q-switching technology can produce pulses with pulse duration from microsecond to nanosecond level and repetition rate in kHz regime through the modulation of the Q-factor or loss in the laser cavity. The pulse could be used to promote the interaction between matter and light for various applications including LIDAR, laser ranging, laser beauty, and holography. Compared with Q-switching, mode locking approach could produce lasers with other excellent characteristics such as higher peak power and narrower pulse width, which provides its extensive application in various fields, such as telecommunications, material processing,