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A Note on Thulium-doped Fibre Lasers with Ta2AlC-Deposited Tapered

Lei*

Department of Applied Physics, University of Eastern Finland, 70210, Kuopio, Finland

Perspective

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***For Correspondence**

Lei, Department of Applied Physics, University of Eastern Finland, 70210, Kuopio, Finland.

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PERSPECTIVE

The discovery of optical fibers by Charles Kao and George A. Hockam in 1966 gave the inroads for optical amplifier development with a wavelength range of 1.46–1.53 μm, 1.53–1.565 μm and 1.565–1.625 μm. Consequently, the development of laser configuration such as pulsed dual and multi wavelength and optical sensors has been the focus of many research laboratories. Although there have been numerous works on pulsed lasers operating at wavelengths of 1 μm and 1.5 μm, there is an increasing interest to generate short pulses in the 2 μm wavelength region for several applications such as in spectroscopy, gas detection, laser ablation, light detection and ranging (LIDAR) for remote sensing plastic and glass processing as well as in the medical field Lasing in the 2 μm is commonly achieved using thulium-doped fibers (TDFs) as the gain medium, as TDFs have a broad amplification range of 400 nm, ranging from 1700 to 2100 nm. The 2 μm wavelength regions is also of interest as it coincides with the absorption lines of water (H_2O) and several leading greenhouse gases such as carbon dioxide (CO_2) and nitrogen dioxide (NO_2). Although lasing in the 2 μm region has traditionally been demonstrated with continuous wave (CW) outputs, recent advances in fiber laser technologies have increased the development of 2 μm pulsed fiber lasers that can generate short pulses with pulse durations in the pico- or femtosecond range.

Pulsed laser generation can be achieved either by Q-switching or mode-locking. In the former, short pulses with high output energies can be produced using an optical component incorporated in the laser cavity to modulate the Q-factor. In the latter, the oscillating longitudinal modes present in the laser cavity are phase locked when an optical component is introduced in the optical cavity. Pulse generation in fiber lasers could be obtained using two main techniques; namely active and passive. Active techniques require the use of external modulators such as acousto-optic and electro-optic modulators it, however, causes the system to be bulky and inflexible due to the extra electronic components needed to be used.

In comparison, a passive technique allows for the development of a more compact and versatile system. Saturable absorbers (SAs) are used to saturate the molecules or atoms, whereby the optical absorption decreases as the light intensity increases. Due to this nonlinear optical response of SAs together with a narrow optical bandage, a high damage threshold, and a wide bandwidth, SAs are suitable devices to generate short pulses using the Q-switching and mode-locking techniques. SAs can be divided into two groups, namely artificial SAs and real SAs. Nonlinear Optical Loop Mirrors (NOLMs), Nonlinear Amplification Loop Mirrors (NALMs), or Nonlinear Polarization Evolution (NPE) is examples of artificial SAs. Artificial SAs are not suitable for commercialization due to its sensitivity to environmental changes and large size despite their positive attributes of near-instantaneous response time and high modulation depth. Semiconductors Saturable Absorbers Mirrors (SESAM), a real SA, were chosen as the SA of choice for nonlinear absorption property that depends on light intensity.

However, the disadvantages of SESAM are the operating bandwidth is narrow, complex design, costly, and has a low-damage threshold. In this work, we explored three different types of SA devices: the tapered fiber, the side-polished fiber, and the arc-shaped fiber to generate mode-locked pulses in the 2 μm wavelength region. A Ta2AlC MAX phase was first prepared in the solution form by ultra sonication Ta2AlC powder in isopropyl alcohol (IPA), deposited onto the three fibers. The MAX phase was composed of tantalum (Ta) as the early transition metal instead of the common titanium (Ti). Each of the SA devices was then individually inserted into a TDFL cavity to generate mode-locked pulses with frequencies between 9 and 11 MHz and pulse widths between 1.678 and 1.817 ps. The pump power of the laser cavity could be increased up to 1 W with all three devices, maintaining the mode-locking operation in the 2 μm without any damage to the SA devices. The results show the role of the SA devices as promising and robust SA devices for the development of high-power fiber lasers.