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Passive mode-locked Er-doped fiber laser pulse generation based on titanium disulfide saturable absorber

Key words: Fiber laser; Passive mode-locked; Saturable absorber; Titanium disulfide

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Motivation

1. Characterization of two-dimensional layered nanomaterials transition metal dichalcogenides (titanium disulfide), exploration of its nonlinear optical properties and applications in ultra-fast photonics.

2. Preparation of the titanium disulfide saturable absorber by the liquid-phase exfoliation and spin-coating methods.

3. Design of passive mode-locked Er-doped fiber laser based on titanium disulfide saturable absorber and its soliton analysis.

Main idea

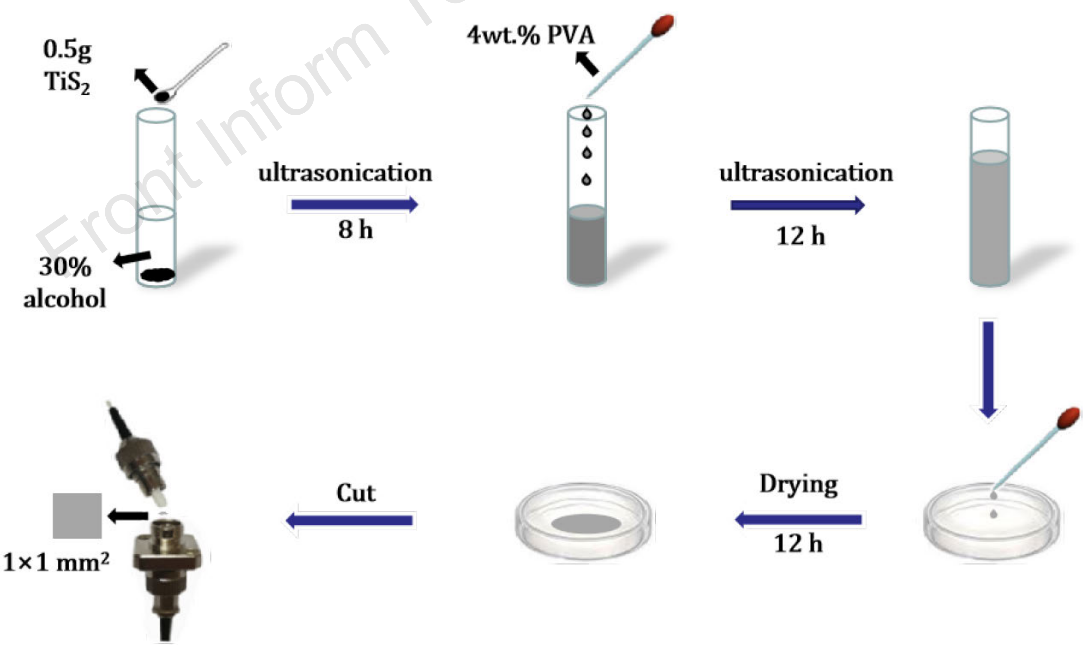
1. TiS_2 is a typical TMD material with layer structure and is made up of a Ti layer sandwiched between two S layers in an octahedral configuration.

2. It is of great significance to explore the nonlinear optical absorption properties of TiS_2 and expand the applications of TiS_2 in different fields.

3. The saturable absorber based on TiS_2 was prepared and applied in ring Er-doped fiber laser to obtain mode-locked pulses.

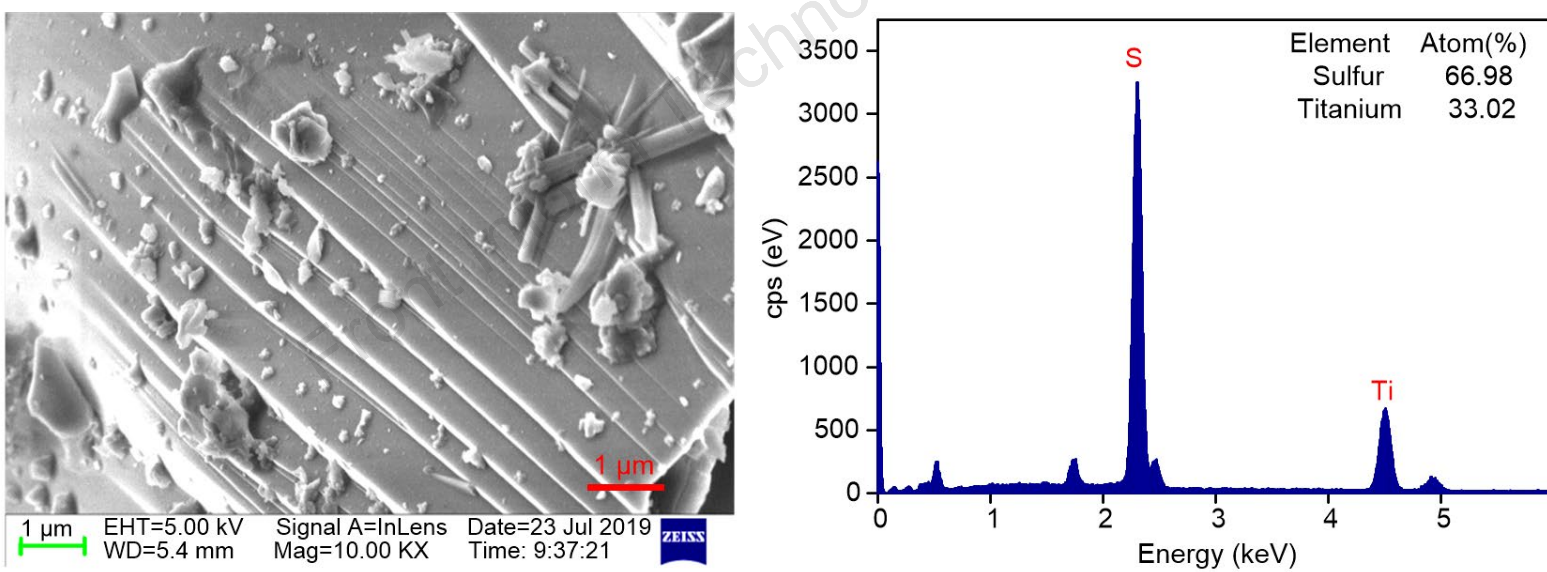
Sample preparation

The few-layer TiS_2 was produced from bulk sample by liquid phase exfoliation method. TiS_2 powder mixed with 4 wt.% PVA solution to obtain the TiS_2-PVA solution. The prepared TiS_2-PVA solution was spin-coated on a sapphire substrate to format the TiS_2-PVA film. Finally, a 1 mm×1 mm film was cut off and put on the end face of the fiber ferrule as SA.



Sample characterization

The surface morphology of samples and the corresponding energy dispersion X-ray spectroscopy spectrum was characterized. The results provided that the TiS_2 nanosheets prepared in the experiment have a layered structure with high crystallinity.



(a) (b)

Fig. 1 Scanning electron microscopy (SEM) image of TiS_2 powder (a), energy dispersion X-ray spectroscopy (EDS) spectrum of TiS_2 powder (b)

Sample characterization

The transmission of the TiS_2-PVA film at the wavelength of 1557 nm was about 81%. A power-dependent transmission technique was used to measure the nonlinear absorption properties of the TiS_2-PVA film-type SA. The fitting curve shows that the saturation intensity and modulation depth are 10.62 MW/cm^2 and 5.08%, respectively.

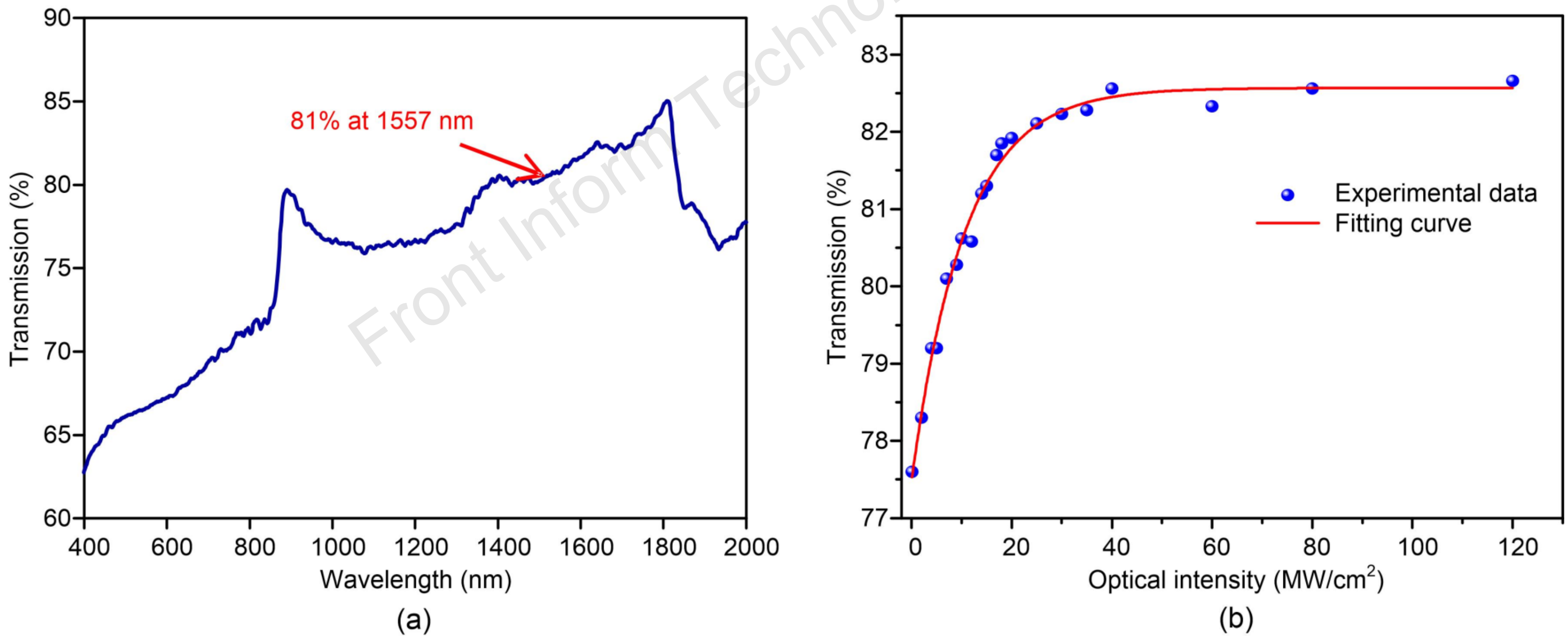


Fig. 3 Linear transmission of the TiS_2-PVA film (a) and nonlinear absorption curve of TiS_2-PVA SA (b)

Experimental setup

The net dispersion of the Er-doped fiber laser was calculated to be −2.75 ps^2. A polarization-independent isolator (PI-ISO) to ensure unidirectional propagation and a polarization controller (PC) were employed for adjusting the net birefringence. A 10% output coupler (OC) was used to direct the output signal.

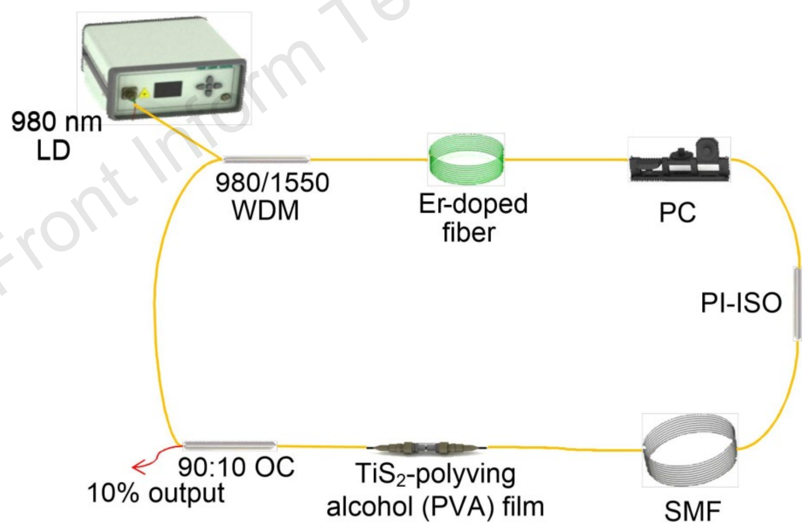


Fig. 4 Schematic of passive mode-locked fiber laser

Major results

Conventional mode-locked pulse

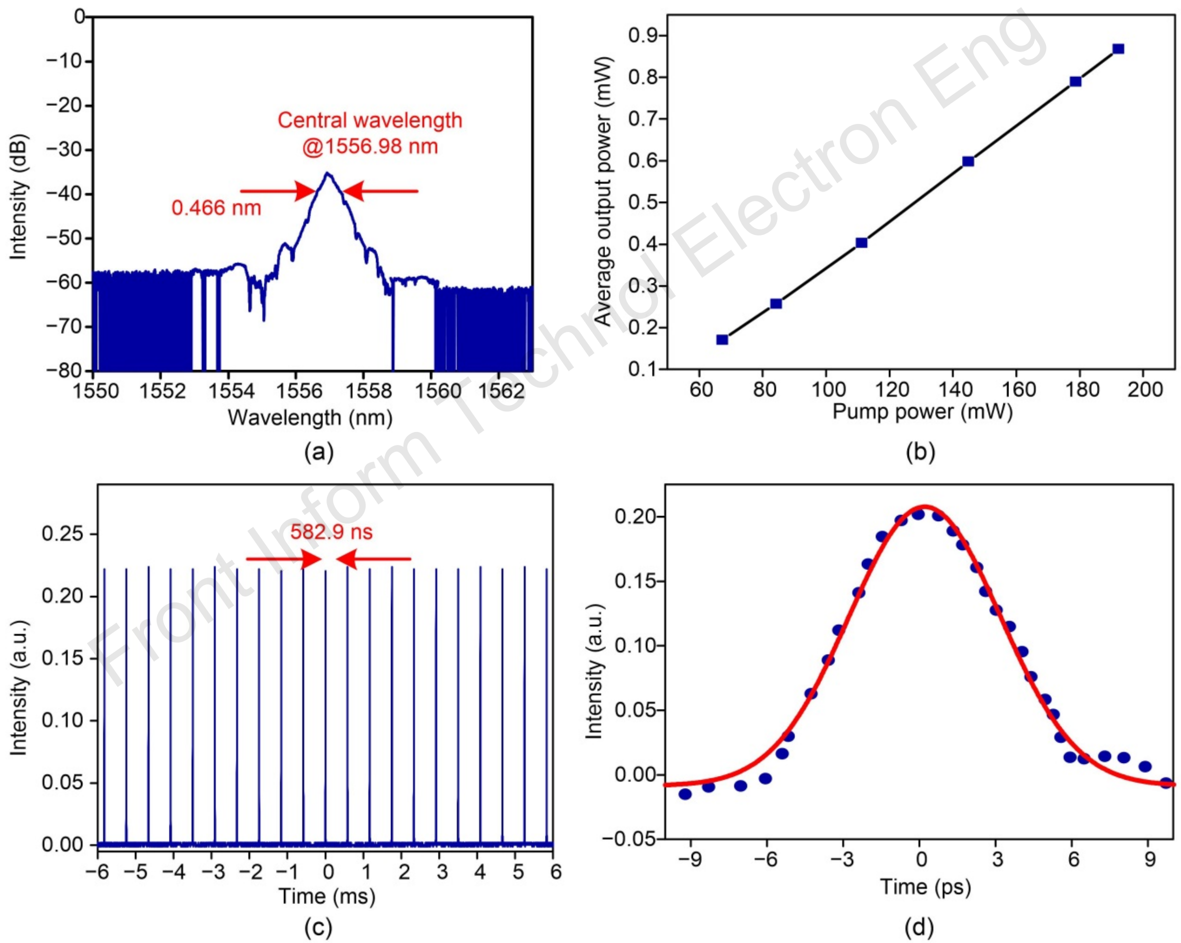


Fig. 5 Typical optical spectrum with obvious Kelly sidebands (a), the relationship between pump power and average output power (b), output mode-locked pulse train (c), and measured autocorrelation trace and its fitted curve (d)

Major results

The stability of TiS_2-PVA based mode-locked laser

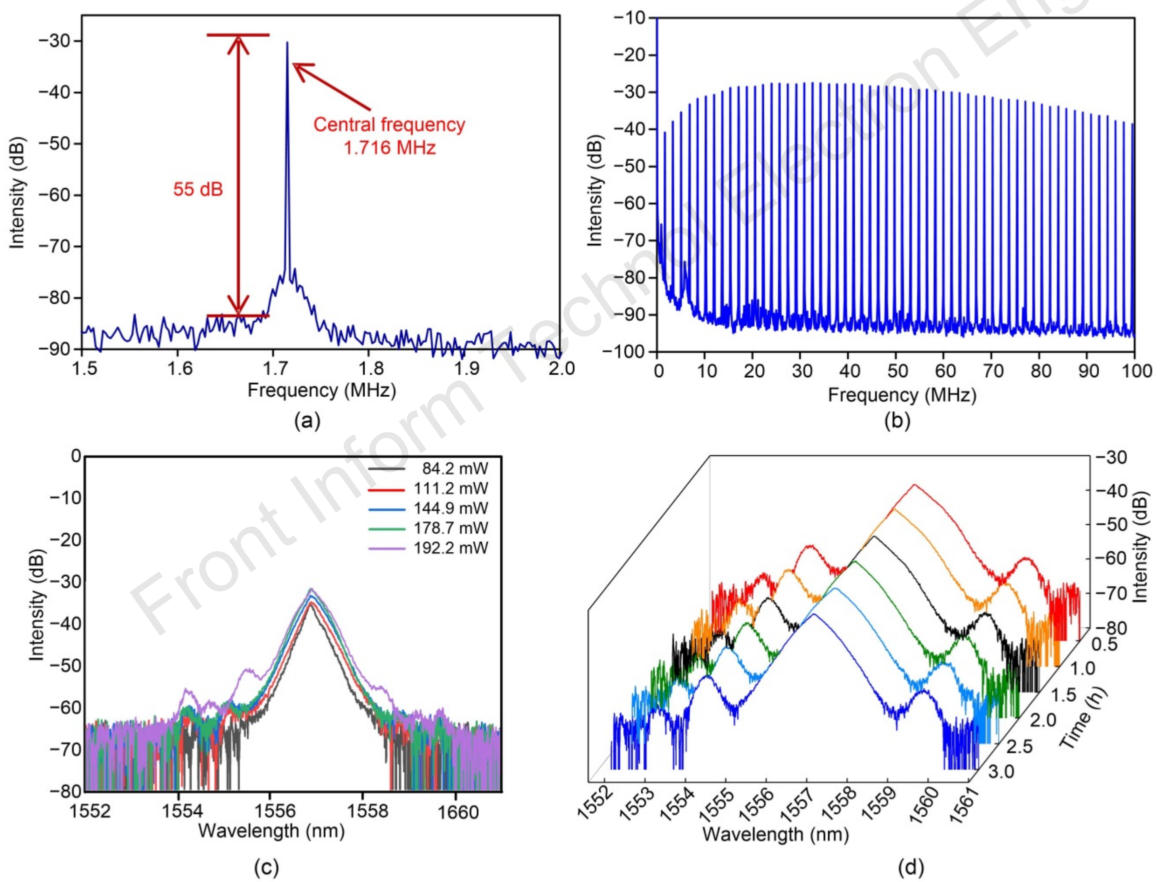


Fig. 6 Radio frequency (RF) spectrum at the fundamental frequency of 1.716 MHz (a), the higher harmonics on a span of 100 MHz (b), the change of the optical spectrum under different pump powers (c), and long-term stability: optical spectra measured at a 0.5 h interval over 3 h (d)

Major results

High energy mode-locked pulse

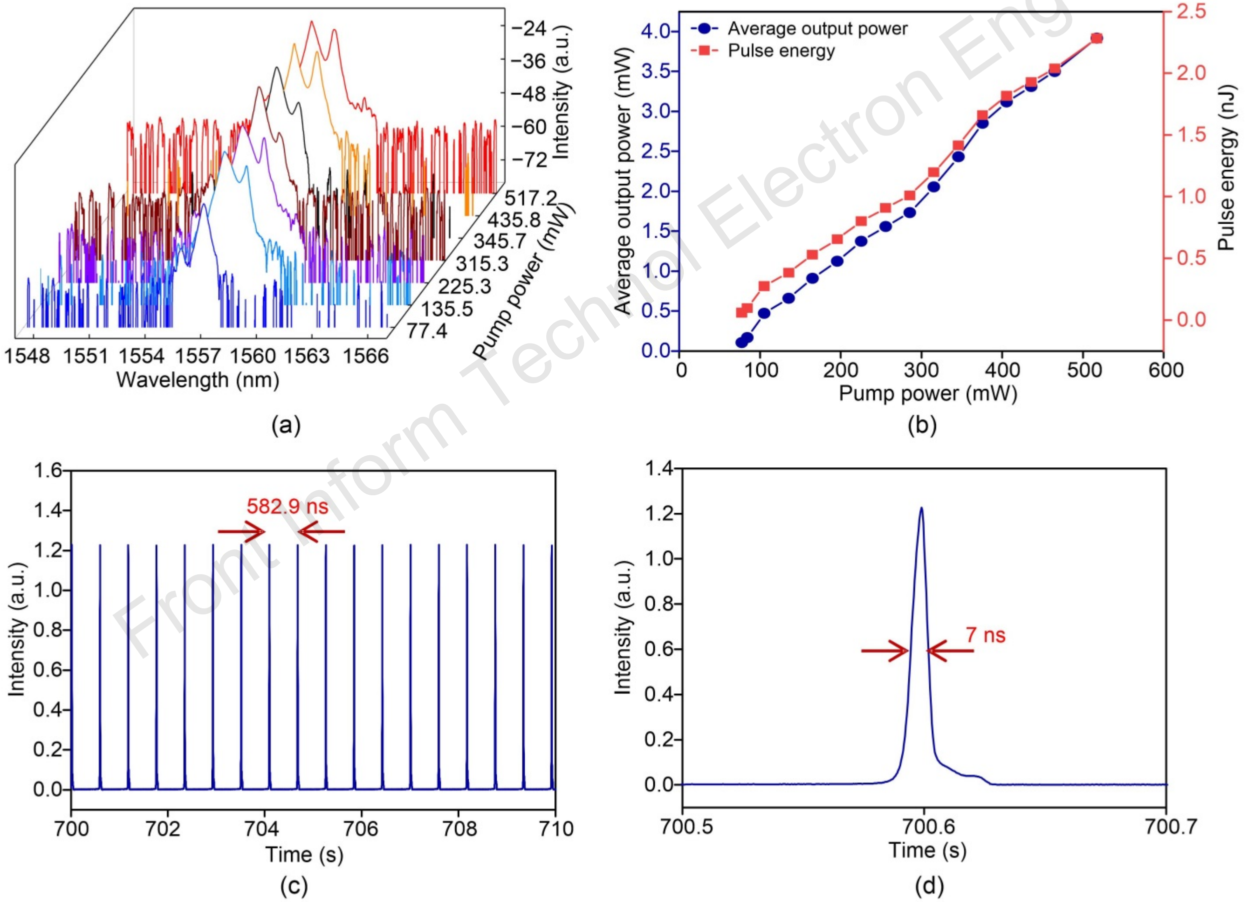


Fig. 7 Change of the optical spectrum under different pump powers (a), average output power and pulse energy performances with the increase of pump power (b), the pulse train at the mode-locked operation (c), and the corresponding single pulse profile (d)

Major results

The stability of the fiber laser

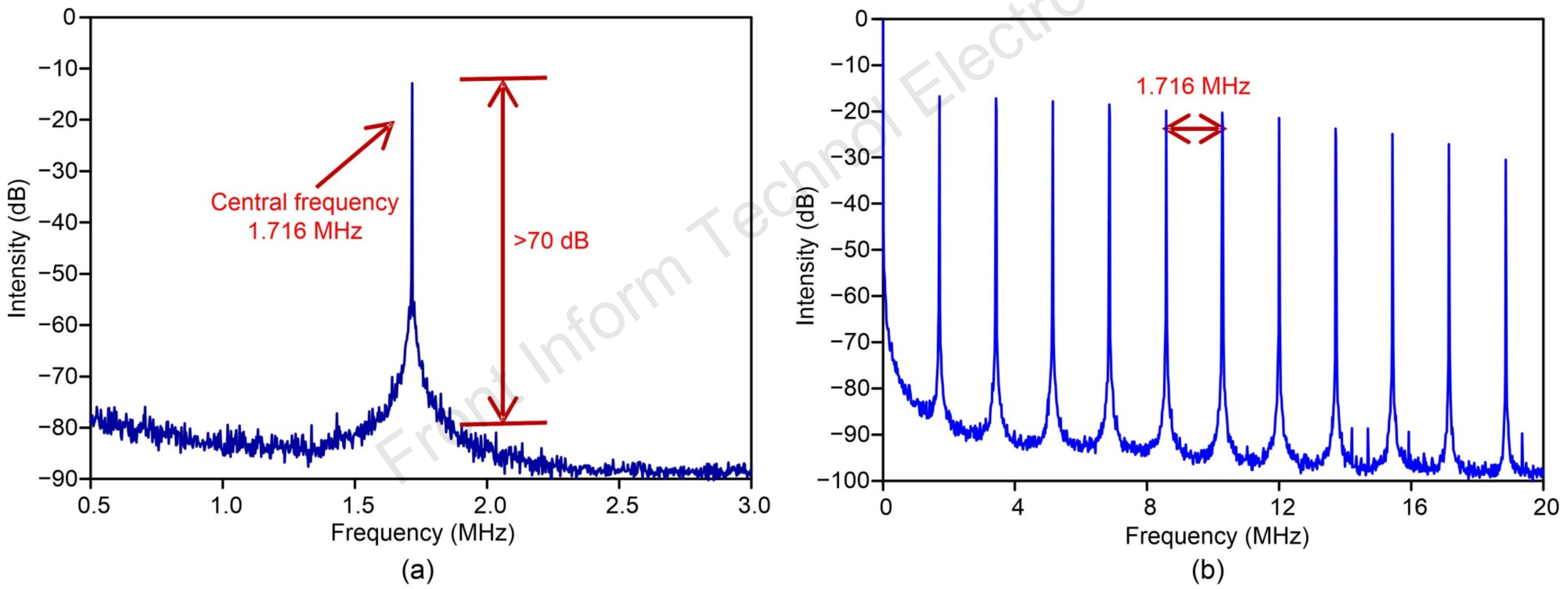


Fig. 8 The fundamental RF spectrum of the laser output (a) and the wideband RF spectrum up to 20 MHz (b)

Conclusions

1. The strong saturable absorption of TiS_2-PVA SA was demonstrated employing the liquid-phase exfoliation and spin-coating methods. The saturation intensity and modulation depth of TiS_2-PVA nanosheets were 10.62 MW/cm^2 and 5.08%, respectively.

2. We obtained both traditional mode-locked pulse and high pulse energy mode-locked pulse in an Er-doped fiber laser based on TiS_2-PVA nanosheet.

3. Experimental results revealed that TiS_2 nanosheets are promising ultrafast nonlinear optical materials for applications in mid-IR mode-locked fiber laser.

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博士，山东师范大学光学工程专业硕士研究生导师。2006年毕业于山东师范大学物理与电子科学学院，获物理学学士学位，2014年毕业于山东大学信息科学与工程学院，获无线电物理博士学位。2019年9月-2019年12月，担任台湾中山大学光电工程系访问学者。主要从事光学成像技术和高效能GaN基LED方面的研究，目前致力于超快成像技术和基于人工智能的便携式光学诊断设备的研究与开发。主持国家自然科学基金一项，山东省自然科学基金一项，参与国家自然科学基金重点项目（培育）一项，参与国家自然科学基金面上项目两项。

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本科就读于山东大学，后保送研究生。博士阶段在国家建设高水平大学项目资助下与澳大利亚悉尼大学联合培养，后在美国斯坦福大学和杜克大学从事博士后研究。主要从事电子信息和人工智能等新一代信息技术的应用研究，包括医学成像与分析、医学物理、医学仪器、超快光子学和光医学成像新技术研究。