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Traditional soliton erbium-doped fiber laser with InSe as saturable absorber

Key words: Fiber Laser; Nanosheets; Traditional soliton

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Motivation

1. Two-dimensional (2D) materials exhibit distinct properties compared with traditional materials, such as high damage threshold, fast response recovery, and excellent nonlinear absorption.
2. The pulsed fiber laser, which has been widely used in the fields of industrial manufacturing and biomedicine, and in scientific research, is typically applied in the field of 2D materials.

Main idea

InSe is a typical III-V group metal-chalcogenide compound, showing four covalently bonded Se-In-In-Se atomic planes. The adjacent layers are bonded through van der Vaals interactions. The nanosheets can be prepared by mechanical exfoliation or the liquid phase exfoliation (LPE) method.

Method

1. The dispersion solution of InSe nanosheets is purchased (Haolai Tech., China) (Fig. 1a).
2. The procedure for the fabrication of InSe-SA is shown in Fig. 1b.

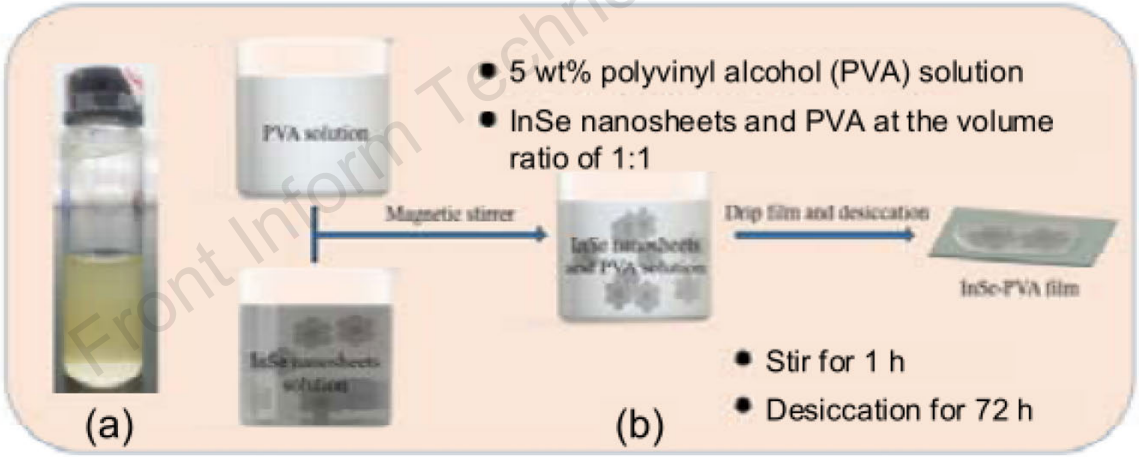
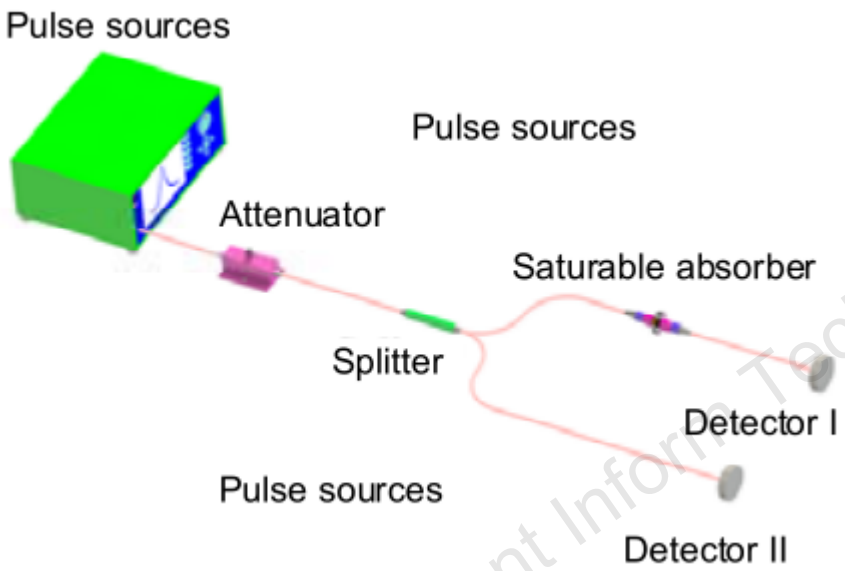
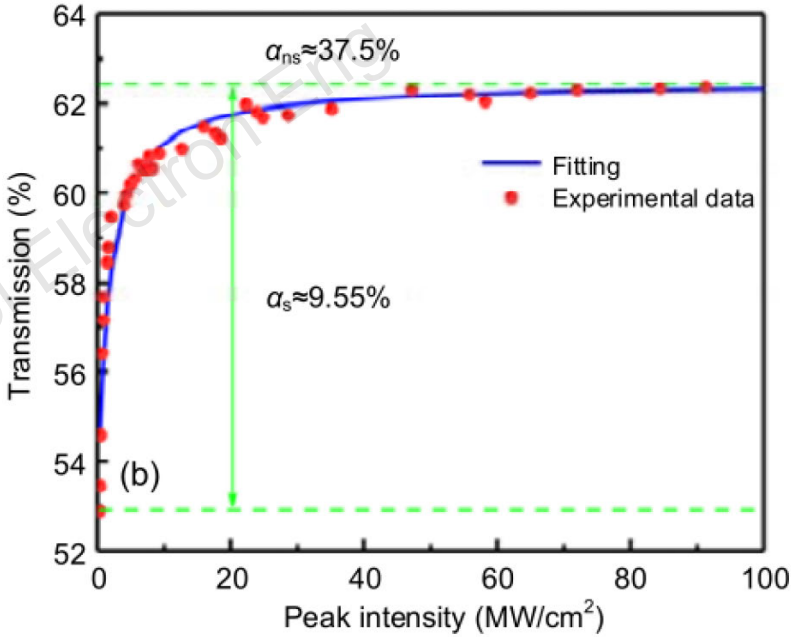


Fig. 1 The image of commercial InSe nanosheets dispersion solution (a) and the procedure for the fabrication of InSe-SA (b)

Method



Setup for measuring the saturable absorption properties



Measured and fitted nonlinear absorption properties of InSe-SA. The nonsaturable absorption and modulation depth are 37.5% and 9.55%, respectively.

Experimental setup

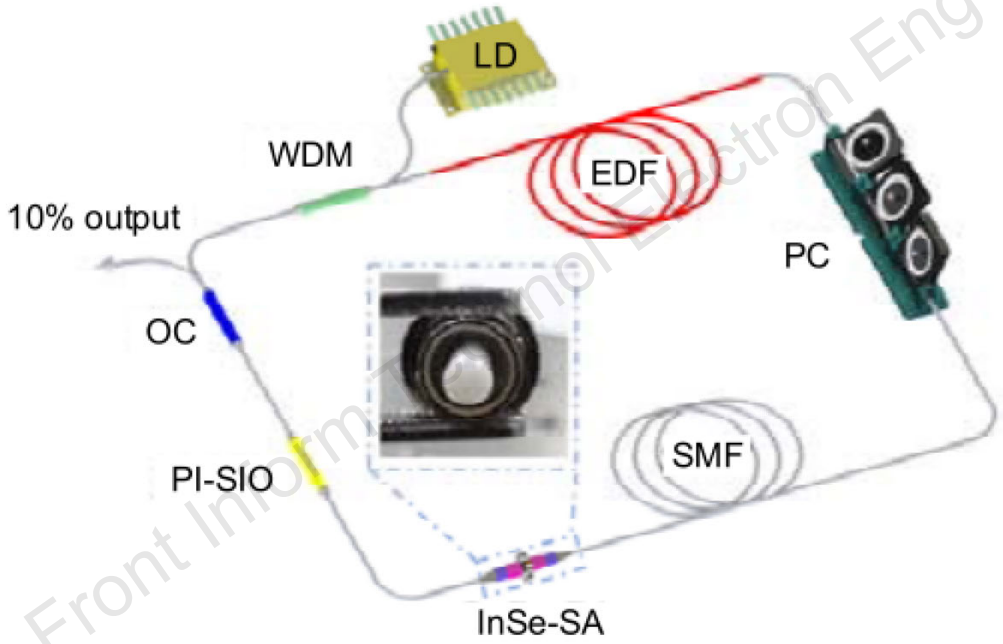


Fig. 4 Schematic of fiber laser setup

LD: laser diode; WDM: wavelength division multiplexer; EDF: erbium-doped fiber; PC: polarization controller; SMF: single-mode fiber; SA: saturable absorber; PI-ISO: polarization-independent isolator; OC: optical coupler

Major results

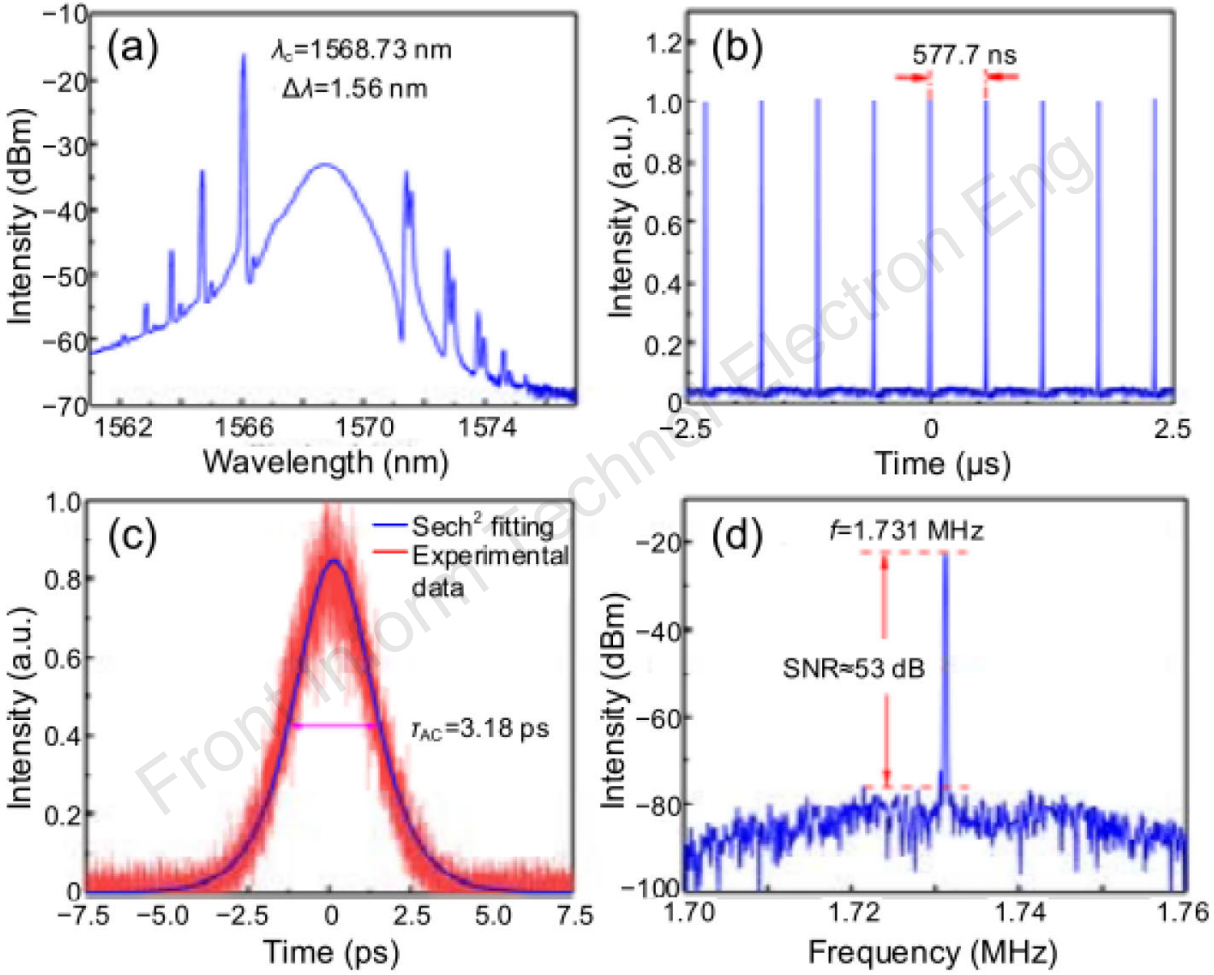


Fig. 5 Characteristics of mode-locked operation: (a) the spectrum with 3-dB bandwidth of 1.56 nm centered at 1568.73 nm; (b) the pulse interval of 577.7 ns between adjacent pulses; (c) autocorrelation trace for an output pulse with sech2 fit and the FWHM being 3.18 ps; (d) the RF spectrum with a fundamental repetition rate of 1.731 MHz and the SNR greater than 53 dB

Major results (Cont'd)

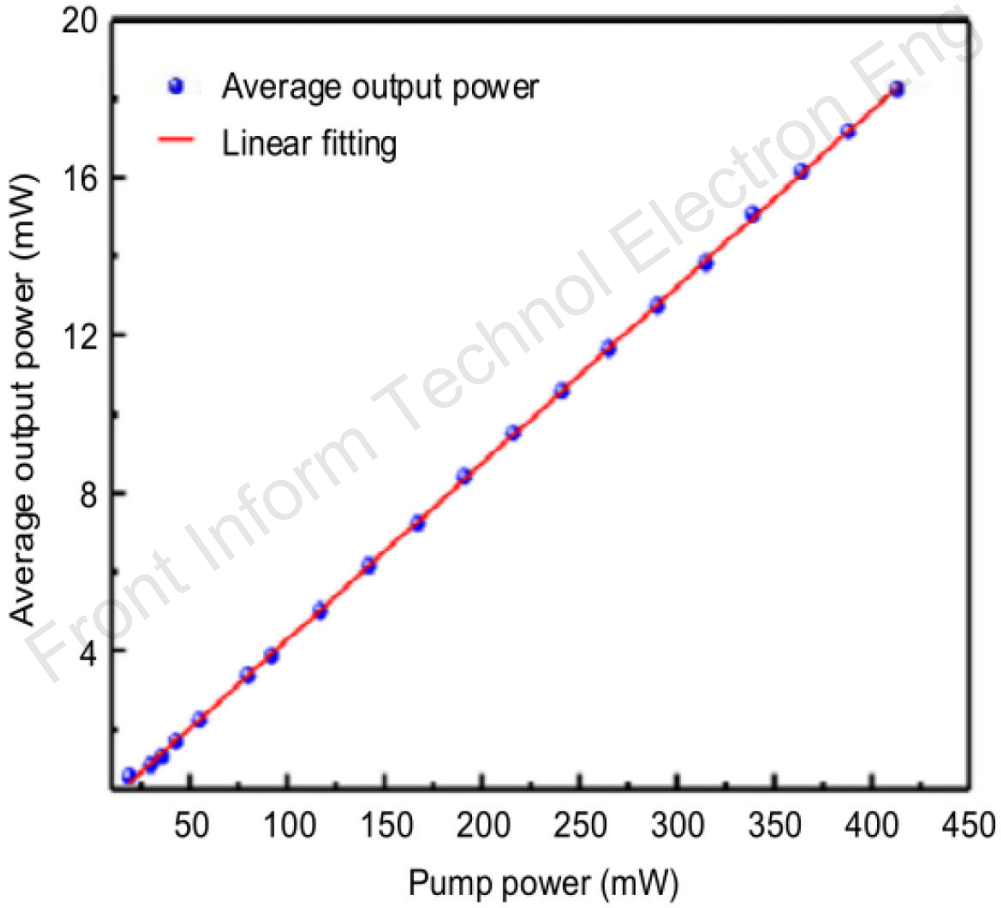


Fig. 7 The evolution of the average output power with the increase of the pump power

Major results

Table 1 Comparison of different In_2Se_3 or InSe based SA fiber lasers

Material	Material fabrication	SA fabrication	Modulation depth (%)	Operation	Central wave-length (nm)	Pulse duration	Reference
In_2Se_3	Mechanical exfoliation	Sandwiched	14.6	Mode-locked	1503.8	5.79 ps	Ahmad et al. (2018a)
In_2Se_3	Mechanical exfoliation	Sandwiched	22.48	Q-switched	Tunable	Tunable	Ahmad et al. (2018b)
In_2Se_3	Magnetron-sputtering deposition	Microfiber	4.5	TS	1565	276 fs	Yan et al. (2018)
			6.9	TS	1932	1.02 ps	
In_2Se_3	LPE	Sandwiched	14	TS	Switchable	1.88/1.76 ps	Wang GM et al. (2019)
InSe	LPE	Microfiber	3.4	Q-switched	Tunable	Tunable	Xu NN et al. (2018)
InSe	LPE	Sandwiched	4.2	Mode-locked	1068.36	1.37 ns	Xu NN et al. (2018)
InSe	LPE	Sandwiched	16.5	Mode-locked	–	389.2 ns	Fu et al. (2019)
InSe	LPE	Sandwiched	9.55	TS	1568.73	2.06 ps	This work

SA: saturable absorber; LPE: liquid phase exfoliation; TS: traditional soliton

Conclusions

1. The InSe-SA was obtained with the nonsaturable absorption and modulation depth being 37.5% and 9.55%, respectively.

2. The traditional soliton was obtained for the first time with InSe as the saturable absorber, whose central wavelength, pulse width, and repetition rate are 1568.73 nm, 2.06 ps, and 1.731 MHz, respectively.

3. The study further shows that InSe is a promising material for developing ultrafast optoelectronics devices.