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Preparation of ultrathin ReS_2 nanosheets and their application to Q-switched Er-doped fiber lasers

Key words: Rhenium disulfide; Saturable absorber; Two-dimensional materials; Q-switched fiber laser

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Motivation

1. Optical modulation is an important area for fundamental research and has specific applications.

2. Recently, two-dimensional (2D) materials, including graphene, black phosphorus (BP), and transition metal dichalcogenides (TMDs), have been proved to exhibit the saturable absorption (SA) property, and can be used as optical modulators to obtain pulsed output in a fiber laser.

3. However, there are some defects in the application of these 2D materials to lasers.

4. It is of great significance to explore novel 2D materials with the SA property.

Main idea

1. ReS_2 is a special member of TMDs. In contrast to other TMDs, the monolayer ReS_2, few-layer ReS_2, and bulk ReS_2 are all direct semiconductors.

2. The bandgaps of monolayer and bulk ReS_2 are 1.44 and 1.35 eV, respectively, showing a small bandgap difference. The physical properties of ReS_2 have little dependence on the layer number, showing a great chance of being used in practical applications.

Method

1. ReS_2 powder was synthesized from rhenium powder and sulfur powder by a simple synthesis method. Ultrathin ReS_2 nanosheets were prepared from ReS_2 powder by liquid phase exfoliation.

2. ReS_2 nanosheets were mixed with PVA solution to form ReS_2/PVA film, which can be used in optical modulation.

3. The ReS_2/PVA film can be directly inserted into the laser cavity with the fiber connector.

Major results

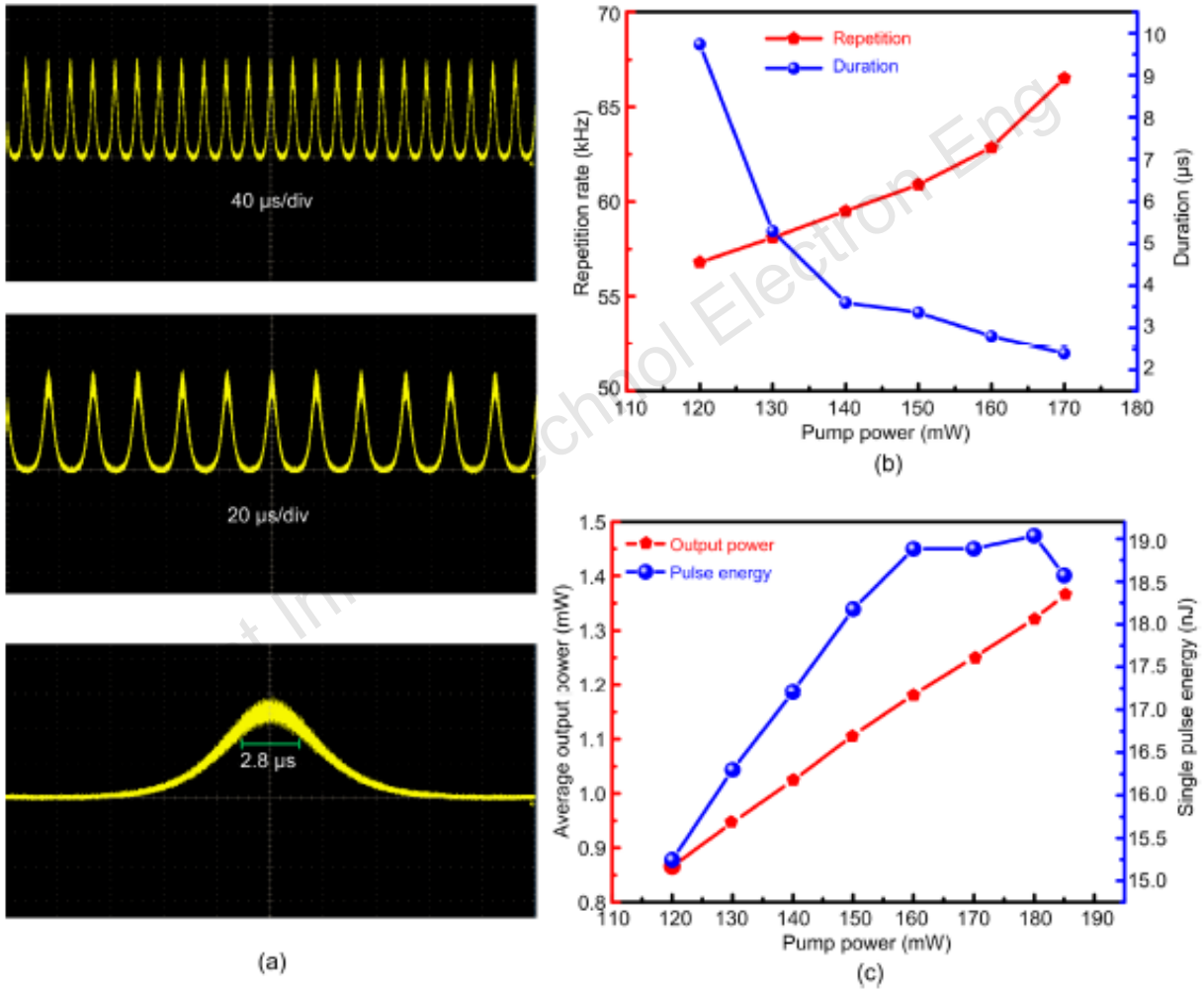

Fig. 4 (a) Q-switched pulse trains in different scales obtained at a pump power of 160 mW; (b) repetition rate and pulse duration vs. pump power; (c) average output power and single pulse energy vs. pump power

Major results

Table 1 Performance comparison of Q-switched Er-doped fiber lasers based on different TMDs

Material	Pulse duration (μs)	Maximum output power (mW)	Repetition rate (kHz)	Maximum pulse energy (nJ)	Reference
MoS_2	23.3–5.4	1.70	6.5–27	63.20	Luo et al. (2014)
WS_2	3.4–1.1	16.40	79–97	179.60	Zhang M et al. (2015)
$ReSe_2$	16.5–4.98	0.76	6.64–21.04	36.00	Du L et al. (2018)
$PtSe_2$	4.6–0.9	11.34	20.5–79.2	143.20	Zhang K et al. (2018)
PtS_2	9.6–4.2	1.10	18.1–24.6	45.60	Wang XY et al. (2018)
ReS_2	7.4–2.1	2.48	43–64	38.00	Xu et al. (2018)
ReS_2	23–5.496	1.20	12.6–19	62.80	Mao et al. (2018)
ReS_2	9.74–2.4	1.25	56.8–66.52	18.88	This work

Conclusions

1. Ultrathin ReS_2 nanosheets were prepared from the prepared low-cost ReS_2 powder.
2. XRD pattern, Raman spectrum, XPS spectra, and EDS results indicated the successful preparation of ReS_2. The thickness of ReS_2 nanosheets was below 5 nm according to the AFM results.
3. The ReS_2-based Q-switched fiber laser was realized with a minimum pulse duration of 2.4 μs and a repetition of 66.52 kHz, indicating the potential application to optical modulation.

Lili TAO received her MS degree in materials science from East China University of Science and Technology in 2009 and her PhD degree in applied physics from The Hong Kong Polytechnic University in 2014. She became a full associate professor at Guangdong University of Technology from 2016. Her current research interests are 2D materials and ultrafast photonics. She has authored and co-authored more than 40 peer-reviewed papers in journals including *Adv Mater*, *Nanoscale*, *Photon Res*, *Opt Lett*, and *Opt Expr*.

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