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Sb₂Te₃ topological insulator for 52 nm wideband tunable Yb-doped passively Q-switched fiber laser

Key words: Topological insulator; Sb₂Te₃; Fiber laser; Passive Q-switching laser; Wavelength-tunable laser

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Motivation

1. Owing to their excellent nonlinear optical characteristics, tunable energy bandgap, and easy processing, various two-dimensional (2D) and quasi-2D materials have become popular choices as modulators in optical devices and pulse fiber laser generation in the past few years.
2. As a typical topological insulator that possesses saturable absorption and giant third-order nonlinearity characteristics, Sb_2Te_3 has also been widely investigated for pulsed laser.
3. Wavelength-tunable laser sources have attracted a lot of attention due to the pressing need in spectroscopy, optical communication, biomedical science, and other fields. Wavelength-tunable Q-switched fiber lasers based on various 2D saturable absorber (SAs) have been widely investigated, but most of them operate at the 1.5 μm region.

Main idea

1. Synthesize high-quality Sb_2Te_3 crystal.
2. Prepare Sb_2Te_3 SA for generating pulse laser.
3. The Sb_2Te_3 SA was introduced into the laser ring cavity. A wideband tunable Yb-doped passively Q-switched fiber laser could be realized with the help of a wavelength-tunable filter.

Method

1. High-quality Sb_2Te_3 crystals were synthesized via the flux zone method.

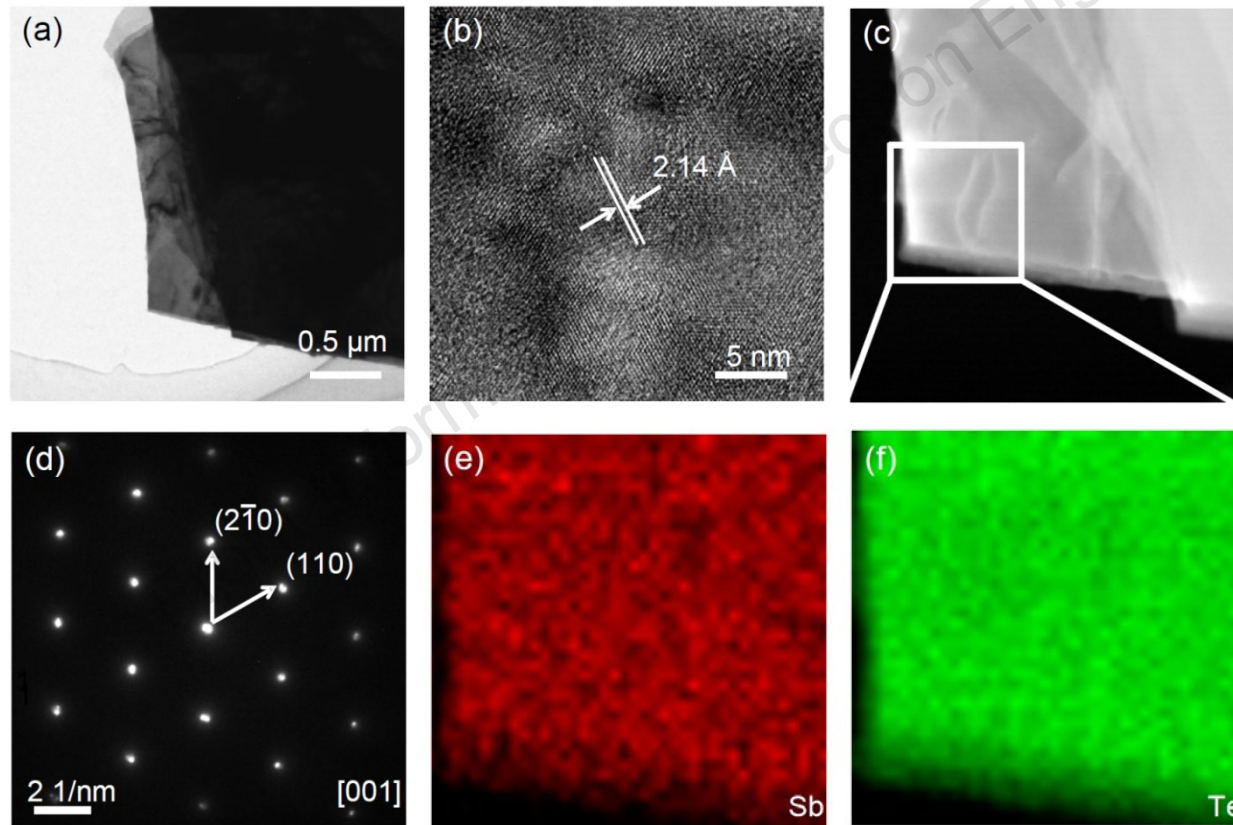


Fig. 1 Transmission electron microscopy (TEM) characterization of the Sb_2Te_3 sample: (a) TEM image of the Sb_2Te_3 sample on a copper grid; (b) high-resolution TEM image of the Sb_2Te_3 sample; (c) HAADF-STEM image; (d) corresponding SAED pattern showing its single crystal nature; (e) elemental mapping of Sb; (f) elemental mapping of Te

Method (Cont'd)

1. High-quality Sb_2Te_3 crystals were synthesized via the flux zone method.

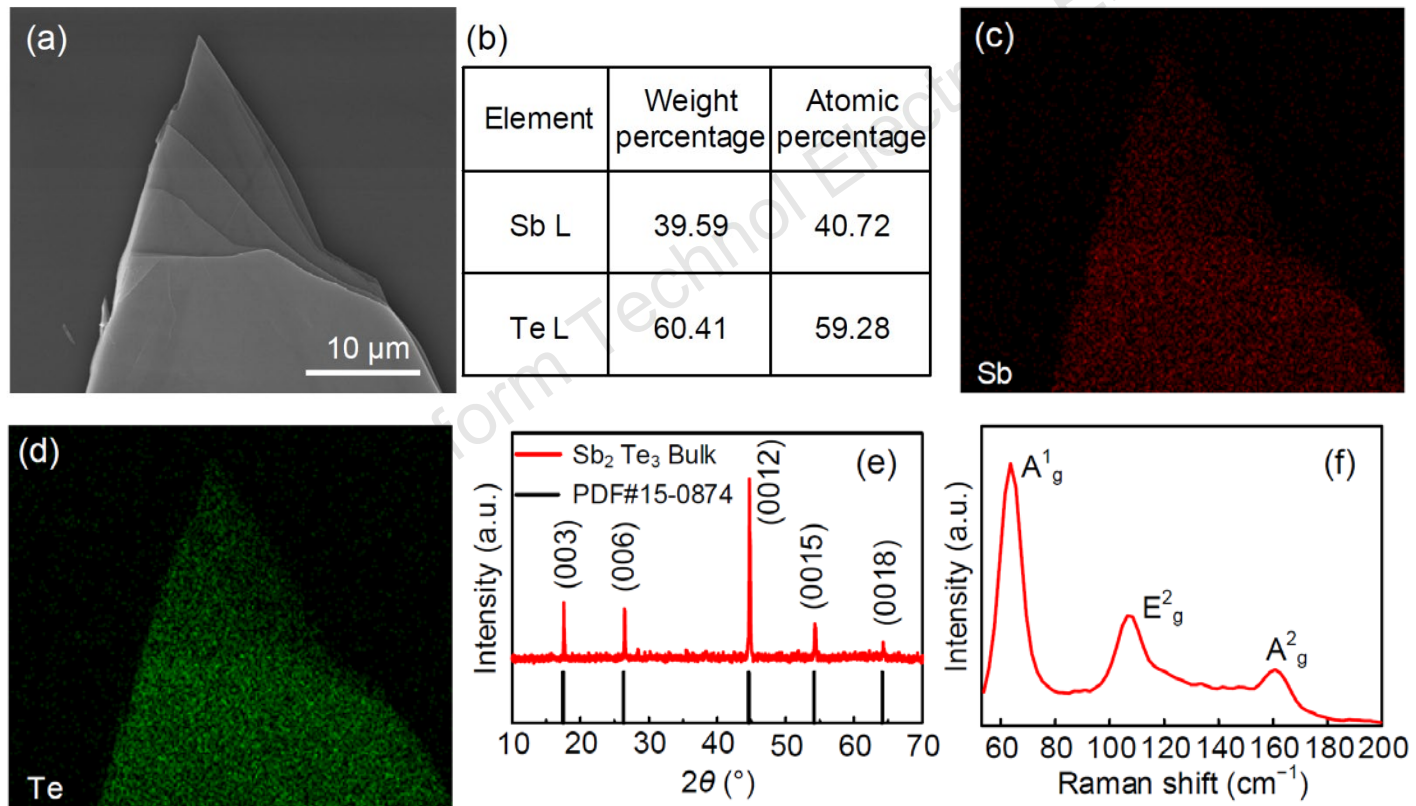


Fig. 2 Characterization of as-grown samples: (a) SEM image of a randomly selected Sb_2Te_3 nanosheet; (b) corresponding elemental analysis of this Sb_2Te_3 nanosheet; (c) EDX element mappings for Sb; (d) EDX element mappings for Te; (e) XRD pattern; (f) Raman spectrum of the Sb_2Te_3 nanosheet

Method (Cont'd)

2. The nonlinear saturation absorption properties of Sb_2Te_3 SA were also characterized by a power-dependent transmission technique.

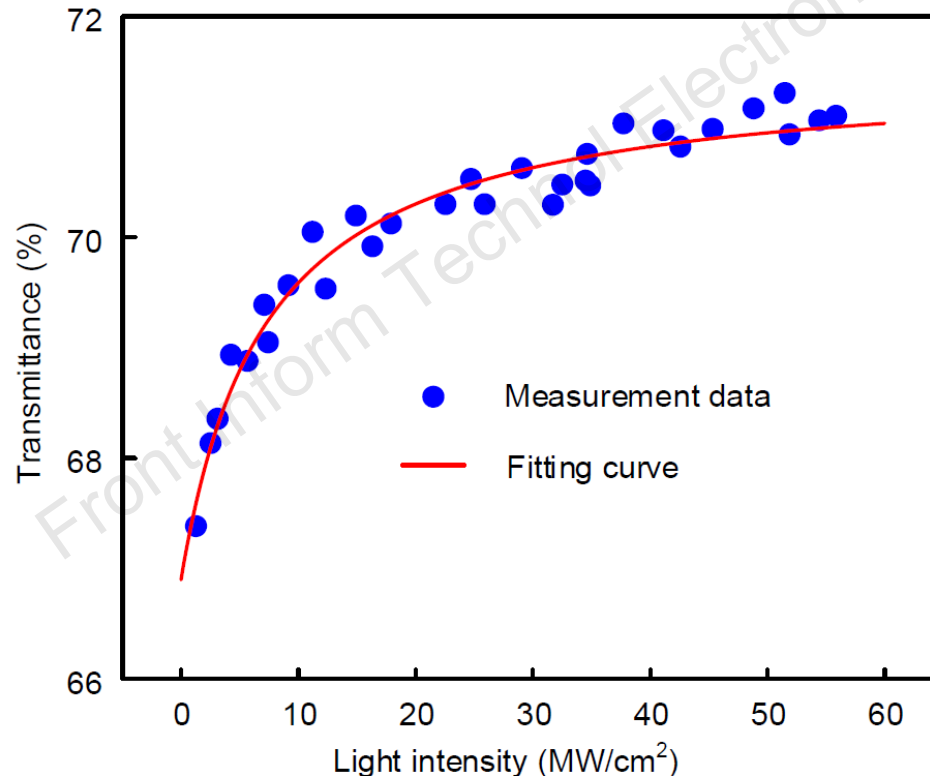


Fig. 3 Nonlinear transmittance of the Sb_2Te_3 saturable absorber at different light intensities

Method (Cont'd)

3. The Sb_2Te_3 SA was introduced into the laser ring cavity.

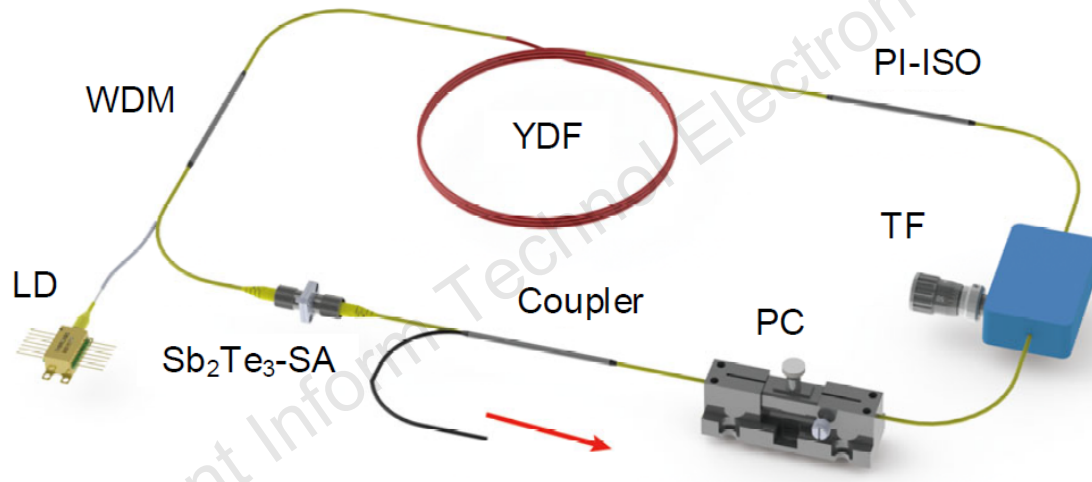


Fig. 4 Experimental setup for the Sb_2Te_3 SA based wavelength-tunable passive Q-switching YDF laser

SA: saturable absorber; YDF: Yb-doped fiber; LD: laser diode; WDM: wavelength division multiplexing; PI-ISO: polarization-insensitive isolator; TF: tunable filter; PC: polarization controller

Major results

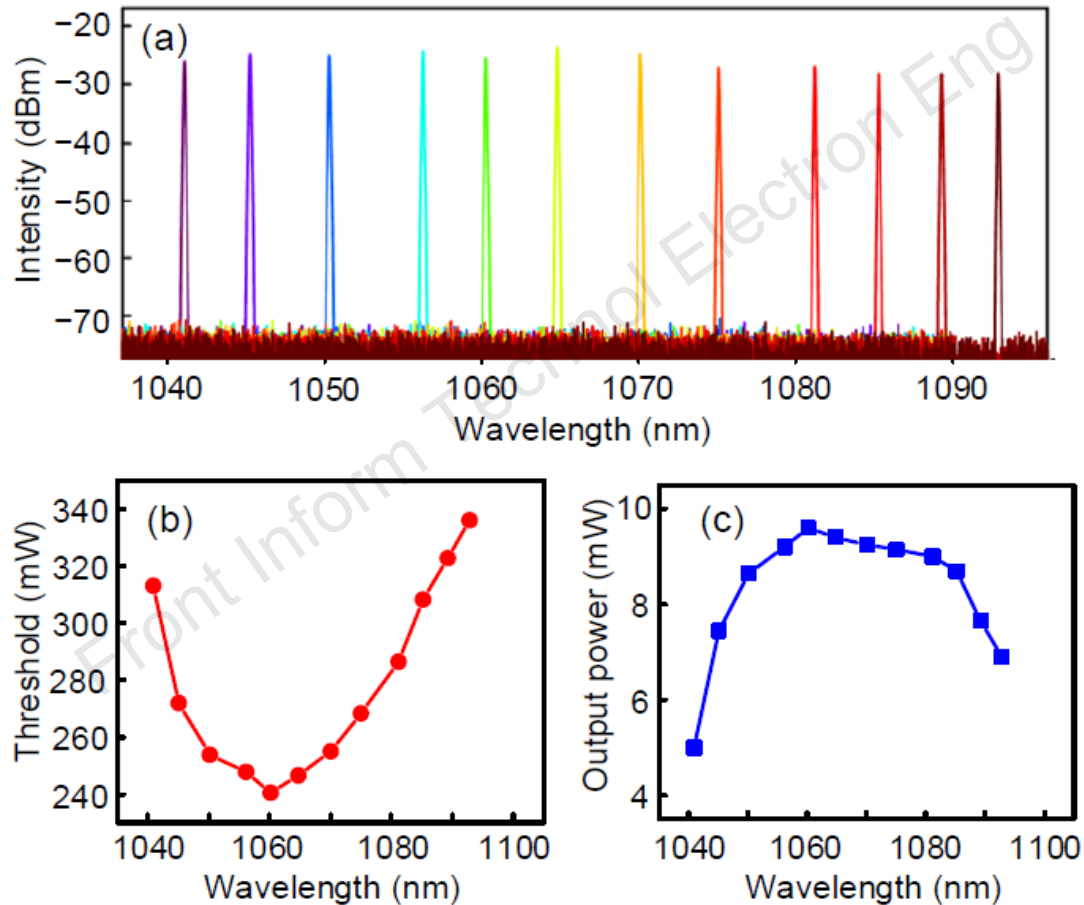


Fig. 5 Pulse characteristics at different wavelengths: (a) spectra; (b) pulse threshold; (c) output power

Major results (Cont'd)

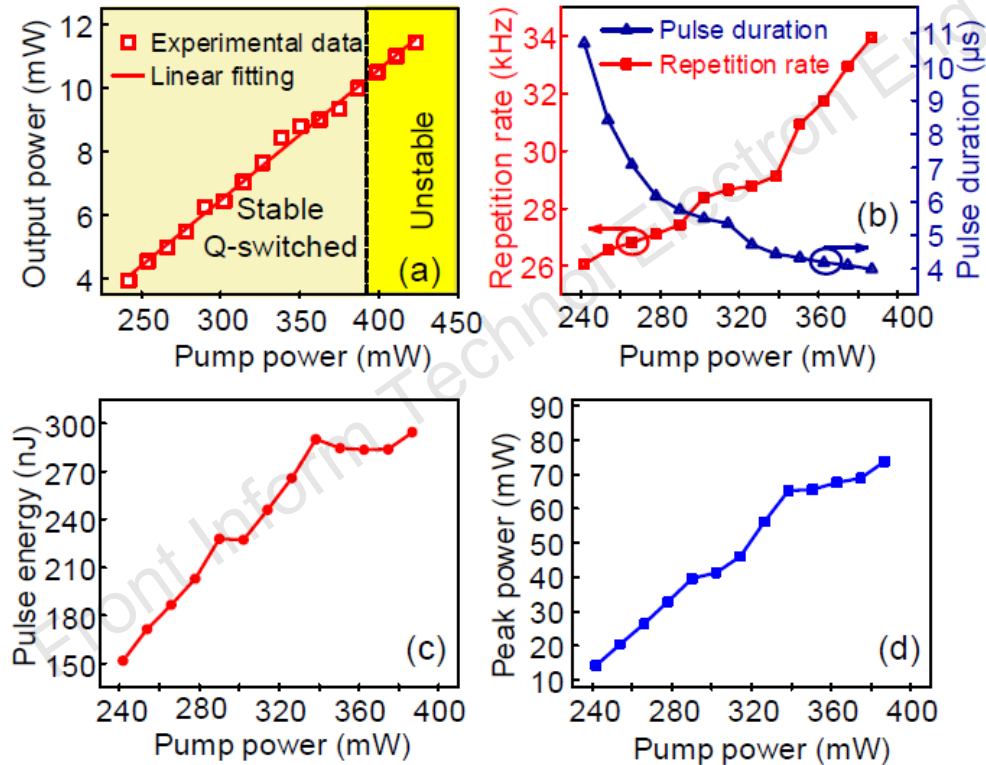


Fig. 6 Q-switched laser properties at 1060.8 nm output wavelength: (a) output power recorded by a power meter; (b) pulse width and repetition rate of pulse train at different values of pump power; (c) pulse energy; (d) peak power

Major results (Cont'd)

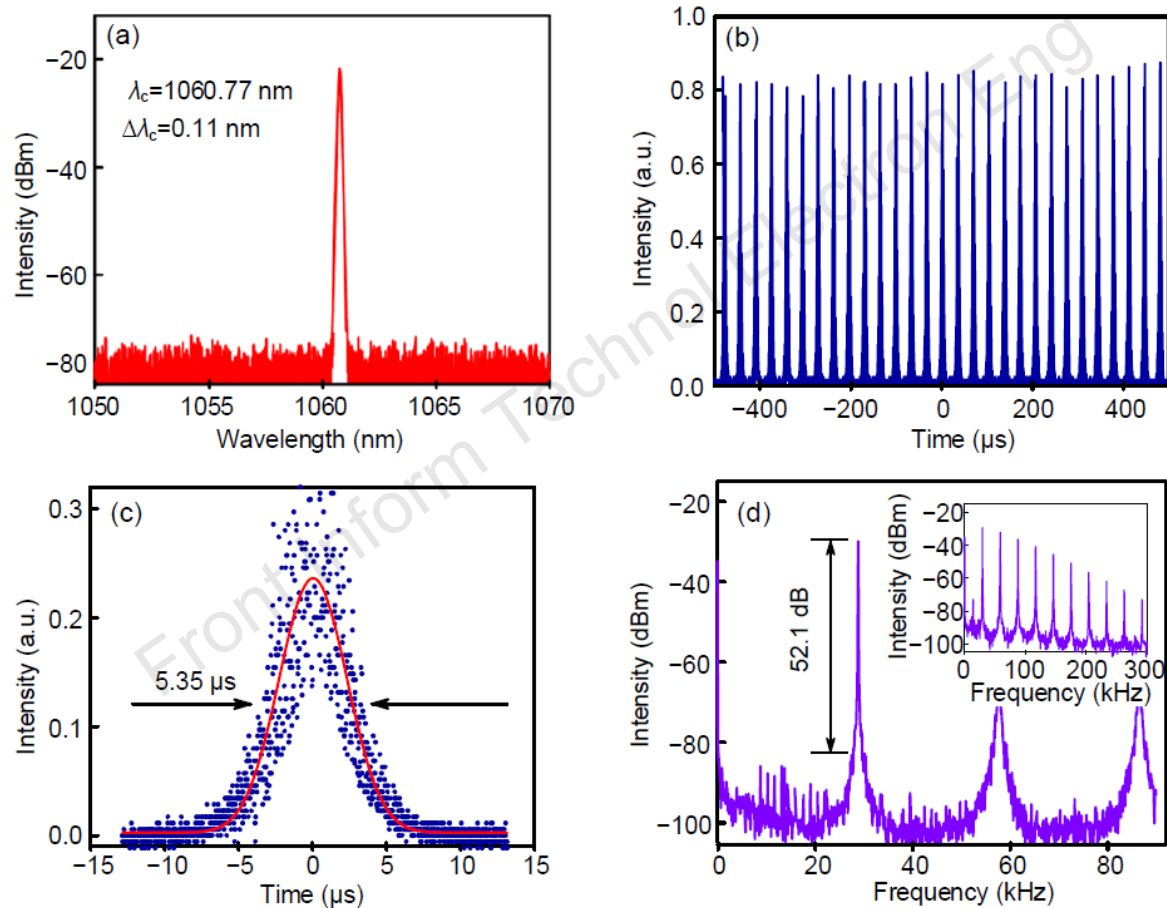


Fig. 7 Pulse properties at fixed pump power: (a) output spectrum centered at 1060.77 nm; (b) pulse train; (c) pulse duration; (d) RF spectra where the inset RF trace ranges from 0 to 300 kHz

Conclusions

1. A broadband tunable passive Q-switching Yb-doped laser based on Sb_2Te_3 was experimentally demonstrated for the first time.
2. The wideband saturable absorption properties of Sb_2Te_3 enable a Q-switched pulse operation range of 1040.89 to 1092.85 nm.
3. With a simple and convenient configuration, this broadband tunable passive Q-switching fiber laser can be highly attractive for applications in optical communication, biomedical diagnostics, environmental sensing, and other fields.



王涛，2017年获北京理工大学光电信息科学与工程专业学士学位，2019年获国防科技大学光学工程硕士学位，目前在国防科技大学攻读博士学位，研究兴趣集中在脉冲光纤激光器。



俞强，2014年获苏州大学光学工程硕士学位，现在国防科技大学攻读博士学位，研究兴趣包括电子显微学表征、低维纳米材料制备及光电子应用开发。发表SCI论文20余篇，获国家授权专利2项。



吴坚，国防科技大学前沿交叉学科学院副研究员。2006年在华中师范大学获物理学（国家理科基地班）学士学位，2015年获上海交通大学光学博士学位。目前从事新型激光器、高功率光纤激光、激光合束和先进纳米材料等方面的教学与科研工作。迄今在Nat Commun、Nanoscale、Langmuir、Opt Lett、Photon Res等学术期刊发表交叉学科论文30余篇，授权国家发明专利10余项。



张凯，研究员，博士生导师，中科院高层次人才计划入选者，国家优秀青年科学基金获得者。分别于2004、2007年在湖北大学获物理学学士和材料学硕士学位，于2011年获香港理工大学博士学位。历经美国麻省理工学院、新加坡国立大学的科研工作，2015年入职中科院苏州纳米技术与纳米仿生研究所。长期致力于窄带隙二维材料与器件的研究，研究兴趣集中在黑磷等窄带隙二维材料的可控生长及其红外、太赫兹激光与探测器件的应用突破。迄今在Nat Commun、Adv Mater等学术期刊发表论文80余篇，论文他引1500余次；申请国际PCT和中国发明专利10余项；近年来在国际学术会议做特邀报告或分会主席30余次。现主持中国科学院、国家自然科学基金、江苏省自然科学基金以及企业产学研合作等多项相关项目。分别入选中国科学院高层次人才计划并获择优支持（2015年），苏州市“紧缺高层次人才”（2016年），江苏省“333工程”（2018年），被评为中国电子学会优秀科技工作者（2018年），获国家优秀青年科学基金资助（2019年）；担任中国电子学会半导体科技青年专委会副秘书长、“新型半导体光电材料”子领域委员，IOP Publishing中国区顾问编委、J Phys Mater编委，环太平洋激光与光电子国际会议（CLEO-PR）等会议程序委员会委员。