

Editorial for special issue on photonics based on two-dimensional noncarbon materials

Scientists are in the constant search of novel materials, or innovative applications of existing materials to solve problems we face in our everyday life. Although graphene, the two-dimensional (2D) form of carbon, has been a star player for the past decade, there is a significant shift towards other noncarbon materials in recent years. Apart from the large family of transition metal dichalcogenides (TMDs), mono-elemental materials, such as phosphorene, arsenene, antimonene, and silicene, are rapidly gaining attention. Composites and heterogenous layered structures are also worthy of interest.

This special issue of *Chinese Optics Letters* entitled “Photonics based on 2D noncarbon materials” includes contributions that explore optical applications of noncarbon materials. The papers showcase recent works in lasers, i.e., laser amplifiers, fiber and pulsed lasers, absorbers, and photodetectors.

In terms of photodetection, black phosphorus (BP) is an excellent candidate due to its narrow band gap and high carrier mobility. We are particularly excited to learn about the excellent performance of a BP photodetector with ultra-high responsivity ($230 \text{ A} \cdot \text{W}^{-1}$) at the telecommunication wavelength (1550 nm) and quick rise and fall times of 4.8 and 6.8 ms, respectively.

The all-optical approach plays an important role in ultrafast signal processing, such as optical logic gate, routing, and sensing. Wang *et al.* demonstrate a proof-of-concept all-optical modulator with a rise time of 526 μs using few-layer MoS_2 polyvinyl alcohol (PVA) thin films based on the thermo-optic effect and obtain a long-time stable modulated output by applying polarization interference.

To fully utilize layer-number-dependent physical property of 2D materials, a fast and accurate determination of their layer number is the priority. Zheng *et al.* review the principles and recent development of the commonly adopted optical characterization methods and compare their advantages and limitations.

As for applications of lasers, there are eight articles, focusing on exploiting Bi_2Se_3 , MoS_2 , MoTe_2 , WTe_2 , WSSe, BP, GaSe, graphene/ MoS_2 heterostructure, or MoS_2 -BP composite as saturable absorbers (SAs) for Q -switching or a mode-locking operation.

A common 1064 nm lasing based on Nd^{3+} -doped laser materials has been mainly studied in bulk solid-state lasers, however, there is no report to date existing for an all-fiber laser configuration. Rong *et al.* demonstrate the dual-wavelength Q -switching operation at 1065.8 and 1074.3 nm of a linear-cavity Nd^{3+} -doped fiber laser based on a few-layer topological insulator Bi_2Se_3 SA. The achieved maximum average output power and maximum pulse energy are about 6.5 mW and 38.8 nJ, respectively.

As a novel kind of 2D material, few-layer TMDs possess broadband saturable absorption and a large nonlinear refractive index, which can be regarded as promising photonic materials. For example, Liu *et al.* experimentally observe the coexistence of a bound soliton and a harmonic mode-locking soliton in an Er-doped fiber laser with a MoS_2 -deposited microfiber device. The bound soliton has a periodic spectral modulation of 1.55 nm. The harmonic mode-locking soliton has a repetition rate of 479 MHz, corresponding to the 65th harmonic of the fundamental repetition rate. Ko *et al.* investigate the potential of bulk-like WTe_2 particles for the realization of a passive Q -switching operating at 1 μm . By incorporating the proposed SA into a Yb-doped fiber laser, stable Q -switched pulses are obtained. Liu *et al.* also achieve a MoTe_2 -based Q -switched Er-doped fiber laser with a minimum pulse duration of 677 ns, repetition rate of 148 kHz, and output power of 25 mW, respectively.

Meanwhile, Tang *et al.* obtain a passively Q -switched Er^{3+} -doped ZrF_4 - BaF_2 - LaF_3 - AlF_3 - NaF (ZBLAN) fiber laser at 2791 nm by using the graphene/ MoS_2 heterostructure as an optical modulator. At an incident pump power of 4.1 W, the laser can yield per-pulse energy of 2.2 μJ with the corresponding pulse width and pulse repetition rate of 1.9 μs and 45 kHz, respectively. Xue *et al.* demonstrate the passively Q -switched Tm-doped YAlO_3 (Tm:YAP) lasers based on MoS_2 , BP, and a MoS_2 -BP composite SA, respectively. Such a composite-based laser with a duration of 488 ns and corresponding peak power of 85.9 W is obtained, which was superior to that of single MoS_2 (616 ns, 68.7 W) and BP (932 ns, 22.4 W). This work opens up the possibility to create an unprecedented SA with exciting properties.

Ahmad *et al.* develop a tunable passively Q -switched Yb-doped fiber laser using few-layer GaSe as an SA. The laser has a tuning range from 1042 to 1082 nm, maximum repetition rate of 92.6 kHz, and minimum pulse width of 2.3 μs , respectively. They also demonstrate a Q -switched Er-doped fiber laser based on a $\text{WS}_x\text{Se}_{2-x}$ (WSSe) SA. It exhibits a tuning range from 1530 to 1570 nm, maximum repetition rate of 61.81 kHz, minimum pulse width of 2.6 μs , and the highest pulse energy of 7.31 nJ, respectively.

In addition, there are seven articles using other mechanisms as pulse-shapers for Q -switching or a mode-locking operation.

The direct generation of passively Q -switched lasers at a green wavelength has rarely been investigated in the past. Interestingly, a passively Q -switched Pr-doped LiYF_4 (Pr:YLF) green laser at 522 nm is demonstrated by Yan *et al.* using CdTe/CdS quantum dots as an SA. A maximum average output power of 33.6 mW is achieved with the shortest pulse width of 840 ns. The corresponding pulse energy and peak power reach 0.18 μJ and 0.21 W, respectively.

By using the gold nanorods as an SA, Zhang *et al.* demonstrate a passively Q -switched Nd-doped $\text{Lu}_3\text{Al}_5\text{O}_{12}$ (Nd:LuAG) laser with an average output power of 516 mW, pulse duration of 606.7 ns, and repetition rate of 265.1 kHz, respectively. This work represents the highest average output power among the reported nanosecond Nd-doped Q -switched lasers by gold nanorods-based SAs. To further develop the potential of silver nanorods for pulse generation in the 1.06 μm region, Wu *et al.* report a passively Q -switched Nd,Gd:CaF₂ disordered crystal laser with a silver nanorods-based SA. The single-pulse energy and peak power can be attained to 2.15 μJ and 2.06 W, respectively.

Interestingly, Zu *et al.* demonstrate a passively Q -switched diode-pumped Tm:YLF laser at 2 μm by using the graphene oxide as an SA. The shortest pulse width of 1.038 μs , the maximum repetition rate of 38.33 kHz, and the single-pulse energy of 9.89 μJ is obtained. A passively harmonic mode-locking Er-doped fiber laser is developed by Huang *et al.* using carbon nanotubes (CNTs)-PVA film as an SA. The laser exhibits a repetition rate of 580 MHz, corresponding to the 22nd harmonics of the 26.3 MHz fundamental repetition rate. The laser attests that it has potential to generate pulses with a high repetition rate by using CNTs.

Ren *et al.* fabricate a type of large-core double-cladding Tm-doped silica fiber with high refractive index homogeneity via the sol-gel method. By using the fiber as a gain medium and a semiconductor SA mirror (SESAM) as a mode-locker, they demonstrate high-power mode-locking operation with an average output power as high as 1.0 W and a pulse duration of 23.9 ps at 1955 nm, respectively.

Ge *et al.* demonstrate a single-mode dual-band pulsed master oscillator power amplifier laser source with simultaneous outputs of 10.7 W at 1061 nm and 25.8 W at 1548 nm through a dual-band pulsed amplification based on an Er/Yb co-doped gain fiber. This laser source is a promising candidate for efficient ultra-wideband supercontinuum generation.

Finally, an invited review paper on the recent progress of mode-locked/ Q -switched lasers (e.g., fiber, solid-state, disk, and waveguide) in this emerging field is given by Guo. In addition, the related nonlinear optical phenomena are also summarized.

We thank the contributing authors for their submissions, the reviewers for their time and constructive criticism, as well as the publication staff for their constant support. Lastly, we hope our readers enjoy this feature issue, and that it will trigger more exciting discoveries.

Sincerely,

Prof. Han Zhang
Shenzhen University, China
Email: hzhang@szu.edu.cn

Prof. Haibo Zeng
Nanjing University of Science and Technology, China
Email: zeng.haibo@njust.edu.cn

Prof. Qiaoliang Bao
Monash University, Australia
Email: Qiaoliang.Bao@monash.edu

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