Supporting information

Indium selenide for Q-switched pulse generation in a mid-infrared fiber laser

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Property measurement of InSe

The morphologies and structural information of InSe nanosheets were characterized by a Transmission Electron Microscopy (JEM-F200, JEOL, Japan) at 200 kV as the accelerating voltage. The XRD date were collected using an X-ray powder diffractometer (D8 Discover, Bruker, Germany) equipped with Cu Kα radiation (λ = 1.5406 Å) and Jade software was used to identify the phase of the powder. For Raman spectrum of InSe nanosheets, 50 μL solution was dropped onto a silicon substrate, following by configuration at a lower speed (500 rpm) for 10 s and then a higher speed (2500 rpm) for 3 minutes. Raman spectra were collected using a dispersive Raman microscope (InVia Reflex, Renishaw, UK) from 100 to 275 cm^{-1}, excited by a laser with the wavelength of 514 nm and an objective lens (100×, diameter of laser spot ~5 μm). The concentration of InSe product in NMP was adjusted to 20 μg/mL for absorption data collection by a UV-Vis-NIR spectrophotometer (Cary 60, Agilent Technologies, USA) in the range of 200-1000 nm. The AFM image was obtained by an atomic force microscopy (Dimension ICON system, Bruker). For optical properties measurement, InSe product was dropped onto a gold mirror and then dried in a vacuum oven at room temperature for 24 h.

Experimental setup

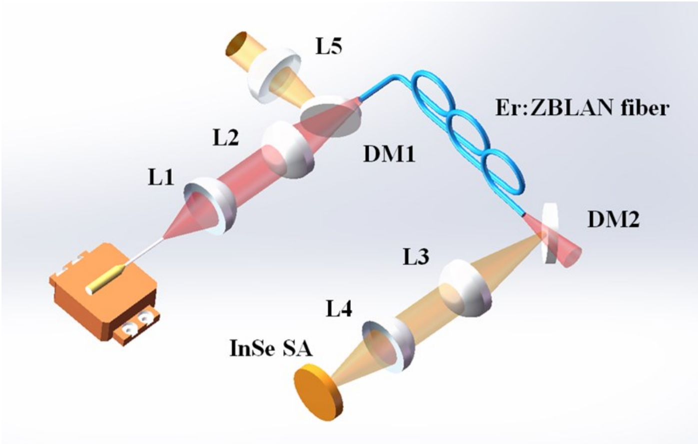

Fig. S1 Diagrammatic scheme of the Q-switched laser.

Fig. S1 presents the experimental schematic of the InSe passively Q-switched Er-ZBLAN fiber laser. A commercial grating-narrowed 976 nm laser diode was used as the pump source, which has a maximum output power of 50W. The pump light was collimated by a plano-convex lens L1 (f = 25.4 mm, B-coated, N-BK7) and focused by L2 (f = 50 mm, B-coated, N-BK7). Through a dichroic mirror DM1 (high reflectivity at ~2.8 μm, high transmittance at ~976 nm) positioned at an angle of 45°, also performing as the output coupler, the pump light was coupled into the inner-cladding of the double-clad Er-ZBLAN gain fiber with a doping concentration of 70000 ppm. The core diameter is 15 μm and its numerical aperture (NA) is 0.12. The 1st cladding diameter is 240*260 μm and the 2nd one is 290 μm (LE VERRE FLUORE, France). Another dichroic mirror DM2 was utilized to eliminate the residual pump and ensure the propagation of pure laser light during the cavity. An identical structure was constructed for the external cavity by the use of two 50-mm-focal-length plano-convex lenses (D-coated, CaF2), through which the laser light beam was focused onto the reflection-type InSe SA. The front-end fiber facet with a perpendicularly cleaved angle and the highly reflective mirror integrated with the InSe SA provided the lasing feedback and the other opposite fiber facet was angle-cleaved at 8° to reduce the adverse effect of the parasitic oscillation formed by the two fiber end facets. Finally, the output light was collimated by the lens L5 (f=30mm, D-coated, CaF2).

The laser output spectrum was recorded by an optical spectrum analyzer (OSA207C, Thorlabs) and the radio-frequency (RF) spectrum was monitored by a RF spectrum analyzer (GA4064, Gratten). The temporal characteristics of the output pulses were evaluated by a real-time oscilloscope (MDO4104C, Tektronix) and an infrared photoconductive detector (PCI-2TE-12, VIGO System).