Laser Mode-locking using SWCNT@BNNT with 1D van der Waals Heterostructure as a Saturable Absorber with a High Optical Damage Threshold

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1. Introduction

In ultrafast optics, a single-walled carbon nanotube (SWCNT) is famous for its high reliability serving as a saturable absorber for the generation of ultrashort pulses. However, the heat generated by the laser may accelerate the oxidization of the SWCNT and shorten its lifetime. Recently, a groundbreaking technique - 1D van der Waals (vdW) heterostructure - was proposed, which enables the "property by design" of 1D nanomaterials such as CNT. In this research, we test and compare the optical nonlinear characteristics and optical damage threshold of SWCNT and a novel nanomaterials named Single-walled carbon nanotube encapsulated in boron nitride nanotube (SWCNT@BNNT) with 1D vdW heterostructure.

2. Experimental Setup

A Z-scan measurement system is used to investigate the optical nonlinear effect on the samples by measuring the change in transmittance when the optical intensity changes. The results suggest that the BN coating on SWCNT only increases the reflectivity by ~1.5%, and does not change its optical absorption and optical nonlinear characteristics.

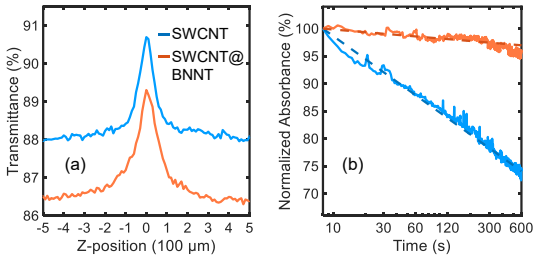

Fig.1 Results of (a) Z-scan measurement experiment and (b) lifetime test on pristine SWCNT and SWCNT@BNNT.

With the same setup, the lifetime tests are performed by illuminating the sample with a focused beam and observing the change in the transmittance of the sample. When the illuminating power is set to 9 dBm, the normalized absorbance of the pristine SWCNT degrades by 25% in 10 mins, while which of the SWCNT@BNNT drops by only 5%.

We then build a short cavity formed by 5 cm of erbium-doped fiber and 5 cm of single-mode fiber using SWCNT@BNNT as a saturable absorber. The cavity is mode-locked at a high reputation rate of 1 GHz and performs a stable output with the ultrashort pulse of ~845 fs.

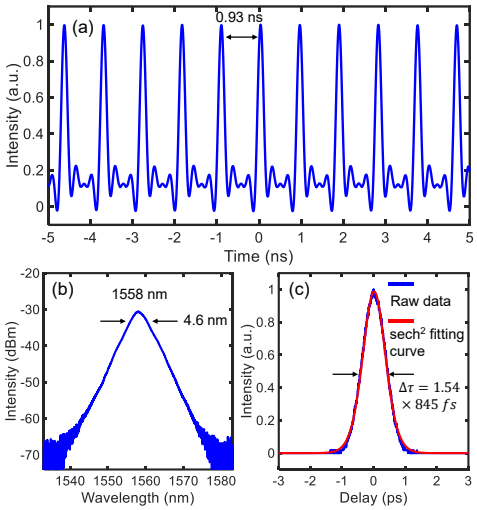

Fig.2 (a) Oscilloscope trace, (b) optical spectrum, and (c) autocorrelation trace of the proposed laser.

3. Conclusions

This is the first time that a nanomaterial with 1D vdW heterostructures is demonstrated performing an enhanced optical damage threshold in laser mode-locking. The BN coating on SWCNT improves its thermal damage threshold by 2 dB and extends its lifetime 214 times longer for 3 dB degradation under optical power intensity of 6.8 kW/cm^2, whilst preserves the optical characteristics. This technique has shown great potential in enhancing and modifying the optical properties of 1D nanomaterials. More special nanomaterials with designed features are expected to be utilized in profuse optical applications in the future.

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