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Sub-100fs pulse generation from a fiber oscillator mode-locked by nanotubes

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Abstract: We report an ultrafast fiber laser based on carbon nanotube saturable absorber. 84 fs pulses are generated directly from the fiber oscillator with 61.2 nm spectral width.

OCIS codes: (140, 4050) Mode-locked lasers; (230.4320) Nonlinear optical devices.

1. Introduction

Ultrafast fiber lasers are attractive light sources for many applications ranging from basic research to material processing and medicine[1]. They have simple and compact design, efficient heat dissipation and high quality pulse generation[2]. The current fiber laser mode-locking technology typically relies on soliton-like operation. In this regime, the nonlinear effects due to the strong mode confinement and long fiber required, typically ~10m, limit the generation of sub100fs pulses[3]. A method to overcome these restrictions is to alternate segments of large normal and anomalous group velocity dispersion (GVD) fiber, which leads to periodic stretching and compression of the intracavity pulses[3]. This configuration is known as the stretched-pulse design[3]. The average pulse width in such configurations can increase by an order of magnitude or more, which significantly reduces the nonlinear effects, thus shorter pulse duration can be achieved.

Single wall carbon nanotubes (SWNTs) and graphene based saturable absorbers (SAs) are excellent passive mode-lockers because of their sub-picosecond recovery time, broad operation range, low saturation intensity, polarization insensitivity, low cost and easy fabrication [4-20]. The shortest pulse duration achieved to date directly from a fiber oscillator using SWNT SA is 113fs with 33.5nm spectral width[4,5]. Here, we demonstrate a stretched-pulsed fiber laser mode-locked by a SWNT based SA. The laser generates 84fs pulses with 61.2nm spectral width. This is the largest spectral width and shortest pulse duration achieved thus far directly from fiber oscillators mode-locked by SWNT-based SAs.

2. Experimental setup and results

We use SWNTs grown by laser ablation [21] to fabricate the SWNT-Sodium-carboxymethylcellulose (Na-CMC) composite. The tubes, with ~1.3nm mean diameter, are ultrasonicated for one hour with Na-CMC. The homogeneous dispersion is then centrifuged at 30krpm for an hour. After slow evaporation at room temperature, a ~30µm free-standing film is obtained. The film is then placed between two fiber ferrules inside a FC/PC connector to form the SWNT-SA device. Power dependent measurement of the device is shown in Fig. 1. The modulation depth is ~20%.

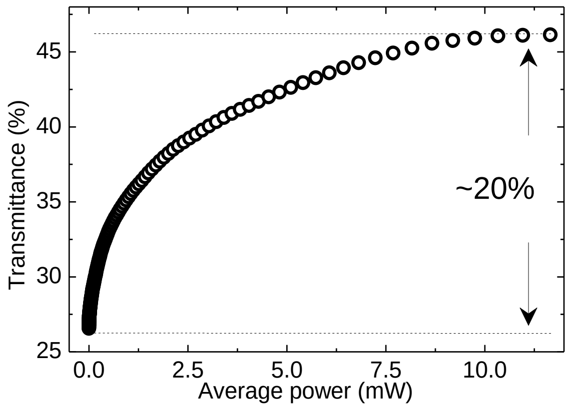

Fig.1. Nonlinear transmittance

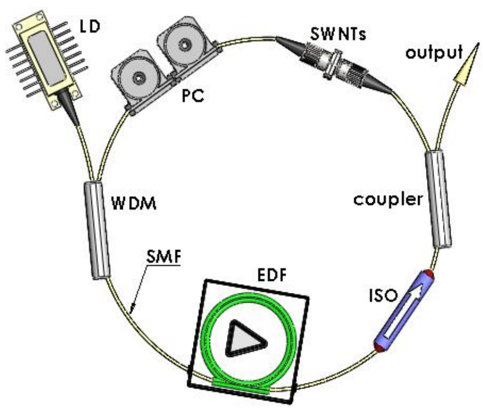

Fig.2. Ring laser setup

A schematic of the laser setup is shown in Fig. 2. The gain medium is provided by a 1.25m highly-doped Er^{3+} fibre (EDF). It is pumped by a 980nm diode laser via a wavelength division multiplexer (WDM). Uni-directional operation of the laser is ensured by an optical isolator (ISO). A polarization controller (PC) is used to adjust the intracavity polarization of light. The 20% port of an optical coupler provides the laser output. The

SWNT SA is placed after the optical coupler. The total length of the laser cavity is estimated to be ~6m. The GVD coefficient of the EDF fiber we used is β_2=48ps^2/km. The rest of the cavity is made of a combination of single mode fibers (SMFs). We used ~1.8m of Flexcor 1060 with β_2=-7ps^2/km and ~2.95m of SMF-28 with β_2=-22ps^2/km. The overall intracavity GVD is estimated to be -0.002ps^2.

Self-starting mode-locking is observed at ~17mW pump power. The output power is ~1.1mW with ~34MHz repetition rate. A typical output spectrum is shown in Fig.3. The full width at half maximum (FWHM) bandwidth is ~61nm. This is the widest spectrum achieved thus far from fiber oscillators mode-locked by SWNT SAs. No soliton sidebands are observed. Figure 4 shows a plot of a typical output second harmonic generation (SHG) autocorrelation trace. The autocorrelation FWHM is ~129fs. Assuming a sech^2 profile, the data deconvolution gives a pulse duration of ~84fs, the shortest reported to date from an fiber oscillator mode-locked by SWNTs.

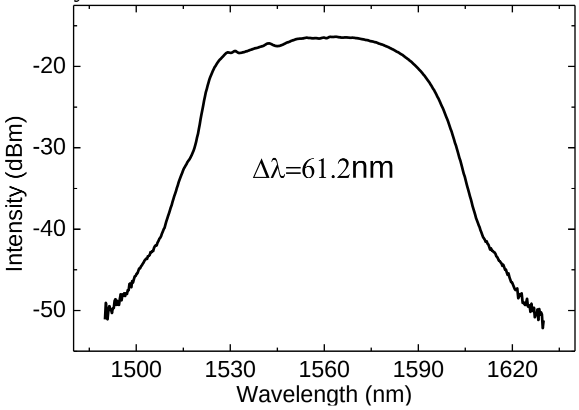

Fig.3 Optical spectrum

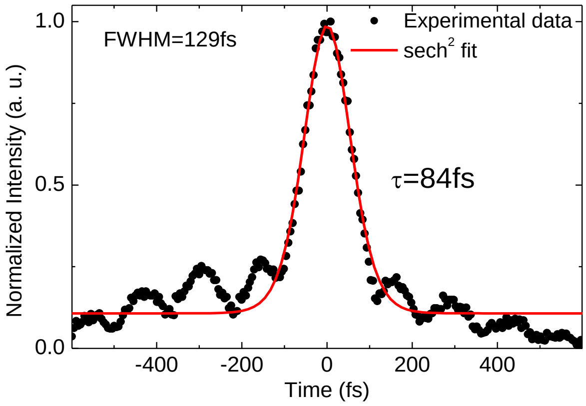

Fig.4 Autocorrelation trace

2. Conclusions

We demonstrate a stretched-pulse erbium-doped fiber laser mode-locked by SWNT-based saturable absorber, generating 84fs pulses at 1.56 μm. The output spectral width is 61 nm.

We acknowledge funding from EPSRC GO30480/1, the Isaac Newton trust, Royal Society, European Research Council Grant NANOPOTs and King's College, Cambridge. We thank F. Hennrich for providing nanotubes.

3. References

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