The 8th Advanced Lasers and Photon Sources (ALPS2019), Yokohama, Japan, Apr. 22 - Apr. 25, 2019

Carbon Nanotube Mode-Locked Cr:ZnS Laser with 400 nm Tuning Range

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Abstract: *We develop a mode-locked Cr:ZnS laser emitting 50-fs pulses using a single walled carbon nanotube film which has a resonant absorption around 2.4 μm, and realize the central-wavelength tuning range of 400 nm.*

1. Background

Ultrashort pulses in the mid-infrared (mid-IR) region have a great potential in the applications of advanced vibrational spectroscopy and strong field phenomena. Cr^{2+}-doped ZnS is an attractive candidate for mid-IR ultrafast light source mainly because of its broad fluorescence spectrum. So far, several groups have reported its passive mode-locking by utilizing a SESAM, carbon nanomaterials and Kerr-lensing [1].

Along with the possibility of octave-spanning few cycle pulse generation [2], an interesting operation of Cr:ZnS laser is central wavelength tuning of the mode-locked oscillation. A prior work showed 300 nm tunability by using a graphene saturable absorber [3]. Single walled carbon nanotubes (SWCNTs) are known as ideal saturable absorbers in the near-IR but they have rarely been applied to Cr:ZnS lasers because typical nanotubes (d_t =1.3~1.6 nm) show an inverse saturable absorption above 2 μm [4]. Here, we achieve Cr:ZnS mode-locking by using a SWCNT film that has a diameter of around 2.2 nm and a resonant absorption at the wavelength of 2.4 μm.

2. Experiment

We develop an astigmatically-compensated Z-folded laser cavity using a Cr:ZnS polycrystalline as a laser crystal as shown in Fig.1. We utilize a SWCNT film attached on a CaF_2 window as a transmission type saturable absorber. Its transmission spectrum in Fig.2 confirms broad absorption of the $E_{11}{}^S$ band around 2.4 μm. The diameter of SWCNTs is calculated as 2.2±0.3 nm from the measured spectrum. The intracavity group-delay dispersion is compensated with CaF_2 windows and a chirped mirror. When the pump power is 7.6 W, the cw mode-locking with a spectral bandwidth of 9.2 THz (Fig.2), a pulse duration of 49 fs, an output power of 186 mW and a repetition rate of 76.0 MHz is achieved. Note that the oscillation is initiated without any perturbation. By inserting a CaF_2 prism into the one of the cavity arms and adjusting the alignment of OC_2 horizontally, the central wavelength is continuously tuned over the tuning range of 400 nm as shown in Fig.3.

3. Conclusion

We successfully demonstrate passive mode-locking of a Cr:ZnS laser by using a SWCNT film with resonant absorption at 2.4 μm. It is, to our best knowledge, the first observation of self-starting and the shortest pulse duration achieved in Cr:ZnS lasers using SWCNTs. Furthermore, mode-locked oscillation is maintained for the wavelength tuning span of 400 nm, which is the broadest range among the ones reported so far for mode-locked Cr:ZnS lasers.

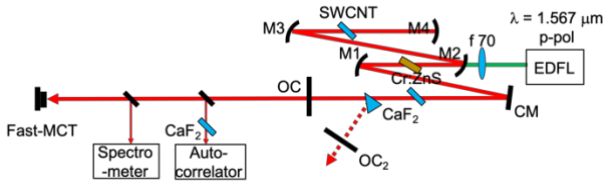

Fig.1 The optical set up.

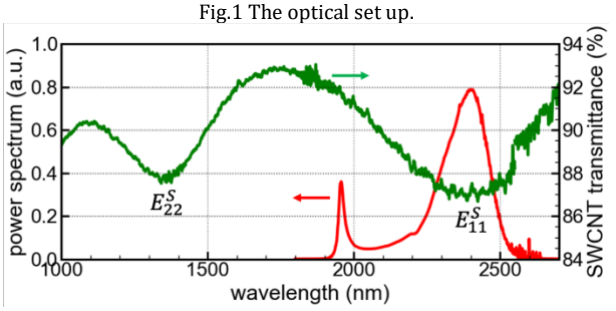

Fig.2 The red and green line represents the measured pulse spectrum (left), and a SWCNT transmission spectrum (right).

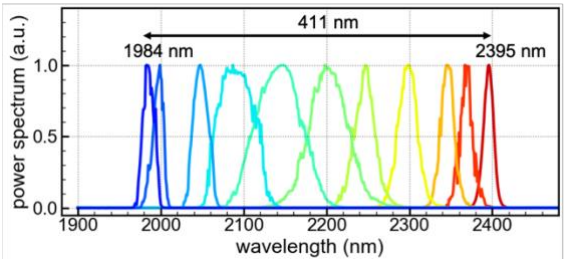

Fig.3 Mode-locked pulse spectra with varied central wavelength.

References

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