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. Cr2+-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, =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 CaF2 window as a transmission type saturable absorber. Its transmission spectrum in Fig.2 confirms broad absorption of the E_1^1 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 CaF2 windows and a chirped mirror. When the pump power is 7.6 W, the cw mode-locking with a spectral width 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 CaF2 prism into the one of the cavity arms and adjusting the alignment of OC2 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.

References