Mode-locked Oscillation of Cr:ZnS Laser using a Single Walled Carbon Nanotube Film with Resonant Absorption at 2.4 μm

Daiki Okazaki[1], **Hayato Arai**[2], **Esko. I. Kauppinen**[3], **Shohei Chiashi**[2], **Shigeo Maruyama**[2,4], **Satoshi Ashihara**[1]

1. Institute of Industrial Science, The University of Tokyo—4-6-1, Komaba, Meguro-ku, Tokyo, 153-8505, Japan

2. Departure of Mechanical Engineering, The University of Tokyo— 7-3-1, Hongo, Bunkyo-ku, Tokyo, 113-8656, Japan

3. Department of Applied Physics, Aalto University School of Science, 15100, FI-00076 Aalto, Finland

4. Energy Nano Engineering Lab., National Institute of Advanced Industrial Science and Technology (AIST), Ibaraki 305-8564, Japan

Ultrashort pulses in the mid-infrared (mid-IR) region have a great potential in the applications of advanced vibrational spectroscopy and strong field phenomena. Traditionally, mid-IR ultrashort pulses are generated by frequency conversion of near-infrared pulses from Ti:S or Yb-based lasers. Laser oscillators which directly emit mid-IR femtosecond pulses are advantageous from the perspectives of simplicity and energy extraction efficiency. Cr:ZnS is an attractive gain medium for mid-IR ultrafast lasers because it has a broad fluorescence spectrum, large stimulated-emission cross-section and high thermal conductivity [1]. So far, passive mode-locking has been realized for Cr:ZnS laser, by employing Kerr-lensing, or by using saturable absorbers based on semiconductors or graphenes [2]. A single walled carbon nanotube (SWCNT) film is also known as a good candidate for saturable absorbers, possessing tunable resonance and large modulation depth. However, SWCNTs have rarely been applied to this laser [3]. Here, we demonstrate self-starting mode-locked oscillation of Cr:ZnS laser by using a SWCNT film which has resonant absorption at the laser emission wavelength of 2.4 μm.

The experimental set up is shown in Fig.1(a). We develop an astigmatically-compensated Z-folded laser cavity using a Cr:ZnS polycrystal as a gain medium. We utilize a SWCNT film attached on a CaF_2 window as a transmission type saturable absorber. Its transmission spectrum shown in Fig.1(b) confirms broad absorption of the E_{11}^S band at the Cr:ZnS emission range. The corresponding nanotube diameter is 2.2 ± 0.3 nm. The intracavity group-delay dispersion is compensated with CaF_2 windows and a chirped mirror. As the pump power is increased, the oscillation transits from continuous wave oscillation, Q-switched mode-locked oscillation and to the cw mode-locked oscillation. When the pump power is 7.6 W, the cw mode-locking with a spectral bandwidth of 9.2 THz (176 nm), a pulse duration of 49 fs, an output power of 186 mW and a repetition rate of 76.0 MHz is achieved, as shown in Fig.1(c). Note that we observe the self-start of the mode-locking with a rise time of less than 100 μs. We also show that the central wavelength is tuned in the range of 400 nm by using a prism.

In 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 the best of our knowledge, the first observation of self-starting and the shortest pulse duration achieved in mode-locked Cr:ZnS lasers using SWCNTs.

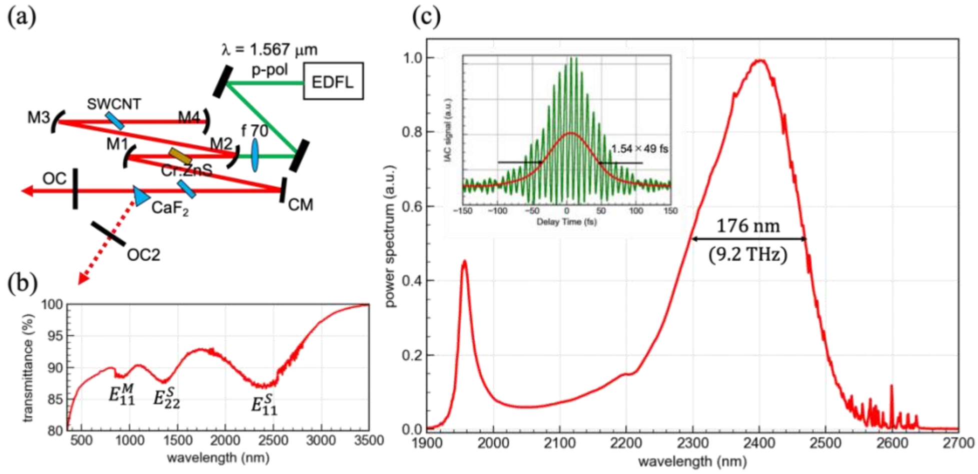

Fig. 1 (a) Schematic of the laser cavity, (b) the transmission spectrum of a SWCNT saturable absorber, and (c) the measured spectrum of our mode-locked Cr:ZnS laser using SWCNTs. (inset: the auto-correlation signal.)

References

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