# Towards Compact, High Power Tunable Laser Sources

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**Abstract:** In this invited talk, we will talk about development of compact, widely tunable high power laser sources pumped by both solid-state laser and fiber laser at DSO National Laboratories.
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High power, compact and tunable laser sources have many applications, such as laser radar, remote sensing and medical applications. In this talk, we will discuss about the progress of compact, high power tunable laser research at DSO National Laboratories. We started work on tunable mid-IR radiation with tandem OPOs pumped by diodepumped solid-state laser (DPSSL). One of the good examples is shown in Section 1. We have demonstrated a watts-level tunable mid-IR laser source based on tandem KTP and ZGP OPOs, pumped by Nd: YALO solid-state laser. Moreover, narrow-linewidth laser source is very useful for high-resolution spectroscopy, cooling and trapping of atoms. We have demonstrated up to 90W output power from a tunable all-fiber based amplifier, details in Section 2. Finally, we will talk about the high power, cascaded Raman fiber laser based on Phosphosilicate fiber in section 3. We believe that fiber laser pumped nonlinear device is the direction toward compact, tunable laser sources.

## 1. Laser integrated with Coupled Tandem OPO

Many applications require high power, tunable mid-IR (3~5-μm) laser, however, it is non-trivial to generate mid-IR laser at watts level, especially tunable within 3~5-μm. At DSO National laboratories, we coupled an intra-cavity Diffusion Bonded Walkoff Compensated (DBWOC), KTP OPO with a Coupled Tandem OPOs (CTOPO) configuration, which was called as Laser Integrated with a CTOPO (LICTOPO) [1]. We have obtained maximum average power of 2.5W of tunable ZGP OPO with only one arm of DBWOC KTP OPO resonating. At the same time, we have simultaneously achieved 7.2W of 2-μm and 33W of 1-μm laser.

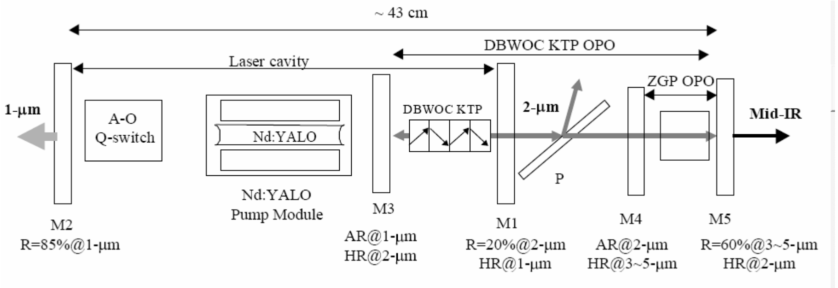
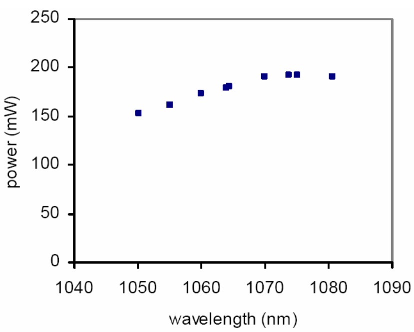



**Fig. 1 Schematically diagram of the experimental setup for a laser Integrated with a coupled tandem OPO (LICTOPO).**

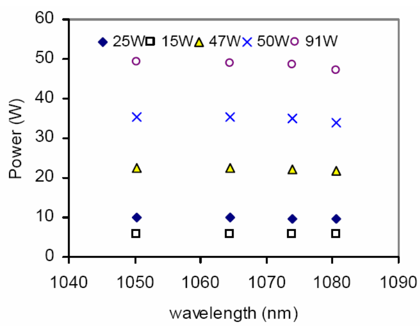
This novel LICTOPO configuration combines the intracavity OPO with a coupled tandem OPO. It takes advantages of: 1) Nd: YALO provides simple configuration for generating high power linearly polarized laser for pumping OPO; 2) DBWOC scheme reduces the aperture effect due to Poynting's walkoff in the critically phase-matched parametric generation, as well as eliminates optical losses and needs for alignment of crystals; 3) CTOPO makes use of recycling effect of nondepleted 2-um. All these result in the compactness and potential high conversion efficiency for mid-IR generation pumped by DPSSL.

## 2. Narrow Linewidth Tunable Yb Fiber Amplifier

External cavity diode laser (ECDL) is very adaptable for many applications; however, the output power is limited to 100mWs-level. In this talk, we will present our work on amplification of such ECDL up to 90W output power with the tunable range of 30nm. The seeder is a commercial product (Model 6300 from New Focus, USA), with output power of a few mW and tunable range at 1050.2~1080.6nm. The single frequency linewidth is typically smaller than 5MHz (5s). The seeder is amplified with two stage of pre-amplifier to ~>150mW-level before going to power-amplifier. The three stage of amplifier is an all-fiber based device. Details of laser output are shown in Fig. 2. The maximum output power is limited by the back reflection due to SBS effects.




(a)

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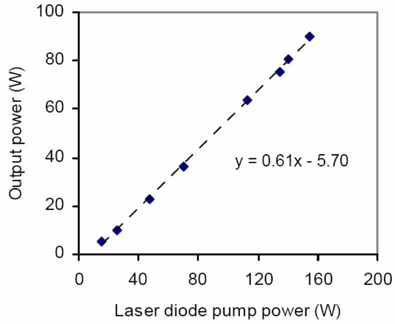


(c)

**Fig. 2 (a) Output power from second stage pre-amplifier vs. wavelength; (b) Output power from power-amplifier vs. wavelength at different pumping level; (c) Output power from power-amplifier vs. pumping power at 1050.2nm.**

Two groups [2, 3] have reported high SBS threshold possible due to thermal gradients along the active fiber, however, no details were reported. We visually monitored the temperature of Yb fiber during lasing with IR camera (Thermoteknix Systems Ltd, UK). When Yb fiber temperature is keep at ~18 $^{o}$C with active cooling, the maximum output power is limited at ~50W-level. In order to introduce the thermal gradient, the same Yb fiber is spooled on a plastic casing with diameter of 12.5-cm. It is interesting to notice that SBS threshold does increased significantly when temperature gradient established after several minutes of lasing. The maximum output power increased to 90W-level when temperature gradiance is ~60 $^{o}$C.

## 3. High Power, Cascaded Raman Fiber Laser

Stimulated Raman Scattering (SRS) in optical fibers is one effective method to generate new laser wavelengths for various applications such as eye-safe laser source. Phosphosilicate fiber has many advantages over Ge fiber because of its larger Raman Stokes shift of 1330 cm$^{-1}$ as comparing to Ge fiber s of ~440 cm$^{-1}$. Fewer pairs of Bragg gratings are required to achieve the same magnitude of wavelength shift for a cascaded Raman fiber laser using P-doped fiber. We have achieved maximum output power of 13.2 W at 1539 nm wavelength with two stages of cascaded Raman laser. This is achieved with ~40W incident power [4]. The conversion efficiency is 32.5% and slope efficiency is 37.4%.

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