Compact Self-started Femtosecond Cr:forsterite Laser for Non-linear Optical Microscopy

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Abstract: We demonstrated a compact, prismless, self-started Cr:forsterite laser generating 300mW of 85-fs pulses around 1226nm. Based on a fiber pump laser, this compact laser system is a promising clinical source for portable nonlinear scanning microscope.

OCIS codes: (140.7090) Ultrafast lasers, (170.6900) Three-dimensional microscopy

Nonlinear optical microscopy based on femtosecond Cr:forsterite lasers was established as a valuable tool for non-invasive, high-resolution, high-penetration 3D imaging of a variety of biological specimens [1-5]. However, most current Cr:forsterite lasers, due to their cavity sizes and peripheral equipments, does not favor portable clinical use. Recently, a compact femtosecond Cr:forsterite ring cavity based on chirp mirrors was reported for the use of telecommunication and frequency standard [6]. However for future clinical applications, a self-started mechanism for Kerr-lens-modelocking (KLM) is required for long-term stability, where modelocking can be easily destroyed by the reflective feedback from the scanning microscopy system. In this report, we demonstrated a compact (<50X50X10-cm), prismless, self-started femtosecond Cr:forsterite laser for non-linear optical microscopy. This was achieved by employing both double-chirp-mirrors (DCM) and a semiconductor-saturable-absorber-mirror (SESAM) in a linear laser cavity. With further improvement on the TE cooler and cavity humidity control, portable non-linear optical microscope based on a Cr:forsterite laser can thus be realized for clinical applications.

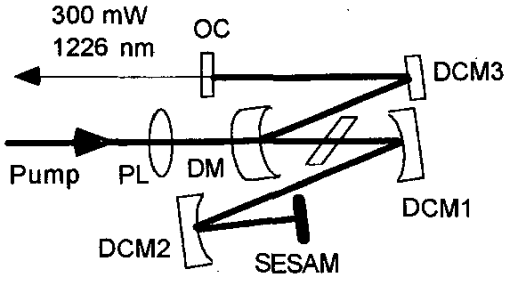

Fig. 1. Schematic diagram of the compact femtosecond Cr:forsterite laser : PL pump lens; DM dichroic curve mirror, DCM1,DCM2,DCM3 double chirp mirrors; OC output coupler; SESAM semiconductor saturable absorber mirror.

Fig. 1 shows a schematic diagram of the compact femtosecond Cr:forsterite laser. The Cr:forsterite crystal is a 5mm×5mm×11.4mm, Brewster-cut crystal with an absorption coefficient of 1.5 cm^{-1}. With nitrogen purging, the crystal was cooled to 1°C with the aid of a TE cooler. Pumped by a Yb:fiber laser with a pump lens PL (f=10 cm), 8.4 W of 1064-nm beam was focused onto the crystal. The laser cavity was a standard z-fold design with 10-cm focusing mirrors (DM and DCM1), in contrast to previous ring structure [6]. Intracavity dispersion was compensated by three DCMs. Each provided -150-fs^2 group-delay dispersion (GDD) around 1230-nm. Considering the dispersion introduced by the Cr:forsterite crystal (GDD= 568 fs^2) [7], the net -332-fs^2 GDD was sufficient for stable KLM.[8]. Self-started with a SESAM, the resulted output power was 300 mW at a 130-MHz repetition-rate with a 6% output coupler. Figure 2 shows the measured laser spectrum (20-nm FWHM at 1226 nm) and its corresponding autocorrelation trace (85-fs under the assumption of $Sech^2$ pulse-shape), with a

time-bandwidth product $\Delta\nu\Delta\tau$ of 0.34 that is close to the value of a transform-limited pulse. By folding the cavity with DCMs, a compact, prismless, self-started Cr:forsterite laser for nonlinear microscopy is thus realized.

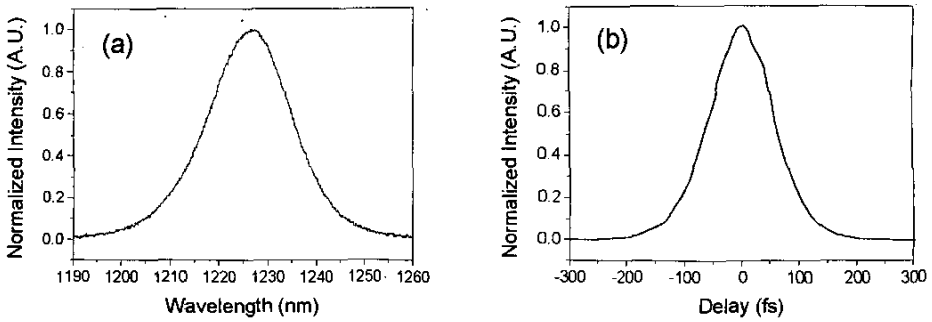

Fig. 2. (a) Output spectrum of the compact Cr:forsterite laser and (b) its corresponding autocorrelation trace.

This developed Cr:forsterite laser was employed as the excitation source of a portable scanning optical microscope. The microscopy system consisted of a scanning unit and an inverted microscope. The output power after objectives could be higher than 100 mW, which is ideal for harmonics-generation microscopy and multi-photon fluorescence imaging. Figure 3(a) shows an example two-photon fluorescence (chlorophyll) image of mesophyll tissue in the leaf of *Rhaphidophora aurea*. Chloroplasts inside the mesophyll cells and the detailed grana distribution inside the chloroplast can all be identified with a sub-micron 3D resolution. Figure 3(b) shows another example second-harmonic-generation (SHG) image of mouse tendon. The distribution of the collagen fibers can be easily resolved through the backward propagating SHG signals with a sub-micron resolution. Various biological applications based on this compact portable nonlinear microscope will be discussed in the conference.

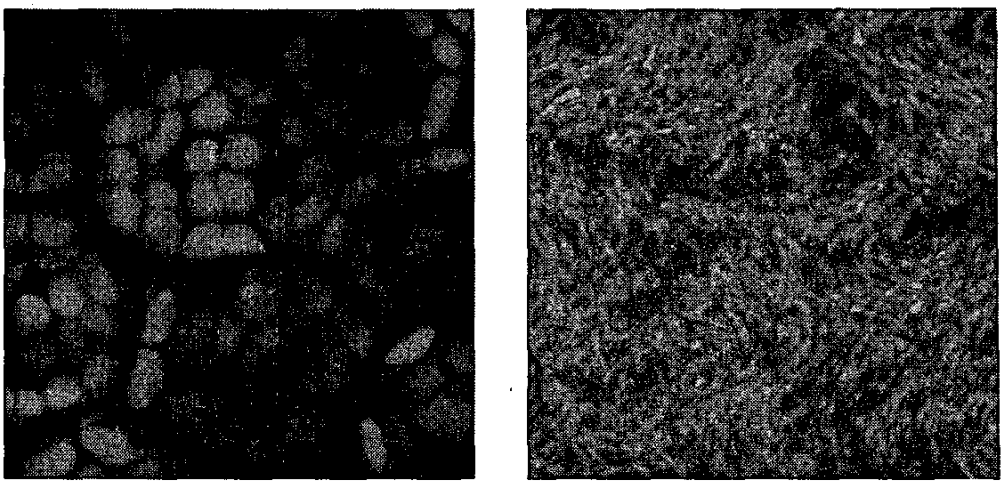

Fig. 3 (a)Two-photon fluorescence image of mesophyll tissue in the leaf of *Rhaphidophora aurea* (80X80 μm).
(b) Backward propagating SHG image of mouse tendon (50X50 μm).

4. References

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