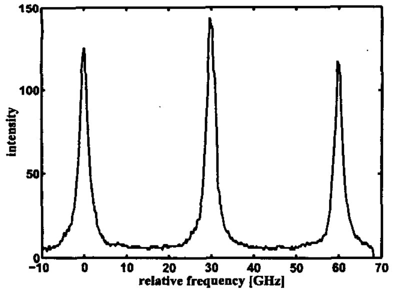

CThP2 Fig. 3. Single axial mode operation of the CGI Cr:forsterite laser was verified using 5 GHz and 30 GHz FSR Fabry-Prot interferometers. The figure shows the transmission fringe pattern for the 30 GHz FSR, finesse 28 interferometer for peak wavelength operation of the laser.

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CThP3 **3:00 pm**

Simultaneous multi-wavelength generation from a modelocked all-solid-state Cr:forsterite laser

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Multi-wavelength generation of ultrashort and highly synchronized pulses directly from a single laser oscillator is of great interest in novel photonic networks utilizing combined optical wavelength-division multiplexed (WDM) and time-division multiplexed (TDM) data format. Many efforts were made already,[1–3] but can achieve relative low output power on the order of several tens of μW up to 1 mW.[1–3] In this presentation, we will demonstrate a multiple-channel modelocked all-solid-state Cr:forsterite laser. By inserting an etalon into the cavity, 12 locked channels with total 280 mW average power were generated. Pulsewidth as short as 1.8 ps can be achieved for a single channel with reflectivity management. Our study of Cr:forsterite laser was also motivated by the recent demonstration of 14-fs pulses from a Cr:forsterite laser cavity with a spectrum covering the whole 1.3 μm and 1.55 μm communication band by Chudoba *et al.*[4]

Structure of the laser resonator is shown schematically in Figure 1. The laser was pumped with an 1064 nm light from a diode-pumped Nd:YVO$_4$ laser (Spectra-Physics Millennia IR). Laser Z-cavity consisted with a 5% output coupler, 3 laser mirrors (M1, M2, M3), and a semiconductor saturable absorber mirror (SESAM). A SF6 prism pair was inserted to provide intracavity group-velocity dispersion compensation. A 0.15 mm cover glass (Matsunami Glass) with 1.5 refractive index was inserted as etlon to divide wavelength.

Without the cover glass, the 8.5 W pumped Cr:forsterite laser obtained 81 MHz 130 fs pulses when sech^2 profile was assumed and the full width half maximum (FWHM) of the spectrum was 13 nm, which resulted in 0.334 time bandwidth product. After insertion of the cover glass and tuning the prism position for dispersion control, the resulted output spectrum (Fig. 2(a)) shows 12 output channels and the corresponding autocorrelation trace (Fig. 2(b)) shows dense modulation over an envelope of 18.5 ps FWHM (dot line in Fig. 2(b)). To investigate the detailed pulse shape property for each channel, we also performed SHG FROG. Results are shown in Fig. 3 with both temporal and spectral modulation. The observation of temporal modulation indicated wide range phase correlation between each channel. After recovery for each channel, we found that the channel pulse width ranged from 9 ps to 19 ps. After reduction of interface reflectivity by turning the incidence angle to 50 degree, resulted channel pulsewidth could be down to 1.8 ps. More detailed data would be presented in the conference.

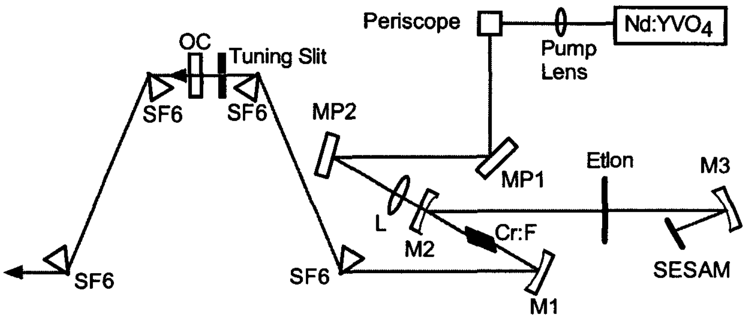
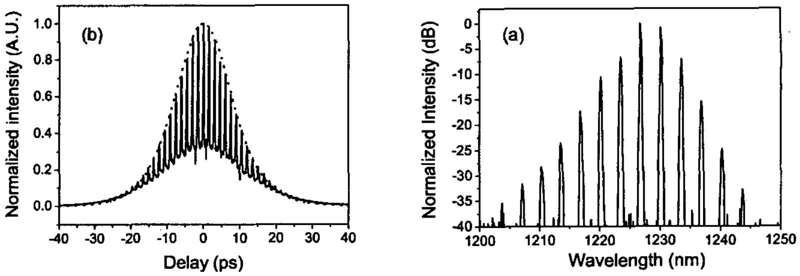
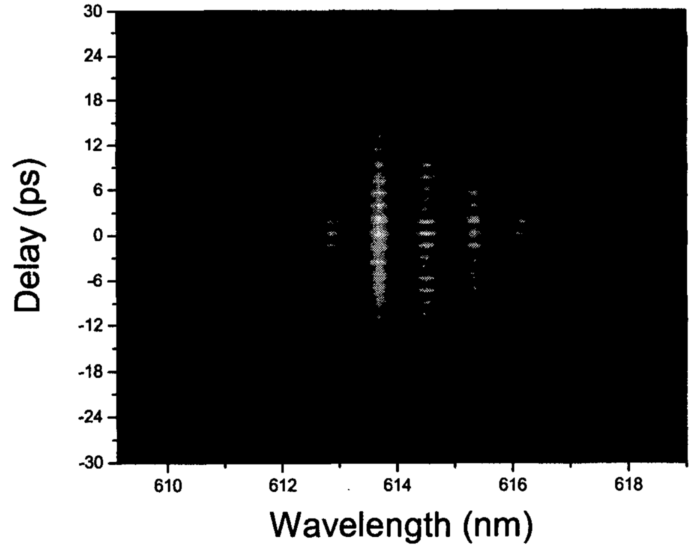


Fig. 1. Experimental Setup

CThP3 Fig. 1. Experimental Setup



CThP3 Fig. 2. (a) Output spectrum and (b) its corresponding autocorrelation trace of the multi-wavelength Cr:forsterite laser output when the cover glass was inserted normal to the laser beam. Dotted line in (b) is a sech square fitting.



CThP3 Fig. 3. Corresponding SHG FROG trace with etlon inserted normal to laser beam.

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CThP4 **3:15 pm**

Mode-locking of Cr^{4+}:YAG micro-chip lasers

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Compact, reliable and cheap femtosecond laser sources with fundamental repetition rates of 10 GHz and above are desirable for applications like high-speed optical data transmission in the 1.5 μm wavelength region, or for optical analog to digital conversion. On the other hand, robust, Q-switched lasers with average output-powers of several hundred milliwatts at the eye-save region around 1.5 μm are needed for light detection and ranging (LIDAR) applications. An interesting approach towards these goals are Cr^{4+}:YAG micro-chip lasers (for micro-chip lasers see e.g. [1]). Cr^{4+}:YAG satisfies both the requirements for femtosecond pulse generation as well as for applicability in fiber-optic communication systems. This paper presents first experimental results towards mode-locking of a Cr^{4+}:YAG microchip laser. Kerr-lens mode-locked operation of a 8.2 mm long Cr^{4+}:YAG microchip laser using a Q-switched Nd:YVO$_4$ laser for pumping is demonstrated. Q-switched mode-locked operation at a fundamental repetition rate of 10 GHz with 200 fs pulses and output powers up to 300 mW is observed. Also passive Q-switched mode-locking with saturable Bragg-reflectors is demonstrated (principle structure of the SBRs see Ref. 3). Numerical simulations of the temporal pulse-shaping dynamics in the micro-chip laser are presented. These simulations are used to determine the minimum intracavity energy needed to overcome Q-switching in order to obtain a continuous-wave mode-locked pulse train.

The experimental setup of the micro-chip laser is sketched in Fig. 1. A diode-pumped Nd:YVO$_4$ laser which can be operated either in continuous-wave (cw) or in Q-switched mode is used for pumping the Cr^{4+}:YAG material. The micro-chip laser consists of the active material sandwiched between two flat mirrors, one of them being used as the output-coupler mirror (OC). The other one is either a high-reflector (HR) for KLM operation or a saturable Bragg-reflector (SBR) as a mode-locker.

Fig. 2 shows the mode-locked spectra emitted by the micro-chip laser shown in Fig. 1 when mode-locked with the Kerr-Lens effect (left) and with a SBR (right). The inset shows the intensity-autocorrelation of the 200 fs pulses emitted by the micro-chip laser mode-locked only with the Kerr-Lens effect. To obtain enough KLM action we increased the intracavity peak power of the micro-chip laser by using a Q-switched pump-source. For the SBR mode-locking, a cw pump-source was used but the system was plagued by Q-switching. A severe problem of high repetition-rate lasers is the Q-switching instability since the achievable intracavity pulse energy is limited. Several techniques to overcome this instability have been proposed.[3,4] To evaluate the effectiveness of these techniques in the micro-chip setup we perform numerical simulations of the temporal dynamics of the system. The results of such a simulation are shown in Fig. 3. The minimum pulse energy W_{crit} needed for continuous-wave mode-locking of the system, shown in Fig. 1, is plotted as a function of the intracavity net-dispersion per round-trip for different thickness of an intracavity indiumphosphide (InP) layer which serves as a two-photon absorber. It can be clearly seen, that an appropriate dispersion compensation in conjunction with a two-photon absorber can lower W_{crit} by one order of magnitude, which should allow cw-modelocked operation of the device in the near future.

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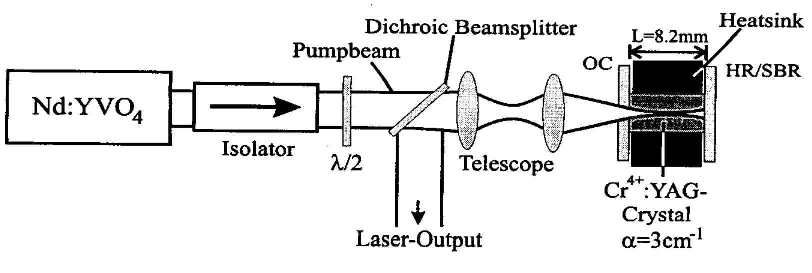
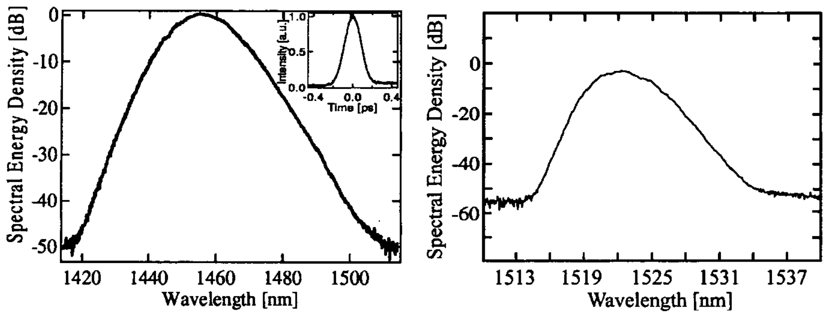


CThP4 **Fig. 1.** Experimental setup of the micro-chip laser.



CThP4 **Fig. 2.** Mode-locked spectra emitted by the system sketched in Fig. 1. Left: mode-locked by the Kerr-lens effect; right: mode-locked by an SBR. The inset shows the intensity-autocorrelation trace of the pulses emitted by the micro-chip laser when operated in the KLM regime.