1-GW-Peak-Power, Cr:ZnSe Laser

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Motivation

Goal:

development of practical femtosecond laser source in mid-infrared (2-5 μm) with high pulse energy output (0.1-1 mJ).

Recent advances:

high-power Tm:fiber lasers ,
progress with quality of Cr^{2+}:ZnSe crystals.

Some of the applications:

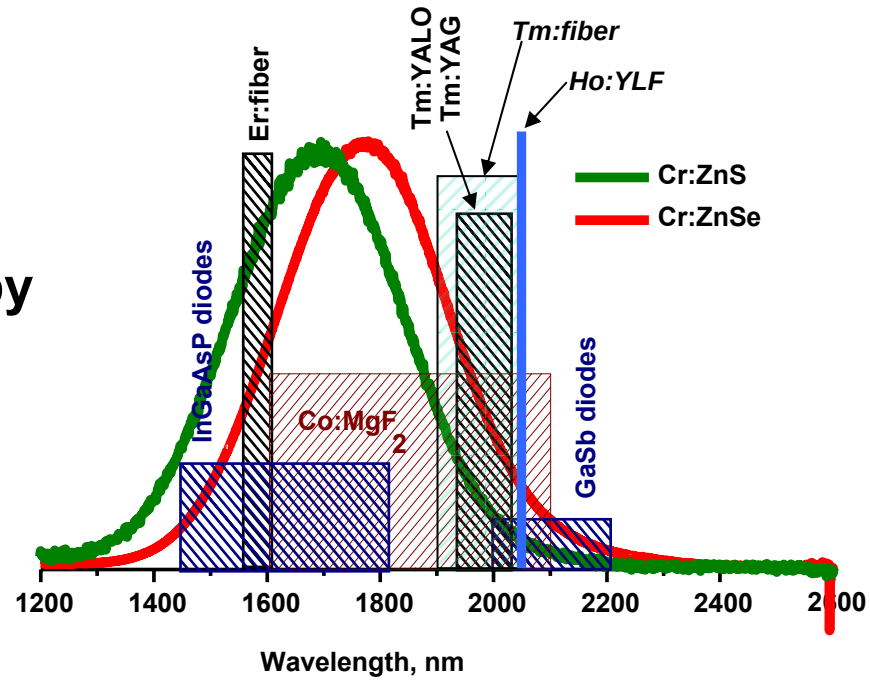
Remote sensing,
Trace gas monitoring,
Medical applications,
Semiconductor spectroscopy.

„Ti:Sapphire of infrared “

	Cr:ZnSe	Ti:Sapphire
Crystal structure	Cubic	Uniaxial
Thermal conductivity	18 W/m°C	28 W/m°C
Thermooptics *dn/dT*	$70 \cdot 10^{-6}$ 1/ °C	$12 \cdot 10^{-6}$ 1/ °C
Third order nonlinearity n_2	$180 \cdot 10^{-20}$ m²/W at 1.6 μm*)	$3 \cdot 10^{-20}$ m²/W
Two-photon absorption	band gap 2.83 eV	~8 eV
Second-order nonlinearity	very high: 30 pm/V	absent
Peak emission cross-section σ_{em} at λ_0	$13 \cdot 10^{-19}$ cm² 2450 nm	$4.5 \cdot 10^{-19}$ cm² 780 nm
Fluorescence bandwidth $\Delta\lambda$	1000 nm (50 THz)	300 nm (130 THz)
Relative bandwidth $\Delta\lambda/\lambda_0$	0.49	0.57
Peak pump cross-section σ_{abs} at λ_{max}	$11 \cdot 10^{-19}$ cm² 1780 nm	$0.65 \cdot 10^{-19}$ cm² 500 nm
Lifetime at room temp.	6 μs	3 μs
$I_{sat} = h\nu/\sigma_{em}\tau$	11 kW/cm²	210 kW/cm²
Direct diode pumping	Yes	No

Pumping options

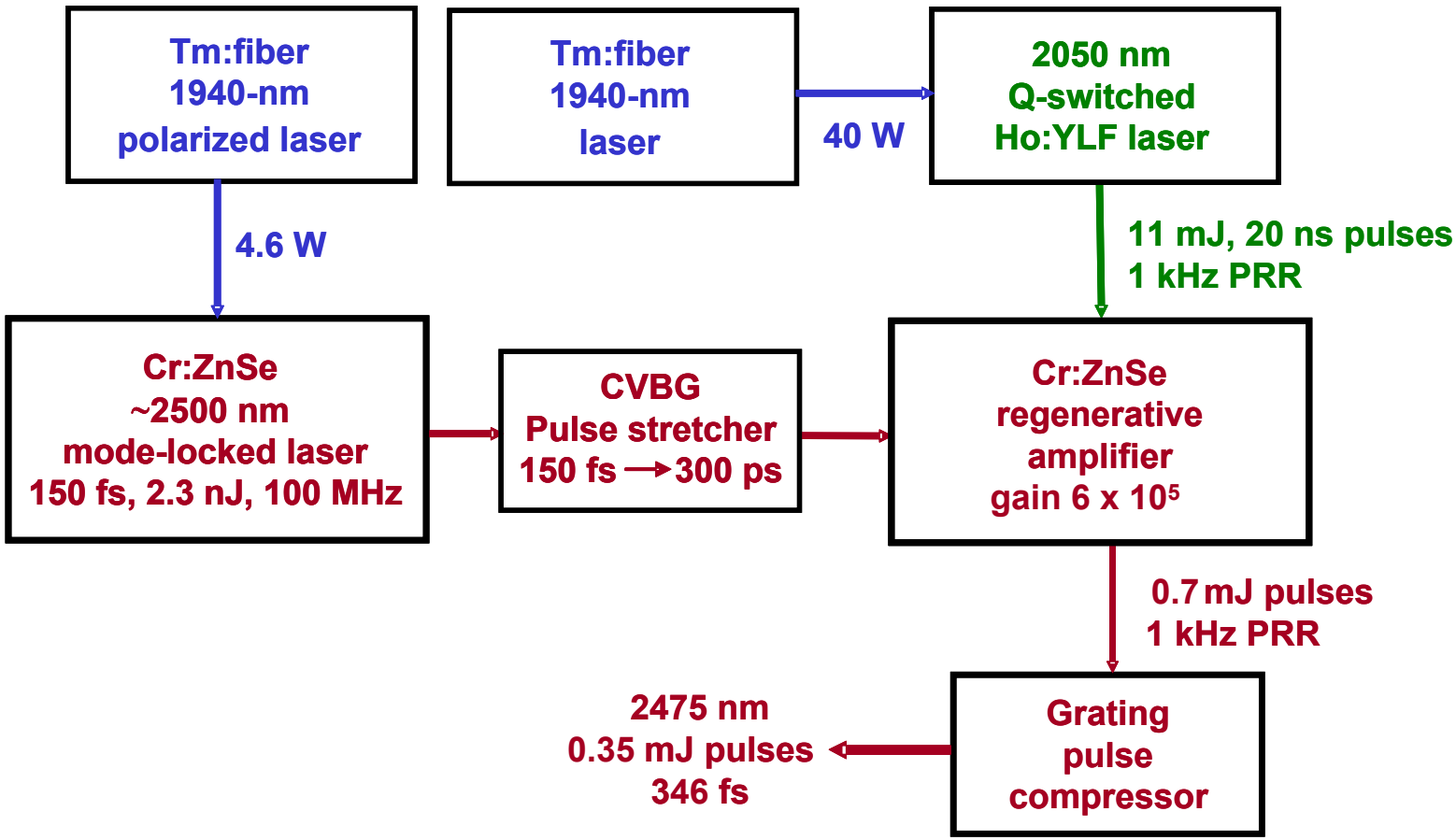
- Femtosecond oscillator can be pumped by either diode, Er: or Tm:doped fiber lasers.
- Due to short upper state life time (6 μs) the amplifier has to be pumped by high energy source.
- Ho:YLF laser can be used as an energy storage:
  - can be pumped by Tm:fiber laser
  - 2.05 μm output is suited for high energy pumping of Cr:ZnSe with reduced thermal stress.



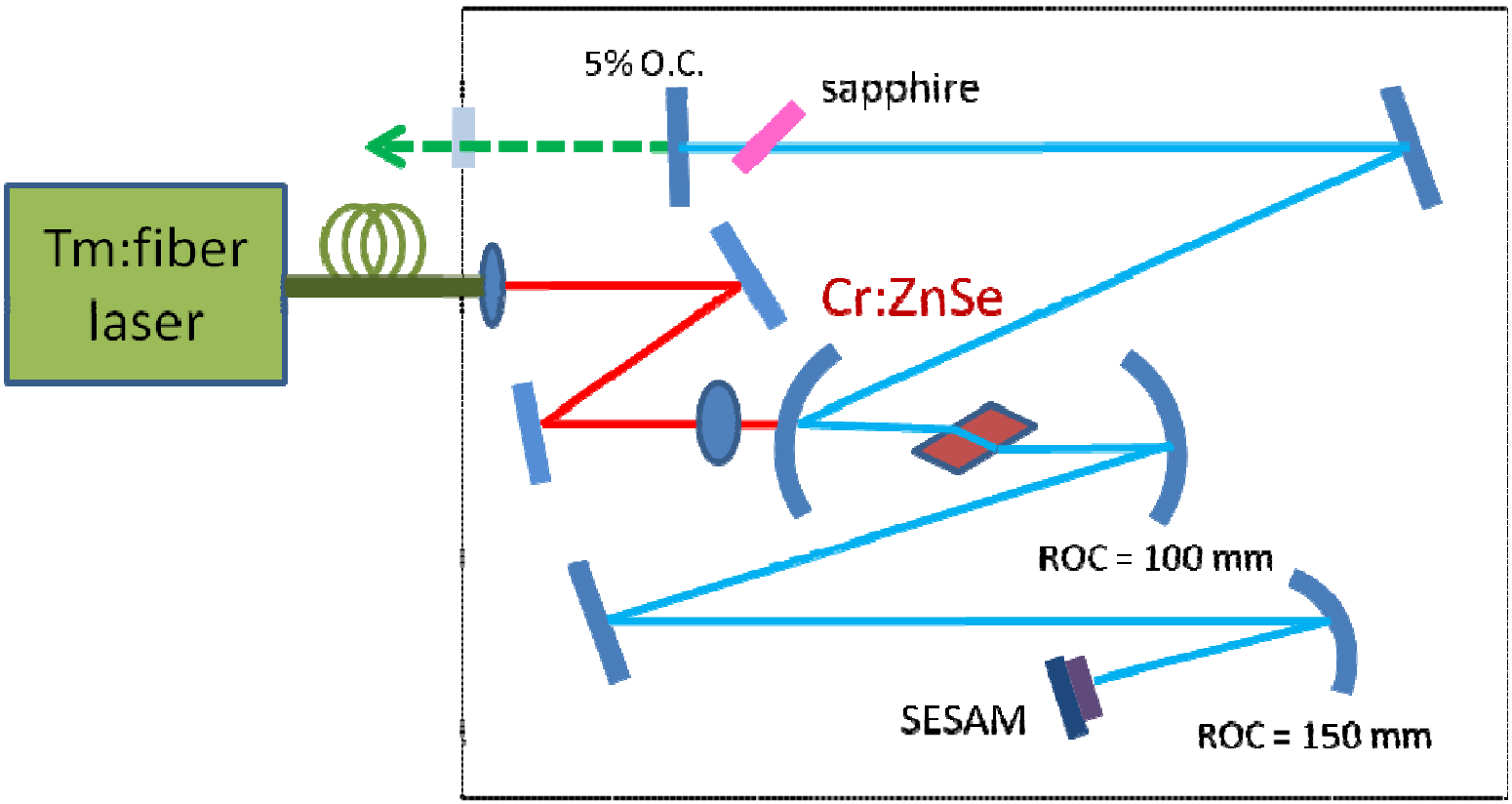
State-of-the-art in Cr:ZnSe lasers

Laser characteristics	Output parameter	Reference
CW, output power, W	15	IPG Photonics
CW, tuning range, nm	2000-3100	Sorokina et al., 2004
CW, efficiency, %	70	Mond et al., 2001
Pulsed, output power, W	18.5 @ 10 kHz	Carrig et al., 2004
Pulsed, output energy, mJ	14 @ 200 μs	Koranda et al., 2006
Pulsed, tuning range, nm	1880-3100	Demirbas et al., 2006
SBR mode-locked	80 fs @ 80 mW	Sorokina et al., 2007

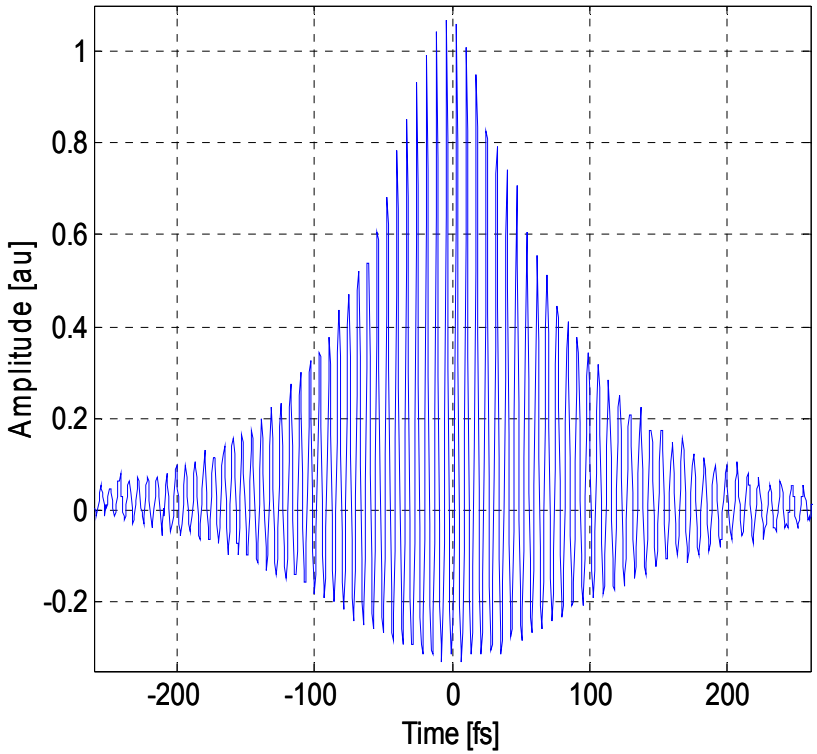
Mid-IR fiber laser-pumped Cr:ZnSe CPA system

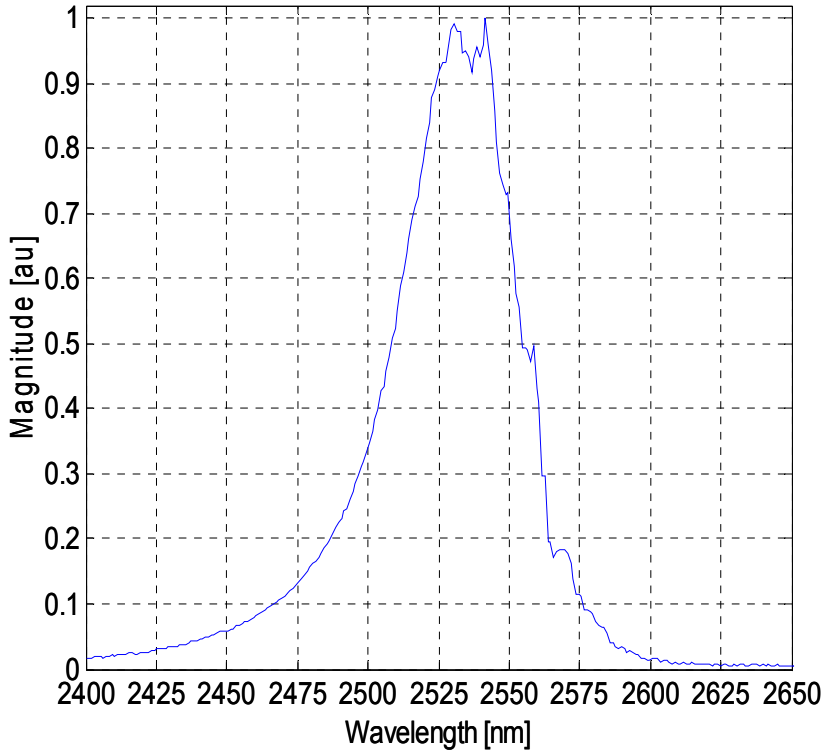


Femtosecond oscillator



Pulsewidth and spectrum

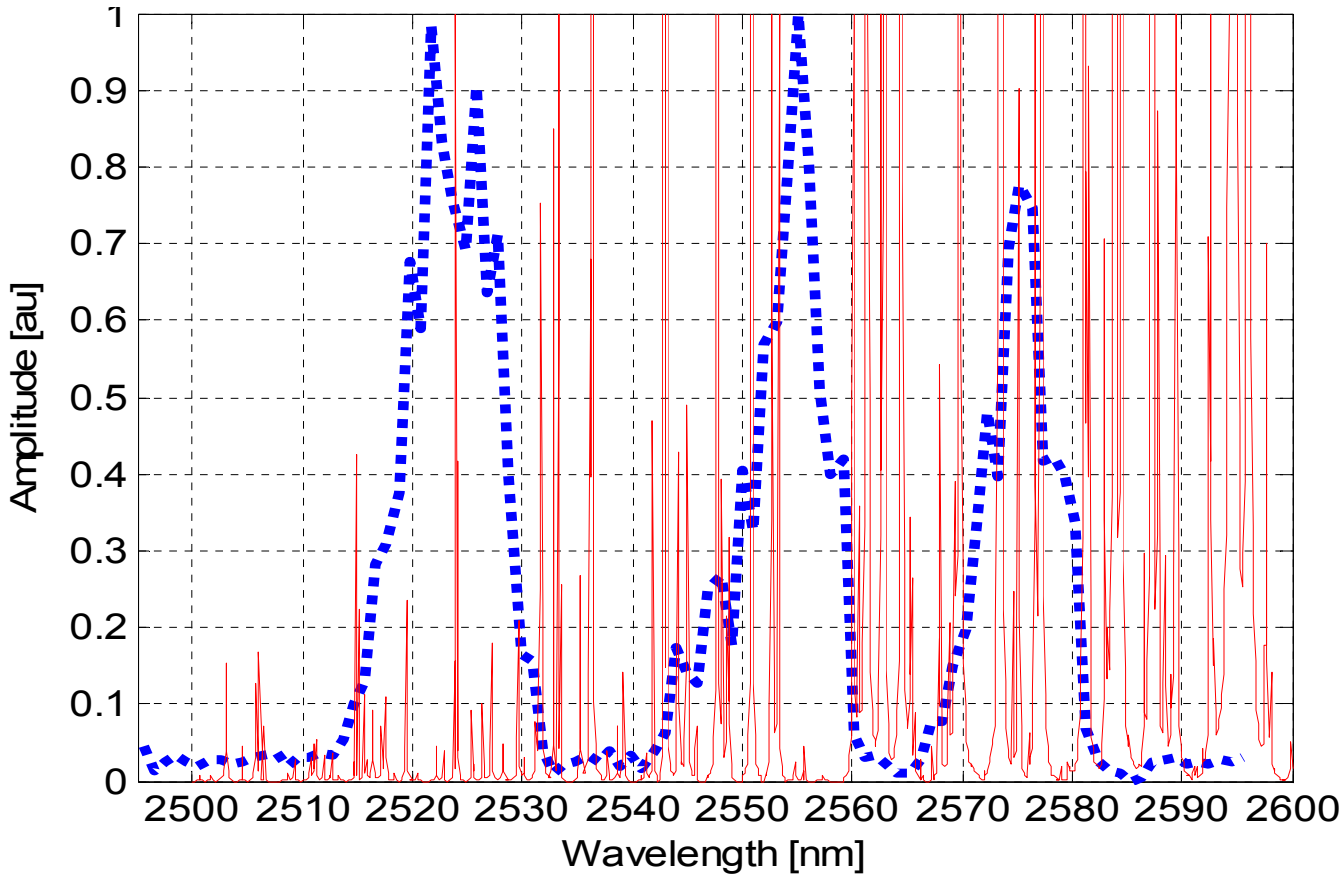




Autocorrelation trace with a FWHM pulse duration of 130 fs.

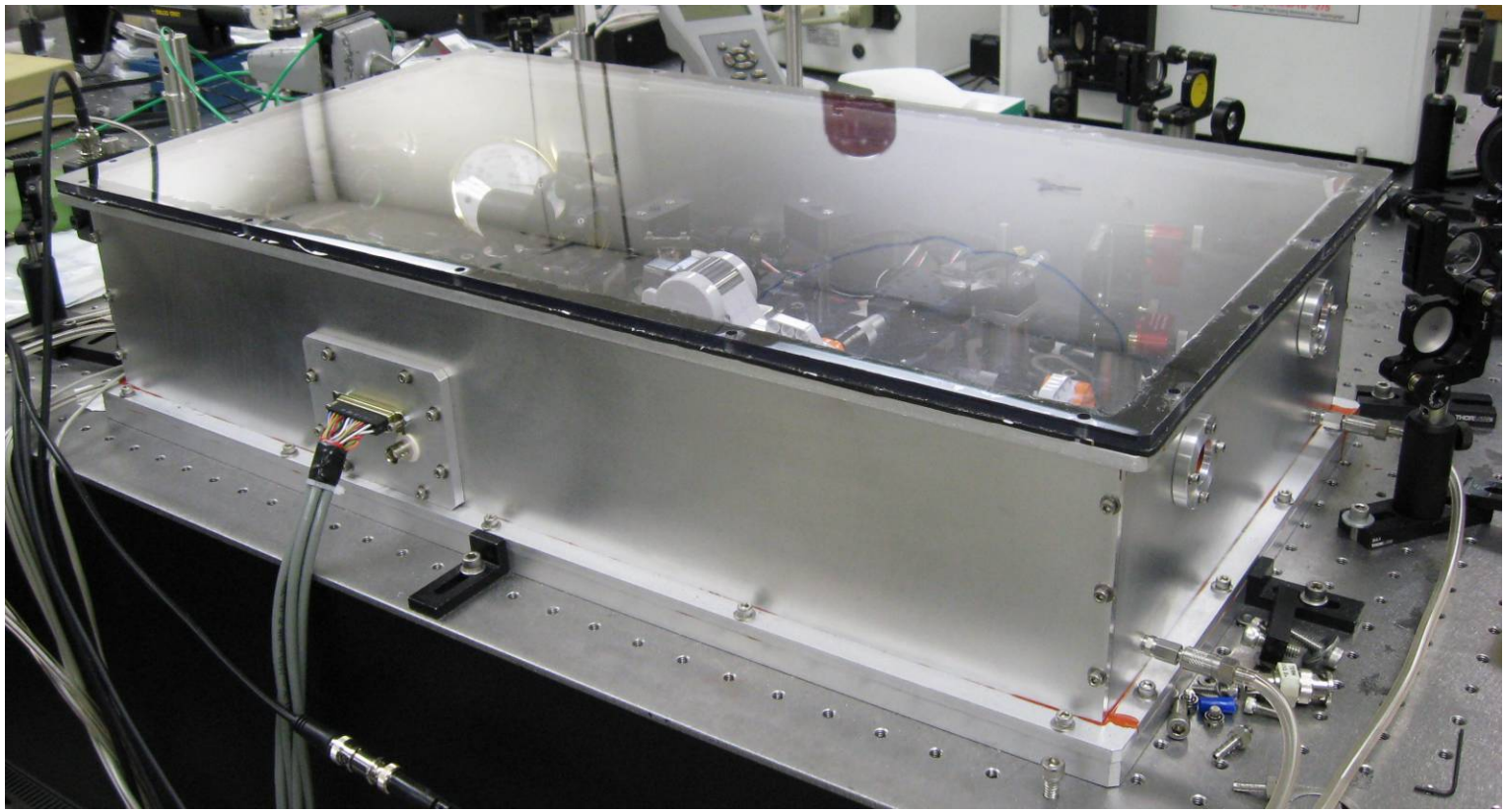
The spectrum centered at 2530 nm with a FWHM of 50 nm.

Water vapor absorption

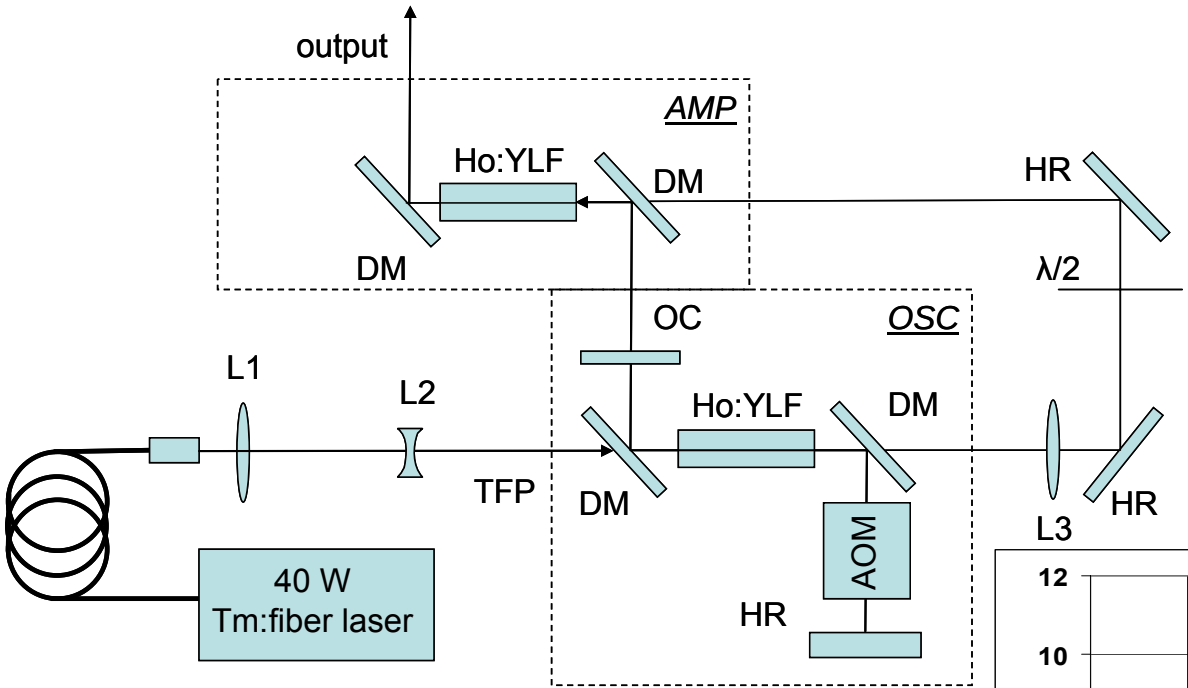


Water absorption lines between 2.5 and 2.6 μm (red) and the output spectrum of Q-switched Cr:ZnSe laser (blue) without N_2 purging.

Sealed box with remote controls



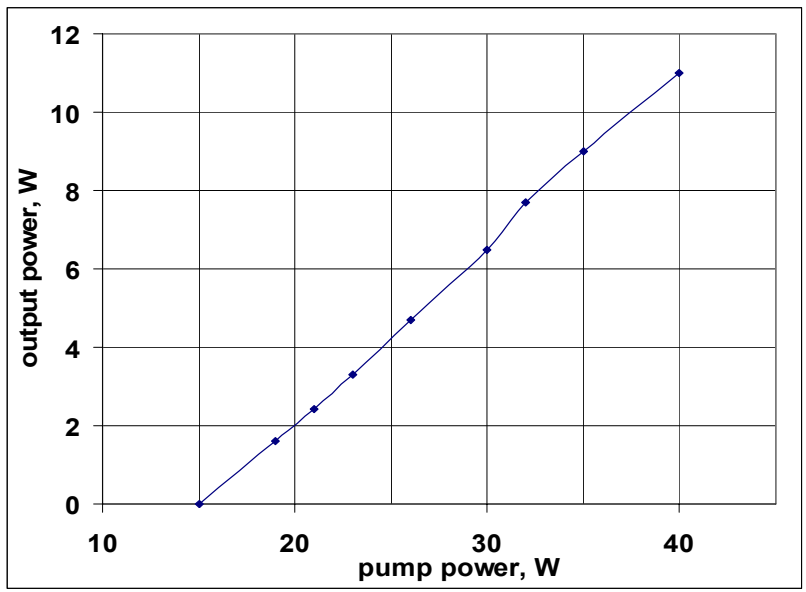
Ho:YLF MOPA



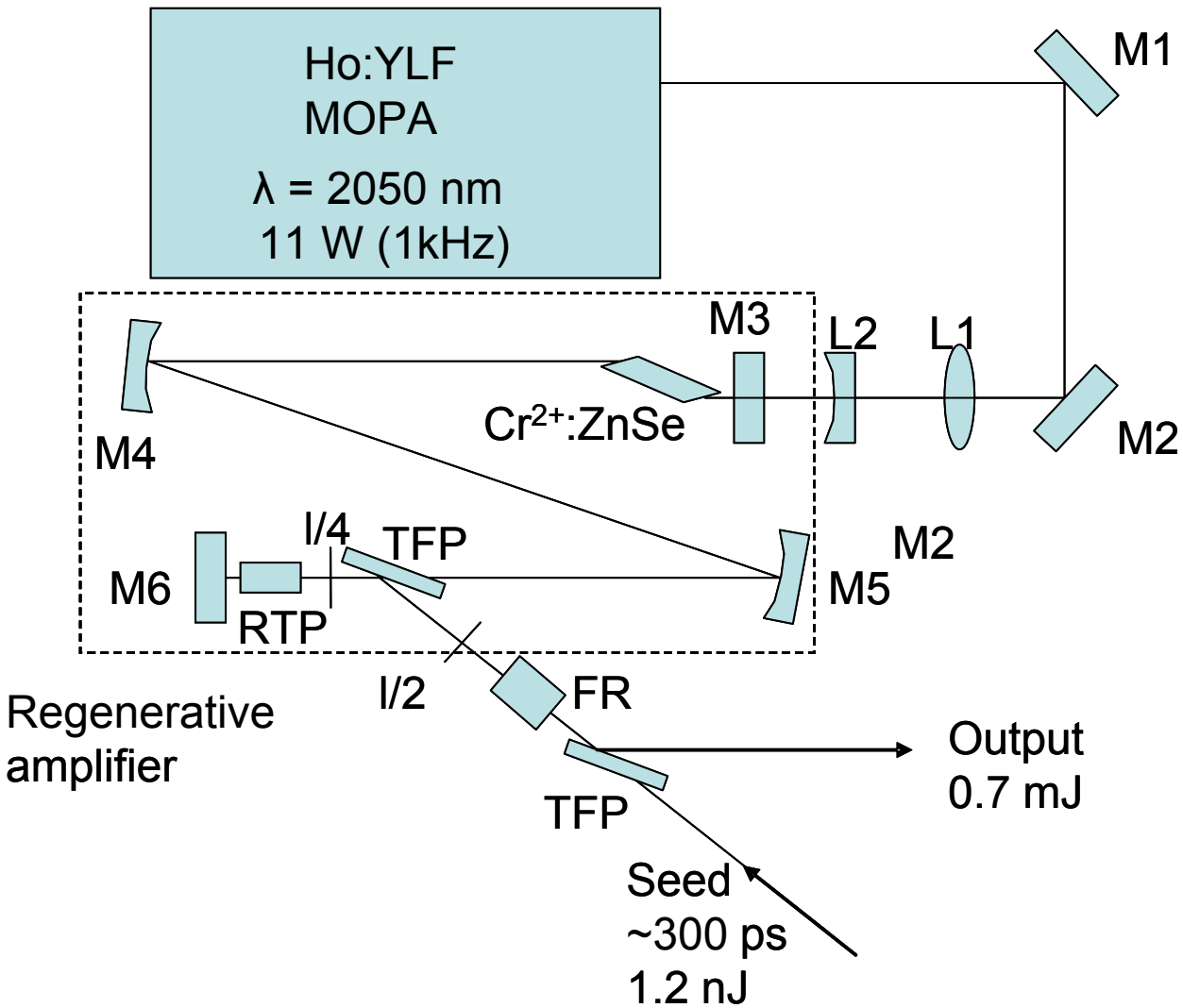
Output power 11 W

Repetition rate 1 kHz

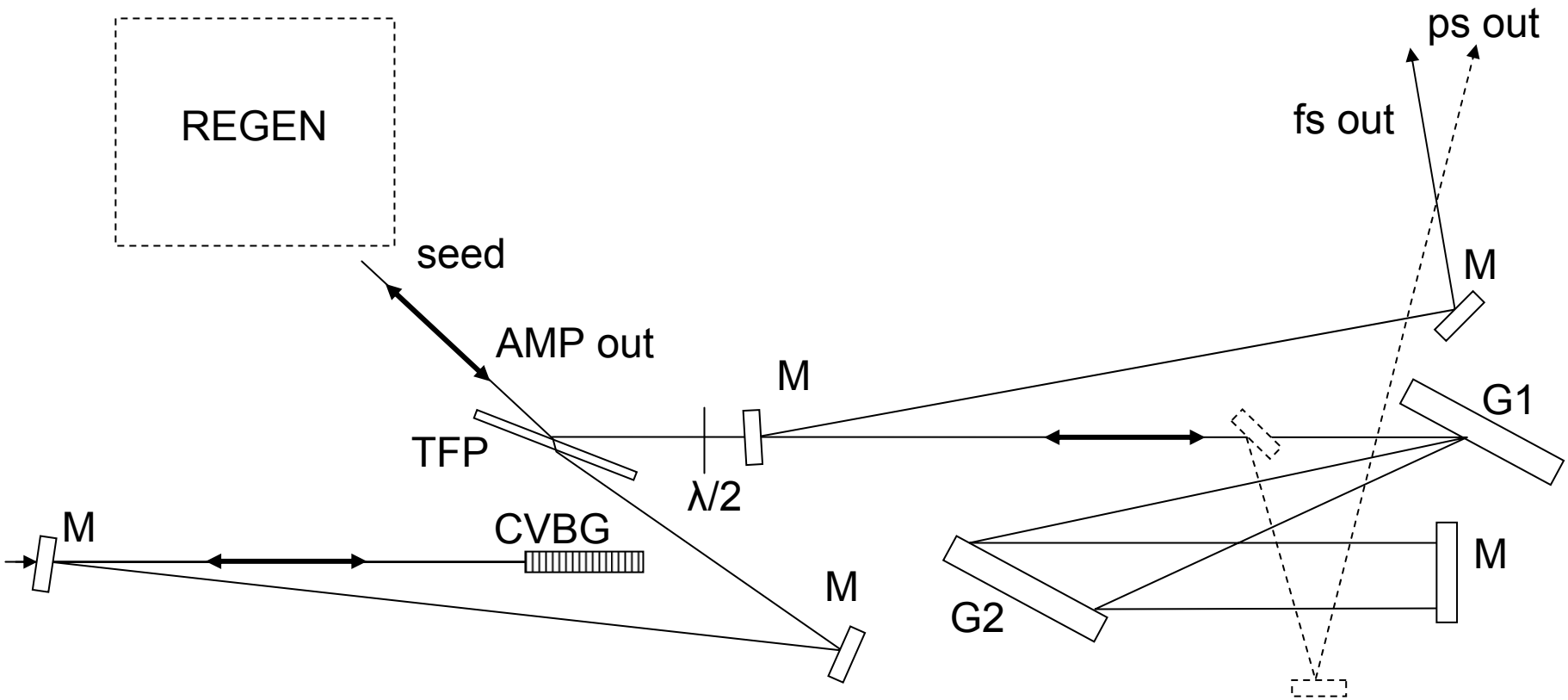
Pulse duration 20 ns



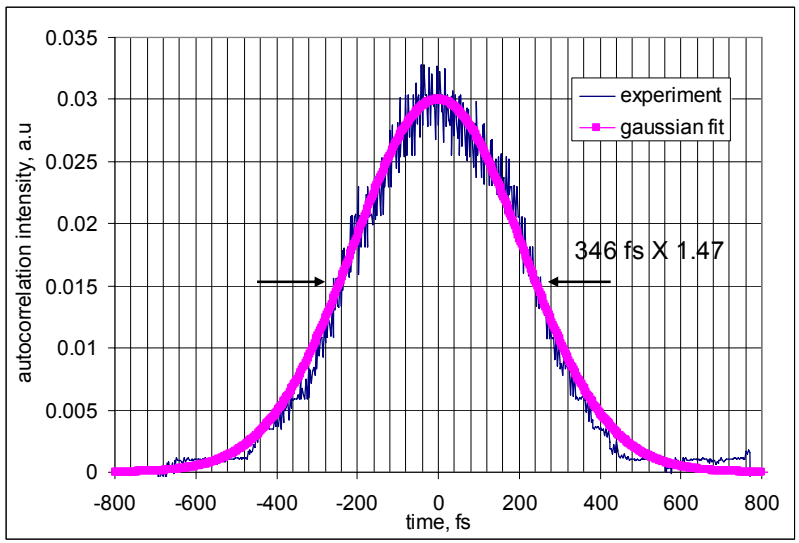
Regenerative amplifier

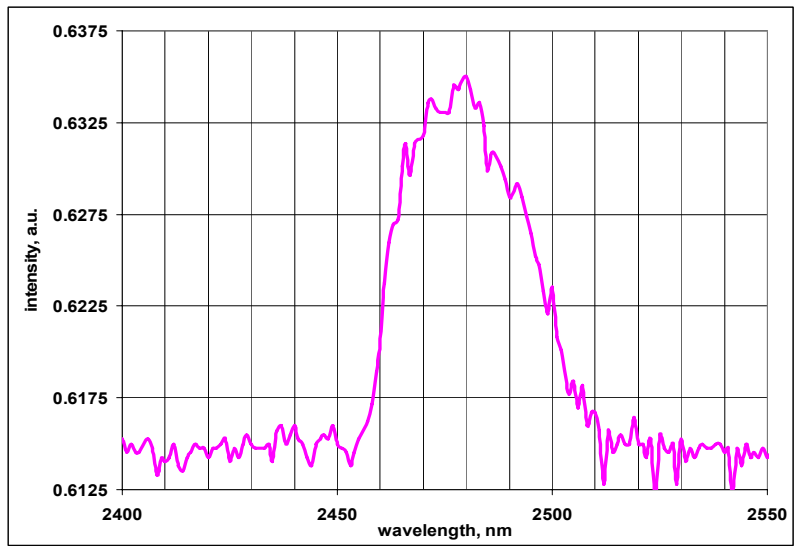


Stretcher-compressor pair



Pulsewidth and spectrum

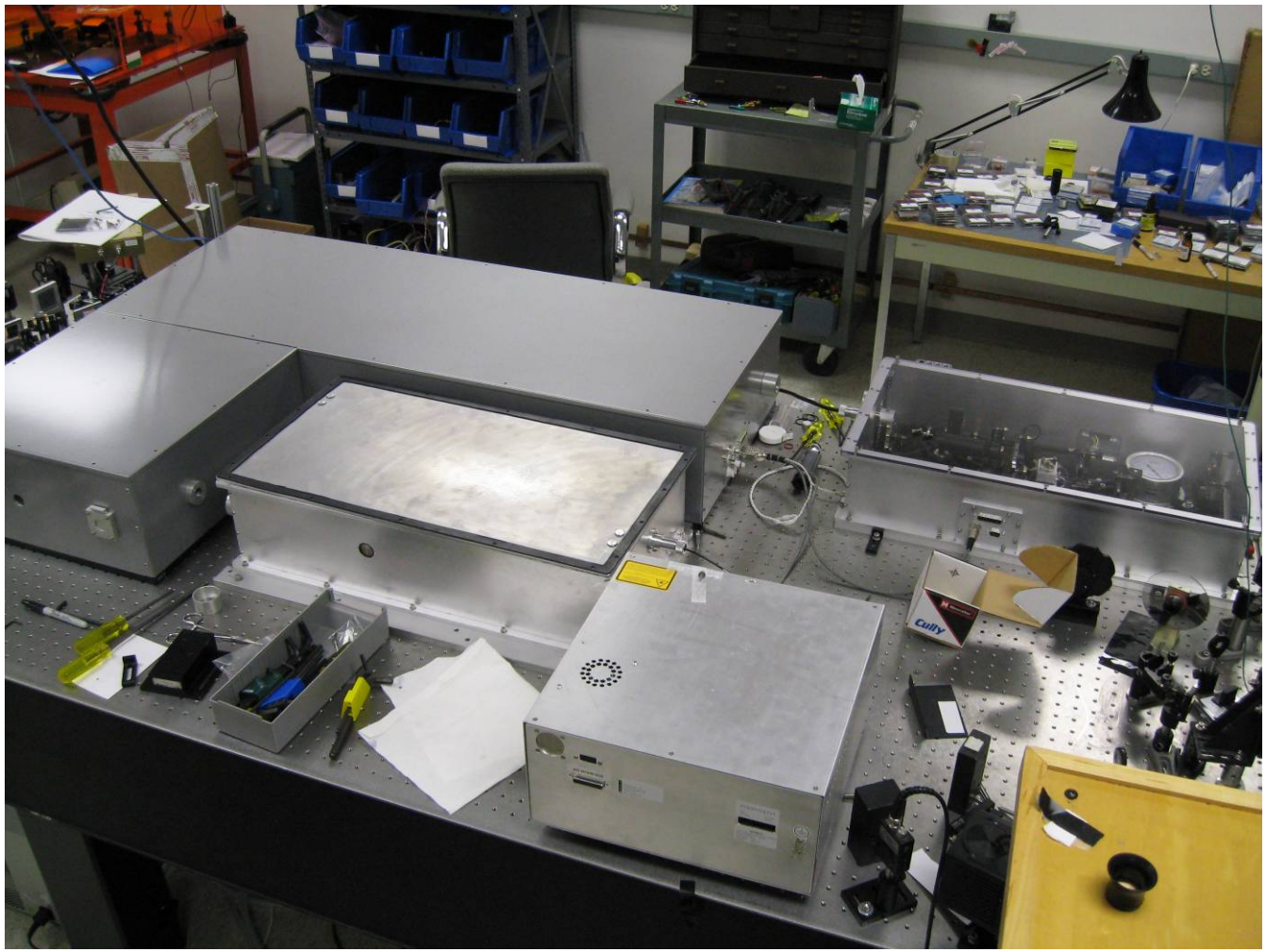




Autocorrelation trace with a FWHM pulse duration of 346 fs.

The spectrum centered at 2475 nm with a FWHM of 37 nm.

Top view of system



Conclusions

- We have developed a 1 GW ultrafast mid-IR high power CPA laser system based on Cr:ZnSe crystals.
- Power scaling is possible with more powerful Ho:YLF lasers.
- Shorter pulses can be achieved with conventional grating stretcher-compressor pairs.

Acknowledgments

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