DFG-based mid-IR laser system for the FAMU experiment

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THE PROTON RADIUS

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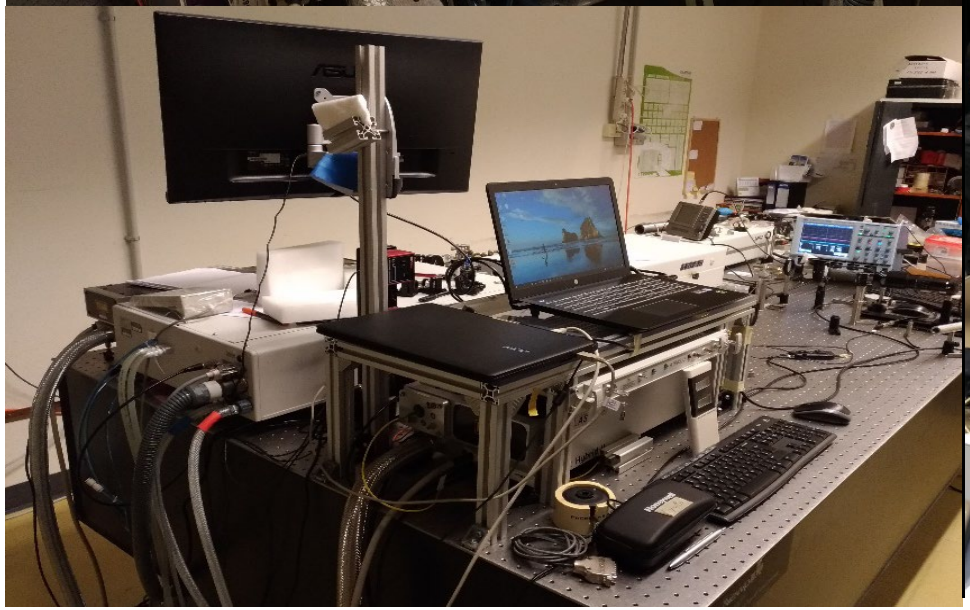
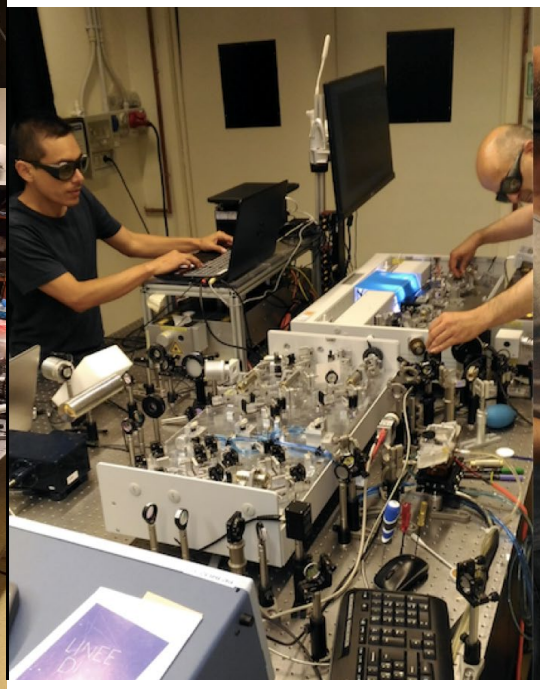
The lab

Q-switched single frequency Nd:YAG (1,064 μm) and a single frequency tunable Cr:Forsterite master-oscillator power-amplifier laser system operating at 1,26 μm, pumped by a Nd:YAG lasers

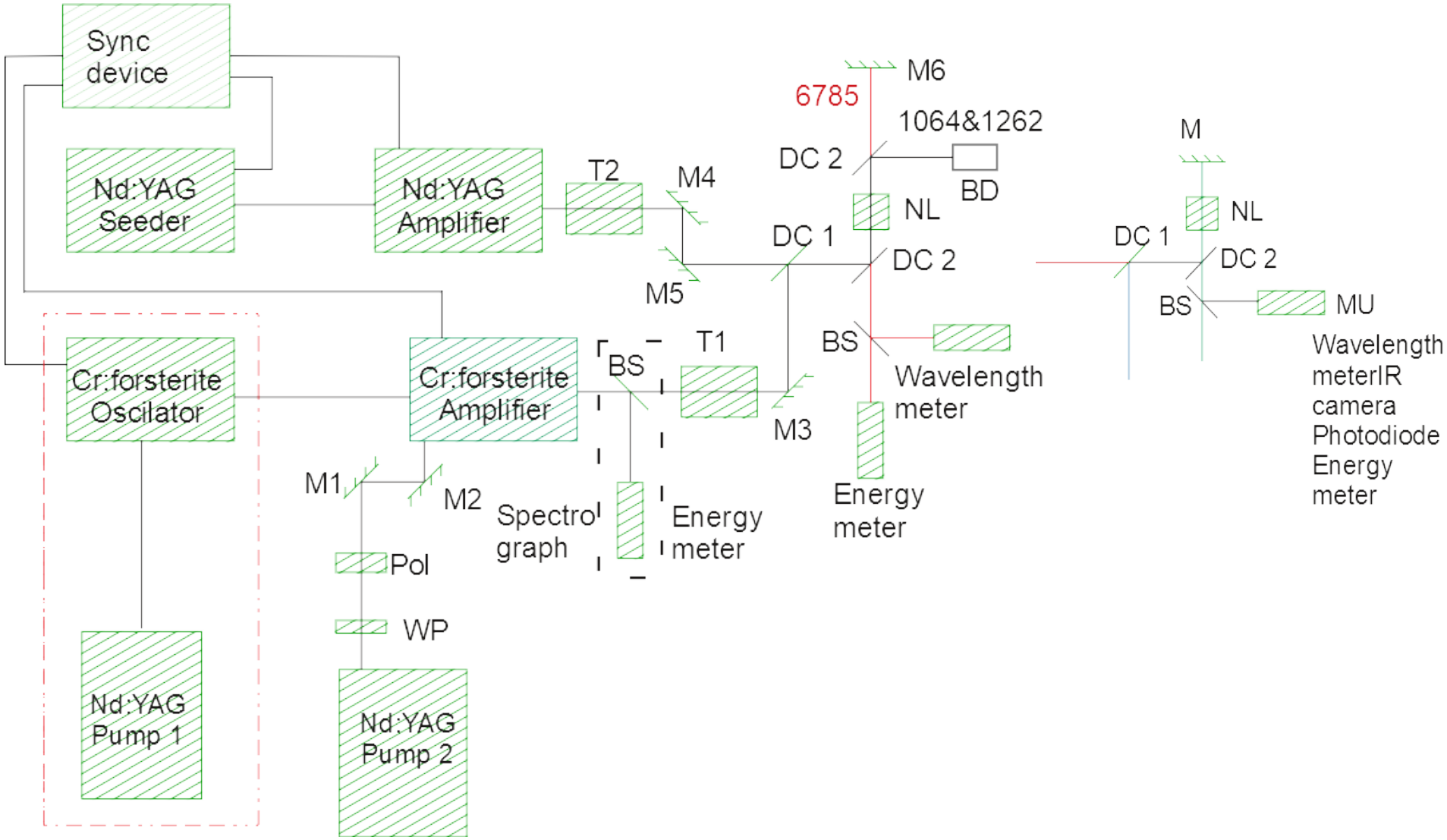




Tunable MIR emission in the 6785 nm range

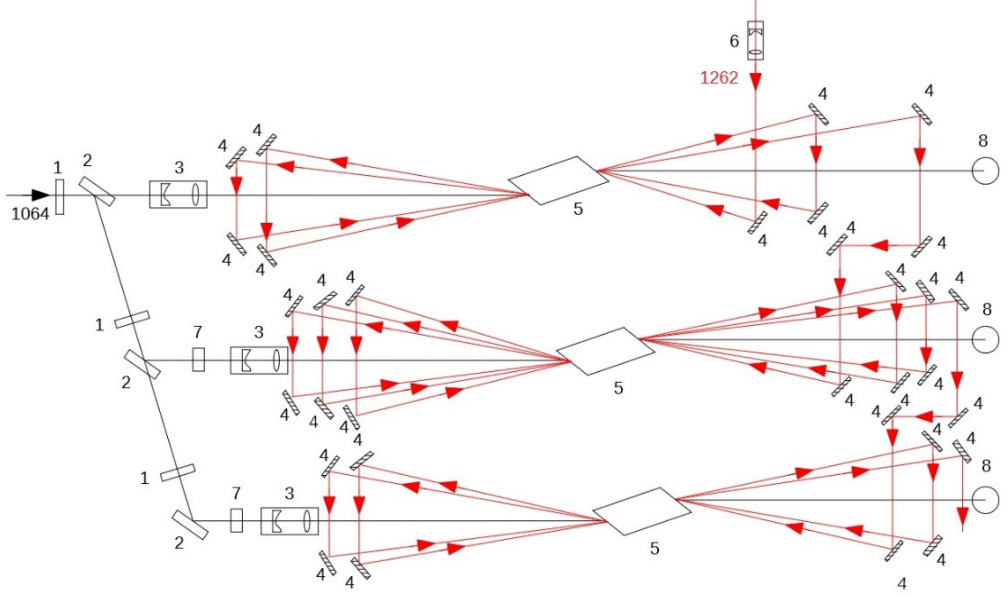
Pulse energy:	> 1 mJ (5 mJ)
Wavelength:	λ =6785 nm
Line width:	$\Delta\lambda$ = 0.070 nm (450 MHz)
Tunability range:	6785 ± 3 nm required (± 50 nm)
Tunability step:	0.030 nm (200 MHz)
Repetition rate:	25 Hz

Final scheme of the DFG based laser system

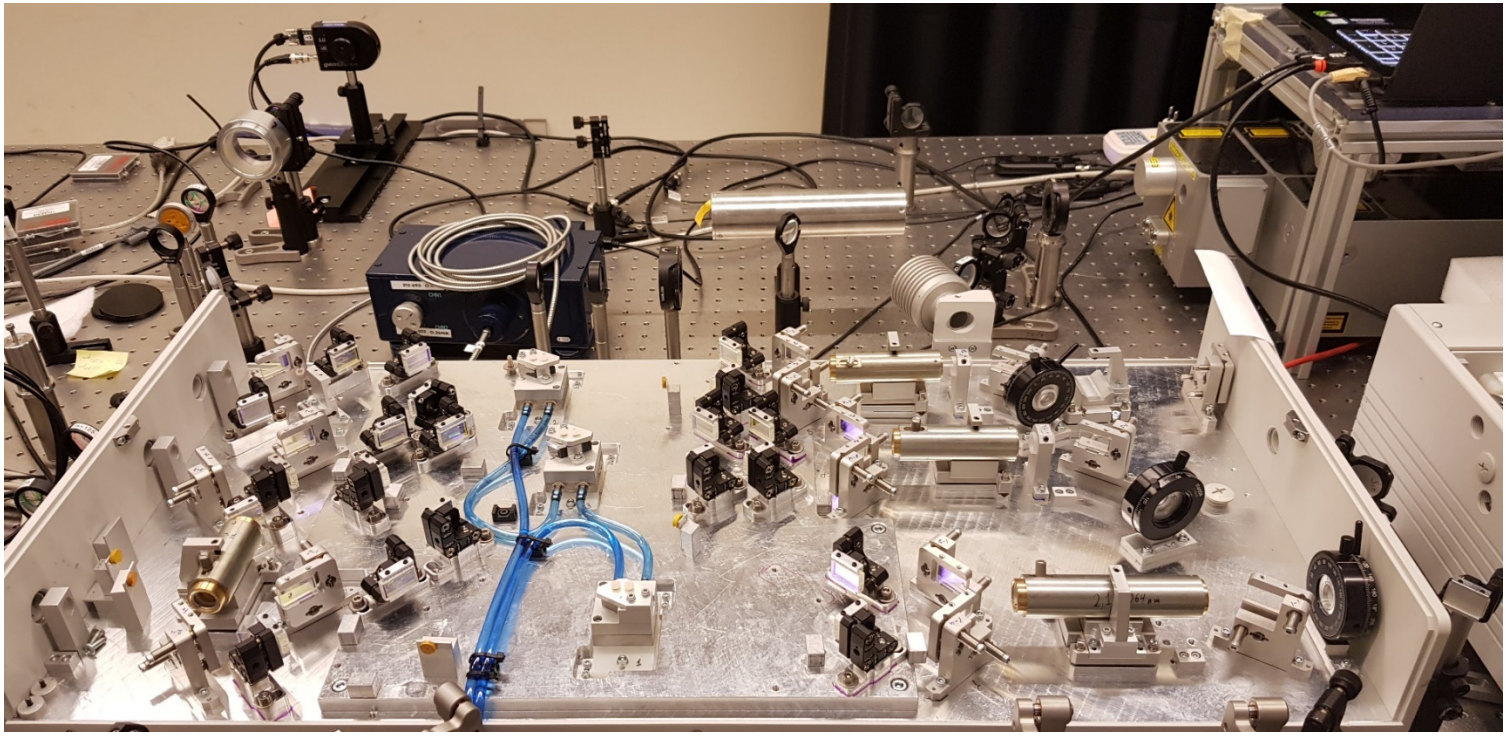


WP - waveplate, Po - polarizer, M1-M5 - mirrors, T1 and T2 - telescopes, BS - beamsplitters,DC1 - dichroic mirror (reflecting 1.26μm, transmitting1.06μm), DC2 - dichroic mirror(reflecting 1.06 and 1.26 μm, transmitting 6.76μm)

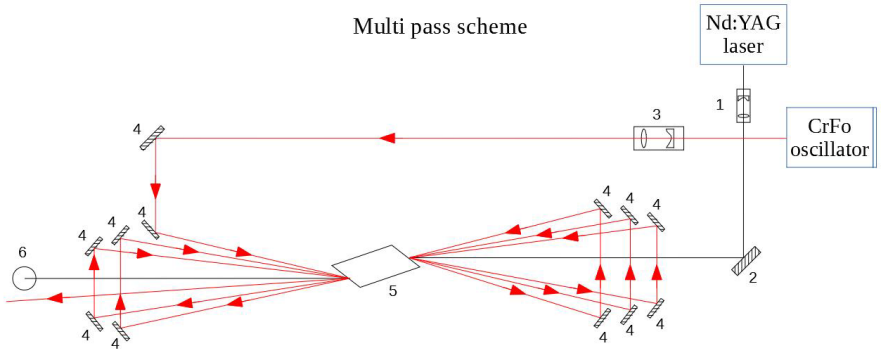
3-stage multipass Cr:Forsterite amplifier 14 pass



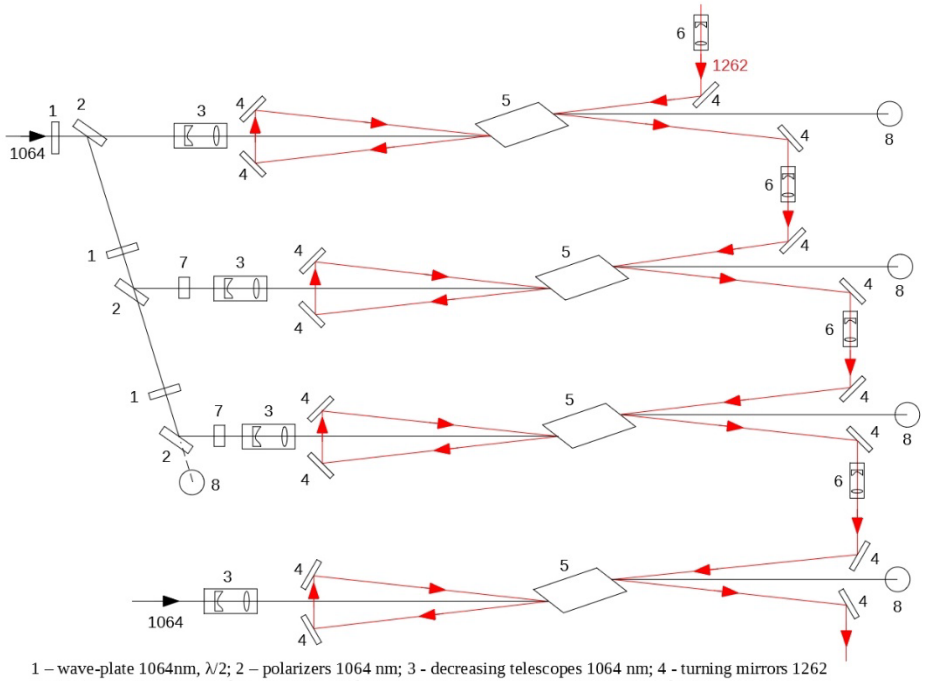
1 – wave-plate 1064nm, λ/2; 2 – polarizers 1064 nm; 3 - increasing telescopes 1064 nm; 4 - turning mirrors 1262 nm; 5 - Cr:Forsterite crystasl; 6 - decreasing telescopes 1262 nm; 7 – rotators 1064 nm; 8 - beam stops



1,5 mJ imput – 24 mJ output, pump energy 730 mJ, ~ 3% efficiency



1 - decreasing telescopes 1064 nm; 2 – turning mirror 1064 nm; 3 - decreasing telescopes 1262 nm; 4 - turning mirrors 1262 nm; 5 - Cr:Forsterite crystal; 6 - beam stops



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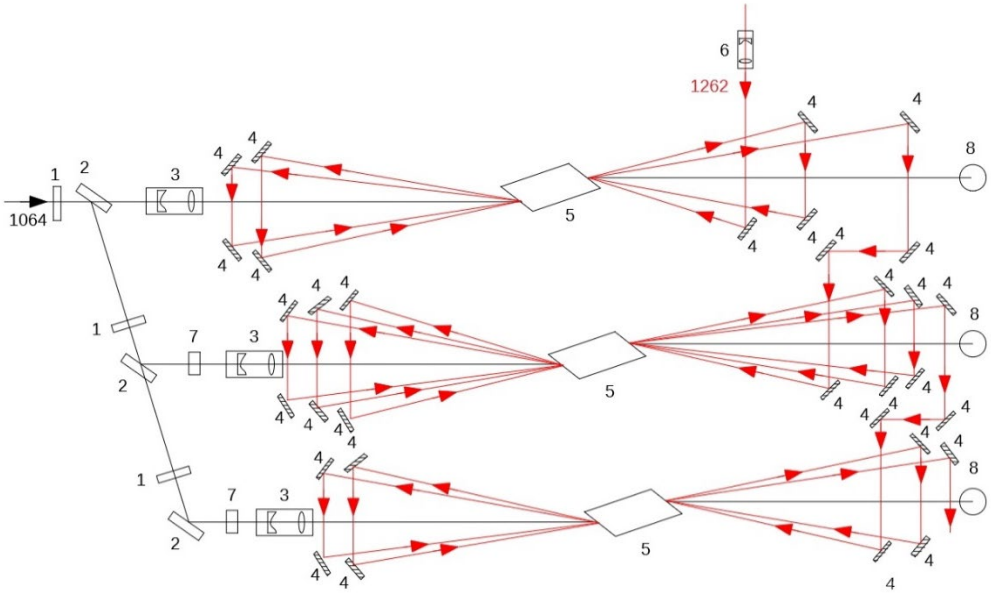
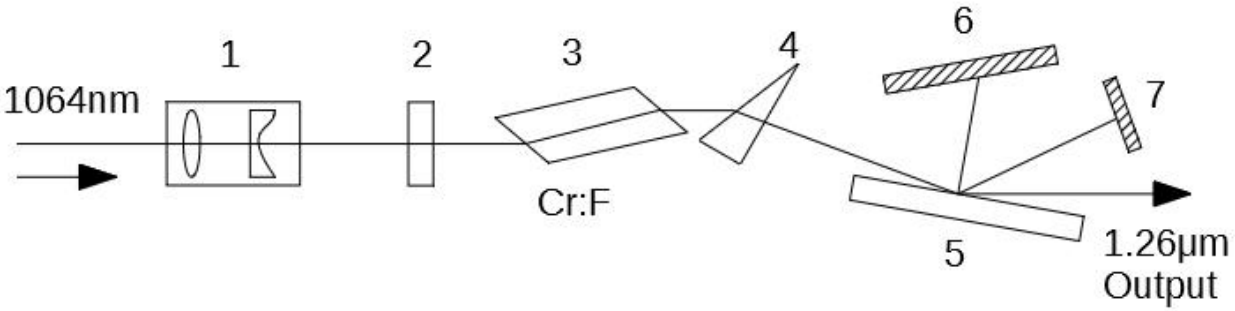
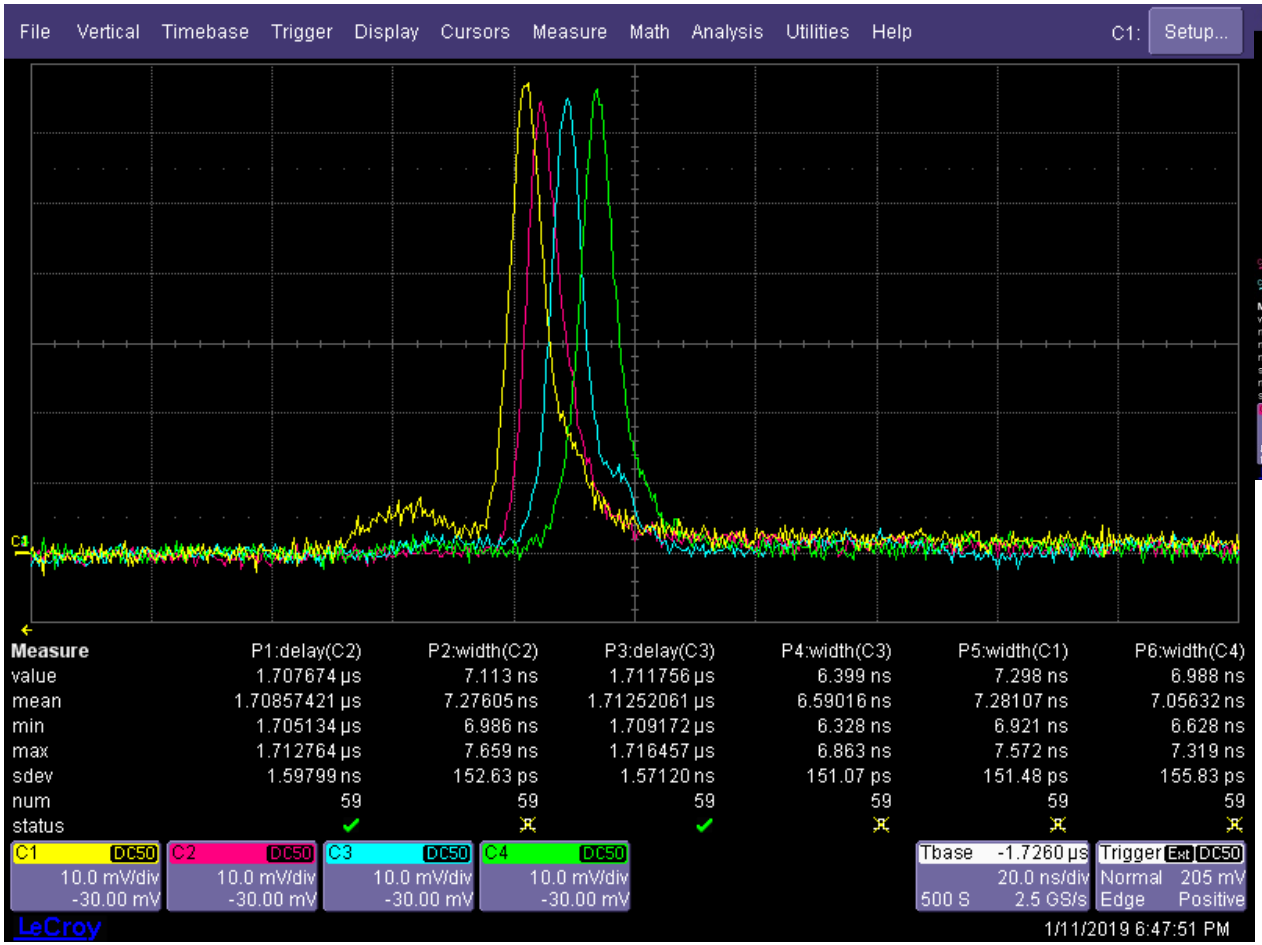


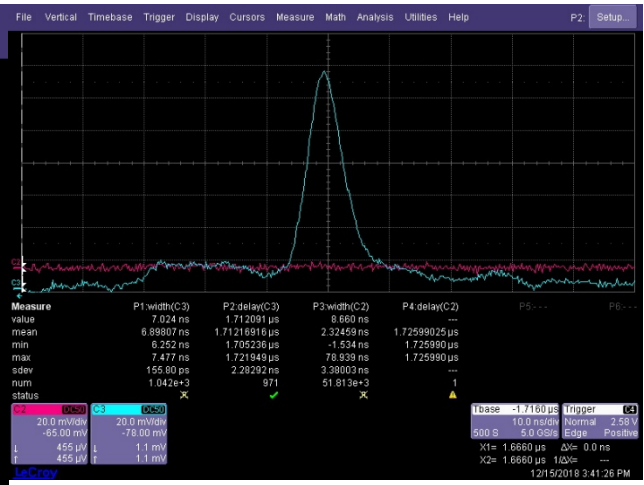
1 – wave-plate 1064nm, λ/2; 2 – polarizers 1064 nm; 3 - increasing telescopes 1064 nm; 4 - turning mirrors 1262 nm; 5 - Cr:Forsterite crystasl; 6 - decreasing telescopes 1262 nm; 7 – rotators 1064 nm; 8 - beam stops

0,8 mJ imput – 32 mJ output, pump energy 540 mJ, ~ 6% efficiency

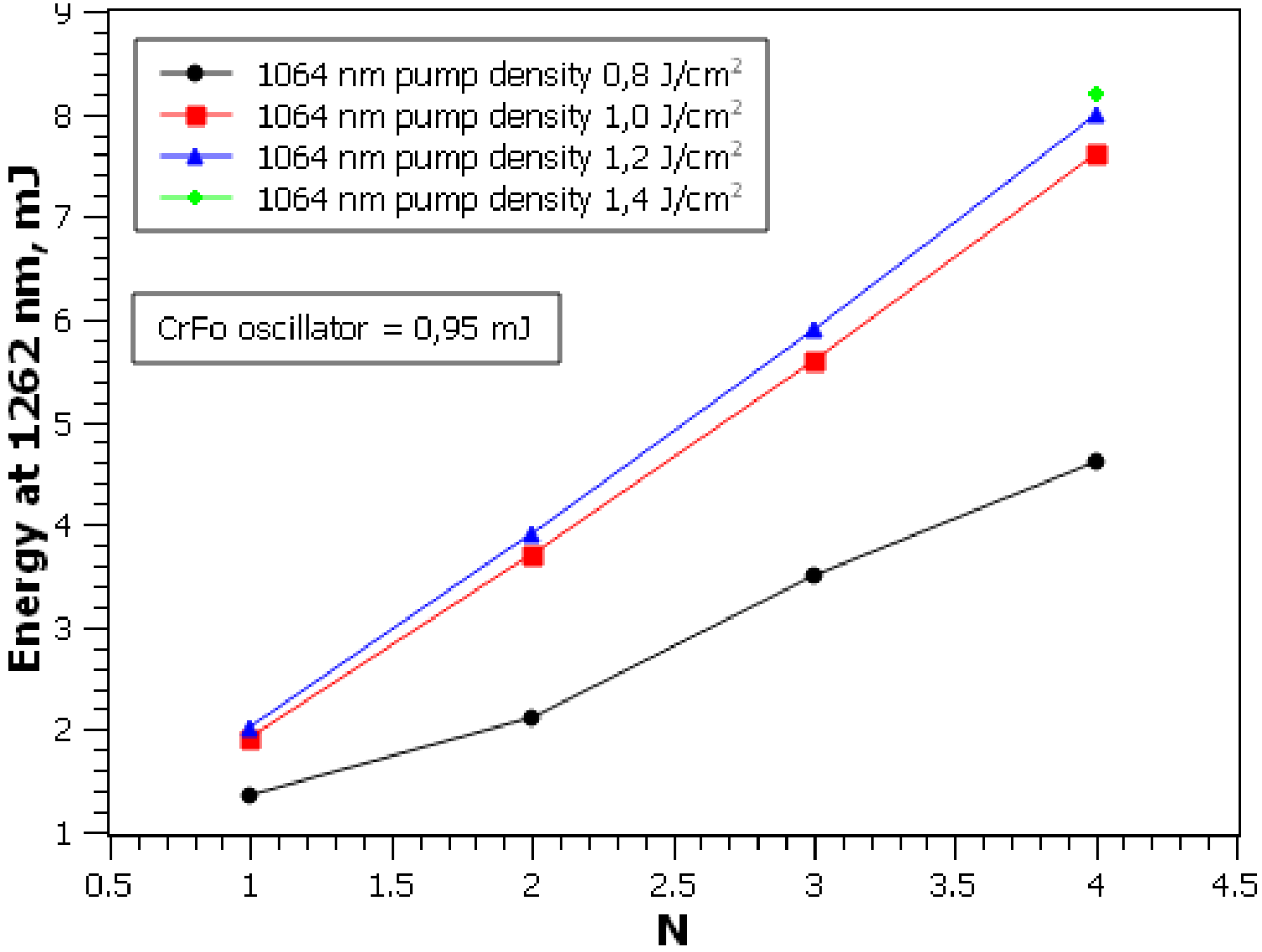
Cr:Forsterite oscillator



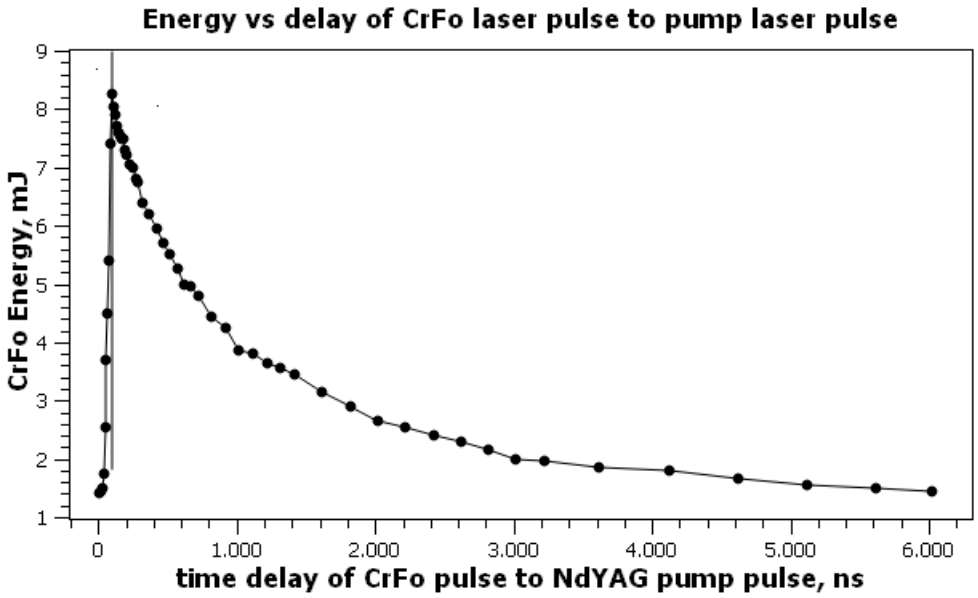


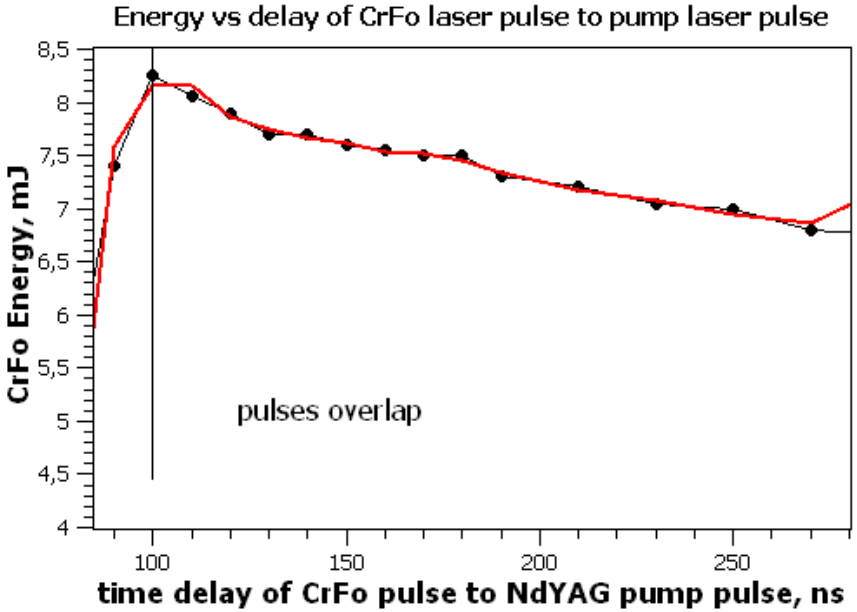


Cr:Forsterite amplifier dependence from pump energy density

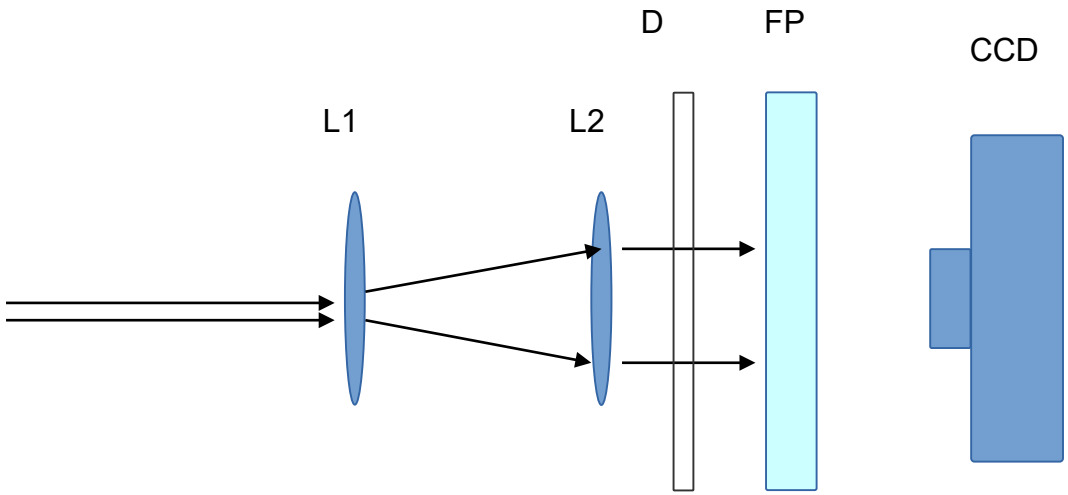


CrFo amplifier Energy vs Time delay of CrFo oscillator's delay to amplifier's pump pulse, 3-pass amplifier setup

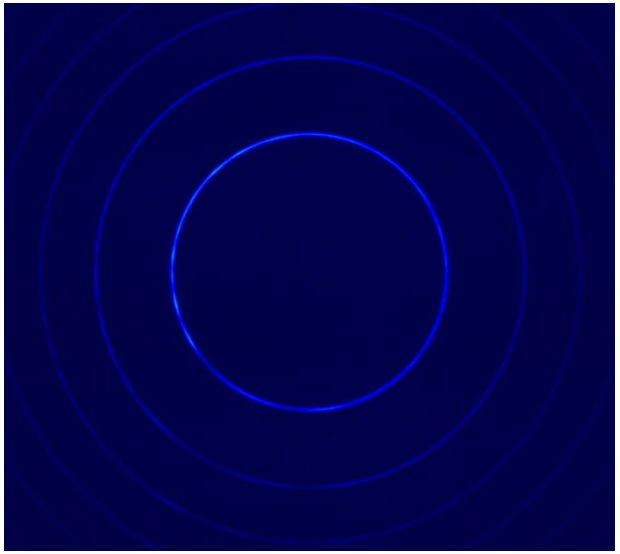




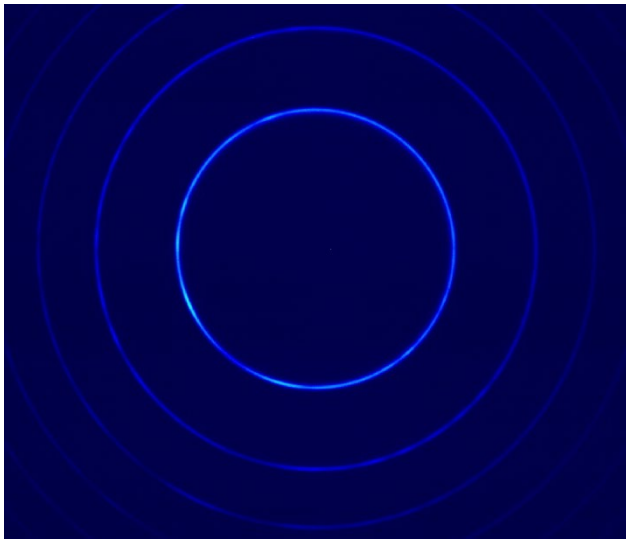
Cr:Forsterite laser linewidth



Linewidth measurement setup: L1 and L2 – lenses,
D - diffuser, FP - Fabry Perot etalon, CCD - Spiricon camera.



CrFo osc FP fringes

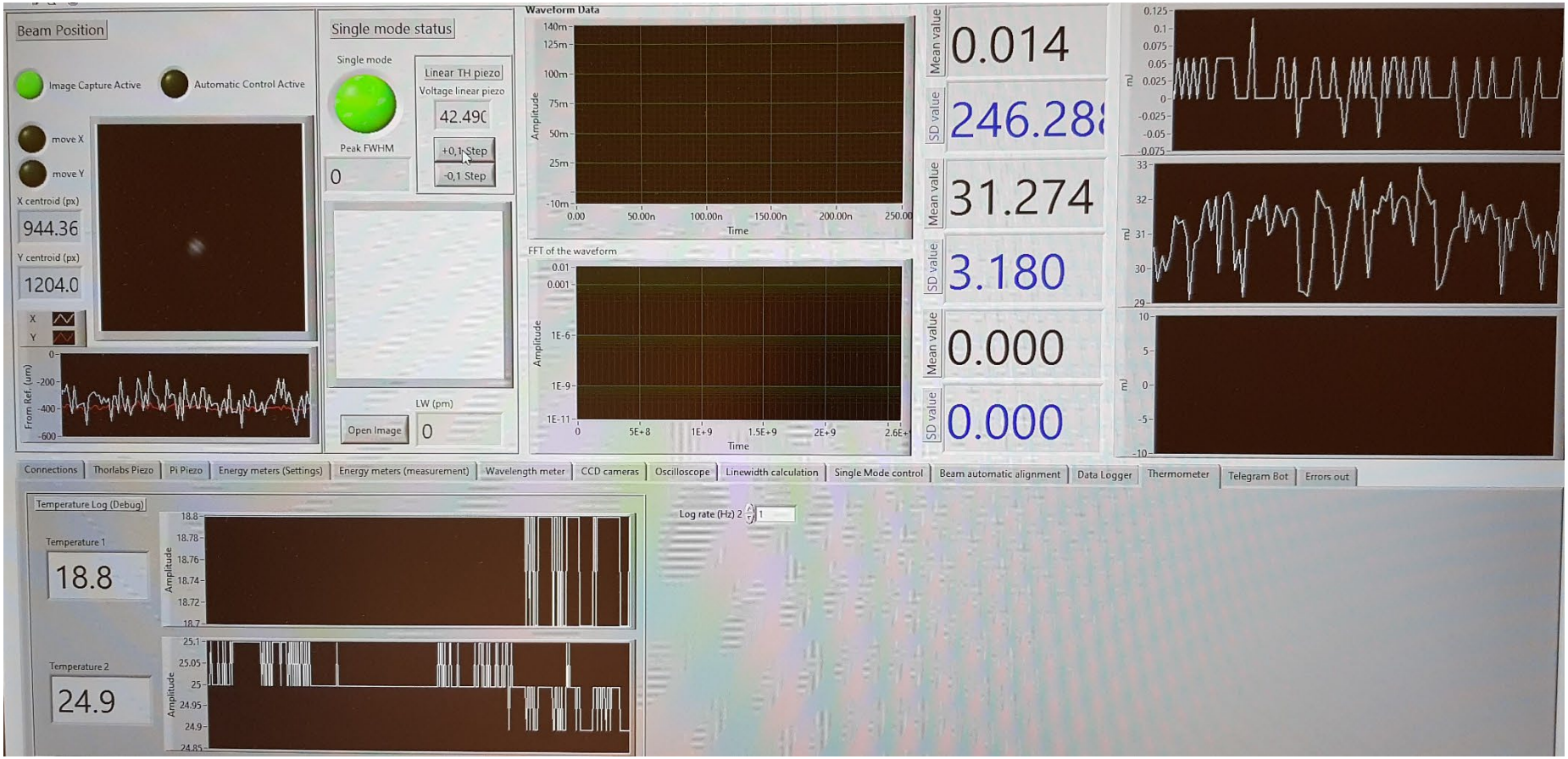


CrFo ampl FP fringes

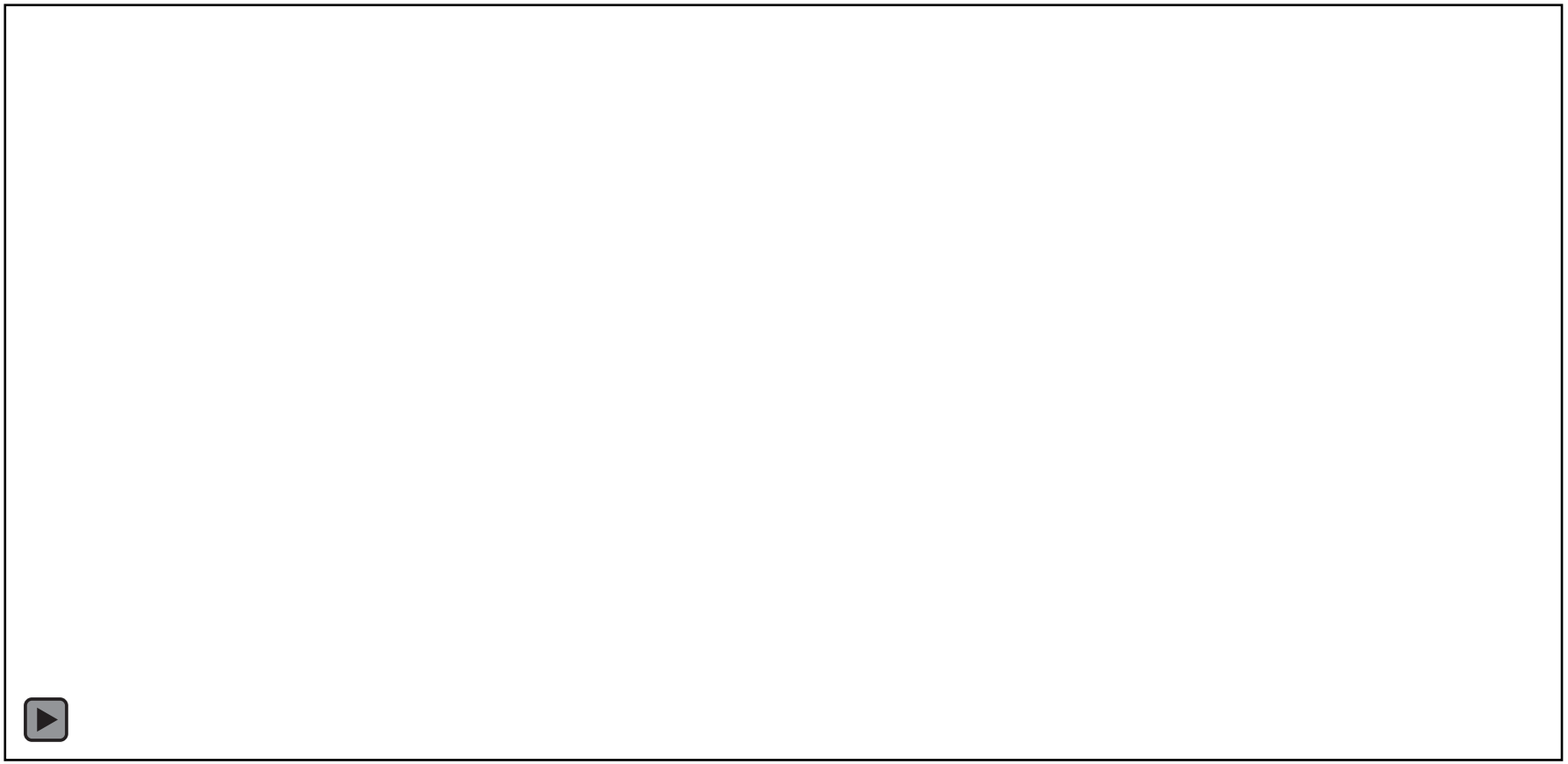
Linewidths measured:
Osc Δλ=0,9 pm at 0,95 mJ
Ampl Δλ=1,1 pm at 32 mJ

obtained up to 0.5 pm at 0,6 mJ

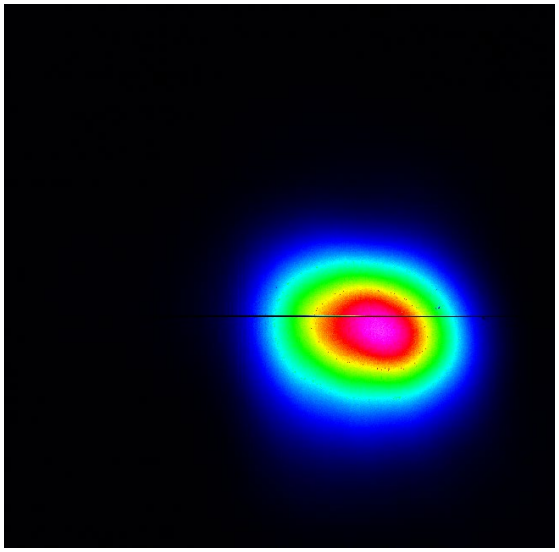
Laser control system

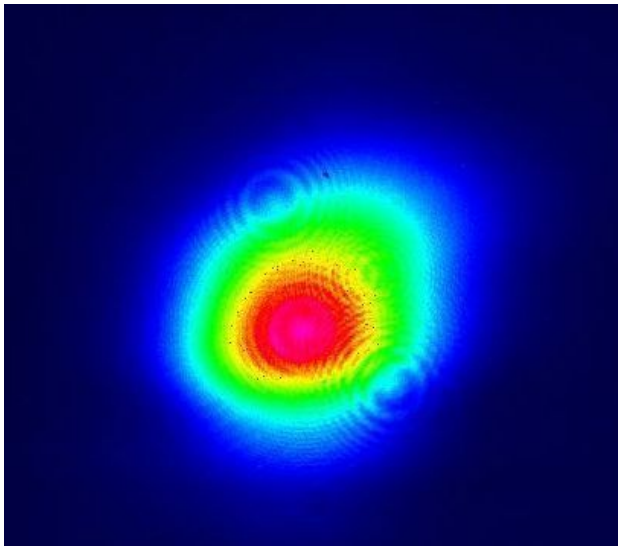


Cr:Forsterite Laser energy & time stability

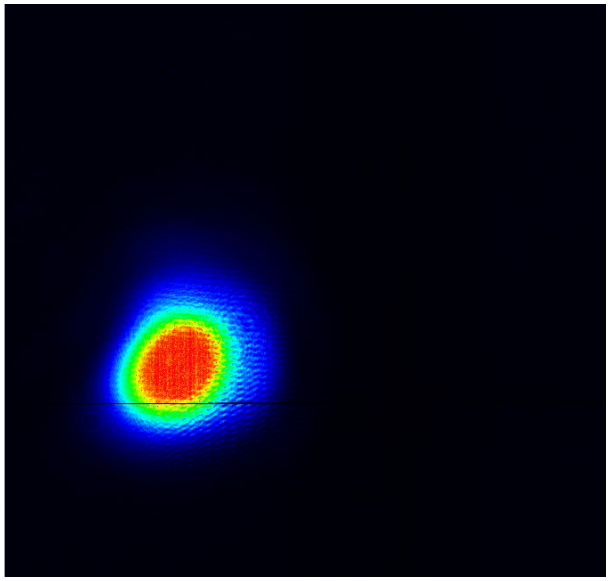


Nd:YAG and Cr:Forsterite beam spots



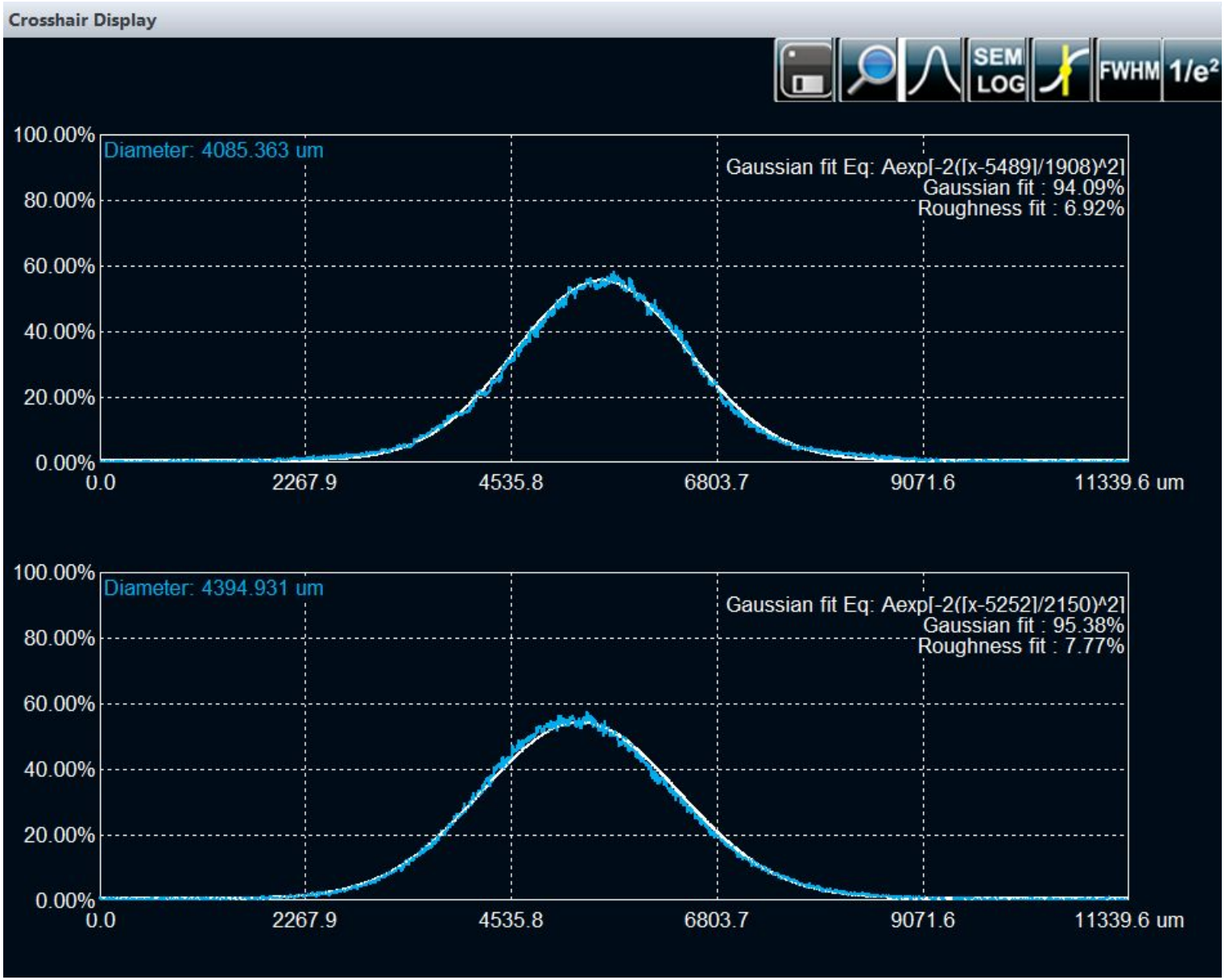


Cr:Forsterite beam spots oscillator and amplifier

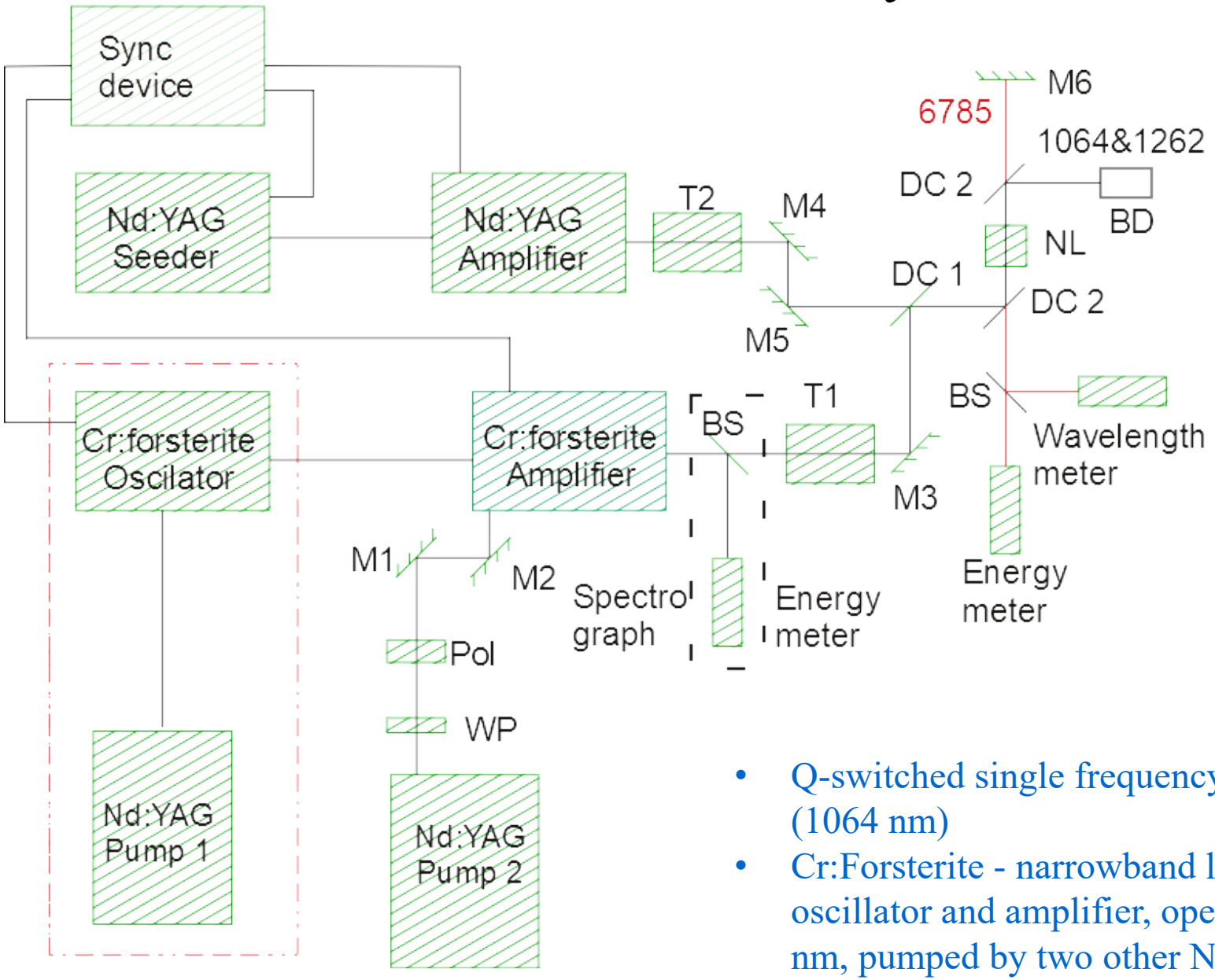


Nd:YAG beam spot at 150 mJ

Cr:Forsterite beam profile

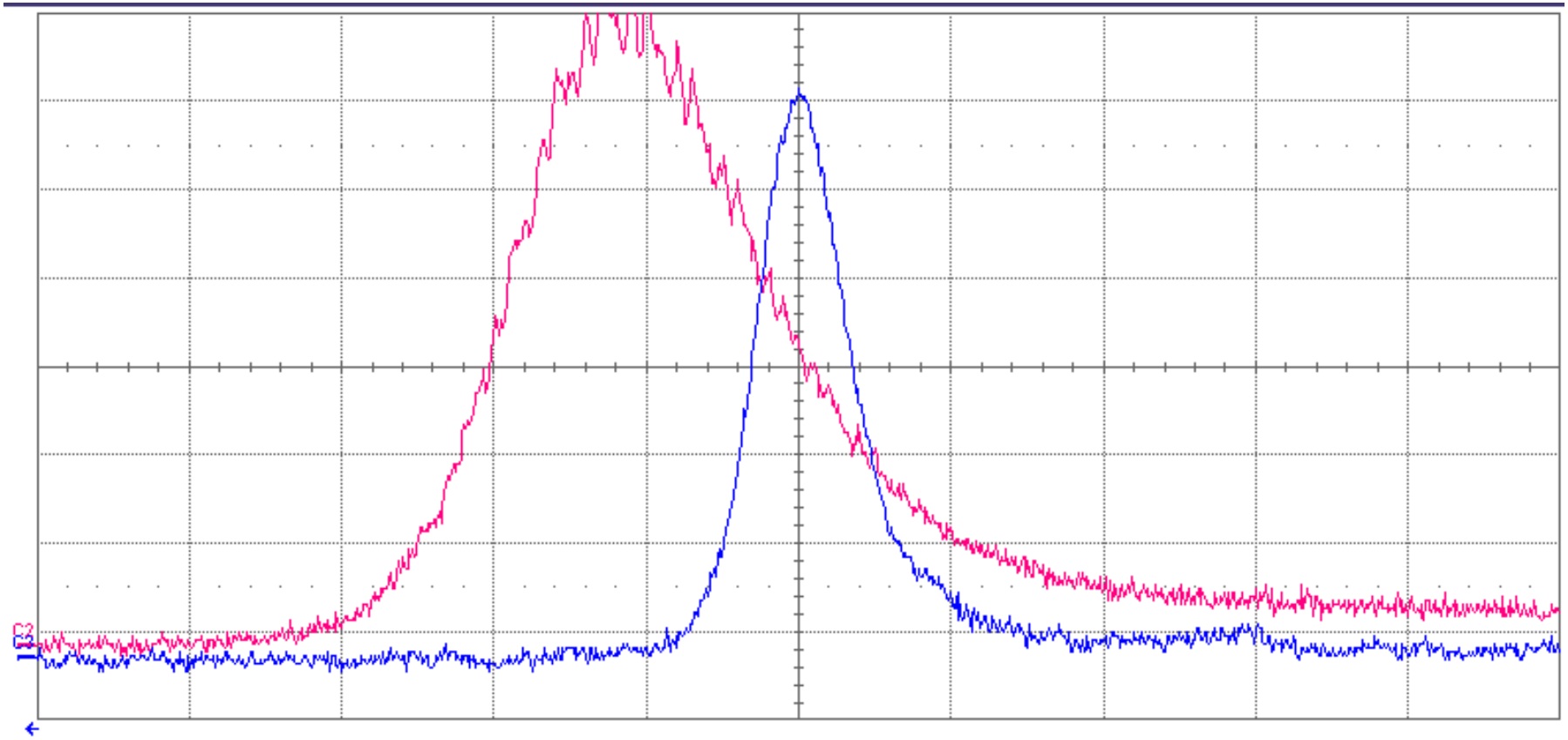


DFG based laser system



- Q-switched single frequency Nd:YAG (1064 nm)
- Cr:Forsterite - narrowband laser system of oscillator and amplifier, operating at ~ 1262 nm, pumped by two other Nd:YAG lasers

Cr:Forsterite & Nd:YAG pulses

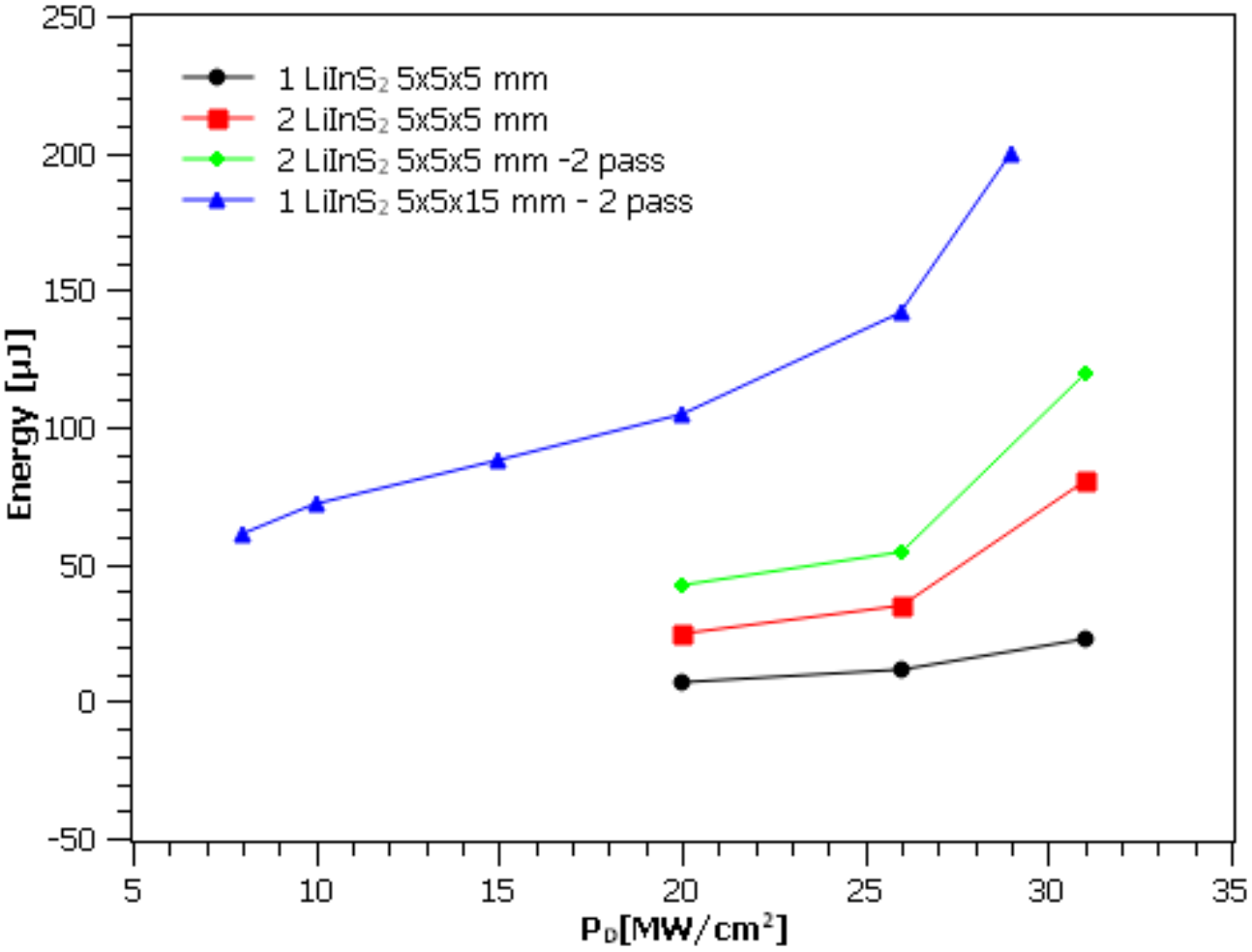


Output energy vs on power density ($LiInS_2$)

beam sizes ~ 5 mm

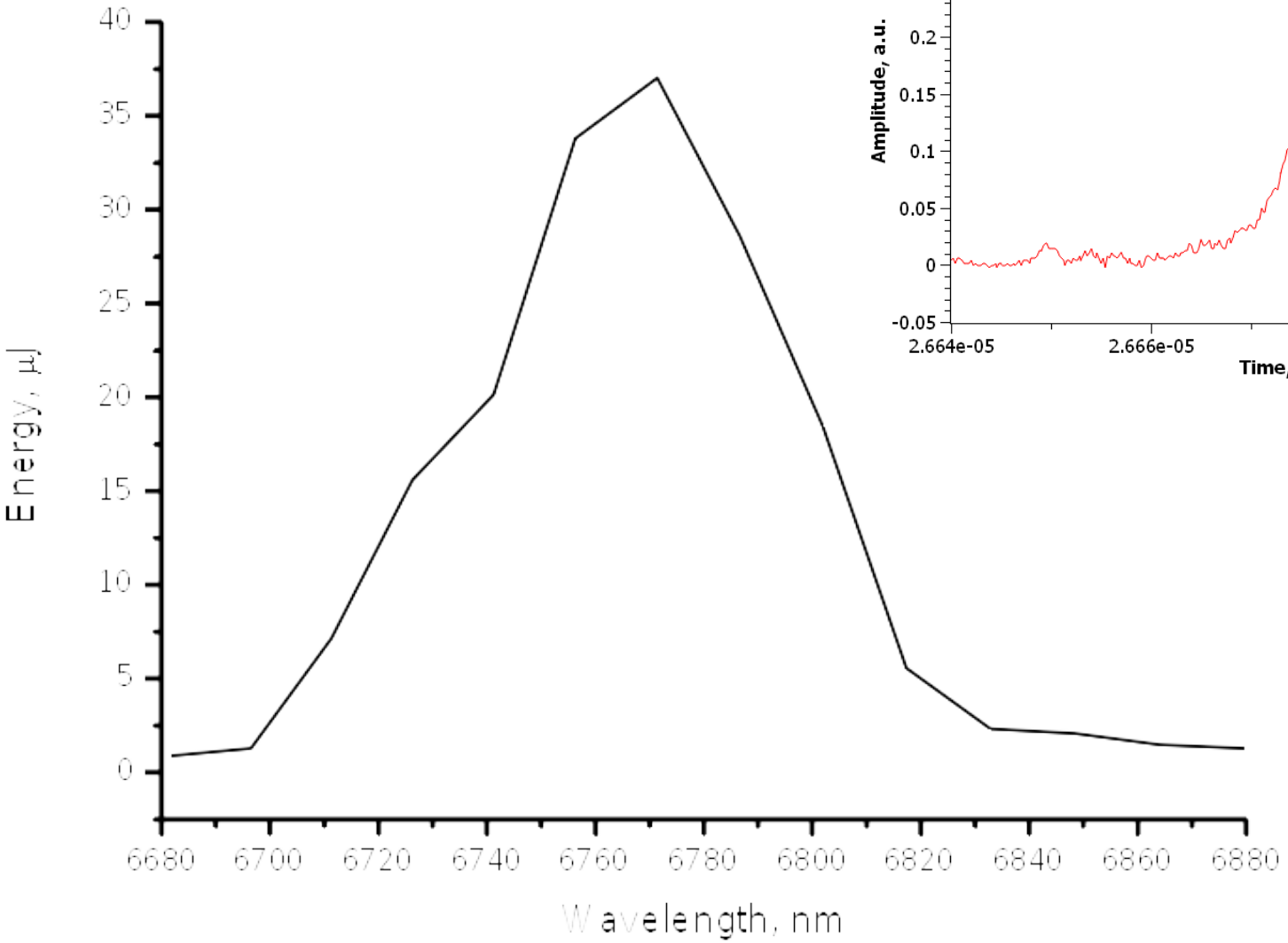
for 1.064 μm – 8 MW/cm^2 to 30 MW/cm^2

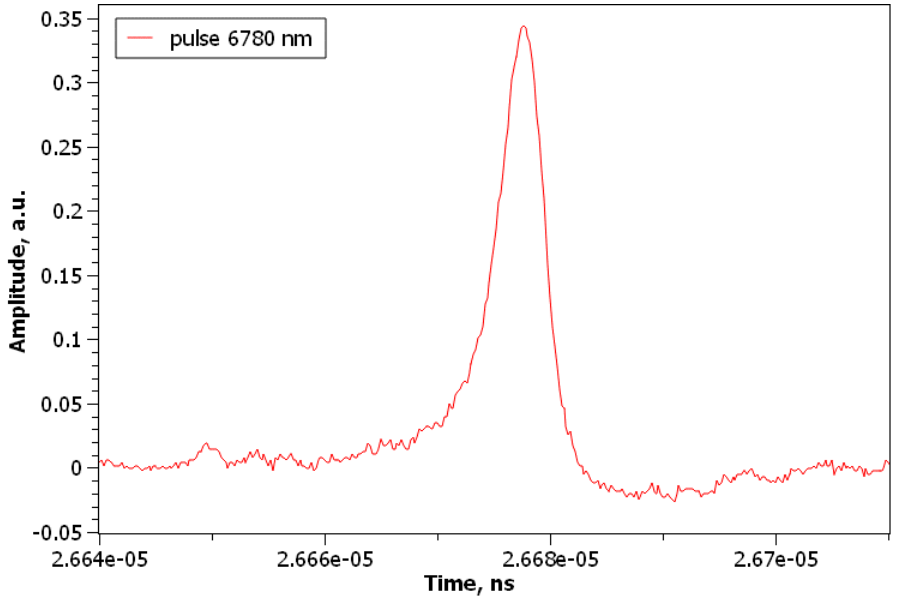
for 1.262 μm – 12.66 MW/cm^2



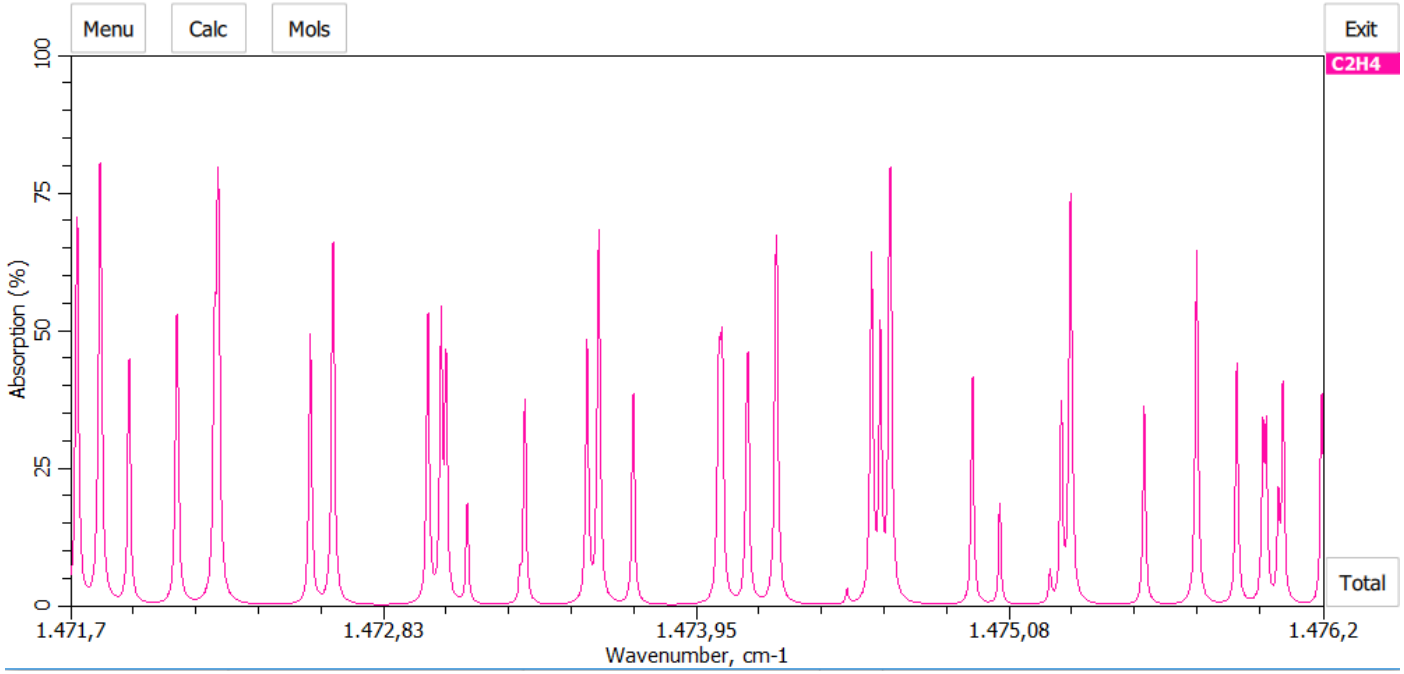
LiInS2 5x5x15 mm

Tunability of the mid-infrared radiation

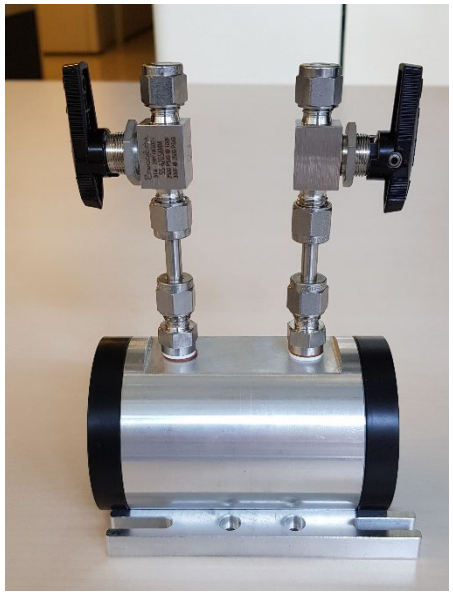




Calibration of wavelength meter



Absorption spetrum of $^{12}C_2H_4$ in the interval 1471.7-1476.2 cm-1, T: 296 K; concentration 2% in air; pressure 50 mbar;



Available NL crystals & Expected output energies at 6760 – 6780 nm

Nonlinear crystals

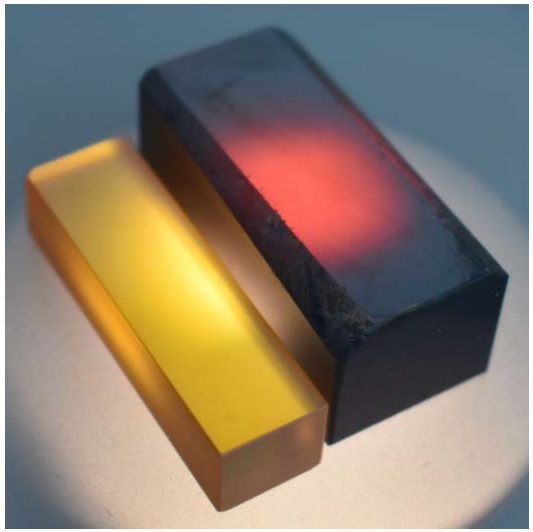
Available
$LiInS_2$ – 5x5x4 / 5x5x3
$LiInS_2$ – 5x5x15
LGS – 5x5x4 mm
$LiInS_2$ - 7x7x20 mm / 8x8x18
$LiInSe_2$ - 7x7x15 mm
$BaGa_4Se_7$ – 12 x 12 x 35mm, 6 x 6 x 6 mm

Expected energies:

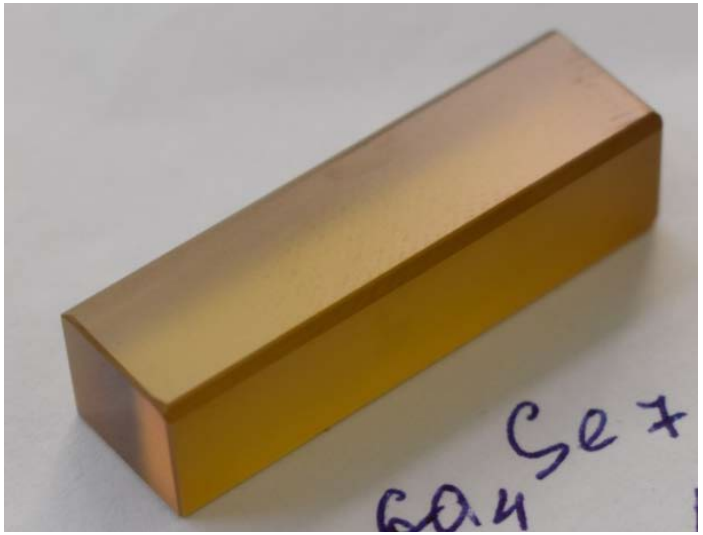
$LiInS_2$ & $LiInSe_2$: 1.3 – 1.5 mJ

$BaGa_4Se_7$ ~ 4 mJ

Continuous quest for higher energies - BaGa4Se7 crystals & new types of NL crystals



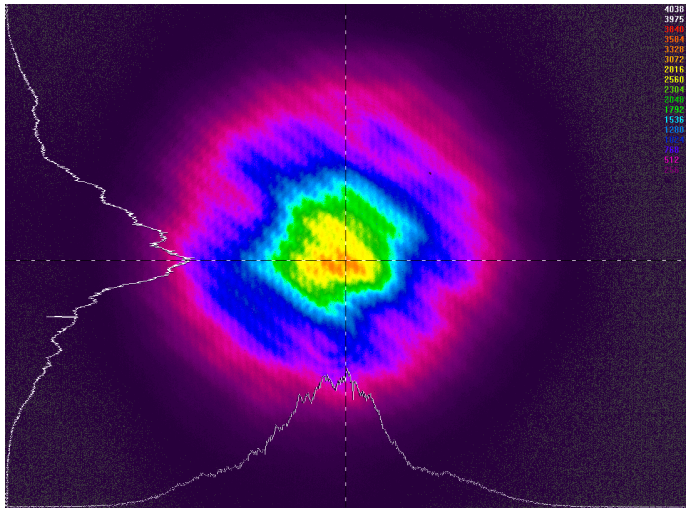
BaGa4Se7 10,4x8,9x35 – yellow &
BaGa4Se7 (+ Ga2Se3) 17x15x35,3
brown

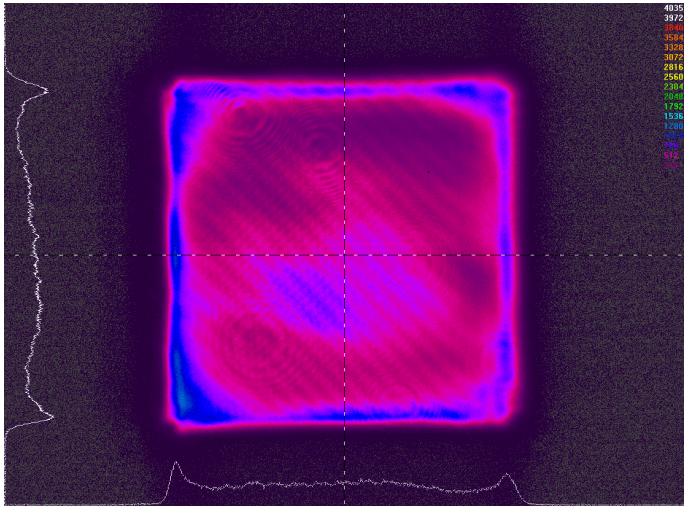


BaGa4Se7 10,4x8,9x35 mm

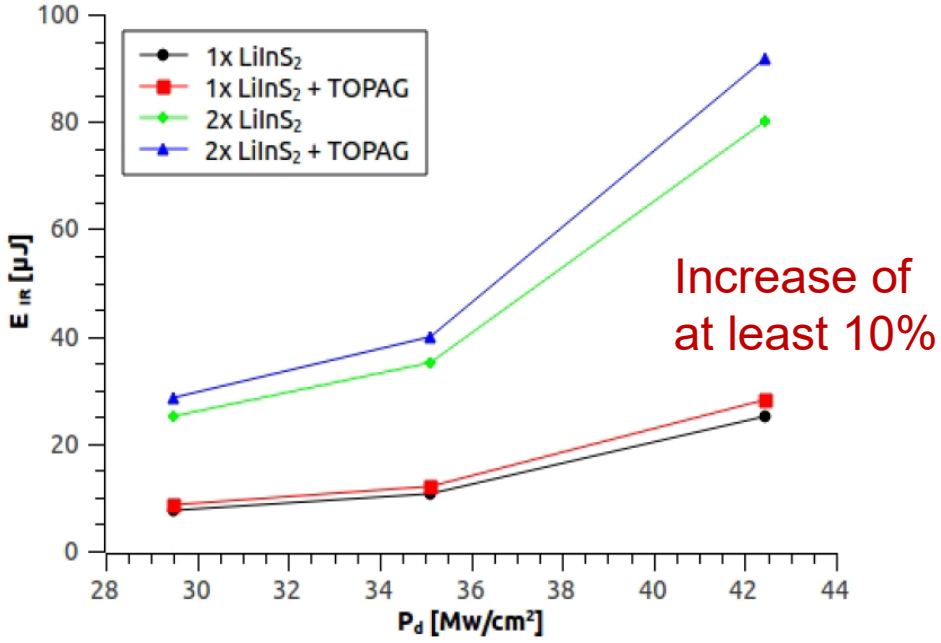
The final available energy implies directly an higher transition probability and hence an improved signal to noise ratio and faster data collection at each wavelength step

Top-Hat beam profiles of the pump beams

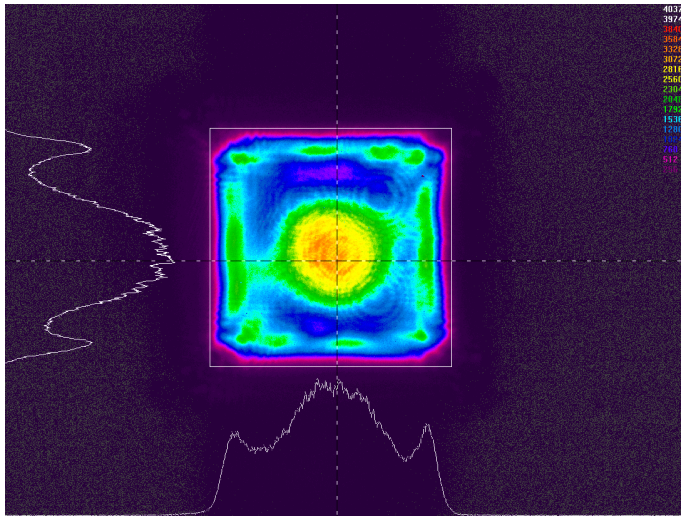




Beam spots without and with beam-shaper.

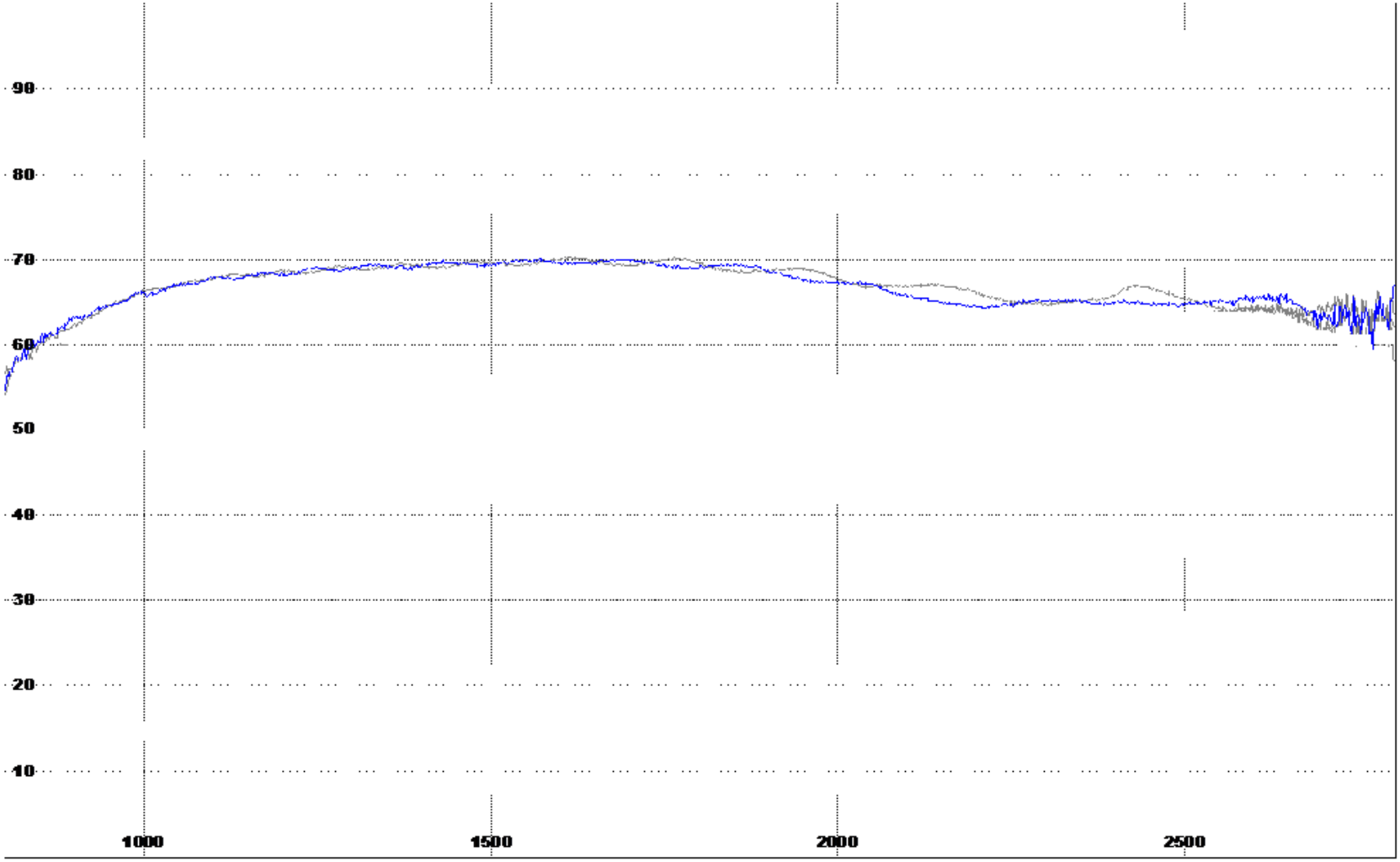


Increase of
at least 10%



Thank You!

BaGa4Se7 transmission



focal length of the Fo thermal lens:
F≈105/I * f, where I - the intensity of excitation (J/cm2), f - prr.

$$M^2 = \frac{\pi}{4\lambda} \frac{D_f D_L}{f}$$