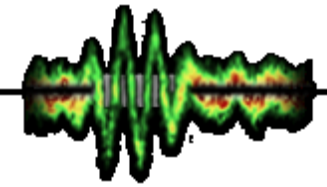

The Petawatt Field Synthesizer – towards high energy few-cycle pulses

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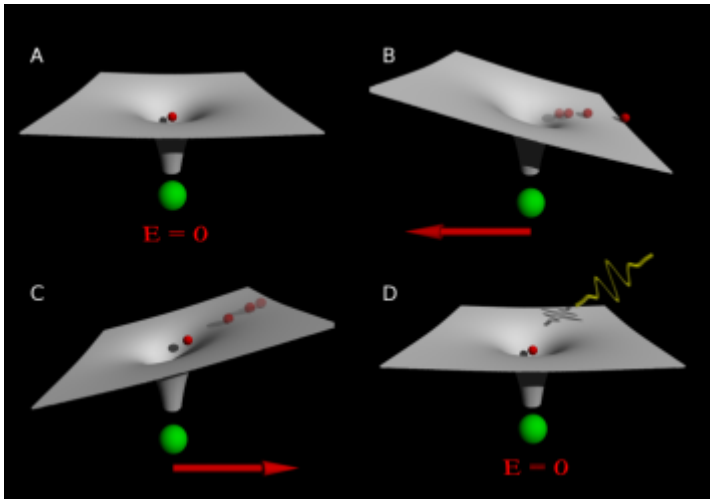
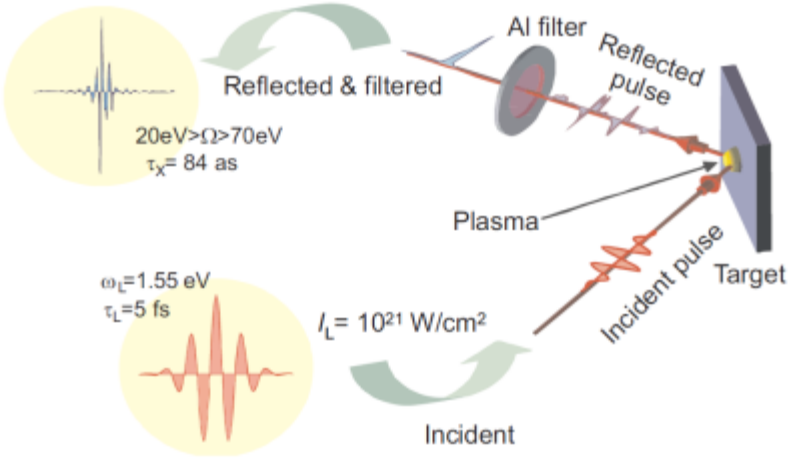
8th International HEC-DPSSL Workshop, March 26-28 2012, Oxford

Motivation: Single attosecond pulse generation



HHG in gas:

- Low efficiency
- Not scalable in laser intensity



HHG from solid surfaces:

- higher efficiency
- Wavelength and photon flux scales with laser intensity
- **For single attosecond pulse: relativistic, CEP-stable few-cycle pulses needed**

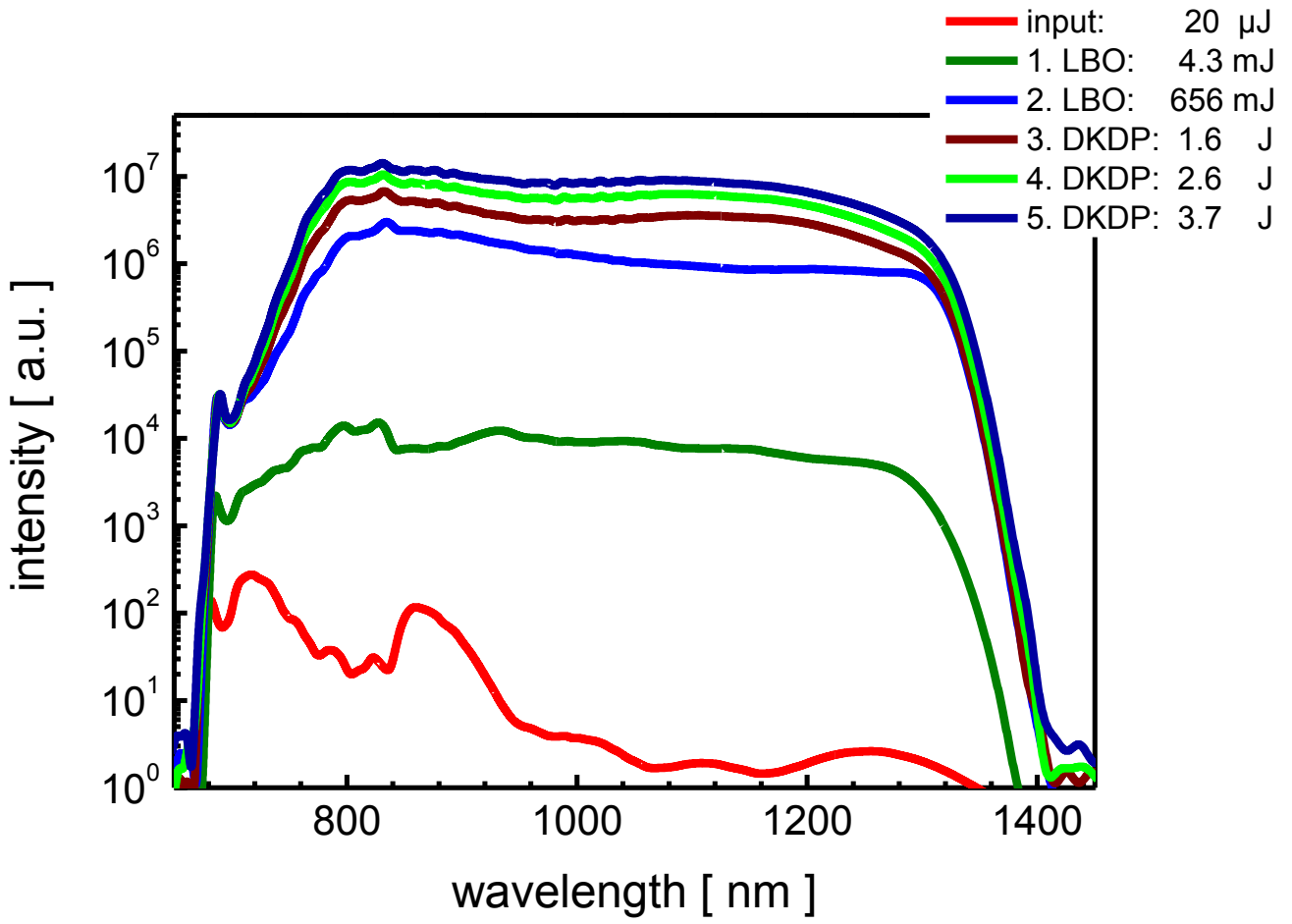
PFS design considerations

Goal: 5 fs, few J

5 fs → broad bandwi
→ High intensity pum

→ Low stretching rat
→ High pulse contras
→ Good seed/pump

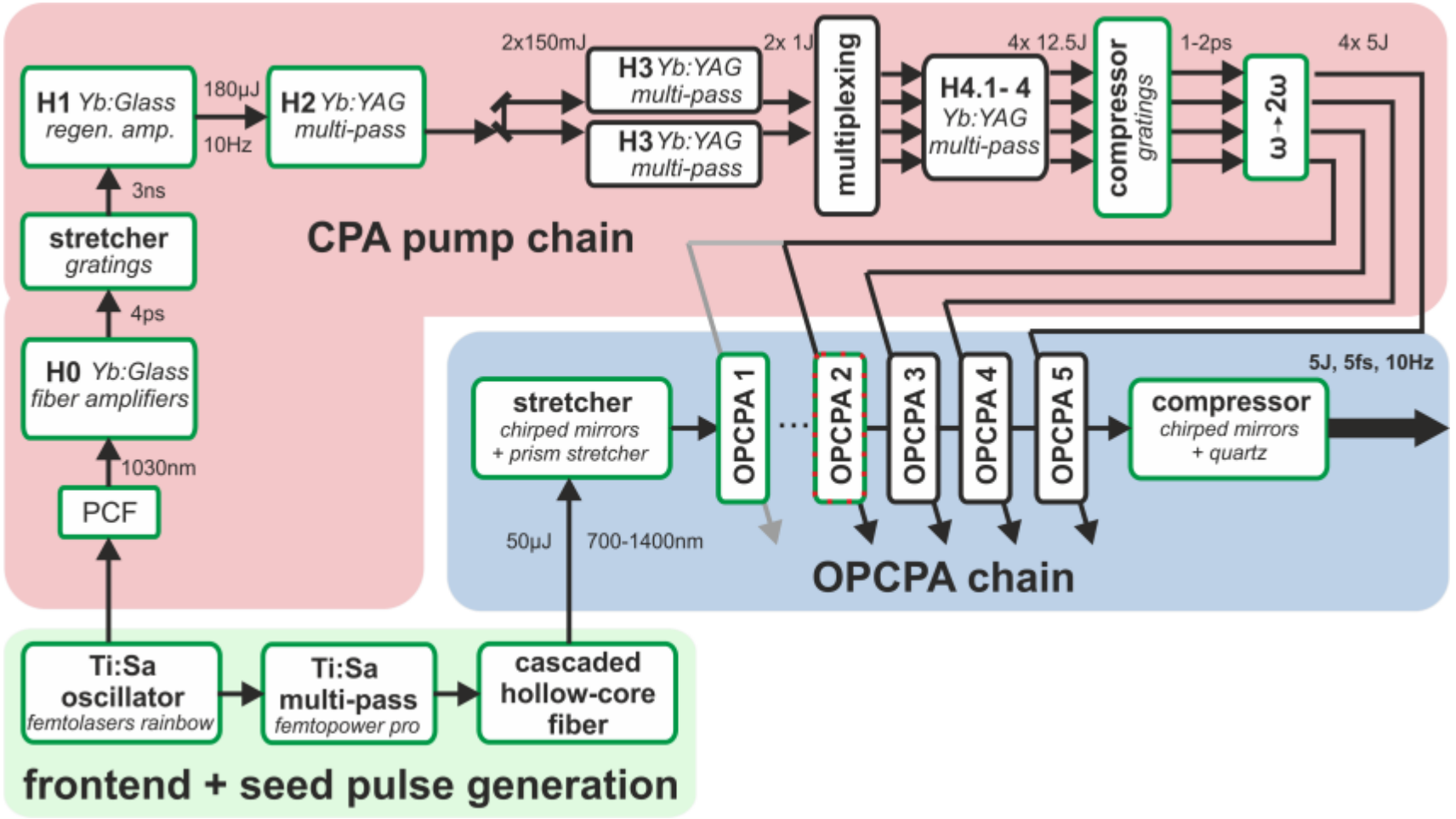
High energy pulses
→ Transmission anc

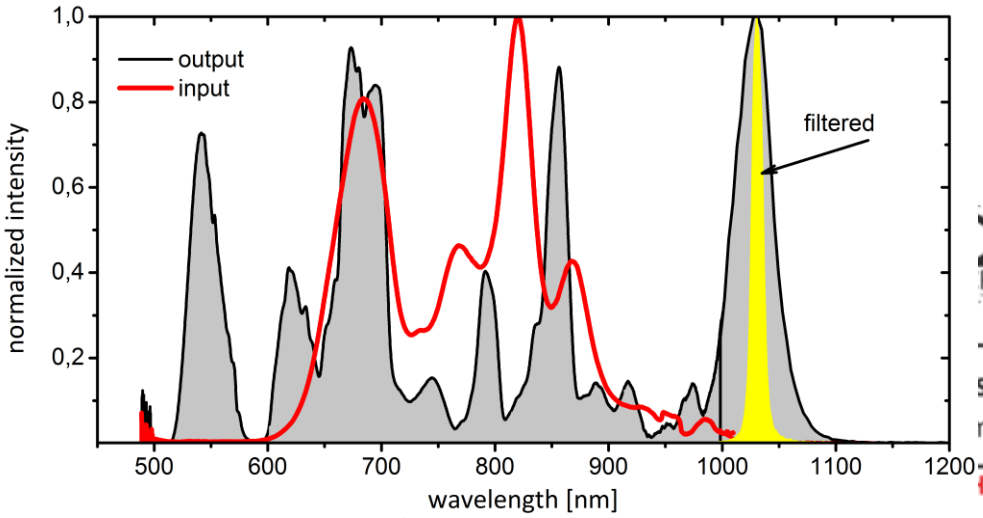


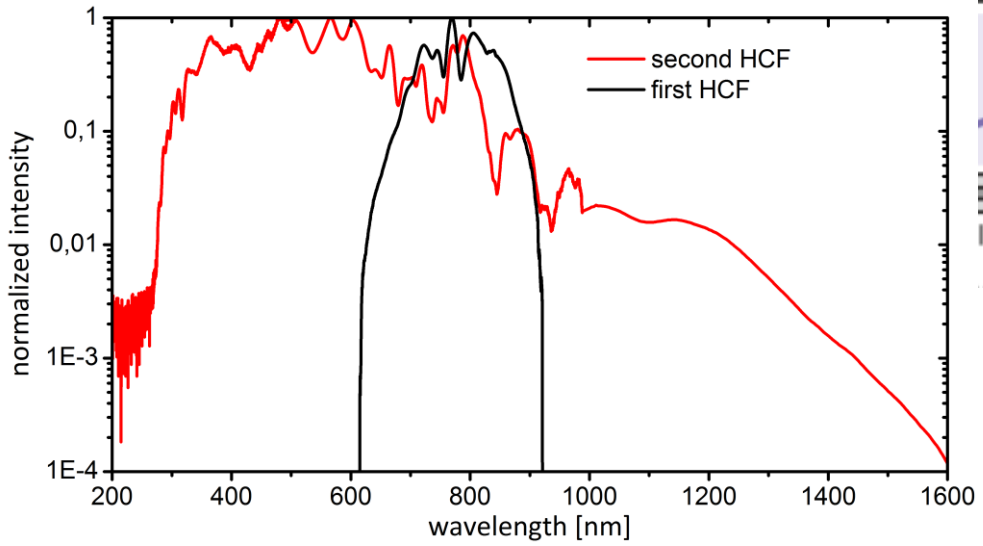
The main challenges :

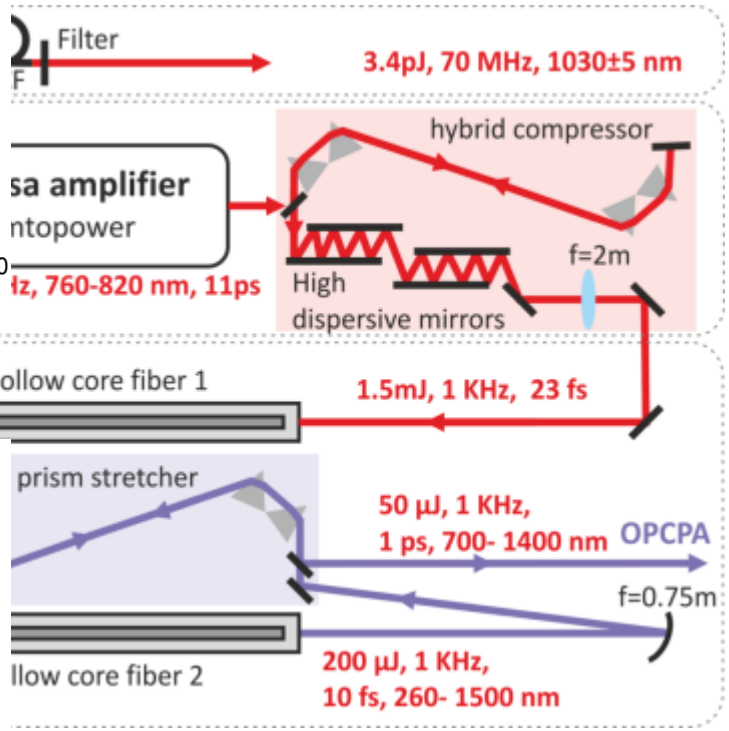
- **seed generation**
- **pump laser development (4x 5J, 1ps @ 515 nm)**
- **Pump-seed synchronization**

PFS Layout

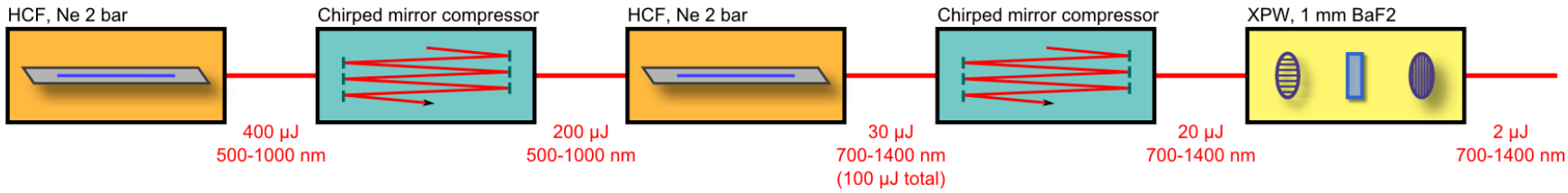

H1 Yb:Glass regen. amp.
180µJ
10Hz
H2 Yb:YAG multi-pass
2x150mJ
H3 Yb:YAG multi-pass
H3 Yb:YAG multi-pass
2x 1J
multiplexing
4x 12.5J
H4.1- 4 Yb:YAG multi-pass
compressor gratings
1-2ps
ω→2ω
4x 5J
CPA pump chain
3ns
stretcher gratings
4ps
H0 Yb:Glass fiber amplifiers
1030nm
PCF
stretcher chirped mirrors + prism stretcher
OPCPA 1
OPCPA 2
OPCPA 3
OPCPA 4
OPCPA 5
5J, 5fs, 10Hz
compressor chirped mirrors + quartz
50µJ
700-1400nm
OPCPA chain
Ti:Sa oscillator femtolasers rainbow
Ti:Sa multi-pass femtopower pro
cascaded hollow-core fiber
frontend + seed pulse generation


output
input
filtered
normalized intensity
wavelength [nm]


second HCF
first HCF
normalized intensity
wavelength [nm]


Filter
3.4pJ, 70 MHz, 1030±5 nm
hybrid compressor
sa amplifier
ntopower
lz, 760-820 nm, 11ps
f=2m
High
dispersive mirrors
Broad band seed generation
Hollow core fiber 1
1.5mJ, 1 KHz, 23 fs
prism stretcher
50 µJ, 1 KHz,
1 ps, 700- 1400 nm
OPCPA
f=0.75m
llow core fiber 2
200 µJ, 1 KHz,
10 fs, 260- 1500 nm

Double HCF + XPW



Pro:

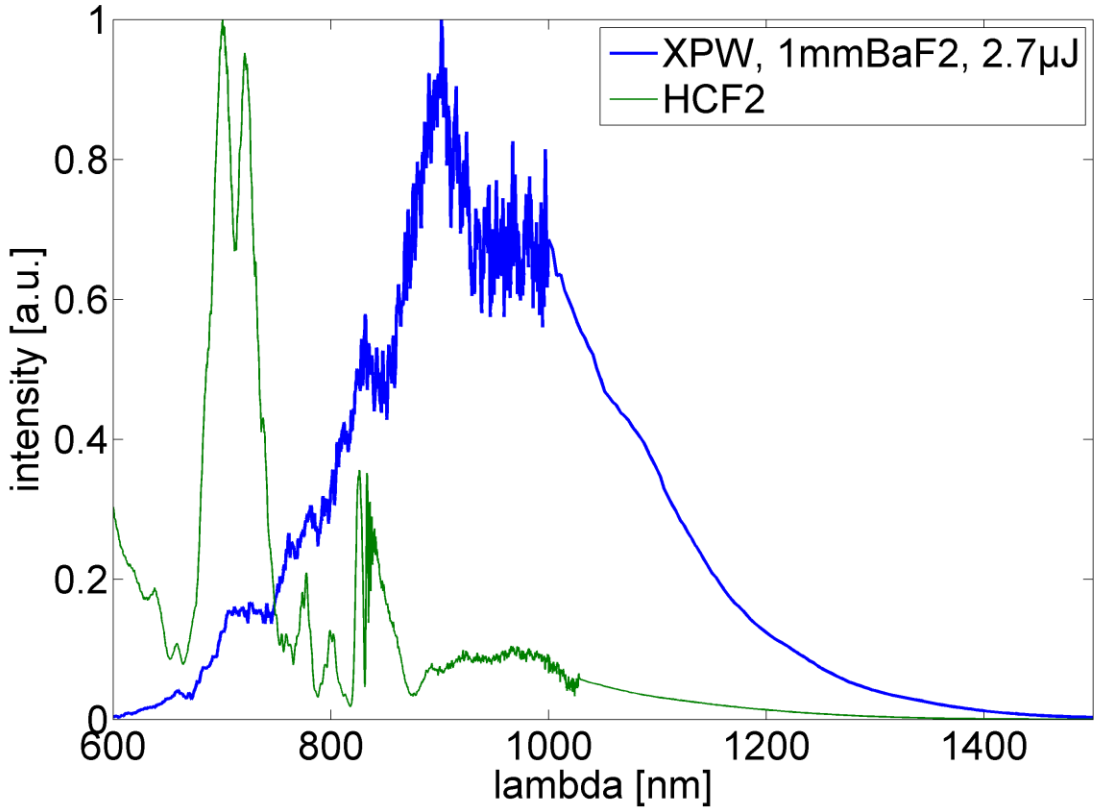
- smooth spectrum
- high contrast

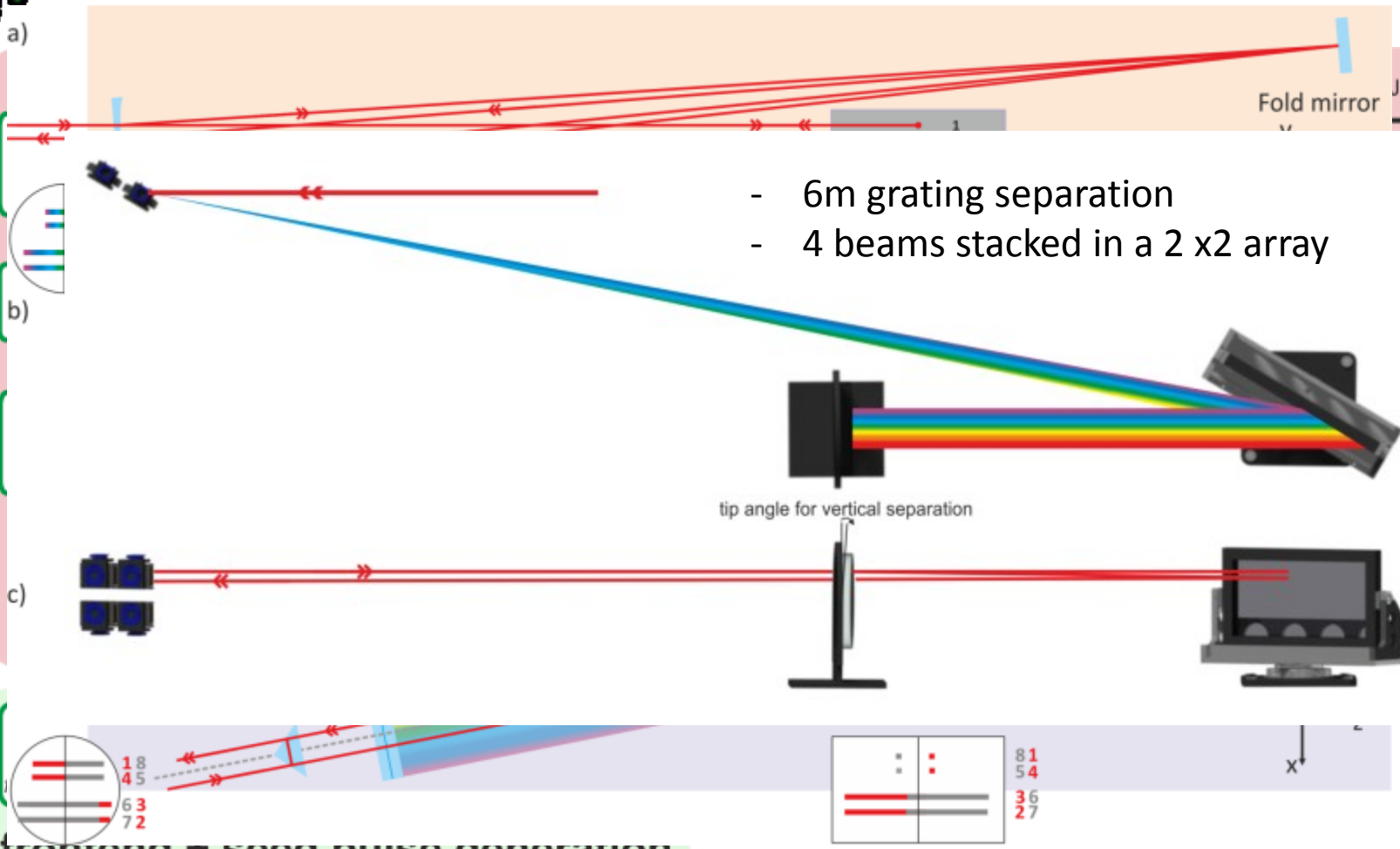
Contra:

- low energy

Open Questions:

- long term stability





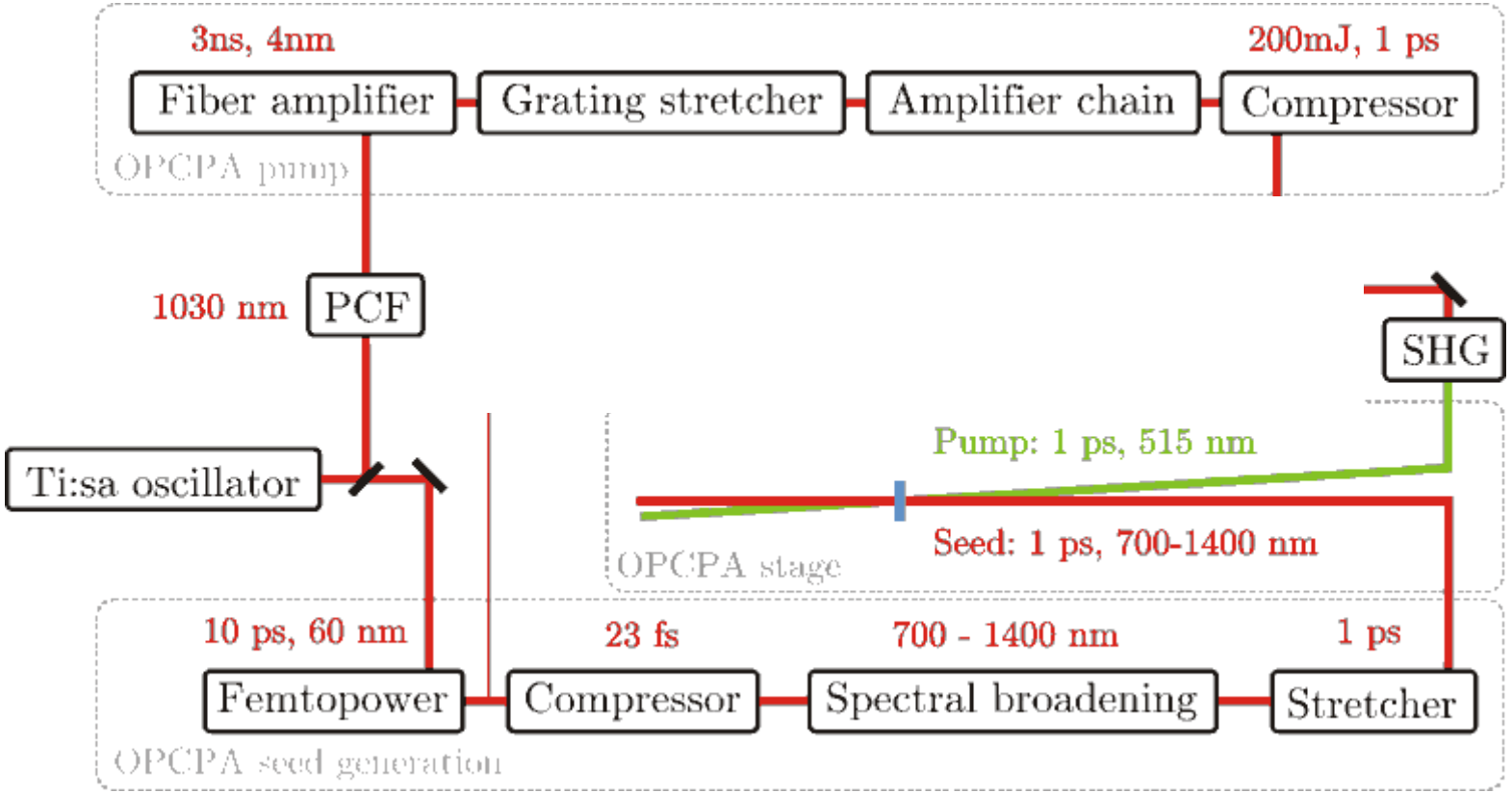
- 6m grating separation
- 4 beams stacked in a 2 x2 array

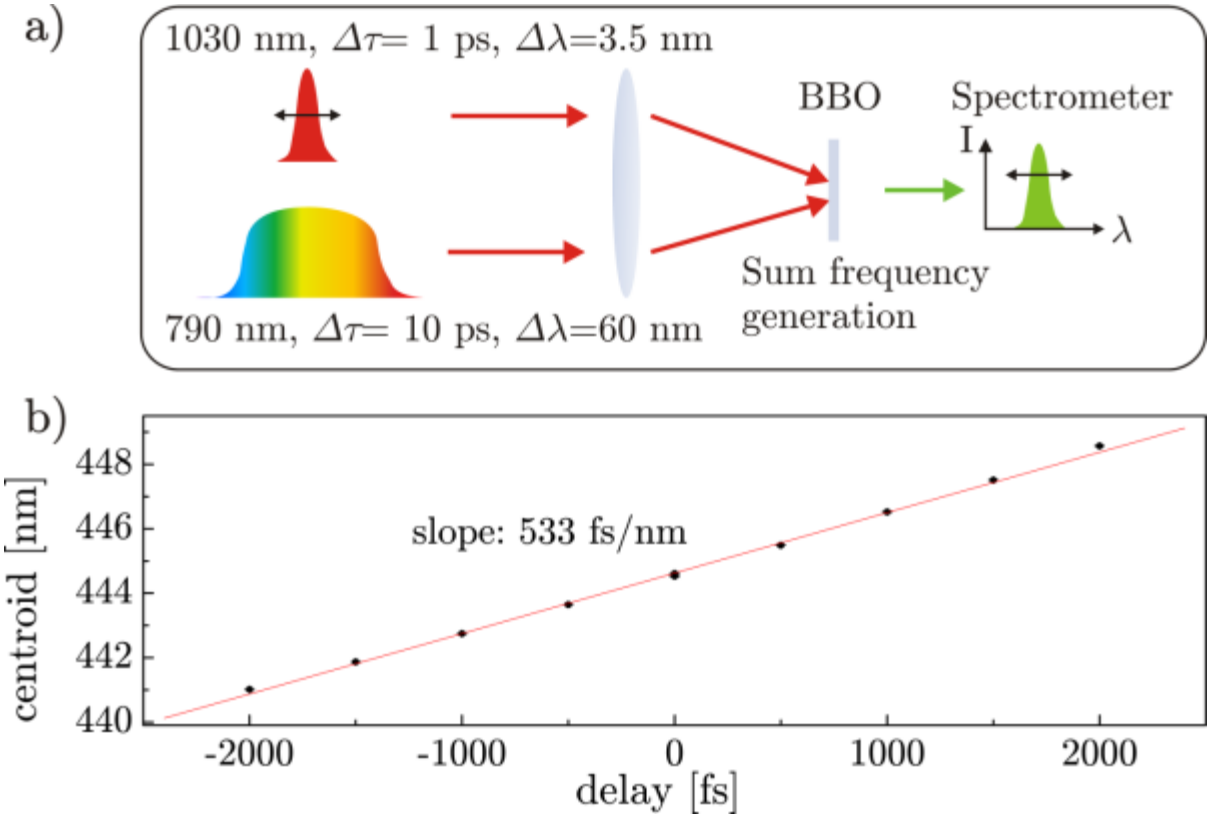
frontend + seed pulse generation

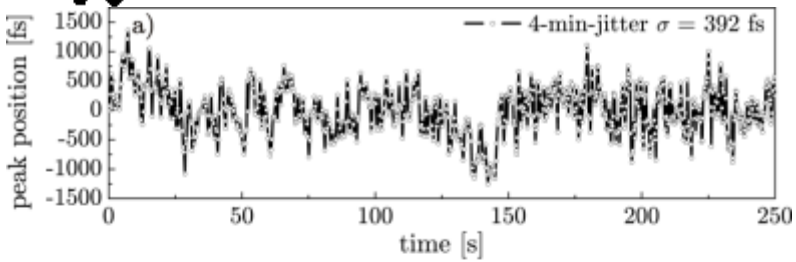
Stretcher

- Stretch 4nm to 4 ns
- Double pass configuration → compact (3m x0.5m)

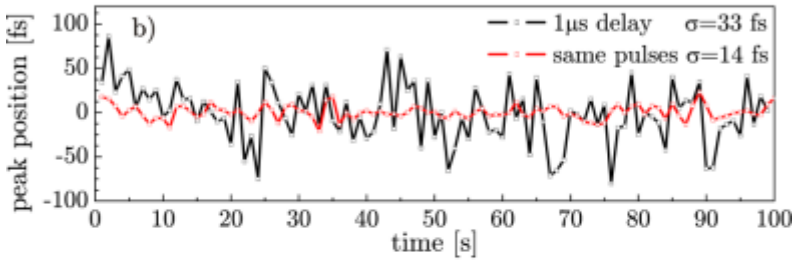
Timing jitter



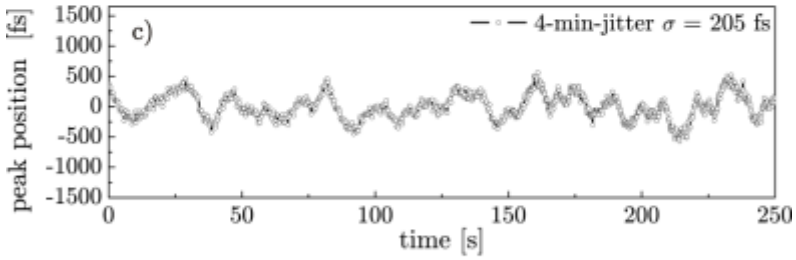

a)
1030 nm, Δτ= 1 ps, Δλ=3.5 nm
BBO
Spectrometer
I
λ
Sum frequency
generation
790 nm, Δτ= 10 ps, Δλ=60 nm
b)
centroid [nm]
448
446
444
442
440
slope: 533 fs/nm
-2000
-1000
0
1000
2000
delay [fs]



Full pump chain



Regen without stretcher/compressor



Full pump chain – reduced air turbulence

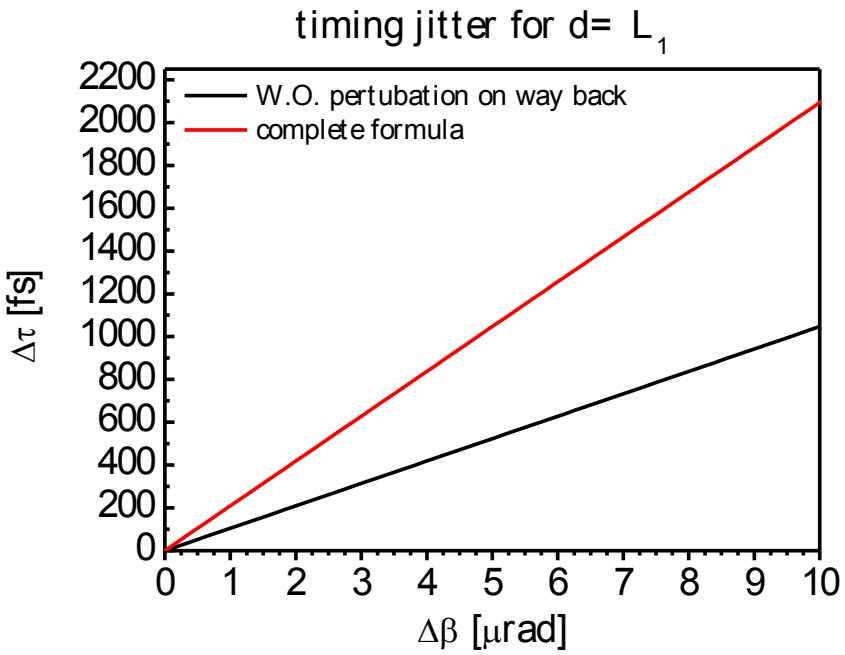
Air-tight housing for stretcher and beam tubes in the compressor reduce air turbulence and timing jitter.

- From experiment we suspect the stretcher/compressor to cause main timing jitter
- beam pointing outside the compressor has negligible effect
- beam pointing inside the compressor can introduce significant timing jitter

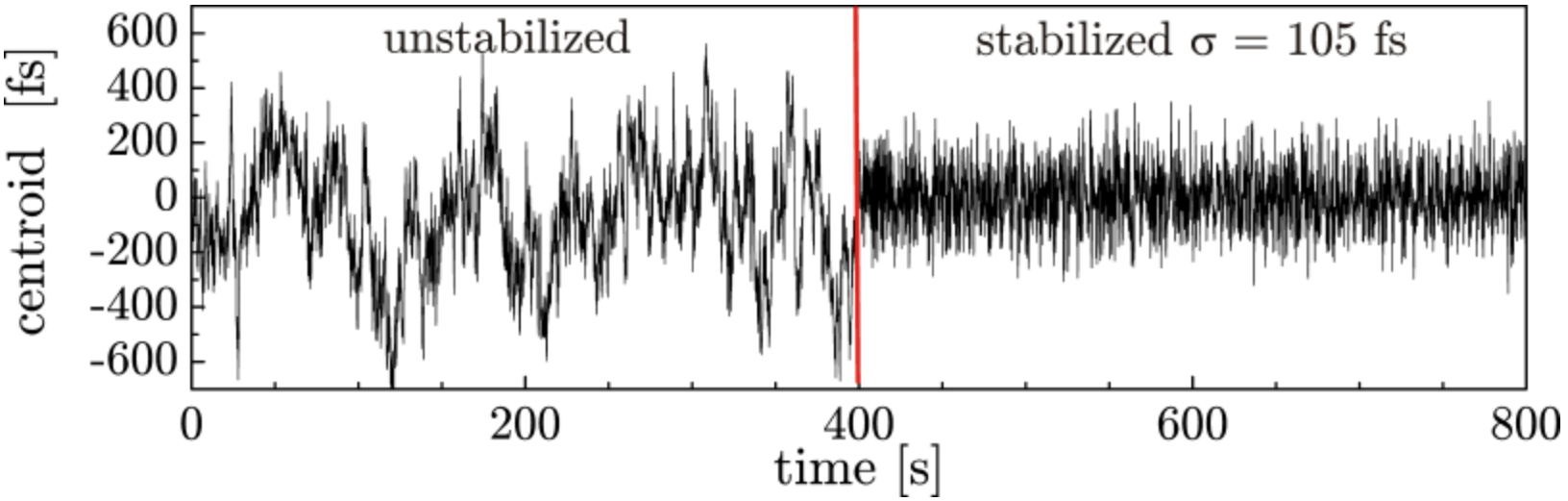
-Angle perturbation could arise from air turbulence or mechanical stability of optical components

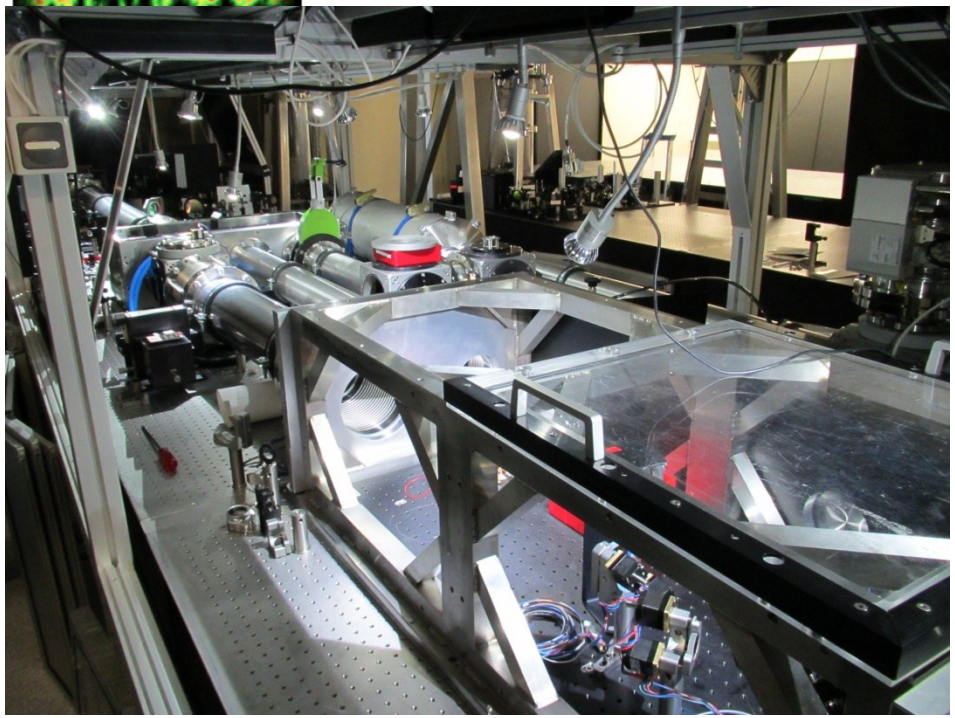
- results account also for stretcher

$$\Delta\tau \approx \frac{2\,N\,\lambda_0}{c\cdot\cos(\beta_0)}\Delta\beta_1\ \mathrm{d}$$

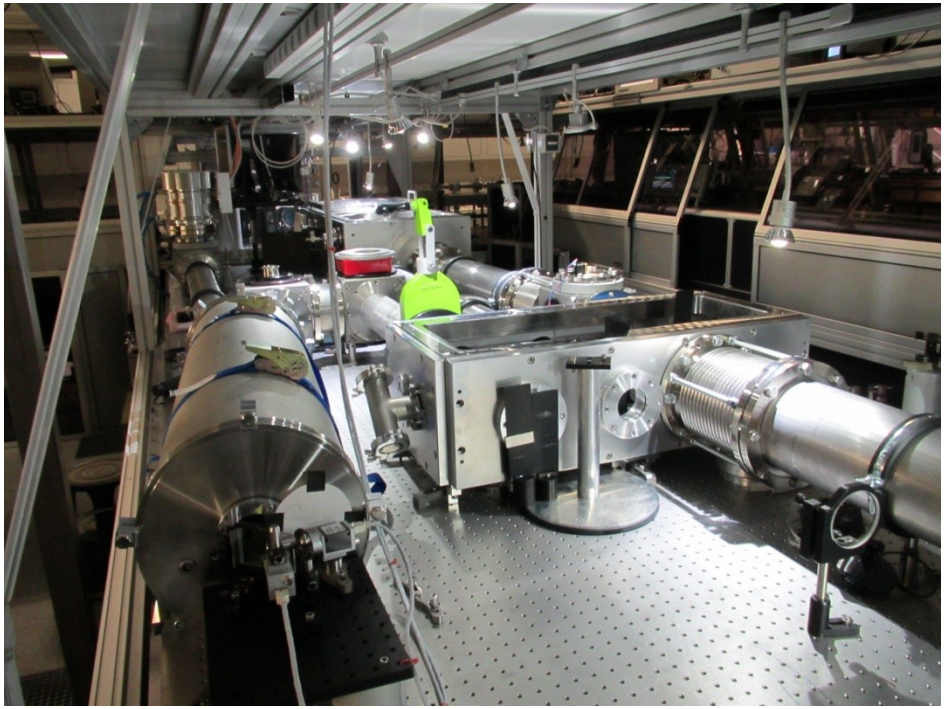


- Move a delaystage acording to measured jitter
- works with 10 Hz (on every shot)





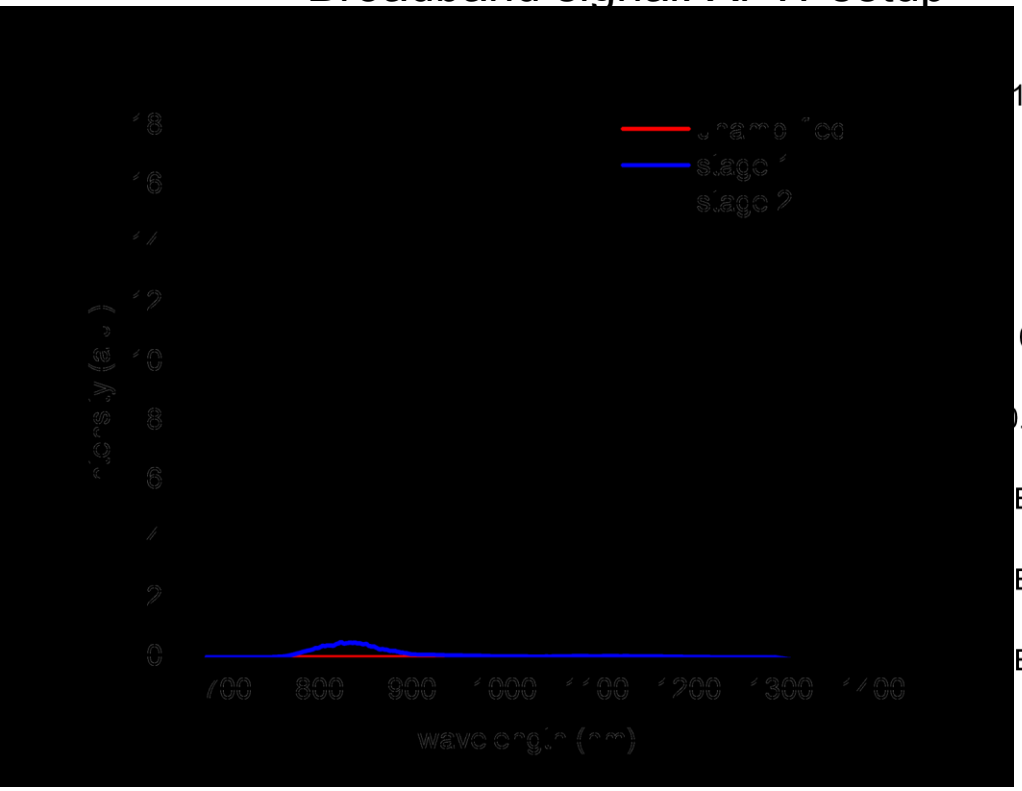
- two LBO stages pumped at 90 mJ total @ 515 nm
- imaging pump system
- 27 stepper motors
- 8 cameras for alignement

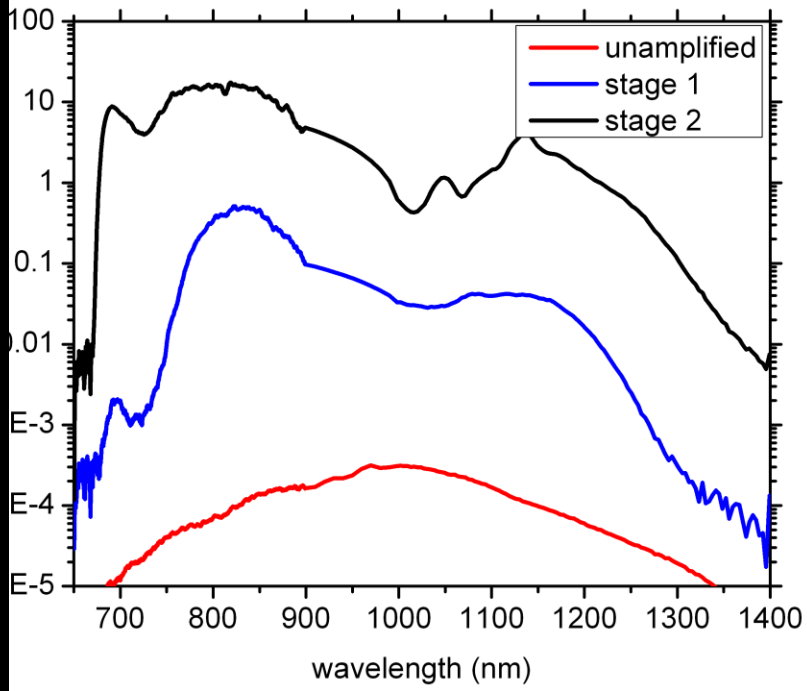


Pump diagnostics:

- high resolution spectrometers for 1030 nm and 515 nm
- power over photodiodes
- jitter measurements
- single shot SHG FROG

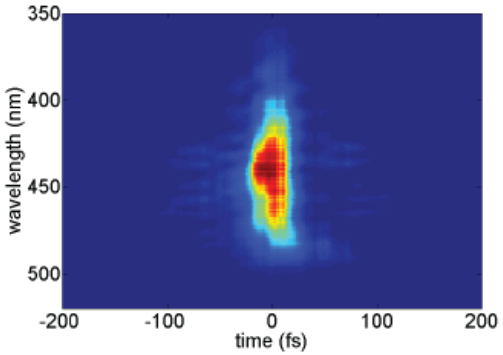
Broadband signal: XPW setup



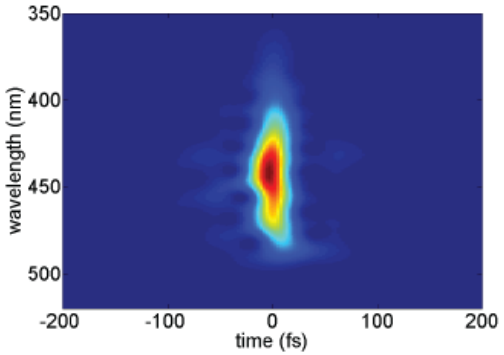


unamplified XPW:	0.3 μJ	pump energy:
OPA1, LBO 4 mm:	180 μJ	4.5 mJ
OPA2, LBO 4 mm:	9.8 mJ	84 mJ

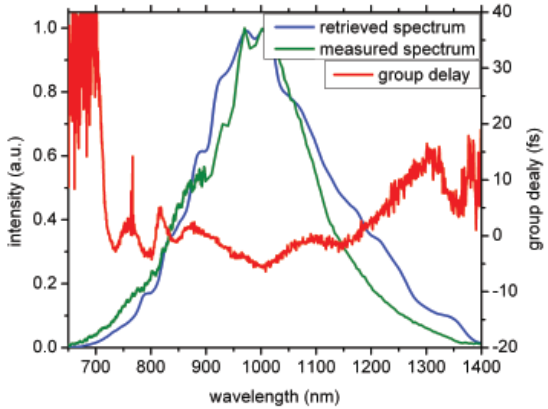
XFrog: unamplified



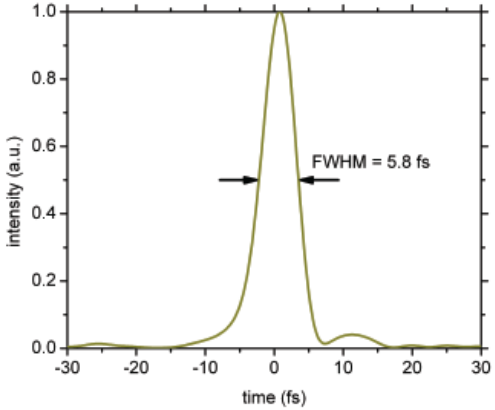
(a) measured X-FROG trace



(b) retrieved X-FROG trace



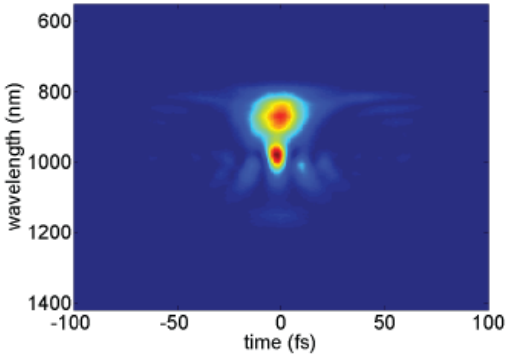
(c) retrieved spectrum and GD



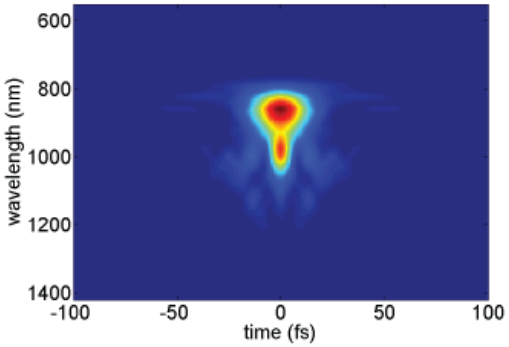
(d) retrieved temporal shape FL: 4 fs

Single Shot SHG Frog: two OPCPA stages running

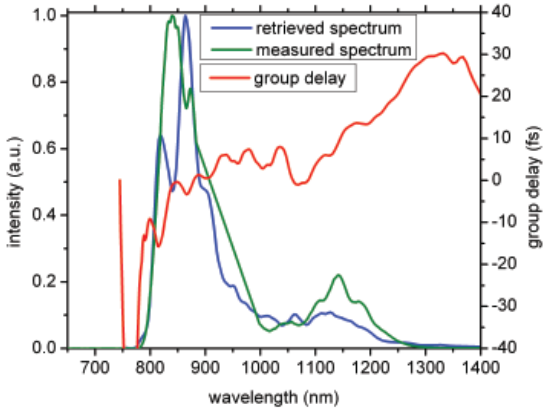
~ 2 mm additional FS



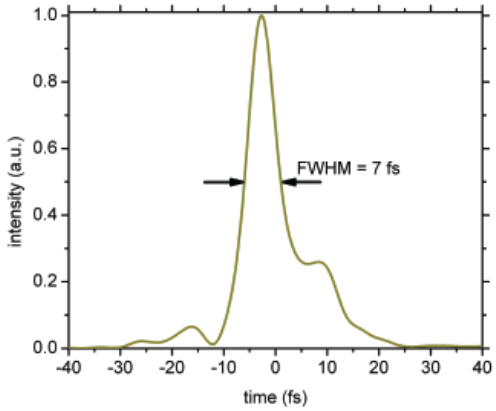
(a) measured FROG trace



(b) retrieved FROG trace



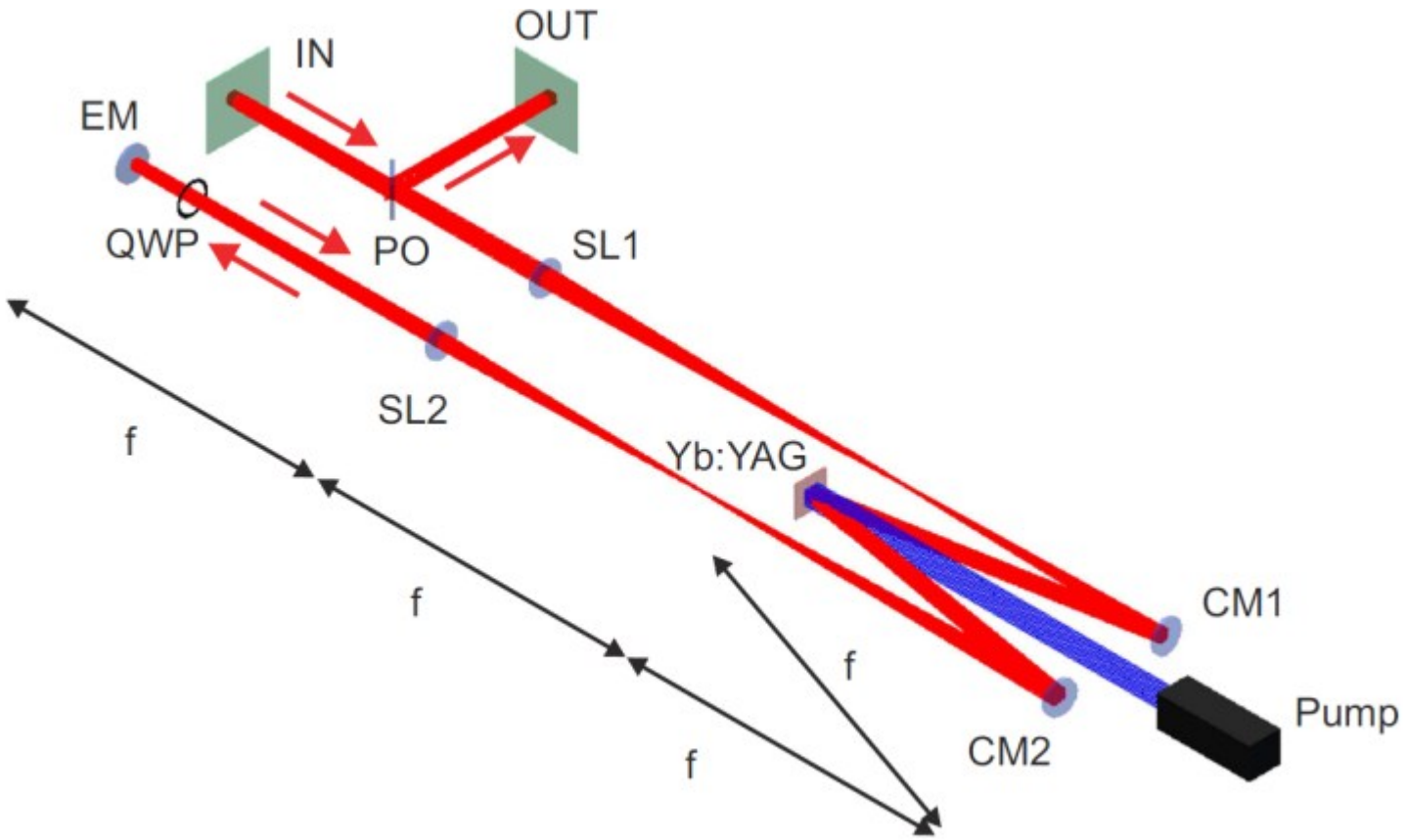
(c) retrieved spectrum and GD



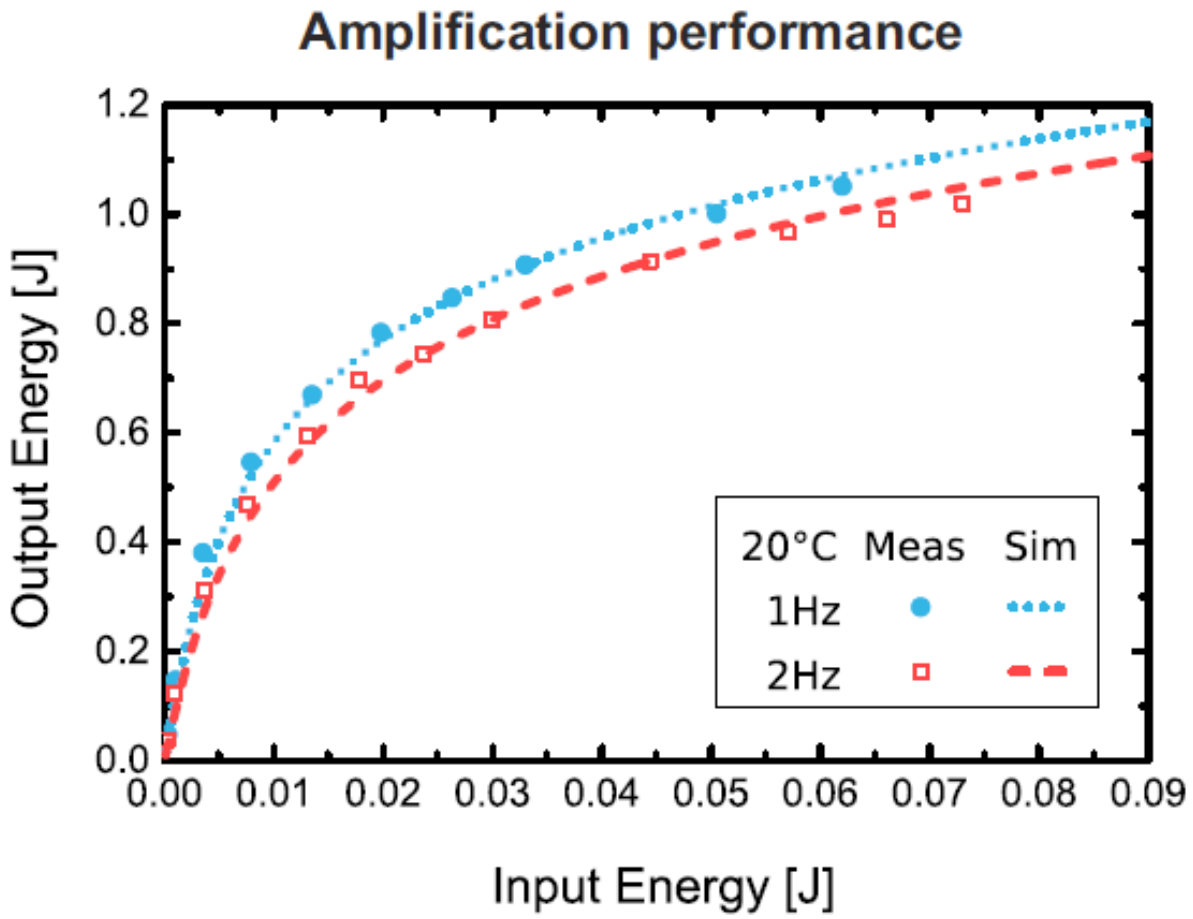
(d) retrieved temporal shape FL: 6 fs

TW-Pulse!

Pump laser: HEC DPSSL development

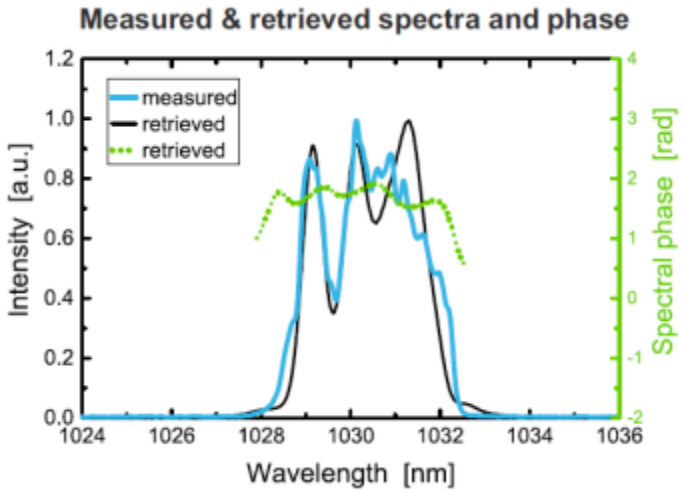


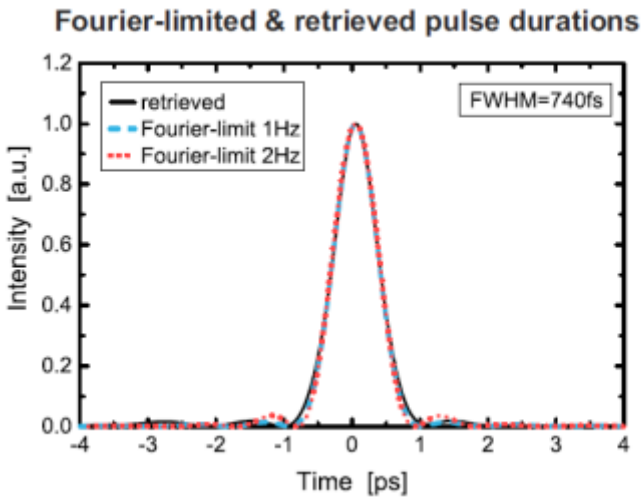
Pump laser: HEC DPSSL development



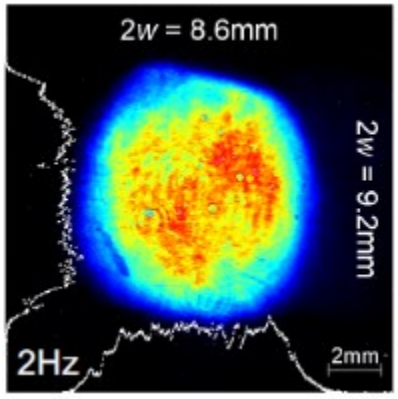
- 20pass amplification in a 2%-doped 6mm x 40x40mm2 Yb:YAG
- pumped by a 11kW pump module @ 1500µs and 940nm
- homogenized 10x10mm2 top-hat pump beam profile

Pump laser: HEC DPSSL development





Beam Profile

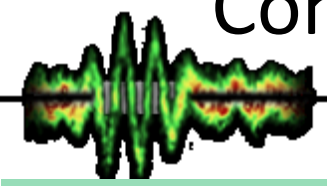


~ 1TW pulses at 1& 2Hz rep. rate

See Poster of Chr. Wandt

Vacuum compressor

Conclusion



- broadband seed generation scheme providing the desired wavelength range of 700-1300 nm

- Stabilized timing jitter ca. 100fs
- smooth amplified signal spectrum after two OPCPA stages
- compression down to 7 fs → improvement with new chirped mirror set

- next amplifier Stage with 1J output energy at up to 2Hz is available
- vacuum compressor is ready soon

Future steps

- alternative seed generation schemes → improve stability, efficiency, energy
- apply available pump power in OPCPA → first experiments
- Build multiple 10J stages based on proposed layout