High-Contrast Ultrabroadband Frontend Source for High Intensity Few-Cycle Lasers

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Outline

- **Motivation**

  Ultrashort seed for the OPCPA based Front End of the ILE 10 PW Apollon

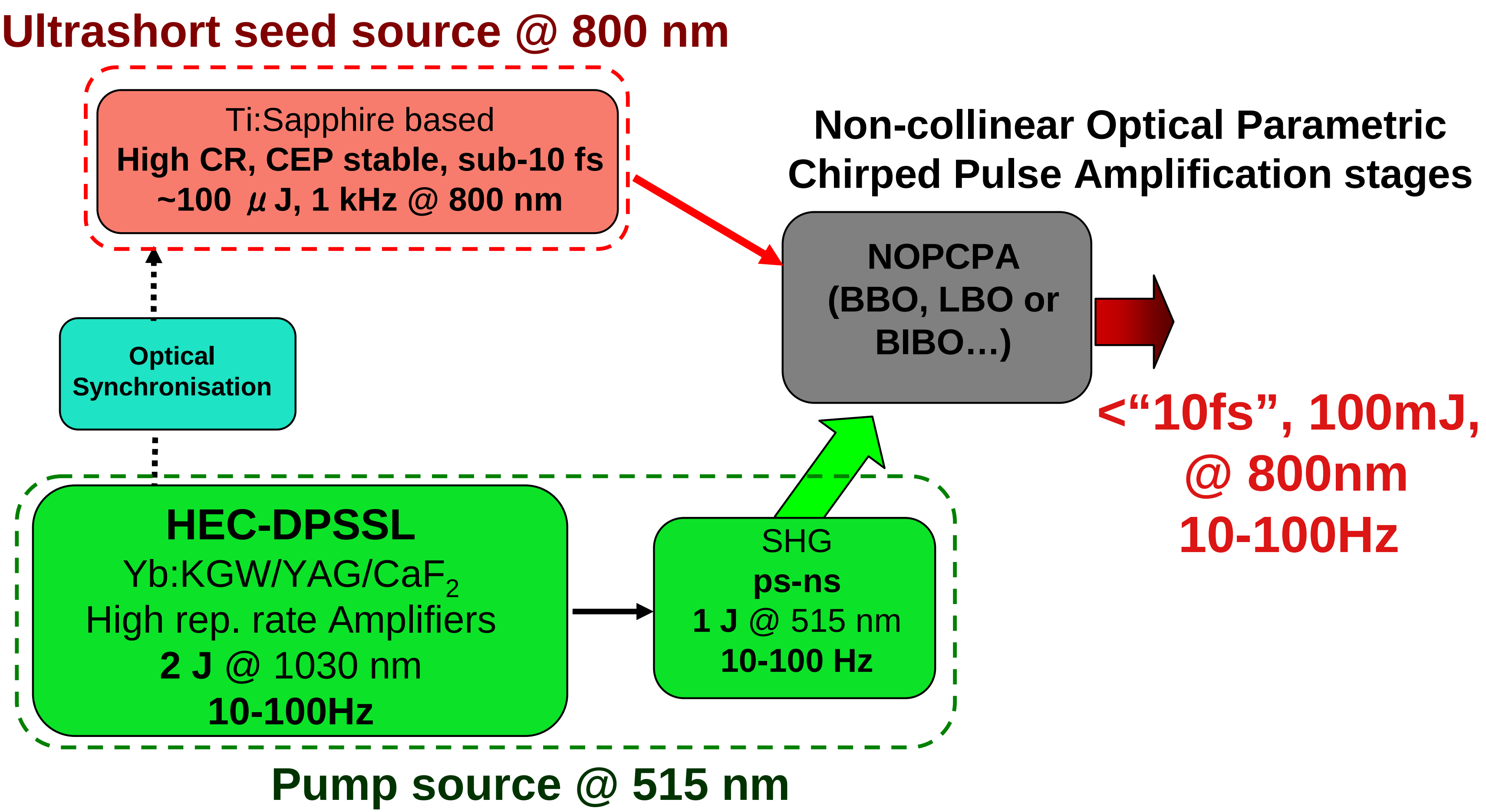
- **Experimental setup/results**

  -HCF spectral broadening/pulse compression
  -Crossed polarized wave (XPW)
  -Spectral/Efficiency (dispersion)
  -FROG/CEP/CR measurements
  -Reliability

- **Summary/next steps**

The front end of a… front end

- The Apollon 10 PW Front End system



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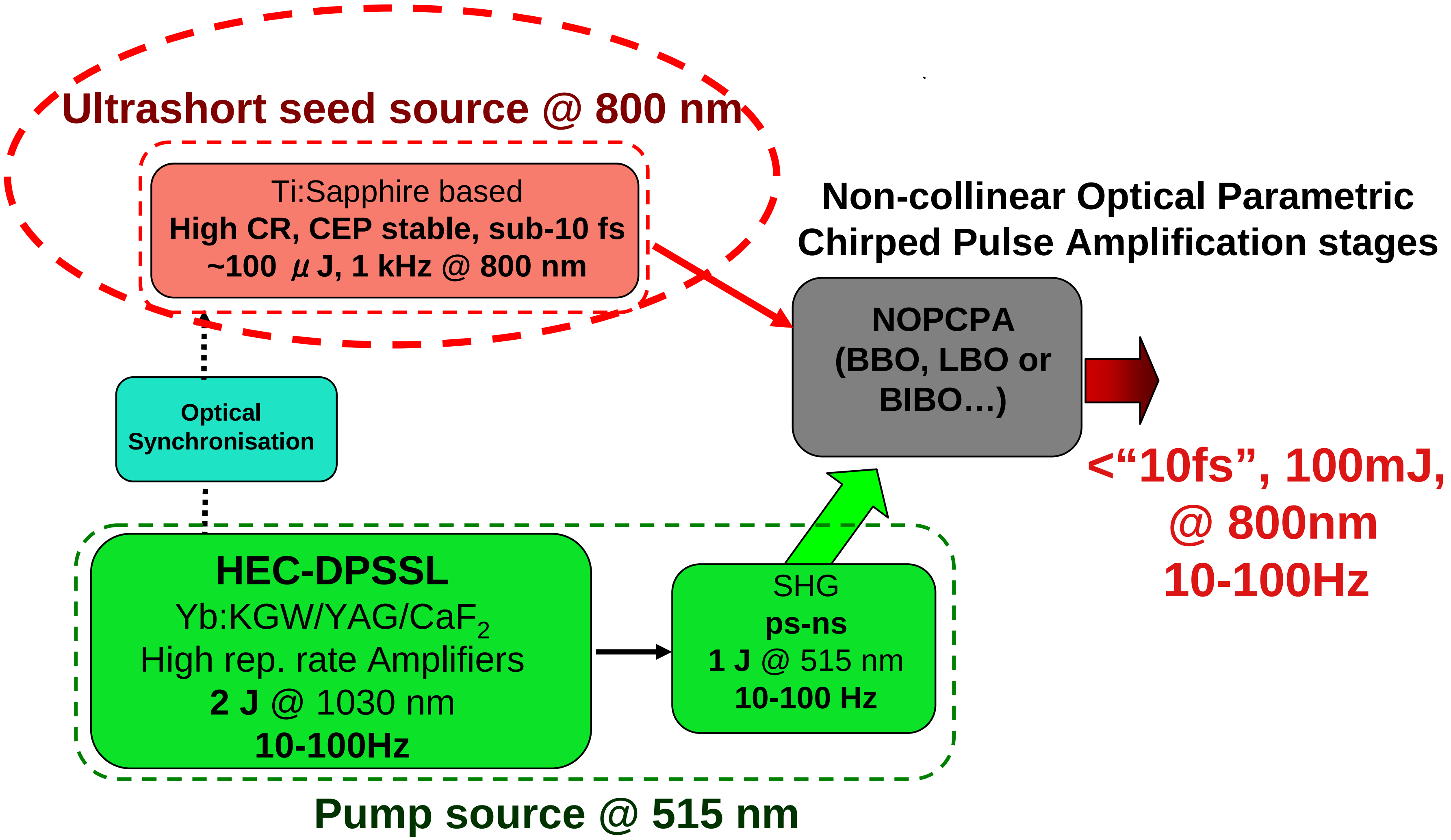

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- The High CR, CEP stable, sub-10 fs, ~100 μJ, 1 kHz seed @ 800 nm

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Ti:Sa system (Femtopower)
CEP stable, CR~10^8
25 fs, 1.5 mJ, 1 kHz

- Commercial system, turn key operation
- Three CEP stabilization loops
- Active pointing stabilization (3x)

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↓

Pulse compression
Hollow core fiber (HCF), Ne
CEP preserving
5-10 fs, >50%, >700 μJ

- **Commercial system, turn key operation**
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- **Well established/flexible technique**
  - **Optimized CM compressor**
  - **Nonlinear stage/stability issues**

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Crossed polarized waves (XPW)
CEP preserving
5-10 fs, CR>10^{10}, ~100 μJ

• Proved CR enhancement capacity ~10^5 (ext. pol.)
• Temporal & Spectral cleaning: $I(t)_{XPW} \propto I^3(t)_{FW}$
➢ Intensity limited process I~10^{12}W/cm^2:max energy, efficiency
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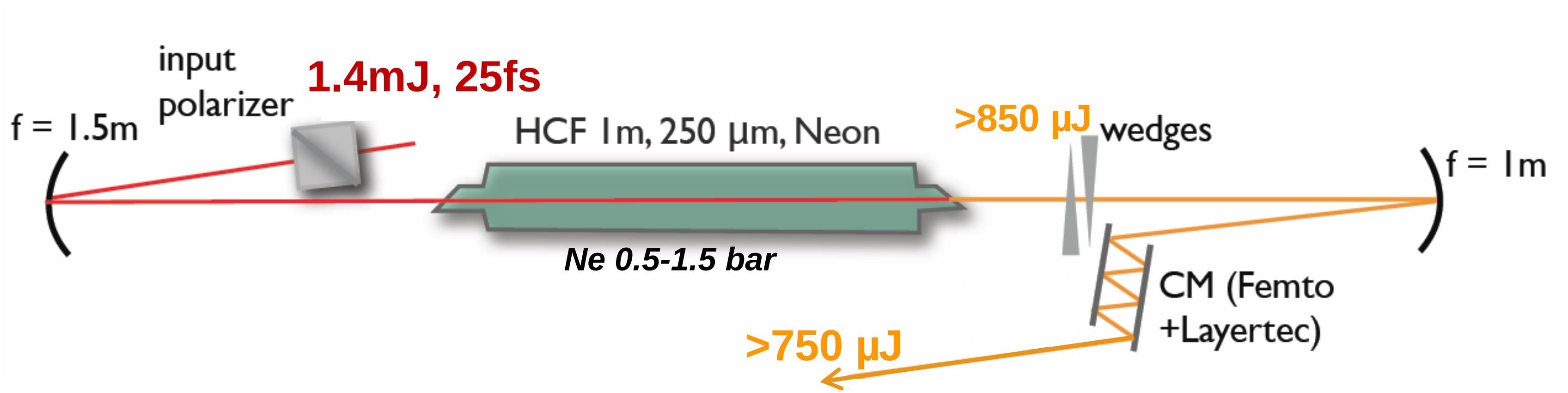
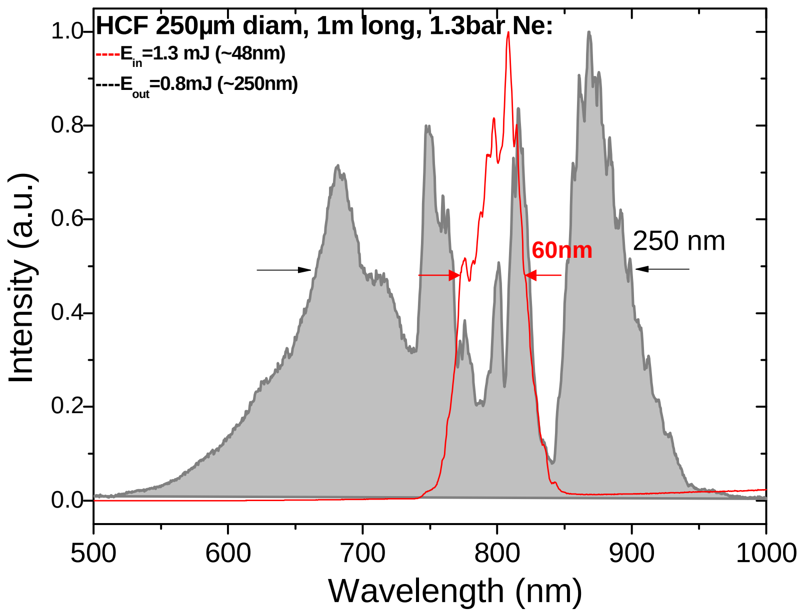
•Challenging combination of the sub-systems capacity towards ~5 fs high energy pulses, reliable seed source

Hollow core fiber pulse compression



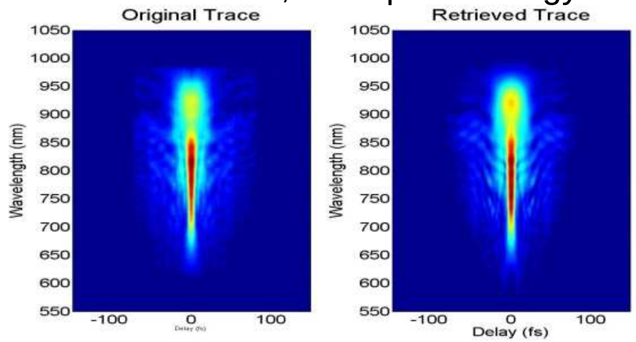
Spectral broadening in the HCF:

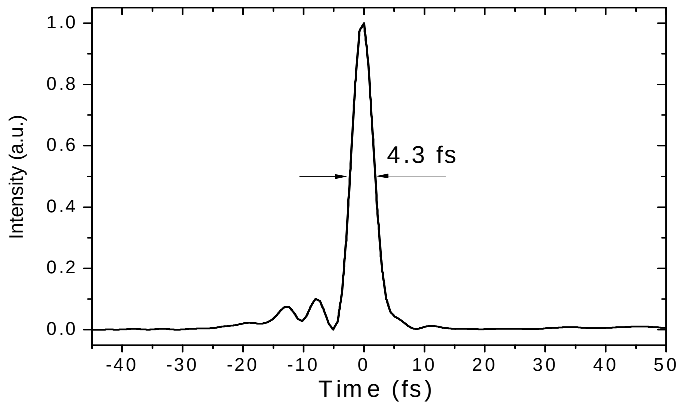
Typical input/output spectrum at full input power (1.4 mJ, 1.3 bar Neon, ~60% efficiency)



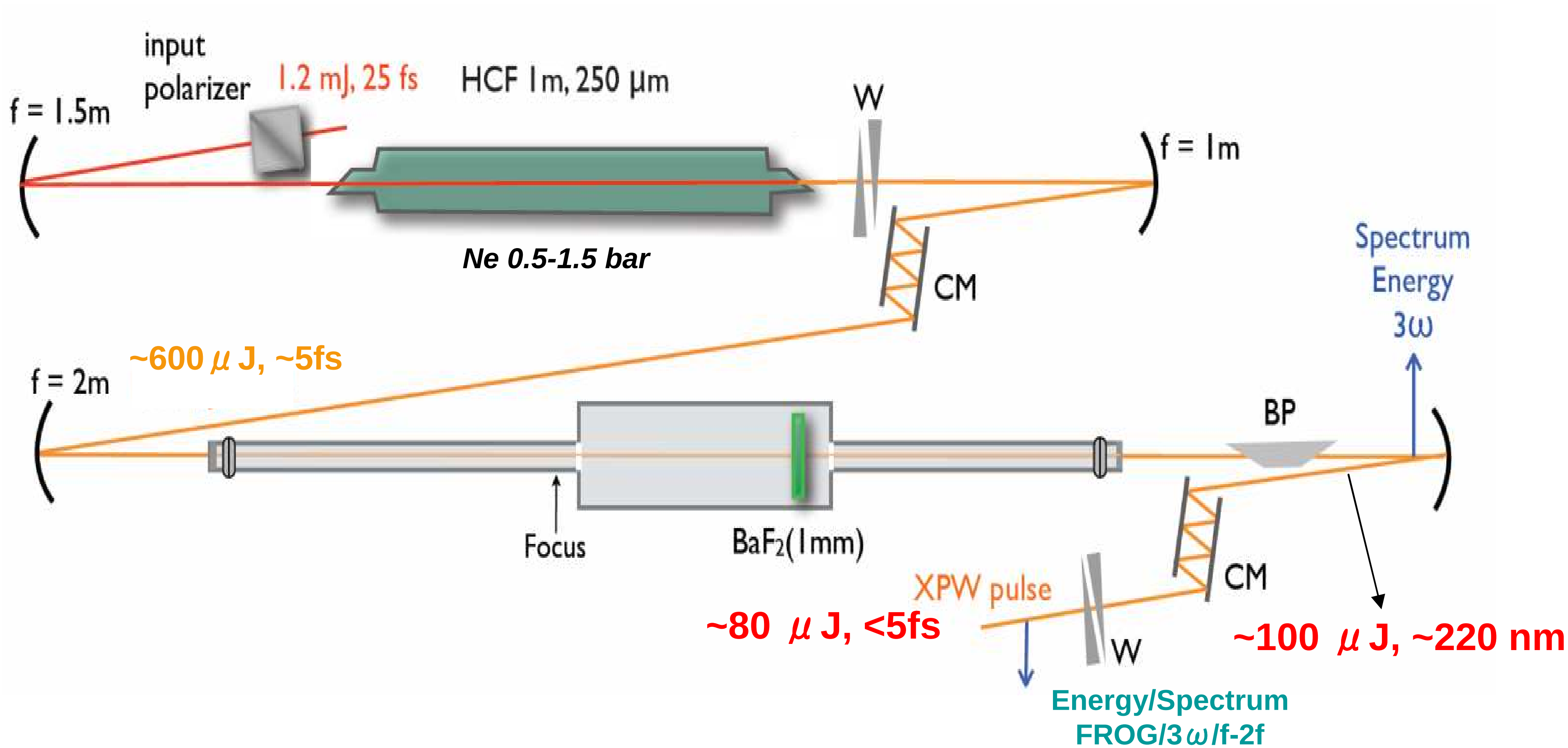
HCF pulse compression:

Strehl ratio:81%, Main peak energy:79%





High energy XPW

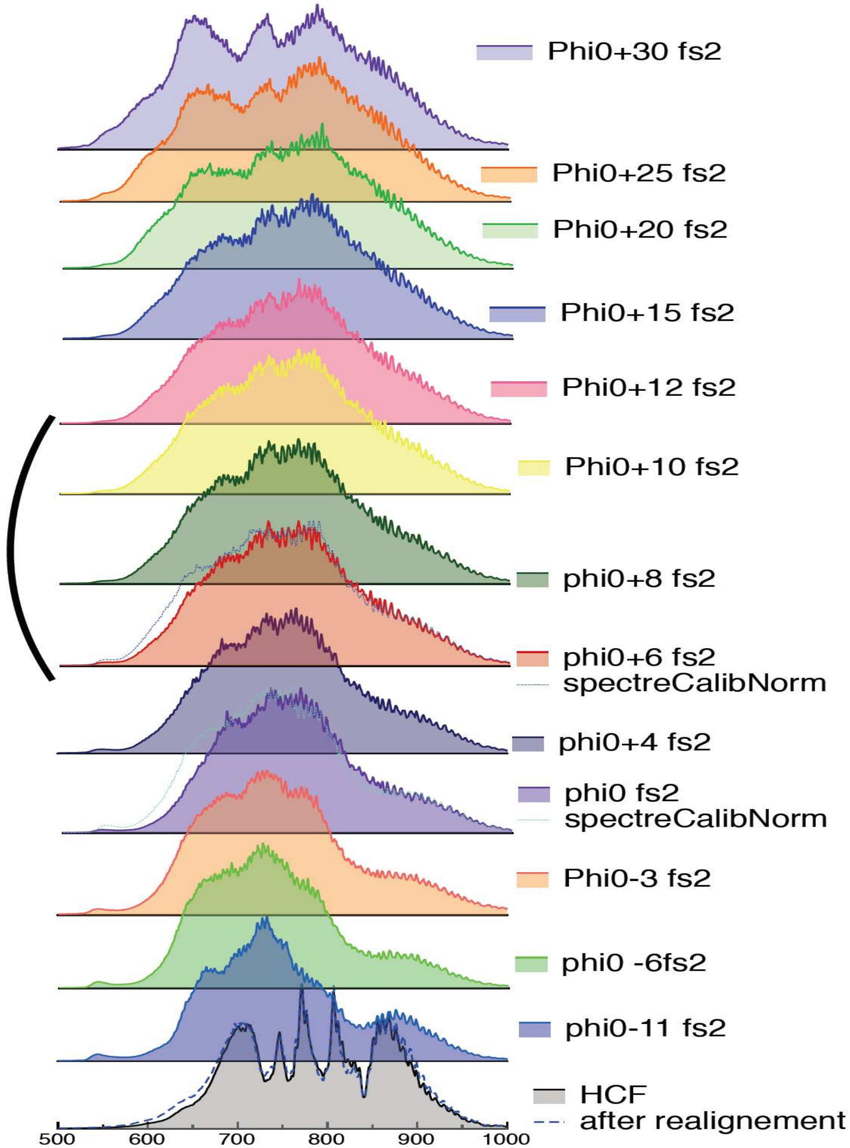


- ~10^{12} W/cm^2 on the XPW crystal: Vacuum, long focal distance
- 1 mm BaF_2, [011]-cut: max XPW efficiency ~15%
- Polarization extinction ratio ~$5{\cdot}10^{-3}$: estimated CR improvement ~10^2

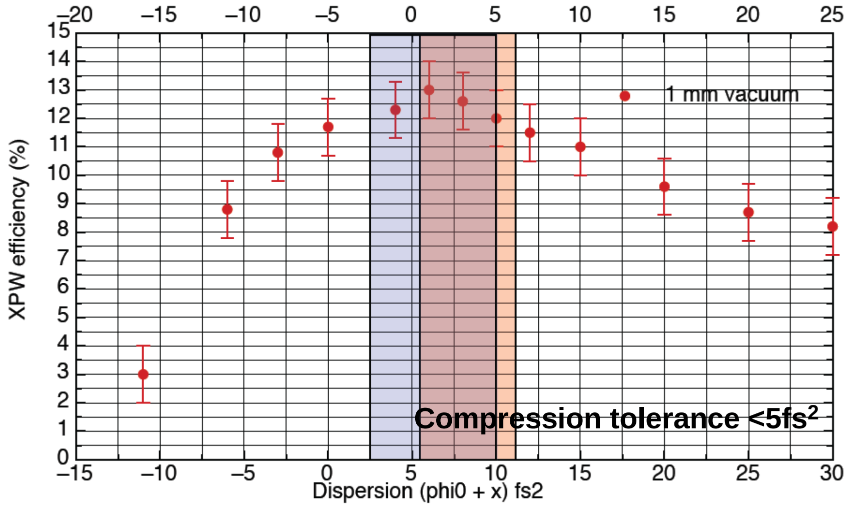
A. Jullien et.al. “High fidelity ultra-broadband frontend for high-power, high-contrast few-cycle lasers,” accepted Appl. Phys. B (08/2010)

XPW Spectrum/Efficiency vs dispersion

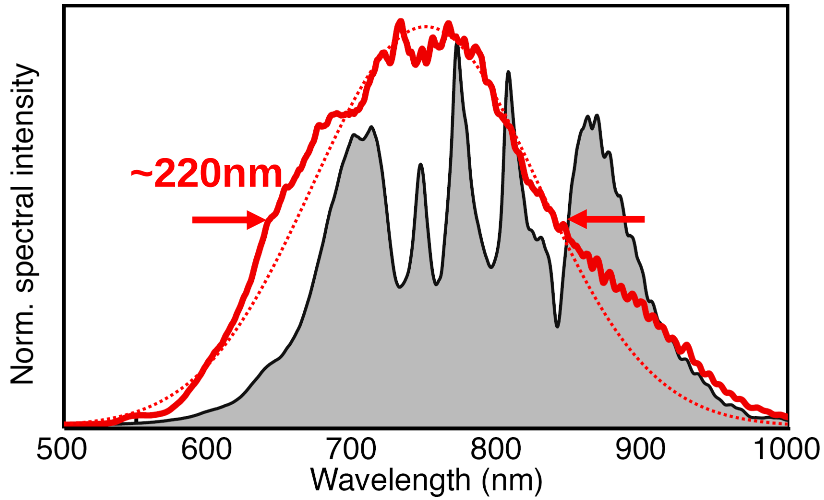
XPW spectrum/Dispersion



XPW efficiency/Dispersion

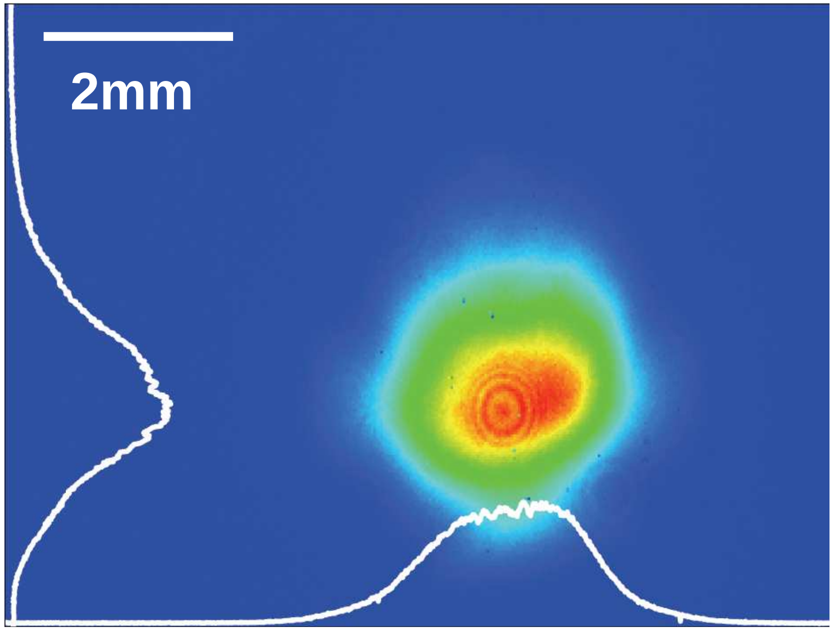


Optimum pulse compression (phi0+6)=> Best efficiency 15% (~20% corrected)=> ~100 μJ

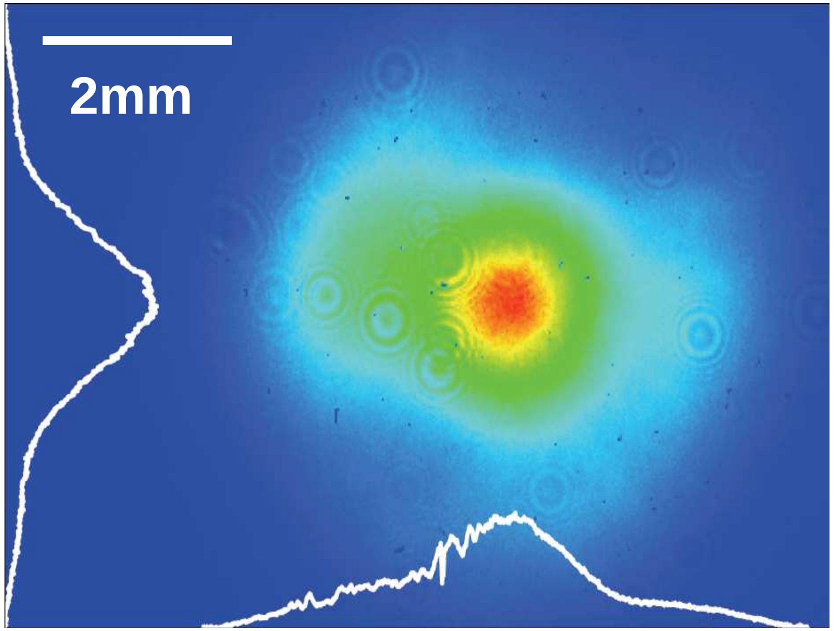


Spatial characterization

Incident beam on the crystal (1.8-2mm diameter)

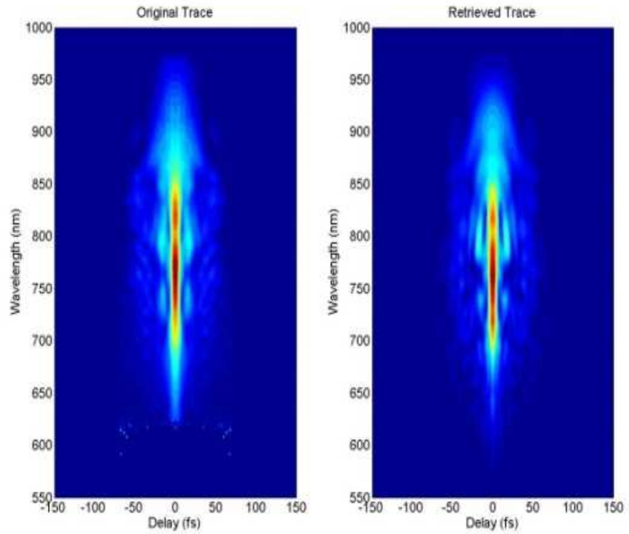


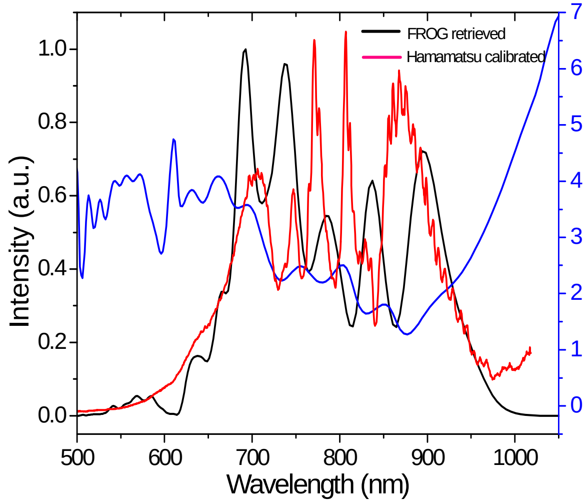
After the XPW (near field)

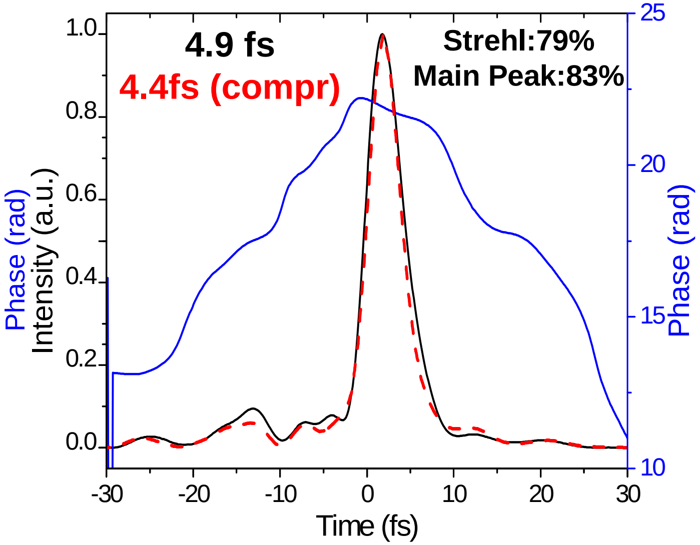


FROG measurements HCF->XPW

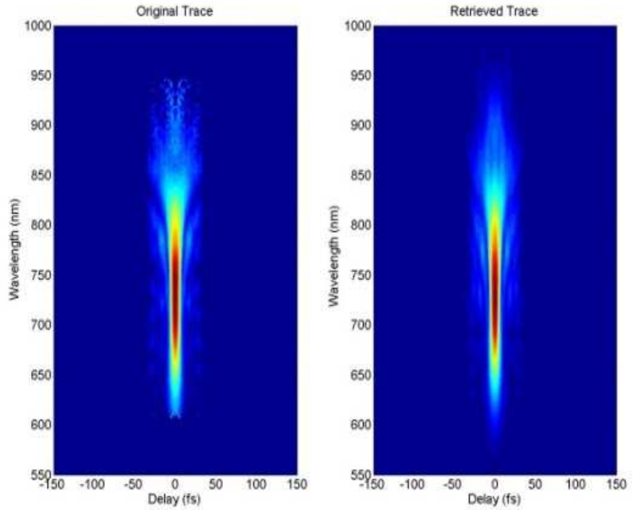
- HCF: 4.4 fs, 0.7 mJ

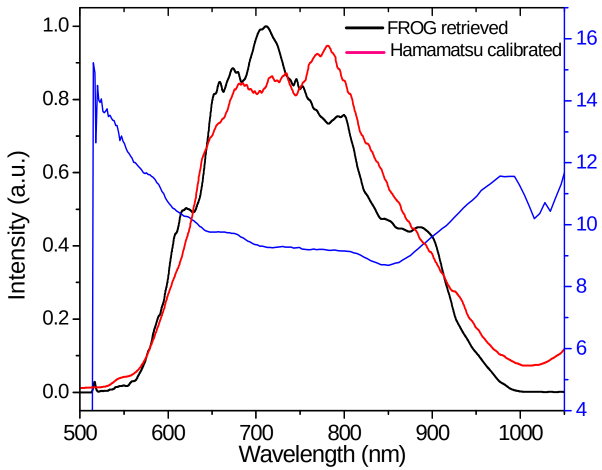


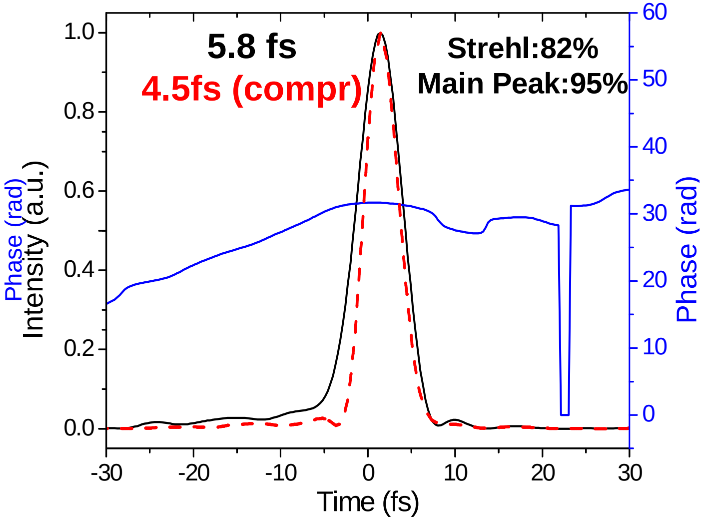




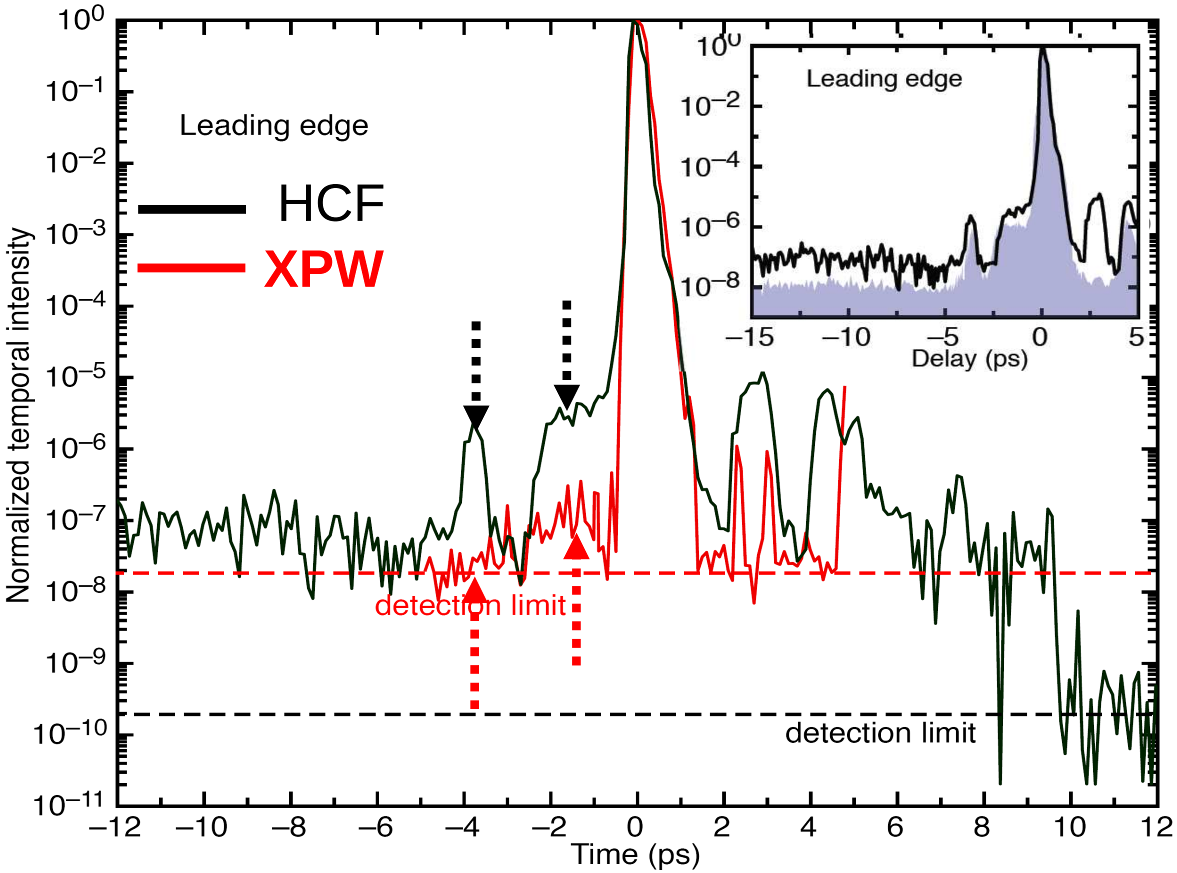
- XPW: <5fs, ~100 µJ (80 µJ)







CR measurements



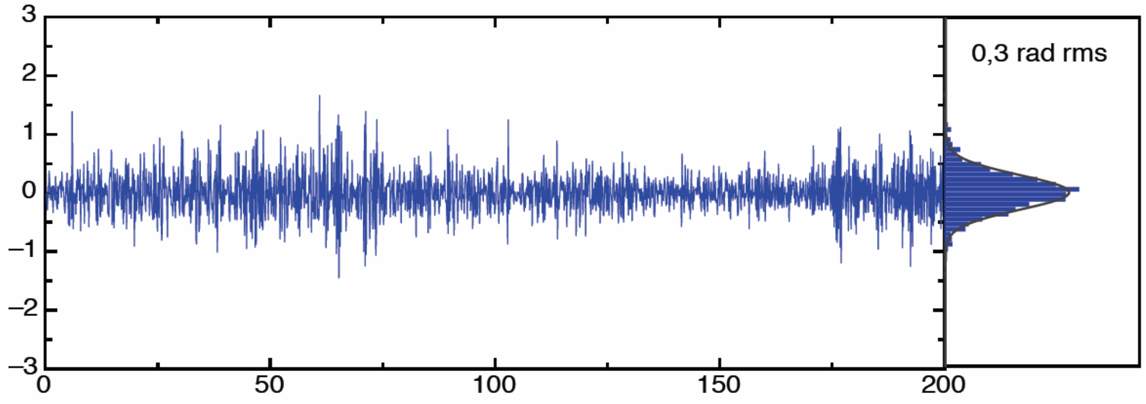
•3 ω correlator, full dynamic range ~10^{11} (1mJ), reduced spectral acceptance (~100 fs pulses)

•CR improvement by at least 10^2 =>HCF CR~10^8 -> XPW CR~10^{10}-10^{11} (estimated)

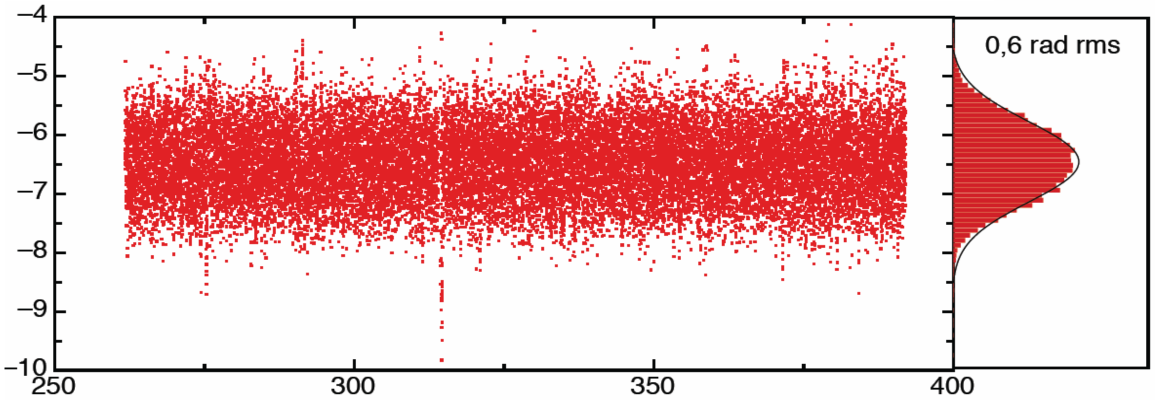
•No compression for the seed=>Glan polar. (ext.10^5)=> XPW CR ~10^{12} (expected)

CEP stability measurements

Int. time : 100 ms (10 shots)



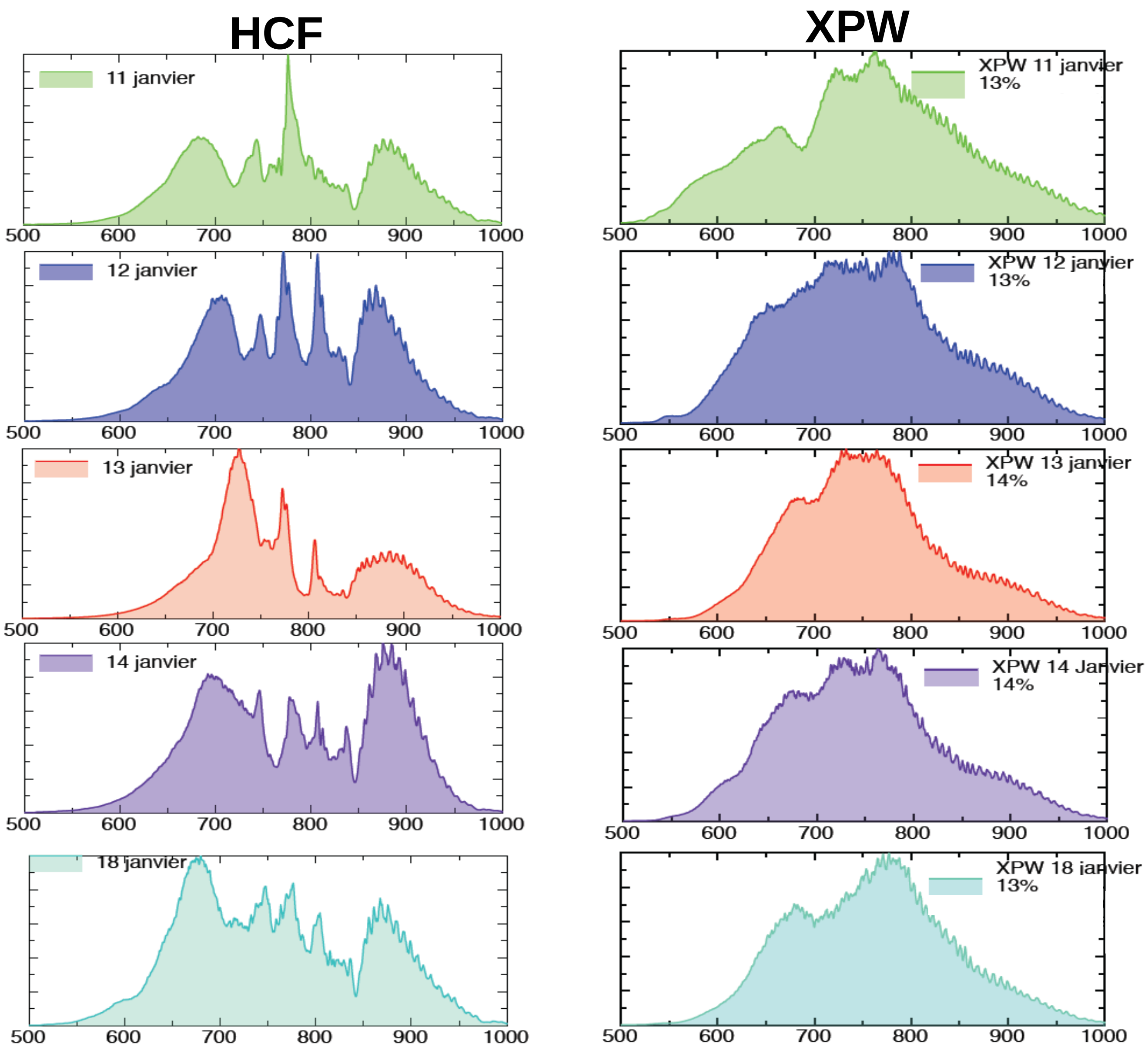
Int. time : 1 ms (single shot)



- Home made f-2f=> feedback to the slow loop of Femtopower (Menlo APS800)
- CEP ~300 mrad=>CEP preservation: (Femtopower alone->~200 mrad)
- Three feedback loops, covered setup, reduced propagation path

Reliability

•Day to day reproducibility



•XPW changes mainly due to variation of the HCF output spectrum almost without effecting the efficiency

•Easy readjustment (gas pressure, HCF coupling, HCF compressor)

•Pulse to pulse rms stability:

✓Femtopower: 0.7%

✓HCF:1.1%

(active pointing stab.)

➢XPW:2.5%

(more compact, double XPW)

Summary/next steps

•Spectro-temporal cleaning of high-energy few-cycle pulses by an optimized vacuum XPW filter

•Generation of high CR, CEP stable, sub-5fs, ~100 μJ (80 μJ) pulses

•Ideal ultra-broadband seed source for high energy/intensity systems

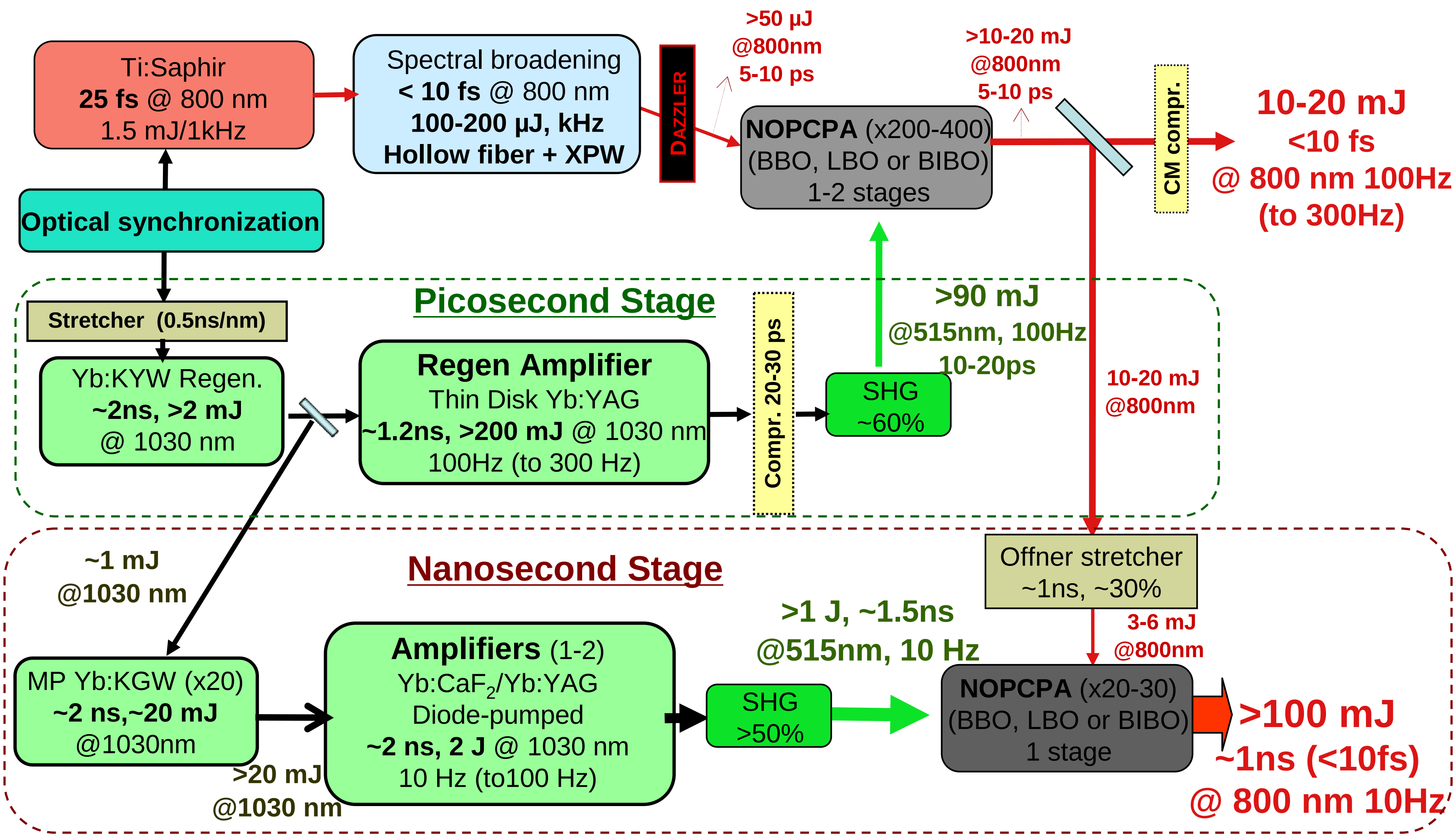
➢…double crystal XPW configuration=> Improved efficiency/stability

➢…preliminary low energy NOPCPA experiments=> CEP stability, max amplified bandwidth, pulses compressibility

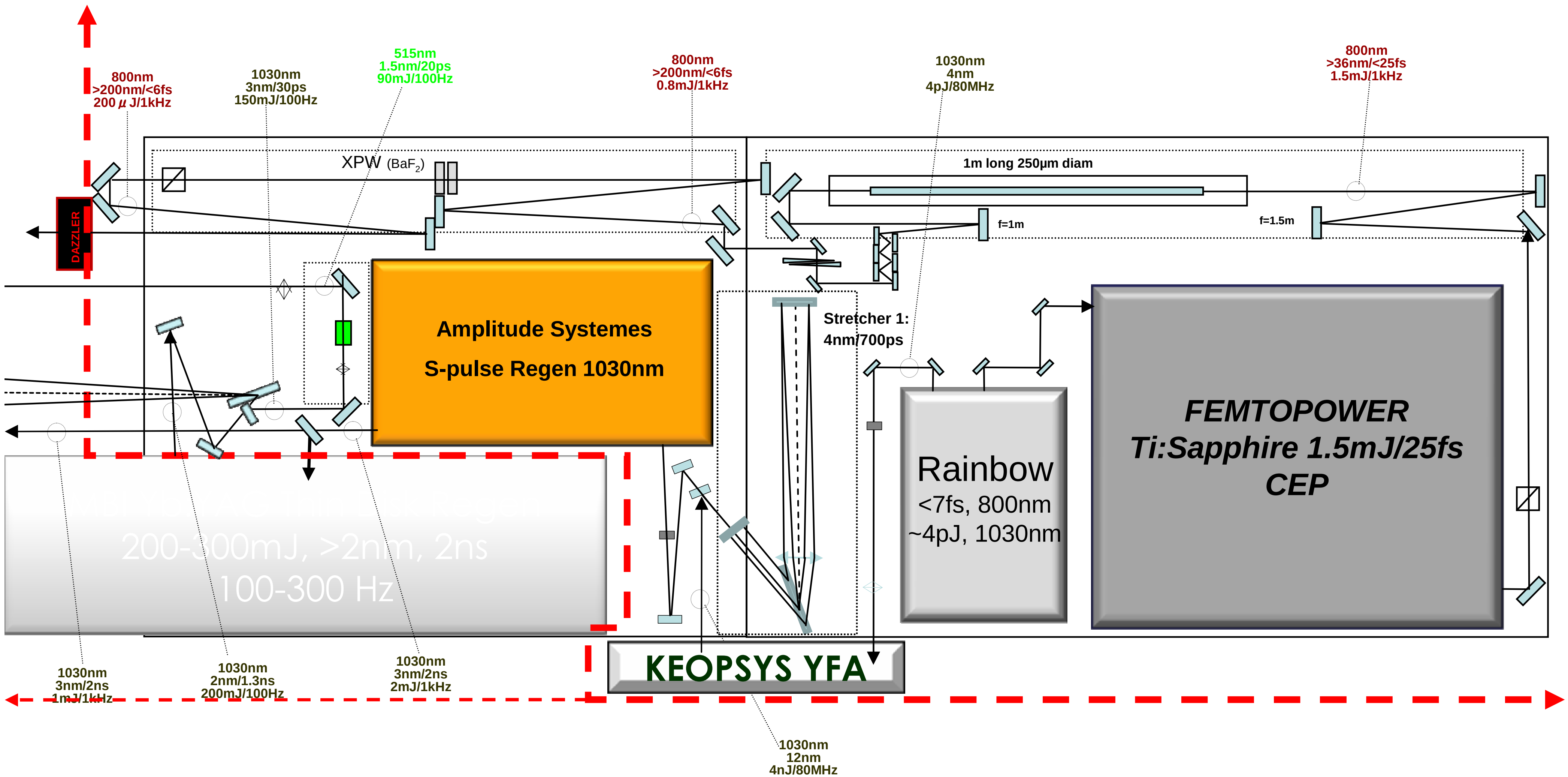
➢…03/2011→ps-NOPCPA (>10 mJ), 2012→ns-NOPCPA (100 mJ)

Thank you!

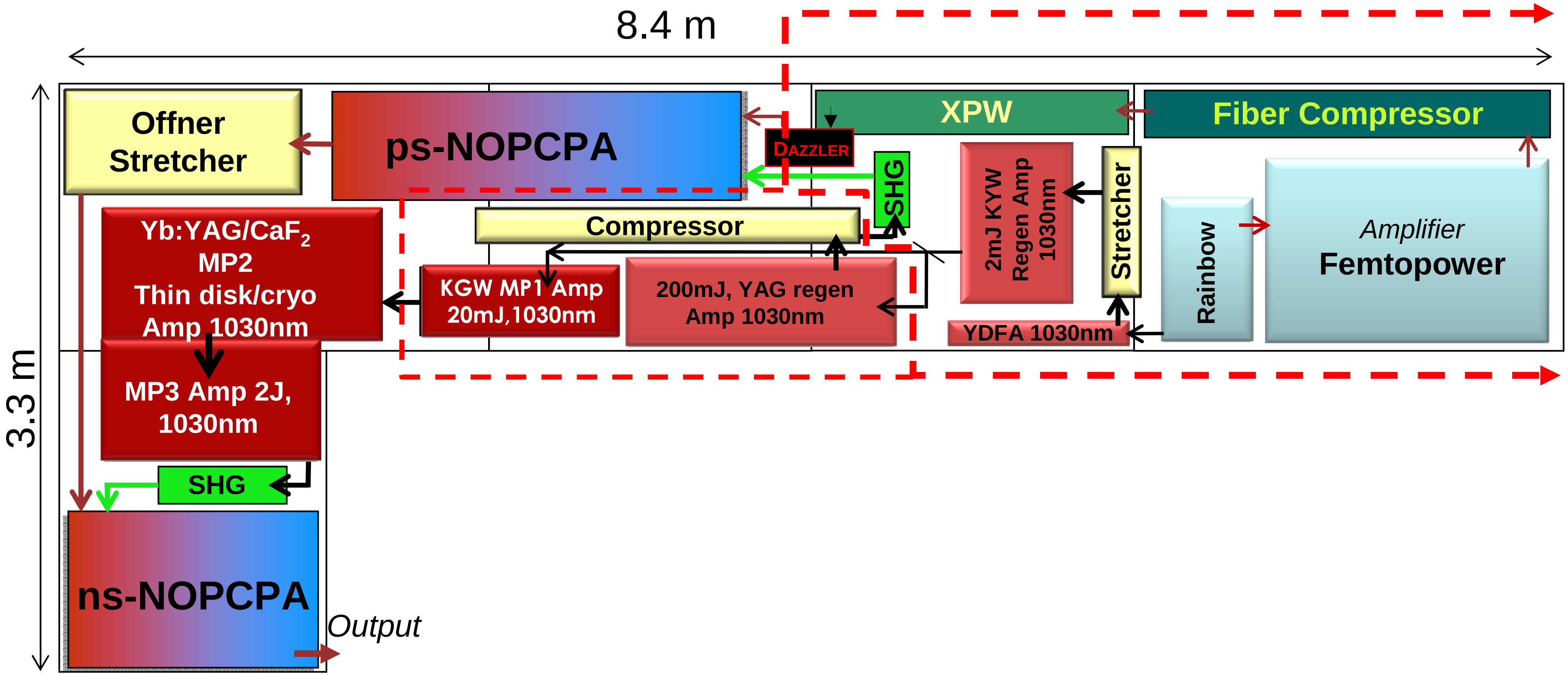
The Front End: ps/ns strategy



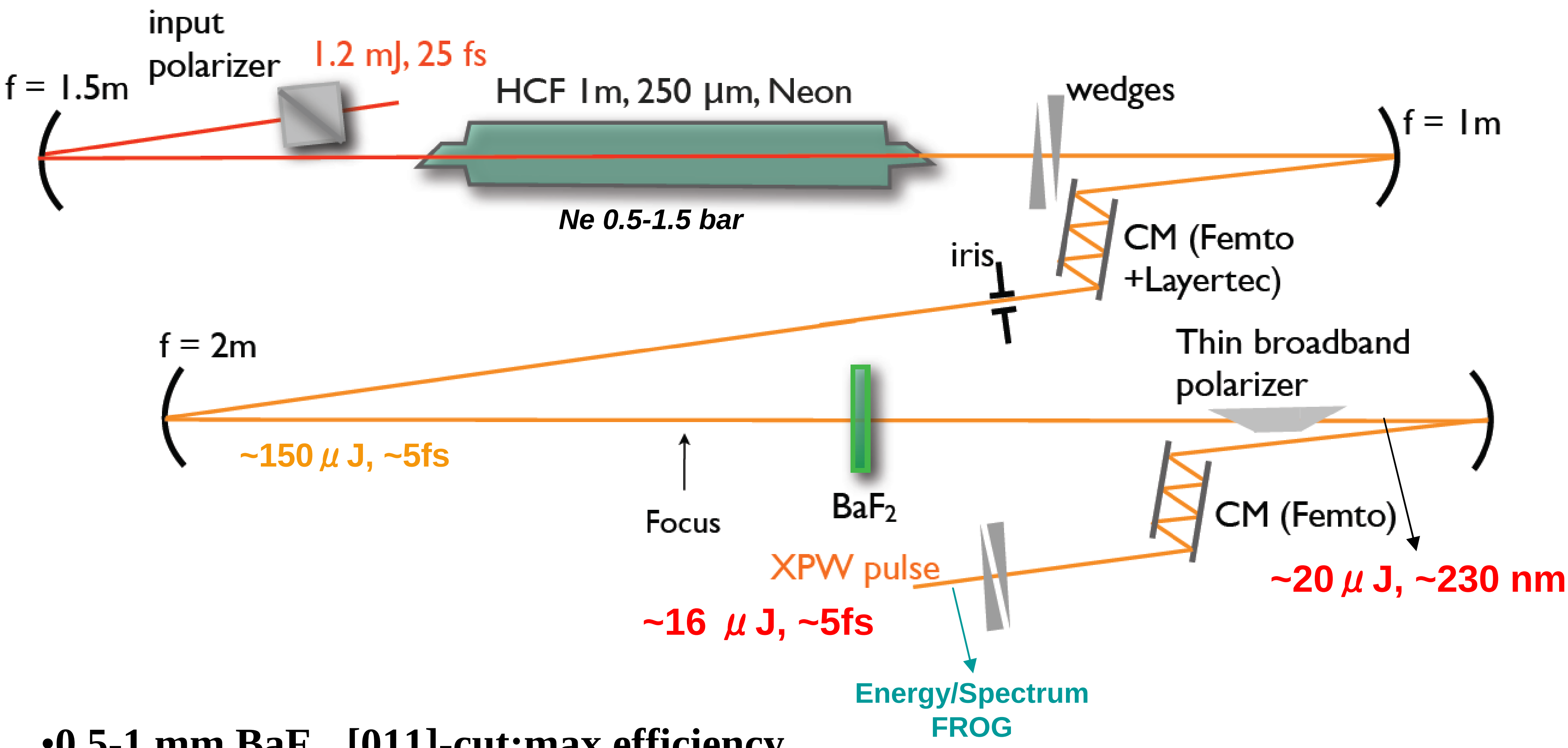
The Front End: Table view setup



The Front End: Table view



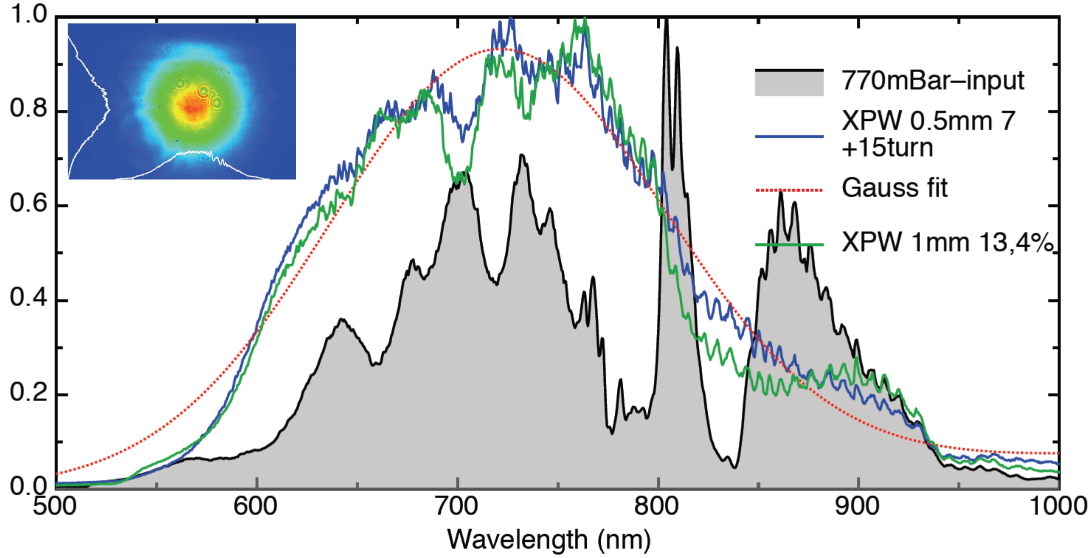
Low energy XPW (in air)



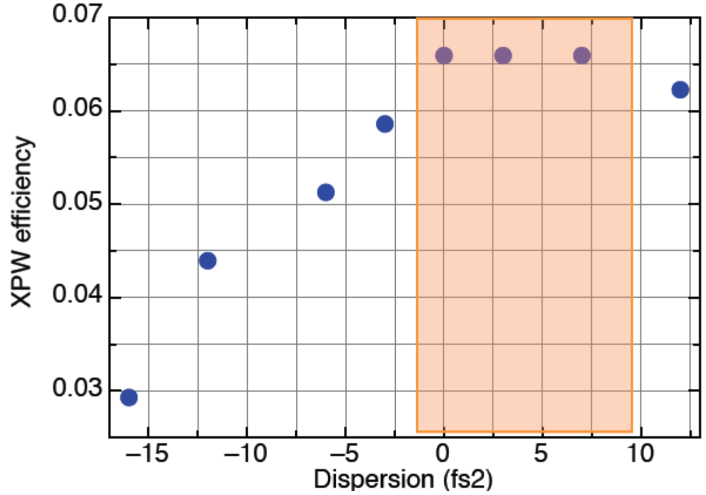
- 0.5-1 mm BaF_2, [011]-cut:max efficiency
- >13% XPW efficiency
- Polarization extinction ration ~5·10^-3
- Estimated CR improvement ~10^2

Low energy XPW: results

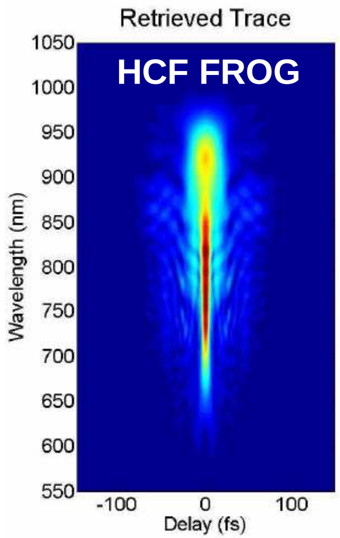
- XWP Spectral filtering

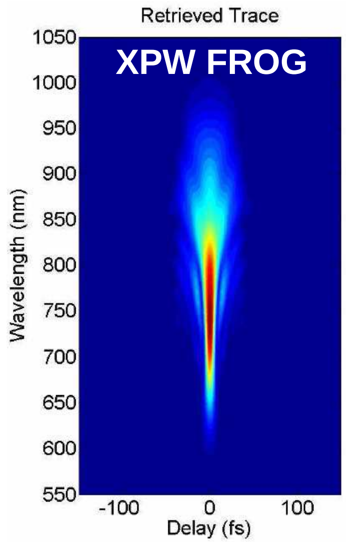


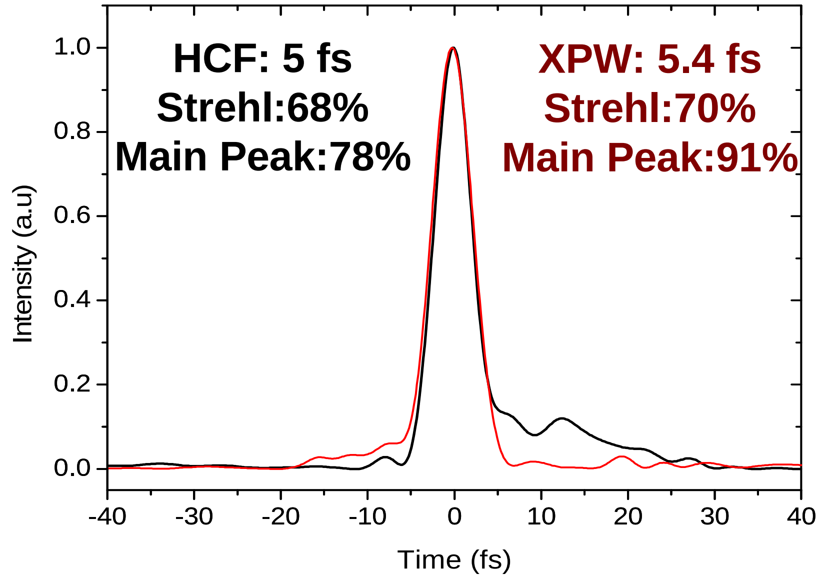
Compression tolerance <5fs²



- XWP pulse compression/cleaning

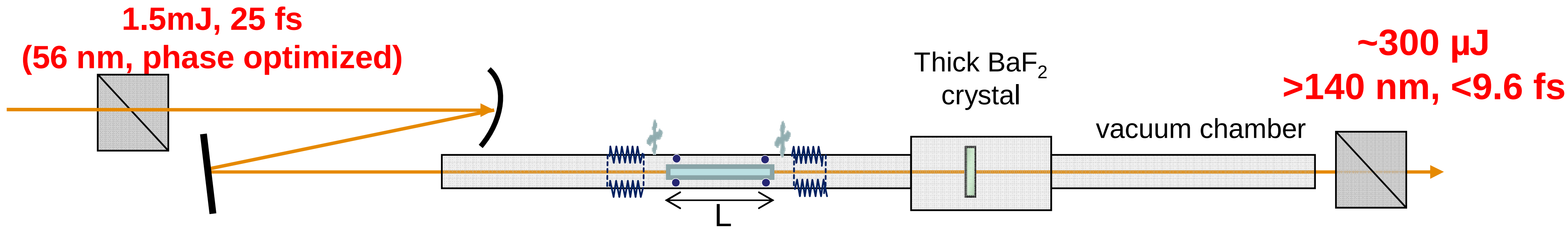


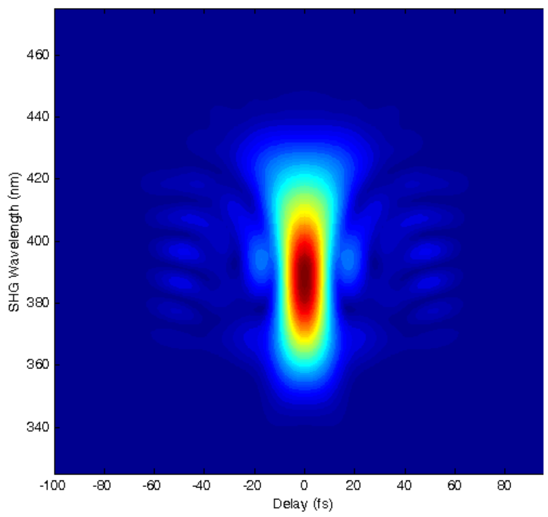


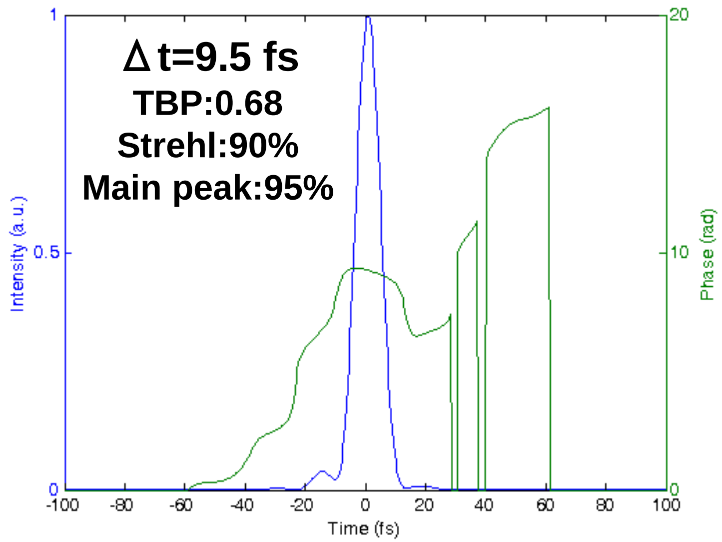


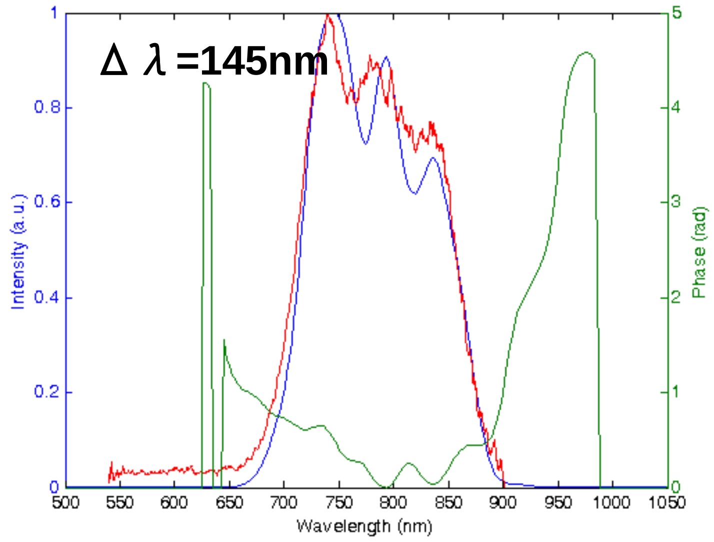
"Direct" XPW perspective

•Direct XPW sub-10 fs seed







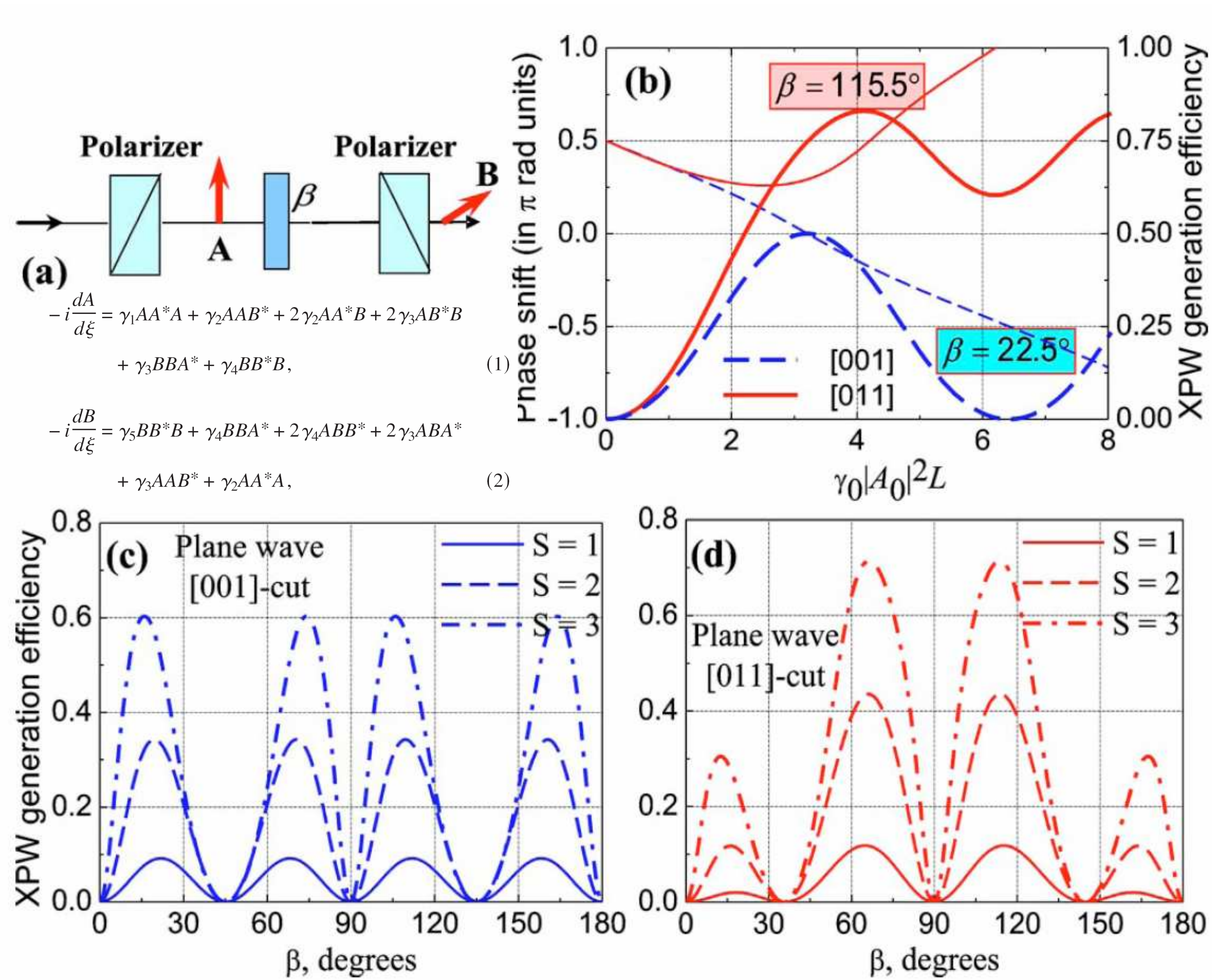


•Compact, reliable, single nonlinear stage seed configuration

•Short enough more energetic pulses, High CR, CEP conservative

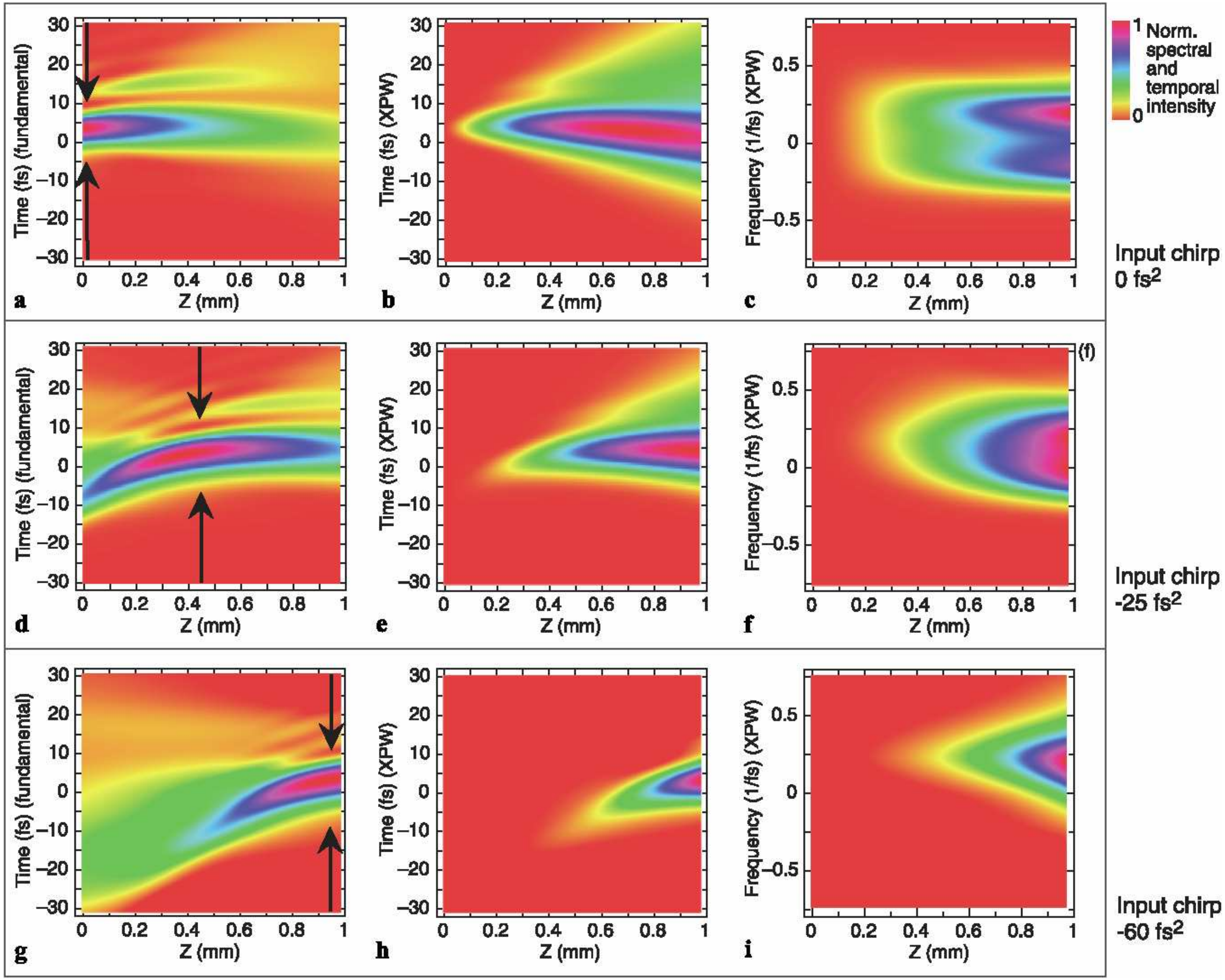
•Lower coherent CR, rectangular like spectrum

z-cut vs holographic cut



L. Canova et.al. " Efficient generation of cross-polarized femtosecond pulses in cubic crystals with holographic cut orientation," Appl. Phys. Letters (2008) 92.

Input dispersion influence



A. Jullien et.al. "Nonlinear spectral cleaning of few-cycle pulses via cross-polarized wave (XPW) generation," Appl. Phys. B (2009) 96.