

THE OPTICAL REPLICA SYNTHESIZER AT FLASH

new diagnostic tool for electron bunches

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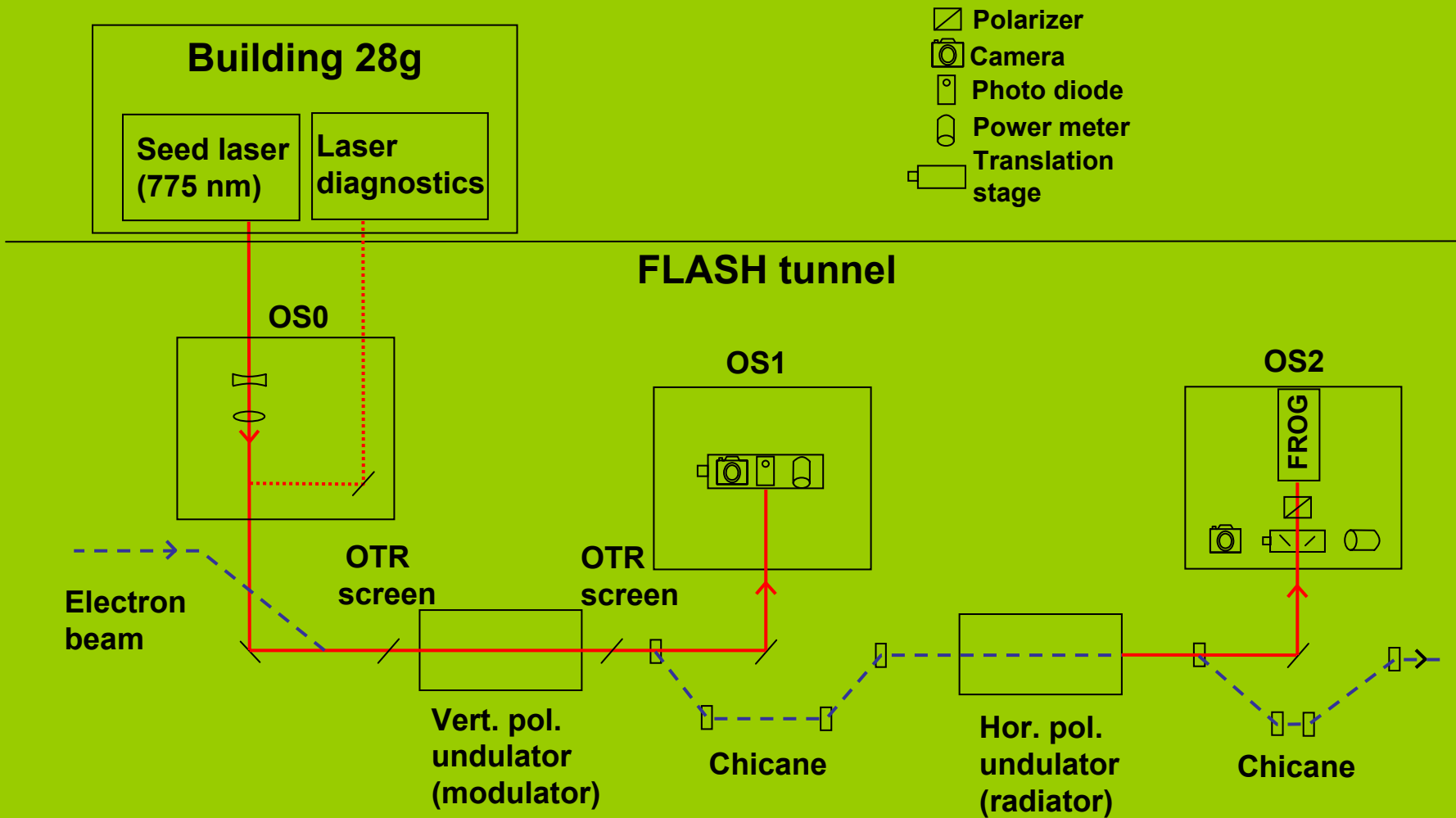
FEL is very sensitive to the properties of the electron bunch

electron bunch properties: longitudinal density profile
slice emittance
slice energy spread

need to control and measure these properties!

electron bunch: moving at $v \approx c$
ca. 20 μm long
ca. 100 μm wide

hard to measure directly
 \Rightarrow measure an optical copy instead



MAGNETIC STRUCTURES



Undulators:

- electromagnets
- 5 periods
- 40 mm gap, 0.5 T max.

Chicanes:

- 4 dipole magnets

SEED LASER

Home built Er Fiber oscillator:

Rep freq=54 MHz phase locked to RF

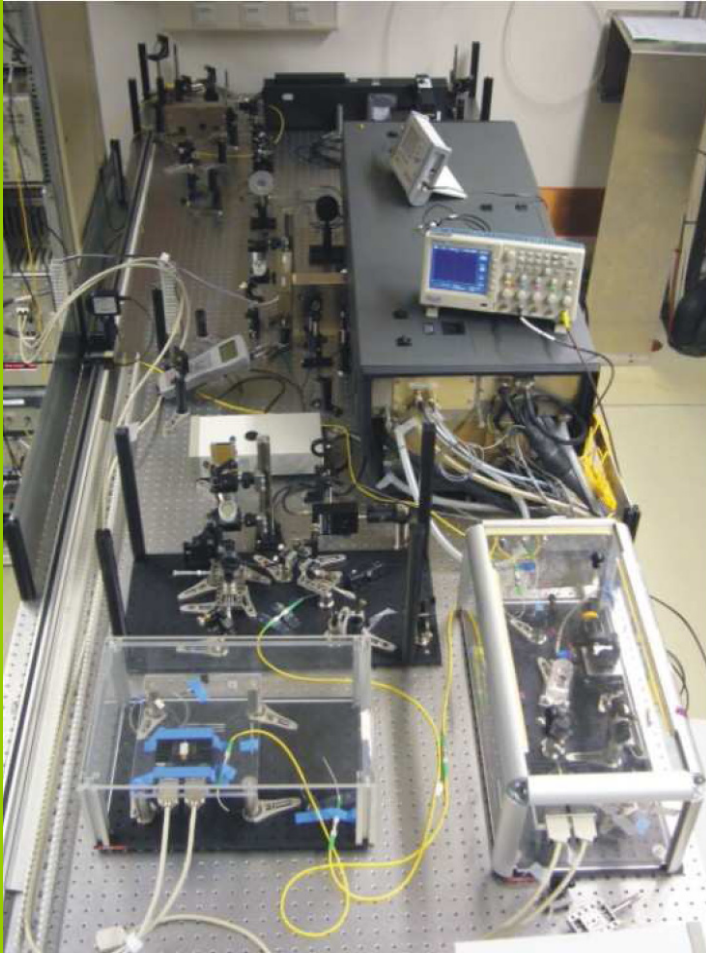
$\lambda=1550$ nm

Amplified and frequency doubled, 1 mW

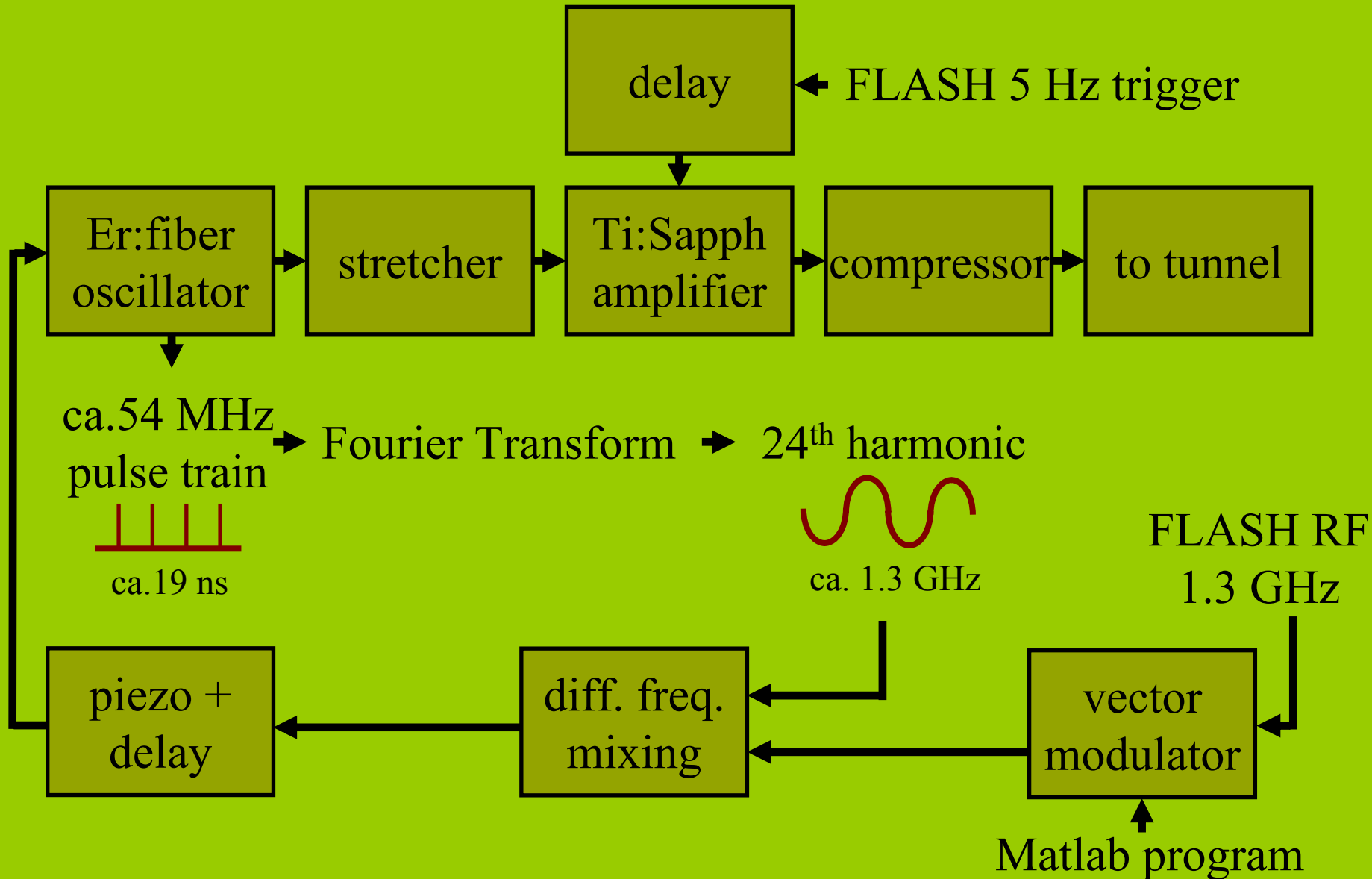
Commercial Ti:Sapph Amplifier:

Works according to CPA

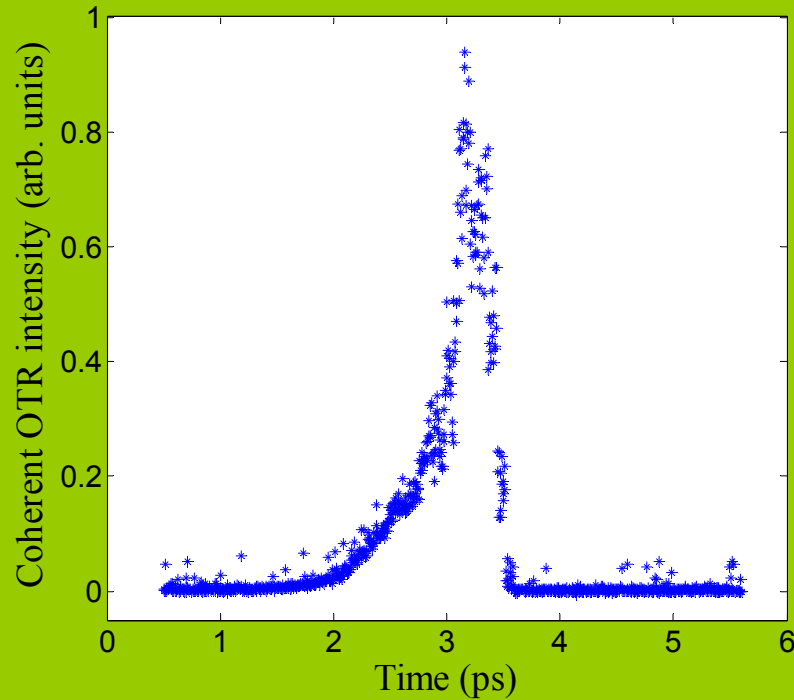
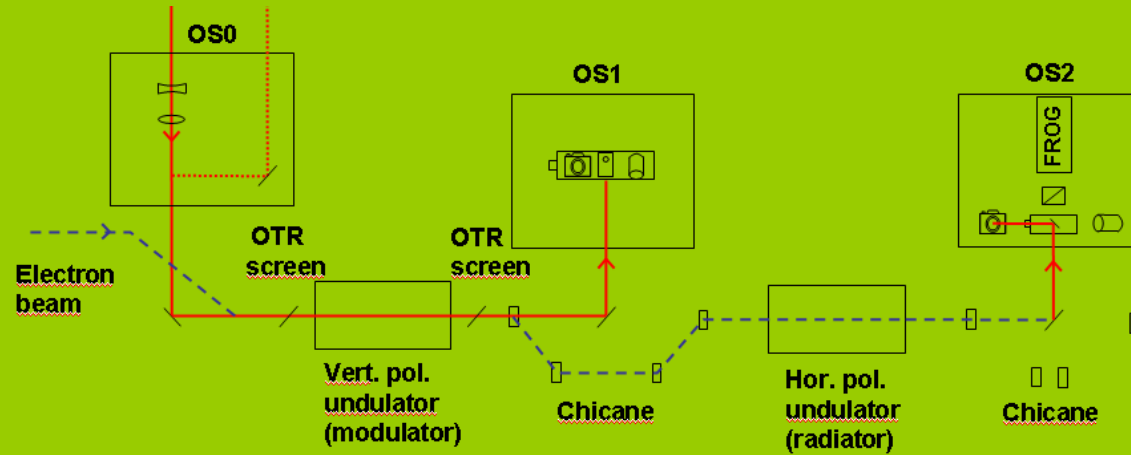
0.7 mJ/pulse at 775 nm, 0.2-3 ps



LASER-ELECTRON SYNCHRONIZATION



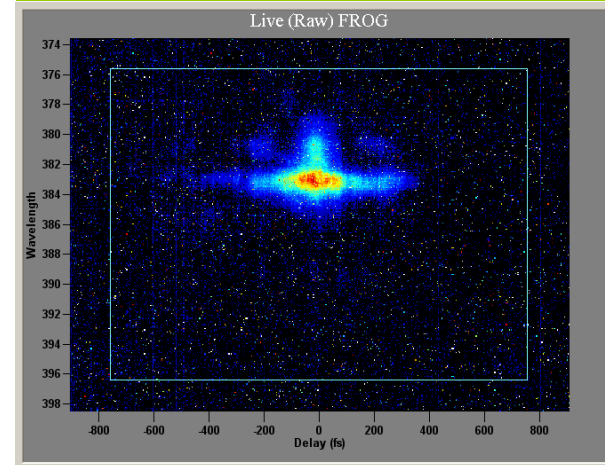
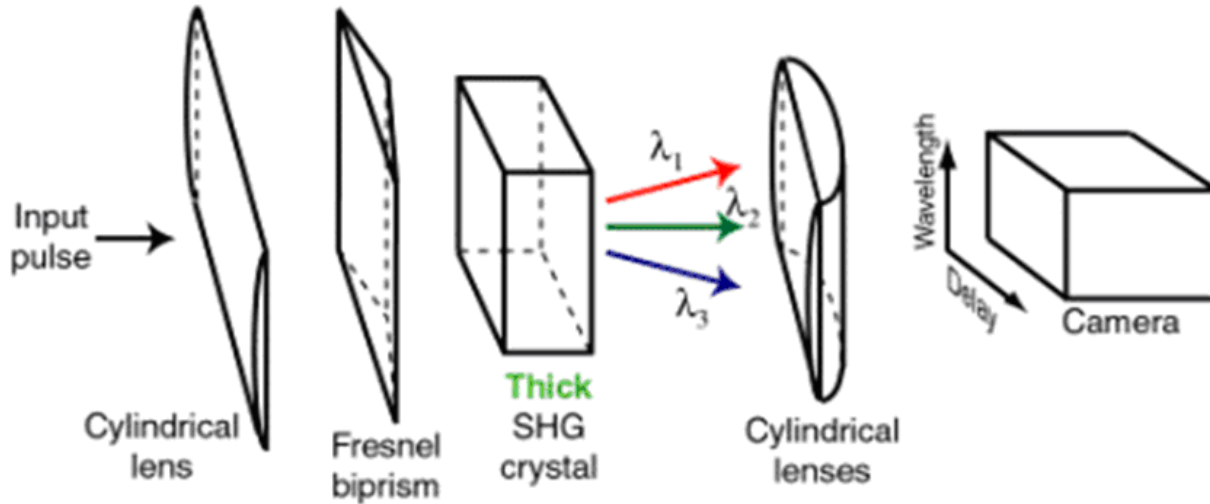
TEMPORAL OVERLAP SCAN



Overlap => microbunching => enhancement of coherent OTR

Longitudinal profile for electron pulse. Distorted by jitter of a few 100 fs.

GRENOUILLE



Based on FROG technique (autocorrelator + spectrometer)

2D phase retrieval algorithm => fully characterized pulse

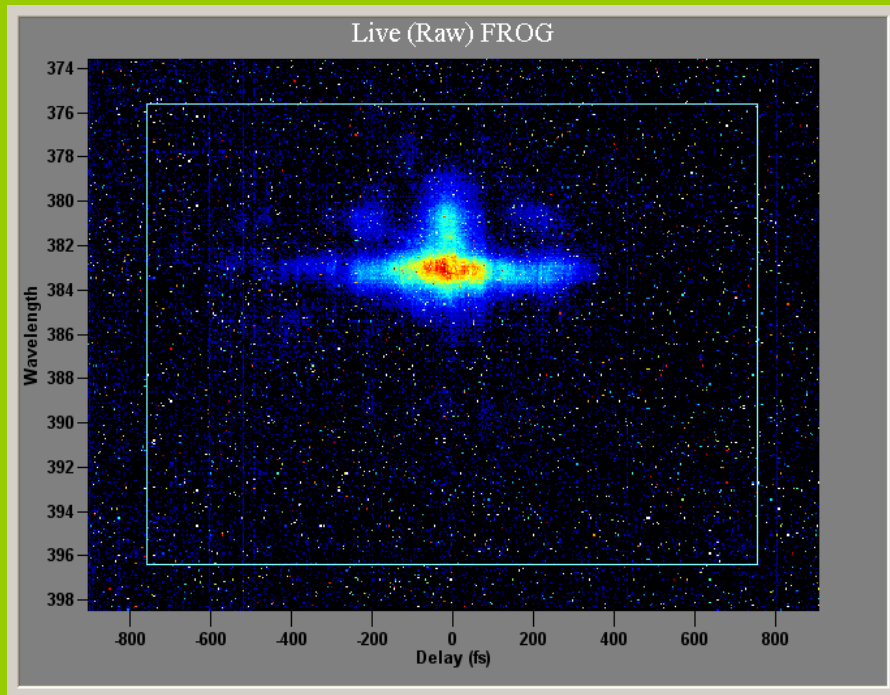
Electric field profile => electron bunch profile

Single shot measurement

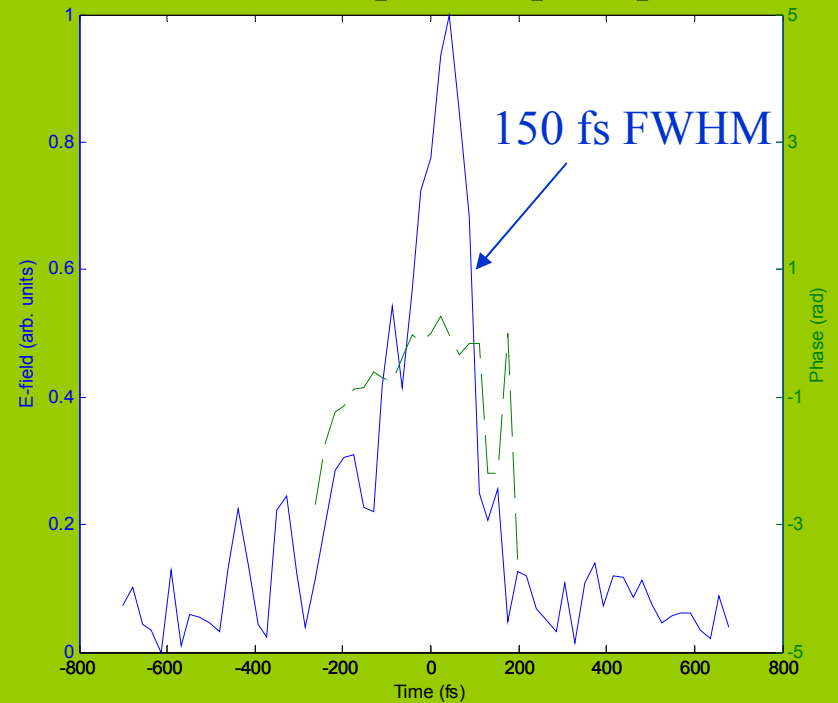
RESULTS

Short electron bunch, 400 fs laser pulse

FROG trace



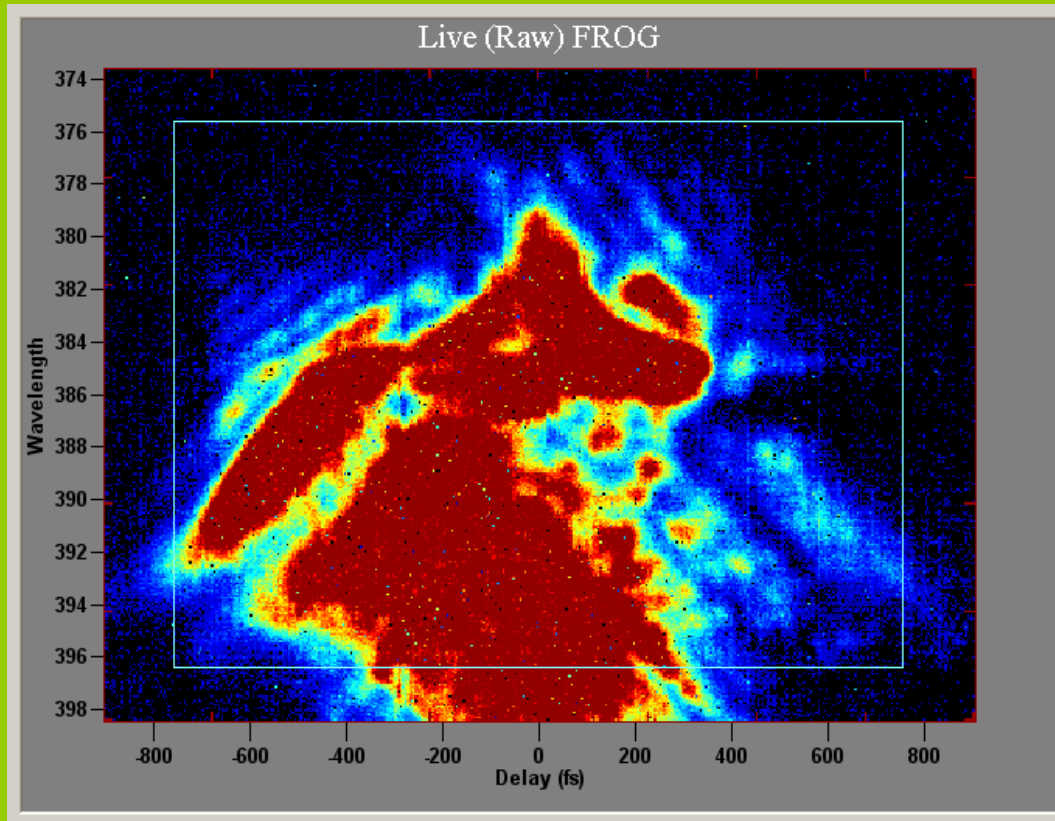
- Electron bunch profile
- Phase of optical replica pulse



Energy of optical replica pulse $\sim 5 \mu\text{J}$

Parasitic run of ORS while maintaining SASE operation

Further compression of electron bunch



Unexpected FROG
trace – not analyzable

Probably CSR from
chicane or undulators

REMAINING ISSUES

- Comparison with other method - check of accuracy
- 8-bit camera depth
- Tests to clarify origin of unexpected FROG trace at high compression
- Need higher laser intensity
- Rebuilding ORS for sFLASH

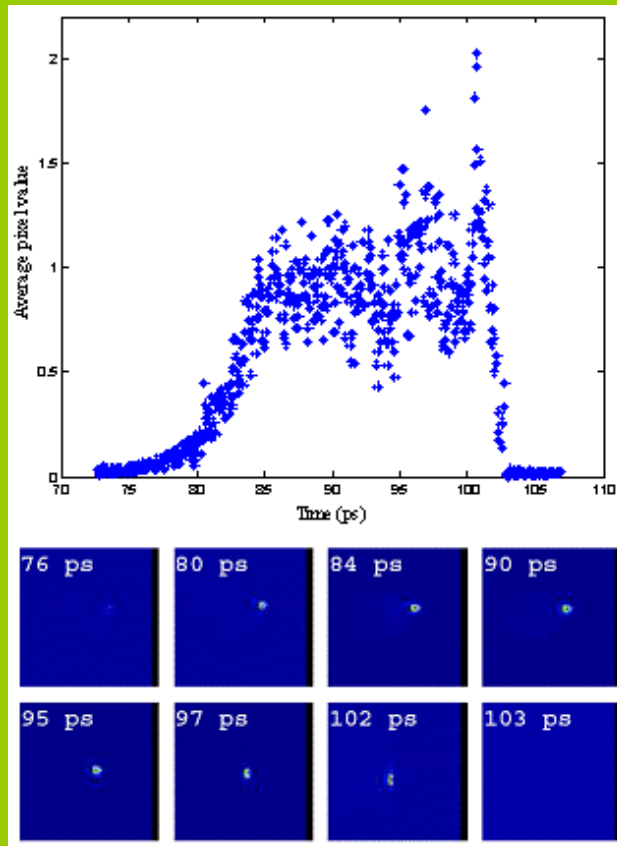
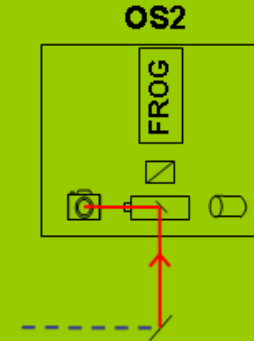
3D ELECTRON DENSITY DISTRIBUTION

ORS-setup without radiator or GRENOUILLE

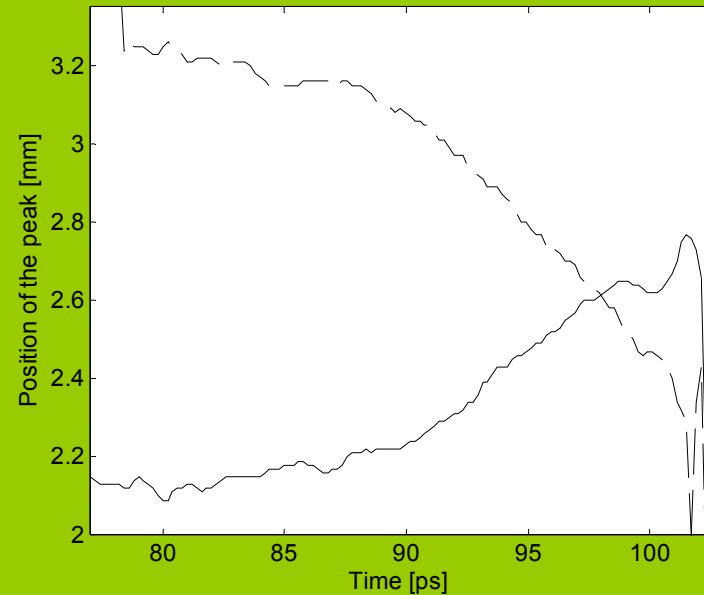
Image coherent OTR on camera.

Short (170 fs) laser pulse =>

2D images of transverse slices of electron bunch as a function of longitudinal coordinate



Horizontal (- -), vertical (-) position of spot



3D electron bunch profile for long bunches > ps

Also by coherent imaging of OTR

OTHER APPLICATIONS OF THE ORS

- Phase of optical replica \Rightarrow energy chirp of electron bunch
- 3D electron density distribution
- Slice energy spread
- Slice emittance
- 'echo' test experiments (G. Stupakov, SLAC-PUB-13445, Oct.2008)
- ORFIR

SUMMARY

- Spatial and temporal overlap between laser- and electron pulse
- Generated optical replica pulses and analyzed with FROG technique, bunch profile extracted
- Parasitic run of ORS while maintaining SASE operation
- 3D electron bunch profile measured on ps time scales and many other applications.

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