Progress of the Optical Replica Synthesizer Experiment

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The Idea

- Problem: measure ultra-short bunches in the 10s of fs range: EOS, TEO, LOLA, ORS
  - too fast for electronics (10 Gsamples/s --> 100 ps)
  - but laser folks know (autocorrelation, FROG)
- Solution: make an optical copy of the electron bunch and analyze that with laser methods.
The Seed Laser

- Er-fiber ring-oscillator (~1550 nm) phase locked to RF (micro-timing)
- Booster amplifier
- 2nd harmonic generation to 772 nm
- CPA 2001 regenerative amplifier on loan from Stockholm
- Pockels cell fire to let the light pulse out (macro-timing)
- 0.7 mJ/pulse, 200 fs
- Safety shutters (ND and other)
- Diagnostics: Frog, virtual waist
Scheme of the ORS synchronization & trigger system
Laser Transfer Line and OS0
The Undulators

- Electromagnets
- Designed and built by Scanditronix, Vislanda
- Period 20 cm
- 5+2 periods
- 4 power supplies per magnet
- Modulator=(V)eronica
- Radiator=(H)ilda

First Field Integral $[Tm]$ over distance $[m]$
Optical Station 1

Essential for timing: Laser + Synchrotron radiation

Pwr meter

Mirror 1, motorized
Mirror 2, motorized

λ/2 mot. rot. stage

Lens (PLCX 50.8-77.3 UV)

Polarizer

10 GHz(Ga-As) 5 GHz(silicon) l”Silver mirror” Silver mirror

Photodiode Photodiode

Basler Camera

080603 V. Ziemann: ORS FLASH-seminar
Optical Station 2

- e\(^{-}\) (C)OTR when hitting the screen
- Synchrotron light from HILDA
- Replica pulse from HILDA
- Power of the light

Grenouille Optical Station 2
8-50USB/8-500USB Fire wire

Iris

GL Polarizer

\(\lambda/2\) plate motor rot. stage

Mirror 1, motorized

Mirror 2, motorized

Mirror 3 motorized

Basler Camera (big objective)

Basler Camera

\(\lambda/2\) plate

Polarizer

BG39 motorized

ND filter 1.5 NOT motorized

ND filter 1.5

Lens (f=150)

Lens (f=100)

Lens (f=200)

Lens (f=50)

Lens (f=100)

Rotation wheel

ND

8-50USB/8-500USB Fire wire

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**GRENOUILLE**

- *Cylindrical lens* makes horizontal strip
- *Fresnel biprism* creates crossing wavefronts in thick *SHG crystal* → auto-correlator
- Effective thickness of SHG crystal varies with viewing angle → Spectrally resolved

- Second double cylindrical lens images onto camera
- Horizontally → time
- Vertically → spectrum
- Possible to reconstruct electric field profile in software from R. Trebino's book on FROG.
Experiments: A day in BKR...

- Start out with e- (preferably compressed nowadays) to beam dump or tuneup dump
- Flatten orbit in 'our section' with undulators off
  - BPMs < 0.1 mm and small steering magnet excitations
Transverse Overlap
Rough temporal Overlap

- Turn on Veronica+Chicane
- Remote 1 GHz scope
- Photo diode on OS1

- Detect signal from
  - attenuated seed laser
  - spontaneous synchrotron radiation from VERONICA

- on photo diode
- good to ≈ 100s ps
- move relative timing with the phase shifter
Problem with Seed laser leakage

- Bunching also causes radiation at higher harmonics
- Insert BG39 filter before camera
With Seed laser filtered

- OTR at 2nd harmonic
- Radiator OFF
- Need signal that identifies overlap
- Use average pixel value in *Region of interest*
After some scanning...
CTR on screen 1SEED while passing a 200 fs laser pulse through an electron bunch
Tune Radiator to 2\textsuperscript{nd} harmonic

- Harmonic Generation
- Tune away from resonance and signal goes down
- Also scanned chicane and found optimum but that varies daily.
Comparison with LOLA

- Simultaneous (almost, 30 min) measurement of bunch profile with transversely deflecting cavity LOLA (blue) and ORS (black).

- Initially the time calibration of LOLA was off by 20 %, now fixed.

- OD2 Neutral density filter before the Basler camera to prevent saturation

- smoothing and sqrt(ORS)

- Very good agreement of the recorded bunch length

- Some saturation of LOLA?
Testing the GRENOUILLE on OS2

- Send seed laser (400 fs) all the way to OS2
- and pass it to the GRENOUILLE
  - observe on spatial camera and on temporal camera
  - and observe autocorrelation and FROG trace
Trying to really make replicas

- Short compressed electron bunch (off-crest)
- Short laser, FWHM=400 fs
- Transverse an longitudinal overlap (works, even when both electrons and laser are short!)
- Put laser on top of electrons
Still trying...

- OS2: HILDA radiation on iris before the GRENOUILLE
- and on the spatial (alignment) camera inside the GRENOUILLE
...and on the FROG camera

- too little signal
- and a glitch in the power grid killed the rest of shift
- that's what we had after the easter shifts, we were close...
...and this is how it went last week

- It started the way it ended: with a power glitch on the friday before the week with our shifts
  - this knocked out a lot of stuff on the optical stations
  - dead power supply
- but we got it fixed up to and during the half-shift on monday (26.5) and the access on tuesday
- so we could start for real on the 12 hrs shift on wednesday.
Setup on Wednesday and ...

- Standard setup with
  - flat orbit and transverse overlap
  - longitudinal overlap (after restarting a DAC of the vector modulator in the timing system)
- Compressed bunches
- HILDA on and a lot of tuning (thanks Dirk)
The first FROG trace

Spend a lot of time improving the signal intensity
Online VideoFROG software

Averaging
TBP too small
Intensity
FROG plus Undulator

- Good transmission through SASE undulators with bumps around OS1 and OS2 and observing FROGs simultaneously.

But very restricted range of SASE tuning knobs available
Current Limitations

- Could find FROG traces during three shifts
  - but with short laser pulse
  - and they were weak
- Need more intensity to permit lengthening the laser pulse to cover larger fraction of the bunch.
- Current GRENOUILLE is for 5 ps and operationally convenient but the pulse is too short
  - replace by 500 fs GRENOUILLE (has only one camera)
- Alignment sensitivity on OS2
Future Plans

- Improve optics on OS2
- Replace GRENOUILLE (is available)
- ORFIR: use ORS to µbunch slice of beam and FIR undulator to radiate 200 fs pulses
  - synchronized 780 nm pulse
  - for pump-probe experiments
  - Simple test once ORS is set up
Conclusions

- We found FROG traces repeatedly 700+900 MeV
  - but with short laser and too weak
  - Have ideas to improve situation

- Comparing with LOLA works well (and found bug)

- New experiment
  - Use ORS in combination with FIR undulator

- Is it crazy to suggest using the HHG laser (much more powerful) to use for sFLASH ORS?
  - HHG would get timing setup for fundamental