Optical Replica Synthesizer
Experimental Shifts

The ORS Collaboration
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Overview

• Where did all the hours go?
  – things that go bump in the night
  – and making lots of ZZs
• Making transverse overlap
• And longitudinal overlap
• When all components worked simultaneously...
• Plans for next time
Undulators

- Worked almost out-of-the-box
  - did not affect SASE operation
- a little out-of-plane steering
  - just center the beam properly on-axis
Undulator control

- Calculate needed magnetic field for resonance
- Setting cycle or just incremental changes
  - uses the tables from Gergana's field measurements
- Turn them off (Cycle to Zero) → transparent
Chicane

- Chicane only well-closed for small excitations
  - extra windings and longitudinal movement
  - imbalance between steerers when excited > 1 A
Optical station alignment

- Spent a lot of time on getting a properly focussed picture of the screens on the cameras both on optical station 1 and on optical station 2.
- Took a lot more time than anticipated
- Three optical stations
  - OS0 with the telescope
  - OS1 with seed laser extraction, camera, diodes, power meter
  - OS2 with Grenouille, camera, power meter
Alignment of the OTR pots

- The OTR chamber in OS1 and 2 were not aligned on the beam axis (off by up to 8 mm both horizontally and vertically)
  - Found out by driving local bumps and looking at downstream screens until we scraped on the OTR frames.
Laser alignment

- The alignment of the entire seed-laser transport system took several iterations after improvements
- Remotely controlled
- Weirdly mounted mirrors
- Got faster in the end

Laser is reflected or hits edge of a mirror somewhere on its long way from the laser table to the screen immediately upstream of modulator (23.9)
Laserbeam walkabout

- Alignment laser into tunnel and back into laser hut onto table.
- Observe spot on camera
- Initially large amplitude (mm rms) wandering
- Fixed by
  - mechanical support under the telescope
  - windows to 'plug the hole'
0.2 mm after fixing

- Focussed beam on laser table in laser hut.
- Alignment laser and CPA beam wander now around 0.2 mm.
- CPA a little worse, we'll investigate
- Should be similar near waist inside modulator.
Other stories to tell

- Mode lock of oscillator took a while
- RF lock worked rather quickly (Florian and Axel)
- Broken amplifier diode laser (Thorlabs driver fried the Peltier element)
- Broken optical fiber (Florian and Axel)
- Interlocks
  - personal protection in laser hut
  - machine protection
  - personal protection in experimental hall
; >( Bloopers (<:

- Initially the polarization of the laser and the electron beam in the modulator were orthogonal to each other.
- We planned to use the last pole of the radiator as the first part of the three-bump to steer around the replica extraction screen on OS2.
  - but by construction the magnet always had \( \int B \, dl = 0 \) because the flux always returns through the other poles.
  - had extra steerer H4SUND3 installed.
Start out with flat orbit

- Within 0.1 mm and weak steerers
- Use 3/6MATCH to take out incoming orbit
Transverse Overlap

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V. Ziemann: ORS Experiments
Rough temporal Overlap

- Remote 1 GHz scope
- Photo diode on OS1

- Signal from
  - attenuated seed laser
  - spontaneous synchrotron
  - radiation
- on photo diode
- good to $\approx 100\text{s ps}$
- move relative timing with the phase shifter
The Seed Laser

- Fiber-ring-oscillator is phase locked to RF (micro-timing)
- CPA is a regenerative amplifier
- Pockels cell fire to let the light pulse out (macro-timing)
- 1 mJ/pulse, 200 fs
Scheme of the ORS synchronization & trigger system

Machine trigger

Timer
Steps 111ns
TTL
CH N2
Delay
Steps 0.5ns
CH 01
Pockels cell trigger
of amplifier

Phase detector

ET-3500 F
BF 1.3 GHz
ZFM 2000
ZRL 1150 LN+
Arra 3193-30
30 dB

Mini
1.9 MHz
15542
LO + 7dBm
IF 1250mV
Monitor
30dBm

Vector modulator
Phase shifter

Digital controller

ADC
Giga-link
DSP
Giga-link
DAC

CH 01
CH 05
DAC
DAC

Piezo driver

PZT

LO 1.3GHz

H. Schlarb
Problem with Seed laser leakage

- Bunching also causes radiation at higher harmonics
- Insert 700nm filter
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...

It's femto-slicing, right?
CTR on screen 1SEED while passing a 200 fs laser pulse through an electron bunch
Every third frame
with the incoherent spot computer-graphically removed, saturation at center.
Position and Width of the 'Spot'

- Clear indication of the centroid moving transversely
- Width dubious
  - generation process
  - difficult to measure in noisy saturated backg.
Horizontal and vertical

- as I said: dubious
Tune Radiator to $2^{nd}$ harmonic

- Harmonic Generation
- Tune away from resonance and signal goes down
Scanning the chicane excitation

- There is a maximum bunching
- between 1.7 and 2.0 A
Coherent synchrotron radiation

- Maximum, when max overlap
- Likely from the last chicane magnet
- Only on second night, when the alignment of mirrors on optical station 2 had changed.
- Everything lights up once overlap is achieved, had to choke laser
We're not done yet

- and applied for more shifts in January and March
  - Systematic studies with short (200 fs) laser pulse
  - Scan radiator field through harmonics
  - Decode longitudinal centroid (wake-field tail)
  - Place laser on steep edge of ebeam → timing jitter
  - Recover overlap with short electron bunches and long (2 ps) laser beam
  - Make optical replica and observe it in GRENOUILLE
  - Emergence of CTR with increasing modulation
Conclusions

• We were extremely well-treated by all@DESY
• We got 15 shifts and could actually use them
• Made most of the hardware work simultaneously
• Developed the procedure to achieve overlap
  – Femto-slicing, sort of
  – Second harmonic generation
  – Longitudinal centroid bunch shape
• We'll be back (hopefully).
  – Systematic studies
  – Short bunches and long laser pulse
  – Replica pulse on to the Grenouille
Extra Slides
Alignment Laser on Wires

- As backup for 'laser-on-screen' we (mostly Holger) tested to get a signal from the alignment laser on the wire scanners
  - works
Electron Beam Alignment

Ziemann: ORS Experiment
Transverse Laser Alignment on Calibration Screens, 1st try
2nd try, focusing and alignment
Electrons, 2\textsuperscript{nd} try, 20:50

\textbf{7MATCH} - horizontal profile: $\sigma_x = 0.27 \text{ mm}$, center($x$) = 14.19 mm

\textbf{3SUND1} - horizontal profile: $\sigma_x = 1.52 \text{ mm}$, center($x$) = 12.89 mm

\textbf{7MATCH} - vertical profile: $\sigma_y = 0.16 \text{ mm}$, center($y$) = 9.54 mm

\textbf{3SUND1} - vertical profile: $\sigma_y = 1.42 \text{ mm}$, center($y$) = 8.61 mm