Coherent radiation diagnostics at FLASH

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Fundamentals of coherent radiation

source characteristics (CSR,CTR,CER,CDR,SP..)

\[
\frac{dU}{d\omega} = C \ N^2 \left| F_{\text{long}}(\omega) \right|^2 T(\omega, \gamma, r_b, \theta, \text{source})
\]

\[
F_{\text{long}}(\omega) = \int_{-\infty}^{\infty} \tilde{\rho}(t) \exp(-i\omega t) dt
\]

- integral intensity

'compression factor', effective bunch length

- spectrally resolved intensity

+ bunch structure, 'longitudinal fingerprint'
CR ports at FLASH

BC2 CDR port

BC2 CSR port feeding “TOSYLAB”

Beamline being ‘revised’
new optics, vacuum

Oliver Grimm

- 5-10 mm diffraction radiator
- cryst. quartz window
- two pyro detectors
- used for ‘compression feedback’
BC3 CDR port
- 5-10 mm diffraction radiator
- cryst. quartz window
- one pyro detectors
- at the moment saturated from single bunch

BC3 CSR port
Newly installed, not used so far

all stations are equipped with new fast and sensitive electronics with single bunch resolution
• diamond window
• full vacuum system
• radiation guided to outside tunnel
• used for instrumentation development

no radiator
What does it see?
The pyro crystal produces a surface charge
~ temperature change

Ideal: charge sensitive amplifiers

+ Best signal/noise
- pile up in 1. Stage prevents long pulse trains

integrating pulse shaping
(used in spectrometer)

- reduced signal/noise
- NO pile up
(now installed BC2/BC3)

Short time const amplification

100 ns
4 µs
Some pyros have “black coating” for improved absorption

- introduces ~ 25 µs timescale for part of the signal
- NOT advisable for fast shaping

The ringing phenomenon

- independent of type of electronics
- depends on size of crystal
- mechanical vibrations!
- (pyro crystals are piezo electric).

Measured at $\lambda = 1 \, \mu m$
Classical approach:

- Michelson-Type spectrometer (autocorrelation function)
- scanning device, no single shot capability
- aim to reconstruct longitudinal profile

Jan Menzel
Enrica Chiadroni TTF/FLASH
Lars Fröhlich

New approach:

- grating spectrometer (wavelength spectrum)
- multi-channel parallel readout
- single shot device
- aim to produce wavelength resolved fast feed-back signals ("fingerprint")

Hossein Delsim-Hashemi
BS
Wavelength range

Gauss bunch

\[ \lambda_{\text{max}} = \frac{\text{fwhm} \mu\text{m}}{2\sqrt{2\ln(2)}} \frac{\mu\text{m}}{\text{fs}} = 0.80 \text{fwhm} \frac{\mu\text{m}}{\text{fs}} \]

\[ \lambda_{\text{max}} = 56 \mu\text{m} \]

Simulations M. Dohlus

ACC1 phase: 8° - 9°

\[ (F(\lambda)/\lambda)^2 \]
Technical implications

diamond window

no humid air

Experimental data
**Gratings**

**Transmission gratings**
- larger usable spectral range
- limited to $\lambda > 20 \, \mu m$
- poor dispersion efficiency (~15%)
- broadband
- needs staging

**Reflective gratings**
- smaller free spectral range (< 1 octave)
- ANY $\lambda$
- high dispersion efficiency (> 90%)
multichannel detectors

Requirements:

- fast, 200 ns for XFEL bunch spacing
- uniform spectral response
- broadband (1 µm - 1mm)
- robust?

Recent development at DESY

Pyro-electric line detector from individual pyros
+ 30 channels
+ room temperature
+ no window, works in vacuum
+ fast read out
+ noise equivalent energy NEE : 60 pJ / pulse
+ smooth response function (suppressed resonances)
First spectra

Up to now: single stage device
• simultaneous wavelength range limited
• patching problematic, machine fluctuations & calibration

• single transmission grating
• during SASE conditions (5.10.06)

• single reflective grating
• during SASE conditions (20.8.06)

~ 20 fs fwhm
more spectra
spectra from different bunches in a train are different

ACC1 phase scan

Only this phase makes SASE

project
Structures ~ 20fs responsible for SASE?

Thanks Michael Röhrs
LOLA profiles

At SASE optics, LOLA resolution limited to ~ 70 - 80 fs.

Spike width ~ resolution

\[ \lambda \text{ cut-off} \sim 50 - 60 \mu m \]
Short wavelength signals and SASE - e

Averaged 10 shots

CR and SASE
.. the other day

There are non-trivial correlations
Summary

• broadband single shot spectroscopy is making progress
• still in experimental phase
• wavelength selected intensities will provide a fast ‘bunch shape fingerprint’

Next Steps

• establish multi-stage version with larger spectral coverage
• develop experimental set-up to compact ‘device’ (CBSS)
• check and establish relevance for SASE operation

More THz diagnostics to come

• equip CSR ports at BC3 and dogleg dipol (?) with “CBSS”
• IR undulator !