Microbunching Studies using IR Spectroscopy and TDS

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Overview

1 Motivation

2 Instrumentation

3 Measurements

4 Conclusion
Oncrest spectra:

- coherent radiation in spectral range of $\lambda = [3.3, 20] \, \mu m$
- intensity level in same order as from compressed bunches
- >1% of the electrons inside the bunch radiate coherently
- strong fluctuations of the oncrest spectrum

$E_0 = 700 \, \text{MeV}, \, Q = 0.5 \, \text{nC}$

→ nearly always present!
NIR CTR

Single shot (SASE conditions)

InGaAs spectrometer:
- extension of IR spectrum \((\lambda = [0.9, 1.7] \mu\text{m})\)
- average intensity decreases down to optical wavelengths
- single shot spectrum consists of extreme narrow and highly fluctuating spikes

→ OTR measurements should confirm coherent signals!
Observation in June ’08 showed first evidence of coherent signals in the optical regime.

Questions:
- reproduceable?
- special FLASH setting?
- location (longitudinal) in electron bunch?
Substructure inside the electron bunch, which is not related through the correlated energy spread and can radiates coherently via CTR, CRD or CSR.

Simple LSC model:

1. Transformation from energy to density modulation is given by R56.
2. Substructure length should be varied by changing R56.
3. Spectrum shape and intensity should be influenced.

Note:
- Both R56 are mandatory for detectable IR radiation.
- See FLASH talk (08-04-08).
IR spectrometer

Characteristics:

- staging of 2 dispersive reflective gratings
- radiation detection by 60 pyroelectric sensors (only coherent signals)
- single shot capability in 3 wavelength ranges
  i. 3.3 \( \mu \text{m} \) - 9 \( \mu \text{m} \)
  ii. 9 \( \mu \text{m} \) - 22 \( \mu \text{m} \)
  iii. 25 \( \mu \text{m} \) - 65 \( \mu \text{m} \)
- CTR off-axis screen served by TDS kicker
- port about 4 m upstream of TDS screen
- beam transport with THz beamline

see H. Delsim-Hashemi FLASH talk (08-03-04)
Port characteristic:

- deflection of single bunch by fast TDS kicker on screen
- imaging radiation by Basler monochrome camera
- 2 color filters (Schott glas BG39 / RG780) in filter wheel to resolve spectral content
Spectral response of camera × incoherent OTR intensity

Intensity variation in respect to camera gain

courtesy H. Schlarb
Plan

FLASH settings:
- $E_0 = 780$ MeV
- $\phi_{ACC1} = \phi_{ACC23} = \phi_{ACC456} = 0^\circ$
- $Q = 0.75$ nC ($\pm$ 1.3%)

Procedure:
0. set BC currents
1. readjust phases
2. focus on TDS screen
3. take TDS images
4. take IR spectra
IR spectrometer I

$I_{BC2}$ - variation:
→ no significant intensity variation except for $I_{BC2} = 64$ A
→ no drift of center wavelength

$I_{BC3}$ - variation:
→ increase of spectral intensity with R56
→ no shift of center wavelength
IR spectrometer II

**I\(_{\text{BC3}}\) - variation:**

\[ \lambda \in [3.4, 13.9] \, \mu\text{m} \]

\[ \langle |F|^{2} \rangle \propto 10^{-3} \]

\[ I_{\text{BC3}} = 62.5 \, \text{A} \]

\[ I_{\text{BC3}} = 64 \, \text{A} \]

**I\(_{\text{BC2}}\) - variation:**

\[ \lambda \in [3.4, 13.9] \, \mu\text{m} \]

\[ \langle |F|^{2} \rangle \propto 10^{-3} \]

\[ I_{\text{BC3}} = 60 \, \text{A} \]

Formfactor:

\[ |F|^{2} = N^{-2} \cdot \left( \frac{dU}{d\lambda} \right)_{\text{incoh.}}^{-1} \cdot \frac{dU}{d\lambda} \rightarrow \text{averaging F over} \]

\[ \lambda = [3.4, 13.9] \, \mu\text{m} \]

Results:

- increasing BC3 current \( < F > \) increases up to saturation (factor of 4!)
- increasing BC2 current \( < F > \) no significant effect
OTR images I

Videos
Σ ROI intensity:

→ intensity increases with decreasing BC3 current for all filters!

→ low BC2 current offers highest intensity in red regime

Note: problems with saturation at oncrest phases!
OTR spectra III

Σ ROI fluctuation:

→ rel. fluctuations 1% to 2% for BG39
→ about 3% up to 4% for RG780 filter
→ low current □ setting shows maximum fluctuations

Note:
charge is stable around 1.3%
RG780 filter images at high current show weak intensity
Intensity ratios:

→ for decreasing BC3 current pronunciation in the red regime is significant

→ comparison between TDS on - off reasonable
Conclusions

I. Coherent transition radiation signals reaches form the infrared into the optical wavelength regime!

II. Spectra and TDS images show rapid fluctuating structure!

III. R56 dependency
   - **IR**: increasing intensity for increasing $R56_{BC3}$
     - no obvious $R56_{BC3}$ dependency
   - **O**: increasing intensity for decreasing $R56_{BC3}$
     - both $R56$ at minimum value create maximum intensity
     - more intensified signal in the red spectral part

IV. Problem of the determination of incoherent OTR!

V. Problem with camera saturation occurs!