Status of the Electron Beam Transverse Diagnostics with Optical Diffraction Radiation at FLASH

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Diffraction Radiation Theory

- DR is produced by the interaction between the EM fields of the traveling charge and the conducting screen.

- The radiation intensity is

\[ I \propto e^{-\frac{2\pi a}{\gamma \lambda}} \]

- DR impact parameter is

\[ \frac{\gamma \lambda}{2\pi} \]

- Excellent candidate to measure beam parameters parasitically

\[ \begin{align*}
& \gg \frac{\gamma \lambda}{2\pi} \\
& \equiv \frac{\gamma \lambda}{2\pi} \\
& \ll \frac{\gamma \lambda}{2\pi}
\end{align*} \]

- No radiation
- DR
- TR
Diffraction Radiation Diagnostics

- Low $\gamma$, $\lambda$ of the order of $mm$ $\rightarrow$ Coherent Diffraction Radiation
  $\rightarrow$ Longitudinal diagnostics*


- Large $\gamma$ of the order of $10^3$ $\rightarrow$ Optical Diffraction Radiation
  $\rightarrow$ Transverse diagnostics**
  - Position
  - Angular divergence
  - Transverse dimensions
  - Emittance

Beam Transverse Diagnostics with ODR

ODR angular distribution gives information on the transverse beam size: increasing $\sigma_y$ both the peak intensity and the central minimum increase.
FLASH is a good test facility for several reasons:

- High energy, up to 1 GeV
- Up to 30 bunches per macropulse
- Repetition rate 5 Hz
Optical System

- Interferential filter at 800 nm
- Interferential filter at 450 nm
- Lens with \( f=500\ mm \) for DR angular distribution
- Lens with \( f=250\ mm \) for beam imaging
- Glenn-Thompson polarizer
- Hamamatsu CCD camera

High Sensitivity Hamamatsu Camera
- High quantum efficiency
- Air Cooling -55° C
- Long exposure time up to 2 hours
Experimental Setup

- Mirror
- Lenses actuator
- Interferential filters
- Polarizer
- Camera holder
Acquisition System

- The optical system is controlled by electronic box placed in the tunnel.

- This is a quasi-standard FLASH electronic box, using can-bus modules, partially integrated in linac control system.

- The more accurate stepper motors for the target and the camera position, as well as the camera, are controlled via Firewire by industrial PC.
Improvements in the Setup: OTR57BYP

Old screen and holder

New holder housing two screens in order to have a target for tests
October 2006
Improvements in the Setup: OTR35BYP

A screen with a hole has been installed at the OTR35BYP to be used both as alignment tool and as background stopper during measurements.
ENERGY: $\approx 680$ MeV

- **January 12th, 2007**
  - Alignment without beam
  - First OTR measurements

- **January 14th, 2007**
  - Beam optimization up and through the bypass
  - Few measurements with 1 mm slit in

- **January 15th, 2007**
  - First measurements with 0.5 mm slit in
  - Several scans within the whole slit in order to see the transition between ODR and OTR
  - Few measurements with a smaller beam
Critical Issues

- Not optimized optics in the by-pass
  ➔ Optimization of the beam transport:
    Low charge, High # of bunches

- Synchrotron radiation background coming from the dipole and quads and multiple reflections in the vacuum pipe

- Strange behavior of this background

- The background must then be subtracted playing with the steerers
  ➔ Severe X-rays background which does not allow to integrate over a long time
The Beam

Charge: 0.7 nC
Exposure Time: 0.8 s
2 pulses

rms beam size = 3.65644 pixel = 83 µm

Data: Data1_H
Model: GaussAmp

\[ \text{Chi}^2/\text{DoF} = 3241.56197 \]
\[ R^2 = 0.959 \]
\[ y_0 = 1936.73382 \pm 2.5681 \]
\[ xc = 234.26423 \pm 0.04808 \]
\[ w = 3.65644 \pm 0.04778 \]
\[ A = 2467.09022 \pm 27.88526 \]
OTR Angular Distribution

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From OTR to ODR

Beam transport optimization:
- 0.7 nC
- 25 bunches
- 1 s exposure time

Optics optimization:
- 800 nm interferential filter in
- polarizer in

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ODR Evidences (1)

Beam transport optimization
- 0.7 nC
- 25 bunches
- 2 s exposure time
- $E_{beam} = 680 \text{ MeV}$
- 800 nm filter and polarizer in

After background subtraction and X-rays cleaning
ODR Evidences (2)

Simulation parameters:
- $a = 0.5 \, mm$
- $\sigma_y = 73 \, \mu m$
- $\sigma'_y = 30 \, \mu rad$
- Both the angular divergence and the beam are assumed to be Gaussian distributed
Conclusions

- The ODR experiment at FLASH is in progress
- The background is a severe limitation for the detailed reconstruction of the beam parameters from the ODR angular distribution
- To reduce its influence we are mounting a new thin shield just in front of the target

BUT...

- The off-line software tool developed to filter x-ray and subtract the background has allowed an interesting analysis
- A qualitative good agreement is evident between measurements and simulations
Outlook

Beginning of 2008

*Measurement shifts*

- 1 GeV electron beam energy

- Reduction of the background thanks to a shield, mounted at 45° with respect to the screen, and to the new holder which is machined such that reflections are reduced.

- Better shielding of the CCD camera thanks to a custom design from Maike Siemens and Silke Vilnius.
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