A Transverse Profile Imager for SwissFEL
Rasmus Ischebeck
Transverse Profile Monitors
Profile Measurement in FELs
Profile Measurement in FELs
x–y Correlations

> Intrinsic correlation

> Explicit x–y dependency introduced by RF deflector
2-Dimensional Profile Monitors

> Optical transition radiation (OTR)

> Scintillation
Imaging Scintillators

a)  
b)  
c)  
d)  
e)  
Electron Beam Profile Monitors
Scintillators, OTR Screens & Wire Scanners

- Alignment hole and calibration scale
- Wire scanner
- Fluorescent crystal (Ce:LuAG)
- OTR screen (Al-coated Si wafer)
- RF shield

High Energy Screen

Low Energy Screen

Installed scintillators
- Ce:YAG
  - 5 µm
  - 20 µm
  - 200 µm
- Ce:LuAG
  - 200 µm
Electron Beam Profile Monitors
Scintillators, OTR Screens & Wire Scanners

Installed scintillators
- Ce:YAG
  - 5 µm
  - 20 µm
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Electron Beam Profile Monitors
Visual Light Optics

- OTR screen / scintillator is at an angle of 45° to the optical axis
- For overview camera (1:5.3 demagnification)
  - Use Scheimpflug criterion to correct image plane orientation
- For 1:1 imaging
  - Perspective control lens is not available commercially
  - Only central part (~1...2 mm) of the screen can be imaged within depth of field

Projected pixel size: 23 µm
Scheimpflug Snell Screen Monitor

> Theodor Scheimpflug (1865—1911)

> Willebrord Snellius (1580—1626)
Imaging Scintillating Crystals

observer

scintillating crystal

virtual image

primary beam

$\alpha$

$s$

$\beta$

$d$
Imaging Scintillating Crystals

Scintillating crystal

Primary beam

\[ \alpha \]

\[ \beta \]

\[ \beta' \]

\[ s \]

\[ s' \]

\[ \ell \]

\[ d \]
Imaging Scintillating Crystals

observer

scintillating crystal

primary beam

virtual image

s

β

α

d
\[ \beta_{\text{ideal}} = -\arcsin(n \sin \alpha) \]

- **Ideal Observation Angle**
- **Primary Beam**
- **Virtual Image Aligned with Beam Axis**
- **Scintillating Crystal**

\( \alpha \)
\[
\frac{\sin \beta}{n} = \sin \beta' \\
\ell := \overline{AB} = \frac{d}{\cos \beta'} \\
s' := \overline{BC} = \frac{s}{\cos \beta} \\
s'^2 = \ell^2 + \left( \frac{d}{\cos \alpha} \right)^2 - 2\ell \frac{d}{\cos \alpha} \cos(\alpha + \beta') \\
s = d \cos \beta \cdot \sqrt{\frac{1}{1 - \frac{\sin^2 \beta}{n^2}} + \frac{1}{\cos^2 \alpha} - 2 \cos \left( \arcsin \left( \frac{\sin \beta}{n} \right) + \alpha \right)} \sqrt{1 - \frac{\sin^2 \beta}{n^2} \cos \alpha}
\]
Observed Beam Size

apparent transverse size \( s / \mu m \)

observation angle \( \beta / \text{degrees} \)
Ideal Observation Angle

a)

b)
Screen Monitor
The smallest beam in this measurement is 50 μm rms. Beams of 10 μm rms have been measured.
Measurements with the Prototype

Slice emittance measurement of a 10 pC beam
Measurements with the Prototype

> Slice emittance measurement of a 1.3 pC beam
Thank You to...

> Hansueli for the technical design
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