THEORETICAL AND EXPERIMENTAL INVESTIGATION ON RESOLUTION OF OPTICAL TRANSITION RADIATION TRANSVERSE BEAM PROFILE MONITOR.

A. Aryshev, M. Shevelev, N. Terunuma, J. Urakawa
KEK ATF
S. Boogert, P. Karataev, K. Kruchinin, L. Nevay
JAI at RHUL
T. Lefevre, E. Bravin, B. Bolzon
CERN CTF3

alar@post.kek.jp

Outline

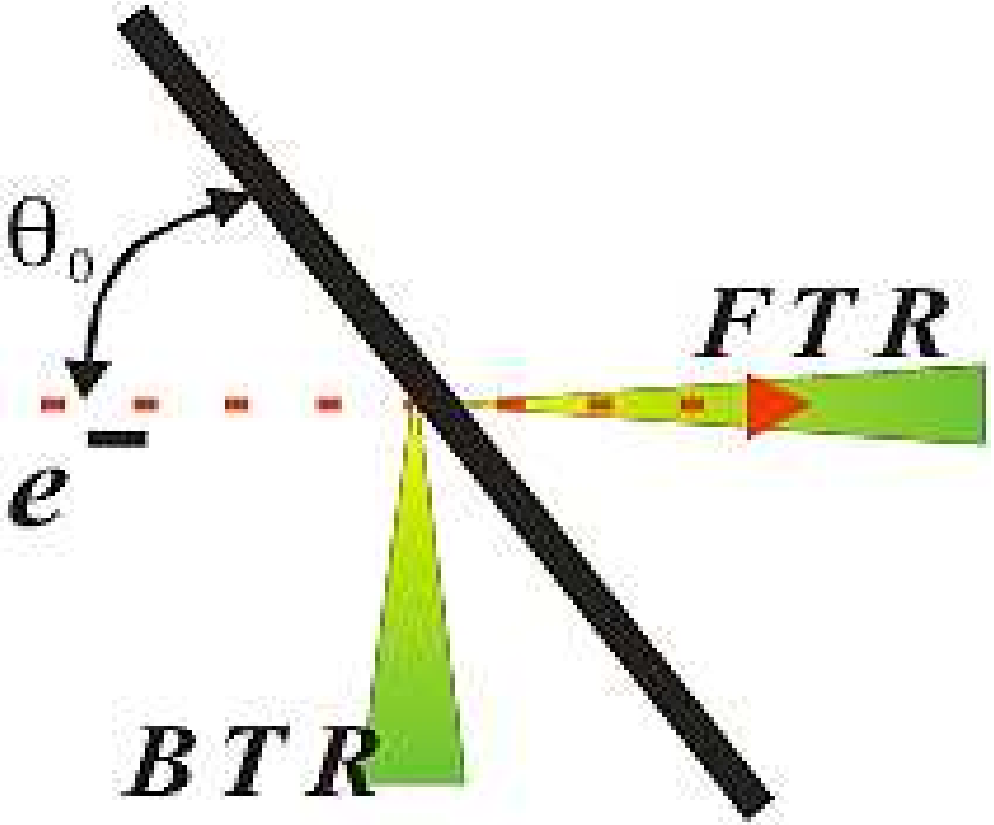
- ATF OTR project milestones
- Very brief introduction
  - More information available @ past ATF2 project meetings, IPACs, IBICs and upon request.
- High resolution OTR: basic concept and possible ways to improve resolution
- Experimental setup
- Recent progress (Spring 2013)
- Future improvements and prospects
- Summary

Milestones

- **Initial setup: spring 2009**
  - A.Aryshev, P. Karataev, et. al., Journal of Physics: Conference Series 236 (2010) 012008.
- **Observation of OTR PSF: end of 2009**
  - P. Karataev , A.Aryshev, et. al., PRL 107, 174801 (2011)
- **e-optics verification, monitor start-up: end of 2009 – 2011**
  - A. Aryshev, P. Karataev, et. al., IPAC'10, Kyoto, Japan, MOPEA053
  - A. Aryshev, P. Karataev, et. al., IPAC'11, San-Sebastian, Spain,WEOBB01
  - A. Aryshev, P. Karataev, et. al., RREPS'11, 12 – 16 September 2011, Royal Holloway University of London, Egham, United Kingdom
- Relocation of EXT LW, OTR re-commissioning: 2011 - 2012
- ZEMAX modeling of the OTR optical system: 2011 – present
- Routine EXT LW cross-check: 2011 – 2013
- OTR optics experimental study: 2013
- Reflective optics trial: 2013
- Analysis upgrade: 2013
- Chromatic aberration study: 2013

} Will be published in IOP: Journal of Instrumentation

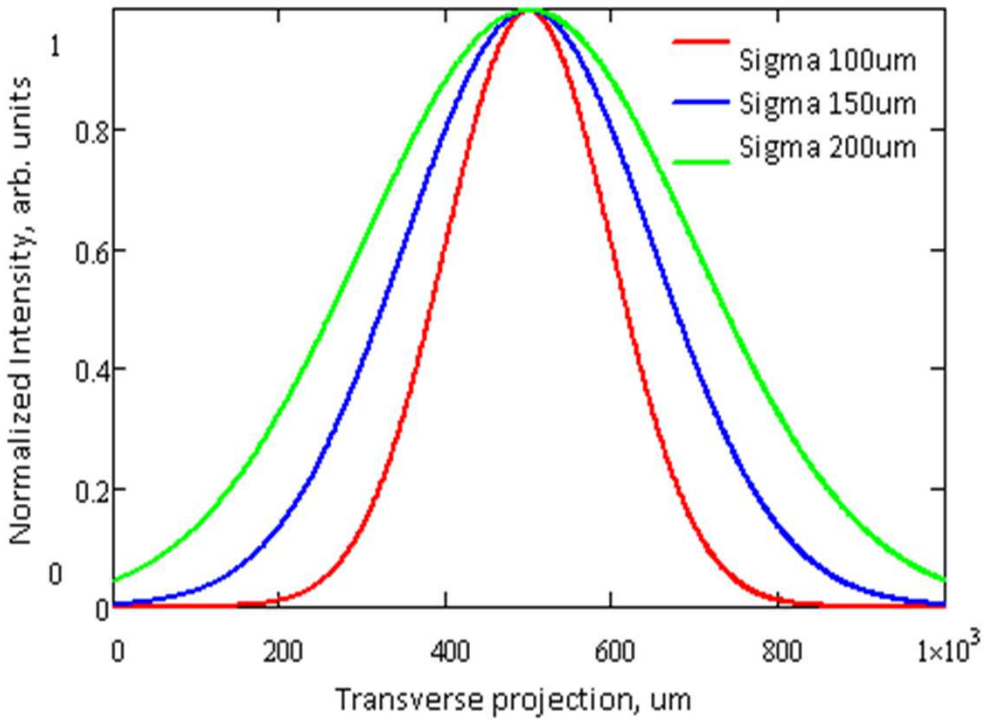
OTR single particle image



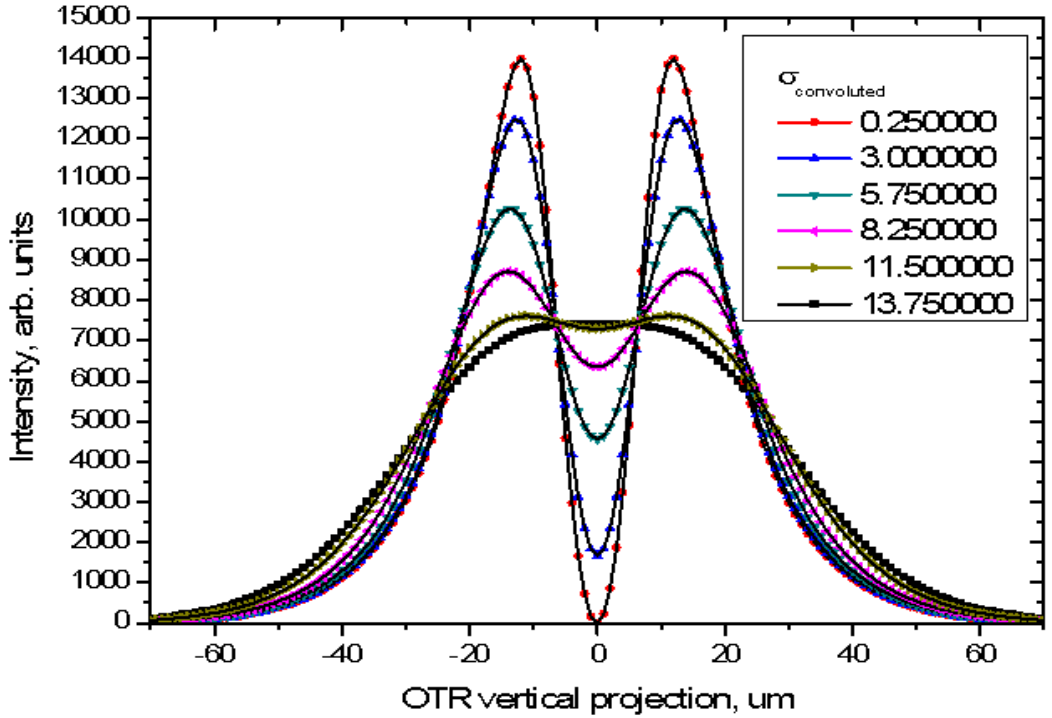
- Transition radiation (TR) appears when a charged particle crosses a boundary between two media with different dielectric constants.
- The resolution is determined by the source dimensions induced by a single particle plus distortion caused by the optical system (diffraction of OTR tails)
- M. Castellano and V. A. Verzilov, PRST-AB **1**, 062801 (1998)
- P. Karataev et al. NIMB 227 (2005) 198–208

Beam size effect on OTR

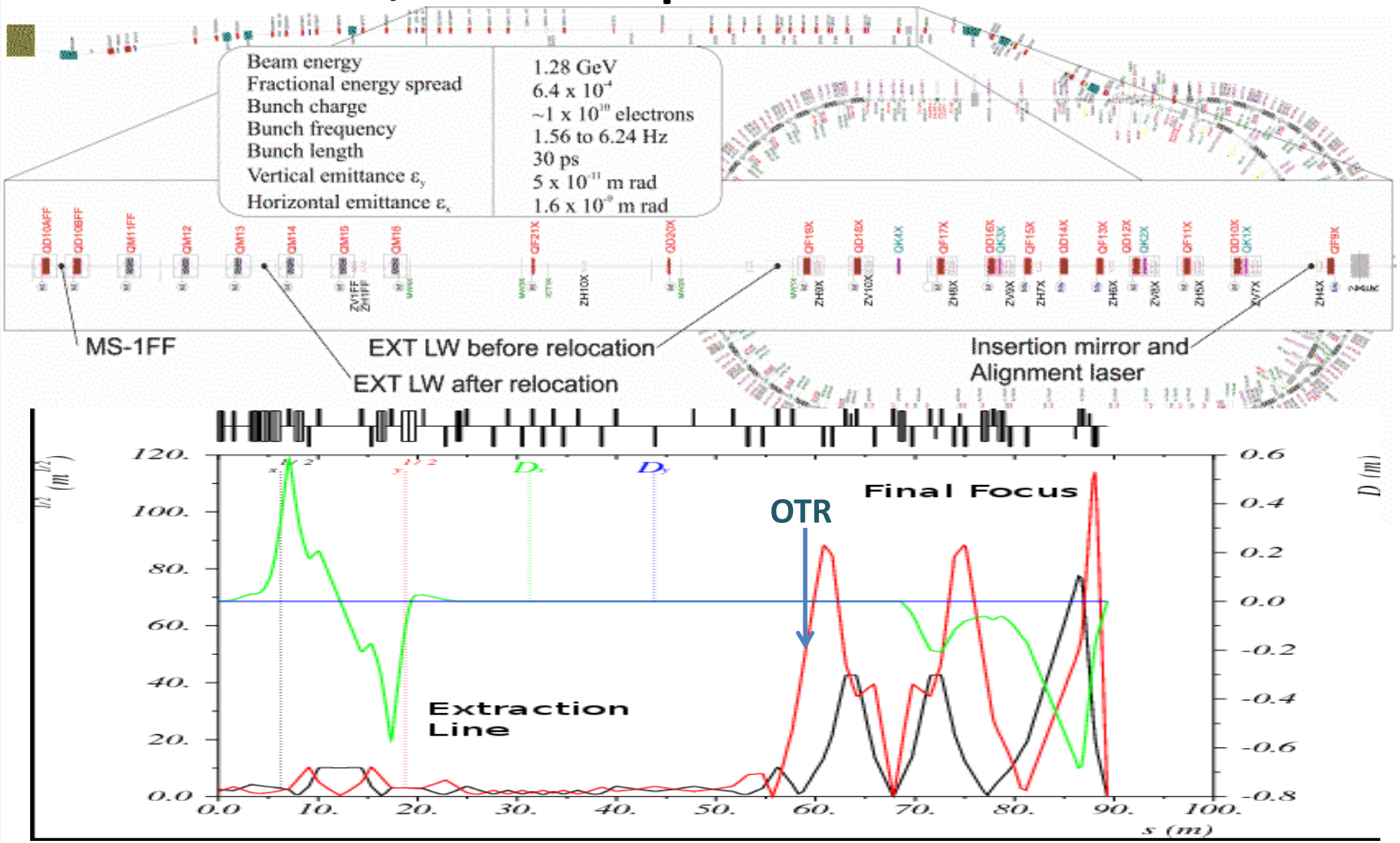
"Usual" OTR image



OTR vertical polarization component, for sigma < ~15 um



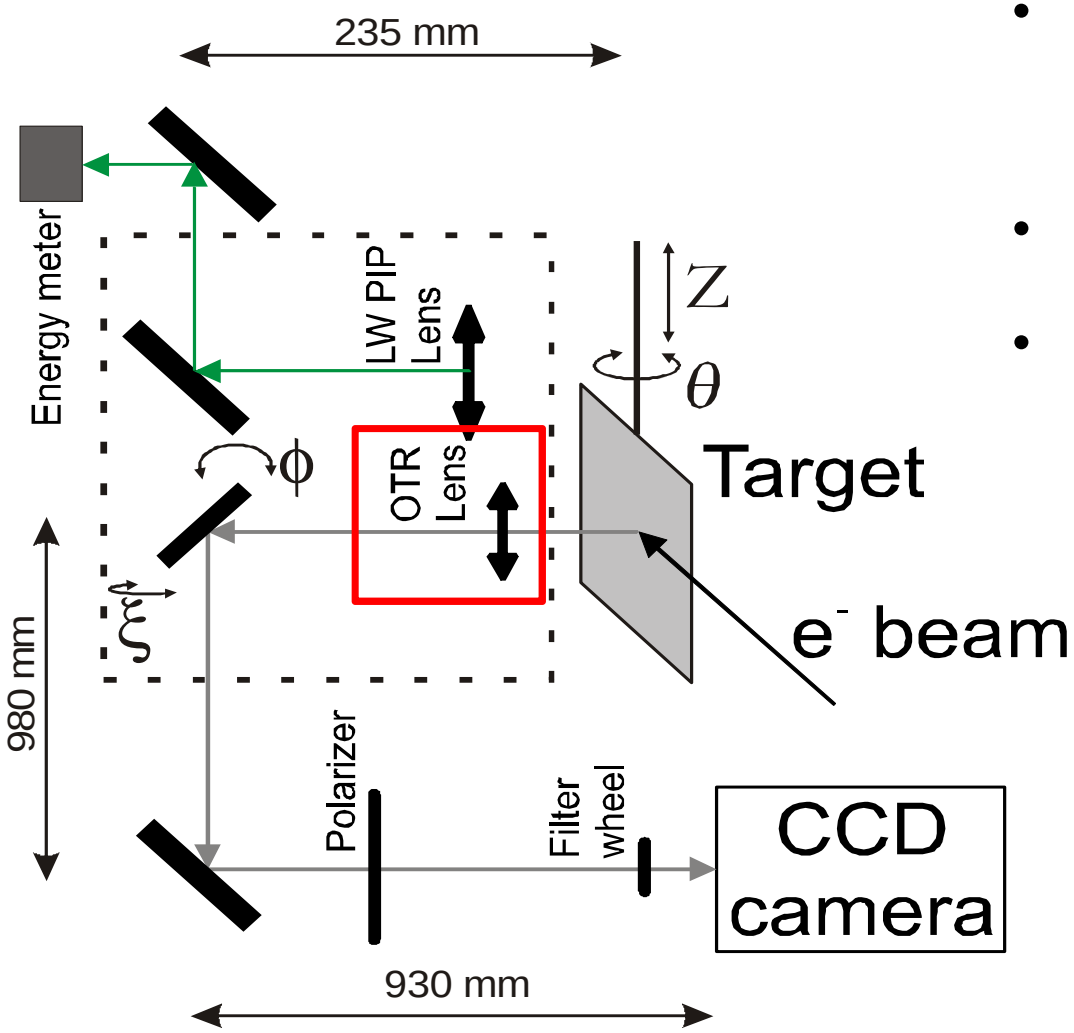
KEK ATF-II, beam parameters



Possible ways to improve resolution

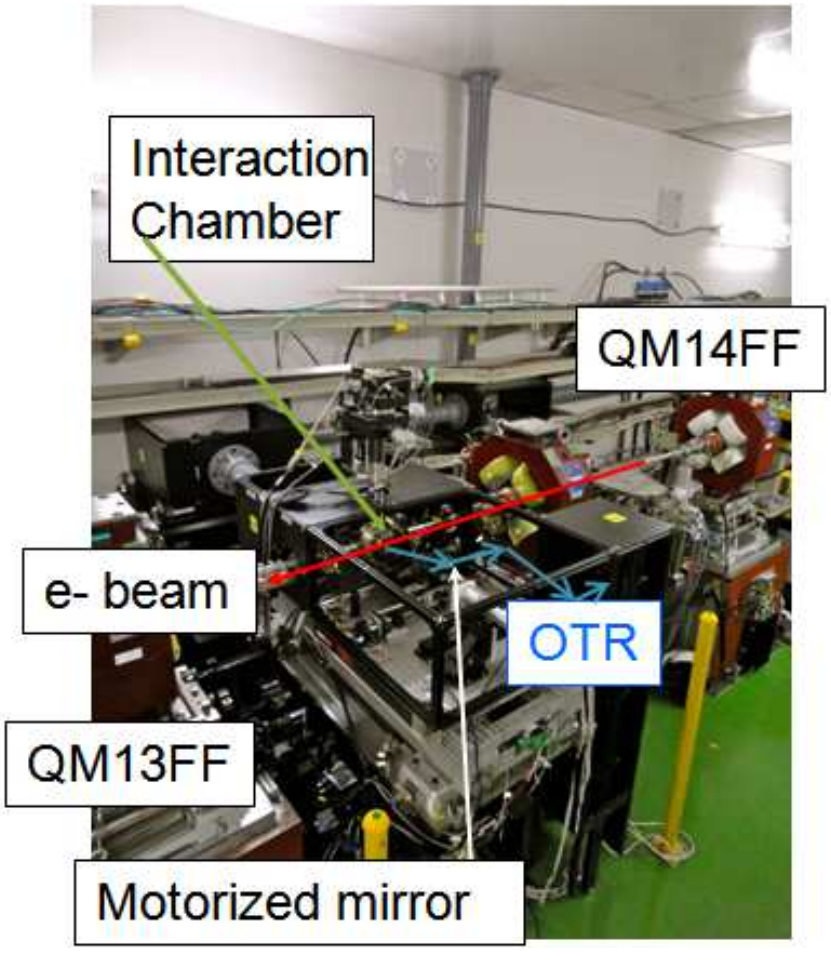
- Optics optimization
  - "Better" or just different lens? Multi-element optics? Reflective optics?
  - OTR-based lens alignment (transverse position, focusing). Need to develop appropriate analysis.
  - Tricks: Iris, narrower band optical filter, "better" CCD.
  - Need trustable (for specific task!) simulation tool: ZEMAX
- Analysis optimization
  - New PSF-like fit function
  - New analysis types with analytical approaches

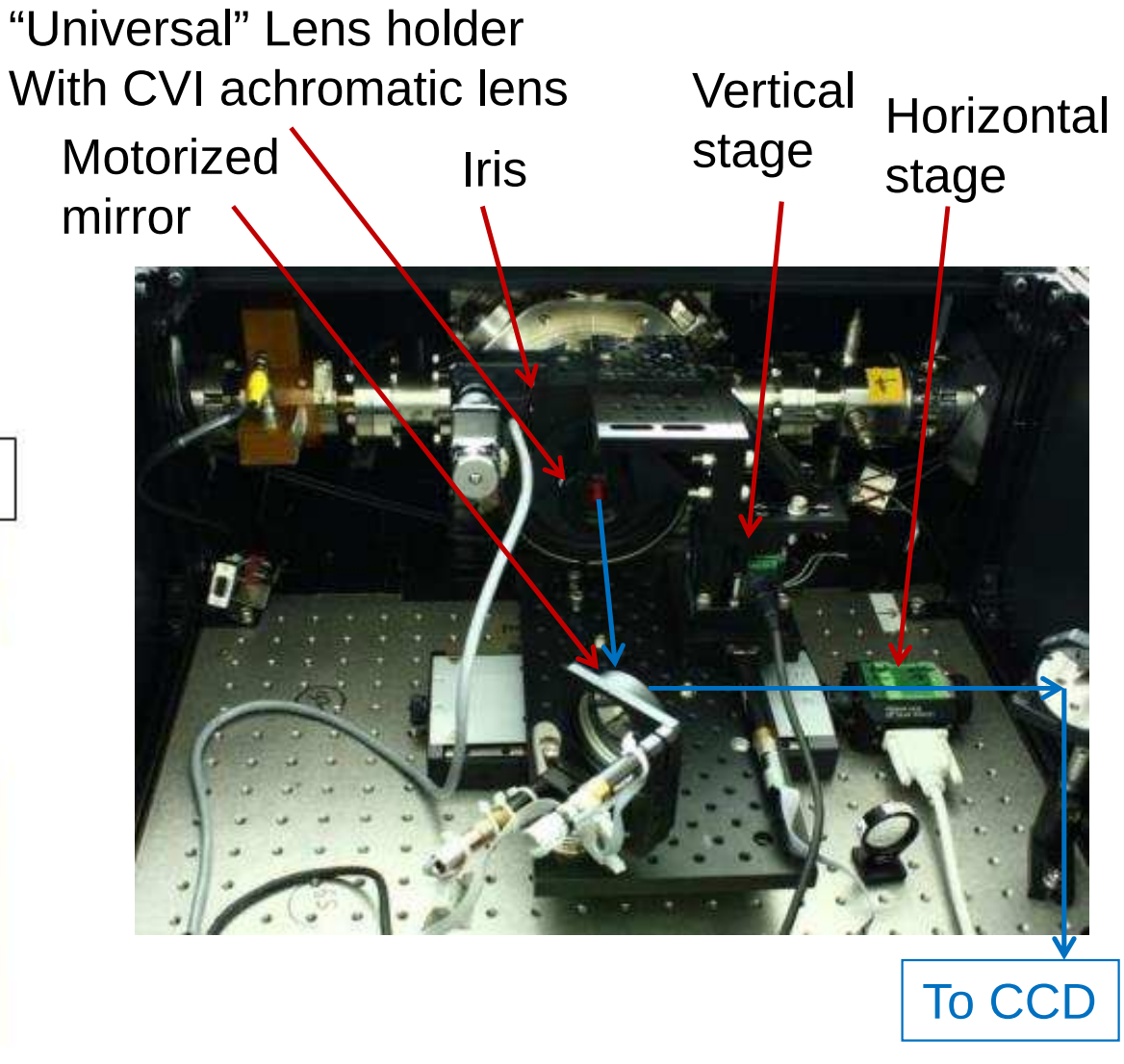
Setup overview



- CCD:
  - SBIG ST 8300 MT
  - ~ 50% Q.E. @ 550nm
  - 5.4 um/pixel
- Target
  - Si wafer coated with Al, 30x30x0.3 mm
- Lens (tested since 2009)
  - 50mm f=120mm (SigmaKoki SLB)
  - 30mm f=120mm (SigmaKoki SLB)
  - 30mm f=120 achromat (CVI, LAO)
  - 12.6mm f=100mm (Thorlabs, LA)
  - 30mm f=100mm (SigmaKoki DLB)
  - 30mm f=120mm (SigmaKoki DLB)

Setup overview



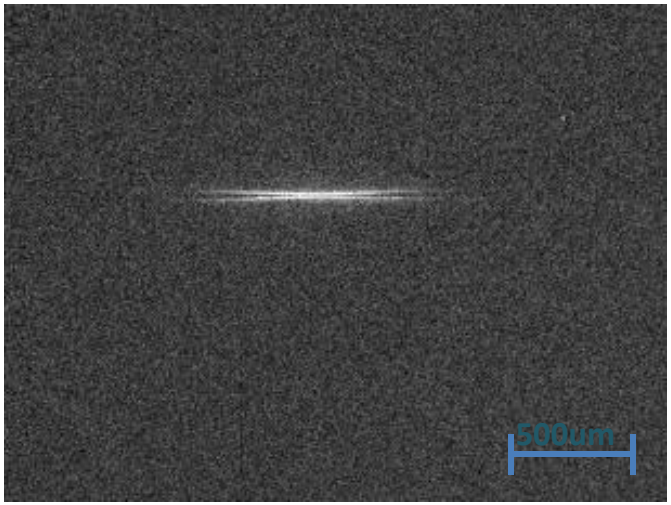


Free space propagation

✓ Zemax simulations: R_{I0}=0.178mm in near field ➔ Match well analytical equations

- References: G. Kube, MDI, “Imaging with Optical Transition Radiation, Transverse Beam diagnostics for the XFEL”, March 18, 2008, equation 29)
- Simulated effects:
  - Chromatic and spherical aberrations
  - Focusing effect of the OTR optical system
  - Reflective optics
  - Lens alignment
  - Iris diaphragm in front of the lens
  - Mask effect before the Lens

OTR image and most recent Quadrupole scan.



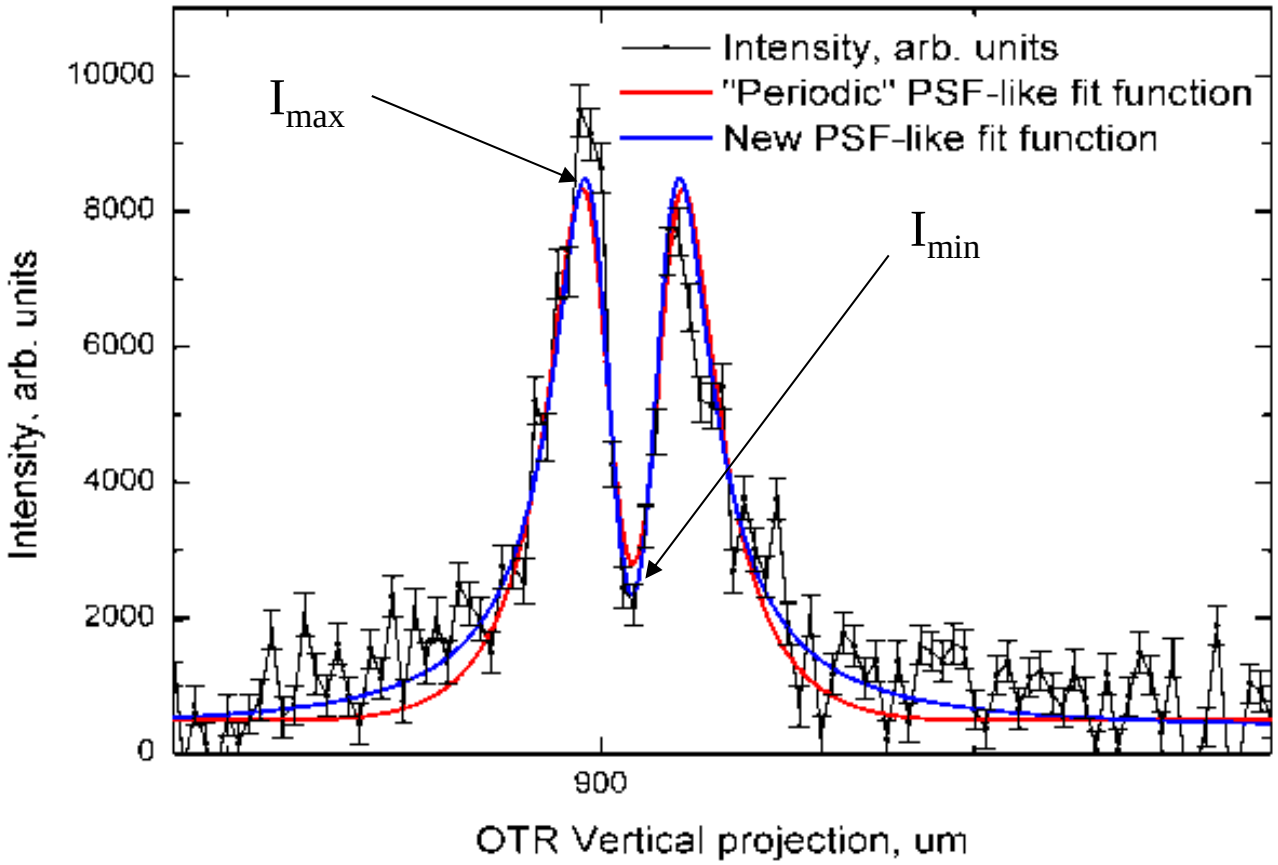
- Last OTR run (3 shifts) was performed in March
- A lot of data collected and has to be analyzed (4 lens, new alignment scans, better optimization)
- Fairly good agreement with ZEMAX model
- New analysis is completed in May
- Test bench is constructed in LW hut (Reflective optics and Chromatic aberrations study)

OTR PSF-like Fit functions

$$f(x) = a + \frac{b}{1+\left[c(x-\Delta x)\right]^4}\left[1 - e^{-2c^2\sigma^2}\cos\left[c(x-\Delta x)\right]\right]$$

"Periodic" PSF-like Fit function

New PSF-like Fit function



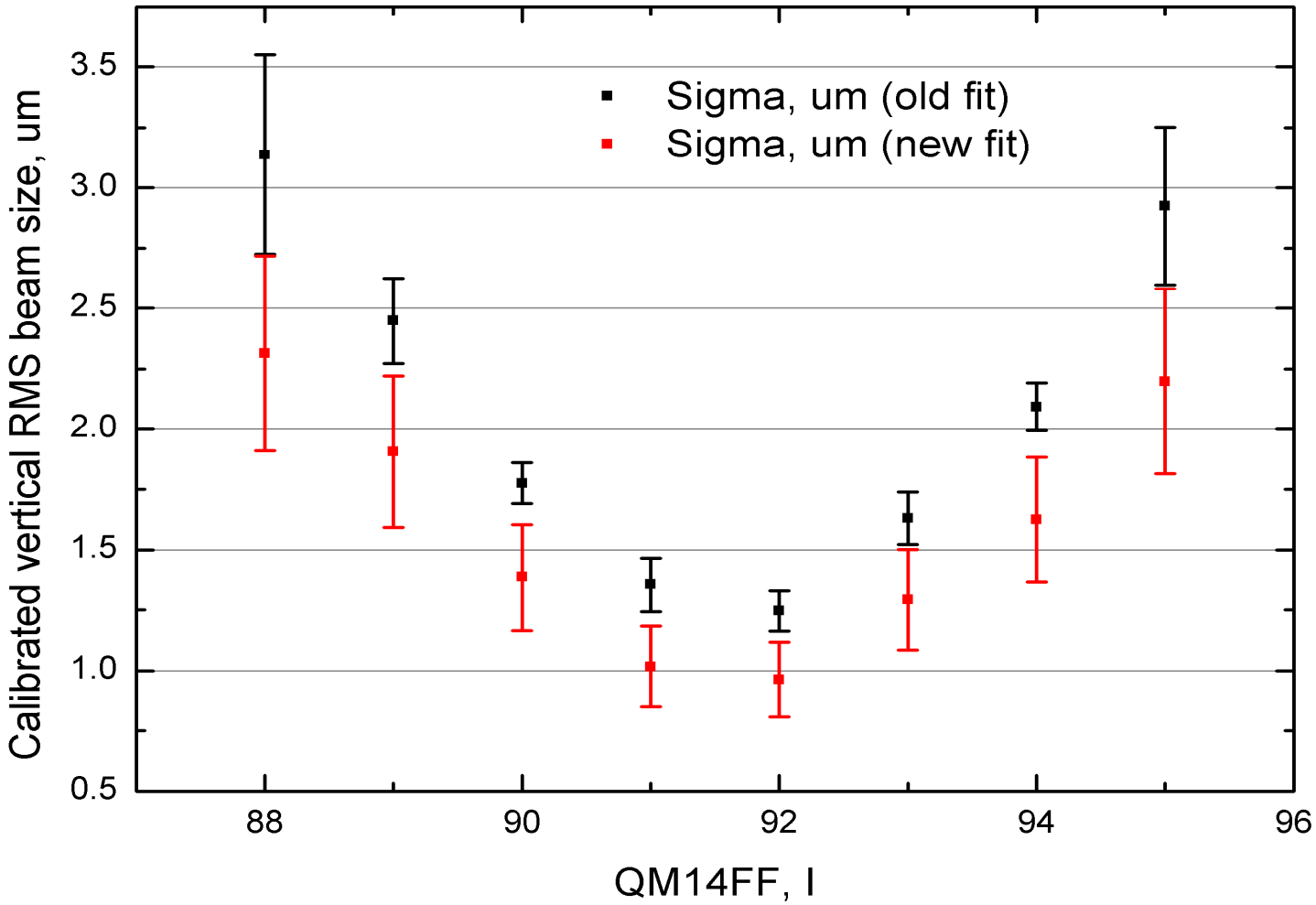
What corresponds to electron beam sire of
$\sigma = 1.28$ **+/-** 0.06
with "old" fit function
and
$\sigma = 0.97$ **+/-** 0.27
with new fit function

New OTR PSF-like Fit function

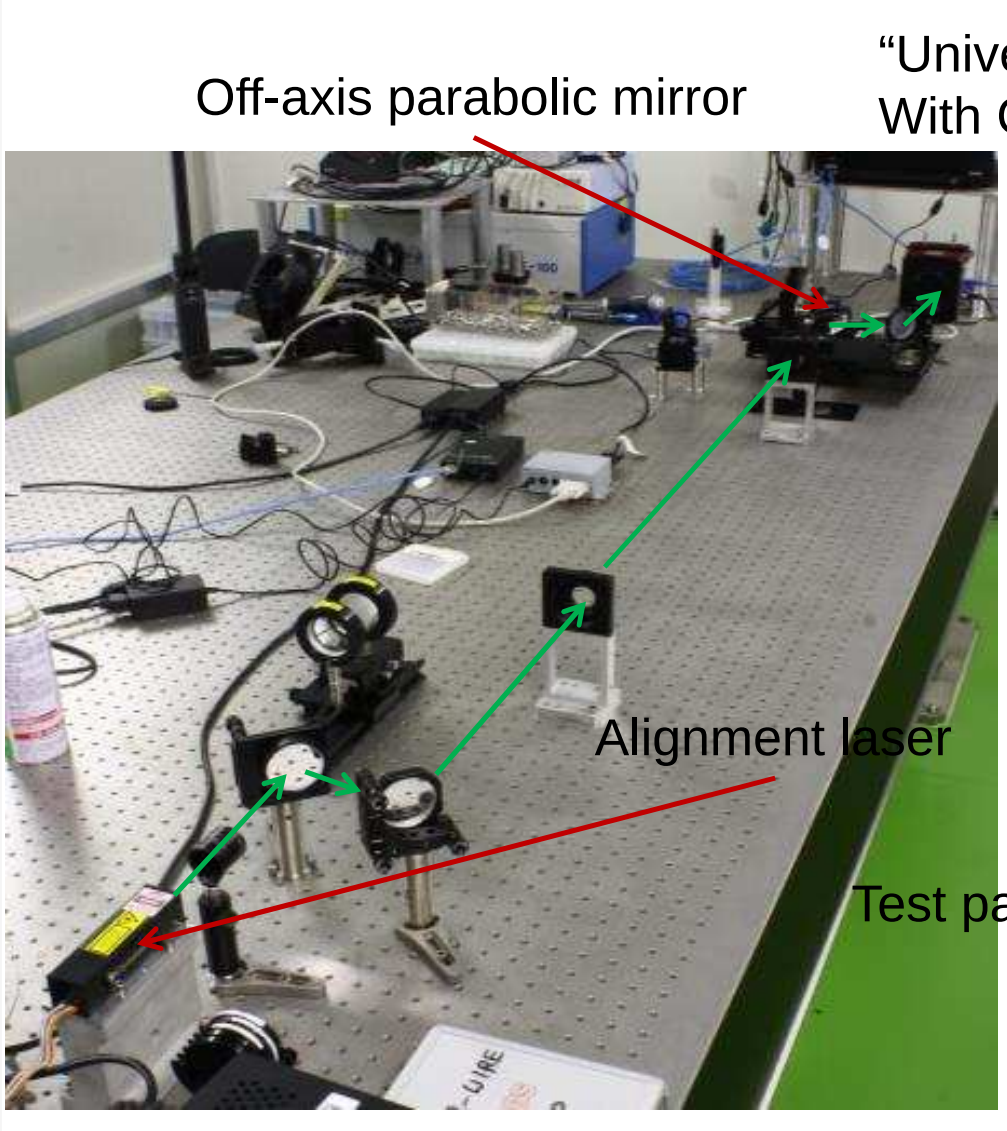
- Analytical calculation of:
  - Minimum to maximum ratio
  - Distance between peaks (focusing, Iris scan, etc)
  - Simpler expressions for error calculation

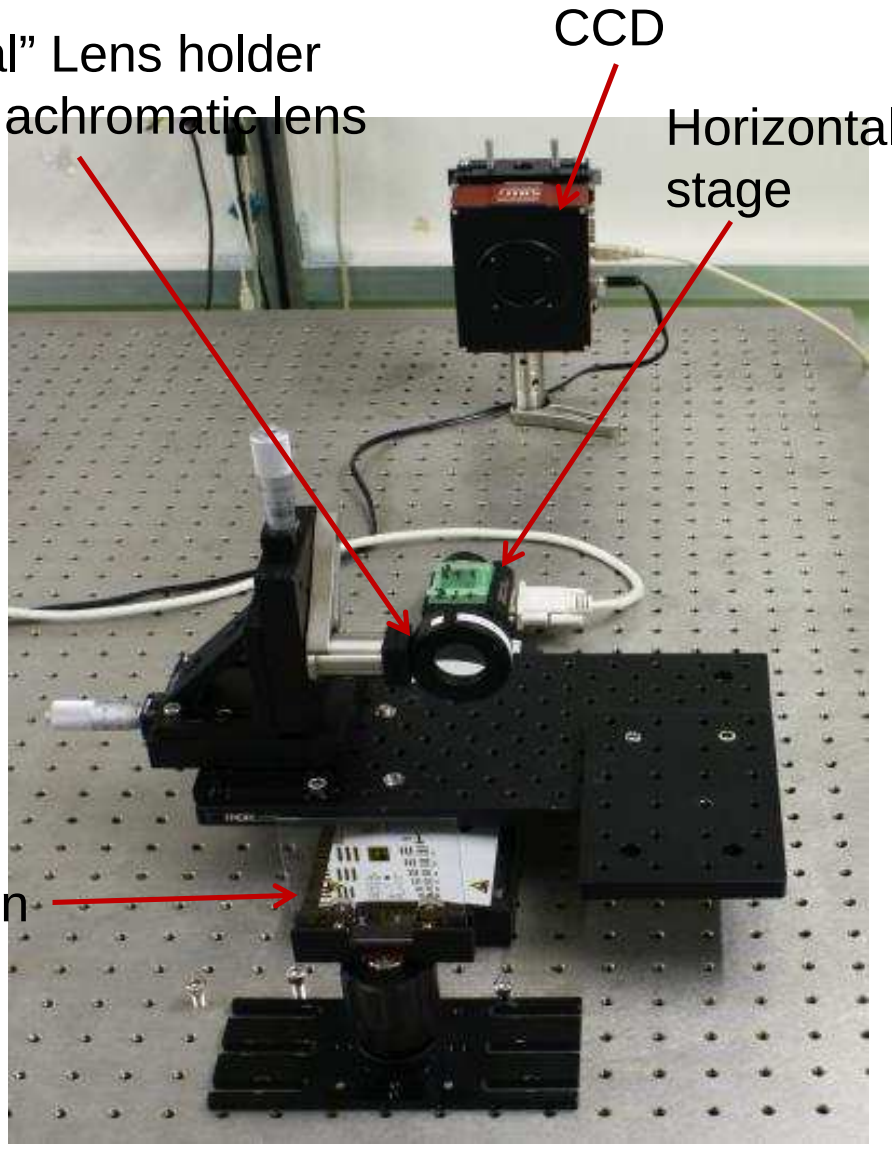
Fit functions comparison

Same quadrupole scan is analyzed: 20130304\CVI LAO 120



OTR test bench





Comparison with reflective optics

Lens: CVI LAO, f=120mm, D=30mm

90 degree off-axis parabolic mirror
EO 87409, EFL=50.8mm

Summary and Conclusion

- Collected Data shows a good progress in optimization of PSF-like OTR monitor system.
- Many improvements has been introduced.
- Work on analysis and simulations shows good agreement with experimental data
- Careful explanation about every aspect of PSF based OTR monitor in a systematic papers (experiment: JINST, simulation: PRSTAB?) is considered as an important step forward.