Beam Size Measurements at ALBA

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Introduction

1. **Pinhole Camera**

2. **Double slit interference**

3. **In-air X-ray Detectors**

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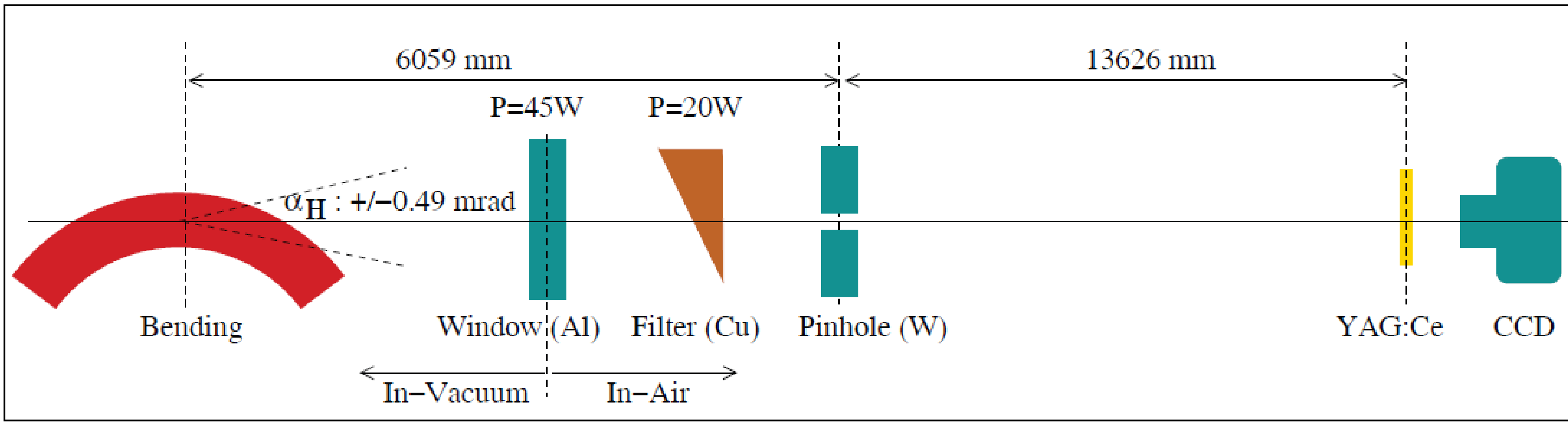
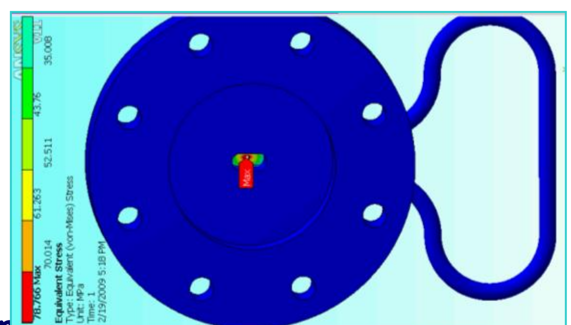
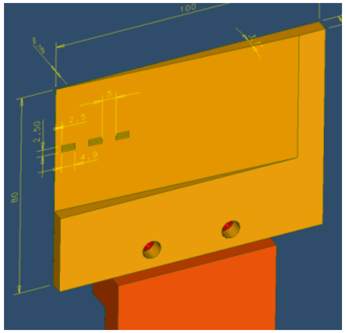
3. In-air X-ray Detectors

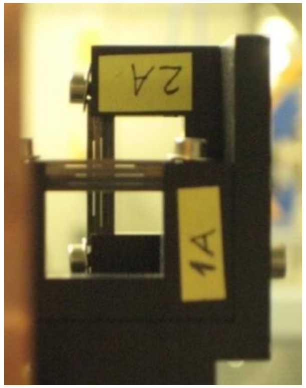
X-Ray Pinhole Camera

- Light from an object (beam) goes through a single aperture (pinhole) and projects an inverted image of the source
- Image is magnified by a factor **L2/L1**
- ALBA magnification factor 2.27 (19m length system)
- Use x-rays: Al-window and Cu-filter (~45keV)





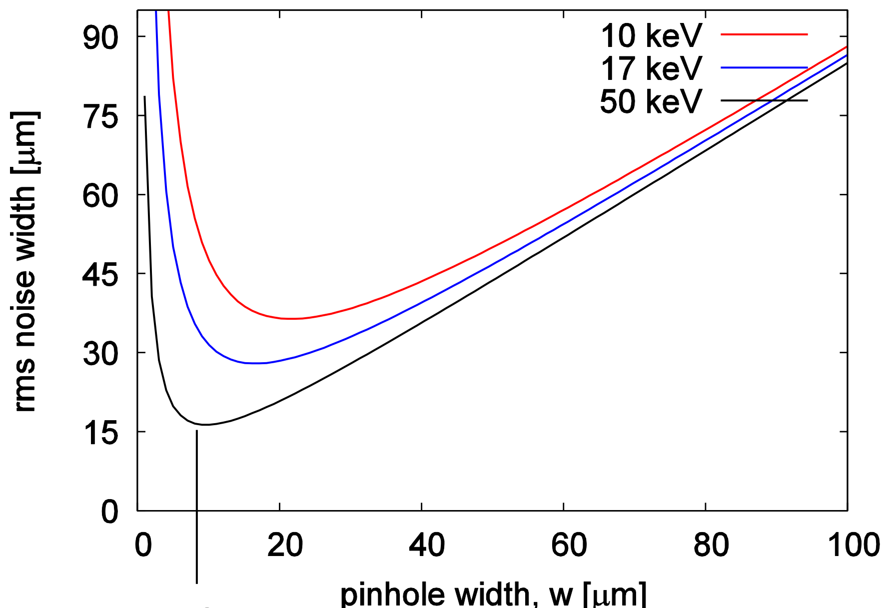




X-Ray Pinhole Resolution

Limited by geometric constrains: while L2 and L1 are usually fixed, pinhole aperture ***w*** can be optimized at design stage to minimize the PSF

Diffraction: $\sigma_{difr} = \left(\frac{\sqrt{12}}{4\pi}\right)\frac{\lambda L_2}{w}$ Blurring: $\sigma_{Blur} = \frac{w(L_1+L_2)}{\sqrt{12}L_1}$



w=10um

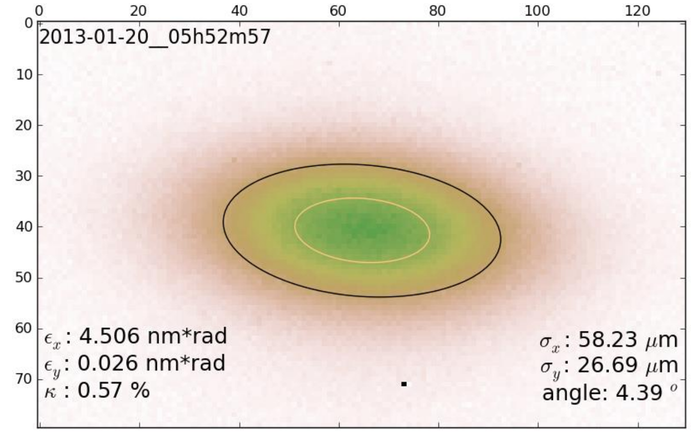
Our system PSF = 15um
Considering our 2.3 magnification, this means we can measure down to ~7um*

*M.A. Tordeaux, et al, "Ultimate Resolution of Soelil Pinhole Cameras", DIPAC'07

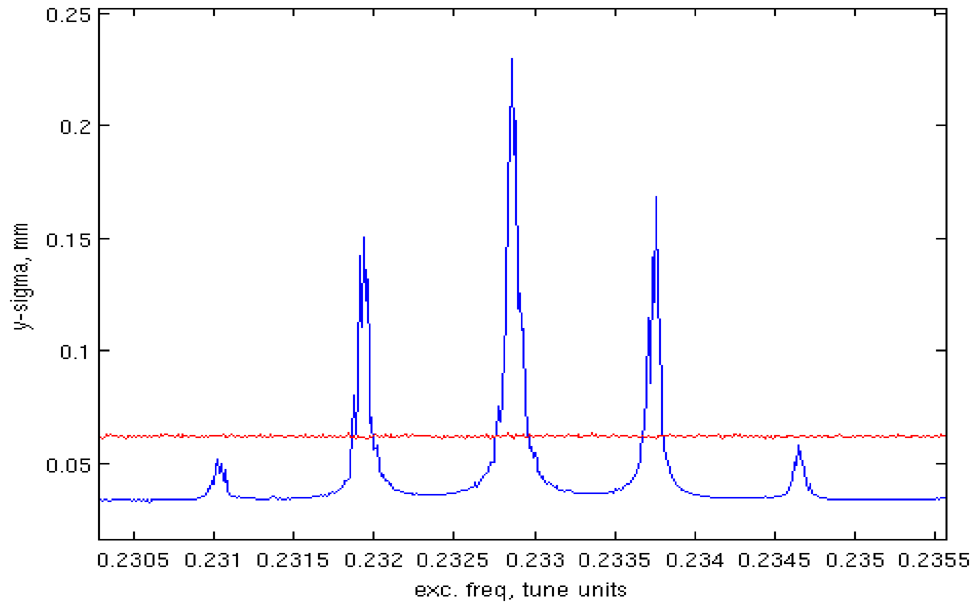
X-Ray Pinhole Results

Beam Image Example in normal operation (0.5% koupling)

Enough to properly measure beam size (16um) for minimum koupling = 0.1%



Example: on-line monitoring during energy measurement scan (sigma from 28um → 200um)



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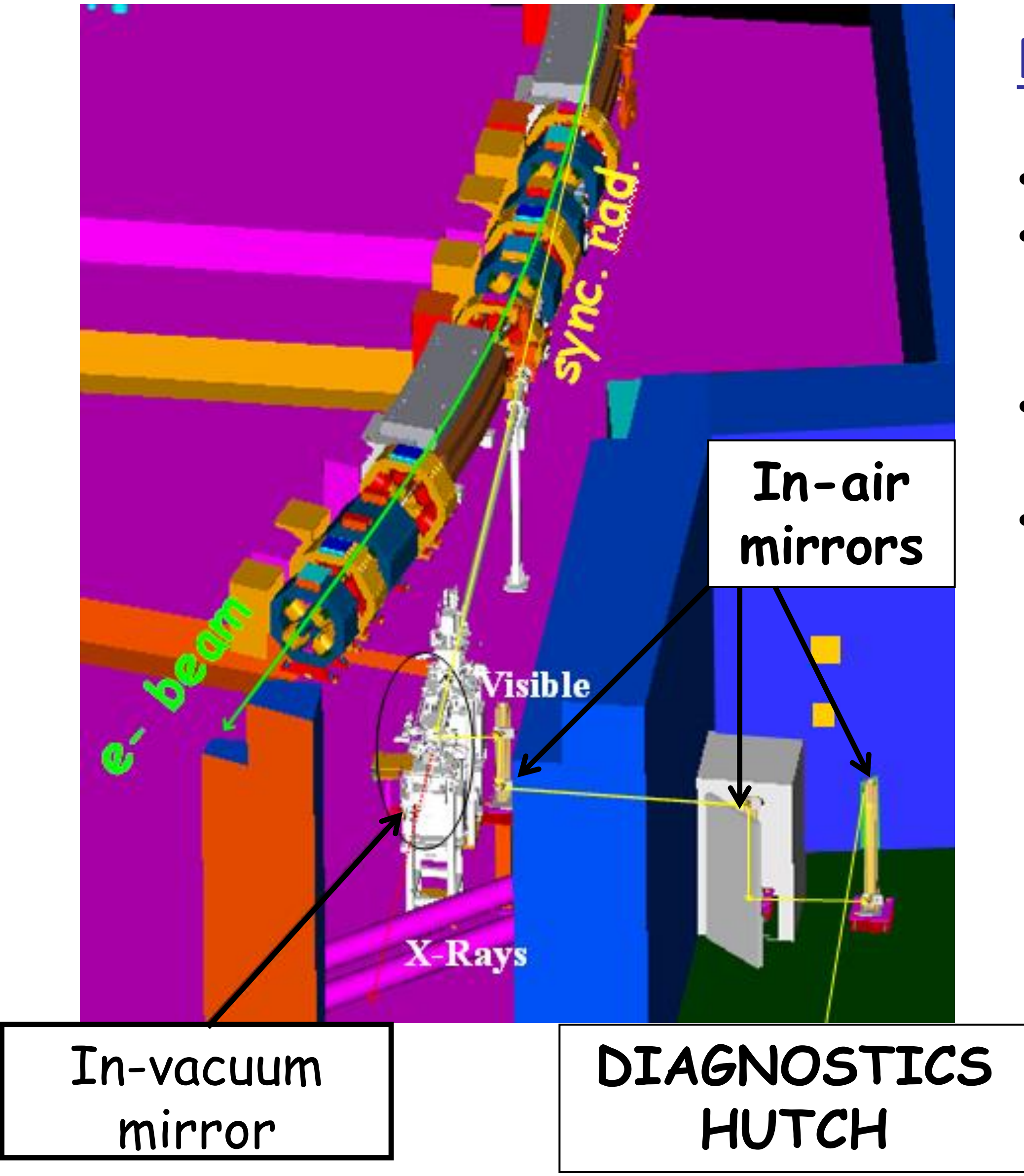
Double Slit Interferogram



MOTIVATION:

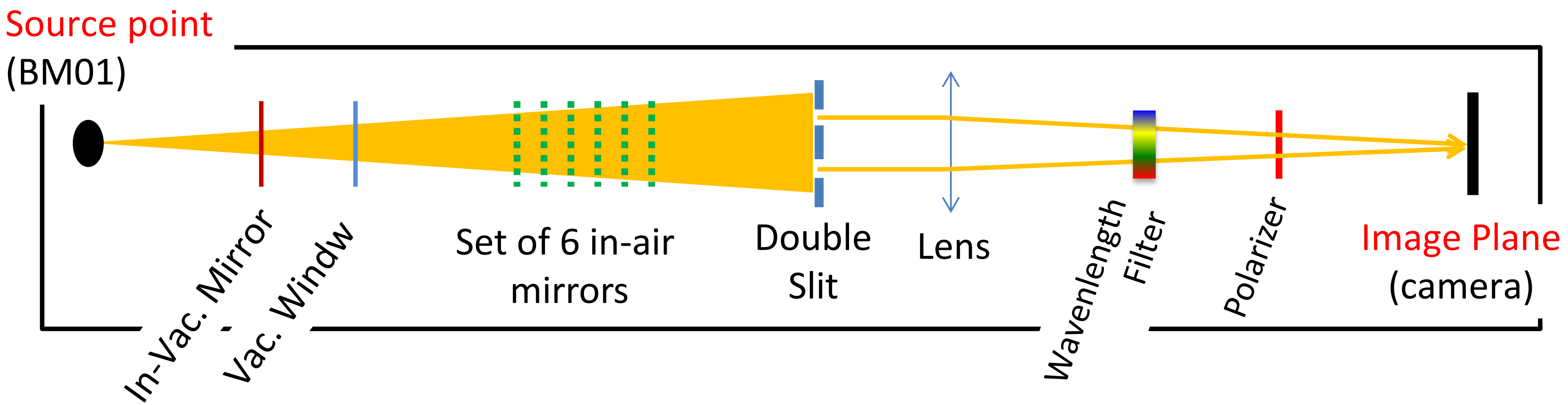
- Alternative emittance measurement
- Almost “for free”, since basic instrumentation is already in place at **Di Hutch**
- Better resolution than pinhole

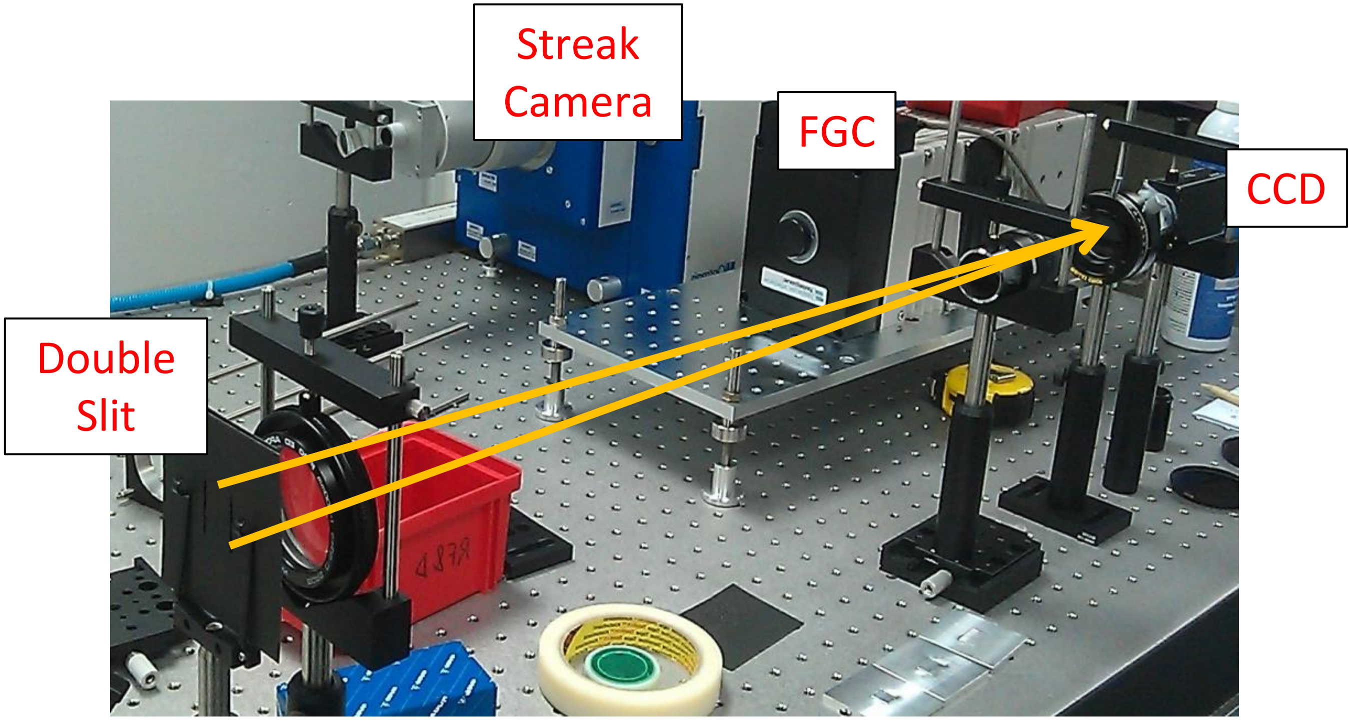
- Using a Fast Gated Camera (FGC), can we have BBB diagnostics?

Instrumentation at Di Hutch:

- Streak camera:
  Longitudinal profiles
- CCD and Fast Gated Camera
  Transverse profiles

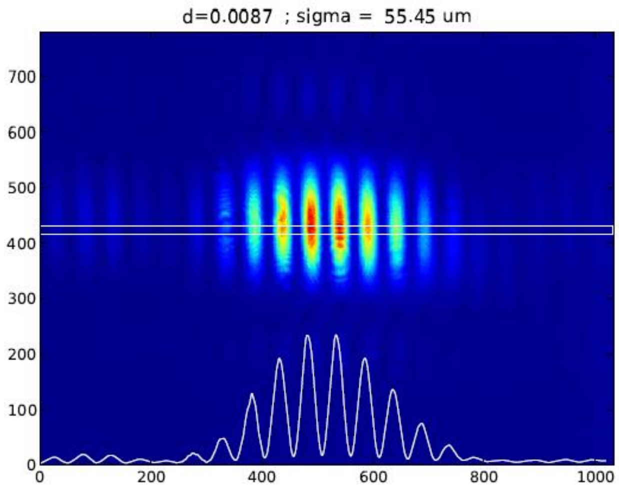
Double Slit Interferogram





Double Slit Interferogram

The double slit system produces an interference pattern at the image plane
The beam size is inferred from "Visibility" of the interference fringes:

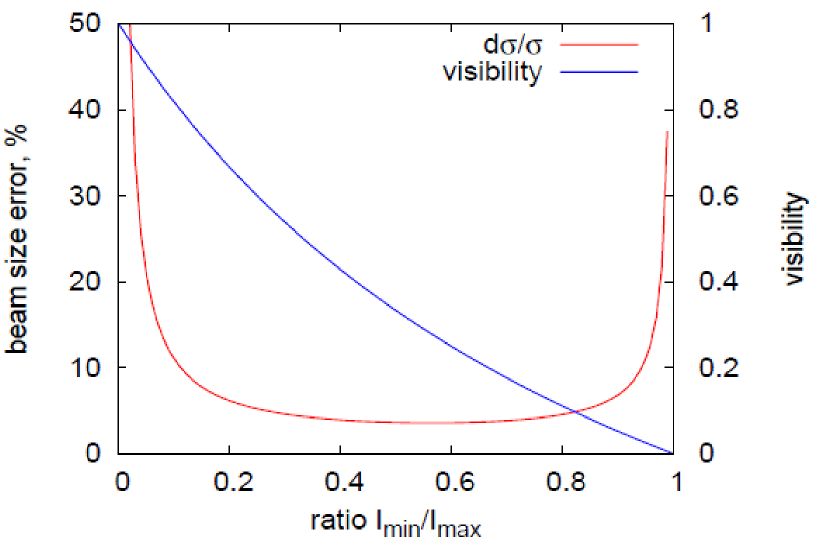


$$\sigma = \frac{\lambda d_0}{\pi D}\sqrt{\frac{1}{2}\ln(\frac{1}{V})}$$

$V = (I_{max}-I_{min})/(I_{max}+I_{min})$, "Visibility"
λ = observation wavelength
d_0 = slit separation
D = distance from source point to double slit

Beam size precision mostly limited by calculation of Visibility - CCD linearity and light background: in the order of 1% when V~0.5

- All in all, resolution easily ~**5%**
- At other labs, meas ~4um with res<1um

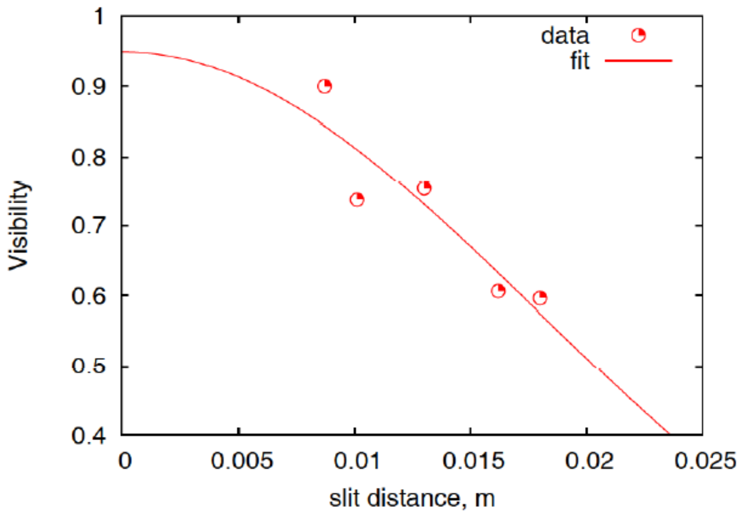


Interference using OLD mirror

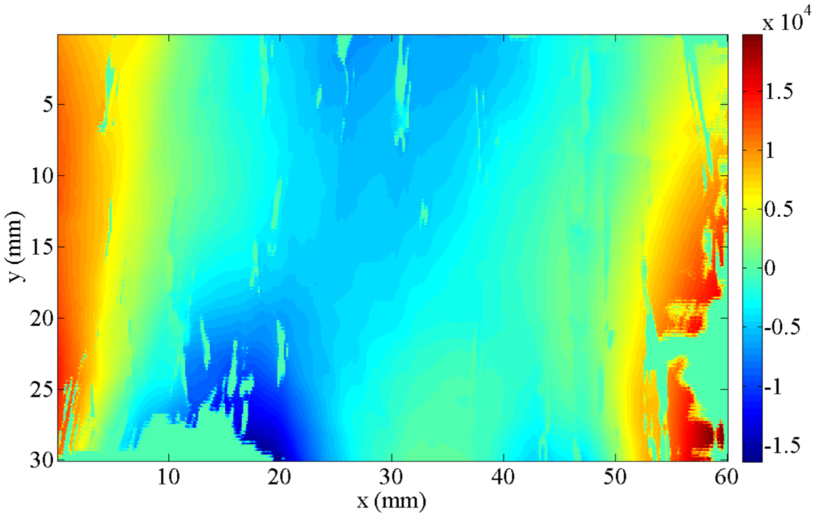
March 2013:

- Measurements limited by wavefront distortion produced by in-vacuum mirror
- Detected using Hartman Mask measurements, analyzing spatial degree of coherence, and finally confirmed with the PTV surface flatness measurement using Fizeau.

Visibility vs slit separation*



Fizeau Measurements: ~ $\lambda/1$



➔ Mirror exchanged in Jan. 2014

New mirror slightly larger (+1mrad vertically more)

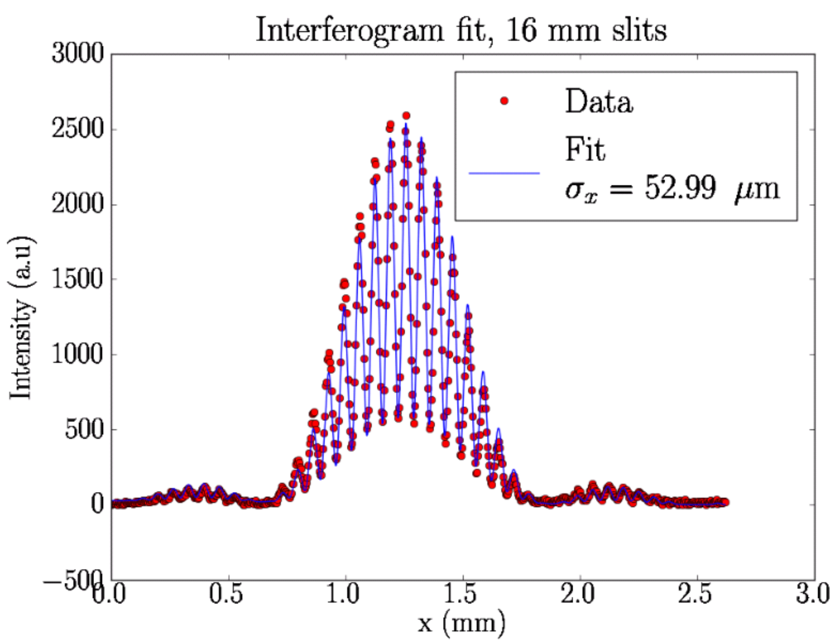
Better PTV flatness and "Kanigen" coating to protect from contamination

*Proc. Of IBIC-2013, "First measurements using interferometry at ALBA", U. Iriso and L.Torino

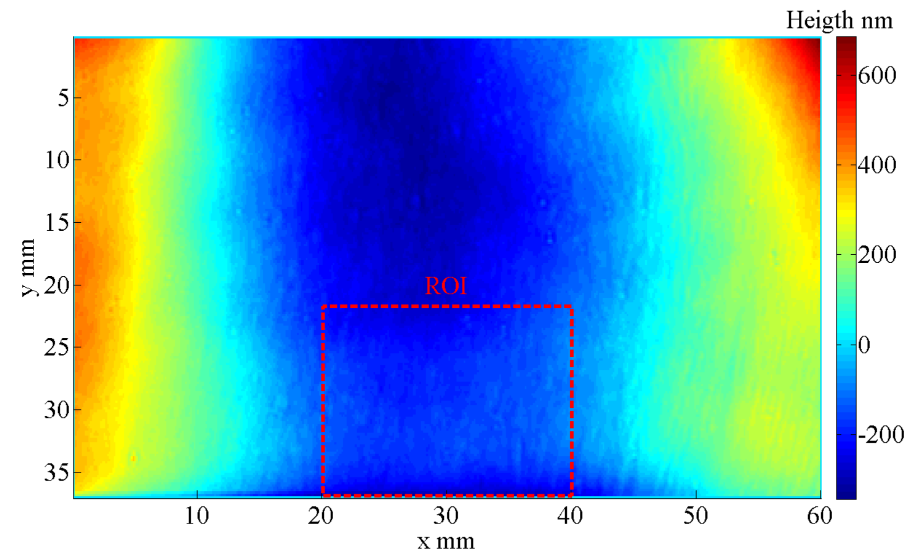
Interference using NEW mirror

March 2014:

- Results after exchanging in-vacuum mirror, vacuum window, and in-air mirrors
- Wavefront arriving at double slit more homogenous
- First measurements showed better reproducibility and in agreement with theory



New Mirror ~ λ/10



NEXT STEPS:

- Increase system robustness and to use it as on/line monitoring
- Bunch-by-bunch size measurements using a Fast Gated Camera (CERN collab.)
- Four-slits interferograms to simultaneously obtain hor and ver beam size

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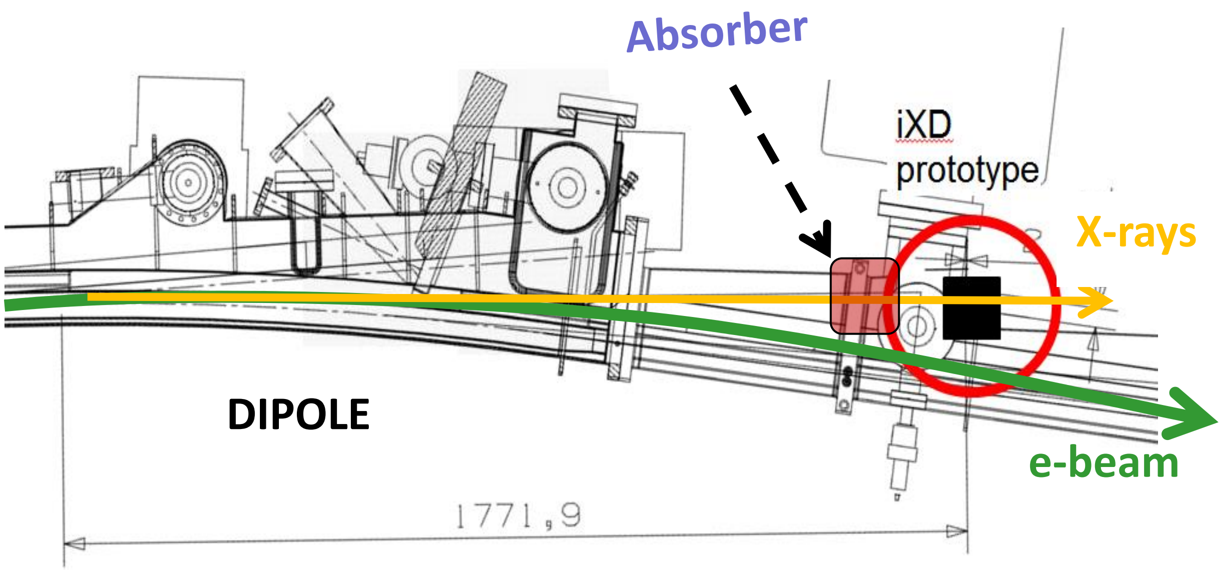
In-air X-Ray Detectors (iXD)

- Based on projection from very hard x-rays from sync. rad traversing the dipole absorbers*



- MOTIVATION: alternative emittance measurement
- PROS: cheap and easy, iXD can be located outside vacuum

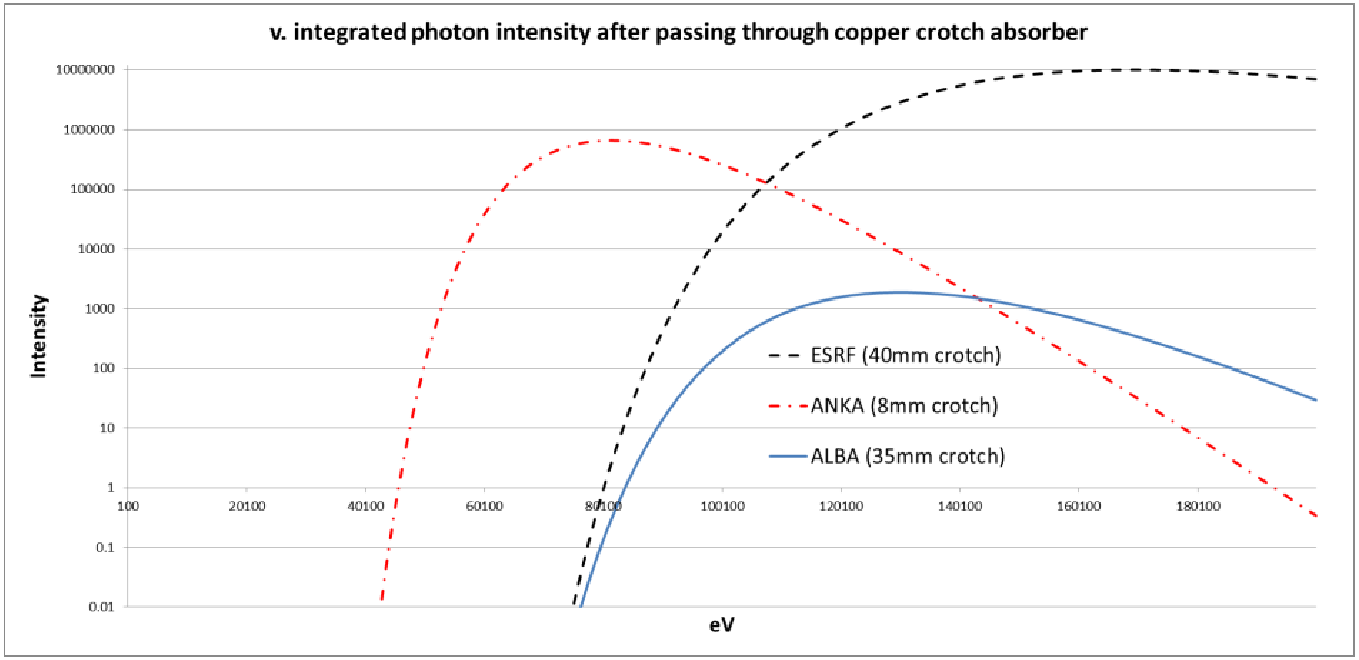
- CONS: Only vertical beam size is inferred
  No much room to improve resolution

*K.Scheidt, Proc. Of DIPAC'05; A.Muller, Proc. Of EPAC'06

In-air X-Ray Detectors

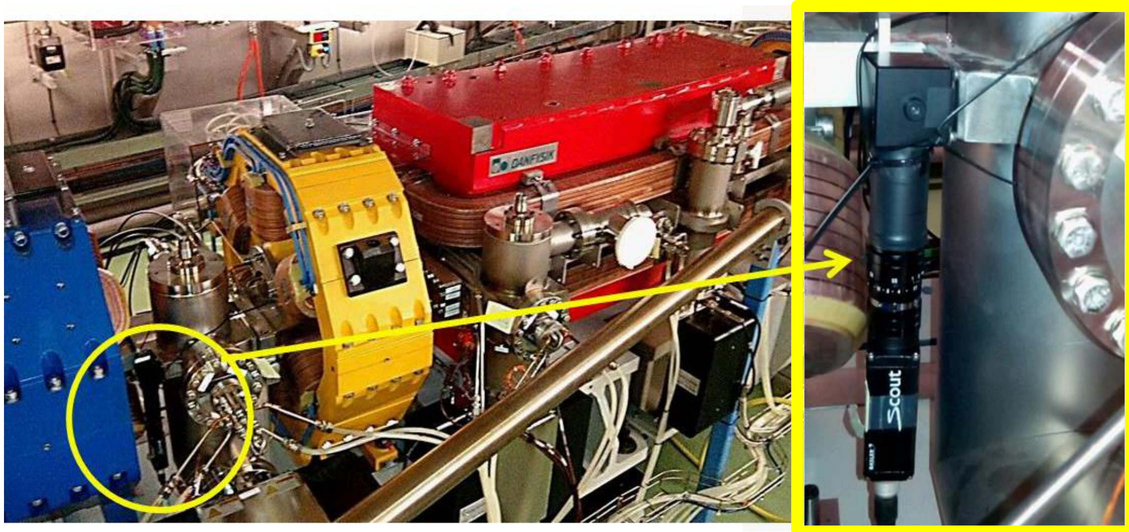
So far, only successfully used at ESRF and ANKA due to favourable conditions (combination of high energy and absorber thickness)

	ANKA	ESRF	ALBA
E, GeV	2.5	6	3
Cu thickness	8mm	40mm	35mm



Need to work on scintillator material and optical system to optimize every photon

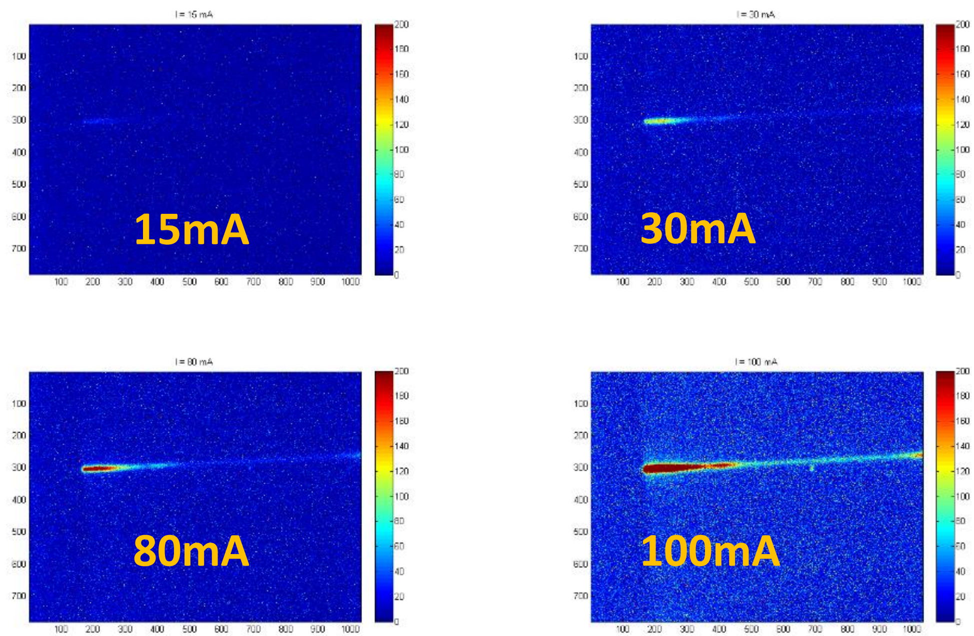
iXD: First Results (March 2014)



For **FIRST FEASIBILITY TESTS** with scintillating material, an iXD prototype was (rudimentary) installed for

Material tested:

- YAG:Ce (no success)
- **Prelude** - LuYSiO5 (success)

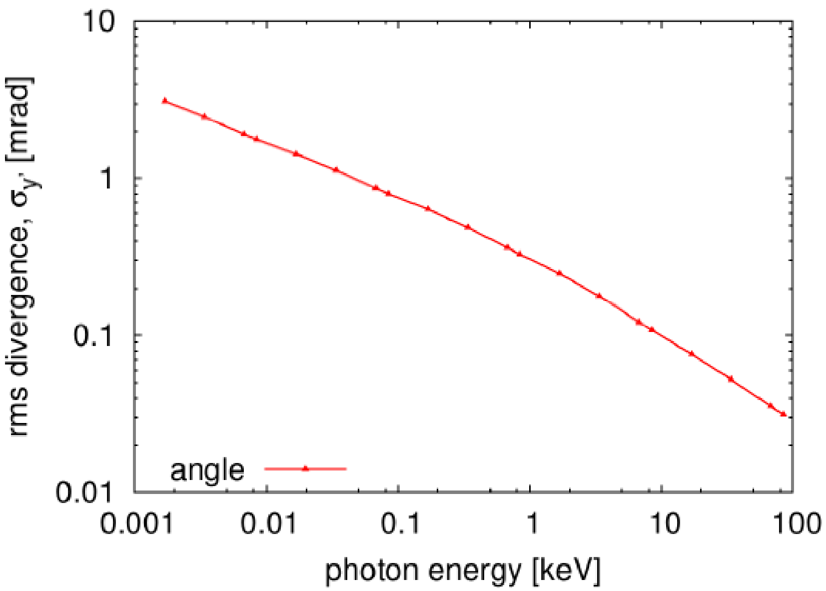


With Prelude screen, 0.8mm an image is obtained with exposure times >1sec

Beam size roughly agrees with theoretical values

In-air X-ray Detector Limitations

- PSF is limited by distance between source-point to iXD location and photon divergence



$$\sigma_{sc}{}^2 = \sigma_b{}^2 + (L\cdot\alpha)^2$$

For this first case, PSF is quite large:
E~130keV; α=0.025mrad; L=1.7m
➔ PSF = $(L\cdot\alpha)$ ~ 42um!

At ALBA, need to look for a closer location, and/or use still harder x-rays

NEXT STEPS:

- use 1mm thick Prelude screen, still looking for better materials
- Better mechanical fixation
- Ray tracing to understand the "comet-like" spot
- To be used at IR beamline to monitor beam position drifts

Summary

1. Classical Pinhole Camera

- Installed and working since Day-1
- Reliable and robust
- Minimum beam sizes ~7um (8pm*rad)

2. Double slit interference

- In progress: in-vacuum mirror and vacuum window exchanged in Jan.2014
- Due care shall be taken to keep wavefront homogeneity
- Expected beam size ~4um, resolution~1um
- Tests to obtain Bunch-by-bunch beam size in the near future

3. In-air X-ray Detectors

- In-progress: feasibility studies done successfully with Prelude
- Two setups going to be precisely installed at dipoles
- Right now, PSF~42um, few room to improve it since we are mechanically limited for the minimum source-to-screen distance