ESRF | The European Synchrotron

Synchrotron Radiation Interferometry Using a Rotating Mask

Laura Torino

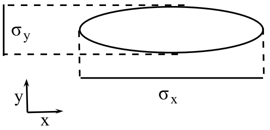
Topical Workshop on Emittance Measurements for Light Sources and FELs
ALBA, January 29, 2018

Beam Shape Reconstruction – Motivations

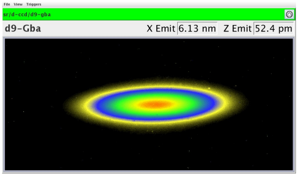
The emittance is a key parameter in every accelerator machine:

$$\varepsilon = \frac{1}{\beta}\left(\sigma^2 - \mathcal{D}^2\left(\frac{\Delta E}{E}\right)^2\right)$$

σ directly measured



Machine parameters from linear optics measurements



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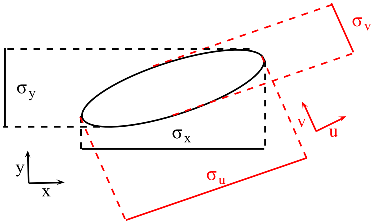

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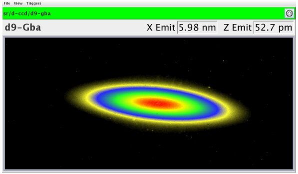

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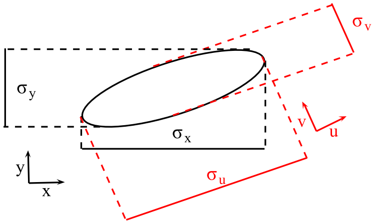


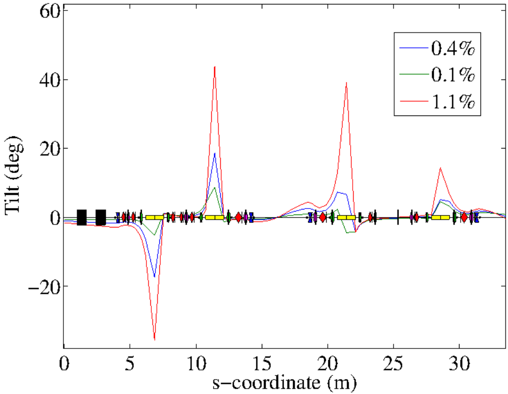
Machine parameters from linear optics measurements

In many accelerators the beam is tilted

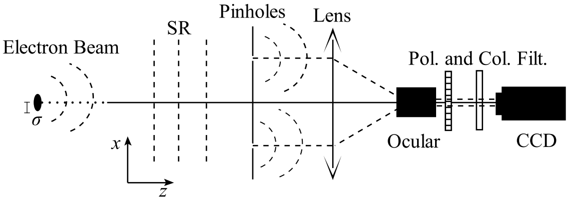
$\Downarrow$

$\sigma_x \neq \sigma_u$ and $\sigma_y \neq \sigma_v$

Transverse Beam Characteristics @ ALBA



Synchrotron Radiation Interferometry (SRI)



$$I = I_0 \left\{ \frac{J_1\left(\frac{2\pi a x}{\lambda f}\right)}{\left(\frac{2\pi a x}{\lambda f}\right)} \right\}^2 \times \left\{ 1 + V \cos\left(\frac{2\pi D x}{\lambda f}\right) \right\}$$

$$\boxed{\sigma_x = \frac{\lambda L}{\pi D} \sqrt{\frac{1}{2} \ln \frac{1}{V}}}$$

- I_0: Intensity
- a: Pinholes radius
- λ: SR wavelength
- f: Focal distance of the optical system
- D: Pinholes distance
- V: Visibility
- L: Distance from the source

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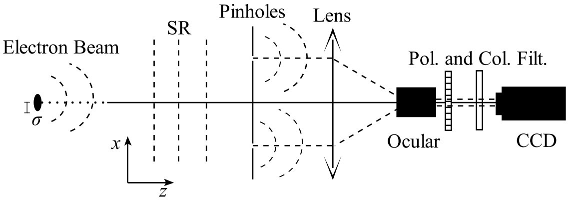

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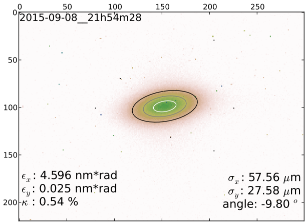
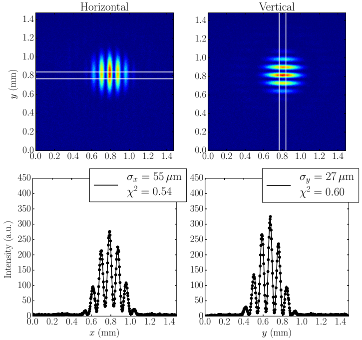
Limitation of SRI

SRI only measures the length of the one dimensional projection of the beam shape on the pinholes axis





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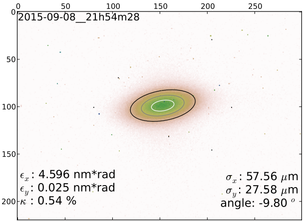
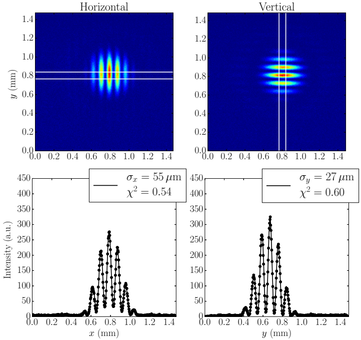
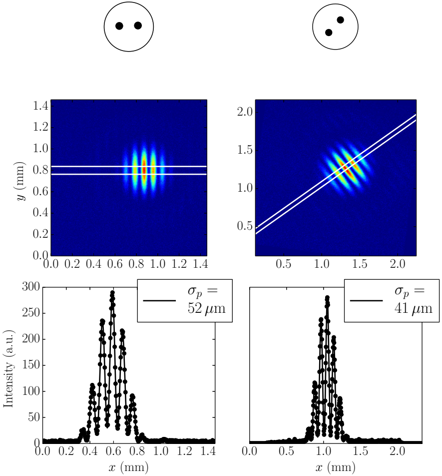


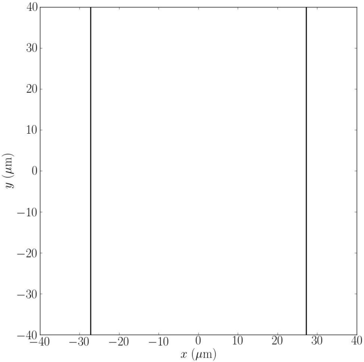


Is it possible to measure beam sizes and tilt using SRI?

Transverse Beam Reconstruction – Pinhole Rotation



Transverse Beam Reconstruction



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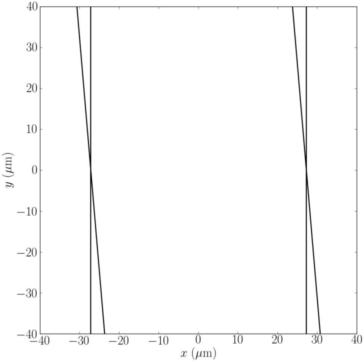
Transverse Beam Reconstruction



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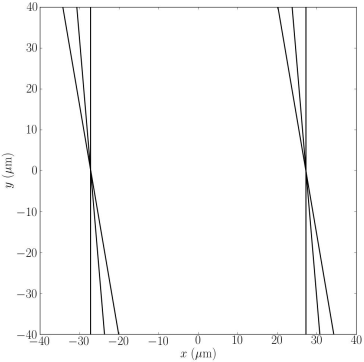

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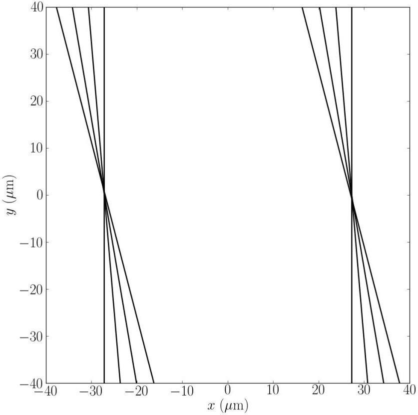

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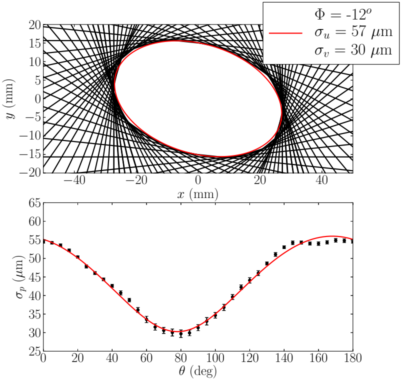
Elliptic Beam



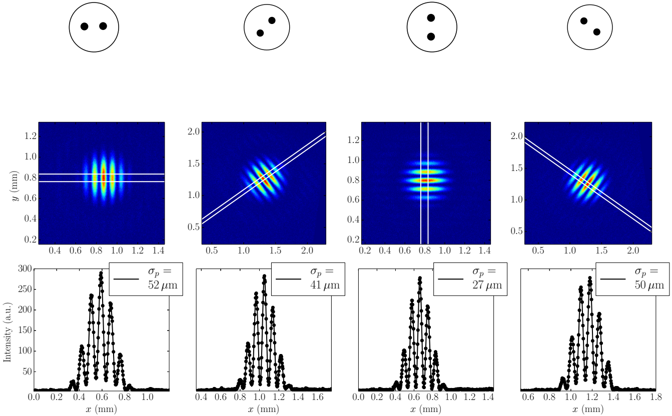
The beam reconstruction shows clearly that the beam can be approximated as an ellipse.

$$x(\theta) = \sigma_u \cos(\theta + \Phi)$$

$$y(\theta) = \sigma_v \sin(\theta + \Phi)$$

$$\sigma_p(\theta) = \sqrt{\sigma_u{}^2 \cos^2(\theta + \Phi) + \sigma_v{}^2 \sin^2(\theta + \Phi)}$$

Transverse Beam Reconstruction – 4 Projections



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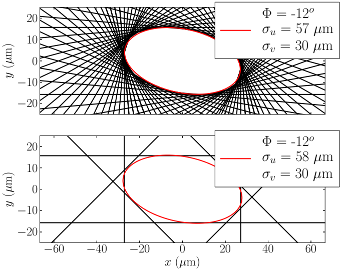
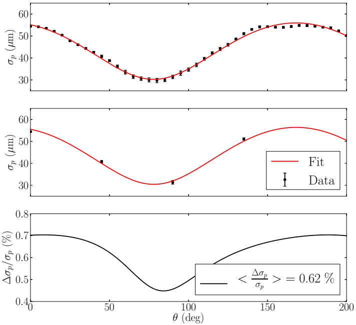
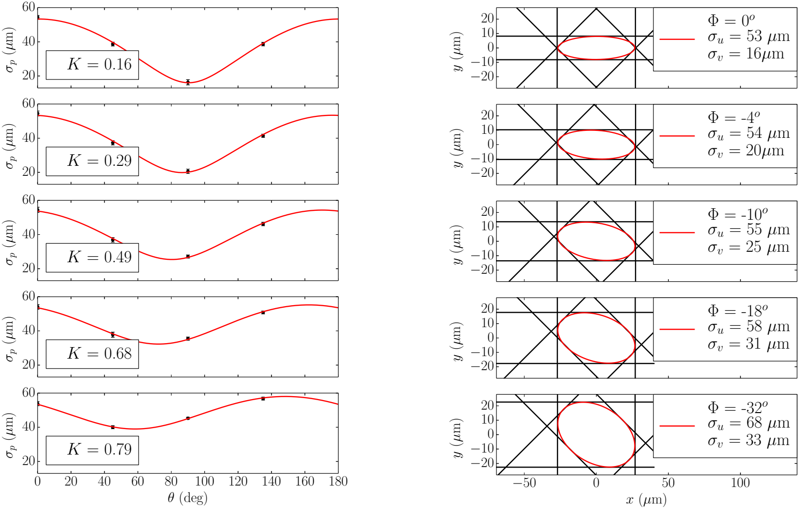




Results at Different Couplings

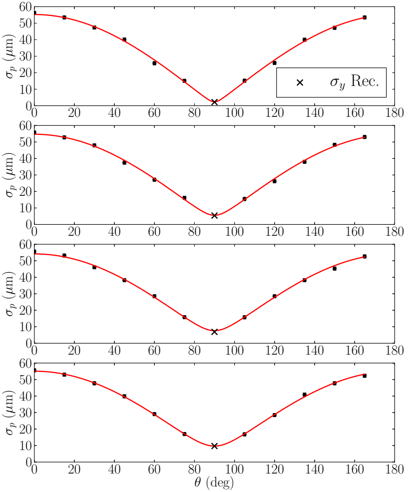


Further Applications

Using a **Fitting Method** we can infer beam sizes at any angle

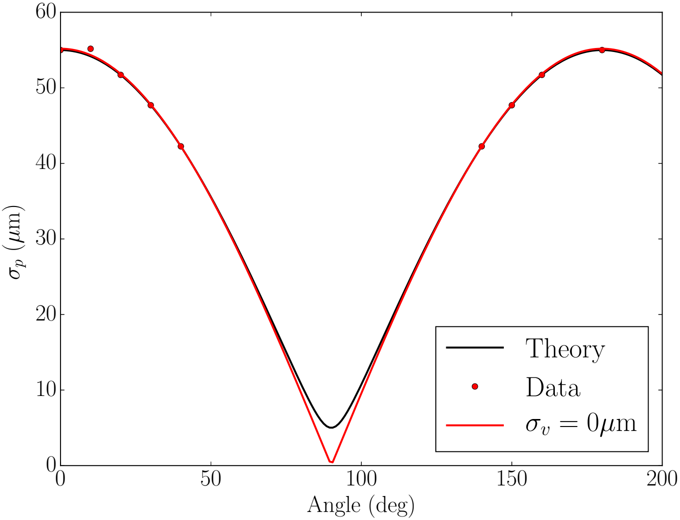
We can use the same technique used for the full beam reconstruction to infer ultra-low beam sizes!

Results using SRW Simulations



$\sigma_x = 55\,\mu m$	
σ_y	
Theo. (μm)	Rec. (μm)
2	2.2
5	5.4
7	6.9
10	9.7

Reconstruction Sampling



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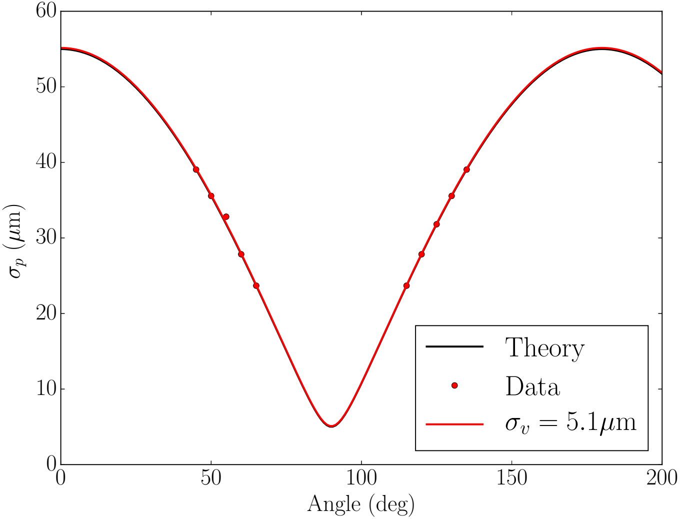

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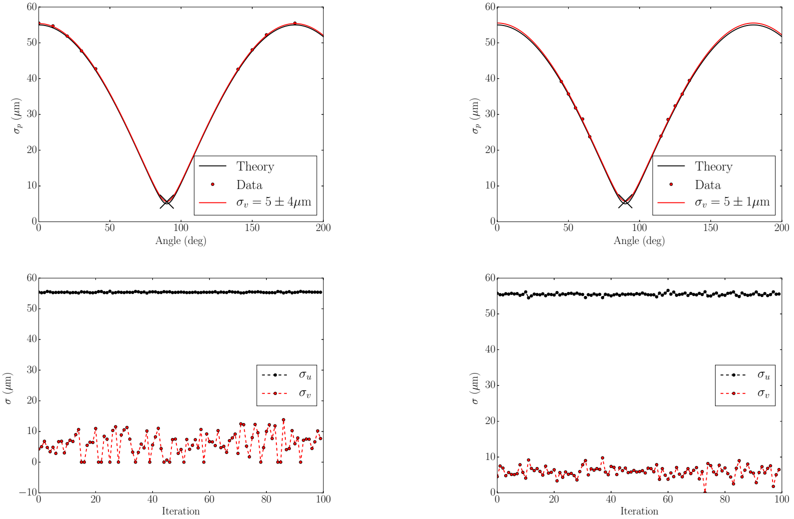

More in general...

Assuming that the beam shape can be approximated by an ellipse, it is not needed to measure the smallest beam size.

The resolution of uni-dimensional measurements can be improved.

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- X-Ray Interferometry
- Diffraction Radiation
- Wire (scan)
- ???

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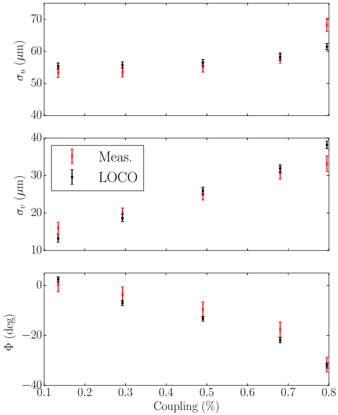
- ???

Many thanks to U. Iriso for the discussions and the diagnostics community for the mutual help

Backup Slides

Comparison with LOCO

A LOCO was applied at each coupling. The beam sizes and the tilt at for each settings has been extracted.



Beam Tomography