Limitations and Solutions of Beam Size Measurements via Interferometry at ALBA

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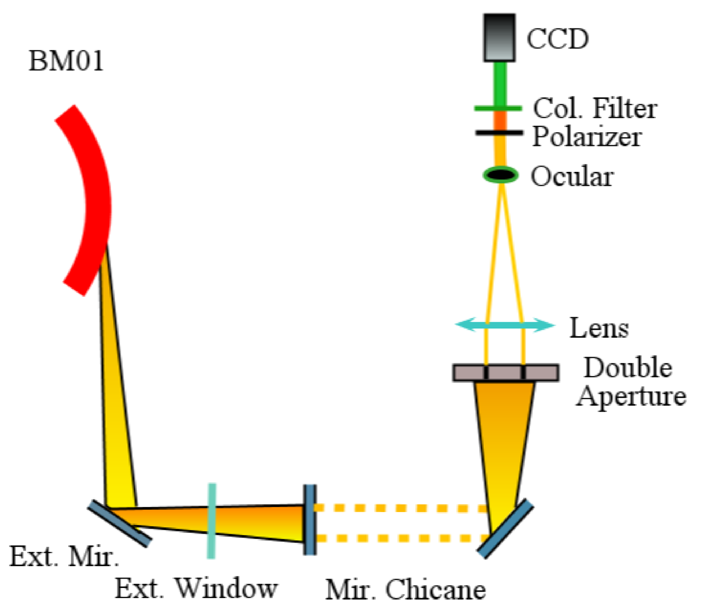
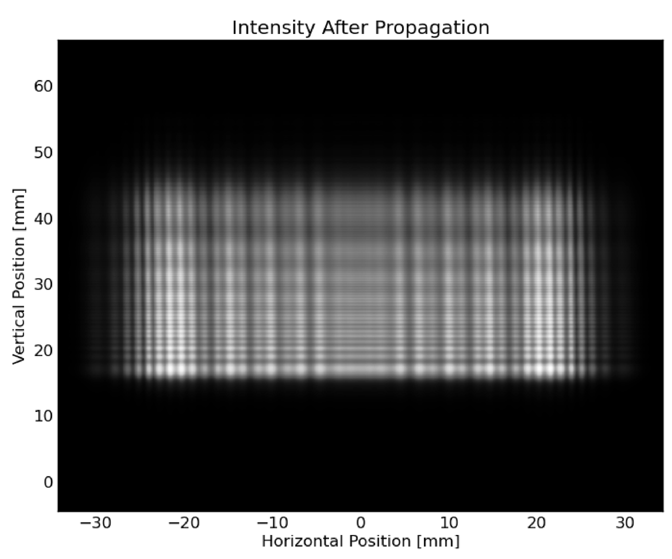
Introduction



ALBA is a 3 GeV third generation synchrotron light source operative for users since 2012.
Due to the machine small emittance it is not possible to measure the beam size by using a simple imaging system because of the diffraction limit.
After two years, interferometry is a reliable technique to measure the beam size at the ALBA storage ring. The diagnostic beamline Xanadu has been updated, analyzed and optimized to achieve good horizontal and vertical results using the this technique. Several limitations due to the beamline layout have been overcome theoretically and practically.

Fraunhofer Diffraction

The footprint of the light reaching Xanadu is strongly affected from Fraunhofer diffraction, due to the photon shutter and the extraction mirror. When trying to perform interferometry, the use of long rectangular slits allows the selection of a large number of Fraunhofer fringes.
The relative phase of these fringes is not necessarily the same and this provokes a modification in the interferogram that leads to a loss of contrast.



Solution

A solution to this problem was found by using pinholes instead of slits

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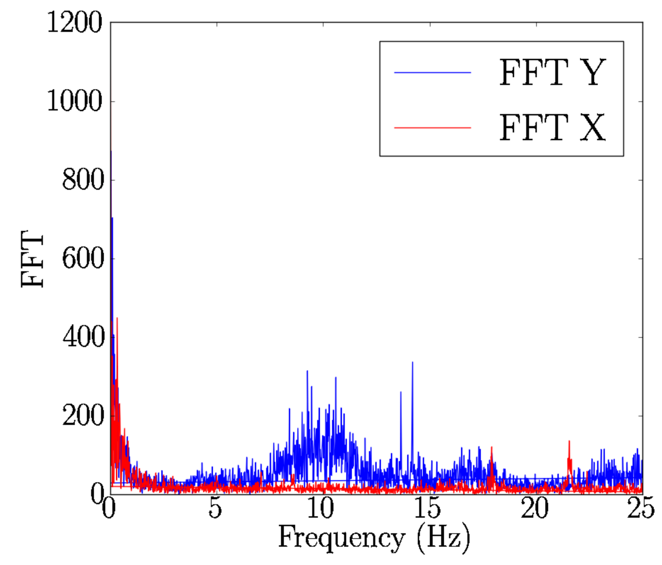
Adjustment of the theoretical formula:

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

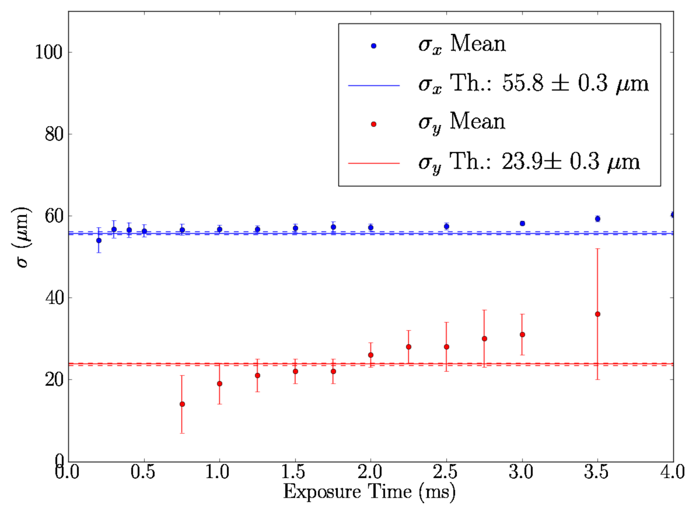
Vibrations



Almost the whole beamline is **in-air**. This originates vibration in the optical components, which are sensible to air turbulence, provoking changes in the interferogram characteristics and a rigid displacement of the centroid of the image. The overall effect is a lose of contrast affecting the beam size measurements.

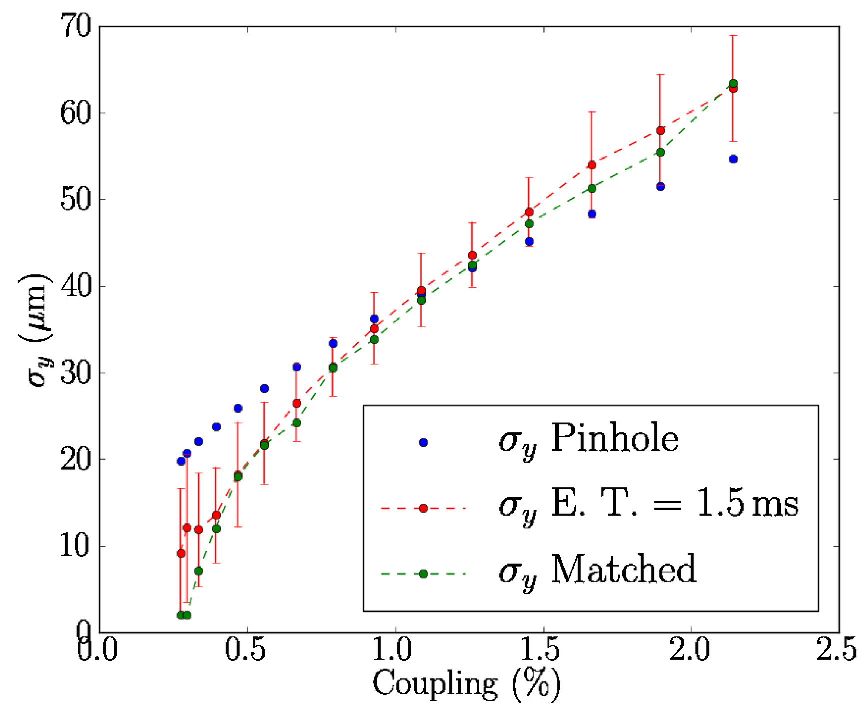
Solution

An intuitive and convenient way to reduce the effect due to the beamline vibrations and the air turbulences is the reduction of the exposure time of the CCD camera, which reduces the number of oscillations during the image acquisition.

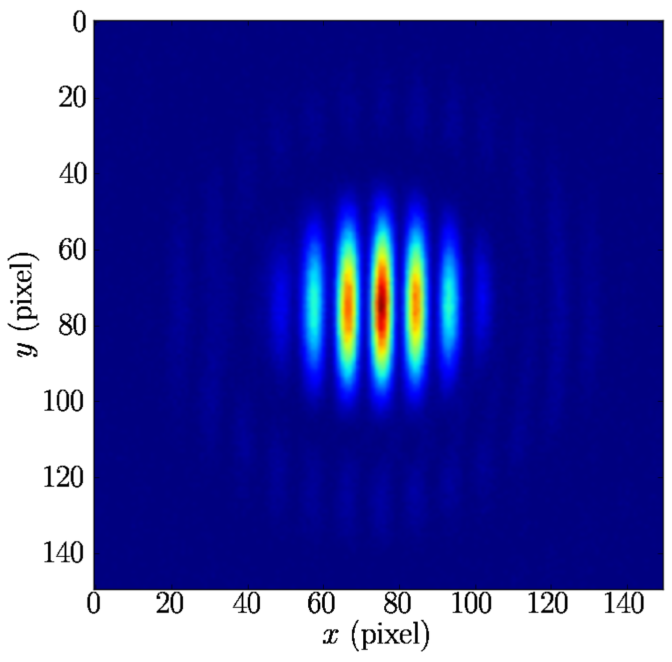


Vertical Beam Size Measure: Coupling Scan

To prove that the vertical interferometry beam size measurements ($\sigma_y \simeq 25\mu m$) are effective, scans of the beam coupling are performed. Varying the current in the skew magnets, the beam coupling varies as well as the vertical beam size.



Horizontal Measurements: Depth of Field

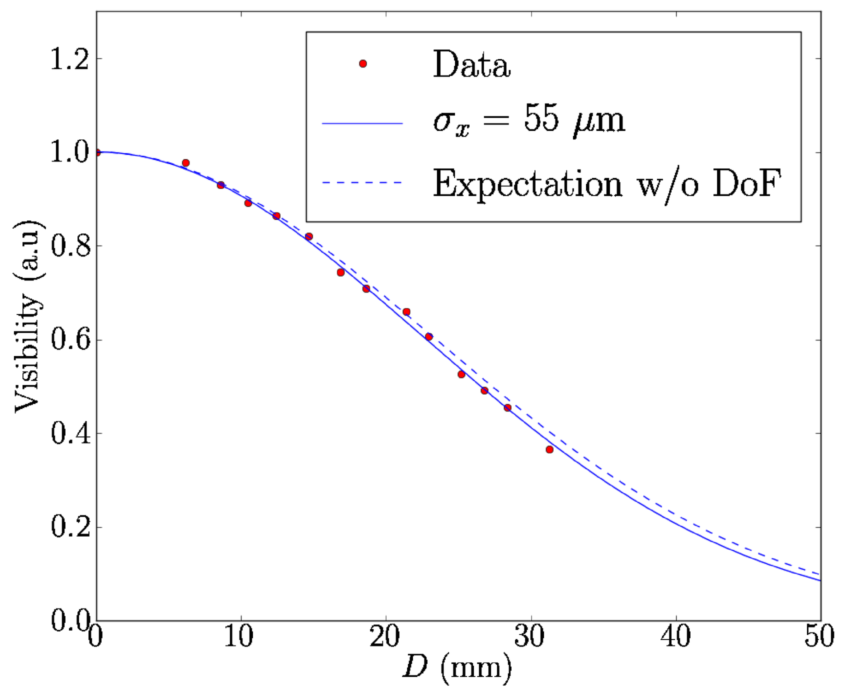


Because this aperture, the light reaching Xanadu is creating a blurring of the image due to the curvature of the trajectory. The bending radius of the magnet producing the radiation is 7.05 m, that leads to blurring of $\pm 13\mu m$. This incoherent effect can be observed when measuring the horizontal beam size using the pinholes distance scan.

$$V = e^{-2\pi \frac{\sigma^2 D^2}{\lambda^2 L^2}}$$

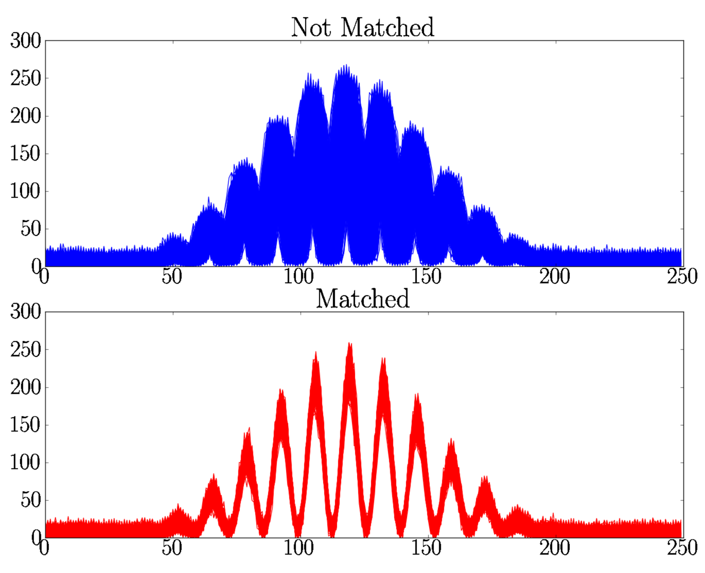
$$\Downarrow$$

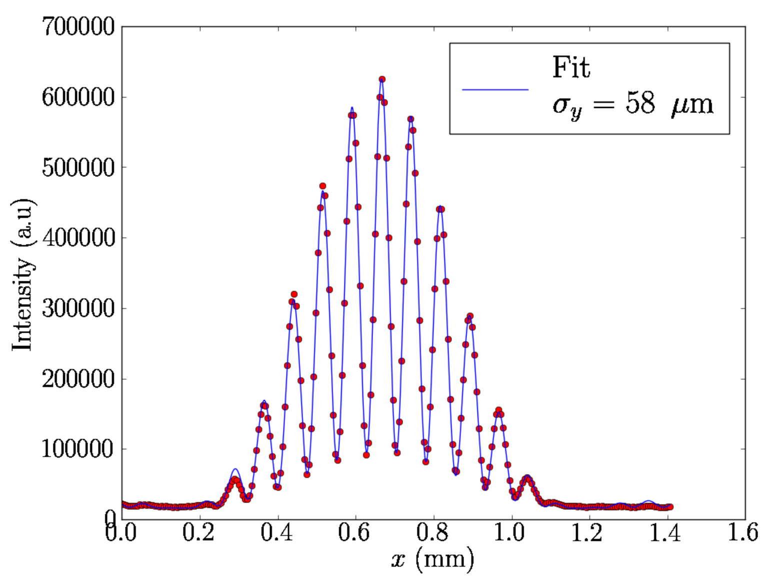
$$V = e^{-2\pi \frac{\sigma^2 D^2}{\lambda^2 L^2} + \sigma_{DoF}^2}$$

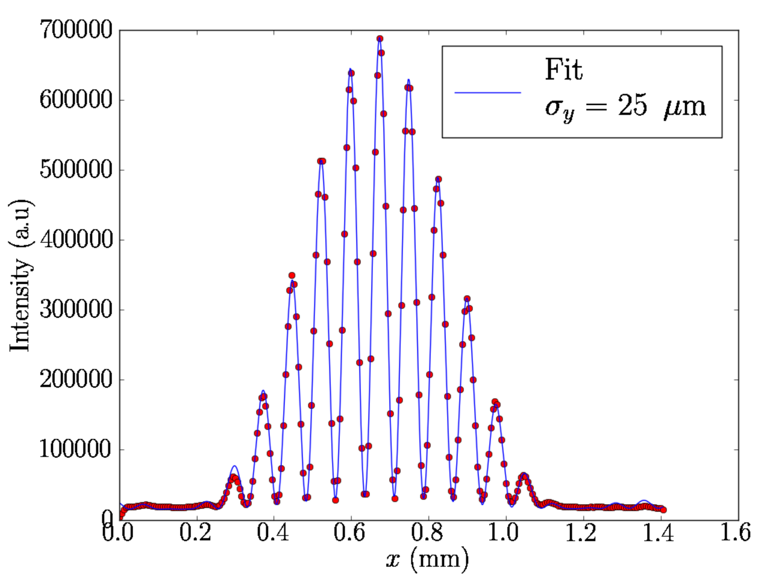


Matching Algorithm

In order to keep the exposure time as low as possible, an algorithm to superimpose several interferograms was implemented. The images are shifted until the interferograms can all be superimposed with the proper centroid match.







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