Electron Beam Size Measurements Using the Heterodyne Near Field Speckles at ALBA

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Abstract

Experiments using the Heterodyne Near Field Speckle method (HNFS) have been performed at ALBA to characterize the spatial coherence of the synchrotron radiation, with the ultimate goal of measuring both the horizontal and vertical beam sizes. The HNFS technique consists on the analysis of the interference of the radiation scattered by a colloidal suspension of nanoparticles with the synchrotron radiation, which in this case corresponds to the hard X-rays (12 keV) produced by the in-vacuum undulator of the NCD-Sweet beamline. This paper describes the fundamentals of the technique, possible limitations, and shows the first experimental results changing the beam coupling of the storage ring.

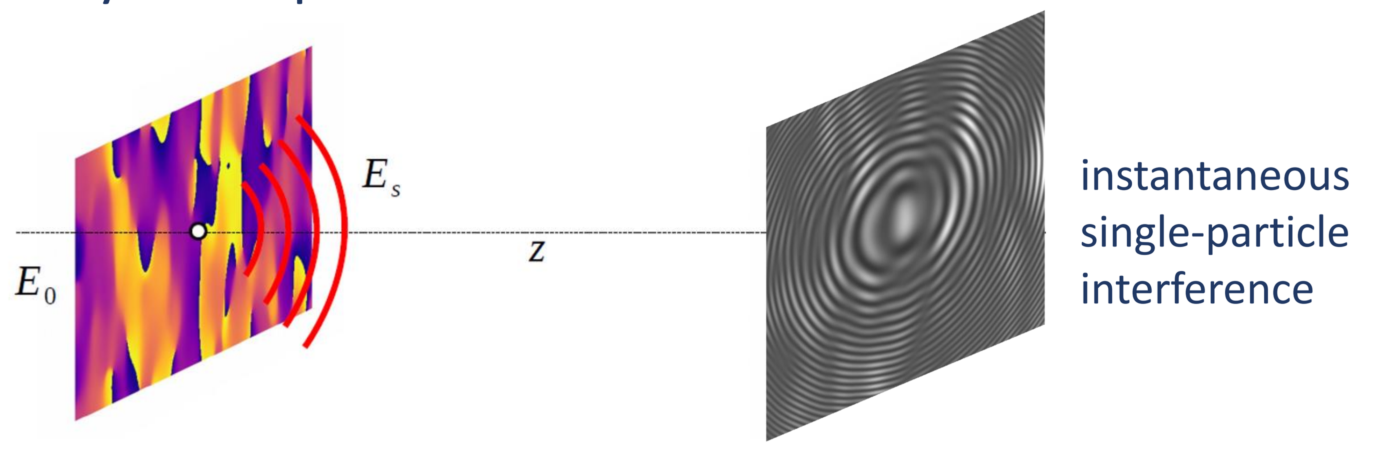
The HNFS technique in cartoons

- For interferometric beam size measurements, the Complex Coherence Factor (CCF) of the radiation is the quantity of interest:

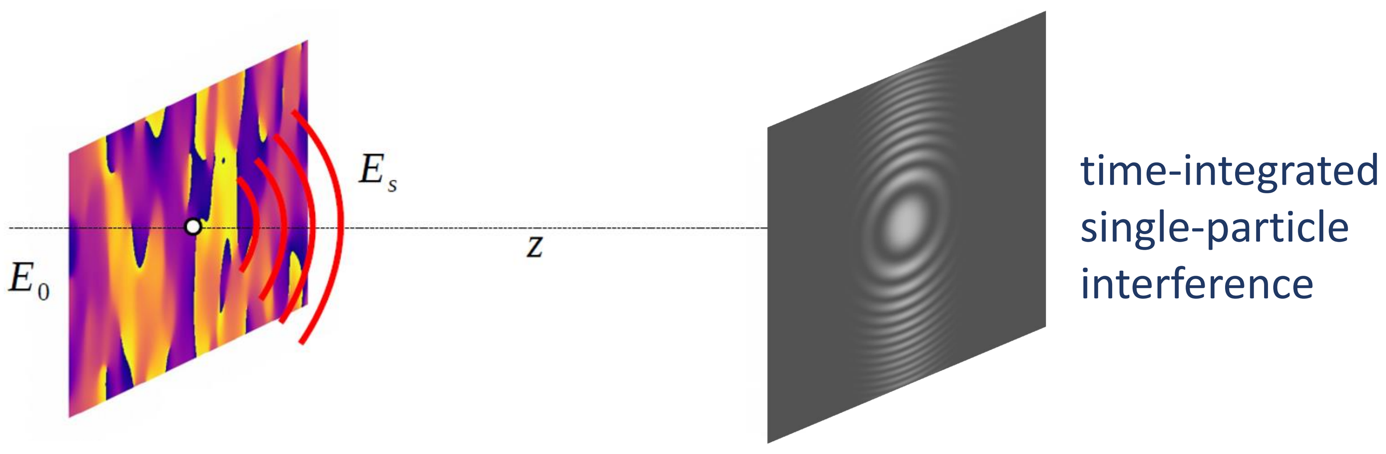
$$\mu(\Delta\vec{r}) = \frac{\langle E(\vec{r})E^*(\vec{r}+\Delta\vec{r})\rangle}{\sqrt{\langle I(\vec{r})\rangle\langle I(\vec{r}+\Delta\vec{r})\rangle}}$$

The electron beam size is then inferred by applying the Van Cittert – Zernike theorem.

- Scattering from a single particle represents the paradigmatic layout to probe the 2D CCF:

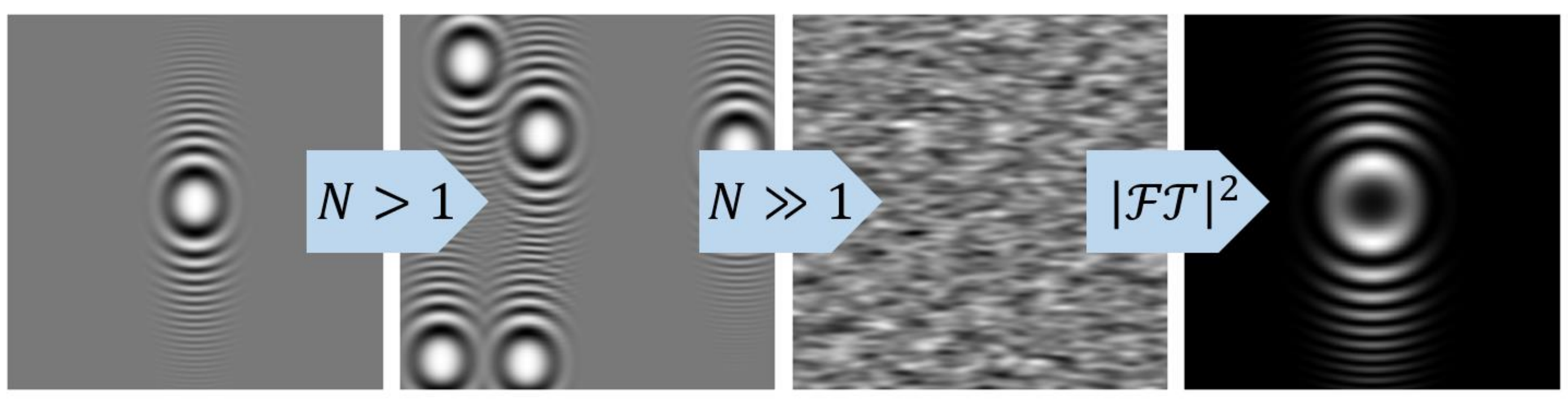


$$I_{inst} = |E_0|^2 + 2\mathcal{Re}\{E_0 E_s^*\} + |E_s|^2$$



$$I = \langle I_{inst}\rangle = I_0\left\{1 + |\mu(\Delta\vec{r})|\ \cos\left(\frac{k\Delta r^2}{2z}\right)\right\}$$

- With many particles, the spatial power spectrum of heterodyne speckles directly provides the 2D CCF:

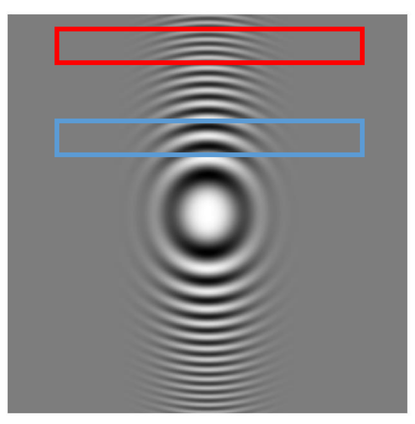


$$I(\vec{q},z) = T(q,z)\,|\mu[\Delta\vec{r}(\vec{q},z)]|^2$$

$$T(q,z) = 2\sin\left(\frac{zq^2}{2k}\right)$$ Talbot Transfer Function (TTF)

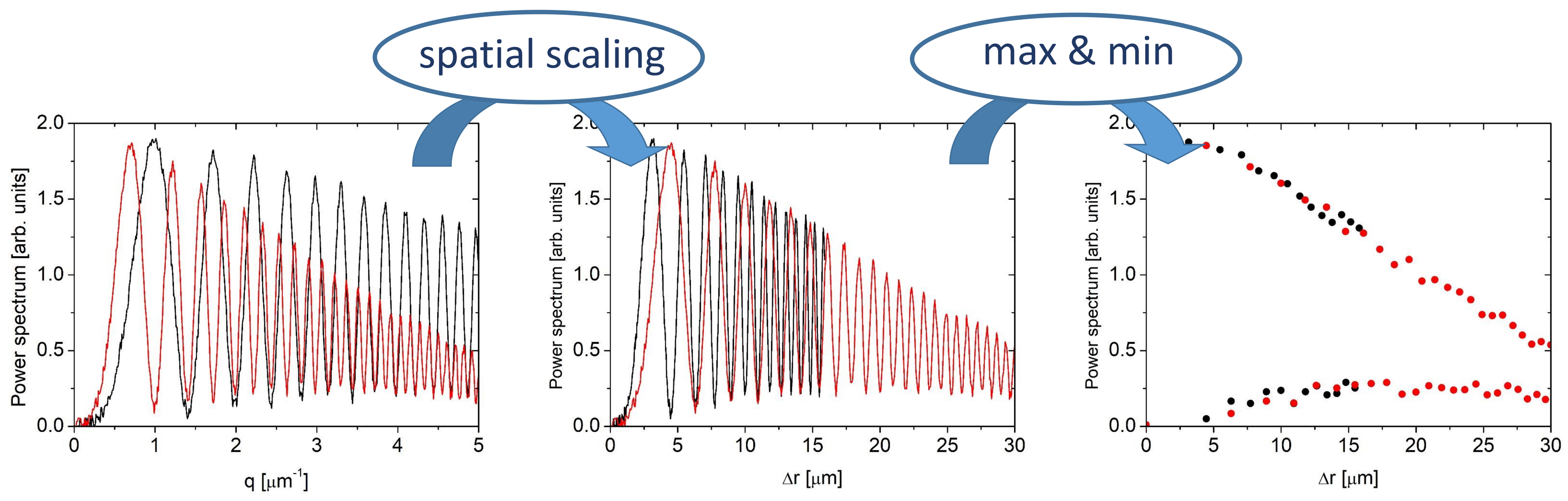
spatial scaling

$$\Delta\vec{r}(\vec{q},z) = z\frac{\vec{q}}{k}$$



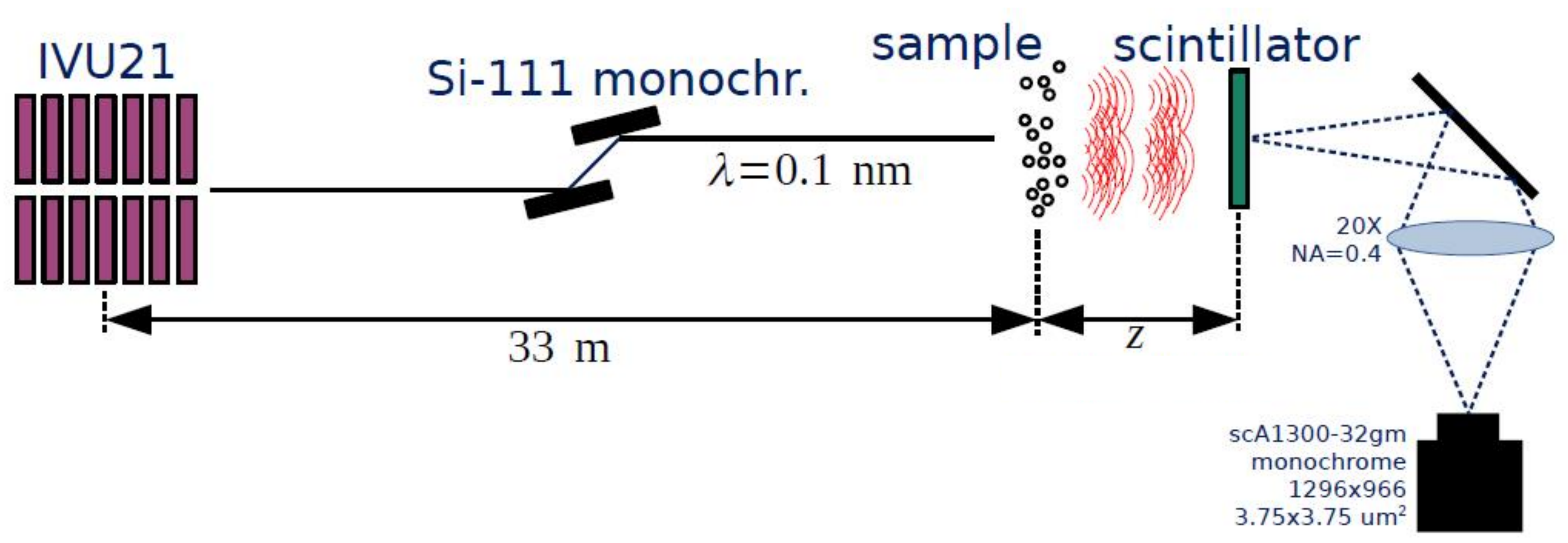
- Since the CCF of radiation is unique, data at different z must superimpose upon the spatial scaling (spatial master curve).

Example of data reduction and visualization



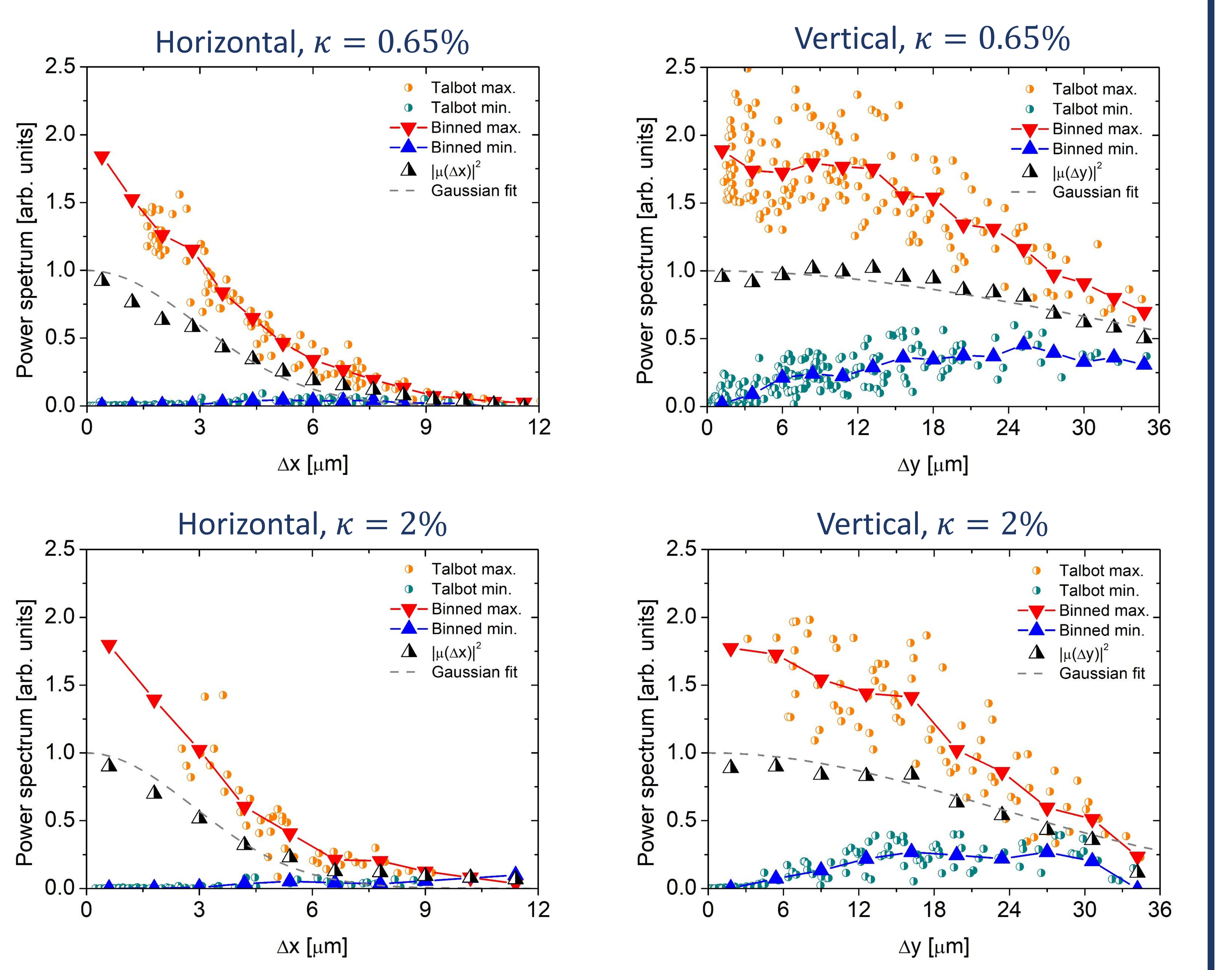
Simulated profiles for two different values of z. The CCF of radiation is obtained by averaging Talbot maxima and minima.

Experimental setup at NCD-Sweet beamline (ALBA)



Experiments

In order to validate the technique, we performed two different sets of measurements for two different values of the beam coupling: $\kappa = 0.65\%$ and $\kappa = 2\%$.



coupling		σ_{coh} [μm]	σ_{beam} [μm]	
0.65%	(hor)	7.4 ± 0.4	125 ± 5	(130)
	(ver)	83 ± 7	11 ± 1	(6.3)
2%	(hor)	7.1 ± 0.5	131 ± 10	(129)
	(ver)	57 ± 5	16 ± 2	(10.7)

open questions →

- VCZ applicability?
- Larger effective source?
- Coherence degradation?

References:

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