ESRF	**Experiment title:** PSF assessment and reduction in synchrotron 3D microtomography	**Experiment number:** MI-712
Beamline: BM05	**Date of experiment:** from: 30-APR-04 to: 02-MAY-04	**Date of report:** 28-FEB-05
Shifts:	**Local contact(s):** Joanna Hoszowska	*Received at ESRF:*

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Report:

Background

Severe artefacts has been observed in 3D images reconstructed using standard tomographic methods on ID19 beamline. White and black alternated streaks are present when the investigated specimen contains alignments of dense inclusions (e.g. the tungsten cores of aligned reinforcement fibres into a titanium/aluminium/vanadium matrix) (see **Fig. 1**). As a consequence, the reconstruction is no longer a quantitative map of the linear attenuation distribution in the sample.

When a polychromatic beam is considered, beam hardening is commonly accepted to generate this kind of artefacts, usually called “cupping effect”, between higher photon attenuation structures.

Nevertheless, a preliminary study demonstrated by simulation that the point spread function (PSF) of the FReLoN (Fast Read-out Low Noise) camera based detector used at ID19 could also be responsible of similar streaks [3].

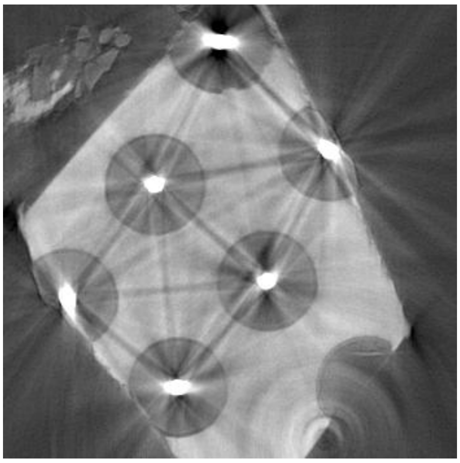

Figure 1: Result of a tomographic scan performed on BM05 beamline

Method

The relative importance of the both possible causes considered above has to be determined.

The camera spatial response should be accurately estimated in order to reduce its effects. Although the principle of the PSF assessment is simple and well known, it is not straightforward at high spatial resolution. An oriented monocrystalline gallium arsenide plate is imaged, so that an oriented edge profile can be extracted with enough samples in the intensity fall. This corresponds to the edge spread function (ESF). The modulation transfer function (MTF), corresponding to the Fourier transform of the PSF, is to be determined using the Fourier transform of the derivative of the ESF [1].

In practice, the PSF is similar to a low-pass convolution kernel. Deconvolution methods have been being investigated in order to reduce this consequence. Although direct inverse filtering is the most straightforward method to achieve, it has not been implemented because it increases high frequencies without taking into account the noise present into the images. Thus, other methods, such as Wiener filtering [2], are considered.

Results

To date, the PSF of the FReLoN camera used at BM05 has been estimated using the analytic model of the derivative of an orthogonal profile of an edge's intensity (see left-hand side image in **Fig. 2**) as follows:

$$\text{edge}_\theta(r) \;=\; d + \frac{1}{f}\,\text{erf}\left(\frac{r+a}{e}\right) + \frac{1}{c}\,\arctan\left(\frac{r+a}{b}\right) \tag{1}$$

where θ is the orientation of the profile, and r represents the abscissa in pixels along the sampled profile. This response is directly related to the edge spread function, also called ESF. Thus, we get the corresponding line spread function (LSF) along the direction θ by differentiation:

$$\text{LSF}_\theta(r) \;=\; \left(\frac{2}{\sqrt{\pi}ef}\exp\left(-\frac{r^2}{e^2}\right) + \frac{1}{bc}\left(1+\frac{r^2}{b^2}\right)^{-1}\right)\left(\frac{2}{f}+\frac{\pi}{c}\right)^{-1}. \tag{2}$$

The LSF is then optimized using a simple gradient-descent technique (see center image in **Fig. 2**). The right-hand side image in **Fig. 2** shows a profile of a projection of the GaAs plate after restoration by Wiener filter using the optimized LSF.

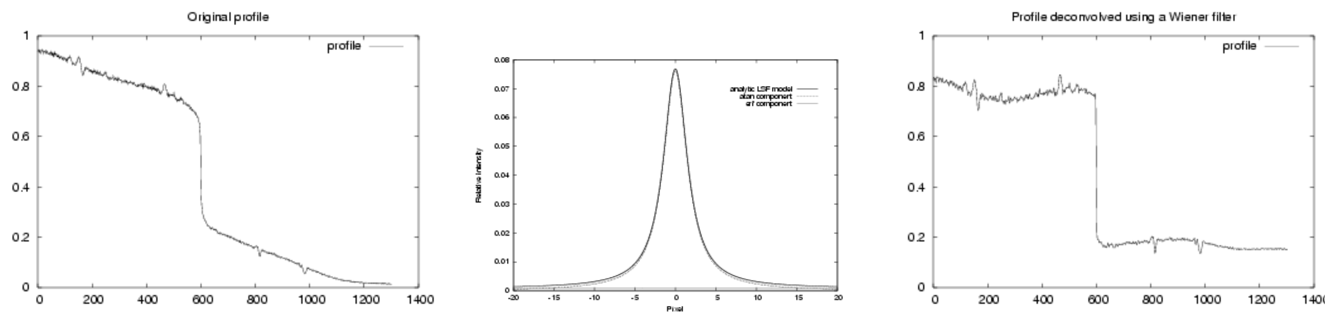

Figure 2: (from left to right) i) original profile, ii) optimized LSF and iii) profile restored using Wiener filtering.

Conclusion

These results justify a larger study, currently underway, to address the feasibility of incorporating a software solution to automatically attenuate artefacts due to secondary radiations and the detector impulse response.

References

[1] EN 13068-1. Radioscopic testing - part 1: Quantitative measurement of imaging properties. European Committee for Standardization, 2000.

[2] Rafael C. Gonzalez and Richard E. Woods. *Digital Image Processing*. Prentice Hill, 2nd edition, 2001.

[3] Franck P. Vidal, Jean M. Létang, Gilles Peix, and Peter Cloetens. Investigation of artefact sources in synchrotron microtomography via virtual X-ray imaging. *Nuclear Instruments and Methods in Physics Research B*, 2005. to be published.