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OPTIMIZATION OF X-RAY DYNAMIC DEFECTOSCOPY USING MEDIPIX-2 FOR HIGH FRAME RATE READ-OUT

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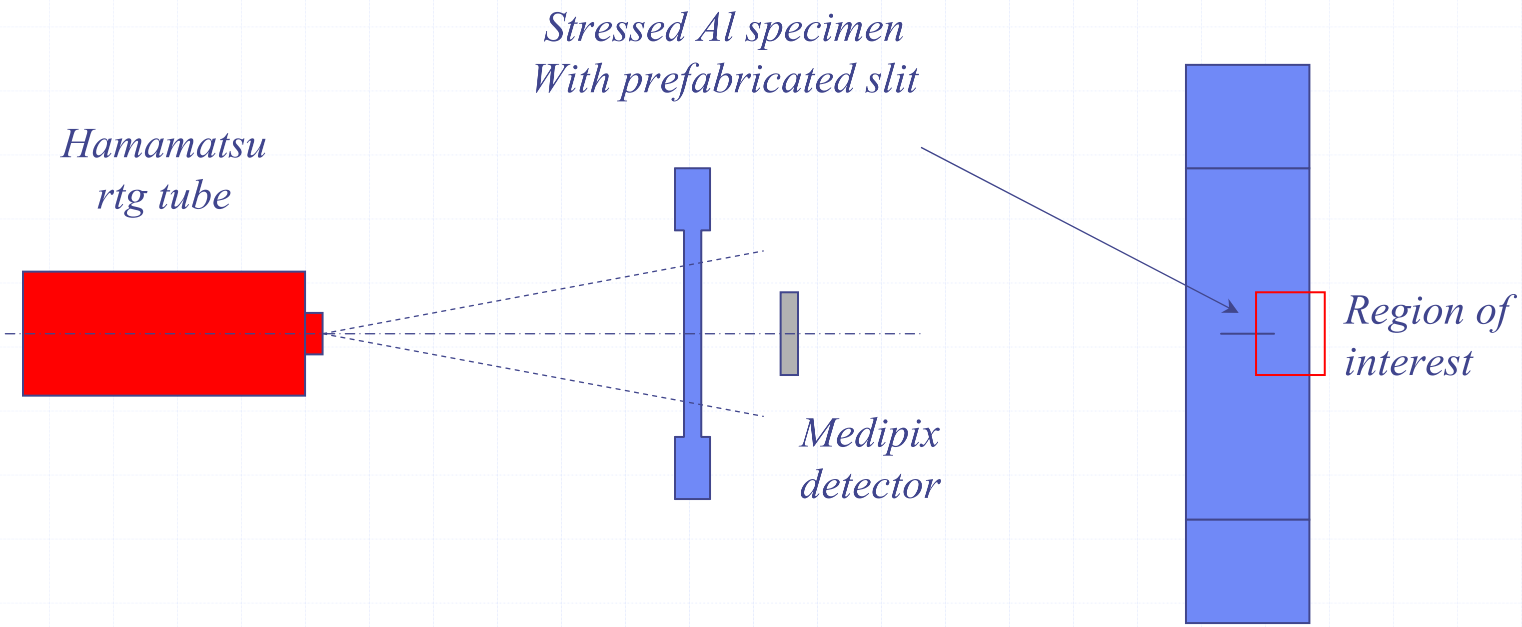
Outline

- X-ray Dynamic Defectoscopy
- Recent status
- Parameters influencing XRDD resolution
- Tuning of selected parameters
- Conclusions

The X-Ray Dynamic Defectoscopy

- Standard X-ray defectoscopy is already widely used diagnostic method.
- Stressed ductile materials (aluminum alloy for instance) are damaged by loading dependent generation and development of voids.
- Using high performance semiconductor pixel detectors (Medipix) it is possible to observe time dependent (dynamic) structure changes in loaded material.

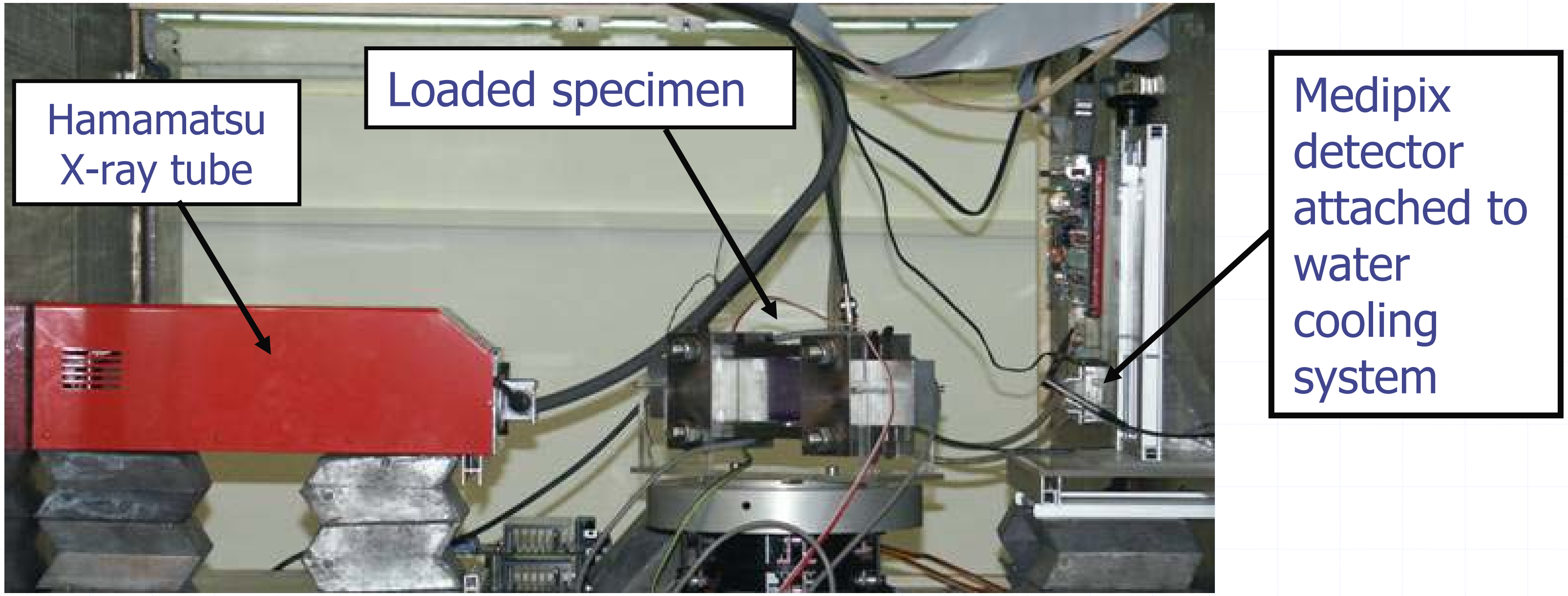
=> X-Ray Dynamic Defectoscopy



XRDD principles

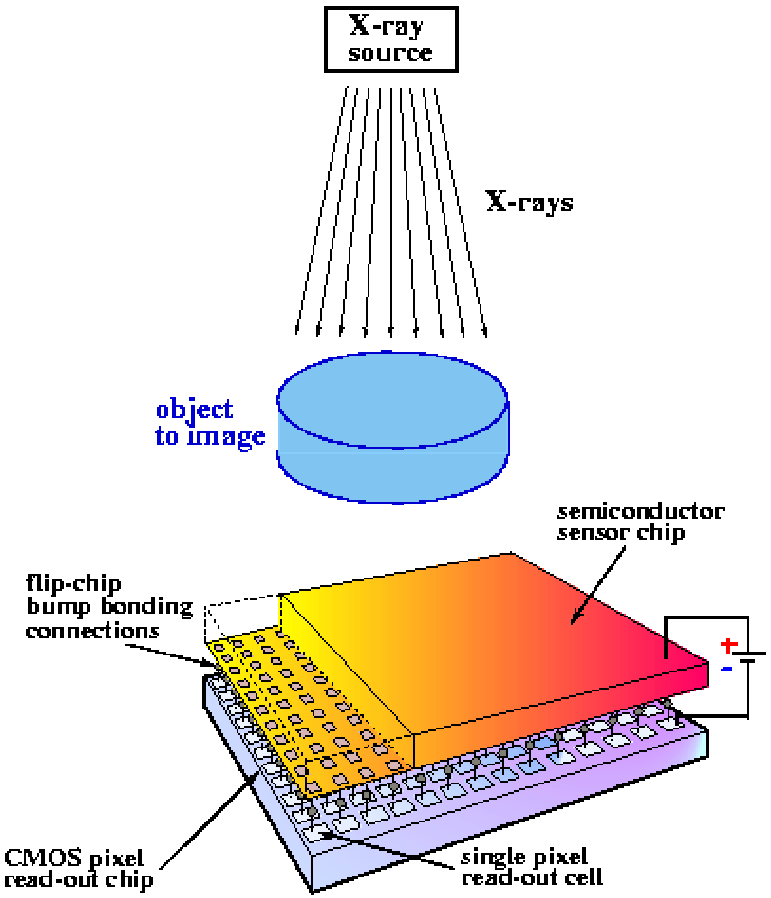
The XRDD measurement is based on attenuation of an X-ray beam passing through the specimen.

This is proportional to an effective thickness reduction by the volume fraction of damage and by contraction.



Experimental setup for XRDD

MEDIPIX-1 detector

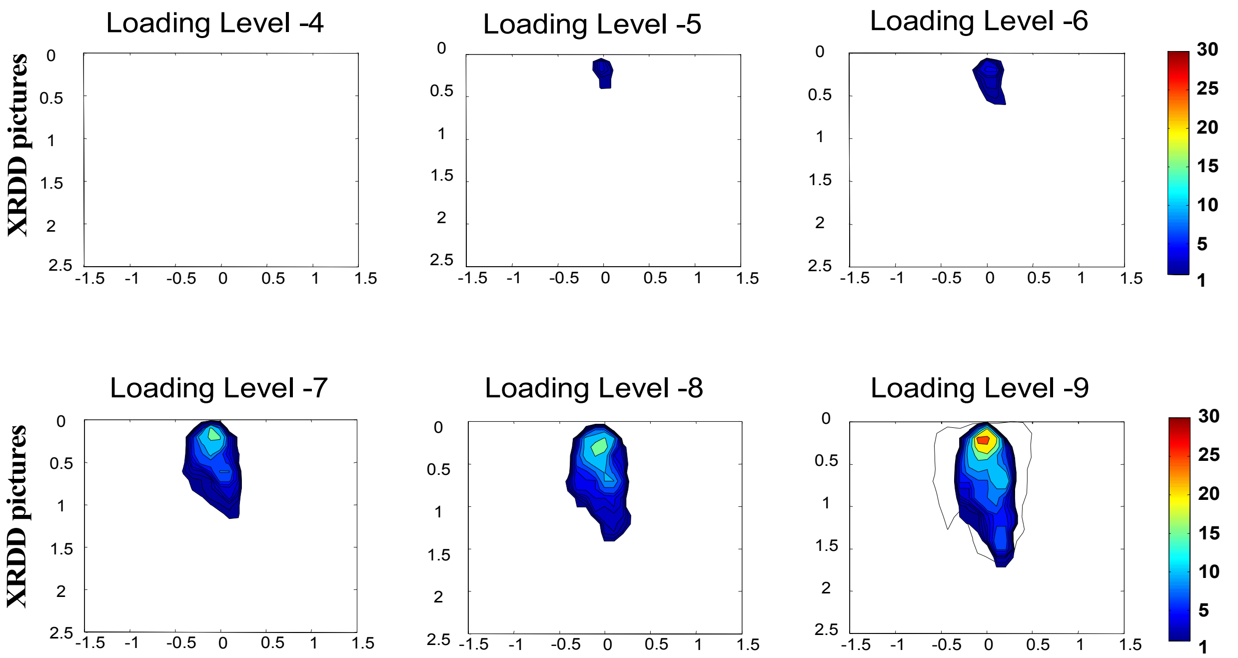


A single photon counting Medipix-2 chip is formed by 256x256 pixels of 55 μm pitch (14x14mm chip size).

http://medipix.web.cern.ch/MEDIPIX/

Recent status of our XRDD experiments

- Still working in semi-static regime. Specimen is loaded gradually and the roentgenogram is taken at each loading level.
- We reached 10 μm accuracy in measurement of the effective thickness reduction (along the X-ray beam direction) of 5 mm thick Al sample for 10x30sec exposures using Medipix-1 detector.
- Such accuracy allows to measure material damage development.



Developing of the damage zone in the loaded specimen

Analyzed parameters influencing XRDD resolution

Observation of time dependent processes require optimization of XRDD settings for minimization of exposure time with respect to required resolution.

Resolution of the XRDD method for thickness measurement depends on:

1. The attenuation of X-ray beam by the observed specimen and on the fraction of transmitted photons registered by the Medipix detector.
   - Spectrum of the X-ray tube at its actual voltage and current used.
   - The efficiency of the Medipix-2 device at the actual spectrum.

2. Flat field correction

   It is necessary to pay attention to various hardening of X-ray beam due to various thickness of the observed object.
   - *Standard flat field correction*
   - *Direct Thickness Calibration*

X-ray tube Voltage and Current

As a source of X-rays, we used a Hamamatsu microfocus X-ray source L8601 with focal spot size 5 μm (tungsten anode).

Maximal available power capacity of X-ray tube has been used for each operation point.

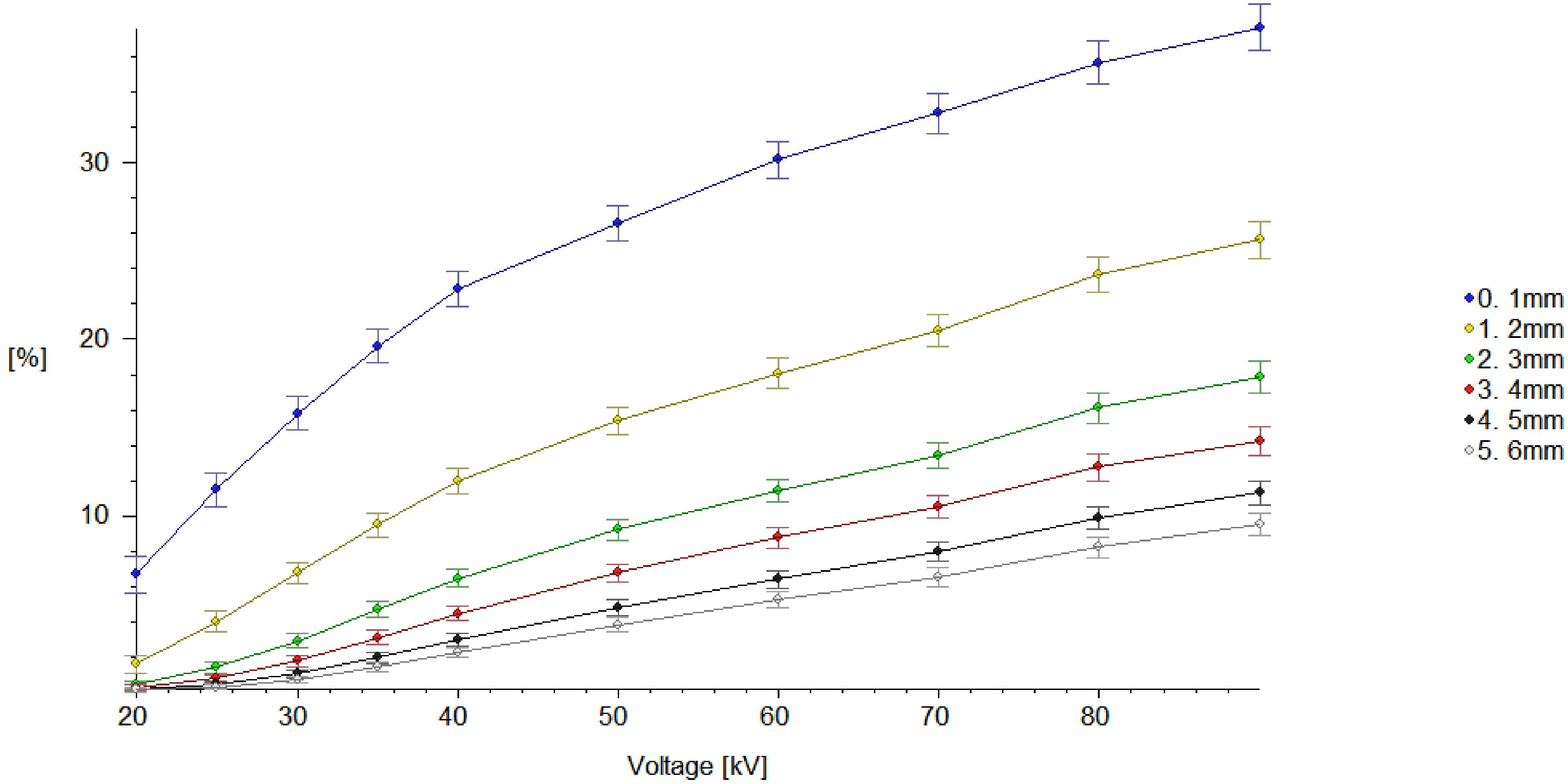
Transmission of X-ray beam passed through Al plate was measured by the Medipix-2 detector at 10 voltage and current levels (see table on the right).

Signal to noise ratio (SNR) has been estimated at each tube working point for each plate thickness (1-6 mm).

These results served as a base for calculation of experimental time needed for required XRDD precision.

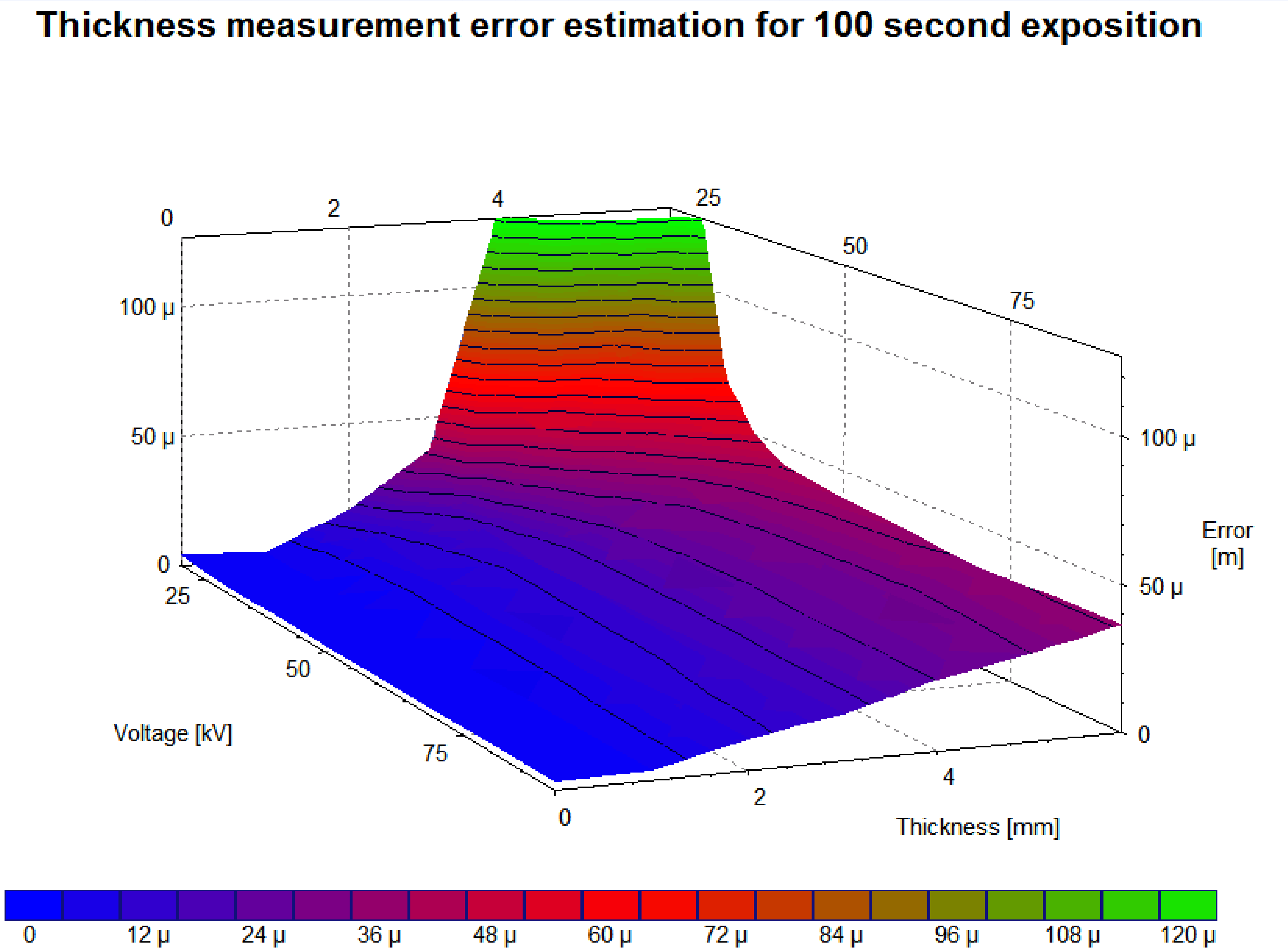
Voltage [kV]	**Current** [μA]	**Power** [W]
20	215	4.3
25	255	6.375
30	255	7.65
35	255	8.925
40	255	10.2
50	204	10.2
60	169	10.14
70	144	10.08
80	122	9.76
90	111	9.99

Measured transmission

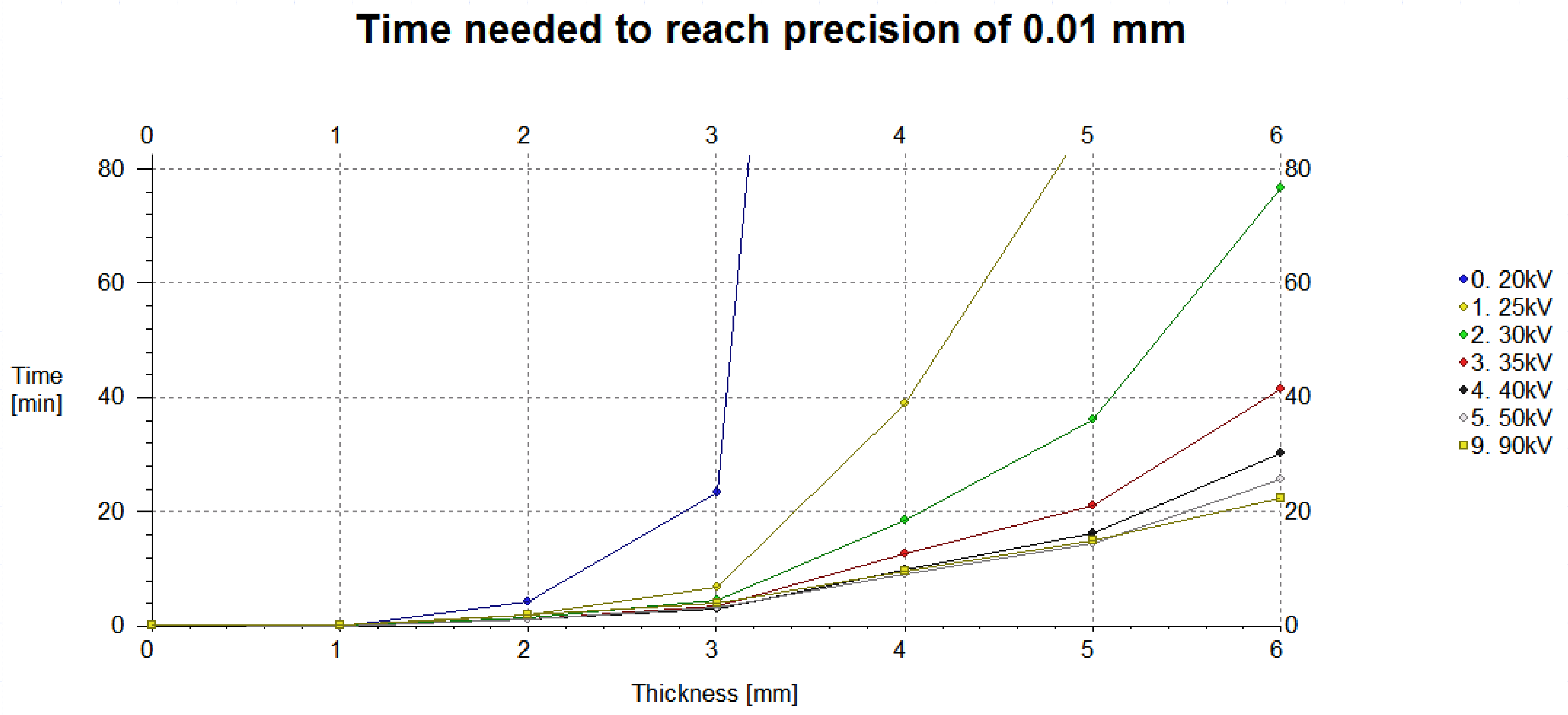


Error bars are defined by poisson law.

Error estimation for 100 sec exposure



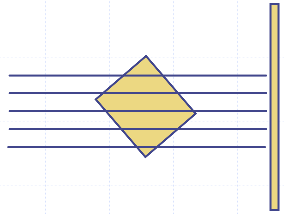
Exposure time estimation



Flat field correction: Direct Thickness Calibration

Standard flat field correction produced poor quality when thickness variations are significant (we observed 30% thickness reduction in our experiments).

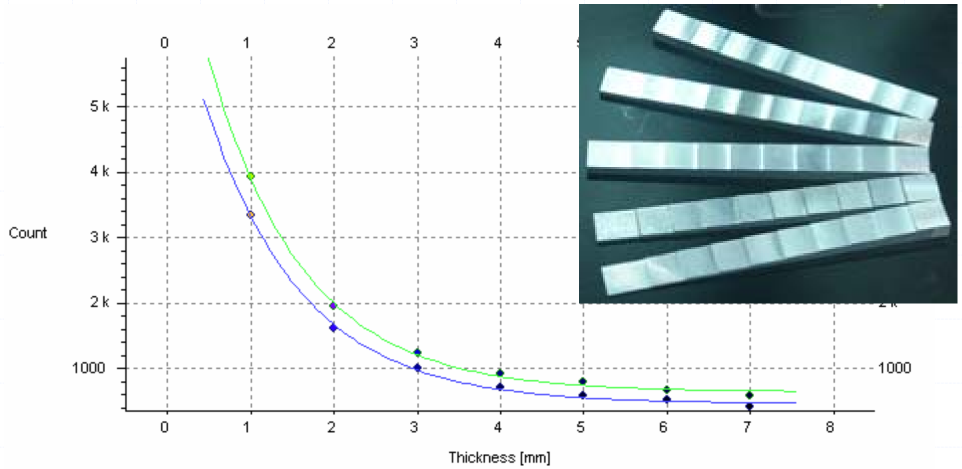
Thickness variations are too large => spectrum differs from pixel to pixel => standard flat field correction does not work.



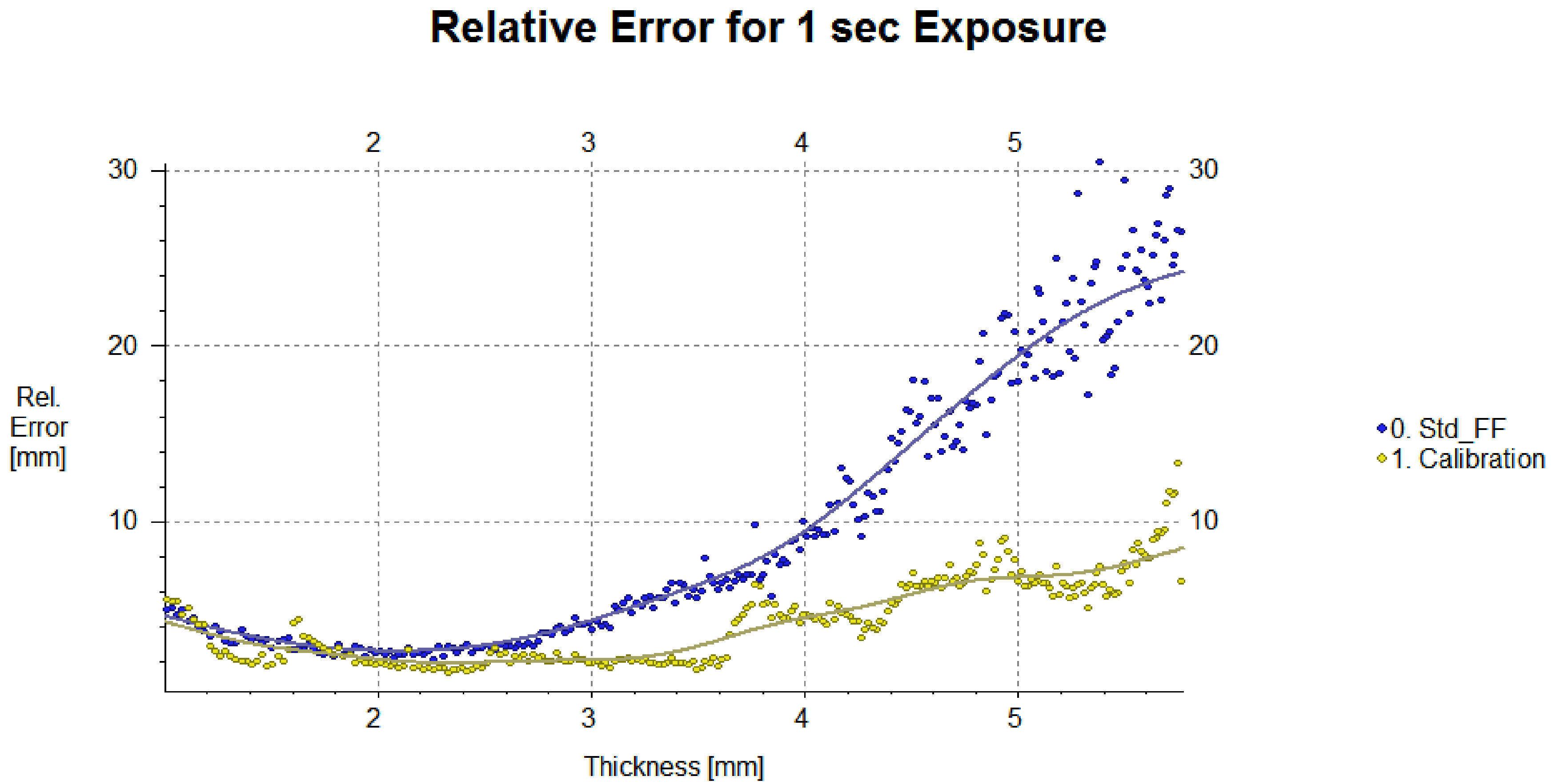
Method of Direct Thickness Calibration for Each Pixel has been used

1. Dependence of count rate on a absorber thickness is measured for each pixel (works for any material with equivalent attenuation).
2. Experimental data for unknown specimen are transform directly into thickness.

Dependence of count rate on thickness of Al sample for two arbitrary detector pixels.



Comparison between standard flat field correction and Direct thickness callibration



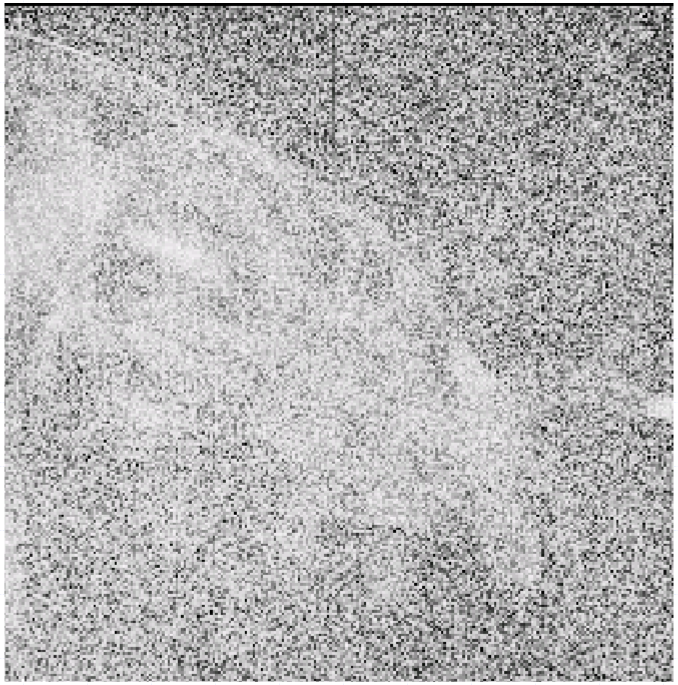
Standard flat field correction has been done using 2 mm thick standard.

Illustration of Direct Thickness Calibration

Ground beetle

Standard flat field correction

1. Acquired image



Very bad result - unusable

2. Standard flat field correction

Direct Thickness Calibration

2. Standard flat field correction

2. Direct Thickness Calibration

Conclusions

- Direct calibration of each individual pixel value to thickness of the absorber is possible and gives very good results.
- Time necessary for required XRDD thickness resolution of 1000 sec is still to long. We can reduce by:
  - Shorter distance between X-ray source and detector.
  - Use of superpixels (2x2 pixels for instance) for higher count of processed photons (it will reduce spatial resolution).
  - Reduction of sample thickness if it is possible.
  - Higher intensity of X-ray source (synchrotron X-ray source) if available.

Acknowledgement

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Illustration of attenuation equivalence for different materials