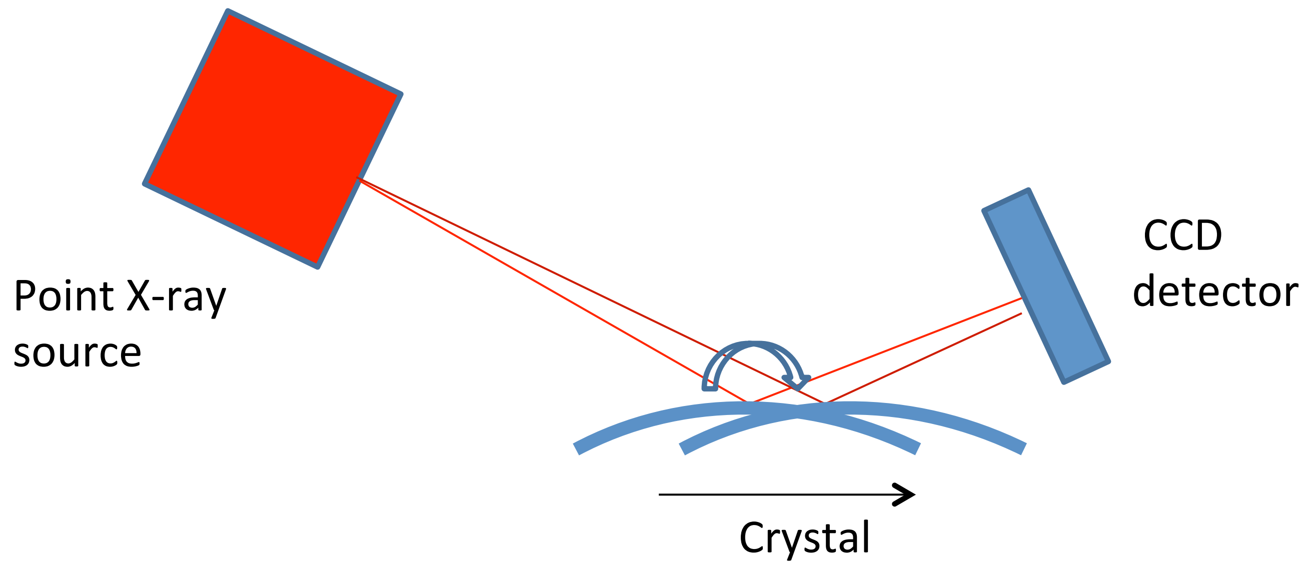
The laboratory X-ray characterization of a Bent Crystals

Stefan Płocieniak
Solar Physics Division
Space Research Center
Poland, Wrocław

Abstract

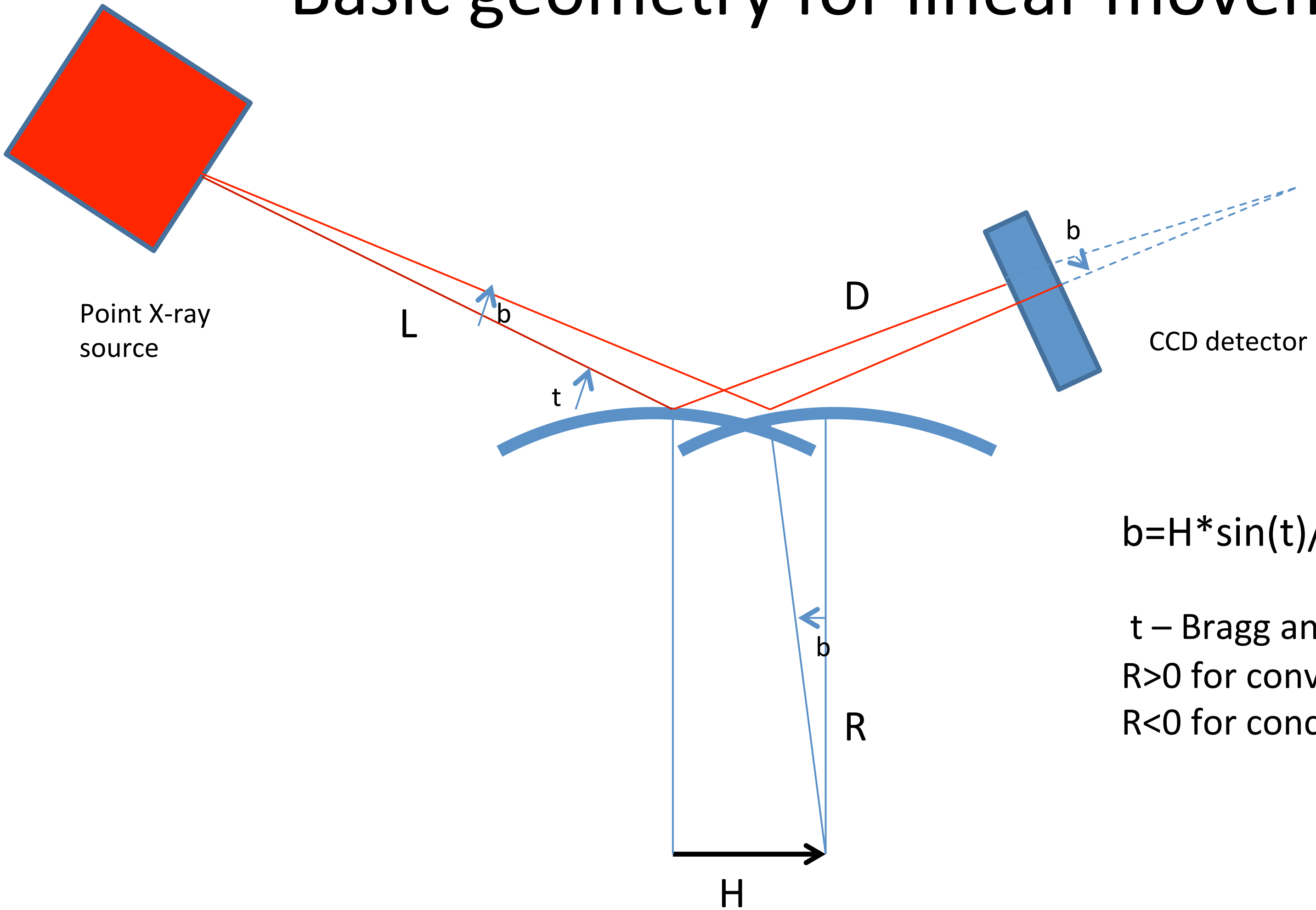
- Bent crystal real curvature was measured in laboratory by simple arrangement consisting of point X-ray source, movable tables and linear CCD as a X-ray detector. Rotational or linear movements were applied to the crystal. The Cu K moving lines were observed by CCD.
- Trajectories of the movements were calculated on the basis on geometry data. Then calculated trajectories were compared to observed data. Differences point at non perfect curvature.

Outline



Linear or rotational movements were applied to the crystal.
The point x-ray source should produce characteristic lines appropriated for experiment: for example Cu K lines.
The movements of crystal causes changes in place where diffracted X-rays are recorded by CCD.

Basic geometry for linear movement

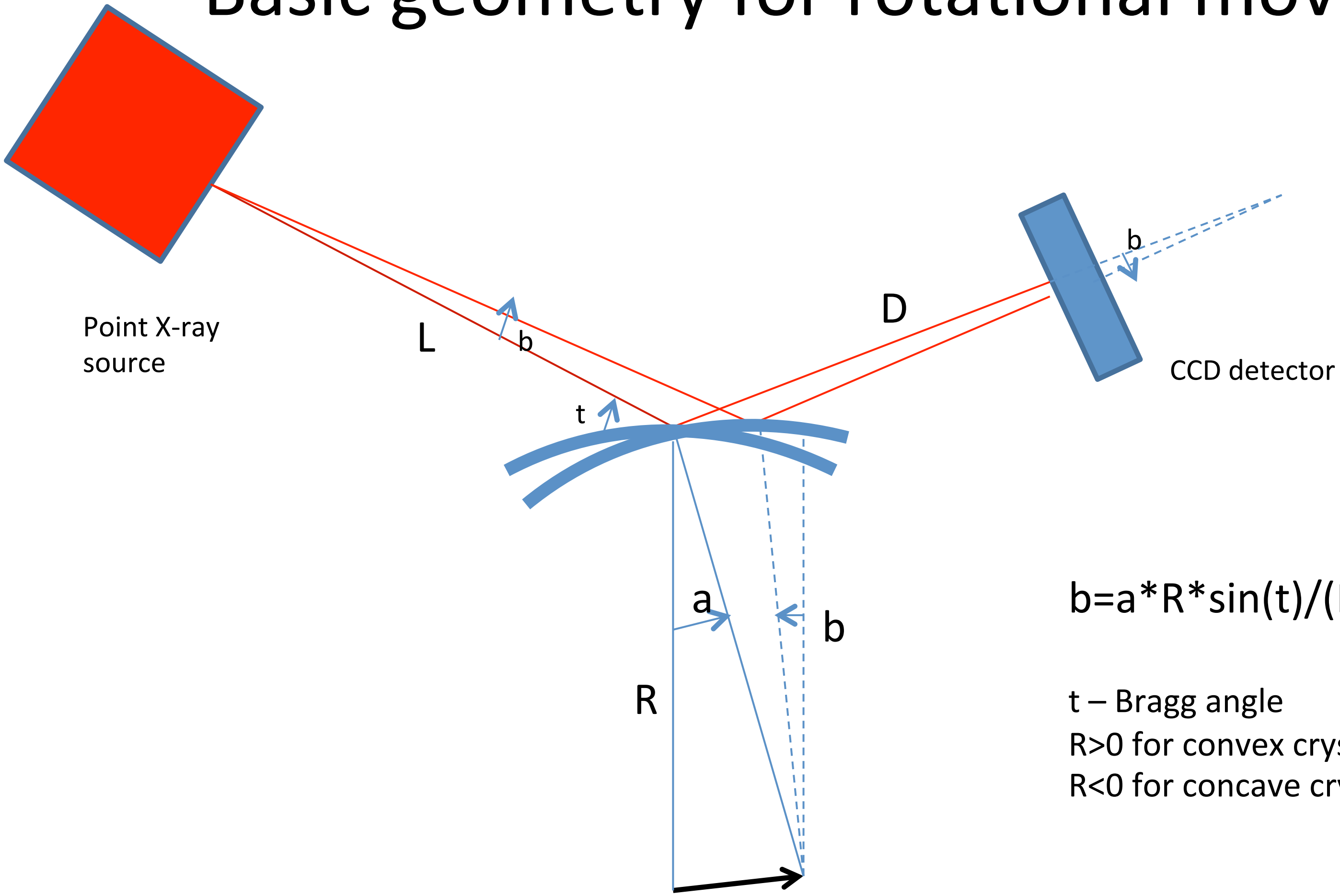


b=H*sin(t)/(L+R*sin(t))

t – Bragg angle
R>0 for convex crystals
R<0 for concave crystals

X-ray with specified wavelength is diffracted accordingly to Bragg law always at the angle „t”. After linear movement by distance „H” the diffracted ray must rotate by the angle „b” according to the approximated formula.

Basic geometry for rotational movement



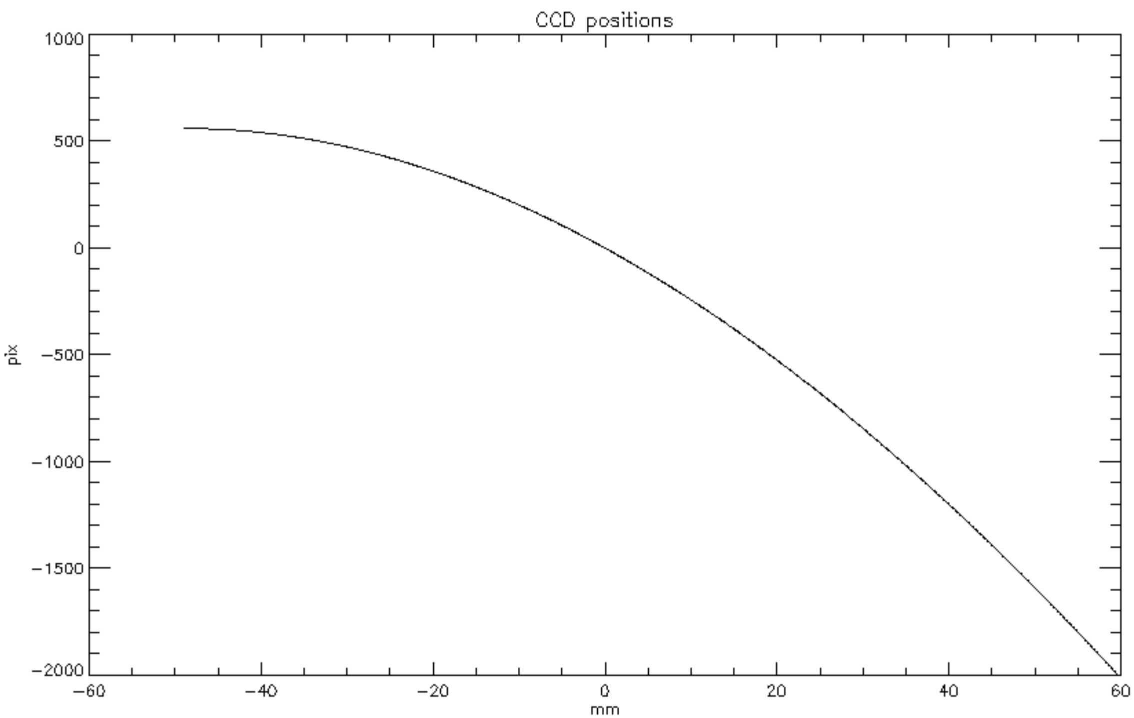
b=a*R*sin(t)/(R*sin(t)+L)

t – Bragg angle
R>0 for convex crystals
R<0 for concave crystals

X-ray with specified wavelength is diffracted accordingly to Bragg law always at the angle „t”. After rotating movement by angle „a” the diffracted ray must rotate by angle „b” according to the approximated formula.

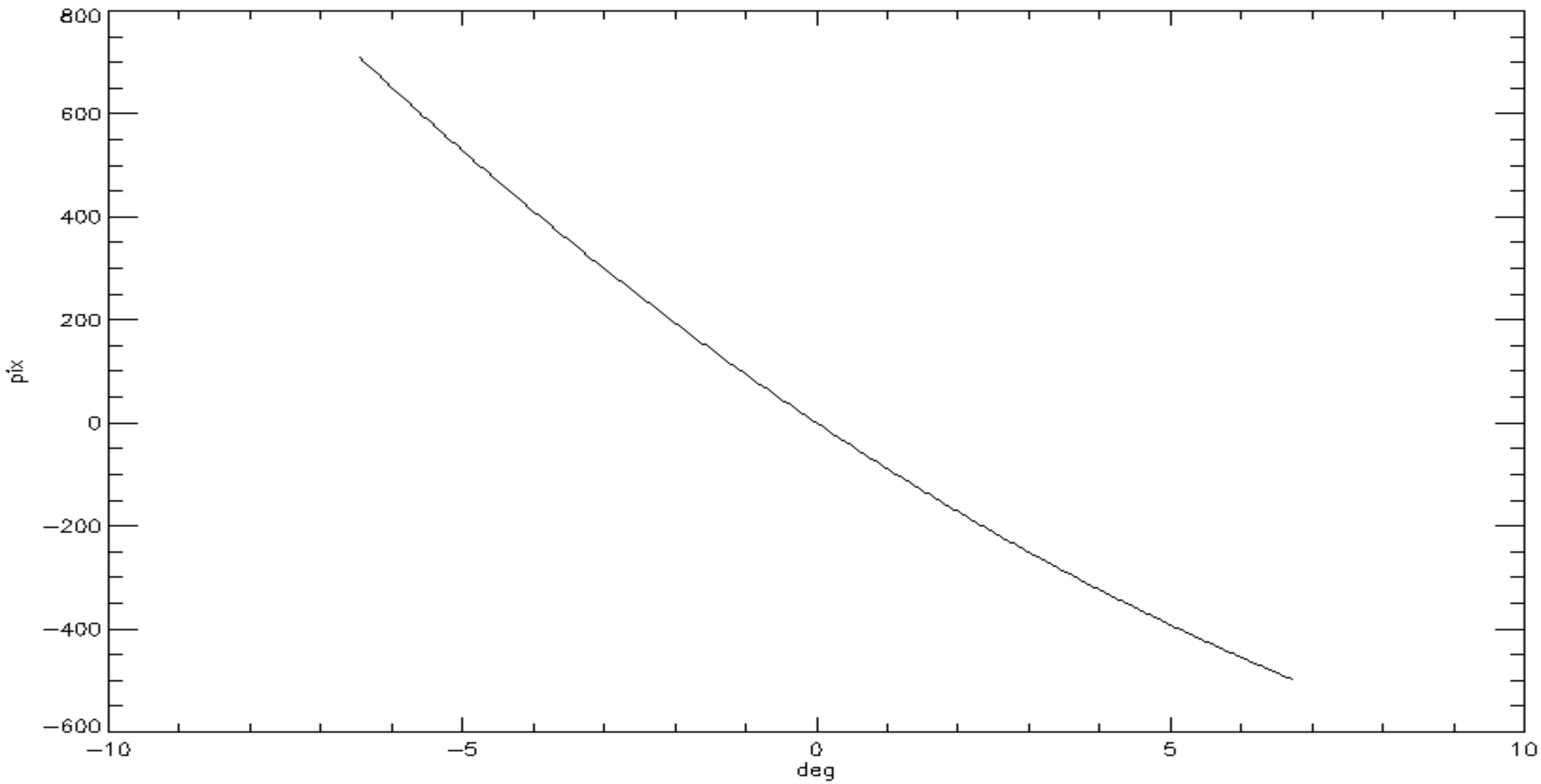
Ray tracing for linear movement

The approximated equations are useful for planning geometry of experiment.
For characterization of crystal curvature the exact trajectories should be calculated and compared with recorded data.
The trajectory was calculated by ray tracing: the angles „b" were established by solving numerically exact equations, and then the location of points was calculated where the diffracted x-rays crossed the CCD detector. The calculations were stopped if the edge of the crystal was achieved.



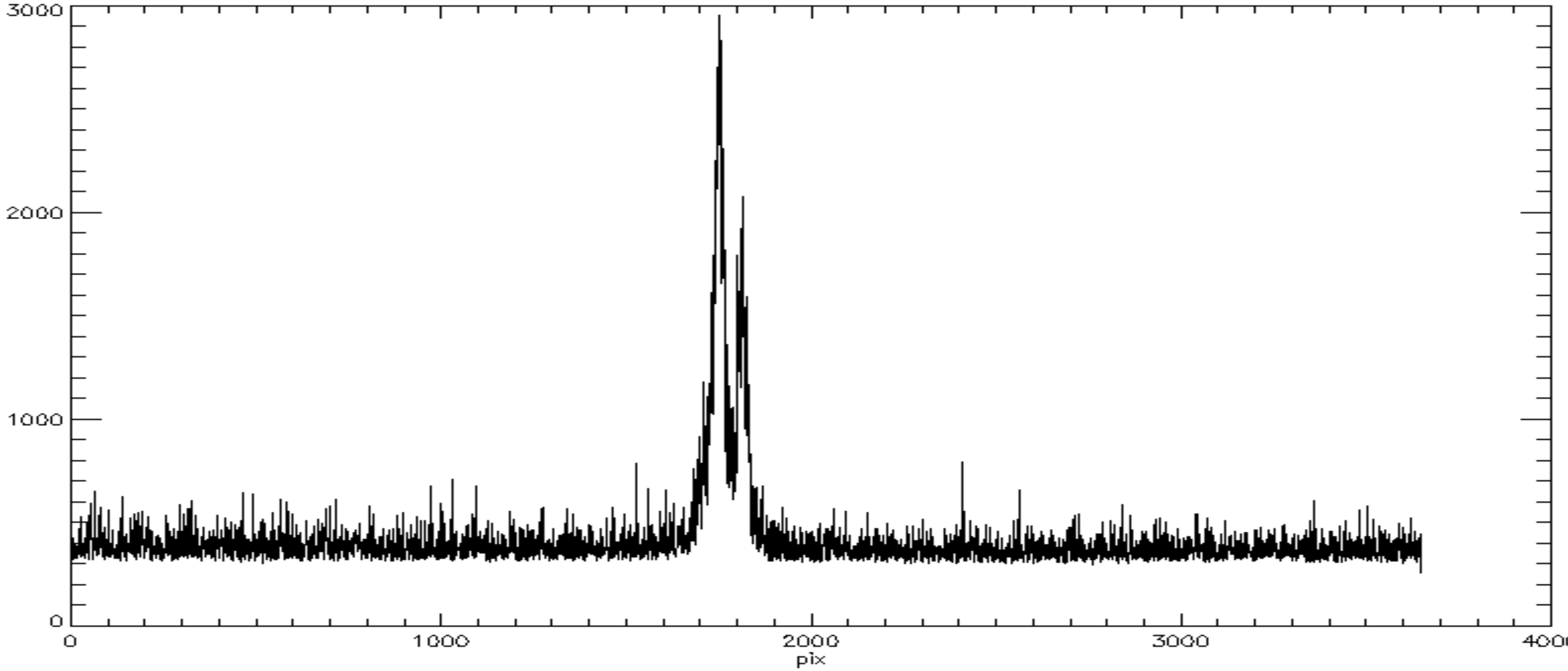
Linear movement
Data for start: L=245 mm, D=120mm
R=250 mm , t=32.75 deg
pix=8 um
Length of the crystal : 36.2 mm

Ray tracing for rotational movement

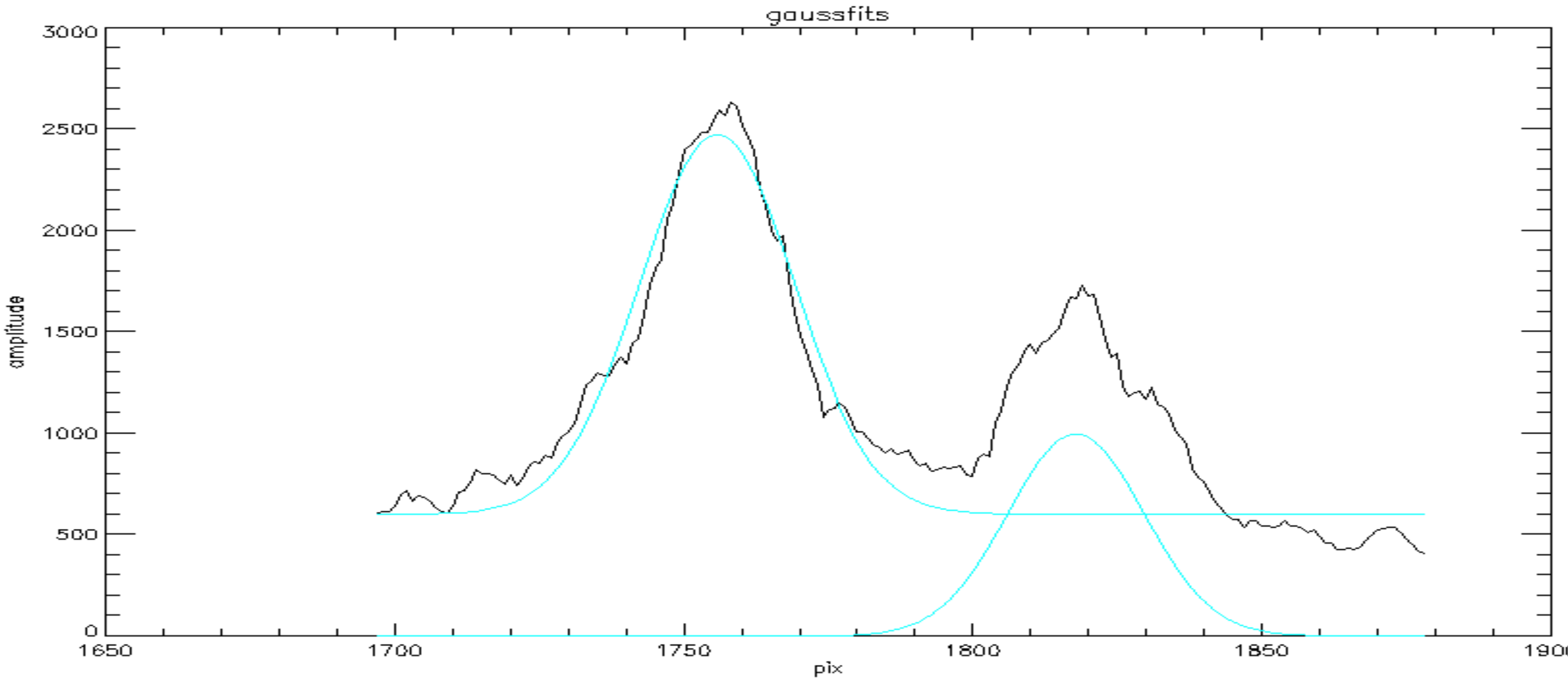


Rotational movement
Start data: mxh=+/-18.1 mm , L=245 mm, D=120 mm.
R=250 mm, t=32.75 deg, pix=8um,
Length of the crystal : 36.2 mm

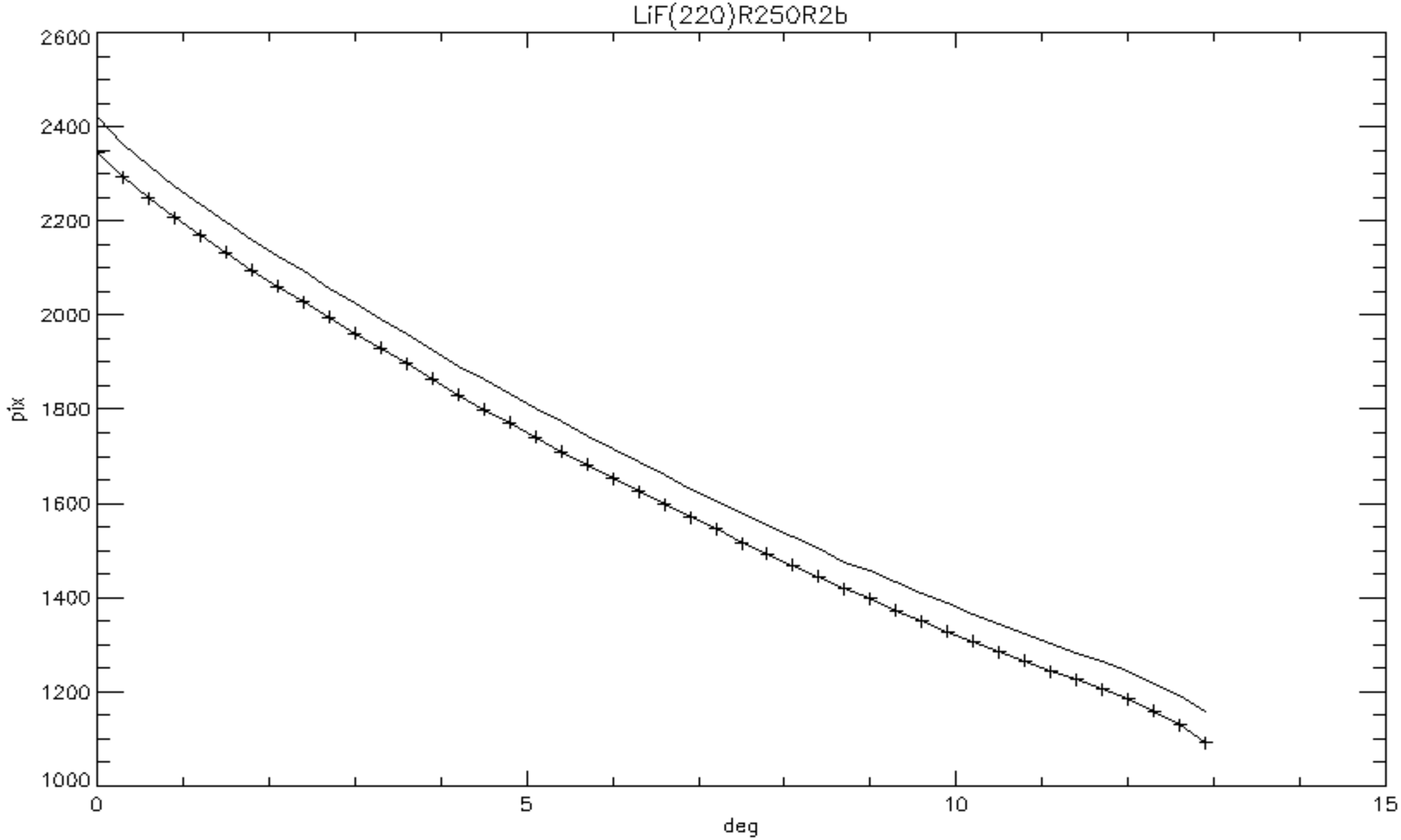
Example of measurements with convex (R=250 mm) crystal LiF(220)



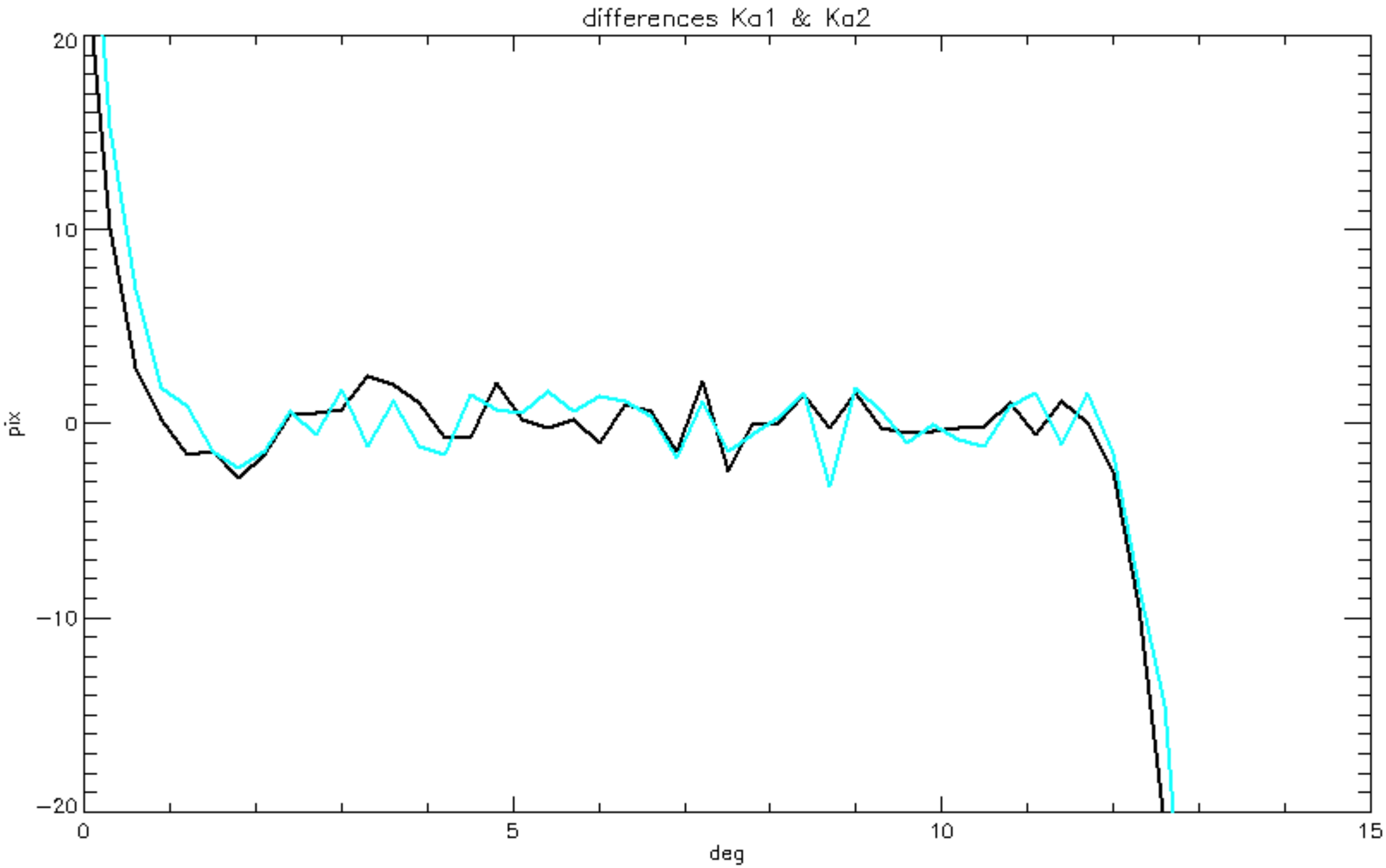
As a X ray detector was used linear CCD with 3650 pixels (each 8x200 um size).
At the record it is seen two Cu spectral lines Ka1 (l=154.06 pm) and Ka2 (l=154.40 pm). For these lines, Bragg angles are t1=32.748 deg and t2=32.839 deg.



The two spectral lines were fitted by two Gauss curves and then the exact position of the recorded lines were established.



When the rotational movement of the LiF crystal rotational was applied the change in positions of the recorded lines gives the trajectories for Ka1 and Ka2 lines.
The movements were stopped if edge of crystal was achieved.

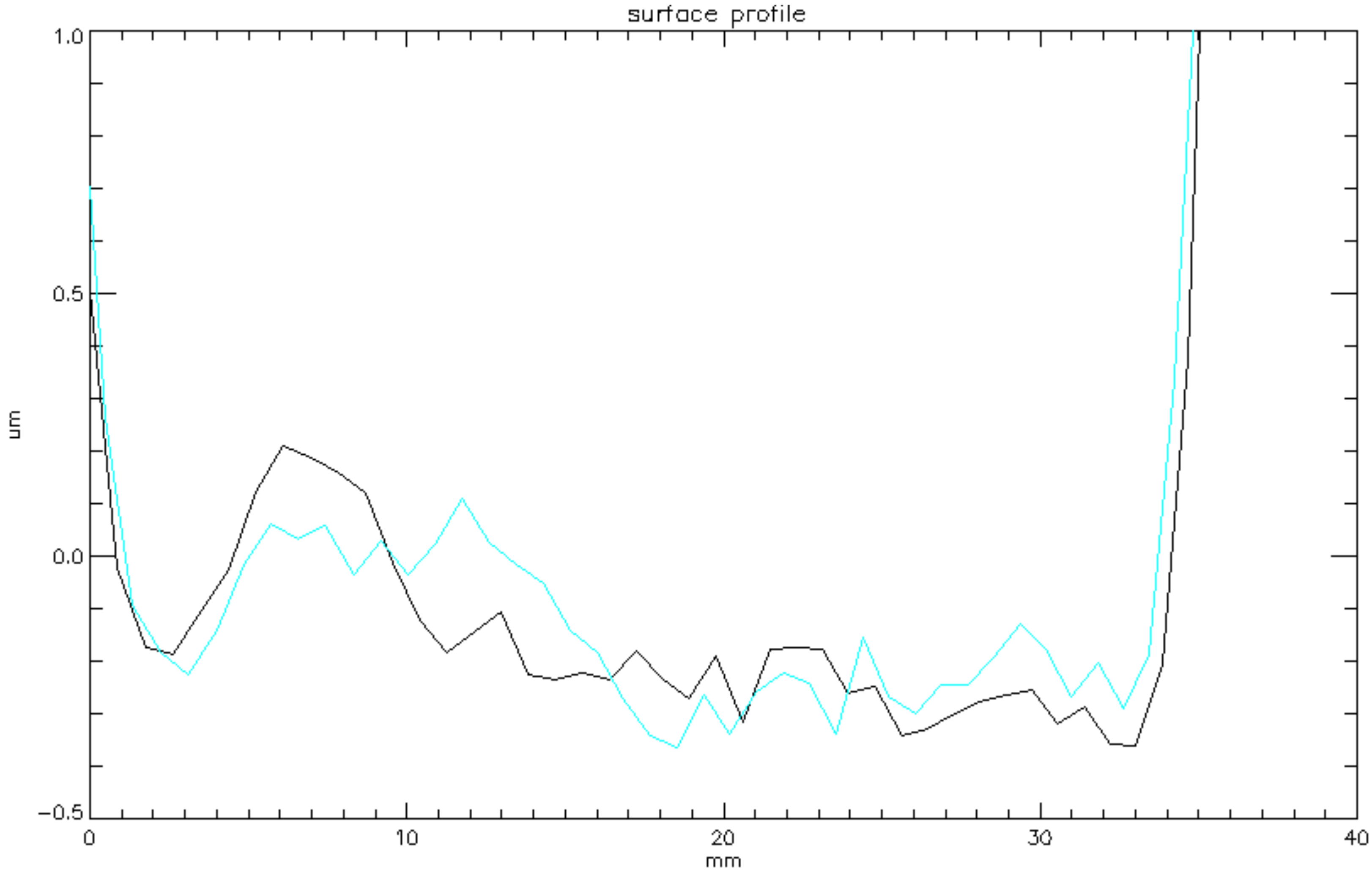


Observed trajectory was compared to calculated trajectory with geometry data: mxh=+/-18.1 mm , L=245 mm, D=120 mm.

The calculated trajectory was substracted from observed trajectory.

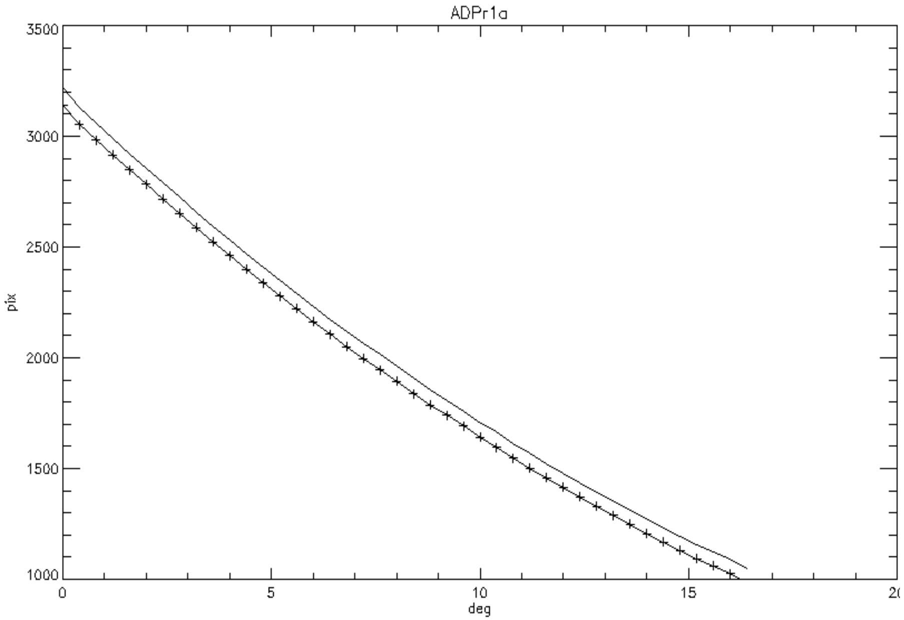
Discrepances point at the crystal surface tilt did not match with perfect curvature.

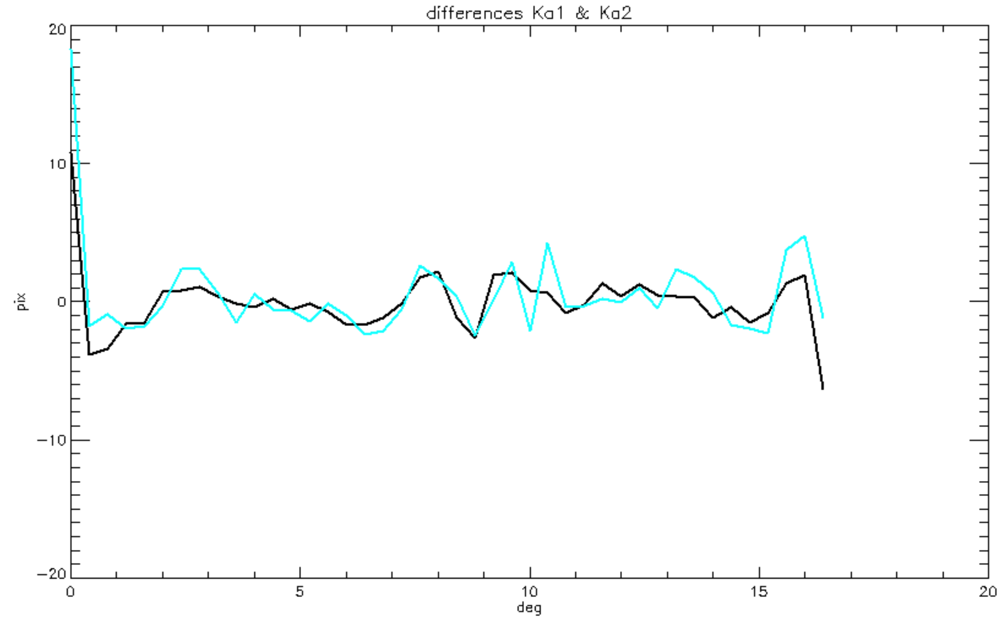
(1 pix discrepance is equivalent 0.068 mrad=14” tilt)

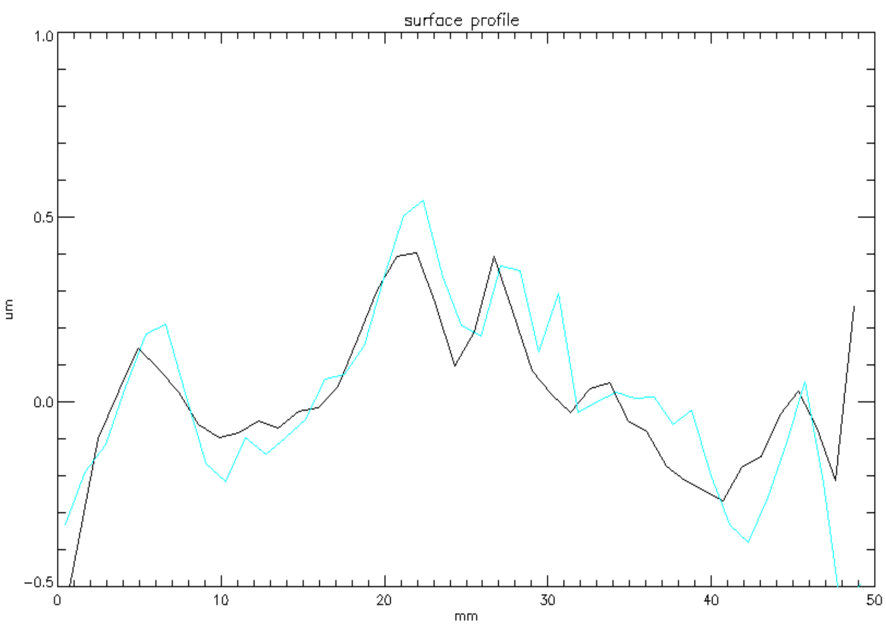


The discrepances were converted to surface tilt and then integrated over scanning steps . As a result of the integration we get the surface profile.
The presented profile show differences between real profile and perfect concave cylinder.

Result of measurements for convex ADP(404) crystal.







1. Trajectories for Cu Ka1 and Ka2 lines.
2. Diffirences between observed and calculated trajectories.
3. Surface profile.

Summary and discussion

The presented procedure enable to make precisely x-ray measurements of bent or flat crystal profile.

For future experiments CCD area detector may be used instead of linear CCD detector. It makes possible to measure crystal profiles at multi lines at the same time.