Ultra precision rotation stage of TXM at NSRRC

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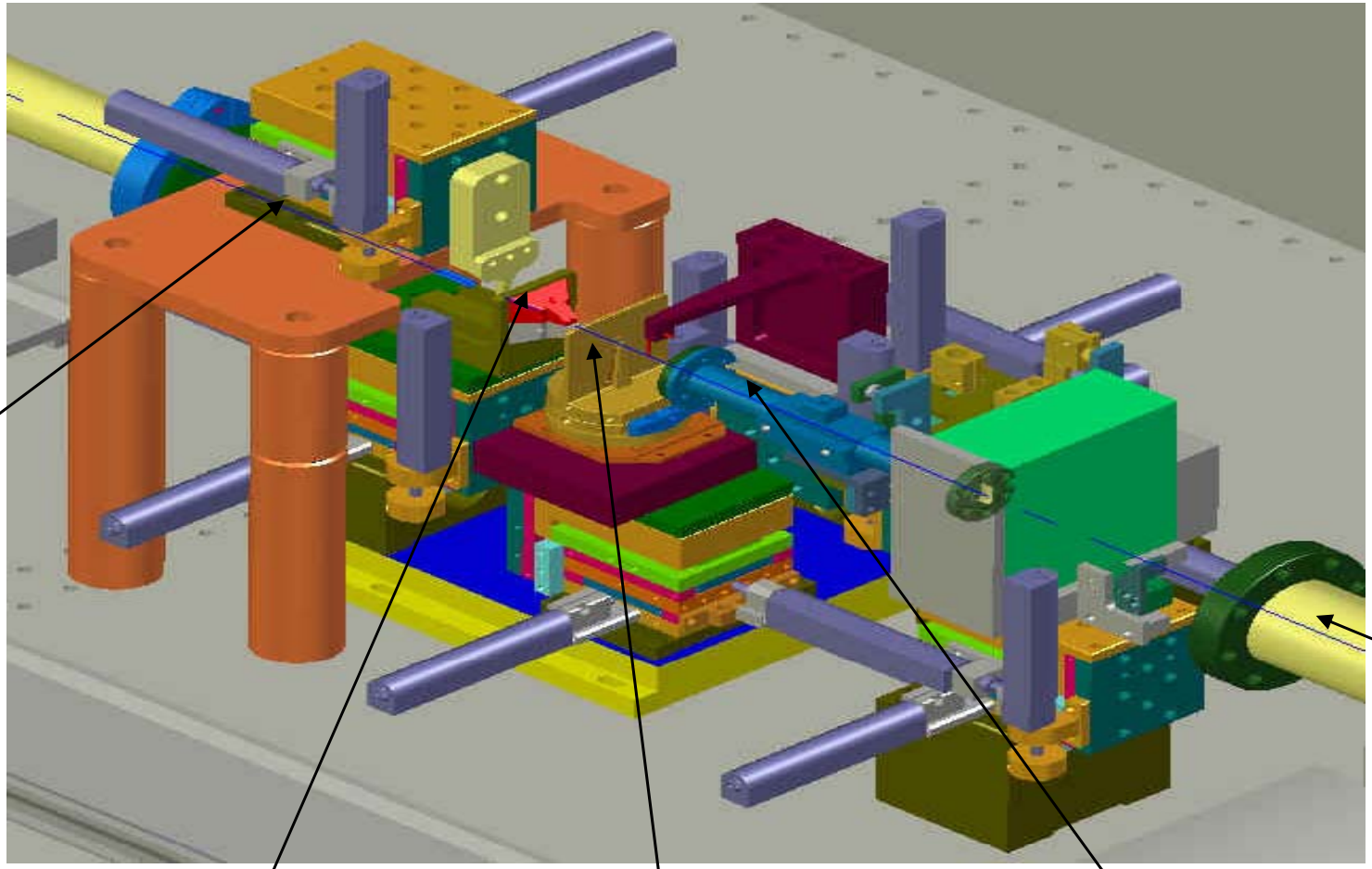
Outline

- Requirement of TXM
- Stage assembly and characterization
- Error separation schemes
- Feedback algorithm
- Summary

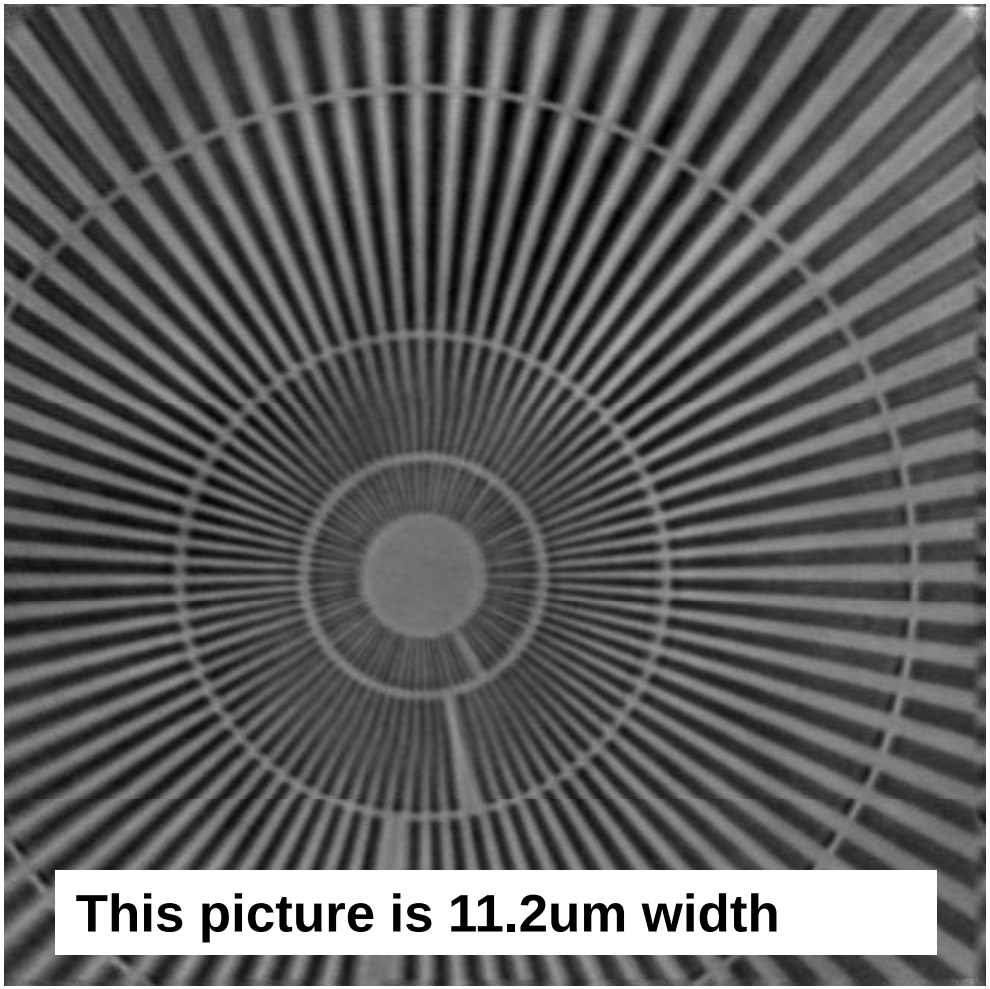
TXM


CCD
hν
Zone plate objective
Sample and rot stage
Condenser Tube

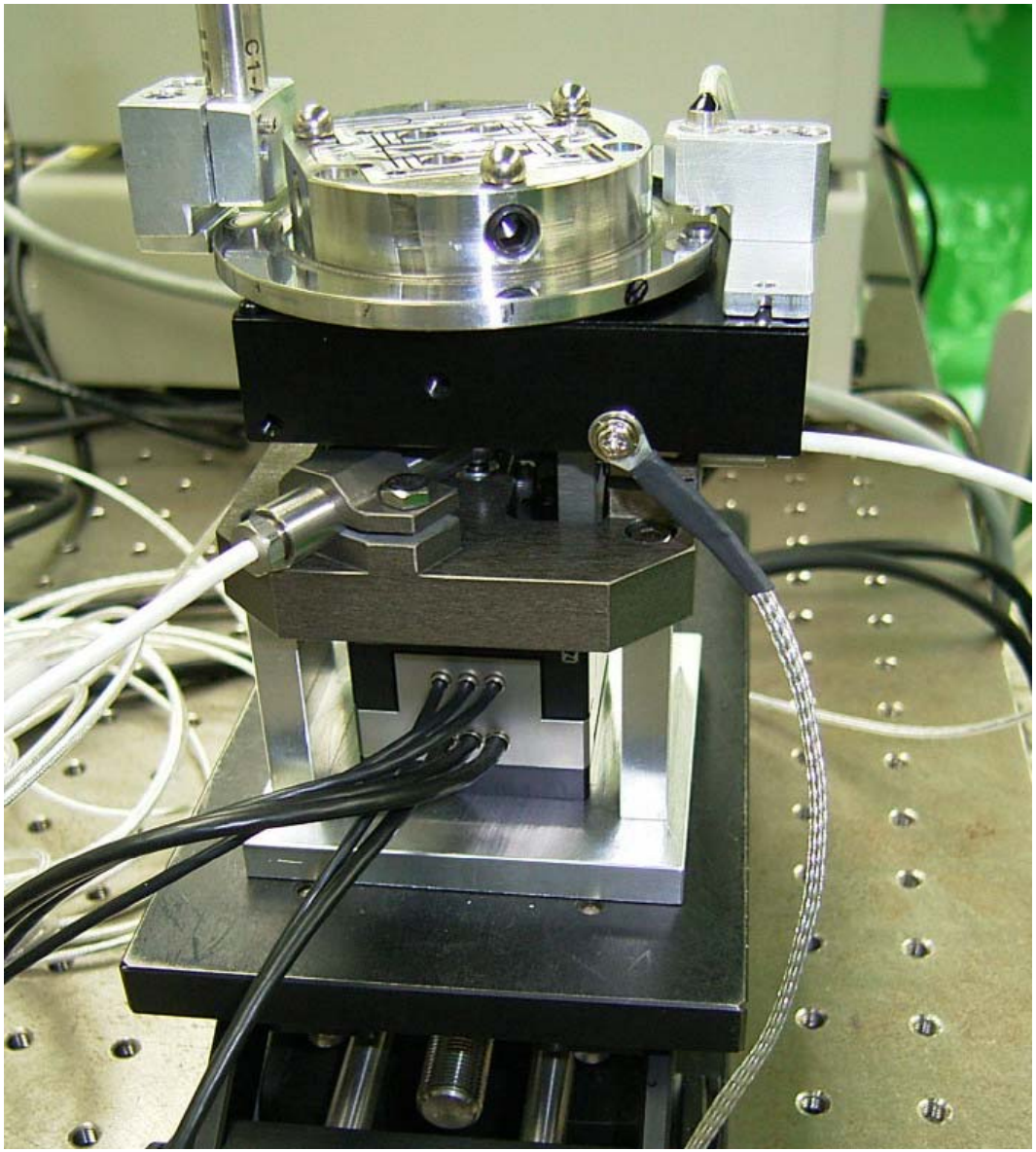
30nm resolution of X-ray image with a gold spoke pattern

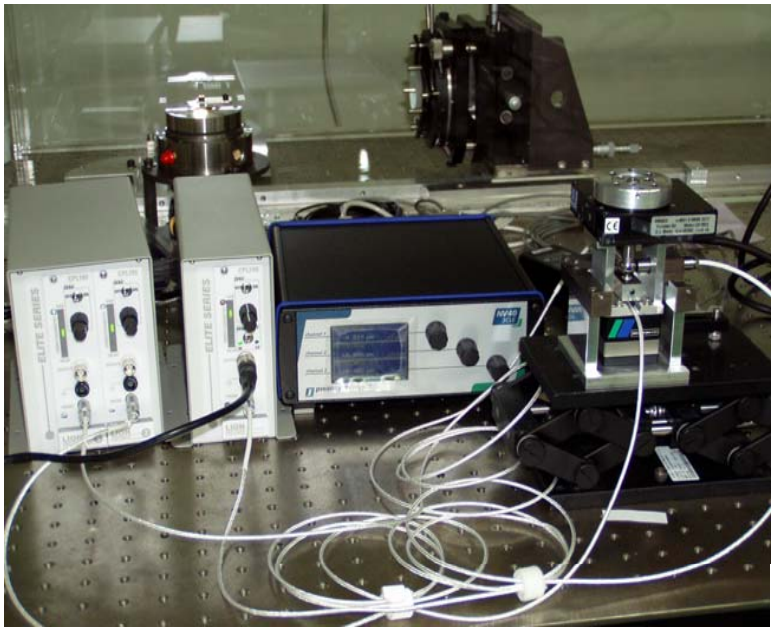
2D has achieved best resolution.
How is 3D image?

20nm level rotation precision is required!



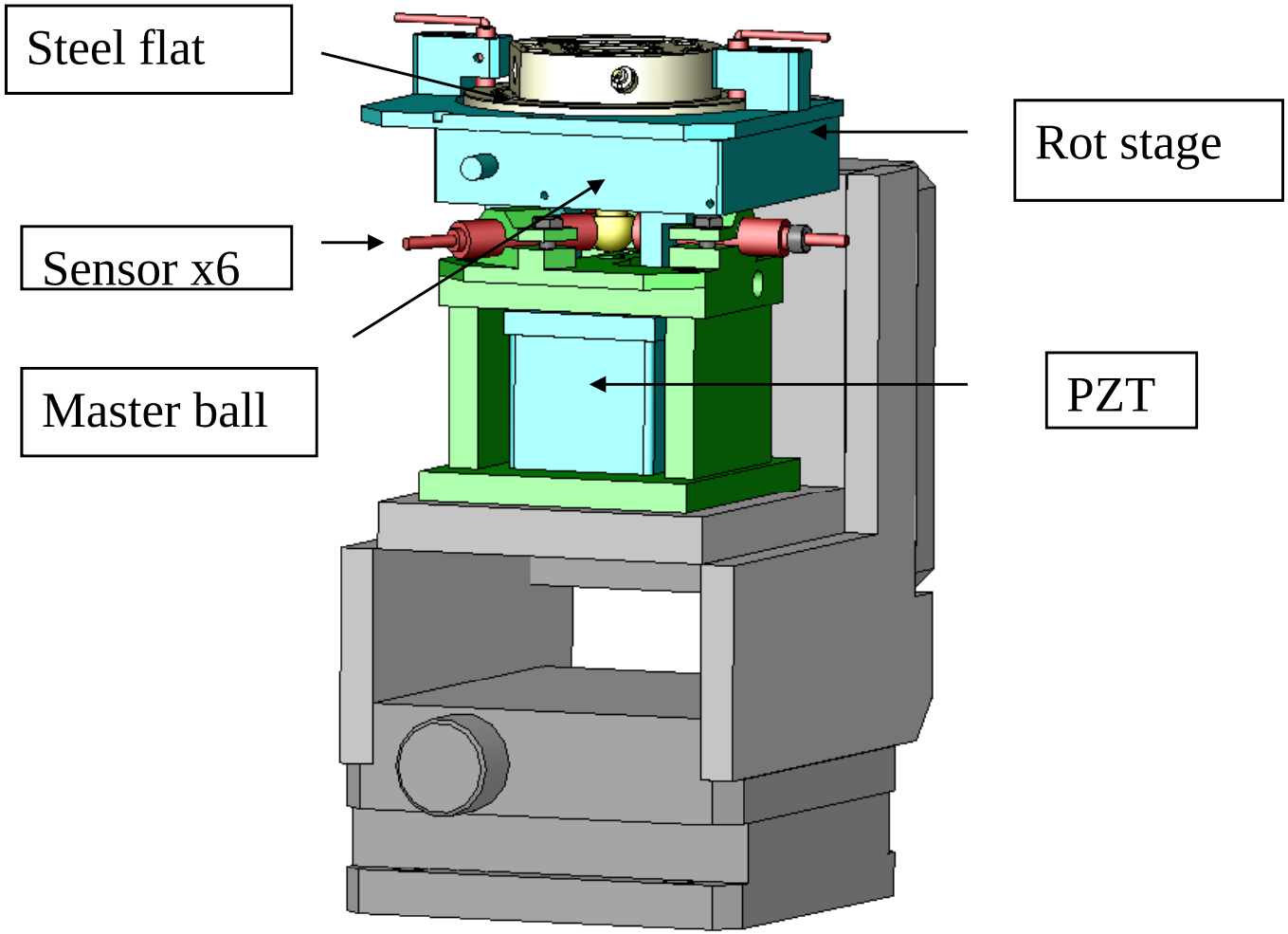
Yin etal, APL 2006,89, p221122.



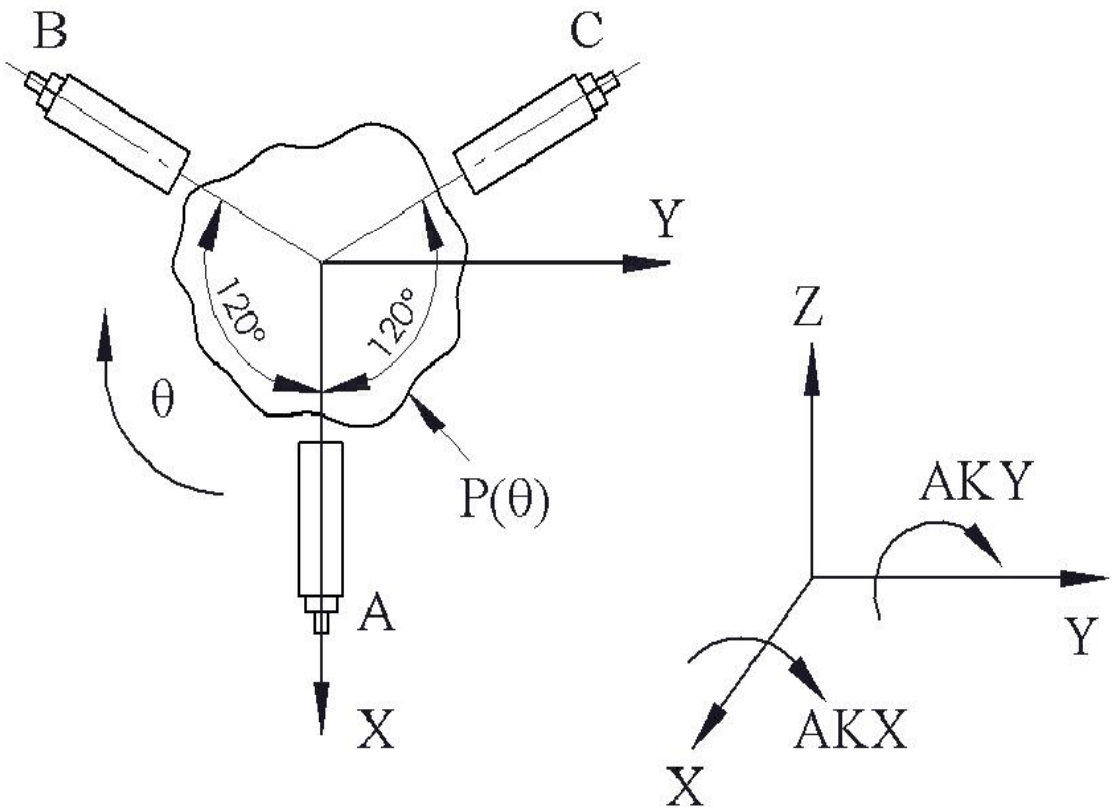

ELITE SERIES
ELITE SERIES

Layout of rotation stage and sensors.

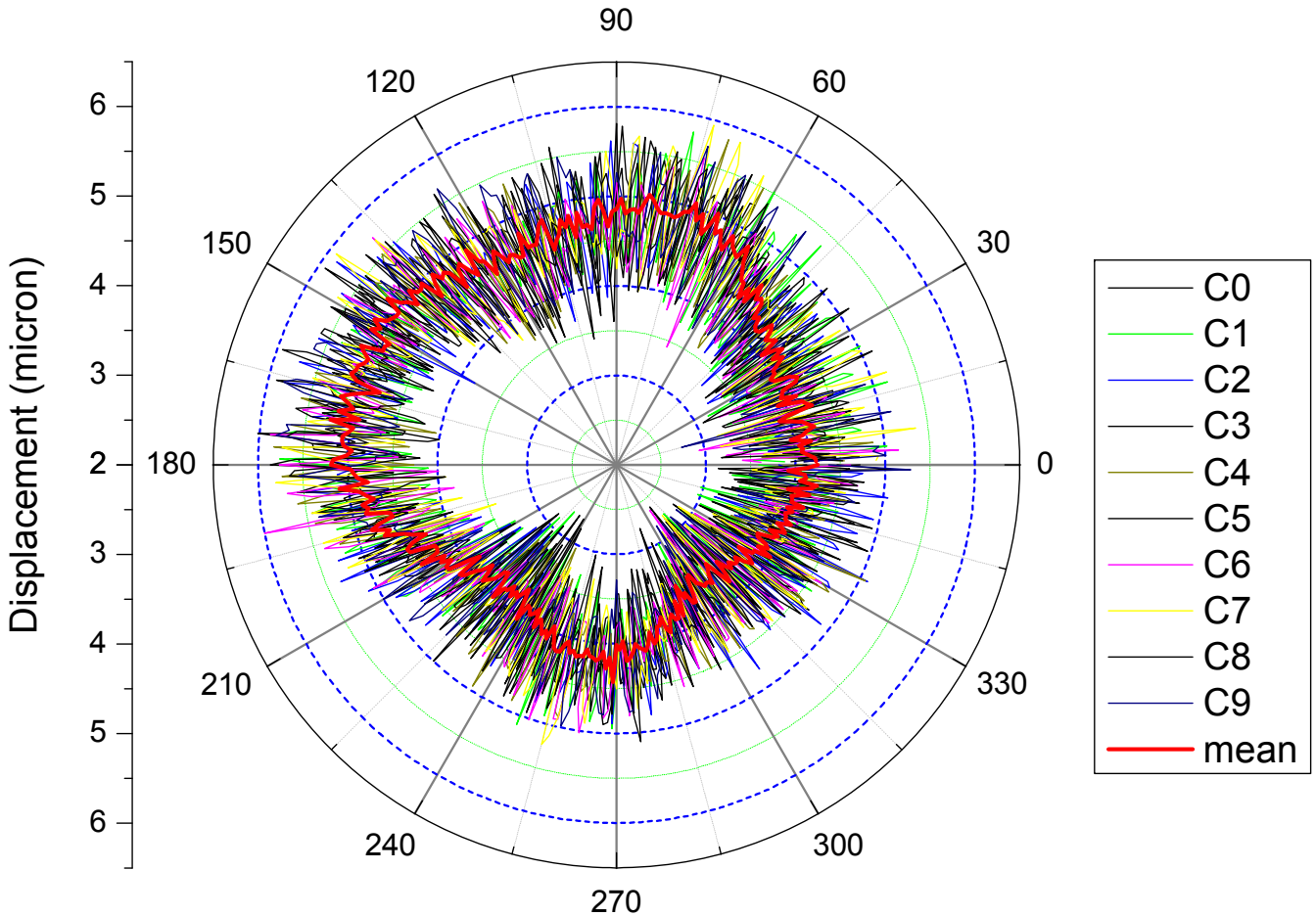
Ball x3, XY plane
Steel plate x2
Ball x1 Z axis



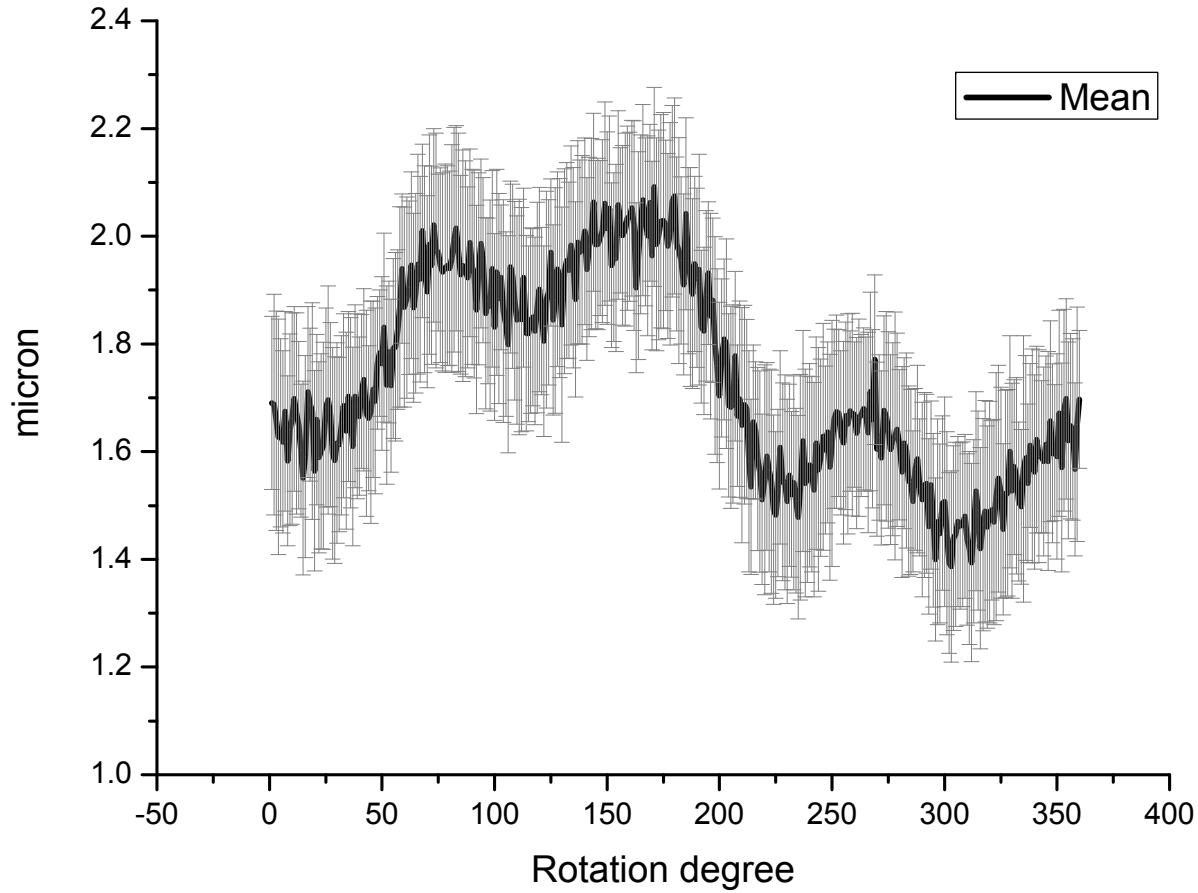
Layout of sensors in X-Y plane



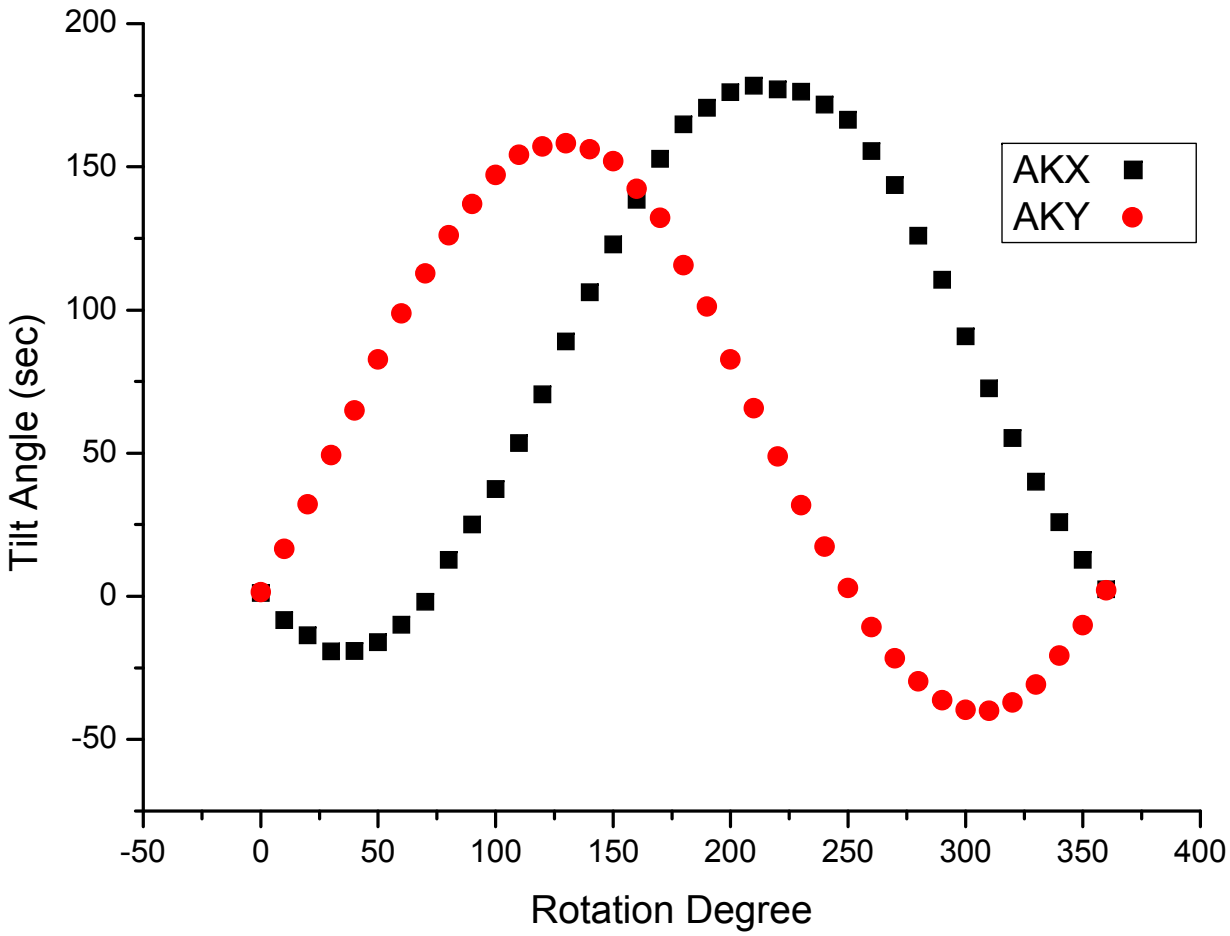
A typical 10 turns measurement for a master ball



Mean and standard deviation of 20 turn measurements



Tilting of rotation motion measured by autocollimator



Systematic tilting error of the rotation motion(AK residual).

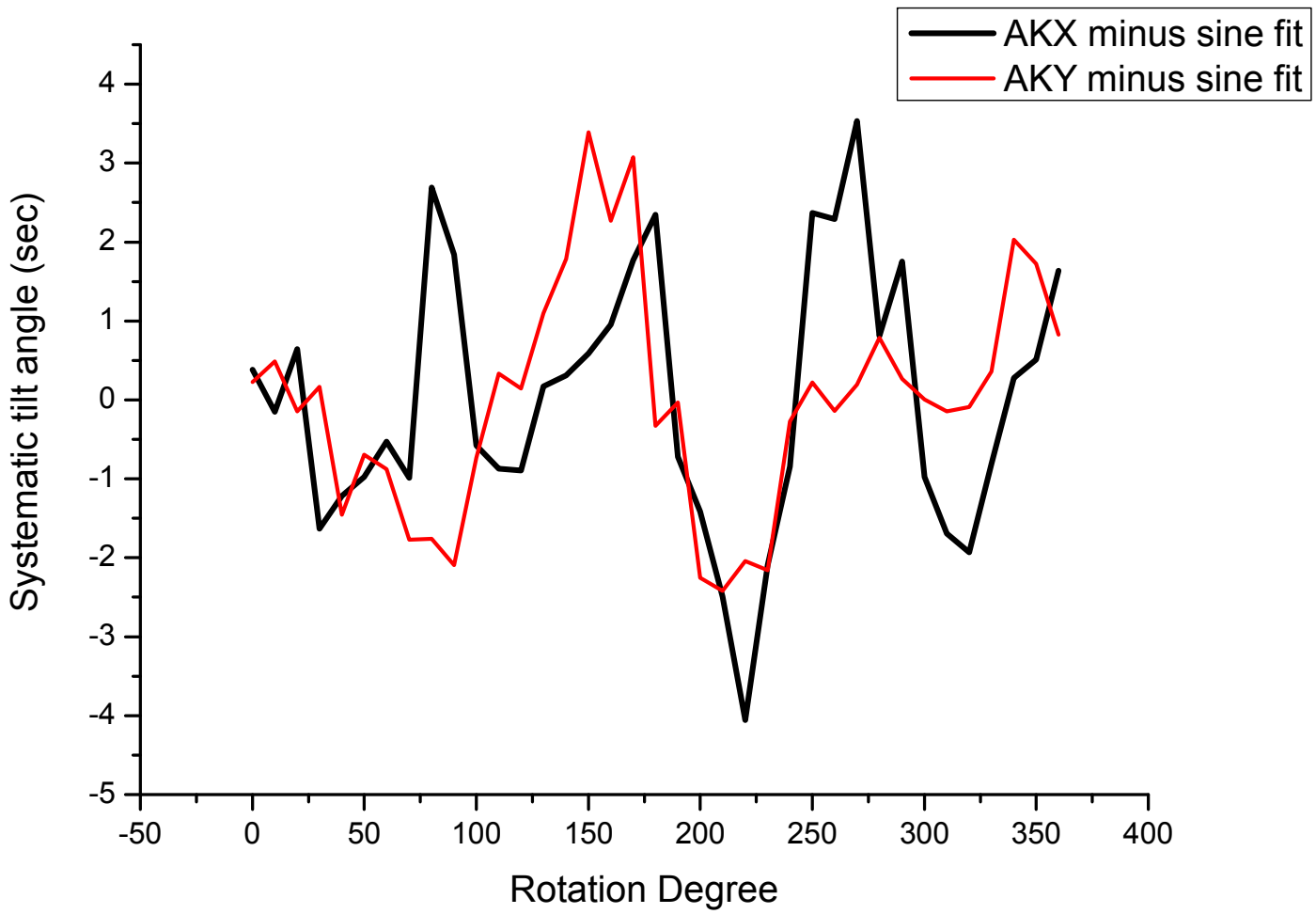
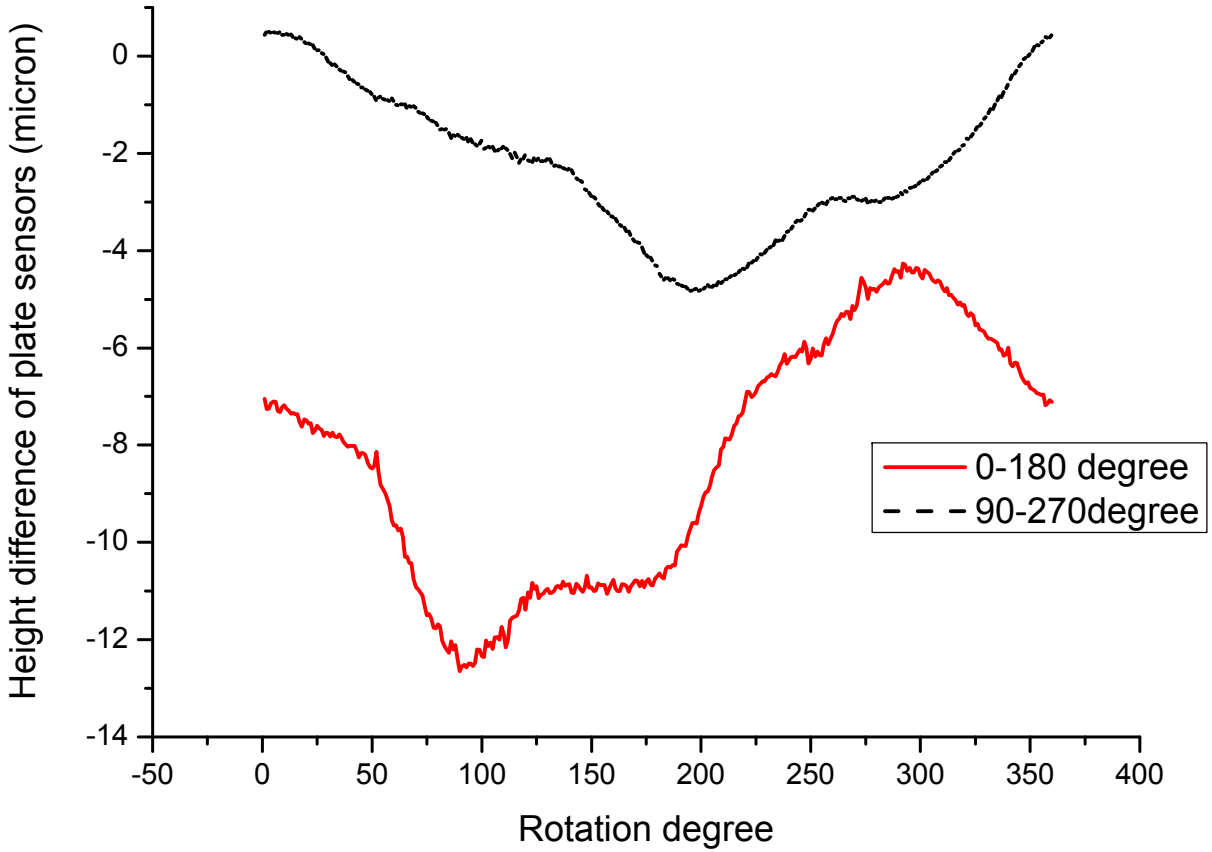
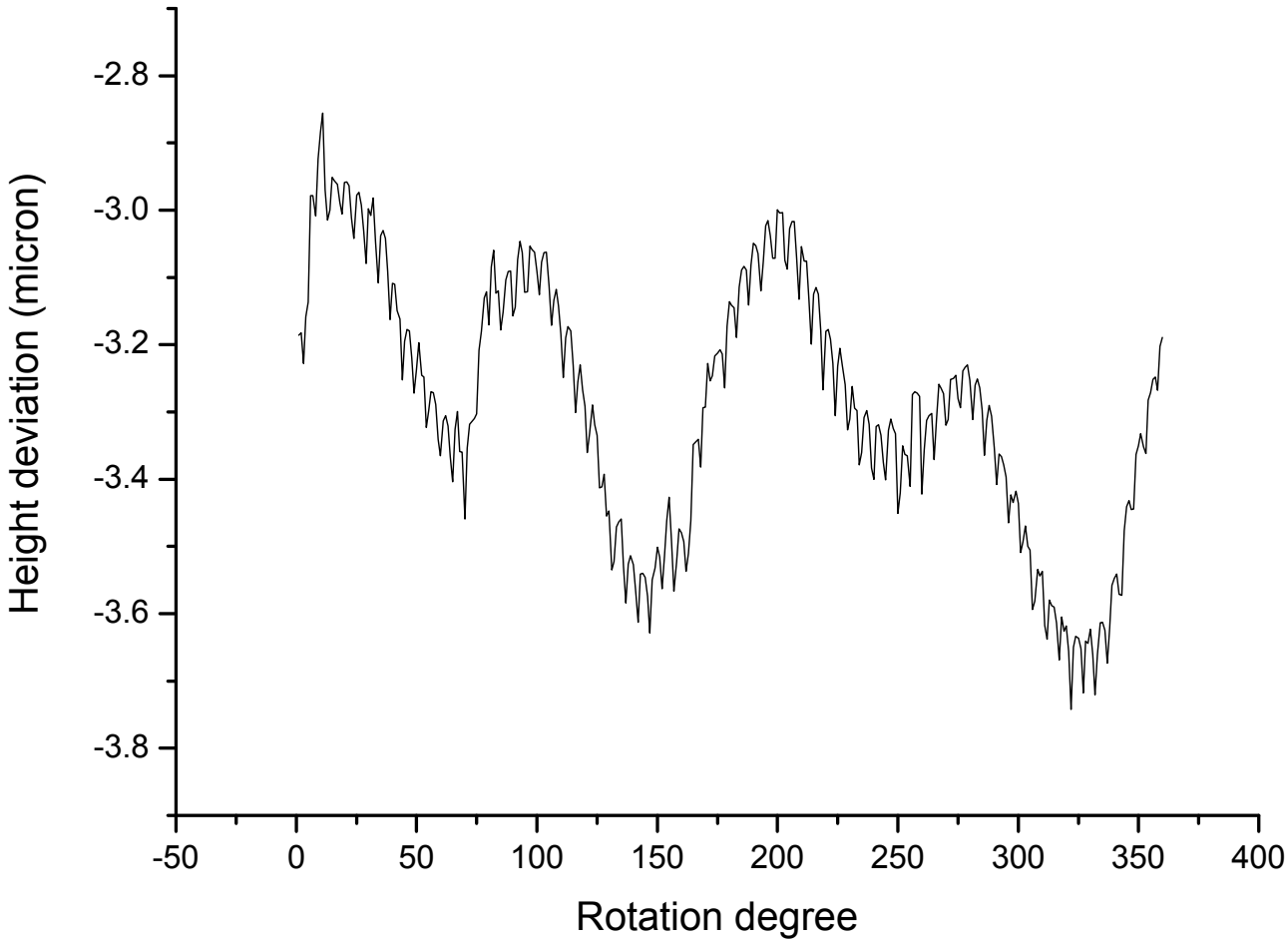


Table tilting by 2 sensors difference



Average of 20 turns of the height deviation of rotation motion.



Error separation

- The measurement data of probe consist of 5 parts
- profile of master ball
- X or Y run-out
- sensor position
- ball offset or tilting
- table tilting.

$$Ma(\theta) = P(\theta) + X(\theta) + P1 + e * \sin(\theta + \delta) + h * \sin(AKYres)$$

$$Mb(\theta) = P(\theta - 120^\circ) + X(\theta) * \cos 120^\circ - Y(\theta) * \sin 120^\circ + P2 + e * \sin(\theta + \delta + 120^\circ)$$
$$+ h * \sin(AKYres)\cos 120^\circ + h * \sin(AKXres) * \sin 120^\circ$$

$$Mc(\theta) = P(\theta + 120^\circ) + X(\theta) * \cos 120^\circ + Y(\theta) * \sin 120^\circ + P3 + e * \sin(\theta + \delta - 120^\circ)$$
$$+ h * \sin(AKYres)\cos 120^\circ - h * \sin(AKXres) * \sin 120^\circ$$

P(θ) is the profile of the master ball,
X and Y is the run-out in the X and Y direction.
P1,P2,P3 is the constant in the sine fitting, it stands for the far or near of the sensor to the ball.
e is the eccentricity of the ball position, also call the offset.
AKX res or AKY res is the table tilting residual in the Fig.5.
h is the length of ball linking rod, from ball center to stage center.

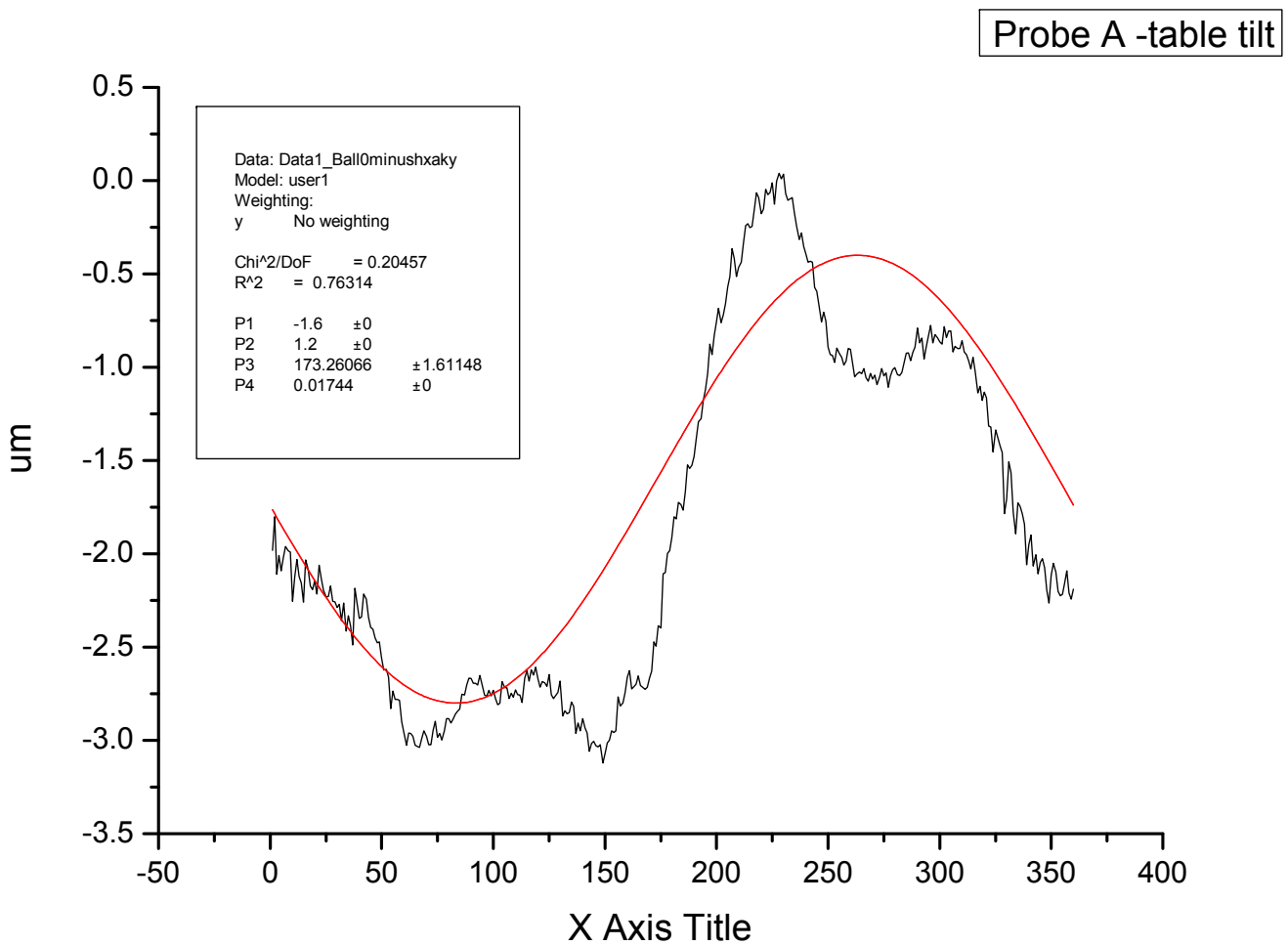
mas(θ)=Ma-tilting part

$$mas(\theta) = P(\theta) + X(\theta) + P1 + e * \sin(\theta + \delta)$$

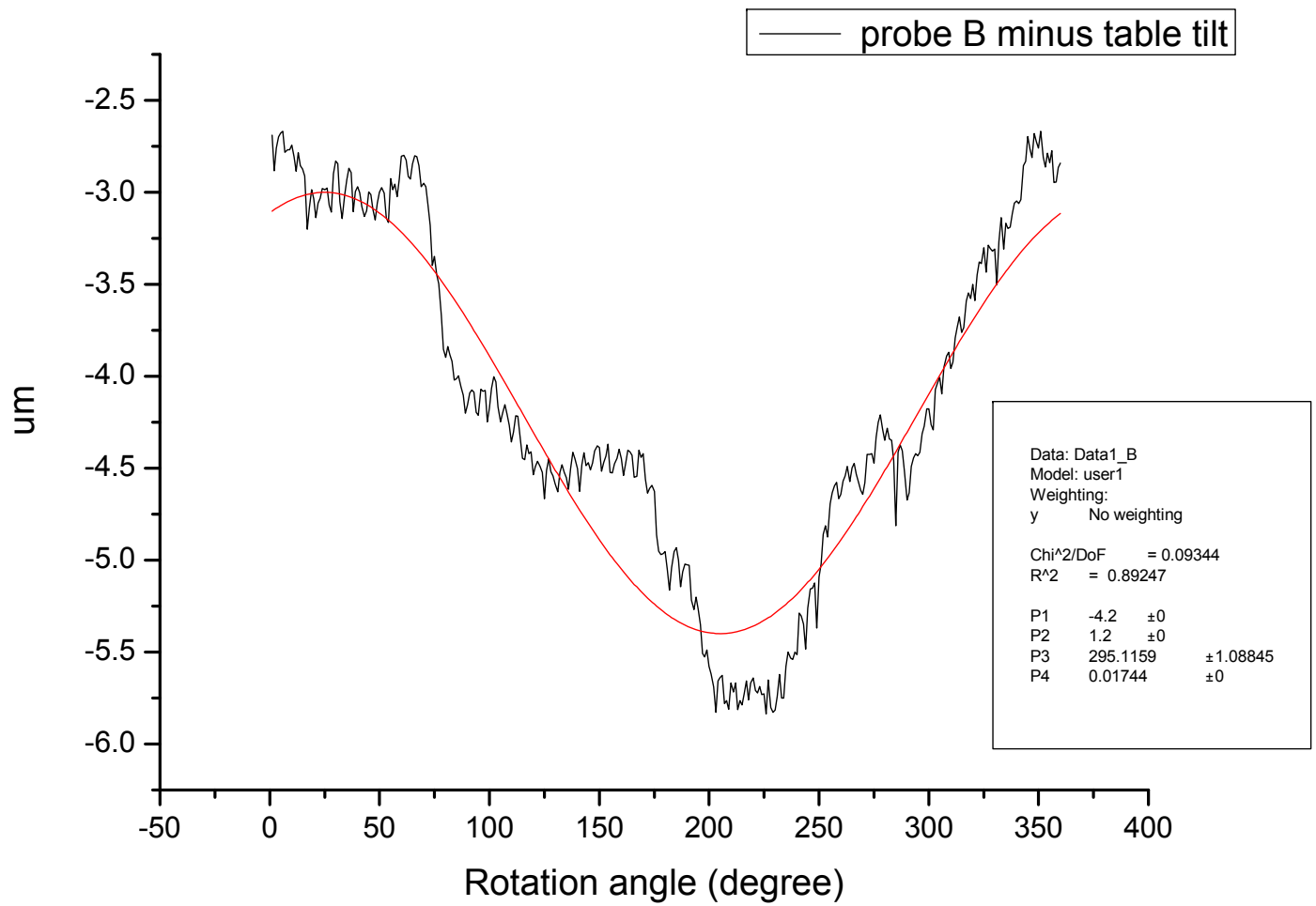
$$mbs(\theta) = P(\theta - 120^{\circ}) + X(\theta) * \cos 120^{\circ} - Y(\theta) * \sin 120^{\circ} + P2 + e * \sin(\theta + \delta + 120^{\circ})$$

$$mcs(\theta) = P(\theta + 120^{\circ}) + X(\theta) * \cos 120^{\circ} + Y(\theta) * \sin 120^{\circ} + P3 + e * \sin(\theta + \delta - 120^{\circ})$$

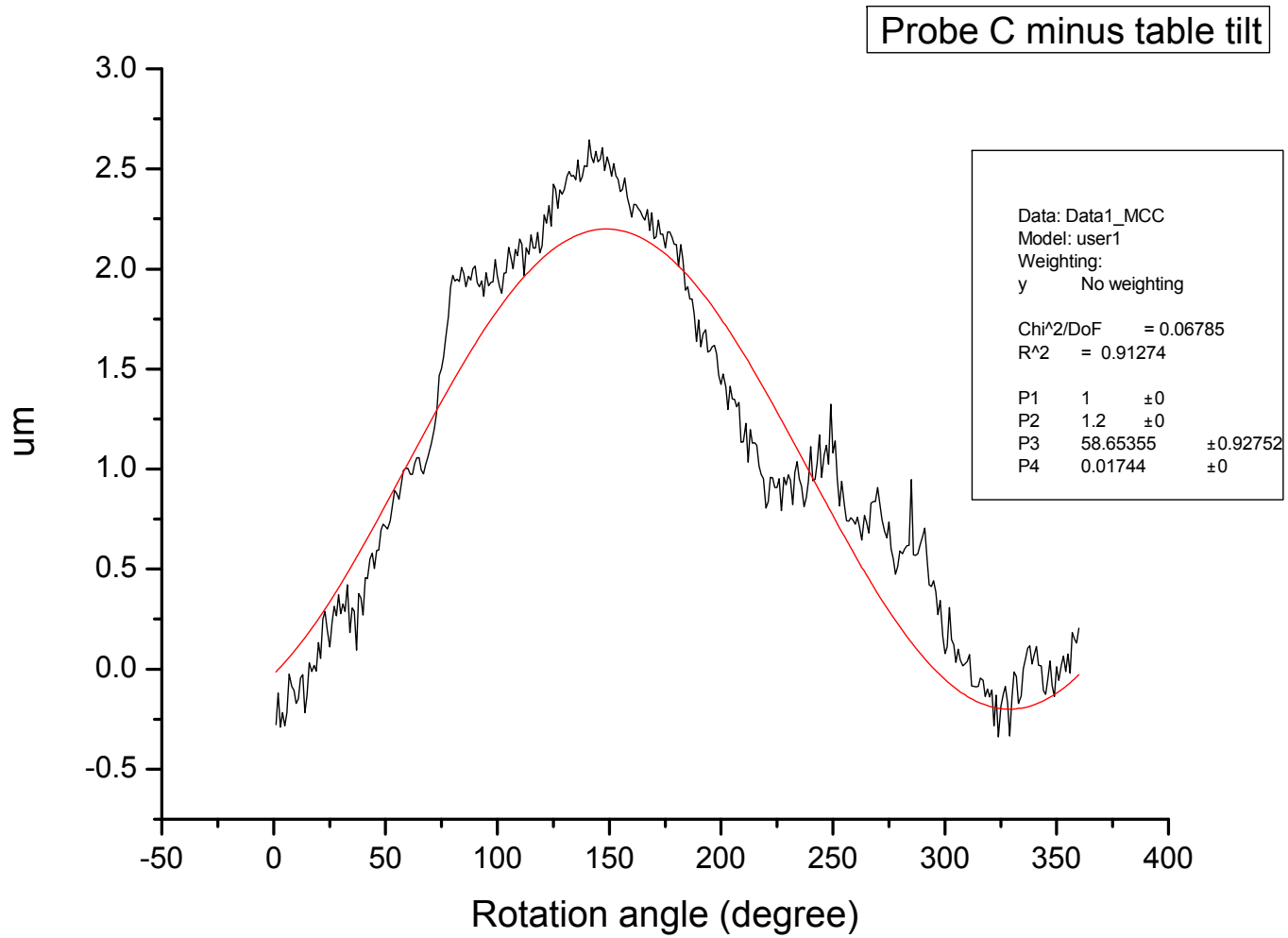
mas of Probe A measurement.



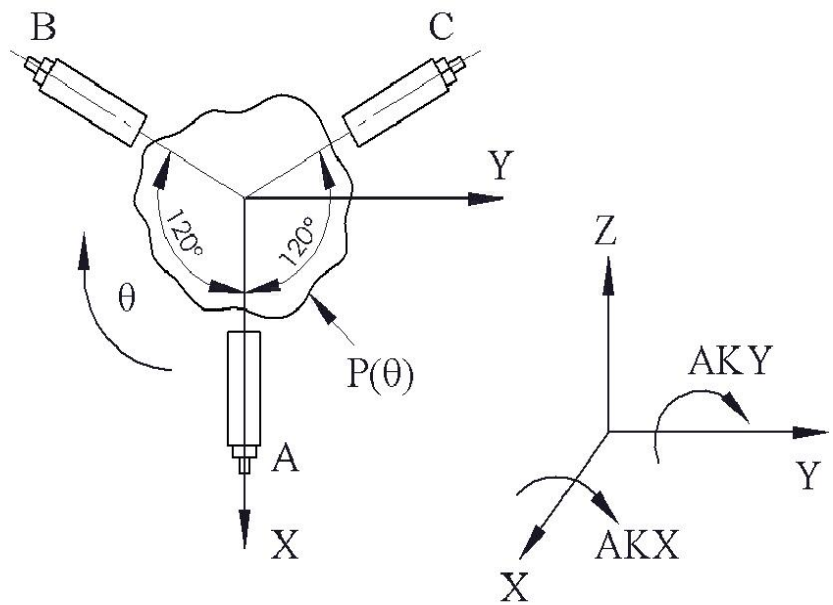
mbs of Probe B measurement.



mcs of Probe C measurement



In- plane measurement

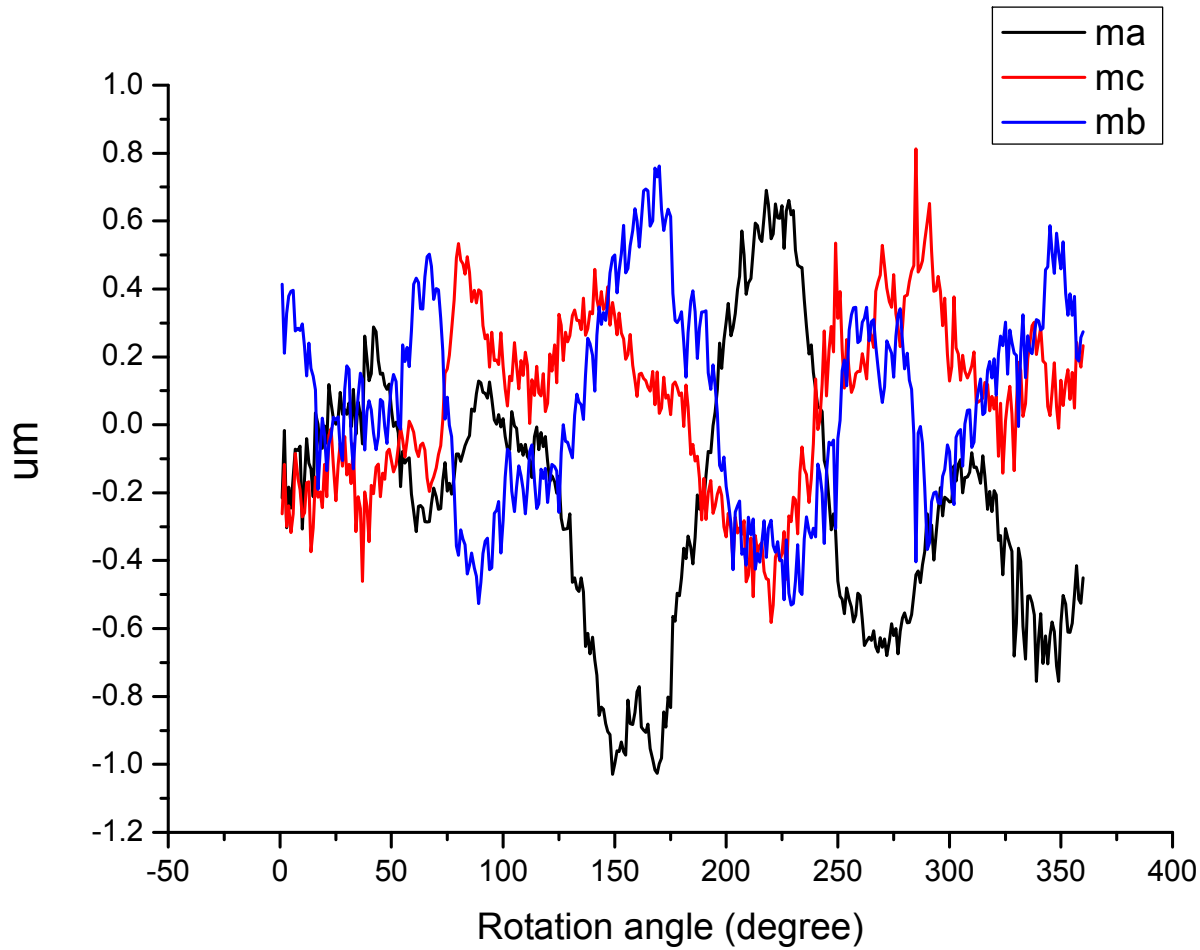


$$ma(\theta) = P(\theta) + X(\theta)$$

$$mb(\theta) = P(\theta - 120^\circ) + X(\theta) * \cos 120^\circ - Y(\theta) * \sin 120^\circ$$

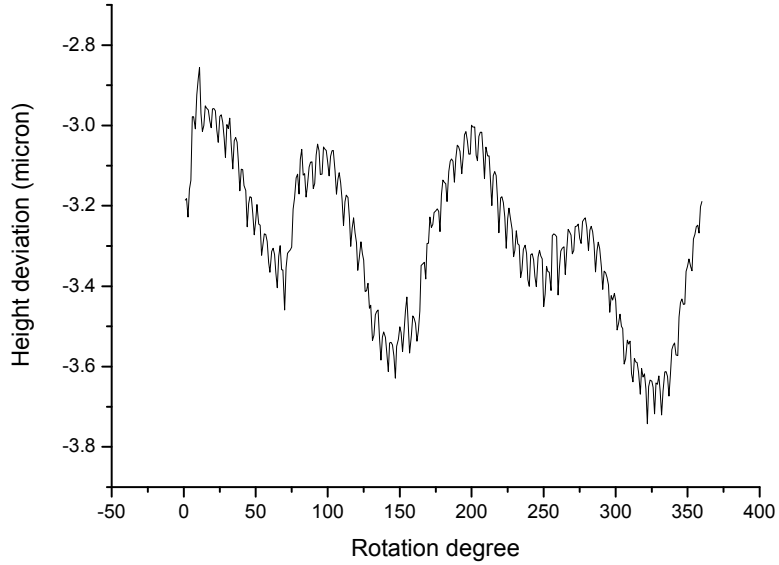
$$mc(\theta) = P(\theta + 120^\circ) + X(\theta) * \cos 120^\circ + Y(\theta) * \sin 120^\circ$$

ma(θ),*mb(θ)*, *mc(θ)* of rotation stage



V. Feedback algorithm

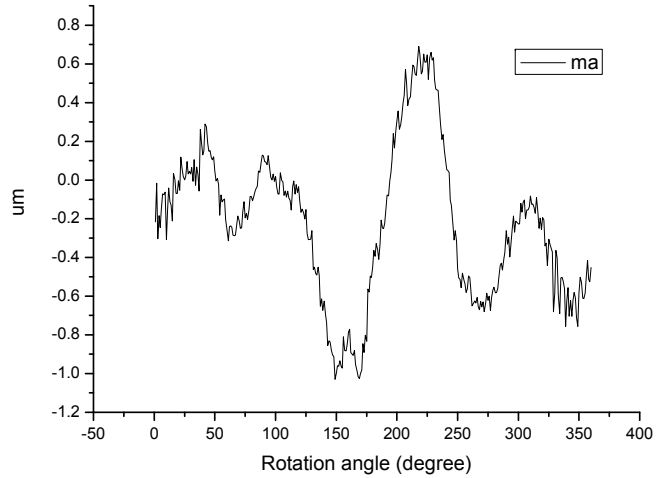
1.Vertical direction:
Real time Z*(θ)* →*fixed value*



2. Horizontal direction: Offset X(*θ)*

new Ma(θ) →*new mas*(*θ*) →*new ma*(θ)

(*Real time X(θ)*= new *ma*- P(θ).



Summary

- 1. The original rotation stage has been characterized in detail. From the average value, the tilting angle is about ±15uradian, height is ±0.3um, X and Y run-out is about ±0.5um.
- For each real time value ,offset X(θ)
  can be compensated by the piezoelectric stage following the above feedback algorithm.