Measuring strong curvatures at the ALBA-NOM

Josep Nicolas, Juan Carlos Martínez

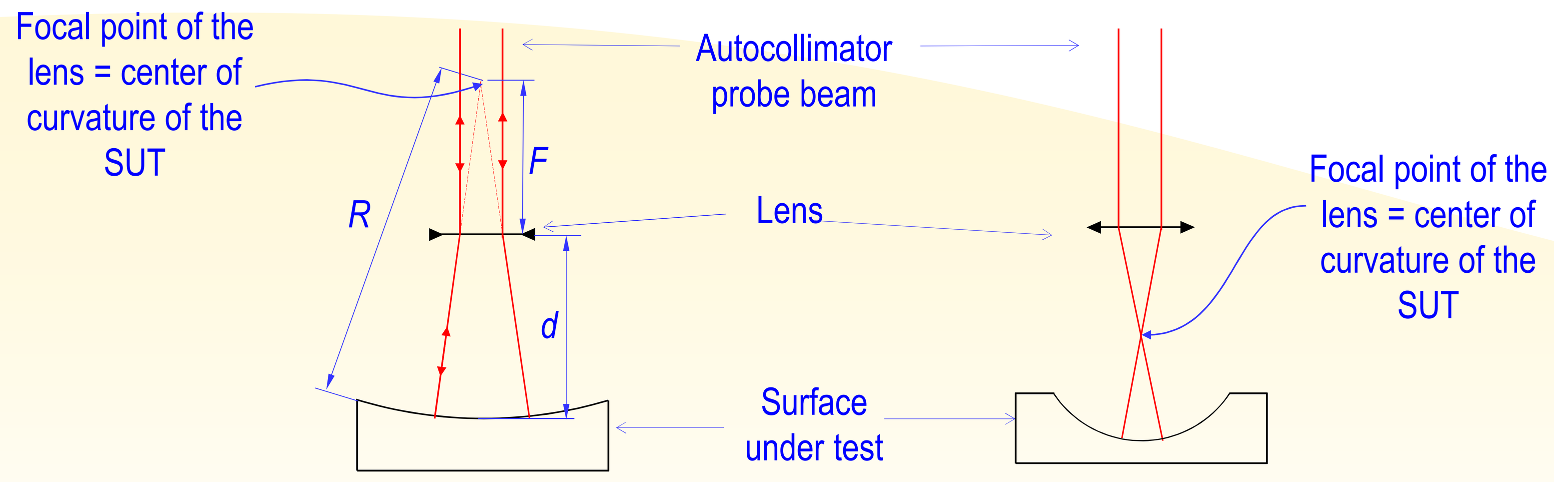
CELLS-ALBA, 08290 Cerdanyola del Vallès, Spain

Abstract

The NOM is limited to provide measurements of very strong curvatures, below 1 m, due to the defocusing introduced on the probe beam by the surface under test. This defocusing can be compensated by introducing a lens between the surface under test and the autocollimator. The lens has to be installed at a position such that the center of curvature of the mirror coincides with the focal point of the lens. When this is done, the beam keeps collimated in the section between the lens and the autocollimator. By doing this, the NOM is able to provide a measurement, but a strong detriment in accuracy is caused. To improve the accuracy, we propose to use an alternative method. It consists in installing the mirror in a goniometer table with high angular accuracy feedback, with an encoder or interferometer, and to measure the surface using the NOM for many different pitch orientations of the mirror. When this is done, one use the data to identify at which pitch angles of the goniometer the mirror and lens return the beam to the autocollimator without deflection. The pitch angles constitute then a measurement of the mirror free of the distortions introduced by the focusing lens installed in the optical path.

Measurement procedure

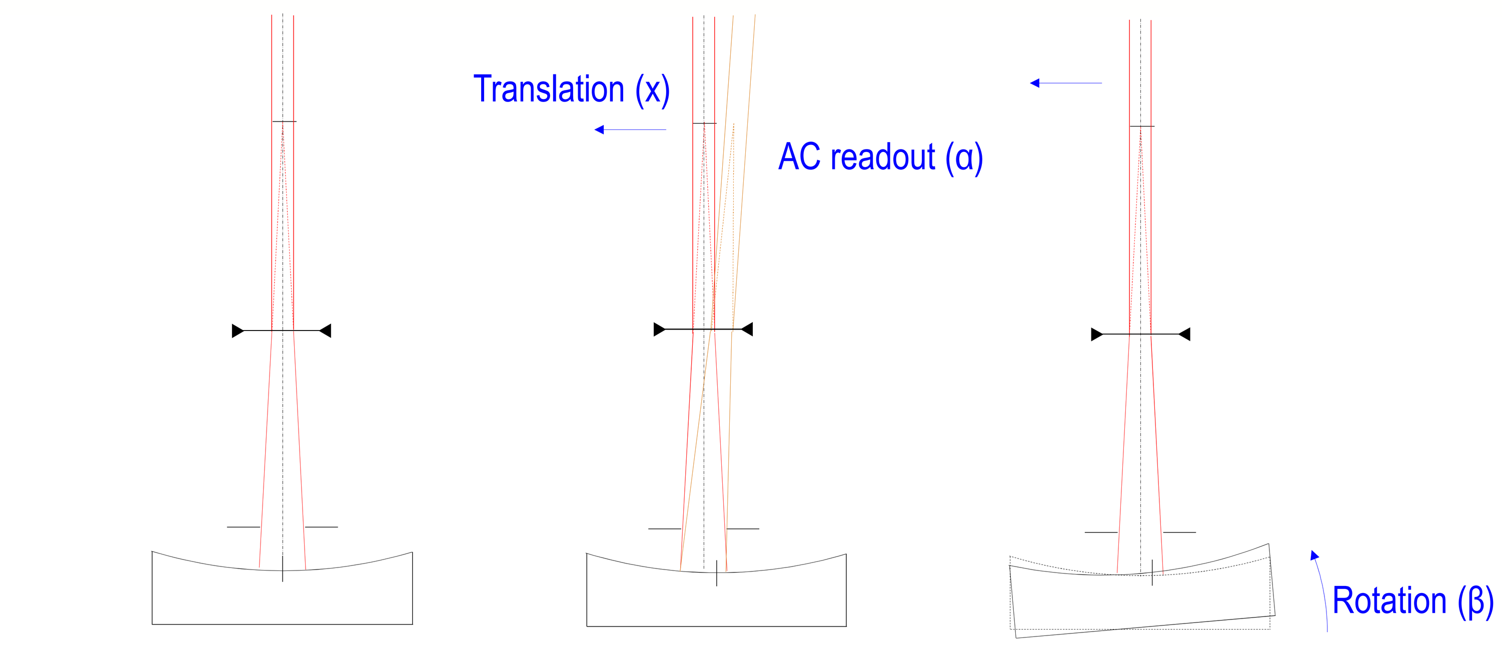
The defocusing of the autocollimator beam, induced by a strongly curved surface can be compensated by a lens. The focal point of the lens must be placed at the geometric center of curvature of the surface.



Setup with a divergent lens, for moderate radii

Setup with a convergent lens for strong radii

In order to avoid the error in the measurement due to the aberrations of the additional lens we propose a self-alignment method.



1) The autocollimator reads zero at the center position of the mirror

2) When the probe beam is shifted by x the beam is deflected

3) The mirror is rotated so as to re-align the autocollimator readout to zero

At step 3, the deflection of the mirror is compensated by the rotation induced in the goniometer, and therefore the following relationship is established between them

$$\beta_{GON} = -\frac{x}{R} - s(x)$$

Here, the right hand side is a convenient expression for the slope profile

Since the goniometer angle can be measured with sub-microradian accuracy (for instance by using a differential interferometer) one can determine the slope profile of the surface under test with good accuracy.

Defocusing

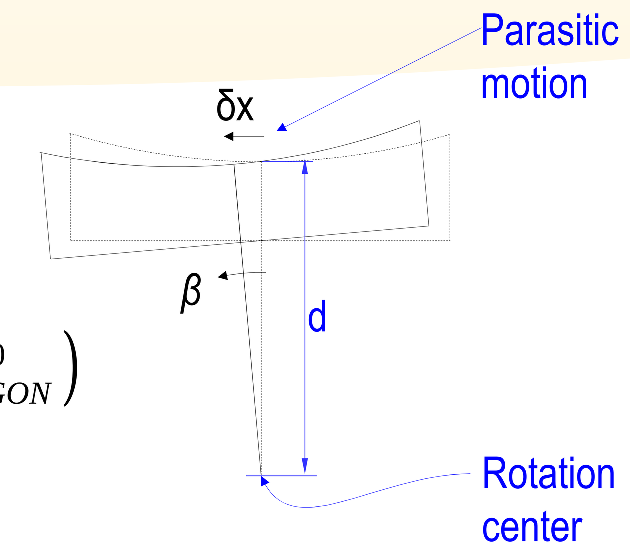
If the distance between the center of curvature of the surface under test, and the focal plane of the lens is ε, the autcollimator angle is given by

$$\alpha_{AC} = (1+D)\left(\beta_{GON} + \frac{x}{R} + s(x)\right) \qquad D = 2\frac{R+f+\varepsilon}{fR}\varepsilon$$

However, since the error is a multiplicative constant, when the autocollimator reads zero, the relationship between the surface slope profile and the goniometer readout is still valid.

Misalignment

When the center of rotation of the mirror is different from the pole of the mirror, an error is introduced in the measurement of the radius of curvature



$$\beta^0_{GON}(x) = -\frac{x - d\sin\beta^0_{GON}}{R} - s\left(x - d\sin\beta^0_{GON}\right)$$

$$= -\frac{x - d\beta^0_{GON}}{R} - s(x) - \left.\frac{ds}{dx}\right|_x d\beta^0_{GON}$$

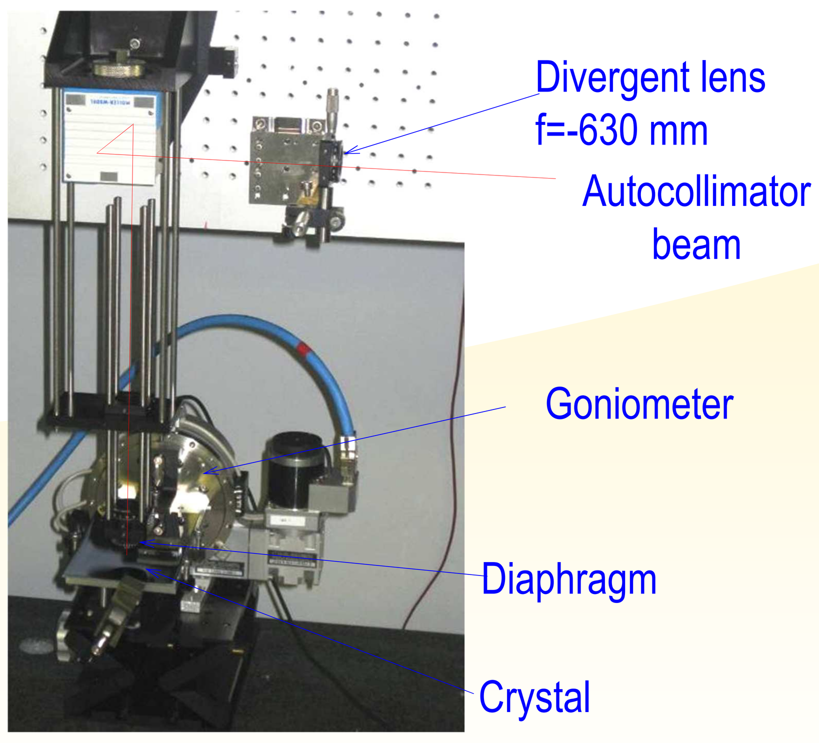
This term vanishes since it is proportional to the curvature of the residual error

$$\boxed{\beta^0_{GON} \cong -\frac{x}{(R-d)} - s(x)}$$

Setup

The setup to measure a R=1 m crystal is shown. The crystal is mounted on a rotatable platform, and the height of the mirror can be adjusted to set the mirror pole at the rotation axis of the goniometer. The accuracy of the encoder of the goniometer is good enough for this sample.

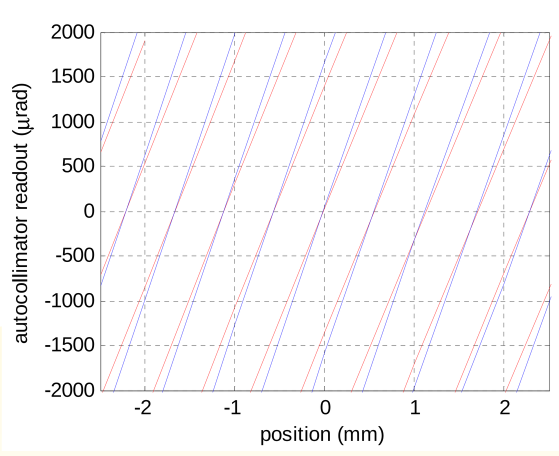
Alternatively, we can measure the rotation of the goniometer with a differential interferometer, with resolution 40 nrad



Results

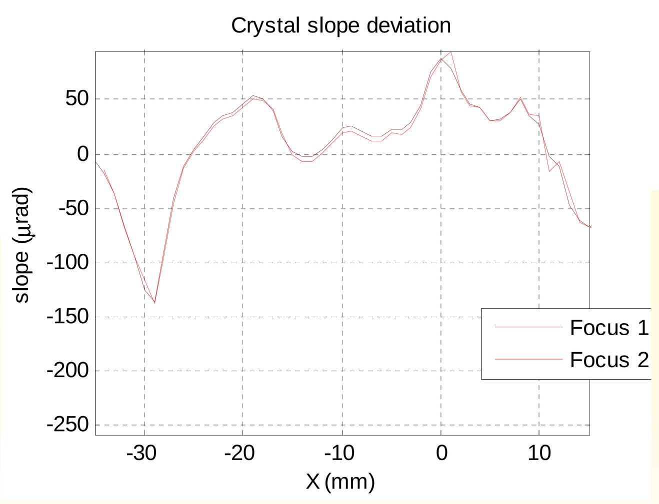
Defocus independence

The independence of the measurement on the focusing error has been checked by taking two measurements with a 10 mm difference in the position of the lens, and checking that the same figure is measured.



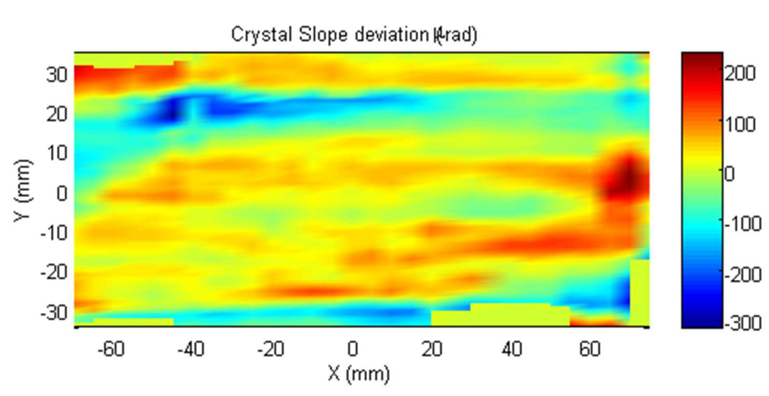
R_{Focus1}= 1.0234 m
R_{Focus2}=1.0230 m

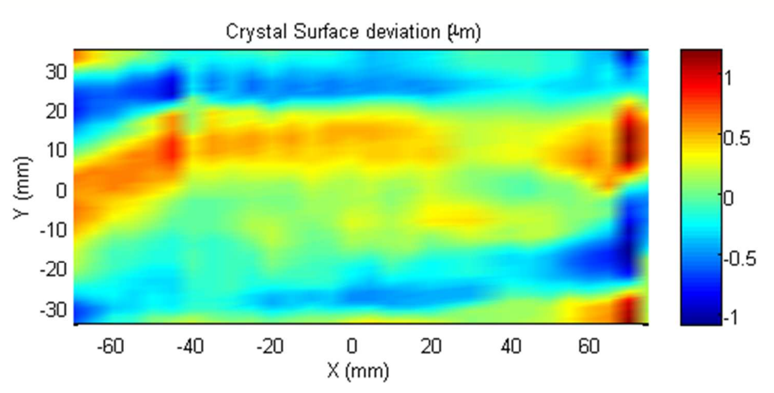
Slope scans obtained at slightly different positions of the lens.

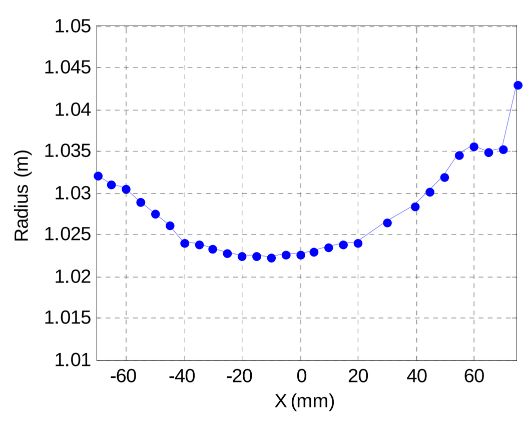


Slope error distribution for the two different focal conditions

Measuring a 1m cylinder







Reconstruction of the crystal surface error for a R=1 m crystal to be used in a reflectometer. The radius has been checked to be around 1.03 m along the whole crystal length