Journal of
Synchrotron Radiation
ISSN 0909-0495

Received 2 July 2010
Accepted 16 October 2010

GROIN: a fast optical adjustment of a Kirkpatrick–Baez set-up

G. Cauchon and P. Lagarde*

Synchrotron Soleil, BP 48, l'Orme des Merisiers, 91192 Gif-sur-Yvette, France.
E-mail: pierre.lagarde@synchrotron-soleil.fr

A very simple and compact optical device aimed at the fast adjustment, alignment and bending of the mirrors of a Kirpatrick–Baez system used in the X-ray domain is described.

Keywords: X-ray microfocusing; KB optics; KB adjustment.

1. Introduction

Focusing systems based on a couple of crossed elliptical mirrors in the so-called Kirpatrick–Baez (KB) configuration (Kirkpatrick & Baez, 1948) are nowadays very common on synchrotron facilities all around the world. While the ultimate focusing ability of a KB is about one order of magnitude inferior than that of a Fresnel zone plate (FZP), its achromaticity plus a larger focal length play in favor of a KB solution for extended X-ray spectroscopy experiments, when moreover some space is needed around the sample.

Nevertheless, in the X-ray regime, that is to say above 1 keV, the actual situation is slightly more complicated than the ideal one for several reasons. First, a set of KB mirrors is more complicated to design and to adjust than a FZP. Second, sweeping the energy by means of a monochromator (a two-crystal or channel-cut) in order to perform spectroscopy will always cause slight displacements of the beam which, given the very grazing incidence of the optics, will perturb the ideal tuning of the mirrors. This is especially the case at low energies (around 2–4 keV) where the change in Bragg angle as a function of the energy is very large. As a consequence, the size and the position of the beam on the sample may change during an X-ray absorption spectrum. While tracking this movement and correcting it can be implemented for a FZP as well as for the sample holder, this becomes barely feasible for a heavy ensemble like a KB. Moreover, most of the microfocused beamlines use an undulator which does not have a very precise definition of its optical source. Finally we may want to slightly change the focusing size or the focusing position for some experiments.

For all these above reasons almost all the KB systems on X-ray synchrotron beamlines are based on bendable mirrors, starting from flat mirrors and using actuators to obtain the correct optical shape. The photon spot size is then classically checked using the well known 'blade-scan' technique: the derivative of the transmitted intensity *versus* the displacement gives the actual shape of the beam. Actually, this method has been criticized for X-ray optics, in a paper where the authors claim that the use of dots of a decreasing size to really measure the repartition of the photons in the focal spot gives more accurate results than the blade scan (Thompson *et al.*, 2001). The true measurement of the wavefront by a Shack-Hartmann optic, very efficient in the visible and XUV (Mercère *et al.*, 2006), becomes unreliable for harder X-rays because of saturation problems of the CCD detectors. Then, obtaining the best focusing by a 'trial and error' process where the actuators of the mirrors are moved, the result measured and so on, can be very time consuming and hardly automated.

We present here a very simple and light set-up which allows this adjustment in terms of minutes instead of hours, while controlling the process at each step. It is named GROIN, an acronym for 'great resolution optics in nanoscale'. The concept and design of this optical system was originally developed and deployed at the Advanced Photon Source (Eng *et al.*, 1998). The version described here is very compact, portable and easily installed on the sample holder. It has been used for the first time at the French Nanospectroscopy beamline at Elettra, and is now installed on the Lucia beamline at Soleil.

The system is shown in Fig. 1: the microscope M (×4) makes at the infinite an image of the visible spot created by the X-ray beam impinging a 500 μm YAG crystal. This visible image can then be monitored by a CCD camera (pixel size = 4 μm) and the only adjustment to be made is the fine positioning of the microscope which has to give a sharp image of the visible spot.

At energies of a few keV the attenuation depth of the X-ray into the YAG crystal amounts to a few micrometers although the waist of the KB system is appreciably larger than that. What is obtained on

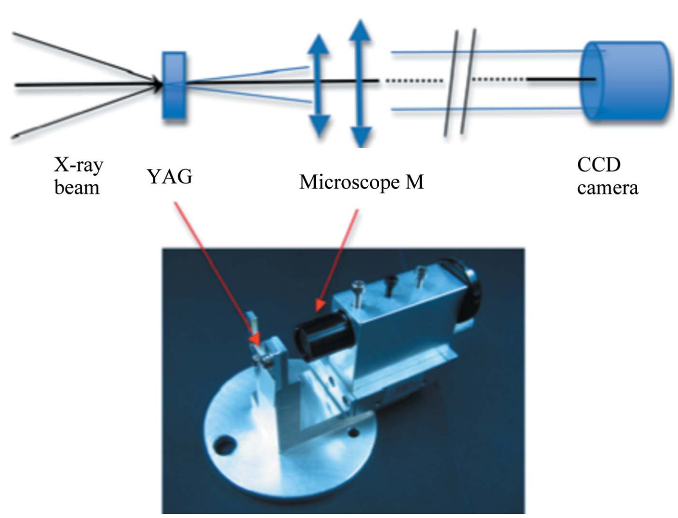

Figure 1
Scheme and photograph of the GROIN system. The YAG–microscope distance is of the order of 2 cm, and the camera can be set at any distance beyond the microscope. The optical adjustment is limited to a setting of the YAG–microscope distance with a micrometer.

the camera is therefore a good image of the X-ray spot. Because the image given by the microscope is set to the infinite, the distance of the camera behind does not need to be well defined. For instance, the camera can be mounted outside of the vacuum experimental chamber used at the Lucia beamline, through an optical window.

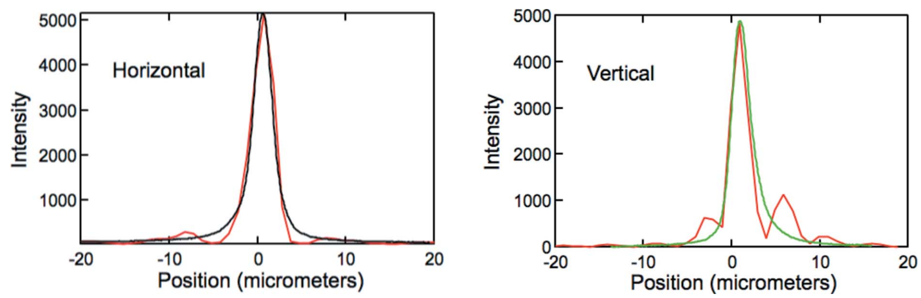

Figure 2
Shape of the beam as given by a blade scan analysis (in red) compared with a line scan of the camera image (black and green). The FWHM of a Gaussian fit of these results is 2.3 μm for both directions.

2. Optical adjustment

The YAG and the microscope are held together on a common support and a micrometer translation allows adjustment of the distance between the microscope and the front face of the YAG where the visible image is created. This ensemble is put on the sample holder in the experimental chamber, which provides transverse and longitudinal (along the beam) movements. The front face of the YAG is set as close as possible to the focal point by a translation along the beam axis, and then the optical axis of the microscope must be aligned to pass through this focal point. This is done by translations normal to the X-ray beam until the visible (green) light from the YAG shines behind the microscope. The image is then easily obtained on the CCD camera positioned on the optical axis.

The next step consists of a precise adjustment of the microscope by a change of its distance to the X-ray focusing point using the micrometer until a sharp image on the camera is obtained. Once this has been completed the final calibration is made by comparing the size of the image with the one given by a conventional blade edge scan. Since the YAG and the microscope are held together the whole system remains stable and the GROIN can be removed and put back very quickly.

3. Results

The image obtained on the camera is therefore a live image of the X-ray spot: it becomes therefore very easy to directly follow the focusing process, as well as the behavior of the position of the beam when the X-ray energy is changed, without the slow process of measuring the shape of the beam with a blade scan and correcting for errors. Fig. 2 shows a comparative analysis of the beam recorded on the camera with a blade scan on the same holder. Given the magnification ratio of the microscope and the pixel size of the camera, one pixel represents 0.06 μm. Therefore the pixel size is not the limiting factor in the set-up. The resolution of the set-up has been tested and is close to 2 μm, which allows a smooth and precise adjustment of a focal spot of the order of 2–5 μm.

The blade scan exhibits artefacts not present in the line profile of the image. Two reasons are at the origin of these differences: (i) the visible image on the YAG is created by the X-rays over a depth of a few micrometers, and therefore the image given by the microscope is slightly blurred, as are the line profiles, and (ii) the edge of the blades used for the 'blade-scan' analysis are not perfect for experiments performed at 4 keV. The agreement between the two measurements is nevertheless very satisfactory since a Gaussian fit of the curves results in a common value (2.3 μm FWHM for both curves in both directions).

In conclusion, the system described here allows a very easy and fast adjustment of the benders of the two KB mirrors with a direct monitoring of the process. The ensemble can easily be mounted on the sample holder of the beamline for a periodic check of the KB focusing system.

References

Eng, P. J., Newville, M., Rivers, M. L. & Sutton, S. R. (1998). *Proc. SPIE*, **3449**, 145–156.
Kirkpatrick, P. & Baez, A. V. (1948). *J. Opt. Soc. Am.* **38**, 766–773.
Mercère, P., Idir, M., Moreno, T., Cauchon, G., Dovillaire, G., Levecq, X., Couvet, L., Bucourt, S. & Zeitoun, P. (2006). *Opt. Lett.* **31**, 199–201.
Thompson, A. C., Underwood, J. H., Anderson, E. H., McHugo, S. A. & Lai, B. P. (2001). *Proc. SPIE*, **4145**, 16–21.