Versatile Focusing Options by Combining a Toroidal Mirror with Kirkpatrick-Baez Mirrors

S. M. Heald

Pacific Northwest National Laboratory, Richland, WA, U.S.A.

The primary focusing optic for the PNC-CAT ID beamline is a toroidal focusing mirror formed by bending a cylinder. By controlling its bend and tilt, the entire undulator beam can be focused at any point in the two sequential endstation hutches (20-ID-B and C). The mirror and bender[1] have been working to specifications and provide a sub-mm image as shown in Fig. 1.

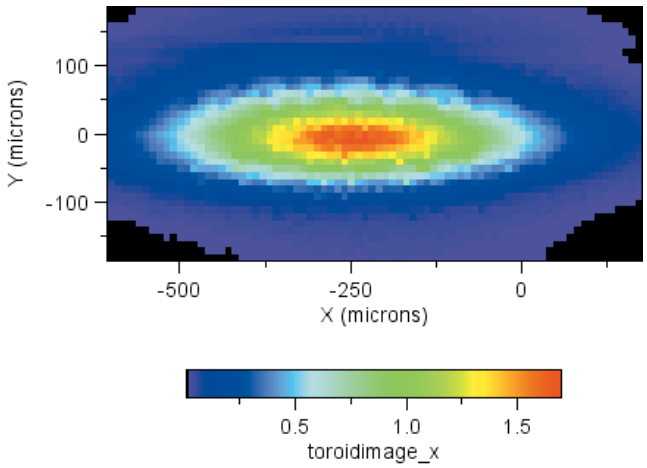

FIG. 1. Image of toroidal mirror focus obtained by scanning a 10 µm pinhole over the focal spot. FWHM is 390 (H) x 94 (V) µm.

For microfocusing, the PNC-CAT also has two Kirkpatrick-Baez (K-B) mirror systems[2] based on a design by the CARS-CAT.[3] A small set collects a 0.25x0.25 mm beam and focuses to 1-2 µm. A longer set collects a 0.6x0.6 mm beam and focuses to 3-5 µm. To provide these spot sizes, the K-B mirrors must be imaging the source and the toroidal mirror is removed. The unfocused undulator beam is about 1 x 3 mm, which means that the K-B mirrors can only collect a fraction of the undulator output. The K-B mirrors also have a relatively short working distance and give a large beam divergence.

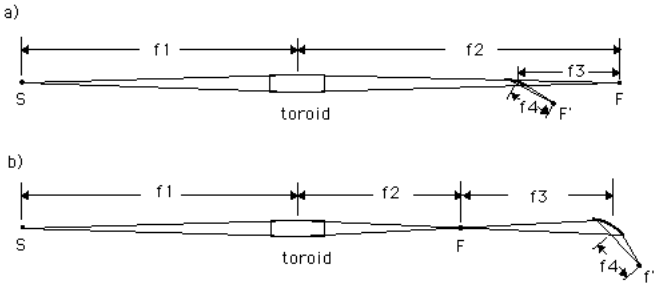

FIG. 2. The two possible geometries for combining a toriodal mirror with K-B mirror. At PNC f1= 34.3 m, and f2 varies from 17-24 m.

Since the acceptance of the long K-B mirrors is larger than the toroidal mirror focus, it is possible to combine the two and still collect the entire undulator beam. Figure 2 shows the two possible arrangements. The K-B mirrors can intercept the beam either before the toroidal focus, as in Fig. 2a, or after, as in Fig. 2b. In both cases, the toroidal mirror focal spot is refocused to a spot with dimensions reduced by f3/f4. For a typical case, f3 is about 5 m and f4 about 1 m giving a size reduction of 5 in the focus. This increases the beam divergence by 5, but it is still much less then the divergence from the K-B mirrors in normal operation. The 1 m working distance and modest divergence make this arrangement well suited to x-ray scattering experiments employing large diffractometers.

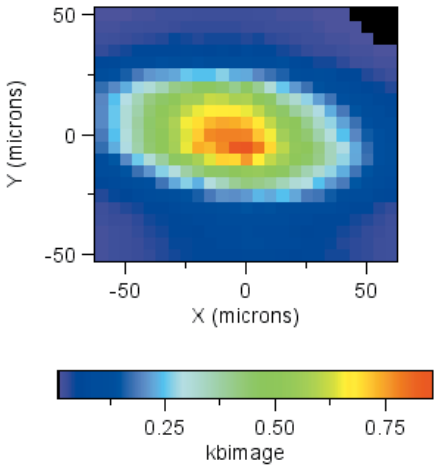

FIG. 3. 10 µm pinhole scan of focus for the Fig. 2a arrangement with f3=5 m and f4=1 m. FWHM is 72 (H) x 39 (V) µm.

For practical reasons related to the range in toroidal mirror angles allowed by the beamline windows, the arrangement in Fig. 2a is most suitable when focusing in 20-ID-B, and the arrangement in Fig. 2b is best for 20-ID-C. The ideal figure for the K-B mirrors in arrangement 2a is a hyperbola. The K-B mirror benders are optimized for bending to a particular elliptical figure. The question arises as to how well they will work for this application. Figure 3 shows the focus obtained by combining the toroidal mirror and long K-B mirrors in arrangement 2a with a 5:1 demagnification of the toroidal mirror focus. The expected reduction is achieved for the horizontal dimension while the vertical reduction is only about 1/2 of the expected amount. This is probably an indication of slope errors in achieving the proper hyperbola. When using non-optimized mirrors, such slope errors can be expected to set a lower limit on the achievable spot size by this method. The vertical beam size from the toroidal mirror is already small enough for many experiments. For those cases, it is possible to only use the horizontally focusing component of the K-B arrangement, simplifying the setup and alignment.

The combination of toroidal and K-B mirrors provides very versatile focusing options. Focal spots from mm to microns can be achieved with independent control of the horizontal and vertical focus. Beam size and divergence can be optimized for the needs of the experiment.

Acknowledgments

The PNC-CAT project is supported by funding from the U.S. Department of Energy, Basic Energy Sciences, the National Science Foundation, the University of Washington, the Natural Sciences and Engineering Research Council in Canada, and Simon Fraser University. The Pacific Northwest National Laboratory is operated by Battelle Memorial Institute for the U.S. DOE. The APS is supported by the U.S. DOE, BES, Office of Science under Contract No. W-31-109-Eng-38.

References

[1] Manufactured by SESO Inc.

[2] P. Kirkpatrick, A. V. Baez, J. Opt. Soc. Am. **38**, 776 (1948).

[3] B.X. Yang, M. Rivers, W. Schildkamp, P.J. Eng, Rev. Sci. Instrum. **66**, 2278-2280 (1993).