Performance of Microfocusing by Elliptical Bendable Mirrors for Soft X-ray

Noboru Kamachi[a], Jun Nakagawa[a], Katsumi Endo[a], Takeshi Kanashima[b]
and Haruhiko Ohashi[c]
[a] Toyama Co., Ltd., 4-13-16 Hibarigaoka, Zama-shi, Kanagawa 228-0003, Japan
[b] Osaka University, Machikaneyama-cho 1-3, Toyonaka, Osaka 560-8531, Japan
[c] SPring-8/JASRI, 1-1-1 Kouto, Sayo, Hyogo 679-5198, Japan

Abstract

In our study on an "Arm Method" mirror bender, we reported the performance of the horizontally focusing mirror. Following those evaluations, we have installed two bendable mirrors in Kirkpatric-Baez geometry to microfocus the SR light in the SPring-8 BL27SU. After careful alignment of the bender, the vertical and horizontal focused beam radii were obtained to be 5.93 μm and 7.44 μm, respectively.

1. Introduction

We have supplied a large number of “Arm Method” mirror benders to SPring-8 and KEK/PF, and have already reported the performance of focal position, spot size, stability, reproducibility and firmness of the horizontally focusing mirror. Following these works, we have installed two bent mirrors in Kirkpatric-Baez geometry to microfocus the SR light in the SPring-8 BL27SU[1,2].

2. Mirror Bender

Concept of the “Arm method” mirror bender is a mechanism to produce an arbitrary magnitude of mirror curvature by asymmetrically pulling two stainless-steel arm shafts equipped on both the ends of the mirror. As shown in Fig.1, the driving mechanism consists of feed screws, worm gears and stepping motors. In order to control the curvature in vacuum, stresses produced by individual stepping motors are added to the corresponding arm shafts. The merit of using the stepping motor is that the generated torque in a stationary state is so high that it can hold the arm shafts firmly. Also by adjusting the shaft diameters, materials and numbers, it is possible to obtain necessary curvature of mirror with various materials and shapes.

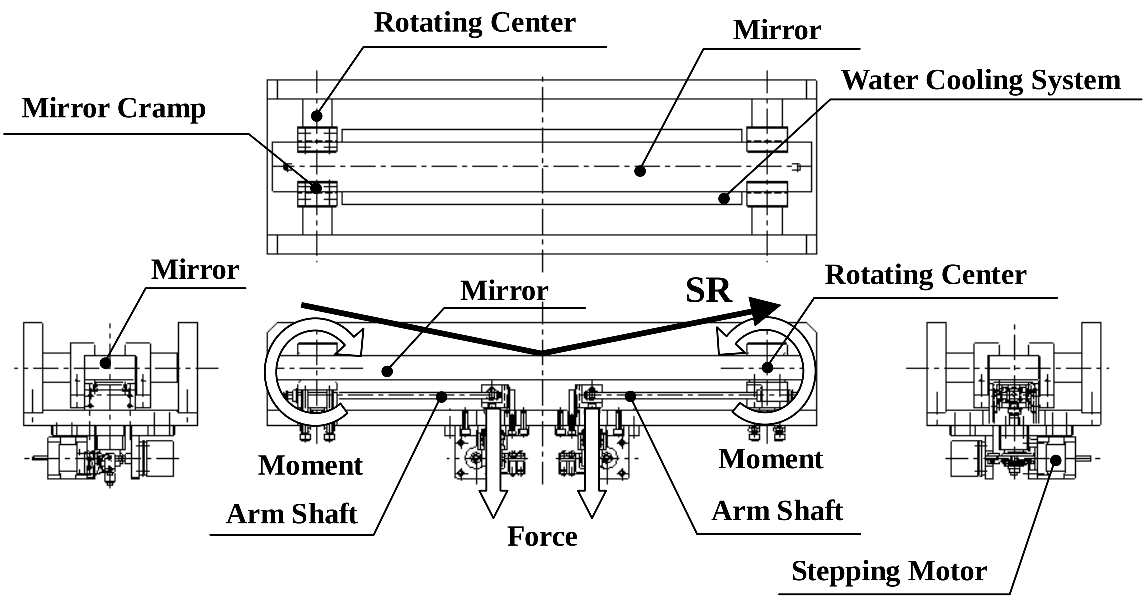


Fig.1 Mechanism of Arm Method Mirror Bender

3. Brief description of previous result

3.1. Evaluation of mirror bender by LTP measurement

In order to evaluate fundamental performances of the mirror bender, following LTP II(Long Trace Profiler) [3,4] measurement were accomplished at SPring-8. The mirror used was made of silicon with 50(W)x540(L)x25(T)mm^3 . The results are as follows, where (1) to (5) performed by shafts pulled symmetrically, while in (6), the shafts pulled asymmetrically.

(1) Slope errors defined as discrepancies of curvatures between actual and ideal surfaces; the rms slope error averaging over the ideal curvatures between 13km and 0.9 km is 0.98 μrad, while the slope error of the mirror without bender, whose curvature corresponds to 13 km owing to effect of gravity, is 1.27 μrad (see Fig. 2)[5].

(2) Reproducibility of the curvature; better than 0.5 % of the curvature[5].

(3) Fluctuation of the curvature for 24 hours; better than 0.5 % of the curvature (fluctuation of the room temperature was ±0.2°C) [5].

(4) Contribution to the slope error by mirror bender; rms slope error averaging over the curvature between 13 km and 0.9 km is 0.74 μrad after being substituted by the original slope error of the mirror itself[6].

(5) Effect of cooling water system; by setting a water cooling plate, the slope error increased amount of 1 μrad[4], though the measured condition was not so good as the cases in refs. 5 and 6. The amount of the slope error depends on torques and mechanism of fittings[4].

(6) Slope error of elliptically bending; horizontally setting the mirror, the slope error was determined to be 0.74 μrad (the elliptical parameters; f1=58.5 m, f2=2.5 m, the incident angle is 178 degree, and these values were selected to fit the one-dimensional focusing of BL27SU beamline at SPring-8) [6].

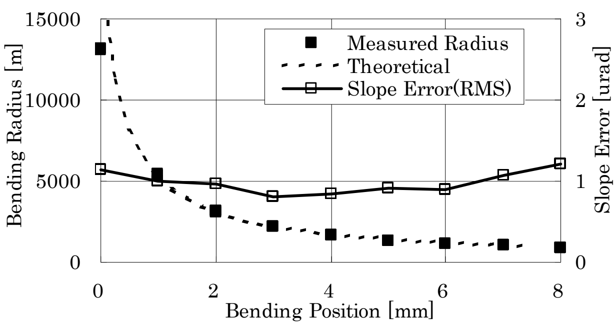


Fig.2 Curvature and slope errors vs. bending

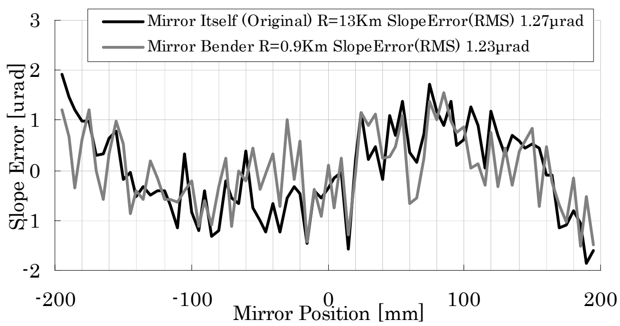


Fig.3 Result of slope error measurement

Fig.3 shows examples of slope error measurements with the curvature of about 0.9 km and mirror itself (without bending moment). From this figure, since the similarity of slope errors between two is clearly recognized, the effect to the slope error from the bender is not large.

Thus, it is concluded that the mechanism of the mirror bender adopted here can bend the mirror to nearly ideal shape. Necessary reproducibility and firmness are also satisfied by the bender.

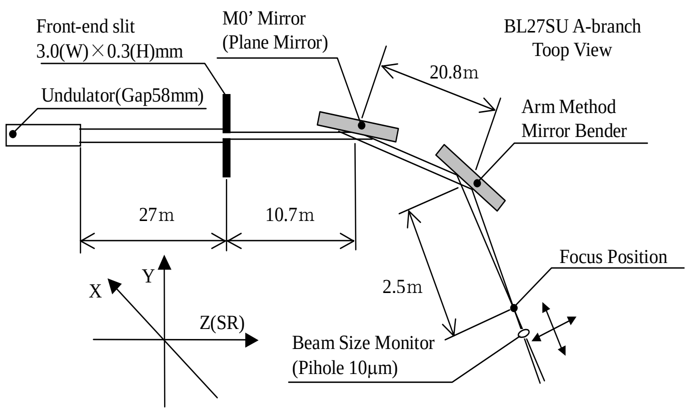


Fig.4 Layout of BL27SU a-branch

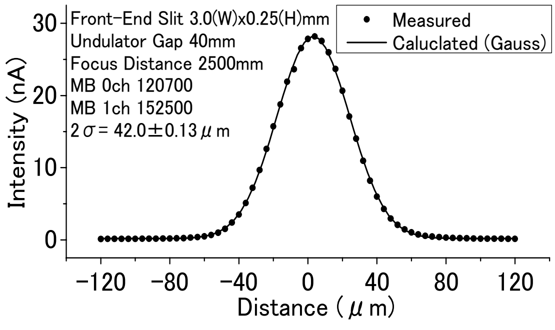


Fig.5 Beam profile of one dimensional focusing

3.2. Result of one-dimensional microfocusing at SPring-8 BL27 a-branch

Installing the mirror bender into BL27SU a-branch at SPring-8, the synchrotron light was horizontally focused, as shown in Fig.4[7]. The focused beam profile was measured by a pinhole beam profile monitor. Since the size of source was 758 μm (defined as twice the rms of Gaussian fitting(2σ)) and demagnification ratio was 1/23, the ideal focusing size should be 32.4 μm. The observed beam pattern was able to be well fitted by a Gaussian pattern and size was 42 μm(see Fig. 5).
After changing the given stress to the shaft and returning to the original position, the profile was reproduced within 0.5 % of the rms.

4. Two-dimensionally microfocusing experiment with Kirkpatric-Baez geometry (SPring-8 BL27 b-branch)

In order to focus to the micro spot, two mirror benders have been installed to Kirkpatric-Baez geometry in SPring-8 BL27 b-branch. The "Arm Method" mirror bender (M1'b bellow in Fig.6) was vertically equipped and fixed bendable mirror (M2'b)was horizontally settled in the beamline. The latter mirror has a trapezoidal shape and its curvature was adjusted to ellipsoidal figure in atmosphere by screw bolts. The curvature was checked by LTP measurement. Pictures of these two mirrors installed in chambers are shown in Figs.7 and 8.
The "double pipe" cooling system as before was used to cool the mirror bender.

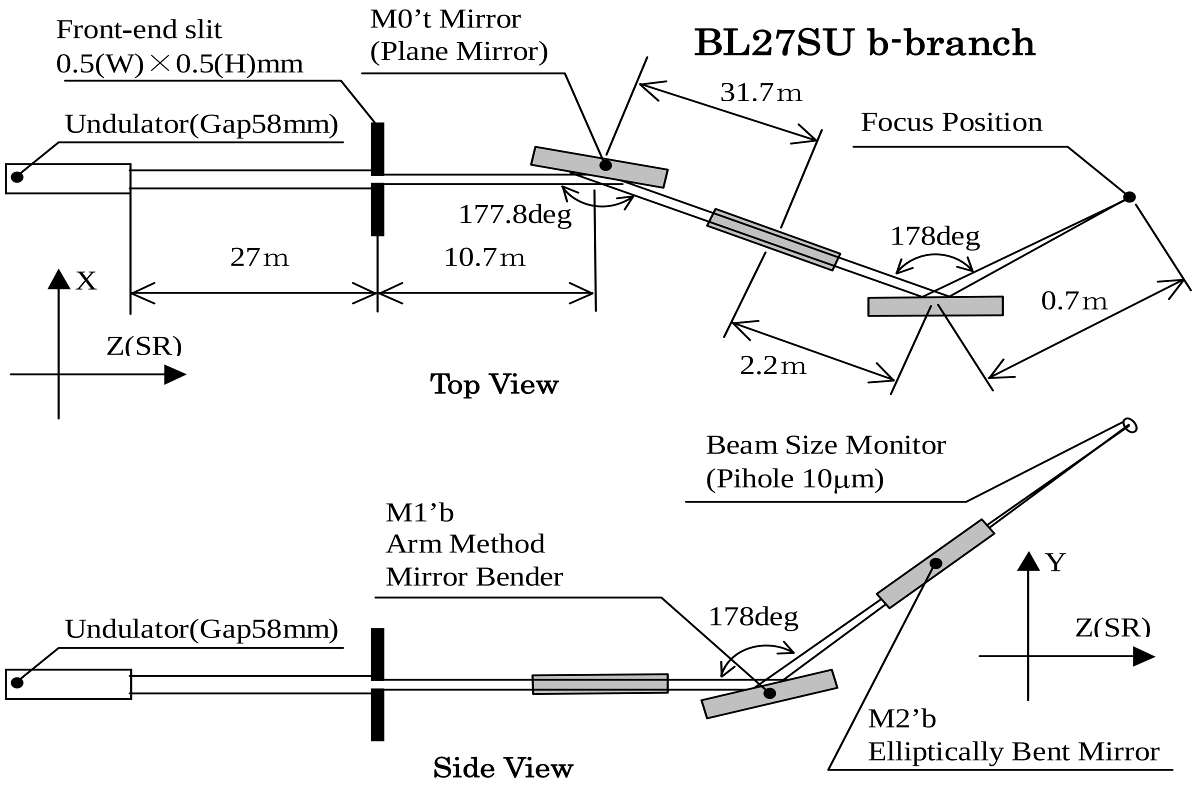


Fig.6 Layout of BL27SU b-branch

Beam profile monitor was composed of 5 μm pinhole and gold coated metal plate. This was settled at the ideal focal position (0.7m apart from the center of M2'b mirror) and was able to be moved with 40 nm/pulse along x, and y-axes, perpendicular to the beam direction. The mechanism to move along the beam axis was not included in the monitor.
Since the demagnification ratios along vertical and horizontal axes of the optics are 1/24 and 1/100, respectively, the ideal spot sizes evaluated from these magnification ratios and SR source sizes (27.2 μm and 758 μm) must be 1.13 μm and 7.6 μm, respectively.

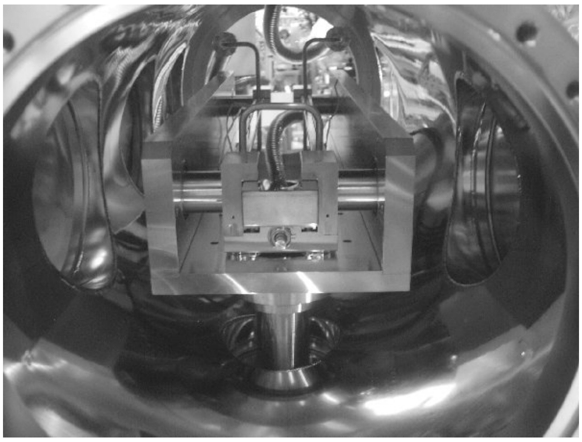


Fig. 7 M1’b mechanism in chamber

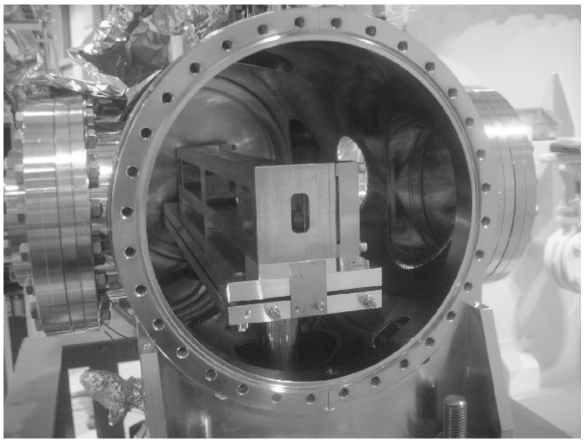


Fig.8 M2’b mechanism in chamber

5. Result of measurement

After adjusting the yaw and pitch angles of M1’b and M2’b, the beam profiles on the ideal focal plane were measured with various bending moments added to the M1’b mirror.

5.1. Variation of the profiles with different moments added to the mirror

The bending moments to the shafts of M1’b “Arm Method” mirror bender were adjusted to get the minimum beam size on the focal plane.

Fig.9 shows dependence of beam widths on given pulling moments to the shafts. The width was defined as twice the standard deviation (2σ) of Gaussian fitting in consideration of convolution of instrument function of the pinhole slit and the amount of the pulling moment was given as pulling position of the shafts.

It was assured that increasing the moments added to the shafts on the lower and upper stream of the beam light, the focus beam size became smaller. When the mirror curvature approached to the ideal one, the variation of the sizes became insensitive on the amount of stress added to the shafts.

Observed and fitted one-dimensional beam profiles along vertical and horizontal axes are shown in Figs. 10 and 11, respectively. The horizontal mirror bender was not able to be adjusted in vacuum.

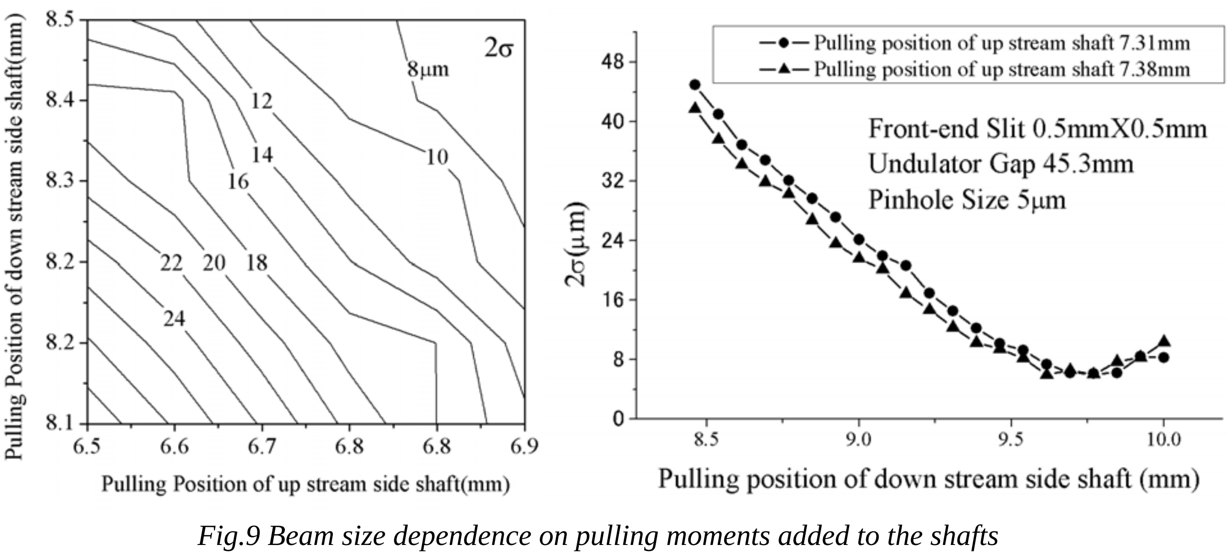


Fig.9 Beam size dependence on pulling moments added to the shafts (given as pulling positions of the shafts)

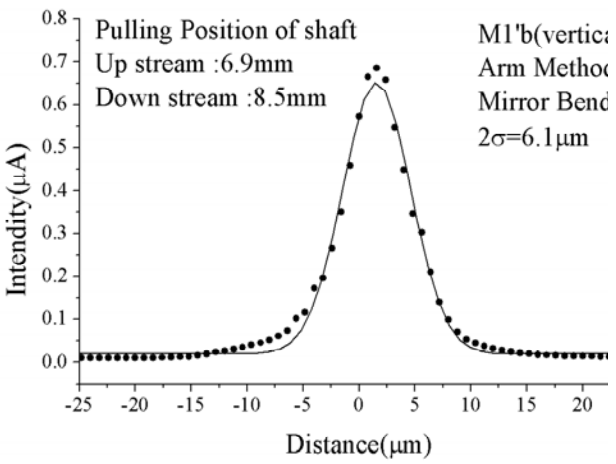


Fig.10 Vertical beam profile by the mirror bender

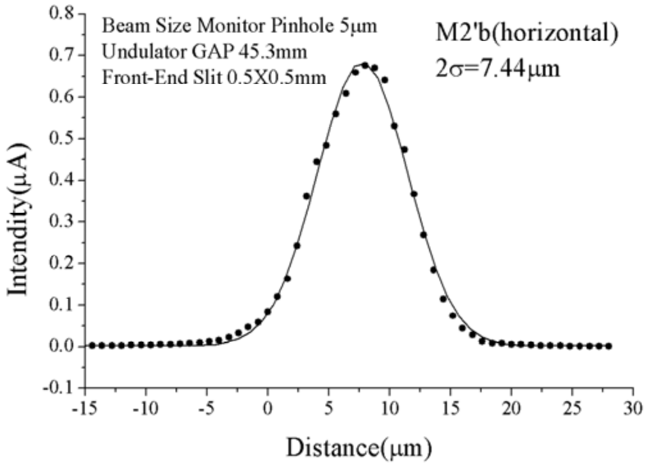
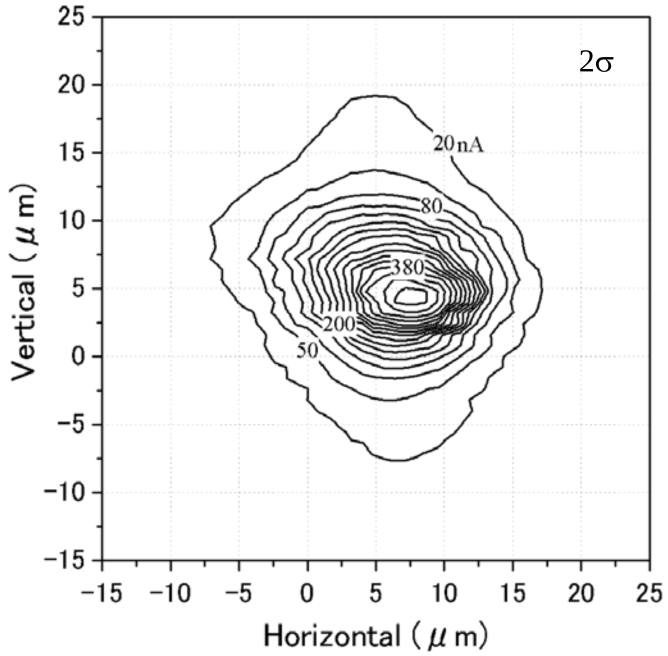


Fig.11 Horizontal beam profile by the mirror

5.2. Two-dimensional mapping

Fig.12 shows the two-dimensional mapping measured with the same condition as Figs.10 and 11. The total focused current obtained by integration of the measured profile was 2.25 μA, that was 49 % of the current measured at just upstream of the M1'b mirror, 4.8 μA, using an Au coated plate.



Pinhole 5 mm
GAP 45.3
Slit 0.5X0.5
Pulling Position of shaft
Up stream :6.9 mm
Down stream :8.5 mm

Background = 0.1 nA
Focus Current =2.25 μA
Total Current = 4.8 μA
Focus/Total = 0.49

Fig.12 Mapping of focused beam image

5.3. Adjustment to final focusing

Further adjusting the curvature of M1'b, the smallest beam size was obtained as 5.93 μm(Fig.13). This beam size is about 10 times larger than the expected focusing size. This discrepancy can be explained by the slope errors of the bent mirror.

There are three sources contributed to the slope error; the slope error originated from mirror itself, that due to the bender, and that due to cooling pipes. Since the mirror used in the present study had its original rms slope error of about 1 μrad (1σ), contribution from this slope error to the beam size was estimated around 6 μm (2σ). The beam size focused can be thus explained mainly by that of the original mirror. This shows that focusing performance of M1'b was limited by the slope error of the mirror surface when polishing and if the mirror with smaller slope error could be used, the focusing beam size will approach to the ideal beam size.

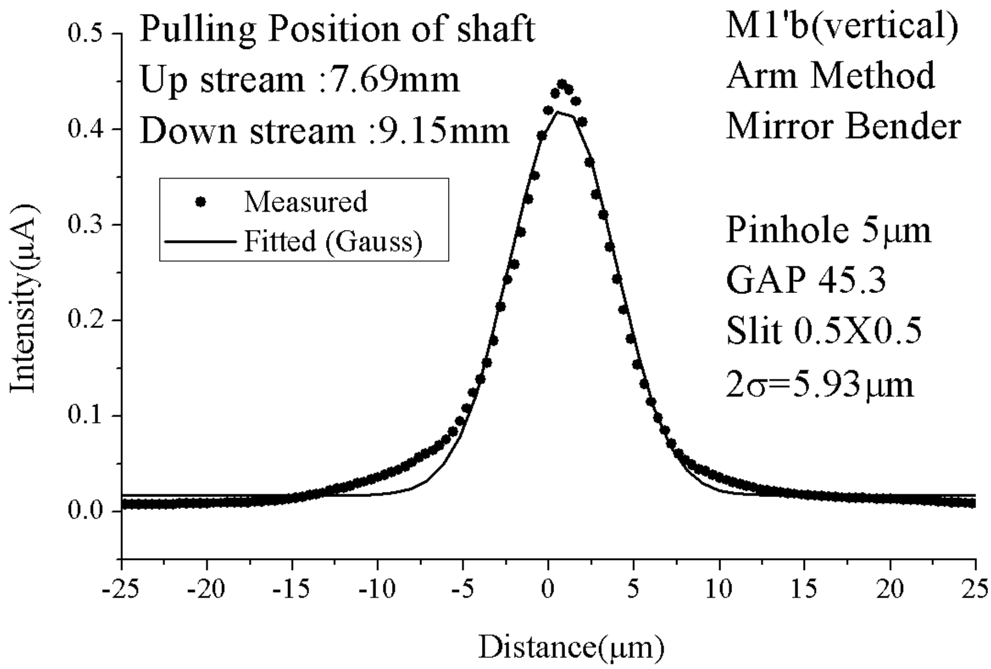


Fig.13 Beam profile focused by the "Arm Method Mirror Bender"

6. Conclusion

Using K-B configuration, the "Arm Method" mirror bender was able to focus the SR beam to 5.93 μm with total reflective efficiency of 49 %. Although this size was larger than the beam size expected from the light source size and demagnification ratio, the slope error of the mirror had a significant role to the beam size. If the mirror with smaller slope error is to be used, the beam size must become smaller. The total reflective efficiency of 49% seems well after reflected by two mirrors.
Thus, the "Arm Method" mirror bender is concluded to be a good mechanism to adjust the shapes of mirrors in vacuum.

7. References

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