X-ray Focusing Mirrors

Technical Datasheet

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JTEC designs and manufactures state-of-the-art X-ray focusing mirrors. The mirrors are produced following original technologies developed at Osaka University. These technologies can reduce shape errors of the mirror surface down to atomic level. The mirrors made by these technologies achieved close to ideal focusing profiles when used at X-ray synchrotron beamlines.

1. K-B mirror system

(1) What is a K-B mirror system?

This optical system consists of two total reflection elliptical mirrors having two focal points: one at the light source and the other at the focal point. One mirror is used for vertical focusing and the other for horizontal focusing. A KB system is achromatic and because of the high reflectivity that can be achieved with our mirrors, X-ray can be focused simply and very efficiently over a large Energy range.

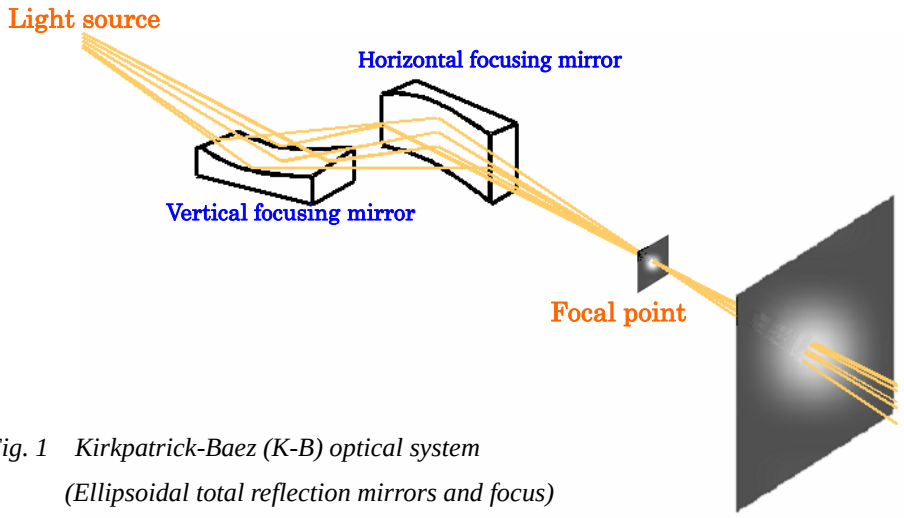


Fig. 1 Kirkpatrick-Baez (K-B) optical system
(Ellipsoidal total reflection mirrors and focus)

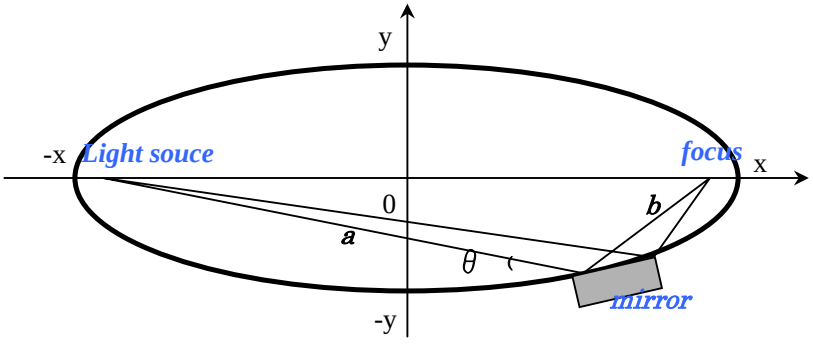


Fig. 2 Physical relation between light source, mirror position and focal point

(2) Technologies used for mirrors manufacturing

We manufacture our K-B mirrors using very high accuracy technologies named EEM, MSI and RADSI that were developed by Osaka University.

① Hyper-precision polishing process technology **(EEM: Elastic Emission Machining)**

EEM is a hyper-precision surface figuring process method based on an innovative machining approach, which uses a chemical reaction occurring between solid surfaces. As a consequence of the chemical reaction between atoms of ultra fine slurry particles and the particles from the mirror surface, the atoms of the surface being polished are stripped away by the ultra fine particles. Therefore EEM generates **no atomic distortions** on the processed surface and achieves the desired finished surface with deviations in the level of atomic size.

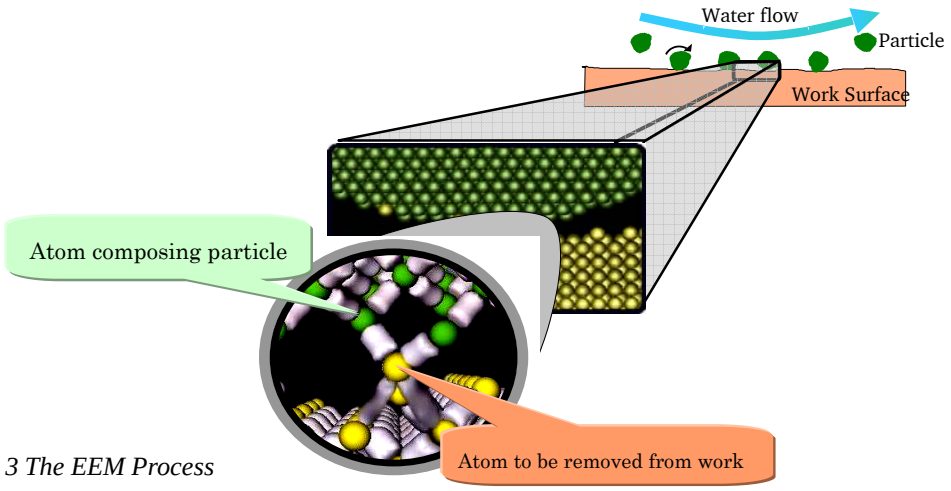
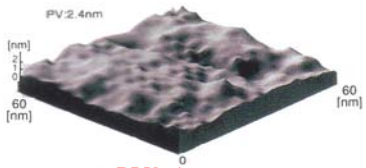


Fig. 3 The EEM Process

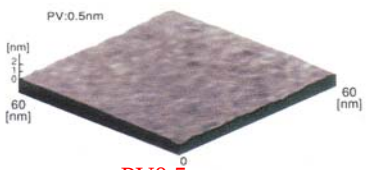
The images below show EEM processed silicon wafer surfaces that were examined by STM. It can be seen that roughness improved from 2.4nm (see Fig.4a) to 0.5nm (see Fig.4b) in P-V. It was observed that the 95% of the finished surface consisted of only three atomic layers. The EEM-polished sample used for these measurements is the flattest finished surface ever achieved.

(see Fig.4c: every bright spot shows one single atom.)



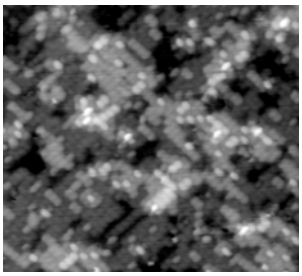
PV2.4nm

(a) A surface of silicon wafer for Ultra LSI



PV0.5nm

(b) The surface with EEM finishing



(c) Field of measurement 40nm ×40nm

Fig.4 EEM processed surface examined by STM
Data provided by Osaka Univ.

② Nano-metrology technique

(MSI: Micro Stitching Interferometry , RADSI: Relative Angle Determinable Stitching Interferometry)

JTEC measures surface shape errors using two different interferometry-based techniques called MSI and RADSI. Using this approach, we can accurately measure long and strongly aspherical mirrors.

(3) Performance of JTEC K-B mirrors

① Convergence diameter

The plots hereafter (Fig.5) report data from the K-B mirror focusing experiment performed jointly by Osaka University and the Institute of Physical & Chemical Research (SPring-8) showing that photon condensing ability has been achieved up to the diffraction limit.

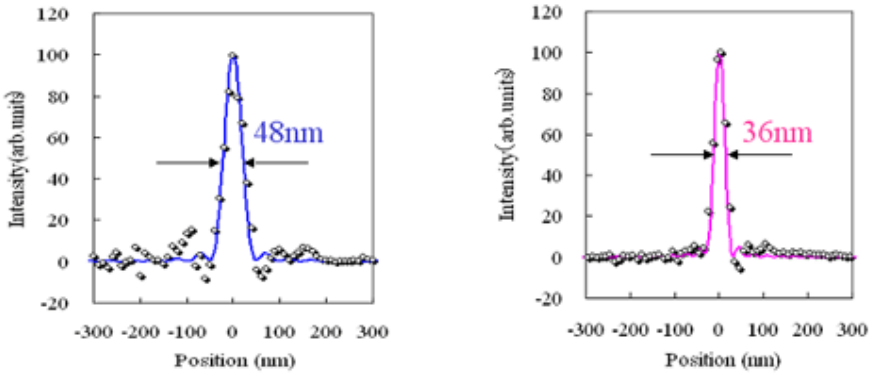


Fig.5 Result achieved at the 1 km Beamline of SPring-8 ; E= 15KeV
Data courtesy of Osaka University

② Work (focal) distance

The distance from the mirror edge to the sample is typically **more than 100 mm**. This relatively large distance will enable the possibility of various studies and installation of sophisticated sample environments.

③ Focal Efficiency

K-B mirrors work in total external reflection and their combined reflectivity will be **more than 50%** .

④ Other Points of Interest

- Achromatic
- Wide angle scattering strongly reduced

(4) Shape Designing

1.Figure Designing

We can design and realize the shape of the mirrors as required by your experimental conditions, taking into account:

a. The distance from the light source to the center of the mirrors (M_1, M_2).

b. The distance from the center of the mirrors（M_1,M_2 to the focus.

c. The distance from the end of M_2 to a sample.

d. The length of the mirrors.

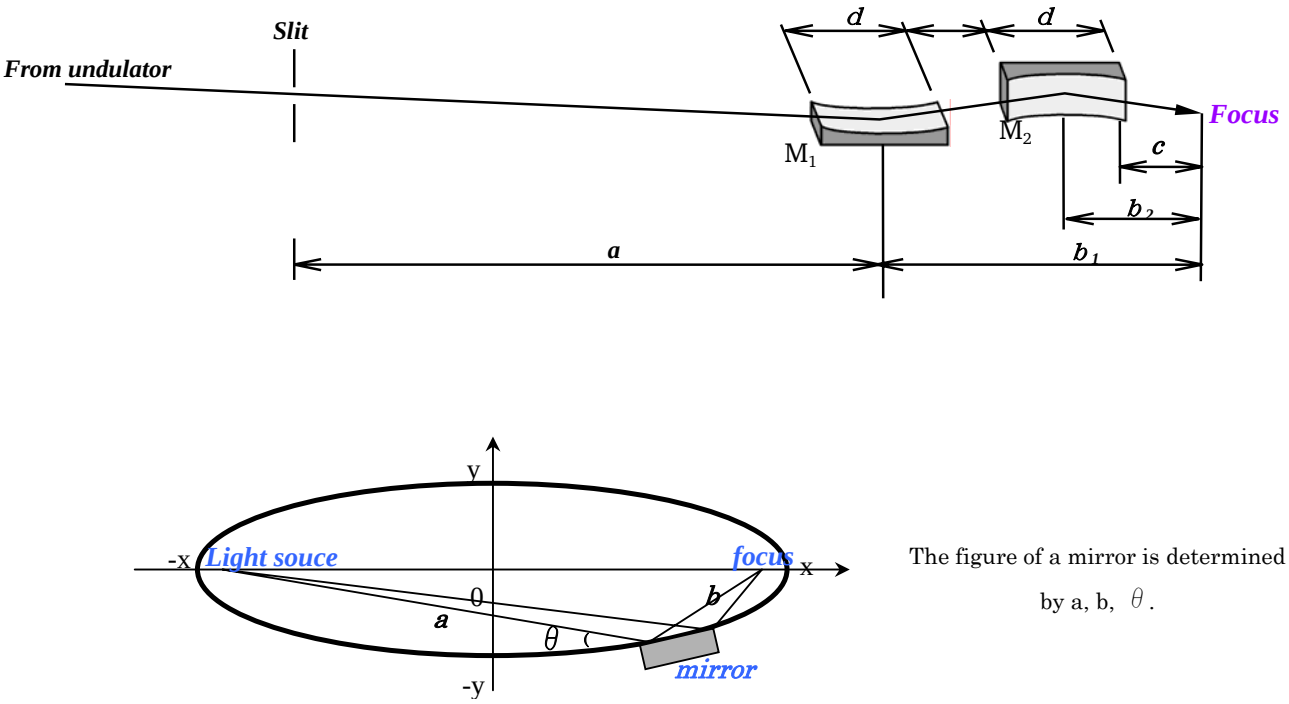
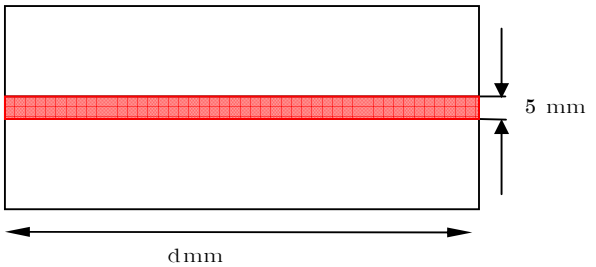


Fig.6 Physical relation between light source, mirror and focal point

2. Useful Area

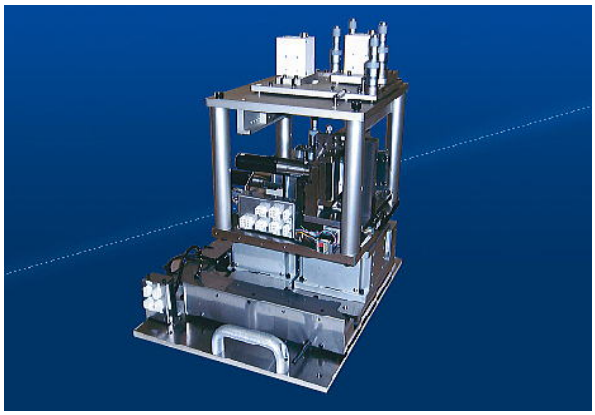
We can currently process the surface of the mirrors to obtain a useful optical area of d (length) × 5mm (width).



A polished stripe every 5mm is possible.

2. Mirror Positioning Unit – JM1000

We can supply not only the K-B mirrors but also a Positioning unit [JM1000] that can set the mirrors at the right position with high accuracy and stability.



Positioning unit 「J M1000」

Our Focusing system allows to accurately determine the mirror orthogonality with auto-collimators and to finely adjust the mirrors relative angle with elastic hinges. (Patent pending)

Mirror installation parts

Auto-collimators

Mirrors installed

3. Made to order

JTEC can manufacture K-B mirrors with state-of-the art peculiarities such high figure accuracy at nm-level and μ-roughness of 0.1 nm rms tailored to your needs.

Substrate Material	Silicon or Quartz glass
Mirror length	From 50 mm to 500 mm
Useful area	Mirror length × 5 mm
Coating @ JTEC	Pt, Au, Rh
Figure accuracy	2 nm P-V for standard process Lower values may be possible and can be quoted on request
Micro roughness	2 Å rms for standard process Approx. 1 Å rms can be achieved and can be quoted on request