An instrument for off line and on line double mirror systems alignment

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Abstract:
Aligning large white beam double mirror systems becomes a challenging task with the only help of classical survey or mechanical techniques. A portable optoelectronics instrument has been developed to control in a clean room the angle of incidence, parallelism and gap value of such systems with respect to survey references. The emitter of the instrument is a transverse mono-mode beam, obtained with a double collimated slits LED based source, and the receiver is an autocollimator measuring the angular and linear beam deviations with better than one µrd and one µm rms precision respectively, as tested in a lab over a 2.5 meters distance .The metrology results are obtained by processing the image of a CCD camera, used in either direct detection of the beam or through the autocollimator telescope. A mirror incidence range from 1 mrd to 1.1 º and a gap range from 0.5 to 34 mm may be used. The system is able to check possible drifts after the closed chamber is transferred on the beamline. The ability to set up precisely the system with manual alignments in a laboratory may allow a restricted number of motorized degrees of freedom, with corresponding stiffness improvements. The instrument also permits the alignment of the yaw and other degrees of freedom of cylinder and toroid systems, as well as beam stops.

1- Requirements and specifications

The ESRF Upgrade program will need 5 double mirror systems [Ref.1], with incidence angles ranging from 3 to 13 milli-radians and gap between mirrors from 1.6 to 8 mm. The required Parallelism accuracy is 20 µrd and the gap accuracy is 30 µm. The designed metrology accuracy of the instrument has to be better then half of these values or 10 µrd and 30 µm respectively. The accuracy of the Survey Group instruments is considered not sufficient with respect to these specifications, which decided the development of a more accurate instrument based on optoelectronics techniques. Furthermore, on line Beamline check up with clean conditions forbidding the opening of the chamber, is not considered possible with survey instruments.

2-Principles of the instrument: incidence angle set up

The emitter is using a high brightness Light Emitting Diode (LED) and the beam structure is defined by a narrow slit, a collimating objective and a double slit. The width of the double slits is chosen so that each beam width φ is minimum along a 2.2 meters propagation, which corresponds to the typical distance L between the emitter and the receiver. $\Phi = k\sqrt{\frac{4\lambda L}{\pi}}$, where λ= 0.53 µm is the wavelength ; k=1 for a Gaussian beam , and k= 0.8 for a uniform beam , therefore φ is chosen equal to 1 mm. The distance between the two slits is chosen equal to the gap. Five different transmission chromium masks corresponding to the five gaps have been manufactured. The receiver is a telescope built with an achromatic doublet of focal length F and a CCD camera placed precisely at the focus of the doublet. The location y of the centroid of the image of the beams, as defined by the slits, is calibrated as the angle position ψ of these beams according to the y= Fψ law .To allows the set up of the first mirror, the gap is set up large so that there is no influence of the second mirror. The incidence set up procedure is shown in Fig.1, where the direct beam is selected by the right slit and the reflected beam by the left slit. The angle of incidence θ on the mirror is adjusted by rotating it around a vertical axis, according to the difference between the angular position of the direct beam set as 0 and the 2θ reflected beam. The 2F θ spacing on the camera as shown in Fig.2 is computed by an image processing program and the result is displayed in real time.

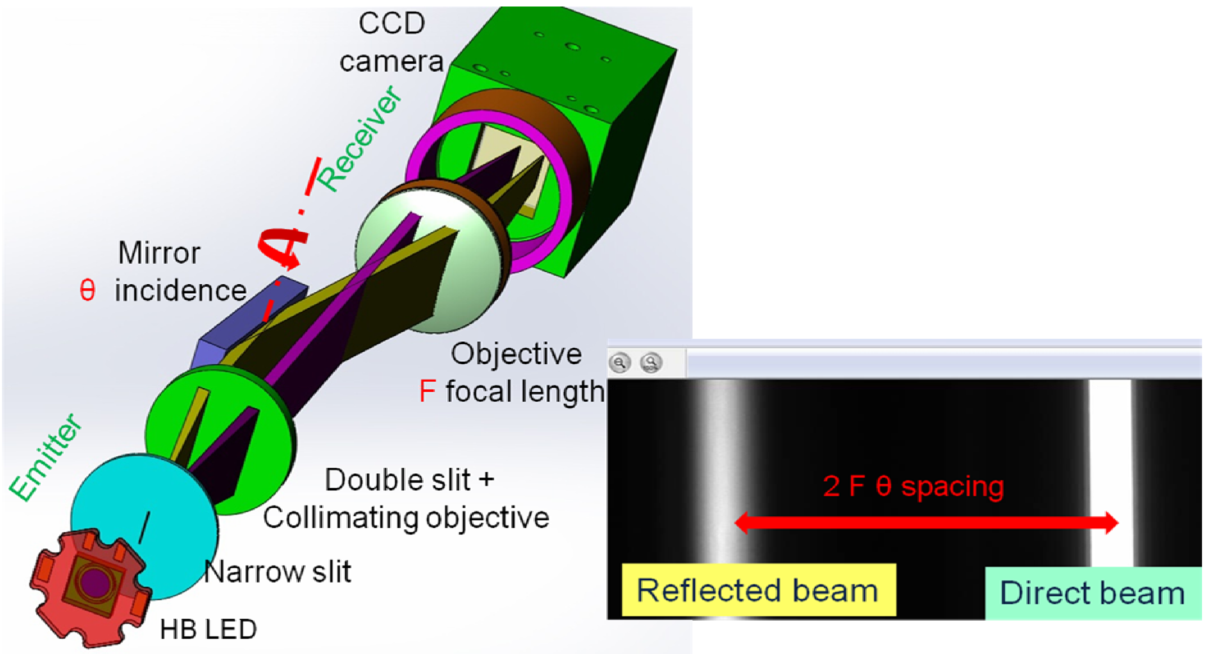

Fig.1 Incidence angle adjustment set up and CCD screen snapshot

3-Principles of the instrument: Horizontal plane parallelism set up

The second mirror is roughly positioned with the proper gap distance so that it can reflect the left beam. The twice reflected beam is focused on the same location as the direct beam as shown in Fig.3 The location of the direct beam is stored by the image processing program, then the relative position of the twice reflected beam with respect to the previous position is displayed in real time by the program as shown in Fig.5 The parallelism is achieved by rotating the second mirror around a vertical axis until the displayed angular position is zero.

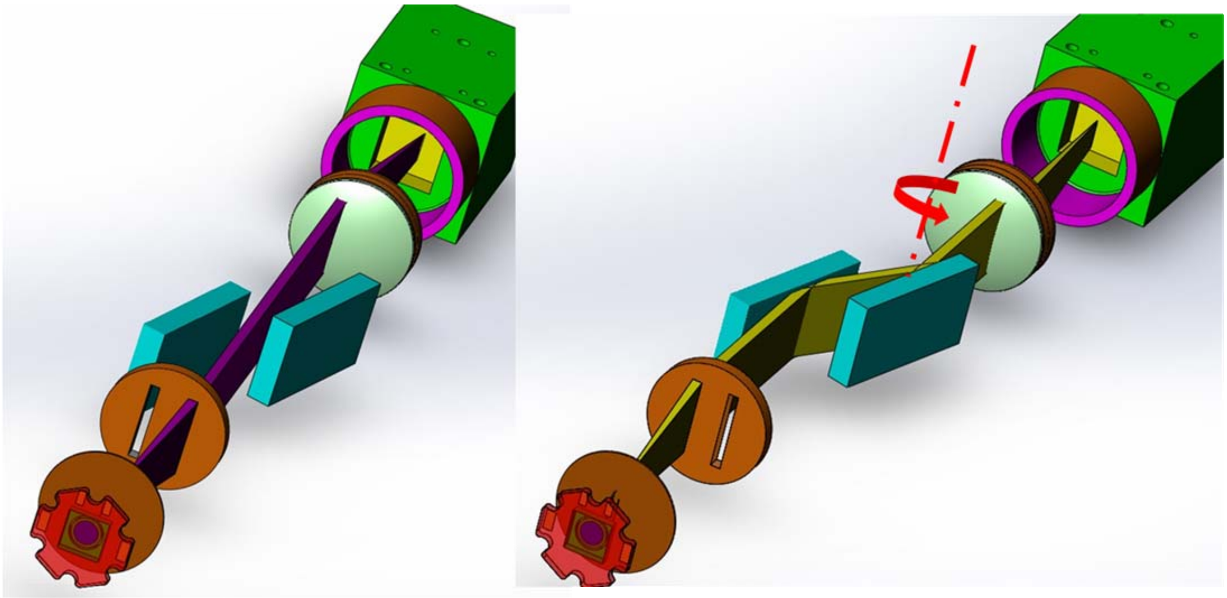

Fig.3 the twice reflected beam is focused on the same CCD location as the direct beam

4-Principles of the instrument: Vertical plane parallelism set up

The first vertical slit is replaced by a pinhole , so that vertical displacement of the focused beams induced by an error ψ in the vertical parallelism is measured in the same way as the previous horizontal displacement as shown in Fig.4

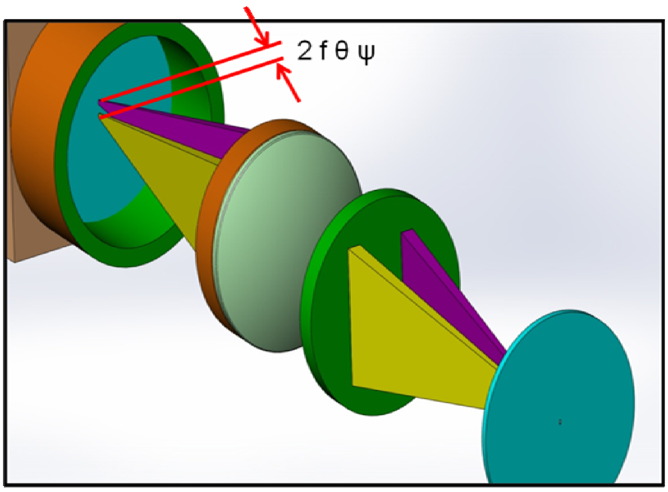

Fig.4 pinhole source when aligning the vertical parallelism

4-Principles of the instrument: Gap set up

The focusing doublet is removed so that the beams positions rather than angle are measured With a slit spacing of g, and a mirrors gap G, the beam spacing between direct and doubled reflected beam is $2\,G\cos\theta - g$. As the slit spacing g is designed to be equal to G, the spacing measured by the image processing program is very close to G with the range of incidence angles considered. With a procedure similar to the parallelism set up, the direct beam position is stored as a reference and the program displays the resulting difference between the two beams locations. The second mirror is translated parallel until the displayed result is equal to G as shown in Fig.5. The objective may be reinserted to check that the mirrors have maintained their parallelism, otherwise the angle –position alignment procedure is iterated.

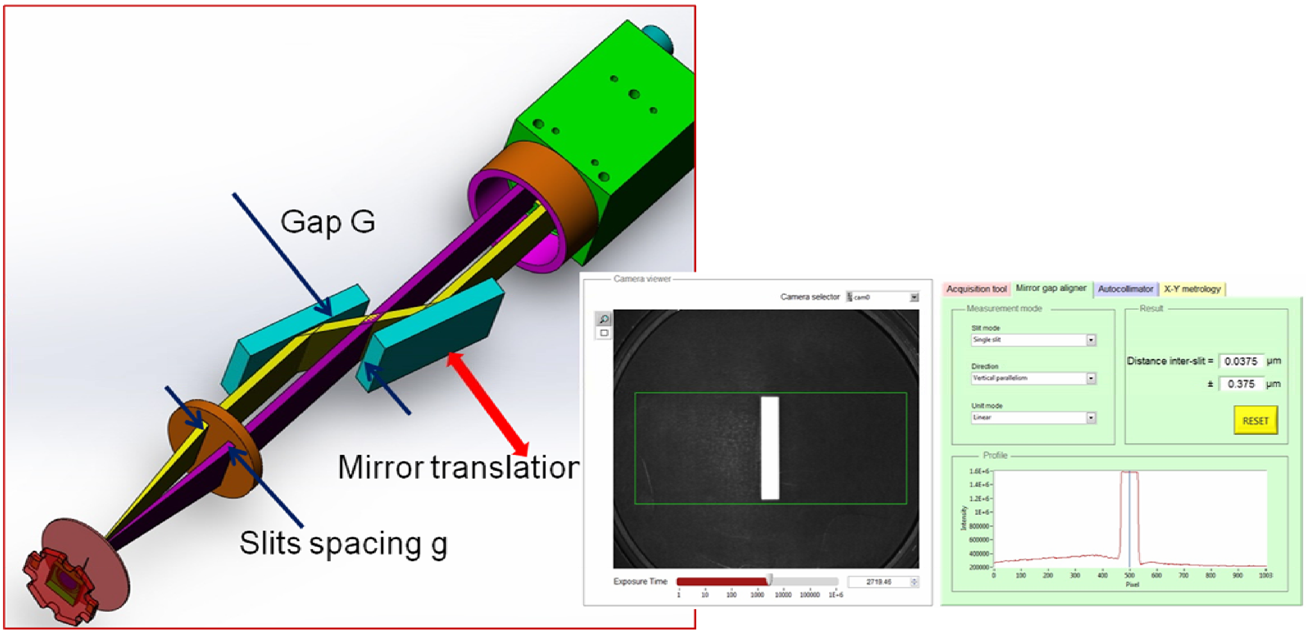

Fig.5 Screen shot of the image processing program displaying the relative positions of the direct and double reflected beam for the gap set up procedure

5-Aligning the first mirror incidence with respect to survey references

Before any beam has been delivered to a beamline, the ESRF survey group is capable of estimating the angular position of the X-ray beam to better than 100 µrd and reference it to the granite base of mirror system. A source is inserted in the receiver to obtain an autocollimation instrument, so that it can be aligned with respect to those references by reflection on a mirror attached to the granite. As the granite base is typically 350 mm below the mirror axis, an optical device is used to translate the beam vertically, without any horizontal deviation, as shown in Fig.6. The four reflections through two roof prisms with precise angles are invariant with respect to a vertical axis rotation of the device.

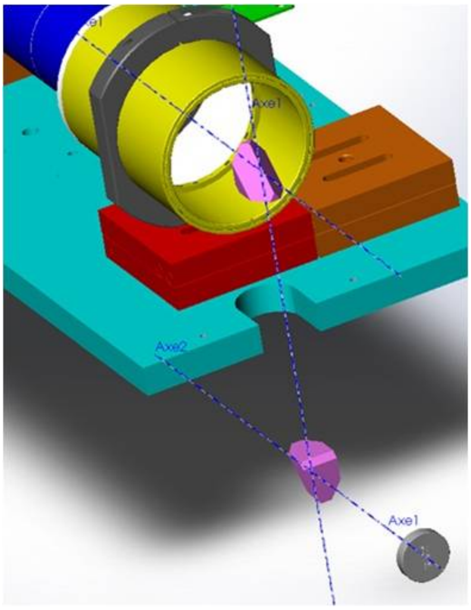

Fig.6 Autocollimator receiver with two roof prisms, translating the beam vertically without horizontal angular deviation. Alignment of the instrument with respect to survey references with an autocollimating mirror.

6-Real instrument in the mechanical lab

Fig.7 shows a mirror vessel with the emitter on the right and the autocollimator receiver on the left. Both emitters and receiver are mounted on survey tripods with proper manual linear and angular degrees of freedom. The same configuration with folding mirrors is used after the vessel is positioned on the beamline, in order to check that the lab adjustments are still valid.

Fig.7 Emitter and receiver mounted on survey tripods, aligning a double mirror system in a vessel

7- Test results

A small mirrors (500+300 mm long) set up has been tested with a 1.6 mm gap and 3 mrd incidence with an emitter receiver distance of 2.2 meters. The time to align it is limited less than 15 minutes with the help of the CCD visualization. A kinematic mount allows switching from the angular to linear mode with micro-radian repeatability. Fig.7 shows the time scan of angular and linear modes with standard deviations of 0.86 µrd rms and 1.07 µm rms precision, with an integration time of 300 ms. the precision is limited by atmospheric turbulences which may be averaged out. When a small (100 µm) single slit is translated horizontally, the resulting intensity drop is monitored and the edges of the mirror are accurately located by the beam shadowing with an estimated precision of 10 µm. This is a valuable procedure to help position the beam stops, an otherwise difficult and imprecise task.

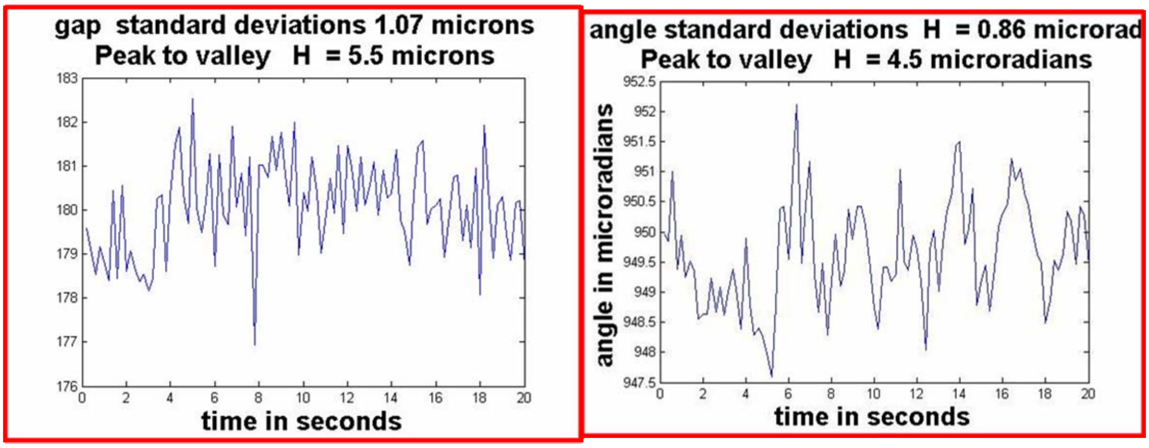

Fig.7 Precision Test results

7- Conclusions

The instrument is operational and due to be first used in November 2012. Its capabilities are within the specifications. The real time display of the metrologic informations necessary for the mechanical adjustments is a significant gain in time and reliability with respect to mechanical probes based methods. The alignment capability with respect to survey references allows to limit the stroke of the motorized movements and even to suppress some of them in some instances, with corresponding stiffness gains. The beamline commissioning time of the system is also expected to be reduced significantly.

References

[1] R.Baker et al. Engineering developments and generic solutions for upgrade mirrors at ESRF.   MEDSI 2012 Proceeding