2007/12 PIR/corrector tests : Input for Echidna Engineering

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- Ver.1.1 : 2008/01/18 : Bug fixed, the FPI coordinate of the distortion center is updated to be (2.4mm, 4.0mm) after applying the SKY and SPINE camera offset. Updated result is consistent with the offset between the CMM center and the rotator axis. The target was M38 (not M37).
- Ver.1.0 : 2008/01/17 : First version circulated AAO/Kyoto/Subaru.

This is a summary of the results of the PIR/corrector testing on telescope related to the Echidna engineering.

1 Echidna work history summary

- 2007/11/02 Transferred Echidna to the summit with Jurek. Thermal stress in the FPI gantry was released by untyng and tyng the FPI gantry fixing bolts. Some positioning tests were done, no obvious problem. Spines No.158 and No.369 are not working well. Illuminating a fibre (No.241) with a green laser and measuring the spot of the laser with the SKY camera, the offset between the SKY and SPINE camera is measured. Center FPI on a fibre, then offset FPI with $(-1200, +200)$, the laser spot is at the center of the SKY camera. (This offset value was used to align a guide fibre to a bright star in the second 2007/12 engineering run.)
- 2007/12/05 Install Echidna into PIR.
- 2007/12/7,8,9,10 First PIR/corrector engineering run with the Echidna SKY camera. Snow and mostly cloudy.
- 2007/12/11 After the engineering run, coolant leakage from the coolant connector on the side of the Echidna electronics enclosure was found. The connector was replaced. No Echidna removal from the PIR unit this time.
- 2007/12/23 During the preparation for the second engineering run, Echidna spines started not working. The left (on GUI) half stopped working in the first positioning test, and the right half stopped working (gradually) in the second positioning test. (No positioning tests were done during the first engineering observation).
- 2007/12/24,25,26 Second PIR/corrector engineering run with the Echidna sky camera. Snow and mostly cloudy.
- 2008/01/08 Remove Echidna from PIR. The coolant leakage was spread wider than that thought from the first glance at 2007/12/11. Some spots were found also on the last surface of the corrector lens. One burned connector on EL711_A board. The board replaced. Replacing the board, Echidna spine movements were recovered.

- 2008/01/10 Check spine tip cleanliness again (spines inside FoV only). Spine No.106 have clear water mark on its surface. But no coolant residual on the spine itself. No similar mark on the other fibres. Dirty fibres in the previous check (before bring Echidna to summit) were still dirty. All fibres cleaned. Two fibres still have bad surface (No.223:small crack?, No.371:cracked). 10% of the fibres have small dark spot smaller than 1% of the area.
- 2008/01/17(planned) Install Echidna to PIR.
- 2008/01/24,25,26,27,28 First Echidna engineering run.

2 Converting the SKY CCD coordinate to the FPI XY coordinate

Using an open cluster region (M38; 05:28:42.95, +35:49:48.00), we made cross calibrations between the SKY camera coordinate, the FPI XY coordinate, and the celestial coordinate. With 30 frames averaging on the sky camera, r=15.5 mag stars can be detected clearly under > 1.0 arcsec seeing condition through thin (thick) cirrus.

The relation between the SKY camera coordinate and the FPI XY coordinates is determined with stars taken with the SKY camera at multiple FPI XY positions (i.e. stars in the overwrapping regions). The CCD camera coordinate (local) can be converted to the FPI XY coordinate (global) with

$$\begin{aligned} X(\mathrm{FPI}) &= A \times X(\mathrm{CCD}) + B \times Y(\mathrm{CCD}) + C, \\ Y(\mathrm{FPI}) &= D \times X(\mathrm{CCD}) + E \times Y(\mathrm{CCD}) + F \end{aligned}$$

$$\begin{aligned} A &= -8.103 \\ B &= 0.677 \\ C &= (\text{FPI encoder x coordinate} \\ &\quad +\text{X correction for the offset between the SKY and SPINE cameras}) \\ D &= -0.668 \\ E &= -8.268 \\ F &= (\text{FPI encoder y coordinate} \\ &\quad +\text{Y correction for the offset between the SKY and SPINE cameras}) \end{aligned} \tag{1}$$

(We use the SKY coordinate definition measured on the images). The SKY camera coordinate is 175.3 degree rotated against the FPI XY coordinate. It is confirmed that the SKY camera is mechanically rotated.

The XY offset between SKY and SPINE cameras are determined by aligning a guide fibre to a bright star. We roughly (the seeing condition was not good) aligned a guide fibre (No.169) to a bright star. When the star is aligned to the guide fibre, the star is at (424, 227) on the SKY camera (in data, not on the GUI) and the FPI is at (−73098, −21822). Therefore without the offset between the SKY and SPINE cameras, the FPI XY coordinate of the star is (−76380, −23982) without the offset corrections. Using the SPINE camera, the position of the No.168 spine was measured to be (−72935, −21106). Thus, (X,Y) offset between the SKY and SPINE cameras are (+3445, +2876). We did the same procedure once more and the results are, star is

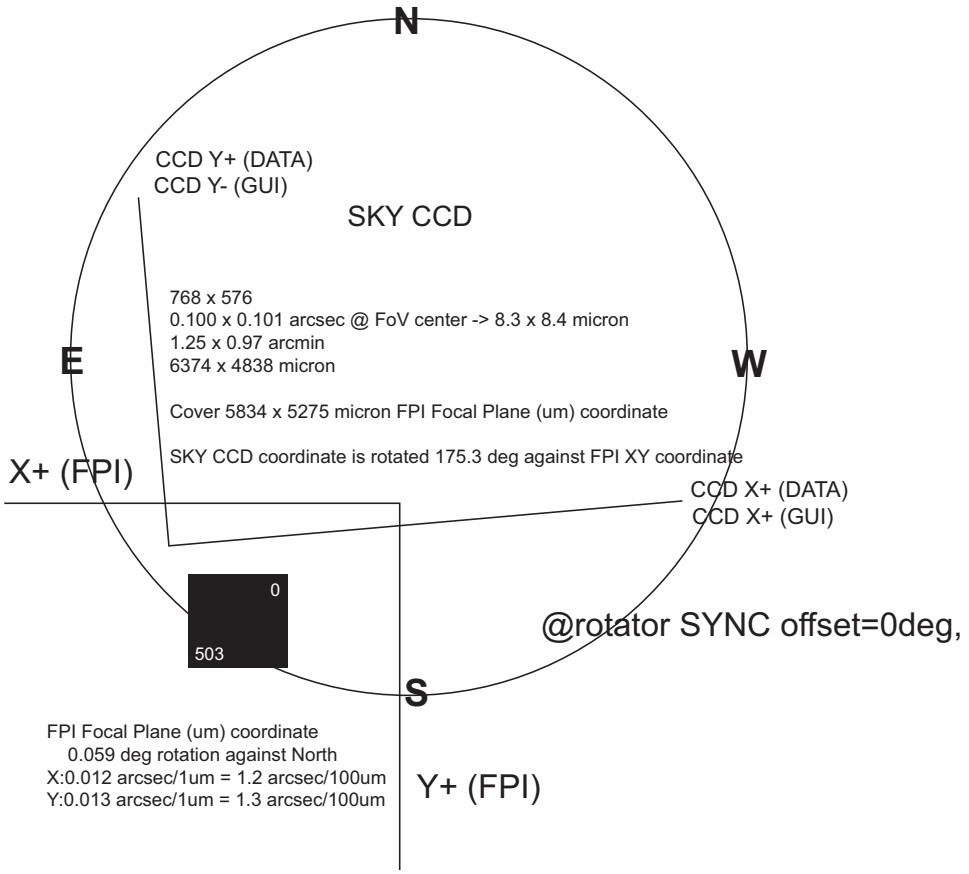

Figure 1: The relation between the sky camera CCD coordinate, the FPI XY coordinate, and the cerestial coordinate. It should be noted that the SKY camera Y coordinate is flipped on the data and the Echidna GUI window).

at (434, 221) with FPI is at (−73098, −21822). The FPI XY coordinate is (−76465, −23939) without the offset correction. This time the No.168 spine was at (−72909, −21118). Thus, (X,Y) offset between the SKY and SPINE cameras are (+3556, +2821). We use the average of the two measurements as the current value, i.e. (+3500, +2849). Using these values as the offset between the SKY and SPINE cameras in relation (1), the coordinates measured with the SKY camera can be converted to the spine positions measured with the SPINE camera.

The FPI XY directions and the celestial coordinates NE directions are aligned well. The relation is summarized in Figure 1.

The axis of the rotator which is the pointing center of the telescope is measured to be (551, 388) with the FPI at (0, 0). Thus, the pointing center is (−702, −727) on the FPI XY coordinate.

3 Converting FPI XY coordinate to the celestial coordinate

We observed an open cluster field (M38) with tiling the SKY camera in 11×11 FoVs (central $10' \times 10'$ FoV of the prime focus; MAP2 taken at secz=1.5), 3×37 FoVs (north-south direction; MAP3 taken at secz=1.4) and 31×3 FoVs (east-west direction; MAP4 taken at secz=1.4). During the observation, the corrector was at (4mm, −4mm) on the CMM (corrector movement

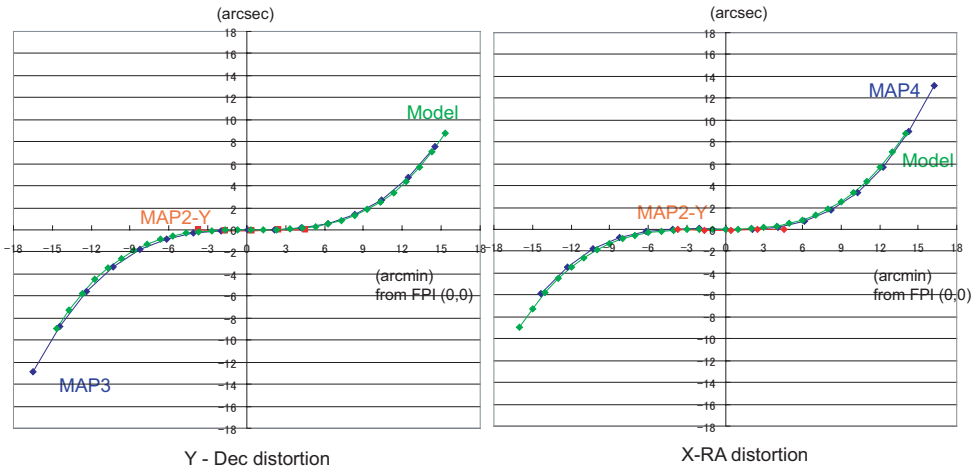

Figure 2: The measured distortion of the corrector lens. Horizontal axis is the distance from the FPI (0,0) position in arcmin. Vertical axis is the offset from the 0.01237 (or 0.01240) arcsec/μm in arcsec. Left) in Y (or Dec) direction, MAP2-X and MAP3 results are shown in red and blue, respectively. Ray trace model is shown in green. The model is offsetted by -1.0arcmin to match the observed distortion curve. Right) in X (or RA) direction, MAP2-Y and MAP4 results are shown in red and blue, respectively. Ray trace model is shown in green. The model is offsetted by 0.3 arcmin.

mechanism) coordinate, and the focus position was FAM z=-0.60mm. The data are taken with the instrument rotator with SYNC status, i.e. the instrument is rotated against the corrector - primary mirror system. The rotater angle during the observation was -97 deg. The measured rotation was about 2 degree during the observation. The measured coordinates of the stars on the SKY camera were at first converted to the FPI XY coordinate using the above relation. Then the FPI XY catalog was cross matched with the RA-DEC catalog of the stars in the FoVs. Using the (X, Y, RA, DEC) file, the distortion pattern of the field is determined by ccmap command in IRAF. The results are shown in Figure 2.

Using the data in the central area, the average plate scale in the area are estimated to be 0.01240 (from MAP3-Y) and 0.01237 (from MAP4-X, MAP2-X, MAP2-Y) arcsec/μm (μm is measured with the FPI gantry), which are slightly smaller than 0.01241 arcsec/μm from the optical design (the focal length of 16623.28mm).

The offset from the 0.01237 (or 0.01240 for MAP3-Y) arcsec/μm is shown as the optical distortion pattern of the field in Figure 2. The distortions are determined by ccmap command in IRAF. The measured distortion is consistent with the ray trace result shown with green lines and dots. The results for the FPI-X/RA (FPI-Y/DEC) direction shows about 0.3 (-1.0) arcmin offset from the ray trace result. Considering the offset, the FPI XY coordinate of the distortion center was estimated to be (2.4mm, 4.0mm).

The estimated positions of the distortion center and the rotator axis, and the relation between the CMM coordinate and the FPI XY coordinate are shown in Figure 3. (!! It needs to be confirmed that rotator angle -97 deg means rotation in the CCW direction seen from above !!)

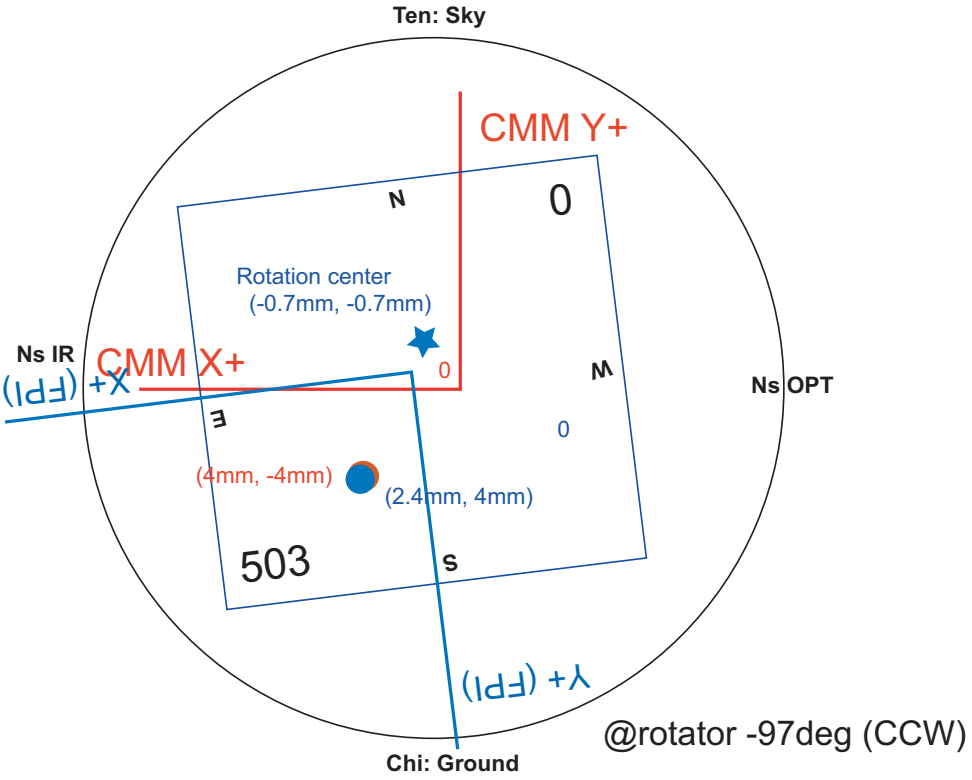

Figure 3: The position of the distortion center and the rotator axis, and the relation between the CMM coordinate and the FPI XY coordinate, evaluated based on the CMM position ((4mm, −4mm) in the CMM coordinate) of the measurements, the rotator angle (−97deg), and the distortion center ((2.4mm, 4.0mm) in the FPI XY coordinate) results. The zeropoint of the CMM coordinate is (−2.1mm, 0.5mm) on the FPI XY coordinate, thus the offset between the CMM center and the rotation center is (1.4mm, −1.2mm), which is consistent with the measurements of the offset between the CMM center and the rotation center (∼1mm, ∼1mm).

4 Focus position of the guide fibre, the sky camera, and the AG/SH camera

We roughly (the seeing condition was not perfect at all) checked the focus offset between the sky camera and the guide fibre. There is a significant offset between the focus position of the sky camera and the tip of fibres. Guide fibre No.168 is on focus at FAM (Focus Adjustment Mechanism) with z=5.3mm, while the sky camera is on focus at z=0.6mm. The AG/SH camera is on focus at z=4.6mm. Considering the allowed (by software) travel range of the FAM mechanism ($\pm$1.5mm), we would like to change the mechanical location of the sky camera by 4.7mm and make all of the cameras and the fibres are on-focus around FAM z$\sim$5mm (current value).

5 Action Items

1. Is the large offset between the distortion center and the rotator axis real ??
2. Change the sky camera focus position with further measurements of offset between the SKY camera and the fibre tip (current estimate is 4.7mm back from the holding mirror).
3. Should we separate Echidna bootup PC from the OBCP, considering the load on the OBCP ?
4. We would like to check connector status (park or prime), back-illumination status, and forward-illumination status.

6 Appendix

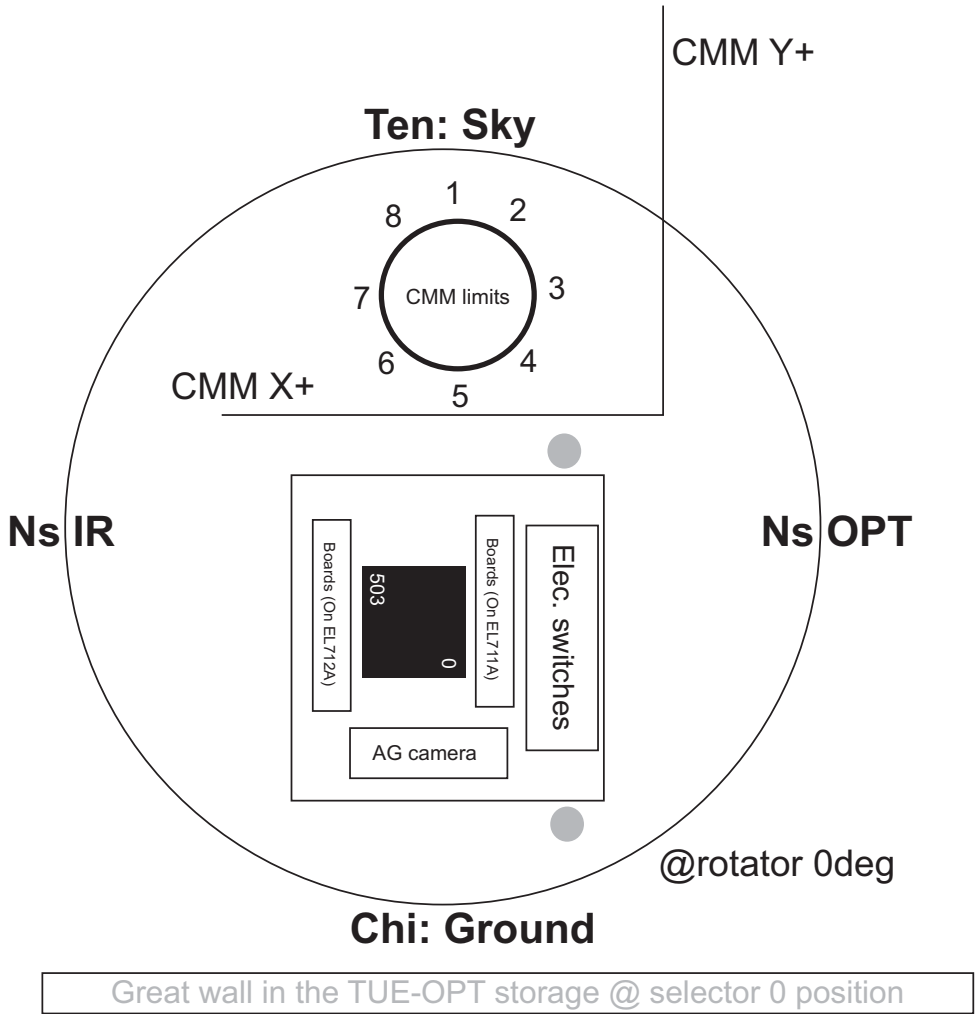

Figure 4: The relation between the Echidna unit and the PIR/CMM unit at rotator angle of 0 degree.