Chapter 6

Installation and Commissioning at IUCAA Girawali Observatory

The installation and commissioning of iRobo-AO on the 2m telescope at the IUCAA Girawali Observatory (IGO) is planned in three phases; in the first phase the first week of February of 2016, the Laser projector was installed followed by telescope balancing and test fire. The second phase was carried out from the first week of March to the first week of June in 2019. The Cassegrain AO facility was then installed at the Cassegrain port followed by telescope balancing, LGS alignment, telescope pupil adjustment on DM, ADC etc. The third phase is to start in late October, after the monsoon break of 2019, when the AO loop will be closed for targets on-sky.

6.1 Installation

Given the delicate nature of the scientific equipment, adequate safety measure were taken during the shipment of the iRobo-AO instrument from IUCAA laboratory, Pune to IGO which is around 80 km by road from Pune city, near the historical Junnar town. Protection against shocks and vibrations as well as dust and humidity proofing were the main concerns. At the observatory, the lifting crane arrangement was checked and verified before lifting Cassegrain AO box from observatory ground floor to telescope floor (Fig. 6.1). The telescope nominal focus is at 220 mm from the A & G box face of Cassegrain port. The distance of the focus and the breadboard from the center of the elliptical mirror are 30.59 mm

FIGURE 6.1: Cassegrain AO unit is being lifted from the ground floor to dome floor.

FIGURE 6.2: Cassegrain main spacer of weight 90 kg.

and 75.891 mm respectively. The thickness of the breadboard is 25 mm. In order to interface the Cassegrain AO facility with the direct port of the telescope, a special spacer of thickness 88.519 mm (=220-30.59-75.891-25) was custom built. A hydraulic trolley was employed for placing and mounting the spacer (Fig. 6.2) at the Cassegrain port, as well as installation of the Cassegrain AO unit (Fig. 6.3). A physical inspection of the Cassegrain unit (Fig. 6.4) was carried out after the installation on the telescope.

As part of the initial check out, a seeing limited image at the science EMCCD Andor camera in 'V' band was taken (Fig. 6.5). That the image appears a little elongated as it was taken with 2 seconds long exposure without the auto-guider.

6.1.1 Bread board aperture and telescope pupil

The next step was verification of the collinearity of the telescope pupil, Cassegrain breadboard aperture and the elliptical mirror. This was done using a pinhole camera setup (Fig. 6.6) placed just below the elliptical mirror and telescope focus.

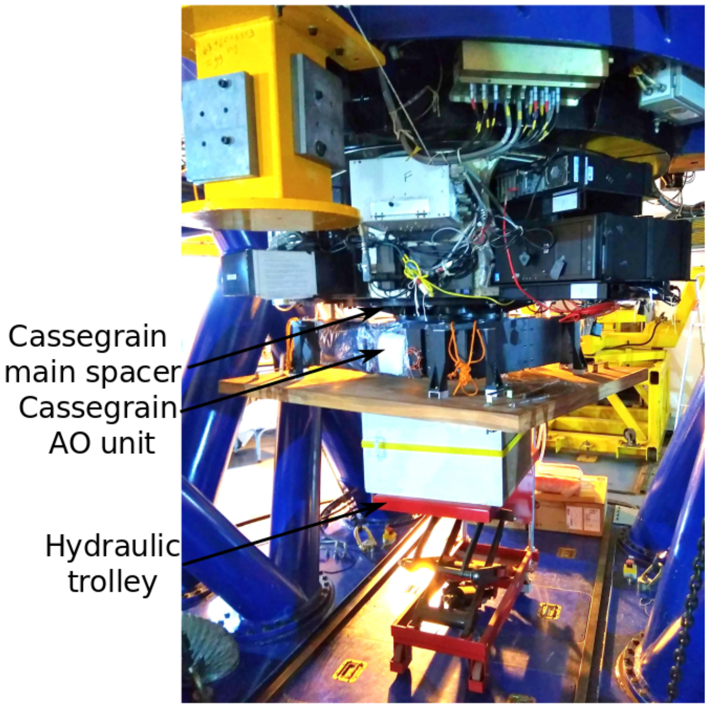


FIGURE 6.3: Cassegrain spacer and AO unit is mounted at the telescope Cassegrain port.

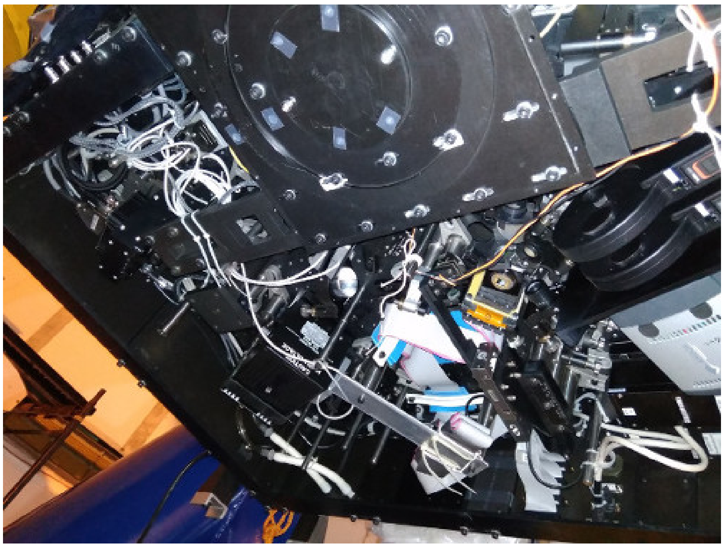


FIGURE 6.4: Inner view of Cassegrain AO unit while mounted on telescope.

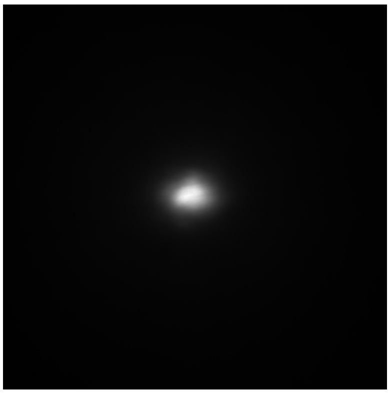


FIGURE 6.5: Non AO corrected image of a natural star at science Andor camera.

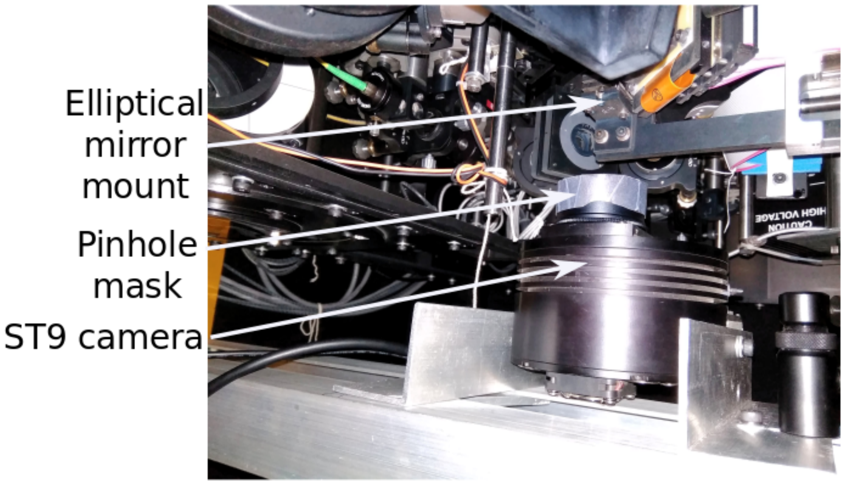


FIGURE 6.6: Pinhole camera setup at the Cassegrain focus beneath the bread-board aperture, a pinhole mask is mounted at the aperture of ST9 camera.

This arrangement allows to simultaneously image bread board aperture, telescope pupil and elliptical mirror mount. It is because to have a simultaneous image of three objects, which is not possible for the standard lens camera. It is found that the breadboard aperture and the pupil are concentric (Fig. 6.7) when the elliptical mirror is out of the path. When the elliptical mirror is moved into the light path the concentric obscuration due to it in the background of the aperture is seen.

6.1.2 Telescope balancing

The altitude axis of the telescope was in balanced condition with the backend science instrument IFOSC[117] mounted at the Cassegrain port. After, the laser

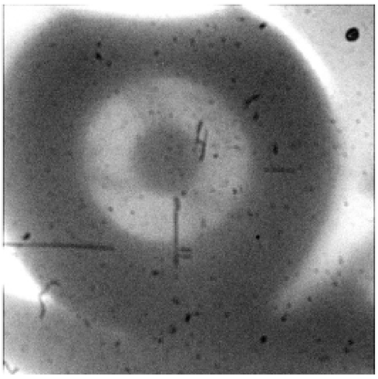


FIGURE 6.7: The image of telescope pupil (white annular light) at the center of the breadboard aperture (big circle) in a frame taken by a pinhole camera at ST9 CCD.

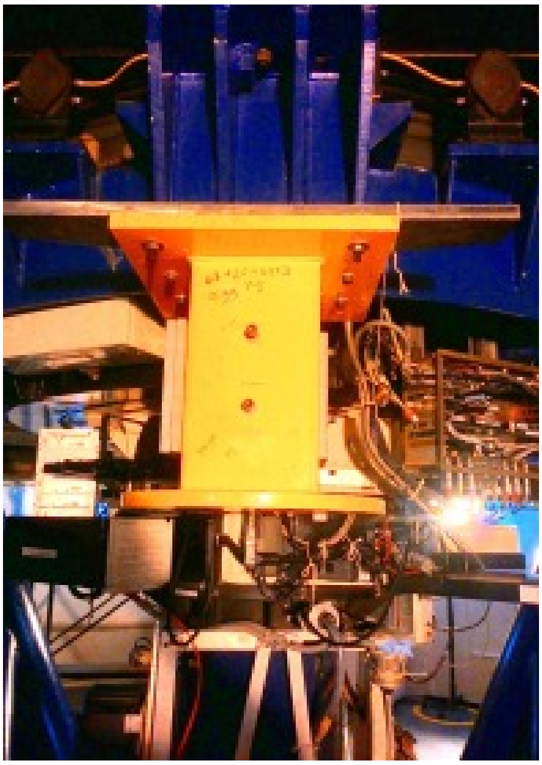


FIGURE 6.8: Yellow mild steel piece is mounted opposite to the laser projector as a counterweight for balancing telescope with laser projector.

Table 6.1: Weight details.

Components	**Weight (kg)**
Laser Projector:	
Laser projector box	65
Laser projector cage	20
Periscope system (mirror=2×3 kg, bracket: 10 kg)	∼16
Total LGS system weight	**∼101**
Laser projector counter weight	∼100
Cassegrain Unit:	
Cassegrain box	130
Cassegrain main spacer	90
Cassegrain auxiliary spacer	10
Total weight	**230**
Electronic Rack:	
Port A: DM controller, DM PS*, Smaract PS*,	
Smaract controller, HE, flow meter	∼10
Port B: TTM Controller (4 channel)	∼15
Port C: Scimeasure controller, Scimeasure PS*,	∼22
RG Controller(10 kg)	
Port E: Telescope simulator controller (×2)	∼10
Port G: iRobo-AO(10 kg), SmarAct CPU (7.5 kg) and	∼25
network hub	
Port H: Mains power distribution box	∼7
Total weight of electronics rack	**∼90**
Counter weight at Cassegrain main port:	
Balancing structure	20
Small counter weight plate	7.5×3
Big counter weight plate	20×1
Total counter weight at Cassegrain main port	**∼ 60**

*PS: DC power supply.

projector was installed at the side of the telescope tube, the telescope was balanced with approximate 100 kg counterweight attached to the side of the telescope opposite to the laser projector. Subsequently, the entire IFOSC unit along with the calibration unit of total weight 340 kg was removed from the Cassegrain main port. iRobo-AO and the spacer (Fig. 6.2) of total weight 230 kg was mounted. There are also several iRobo-AO related controllers mounted at the telescope side ports. For balancing, a separate structure of weight 60 kg was fabricated and mounted in place of IFOSC. At present, the entire telescope with iRobo-AO (the laser projector, Cassegrain AO box and several controllers) is balanced with the counterweights. Approximate weights of all the parts/component are given in Table 6.1.

FIGURE 6.9: Balancing arrangement for the Cassegrain AO unit, to be attached with the Cassegrain main spacer.

Balancing arrangement of laser projector and Cassegrain box are shown in Fig. 6.8 and Fig. 6.9 respectively.

6.2 Alignment of the Cassegrain AO unit to the telescope (pupil matching)

The crucial job of alignment of the Cassegrain AO unit to the telescope is accomplished by placing the image of the telescope pupil within the active area, i.e. centre of the DM. This is achieved by tweaking the tip-tilt stage of the elliptical mirror under dome light and late afternoon skylight. An image of the pupil at the centre of the DM is shown in Fig. 6.11. The image of the same pupil is also observed at the centre of ADC plane (Fig. 6.12) which ensures the alignment of the axis of the Cassegrain AO unit with that of the telescope.

6.3 Laser guide star alignment

Laser guide star alignment is achieved in two steps. One of them is the alignment of the laser to the telescope axis, and the other is the formation of the LGS by capturing an image of it. Both steps are explained below.

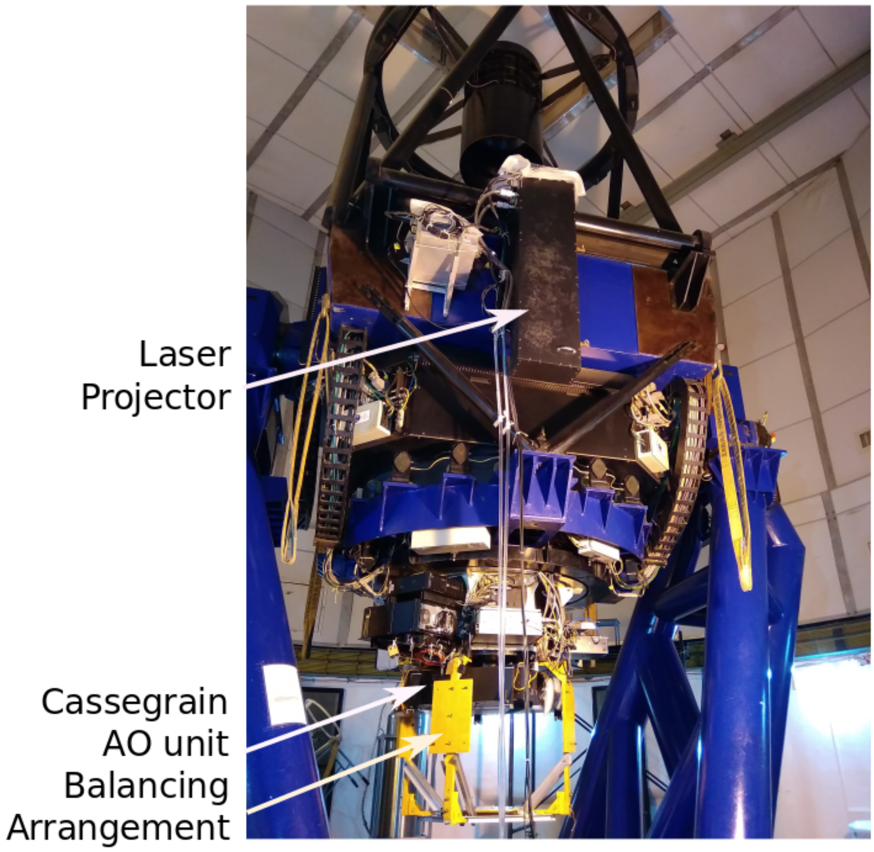


Figure 6.10: Entire iRobo-AO mounted on telescope.

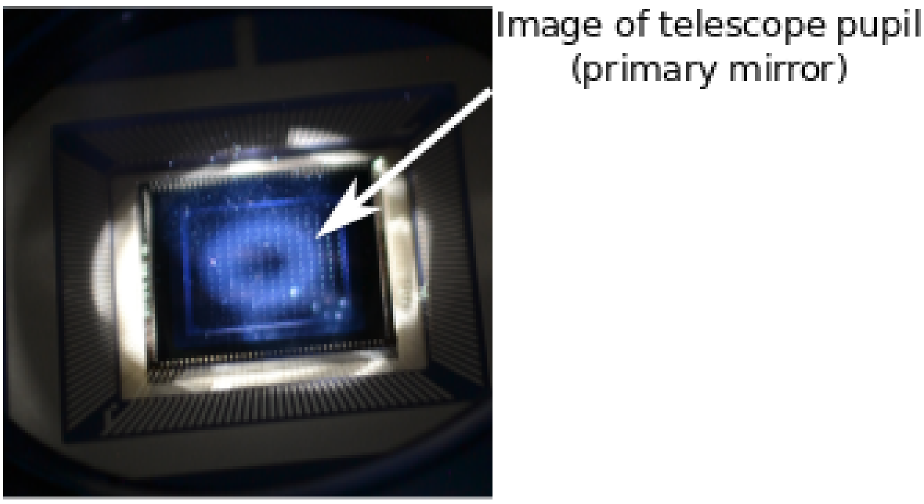


Figure 6.11: The white annular light in the center of the MEMS DM is the image of telescope pupil, illuminated by the dome and late afternoon skylight with secondary obscuration.

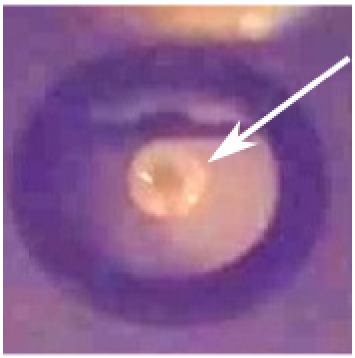


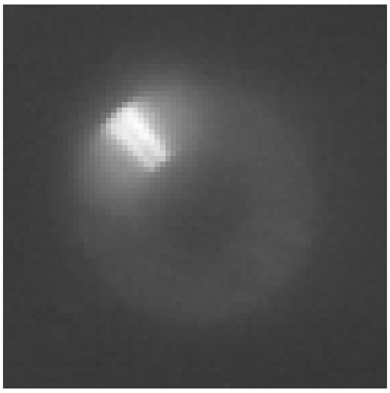
FIGURE 6.12: The white annular light in the center of the ADC is the image of telescope pupil, illuminated by the dome and late afternoon skylight with secondary obscuration.

6.3.1 Alignment of the laser to the telescope

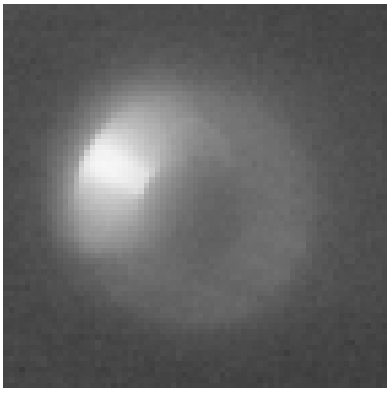
The laser beam is projected from the back of the secondary mirror and is to be aligned along the optic axis of the telescope. The entire primary mirror of the telescope gets fully illuminated by the laser backscattered light when the laser beam goes up along the telescope axis. Otherwise, the primary mirror gets partial illumination. The images of the pupil illumination are captured by an SBIG ST9 camera placed at the eye relief plane of an eyepiece of focal length 30 mm at the side port of the telescope. After this the SBIG ST9 and a Nikon 50 mm lens assembly was placed at the Cassegrain focus underneath the Cassegrain AO unit (Fig. 6.14) and by fine adjustment of the first mirror, obtained the best image of the fully illuminated primary mirror, as shown in Fig. 6.15. It is to be noted that there is a difference between the image quality of Fig. 6.13d at side port and Fig. 6.15 at Cassegrain port. It is due to the dust layer at the science fold mirror of the side port.

6.3.2 Formation of the Laser Guide Star

As the laser propagates into the sky, the converging laser beam produced by the focussing lens of the laser projector (see Section 3.3.2 for more details), creates the Laser Guide Star (LGS) the LGS at a suitable altitude of about 10 km in the atmosphere. The focusing of the laser is very sensitive to the position of the convex lens of the laser projector. In order to ascertain the formation of the LGS,



(A)



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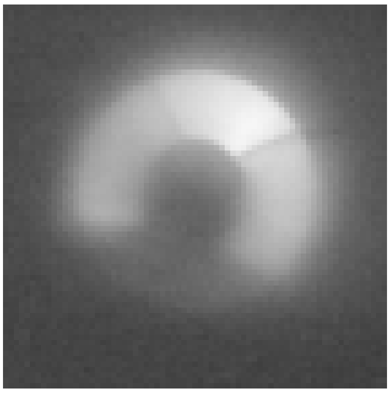

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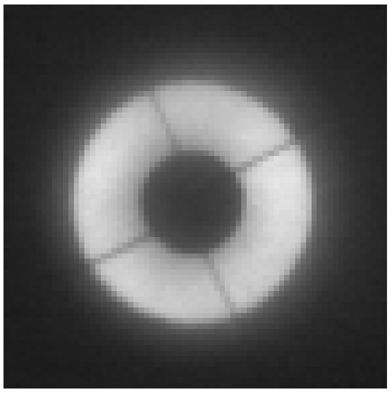

(D)

FIGURE 6.13: Image of the primary mirror illuminated by the laser in high power mode taken at SBIG ST9 camera by using an eyepiece of focal length 30 mm at the telescope side port. The bright light stripe in Fig. A is the laser beam propagating from behind of the secondary mirror, and that light stripe broadens due to the adjustment of the first mirror of the periscope system shown in Fig. B and C. In the end, the pupil become fully illuminated shown in Fig. D. when the laser coaligned with telescope axis.

an image of it is to be captured. For this, the pinhole cap is removed from the ST9 aperture shown in the setup of Fig. 6.6. The camera is mounted at the Cassegrain focus for grabbing an image of the LGS. It is to be noted that the pinhole camera setup (Fig. 6.14) and the Nikon lens setup (Fig. 6.6) are not at the same place. The CCD of ST9 camera in the pinhole camera setup is ∼40 mm away from the nominal telescope focal plane. But when the reimaging Nikon lens setup is used, the focus is formed ∼150 mm below the focal plane. That's why the image of LGS on ST9 camera is obtained by just removing the pinhole mask without disturbing the camera location. An image of LGS thus grabbed is shown in Fig. 6.16 after focusing the LGS (explained in chapter 3, section 3.3.2) by changing its height using the computer-controlled high precession motorized linear actuator of the

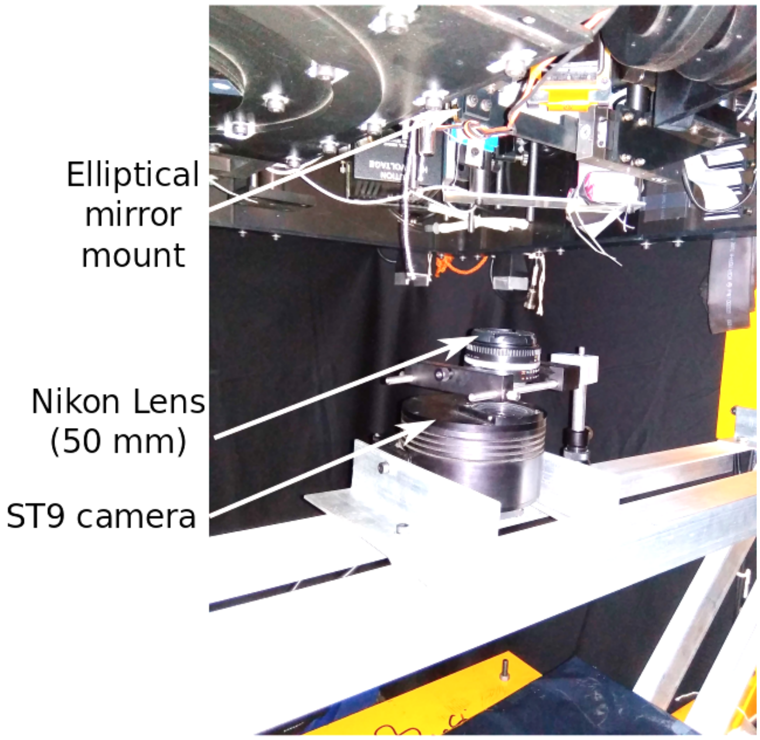

Figure 6.14: Nikon lens (50 mm) setup for grabbing the pupil at Cassegrain port.

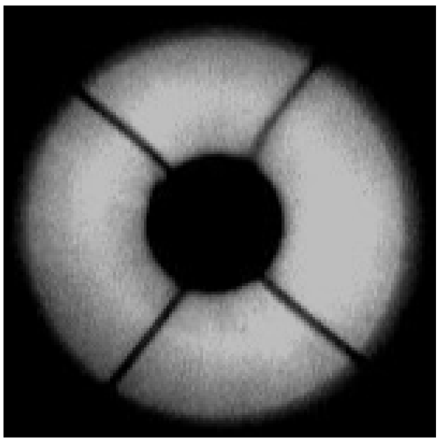

Figure 6.15: Best fully illuminated image of the entire primary mirror at ST9, using a Nikon 50 mm lens in UV, High power mode, at Cassegrain port of telescope.

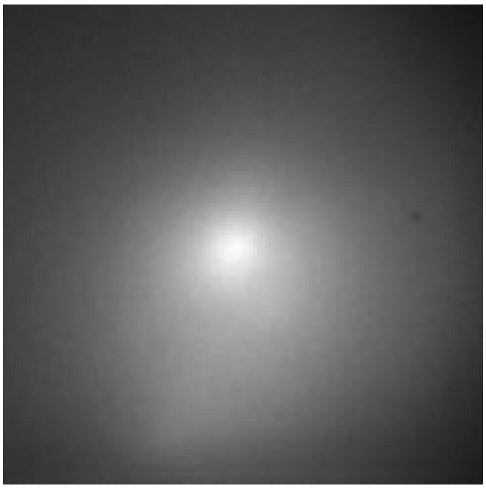

FIGURE 6.16: Image of LGS at Cassegrain focus of telescope without range gating at ST9 camera(binning: 3×3).

convex lens of the laser projector (Fig. 6.17). The extended fuzzy illumination around the laser spot is due to the photons back scattered from all along the path of the laser beam propagation. There is no variation of the image size of the LGS for a few millimetres shift of the ST9 position. A line plot of the LGS spot along the centre is shown in Fig. 6.18. The FWHM of the laser spot and the fuzzy illumination is $\sim 40''$. A field stop placed at the intermediate LGS focus in front of OAP5 will reduce the spot size by cutting all the stray light coming due to the Rayleigh scattering from air molecules of low altitude atmosphere.

Now that, the laser and the Cassegrain AO unit are aligned with the axis of the telescope, the laser will follow the prescribed path inside the Cassegrain AO unit for the wavefront sensing arm. The resultant defocused array of Shack-Hartman lenslet spots at the CCD39 is shown in Fig. 6.19. As part of future work, the range gate system and associated optical components need to be introduced into the beam path. All the spots produced by the lenslet are needed to be placed at the center of 6×6 pixel boxes of the WFS fast readout CCD39 camera by tweaking the last lens of the relay lens system. The computerized rotating stages of the ADC prisms and the retarder (in front of the Pockel cell) are to be calibrated followed by the on sky performance of the entire iRobo-AO system.

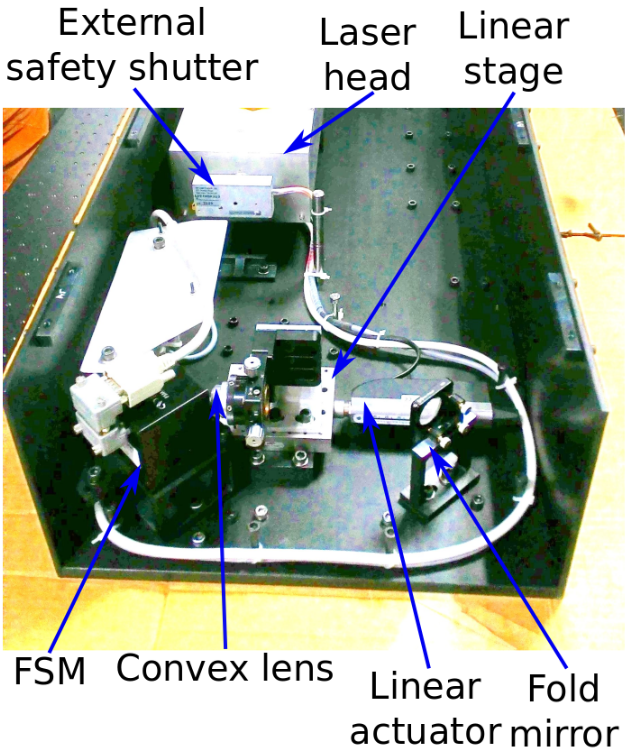

FIGURE 6.17: LGS focusing mechanism: Computer controlled high precession motorized linear actuator of the convex lens of the laser projector.

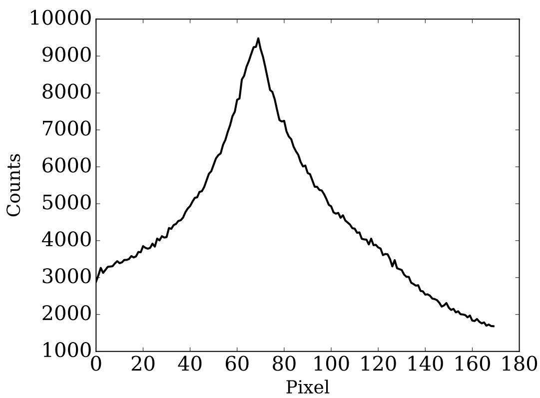

FIGURE 6.18: Line plot of the image of LGS (Fig. 6.16) at Cassegrain focus of telescope without range gating at ST9 camera (binning: 3×3), FWHM: $\sim 40''$ (66 pixels, Plate scale: $0.6''$/pixel).

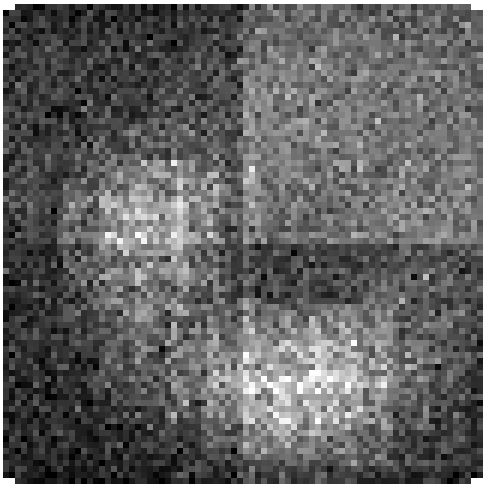

FIGURE 6.19: Defocused array of Shack-Hartman lenslet spots at the CCD39 (frame: 80×80).