SAM LLT quick guide

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1 Geometry and coordinates

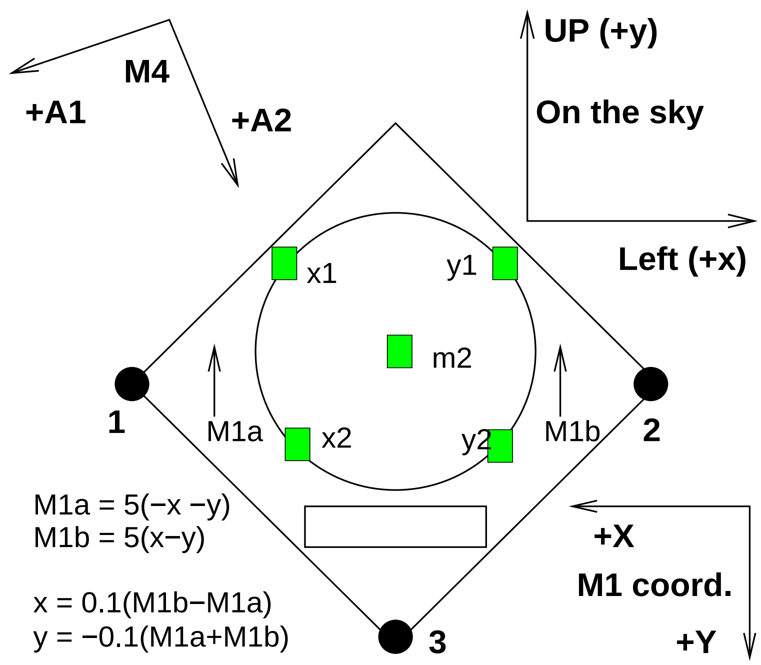

Figure 1: Three support points 1,2,3 of the LLT and the coordinate systems as seen looking "into" the LLT. Five green rectangles indicate locations of 5 photo-diodes used to monitor the laser beam position on M1. The direction of beam motion corresponding to the M4 axes A1,A2 is indicated. The M1 actuators M1a and M1b move the primary mirror in x,y to point LLT (arrows).

Figure 1 shows the coordinate system as seen by looking "into" the LLT from the front. The +X direction corresponds to SOAR *Left*, +Y to *Up*. The correspondence between Up and South is, of course, dependent on the telescope pointing direction. The coordinates X,Y correspond to the M1 actuation by its motors. The nominal scale is 2.04 μm per acrsec, the actual measured scale in (X,Y) is (3.85, 2.99) μm per acrsec or (260,347) arcsec/mm, with motions not exactly orthogonal. The pointing range in (X,Y) is a diamomd-shaped region defined by the conditions $|x + y| < 0.3$ mm and $|x − y| < 0.3$ mm. Its projection on the sky is shown in Fig. 4 below.

Actuation of the M4 mirror in A1 and A2 moves the beam on M1 in directions inclined by 19.9° w.r.t XY coordinates, as indicated in the Figure. Beam centering is achieved by approximate equalization of photo-diode signals x1, x2, y1, y2.

Three support points of the LLT are located at the vertices of a square with diagonal of 430 mm (distance between 1 and 2). To adjust the LLT pointing, we rotate the screws at points 1 and 2 by their hex heads. Moving 1 and 2 both by 1/6 turn up (extend) moves the LLT axis by 150″ down. Moving 1 up and 2 down by 1/6 turn displaces the LLT axis by 150″ left. Note that when LLT is co-aligned with SOAR at zero elevation, the telescope active optics is out of range. So, after the co-alignment the LLT axis must be moved *up* by 90″ to approximately correct this bias. If the LLT pointing offset on the sky (as determined by pointing a star) in azimuth and elevation is (dA,dE) arcseconds, then the screw #1 (left) has to be *shortened* by turning it (dA+dE)/2.5 degrees, the screw #2 (right) must be shortened by (-dA+dE)/2.5 degrees.

2 The ATP

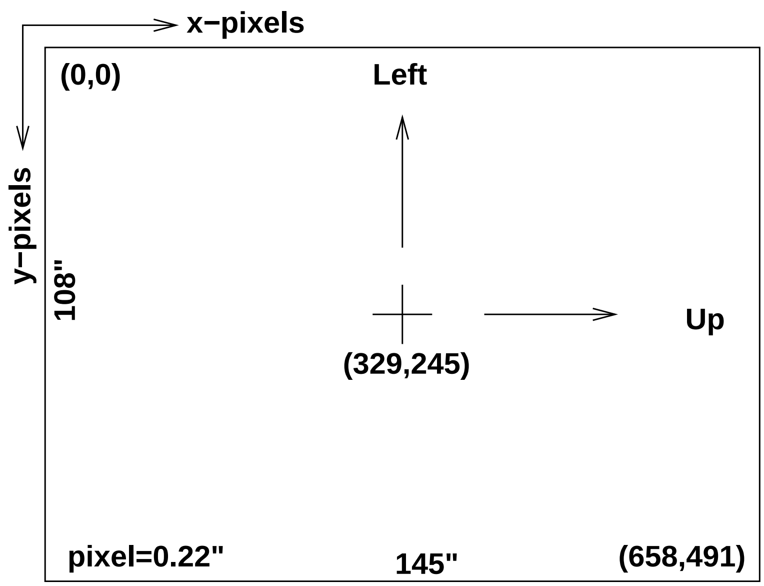

Figure 2: ATP field as displayed on the screen with directions on the sky and some useful numbers. When SOAR points near the meridian to the North of zenith, the SOAR offset to the North (down) moves the star right, offset to the East (right) moves the star up. The North/East directions are reversed when SOAR points near the South Pole.

The Alignment Telescope-projector (ATP) serves for observing stars through the LLT. It can also project a red collimated light (laser diode) to mark the LLT optical axis. The Prosilica GC650 camera with GigE interface is used[1]. The camera control and image display are done by the SAM AOM computer in the same screen as the ICSoft (`vncviewer 139.229.15.32:2`) by `/home/ao/Prosilica/bin/x86/SampleViewer` (it can also be called from the ICSoft). The ATP camera has a fixed IP 169.254.200.2.

In the viewer program, click on the *eye* icon to start real-time display. Click on the *tools* icon to evoke camera controls. Most useful is the exposure control. The exposure time units are microseconds.

[1]SAM-AD-02-7501. SAM Acquisition Camera and LLT ATP Camera http://www.ctio.noao.edu/new/Telescopes/-SOAR/Instruments/SAM/sdn/SAM-AD-02-7501.pdf

Set maximum exposure to 500 000 (0.5s), mode Auto-FitRange to get signal in the right range (0 to 255 counts, unsaturated). For searching stars, the Auto-Mean exposure mode is more useful.

The ATP field of view is depicted in Fig. 2. The total field is 658x491 pixels or $2.4' \times 1.8'$ ($0.22''$ per pixel). Typical XY motion of M1 needed to center the star is on the order of 0.1 mm ($40''$).

Example. Suppose that when SOAR is pointed to a bright ($V < 4^m$) star, we see it in the lower-left corner of the ATP screen. It means that the LLT axis is displaced up-left w.r.t. SOAR. We move M1 in $(-x, -y)$ (point down and right on the sky) to re-center the star. This increases the M1a actuator, leaving M1b unchanged. To correct the offset, we can extend the screw #2 (Fig. 1) by suitable amount.

3 Tip-tilt platform

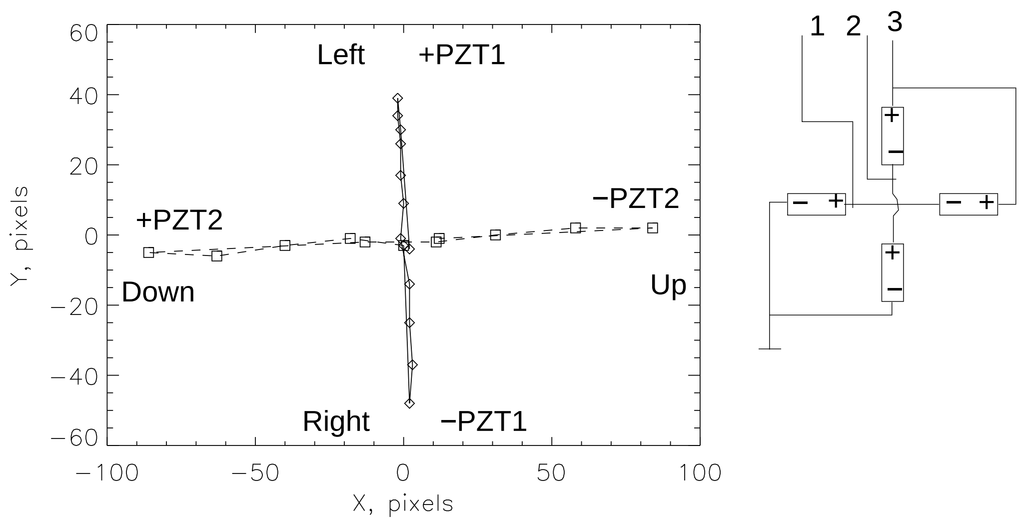

Figure 3: LLT pointing reaction on changing voltages on the tt platform (in auto-collimation). Up-left directions correspond to beam displacement on the sky, XY – to ATP pixels. The scheme on the right shows the connection of four piezo actuators to the driving voltages on PZT1 and PZT2 (variable from 0V to 100V) and PZT3 (constant 100V), with the common line grounded.

The LLT tip-tilt mirror (M3) is driven by the tt platform S-330 from PI. The tilts are controlled in two orthogonal directions by applying voltages to the PZT1 and PZT2 (range 0–100V) lines, while PZT3 is kept constant at 100V. Nominal (central) M3 position corresponds to PZT1=PZT2=50V. The tt platform has a hysteresis of $\sim$16%.

The PZT1, PZT2 high voltages are generated by the control signals from SAM RTC (updated only when the WFS CCD is running!) which range from 0V to 10V, centered at 5V (amplification 10x from low to high voltage). Offsets to the central position can be introduced by the RTSoft command `rt tt llt offset n1 n2` where `n1` and `n2` are numbers in the ± 5 range. The +PZT1 offset moves the LLT beam to the left with response $1.9''/V$, +PZT2 moves the beam down with response $4.3''/V$ (see SDN 2323, measured on Nov. 15 2011). The total range is therefore $\pm 9.5''$ left-right and $\pm 19''$ up-down. Note however than on-telescope calibration in February 2012 have revealed non-orthogonality

Table 1: LLT and SOAR focusing

LGS distance Km	LLTm2-m1Delta mm	SOAR focal plane mm	SOAR M2 up mm
7	0.026	708.96	6.60
10	0.018	486.26	4.62
14	0.013	342.72	3.30
infinity	0.000	0.00	0.00

of the motion and a reduced response of $1.6''/V$ for PZT1 and $2.8''/V$ for PZT2 (see SDN 7121, Sect. 1.4).

4 Focusing and pointing

The LLT focus motor position is displayed in mm. Focus on stars is about -0.05, possibly temperature-dependent. Nominal focus offsets for other ranges are given in the Table 1. To focus SOAR at 7km, we need to *decrease* the reading of its focus by 6600 (the M2 hexapod reading increases when the M1-M2 distance is smaller).

Nominal positions of the pointing and focus motors are listed in Table 2 (data of Dec 21 2010). To move M1 in +Y (point up), we apply same negative increments to the M1a and M1b motors. To move in +X (left), M1a is decremented and M1b incremented, see formulas in Fig. 1. The actual displacement on the sky is not exactly orthogonal: $dA = 259X - 98Y$ and $dE = -45X + 348Y$ in arcseconds/mm. As a result, the full pointing range of ± 0.3 mm maps on the sky as shown in Fig. 4, right.

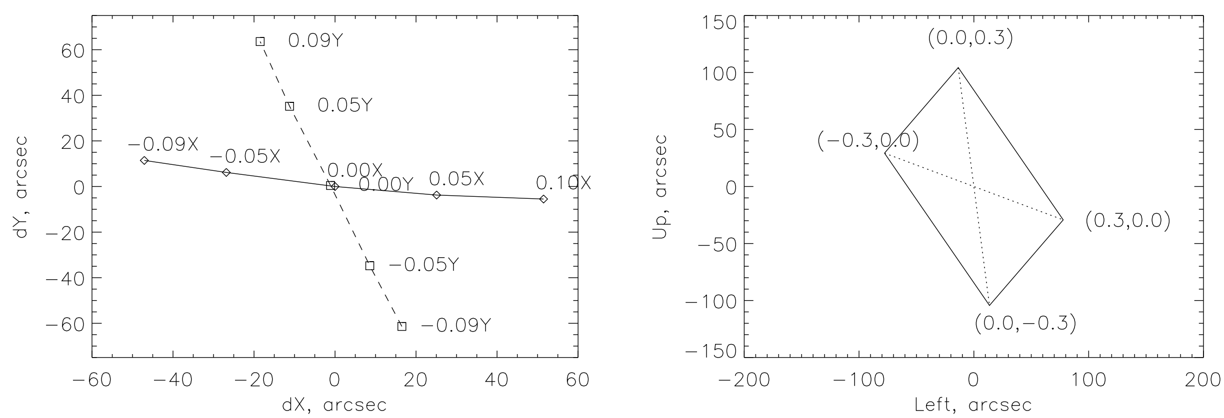

Figure 4: Left: motion of the spot on the sky (Y up, X left) when M1 is actuated in X and Y. The commanded M1 displacements in X and Y (in mm) are indicated near the curves (data from SDN 2323, Sect. 4.6). Right: range of the LLT pointing adjustment by M1 motions. The numbers indicate the (X,Y) coordinates of M1.

The gaps between M1a and M1b levers and motor clamps are both 3.0 mm. The gap between M2 moving part and M2 pedestal (focus) is 6.02 mm.

Table 2: Nominal positions of LLT motors

Parameter	M2 (focus)	M1a	M1b
Home	12.69	12.56	12.13
Offset	4.887	4.710	5.295

5 Photo-diodes and beam size

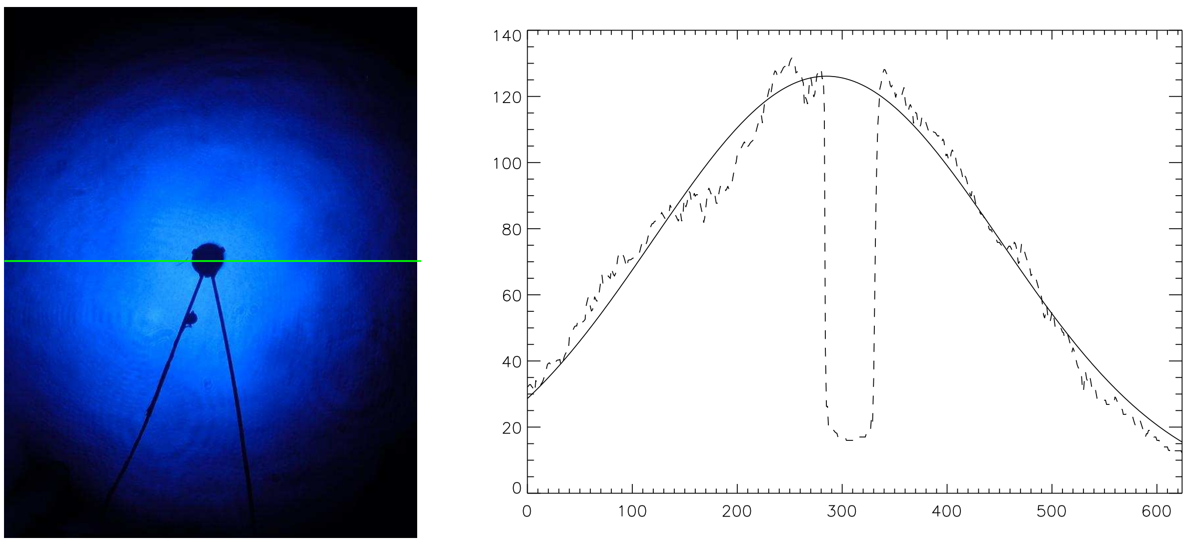

Figure 5: Measurement of the beam size in the LLT after BE refocusing. The horizontal cut of the image (left, green line) is fitted to a Gaussian curve, the scale is determined by the size of the M2 shadow.

The locations of the photo-diodes is given in Fig. 1. The feedback resistors in their amplifiers were adjusted to give few volts at nominal laser power 10 W and wide beam (5.6MOhm in lateral diodes, 2.2MOhm in the center). By moving the M4 actuators, we try to equalize the signals of peripheral photo-diodes, at least within a factor of two. Representative photo-diode readings are listed in Table 3 (Feb. 6, 2012, M4 at 0.000 and -0.003).

Table 3: Typical signals of the LLT photo-diodes

phm1x1	phm1x2	phm1y1	phm1y2	phm2
0.33	0.16	0.11	0.21	2.33

The FWHM of Gaussian LGS beam on M1 was reduced from 220 mm to 150 mm on January 24, 2012 (Fig. 5). The FWHM diameter is $FWHM = 2\sqrt{\log 2}\ a = 1.66\ a$, where a is beam radius at $1/e^2$ level. It can be calculated from the ratio ϵ of photo-diode fluxes at the periphery of M1 and its center[2] (the ratio of signals multiplied by the ratio of feedback resistors, 0.39) as $a = R/(-\log \epsilon)$,

[2] In fact the M2 photo-diode is displaced by ∼30 mm from the center.

where $R = 125\,\text{mm}$ is the M1 radius. As the 4 signals at M1 edge are usually very different, we take their median as representative and calculate the beam size with `beamsize.pro`.