SOUL project status

Single Conjugated Adaptive **O**ptics **U**pgrade for **L**BT

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ABSTRACT

Currently, there are 4 SCAO systems operating at LBT, all composed by an Adaptive Secondary Mirror (672 actuators) and a Pyramid Wavefront Sensor (30x30 sub-apertures). Two of these SCAO systems feed the interferometric focal stations of LBTI, while the remaining two provide the correction for the two LUCI spectro-imagers. Replacing the current wavefront sensor camera with an Electron Multiplied CCD, we will provide: a faster read out and framerate (2kHz instead of 1kHz) at lower noise (< 1e^- instead of ~ 10e^-) for better rejection of disturbances, and a higher spatial sampling (40 instead of 30 sub-apertures on the pupil diameter) for an improved reduction of aliasing error.
We report here the project status together with the updated estimation of the main system performances. In brief, the project passed the Design Review in 2016 and completed the AIT phase for the first 2 systems in spring 2017. The integration and commissioning of the first system is foreseen in 2018.
We updated the numerical simulation using the measured obtained during the laboratory test on the new devices. The new results confirm the gain around 1.5-2 magnitudes at all wavelengths in almost all the range of reference star brightness (7.5 < m_R < 18). This improvement will open the SCAO correction to a wider number of scientific cases from high contrast imaging in the visible to extragalactic source in the NIR.

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New wavefront sensor camera

FIRST LIGHT IMAGING CORP. customized **OCAM2k**

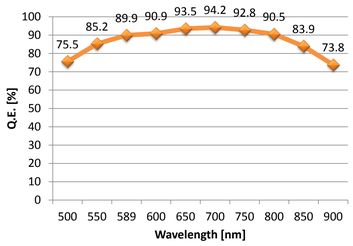
PROCURED TESTED

- ✓ Custom mechanical layout coping existing WFS layout
- ✓ Extra RO modes:

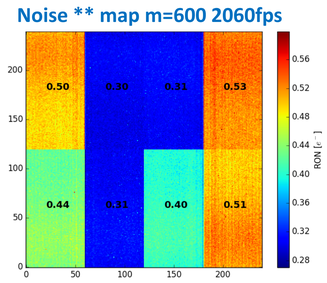
Bin	Size [pix X pix]	RO Time [ms]
1X1	240x240	< 0.50ms
1X1	120x120*	< 0.24ms
2X2	120x120	< 0.24ms
3X3	80x 80	< 0.24ms
4X4	60x60	< 0.24ms

* Cropped

Quantum Efficiency (E2V measurements)



Noise ** map m=600 2060fps



Measured dark current = 1.4 e^-/s/pix

Noise measurements in specification

		RMS [e^-]				
Camera ID		039	040	041	041**	Spec.
e2v (m=1000, 1274fps)		0.29	0.33	0.35	NA	0.5
First Light (m=600, 2000fps)	bin 1x1	0.38	0.34	0.34	NA	
	bin 2x2	0.52	0.43	0.48	NA	1.0
Arcetri (m=600, 2060fps)	bin 1x1	0.37	0.34	0.34	**0.40**	0.5
Arcetri (m=600, 3620fps)	bin 2x2	0.49	0.42	0.46	**0.38**	
Arcetri (m=600, 4890fps)	bin 3x3	0.63	0.60	0.56	**0.45**	1.0
Arcetri (m=600, 5900fps)	bin 4x4	0.74	0.67	0.67	**0.51**	

**the value in e- consider the measuered values of e-/ADU and multiplication gain

Upgraded slope computer

PROCURED TESTED

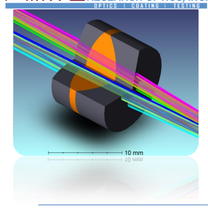
- ✓ New framegrabber with cameralink connection and higher throuput
- ✓ 2848 slopes at 2kHz of framerate
- ✓ Slope computation time 0.205ms (starting at ½ of RO time)
- ✓ Diagnostic recording slopes at full rate (2kHz)

MICROGATE

New camera lens for higher pupil sampling

RAINBOW RESEARCH OPTICS, INC.

PROCURED



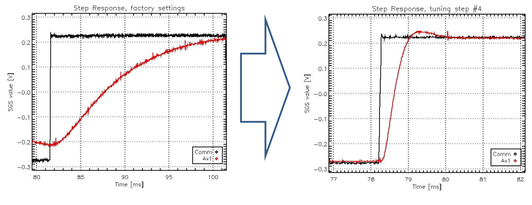
- ✓ From 30 to 40 SAs on the pupil diameter
- ✓ Residual lateral color 0.2SA (max P2V)

CCD binning	Pup. Sampling on diameter [SA]	Pup. distance center to center [SA]
1x1	40.8	48.0
2x2	20.4	24.0
3x3	13.6	16.0
4x4	10.2	12.0

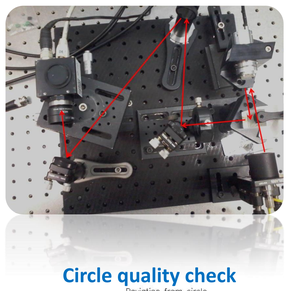
Tip-tilt modulator S-325 tuned for 2kHz framerate

PI TESTED

Electronic tuning for high frequency application

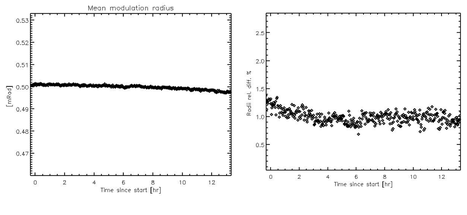


Optical feedback for:
- circle optimization
- Performance measurement

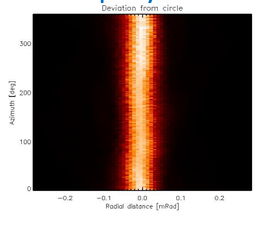


Fatigue test results

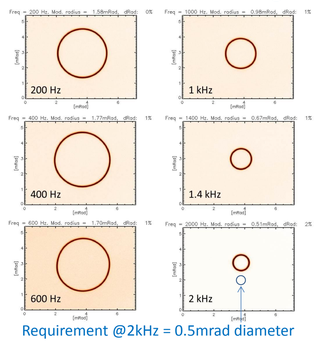
Run #	[hr]
1	1.5
2	4
3	4
4	7
5	24



Circle quality check



Performances at 1/3 of range

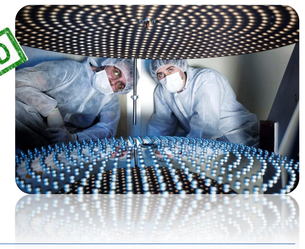


Requirement @2kHz = 0.5mrad diameter

Adaptive Secondary @2kHz + 2848 slopes

TESTED

- ✓ New configuration for adaptive secondary allowing 2848 slopes
- ✓ Adaptive secondary runs at a framerate of 2kHz after DSP code upgrade
- ✓ BCU2k interfaced with adaptive secondary
- ✓ Closed loop (no optics) run at 2kHz with 2848 slopes



Updated E2E simualtion

	FLAO	SOUL
RON [e-] Binning: 1x1, 1x2, 3x3, 4x4	10.5, 4.5, 4.5, 4.5	0.4, 0.38, 0.45, 0.51
Excess noise	None	statistics of electro-magnifying process
Read Out Time [ms] Binning: 1x1, 1x2, 3x3, 4x4	0.95, 1.56, 0.89, 0.68	0.24, 0.24, 0.24, 0.24
Maximum framerate [Hz]	1000	2000
Maximum # of controlled modes Seeing < 1.2” Seeing > 1.2”	 400 300	 600 300

FLAO ⇨ **SOUL**

Simulation parameters

Telescope:
Diameter of 8.222m with a central obstruction of 11.1%

Observing conditions:
Atmospheric turbulence: 0.6-1.5 arcsec seeing, L_0=40m, 4 turbulent layers with C_N^2 and wind profiles as reported in Table 1.

Transmission:
NGS total transmission (atmosphere, optics and quantum efficiency): 0.32

Guide Star:
0-magnitude star brightness: 1.99x10^{10} ph/m^2/s

Deformable mirror:
Set of 630 modes measured at LBT (KLv10).

Vibrations:
Tip-Tilt 600nm RMS

Turbulent layers

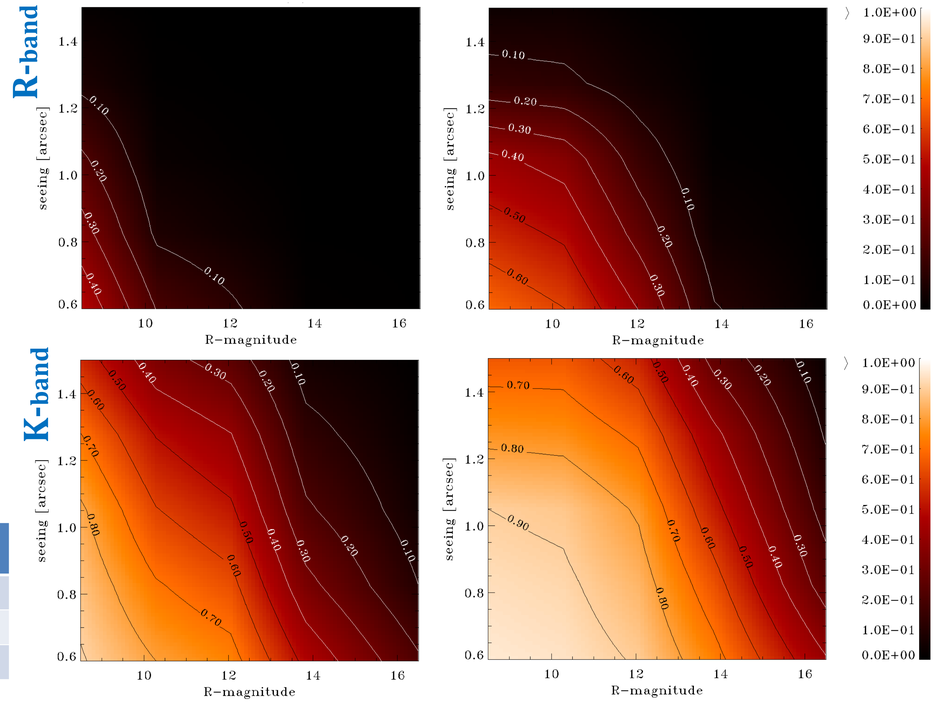
Layer number	1	2	3	4
Height [m]	119	837	3045	12780
Cn^2 fraction	0.70	0.06	0.14	0.10
Speed [m/s]	2.0	4.0	6.0	25.0

AO system configurations

R	8.5	10.5	12.5	14.5	16.5
fr. [Hz]	1000	1000	500	300	200
mod. amp. [±λ/D]	3	4	4	6	6
binning	1	2	2	3	4
no. modes	400	152	152	77	35

R	8.5	10.5	12.5	14.5	16.5
fr. [Hz]	2000	2000	1000	500	300
mod. amp. [±λ/D]	3	4	4	5	5
binning	1	1	1	2	4
no. modes	600	600	400	209	54

Strehl ratio



Timeline

- 2016-03 SOUL Design Review succesfully completed
- 2016-06 AIT phase started
- 2017-04 HW for the first LBTI system upgrade delivered in Tucson
- 2018-TBD First system upgraded
- 2019-TBD All 4 systems commissioned