ARGOS - the LBT Laser AO facility

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On behalf of the Argos consortium
ARGOS Consortium

- Max Planck Institut für extraterrestrische Physik, Garching
- Osservatorio Astrofisico di Arcetri, Florence
- Max Planck Institut für Astronomie, Heidelberg
- Center for Astronomical Adaptive Optics, Tucson
- Astrophysikalisches Institut, Potsdam
- Landessternwarte, Heidelberg
- Large Binocular Telescope Observatory, Tucson
- Max Planck Institut für Radioastronomie, Bonn
- Max Planck Institut Semiconductor Laboratory, Munich

The LBT Telescope

- 2x 8.4m mirrors on a single mount
- 22.5m mirror edge distance
- 6 bent gregorian focal stations
- 2 Primefocus cameras
- 2 direct gregorian focal stations
- Adaptive secondary mirrors
AO at LBT

Deformable M2 unit

NGS Wavefront sensor

LBT is designed already as an adaptive telescope, as needed for ELT’s
LBT Instrument Suite

LUCIFER:

- z, J, H, K bands
- Wide field and DL cameras
- 4' x 4' Imaging FOV
- 4' x 2' MOS FOV
- Cryo- exchangeable Masks
- 0.25" Slits
Laser Guide Stars for LBT

First Phase: GLAO

• Decrease PSF size by a factor 2-3
• Increase EE by a factor of 2-3
• Gain a factor 4-9 in integration time
• Correction over large field
• Correct at nearly any position on sky
• Operates under most seeing conditions

Next Phase: DL/MCAO

Strong increase of the LBT science capabilities

LUCIFER

• Diffraction limited imaging
• Wide field imaging over 4x4 arcmin
• Long slit spectroscopy

• Multi-object spectroscopy 4x2 arcmin

LINC/LBTI

• High resolution studies of single targets
ELT-AO related topics at LBT

- Large deformable secondary mirror
- GLAO seems to be the common sense baseline mode for ELT's...
- Laser guide stars are mandatory to achieve the science goals
- Multiple guide stars
- Large WFS detectors
- Sodium laser needs
- Spot elongation issues
- Gated systems...
Science Case - Why ARGOS is required

GLAO benefits

- Increased point source sensitivity
- Increased slit coupling efficiency
- Reduced crowding noise
- Enhanced spatial resolution

-> yields gains in observing time of a factor of 4-9

- high-z galaxy dynamics,
- AGN and QSO host galaxies
- planets,
- cepheids
- stellar clusters

AO4ELT Paris
GLAO on sky

- GLAO has been demonstrated on sky already:
- MAD system: NGS
- MMT Laser AO

MMT Lasers (M. Lloyd Hart et al.)

MMT GLAO images, 0.26 arcsec FWHM
GLAO Performance: Cn2 and Modelling

- Results from Scidar measurements
- Collection and comparison with other facilities in the area

-> GLAO gains a factor 2-3 in FWHM and EE over a large Field

Cn2(h) profile from Mt Graham (S. Egner, E. Masciadri)

Strong ground layer is often seen!
GLAO Performance

GLAO turns a 0.6'' site in a 0.3'' site!

Probability of getting a performance at a given night of better 0.3' is 50%
Design basics

Basic GLAO choices
- Rayleigh lasers are easily available
- Multiple stars create a homogeneous field correction

Robust AO operation
- Ensure enough photons on the detector
- Ensure large FoV subapertures
- Use lowest noise detectors
- Operate at high bandwidth
- Correct a sufficient number of modes

Ensure upgrades
- Plan for a sodium laser launch and detection
- Allow for Rayleigh tomography upgrade
Overview

• LGS system consists of a constellation of 3 Rayleigh guide stars above each eye of the LBT
• One laser head per beam
• Refractive beam expander in the LBT structure
• WFS with Shack-Hartmann setup using a single detector for all guide stars.
• Gating of the light is done with Pockels cells
Rayleigh photon return

Photon flux calculation

\[ N_{ph} = \eta_t \frac{ED^2 \rho(H) \frac{d\sigma}{d\Omega} \Delta H}{N^2 \gamma H^2} \]

1.8mJ per pulse, 10kHz
(18W lasers), 1kHz framerate

Calculated values

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Rayleigh Lasers are bright!
At least 1000 Photons @ 1kHz and 12km expected
Hardware at the telescope

- Laser system mounted between windbraces
- Launch system uses LBT structure as stiff frame
- Long focal length expanded
- Two fold mirrors to direct the beam behind of M2
- A calibration unit can be placed at the short focal position of M2

Distributed System! Flexure control, vibrations, etc are an issue!
Laser system

- 3 pulsed lasers per LBT side
- 18W per Laser
- 10kHz repetition rate
- 532nm wavelength
- Variable constellation diameter
- Position tracking of the beams
- Sealed enclosure
- Temperature stabilized
Launch system

- Refractive, aspheric design 40cm clear aperture
- Launch behind M2
- Long focal length
- Uses the LBT structure
- Flat Mirrors to launch the beam
- Sealed beam tube
- Dust covers on mirrors
WFS Solution

- Laser beacon light is picked in front of rotator.
- 3 guide stars are sensed individually, but with one detector.
- SH-detection
- Range gate is done with Pockels cells
- Internal field stabilization
- Allows Rayleigh tomography and Sodium upgrade
- Integrated patrol cameras for guide star acquisition
WFS detectors

- MPI / PnCCD
- 264x264 pixel
- 48µm pixels
- QE~1
- RON ~2.5e-
- 1kHz full frame
Range Gating of the laser pulses

- Range gate carried out with Pockels cells in front of detector
- 10ns rise/fall time
- Wide field of view Pockels cell developed
- Suppression >10^3
Calibration

- Dedicated swing arms can move a calibration unit in the prime focus
- Off-axis sources with the use of DOE’s allow to perform daytime LGS AO calibration
- An on axis source allows to measure the non-common path and proves performance on the science instrument

- Poster by Christian Schwab today
Spot elongation

- Spots on SH get elongated
- 2" elongation reached at ~300m range gate

- For pulsed laser guide stars the travelling pulse and the shutter opening creates elongation
- For Sodium guide stars the thickness of the layer elongates the star
- Error propagates into high order radial modes
- Calls for complicated and large CCD's
Compact refocus system

Simple gating

• Removes spot elongation
• Removes the need for radial / special CCDs
• Saves in laser power

Membrane refocus upgrade

R(t)

- Removes spot elongation
- Removes the need for radial / special CCDs
- Saves in laser power
From GLAO to Diffraction Limit

Hybrid solution I

Operate Rayleigh AO together with NGS
-> Increase limiting magnitude for the NGS AO

Hybrid solution II

Operate Rayleigh AO together with central Sodium
-> Full DL gained
-> Only low power sodium laser needed
-> SCAO, MCAO path open
-> Breaks low order degeneracy in tomography
-> Only one TT-star needed
Sodium line solid state laser options

20W SOR based system

20 W Fibre laser
ESO, Toptica

Low power version would be ok for ARGOS

Pulsed laser development???
Would greatly reduce the power needs for ELT’s / nicely fit into the ARGOS system!
Project status

• Phase A Kick off May 2007 ✓
• Phase A Review March 2008 ✓ ✓
• LBT board approval ✓ ✓
• Preliminary design March 2009 ✓
Final Design 2010
Installation at telescope ~2012