ARGOS - the LBT Laser AO facility

S. Rabien

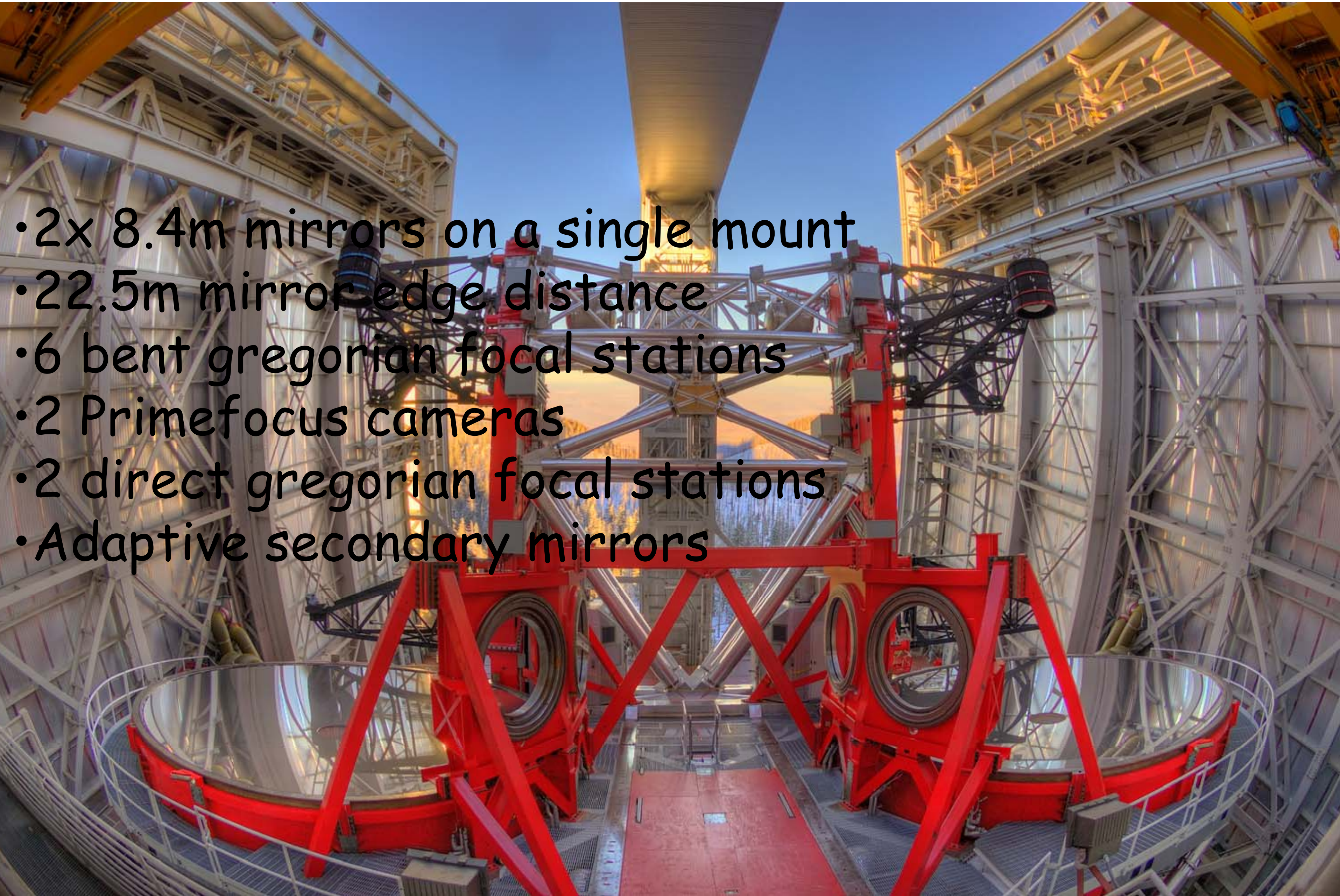
On behalf of the Argos consortium

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

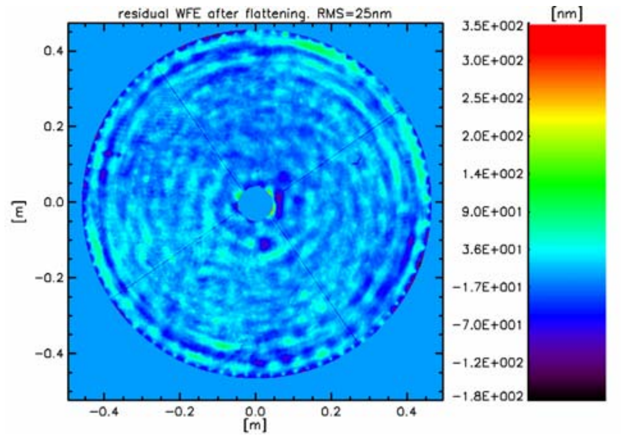
N. Ageorges, U. Beckmann, J. Brynnel, L. Busoni, R. Davies, M. Deysenroth, S. Esposito, N.M. Förster Schreiber, W. Gässler, H. Gemperlein, R. Genzel, R. Green, M. Lloyd Hart, E. Masciadri, D. Peter, A.Quirrenbach, M. Rademacher, H.W Rix, P. Salinari, C. Schwab, J. Storm, L. Strüder, M.Thiel, G. Weigelt, J.Ziegleder

The LBT Telescope

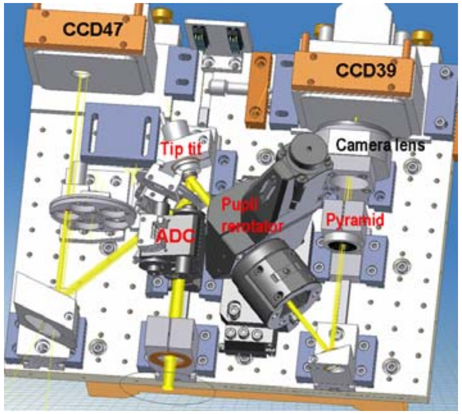


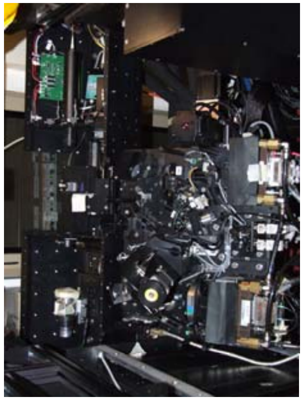
- 2x 8.4m mirrors on a single mount
- 22.5m mirror edge distance
- 6 bent gregorian focal stations
- 2 Primefocus cameras
- 2 direct gregorian focal stations
- Adaptive secondary mirrors

AO at LBT

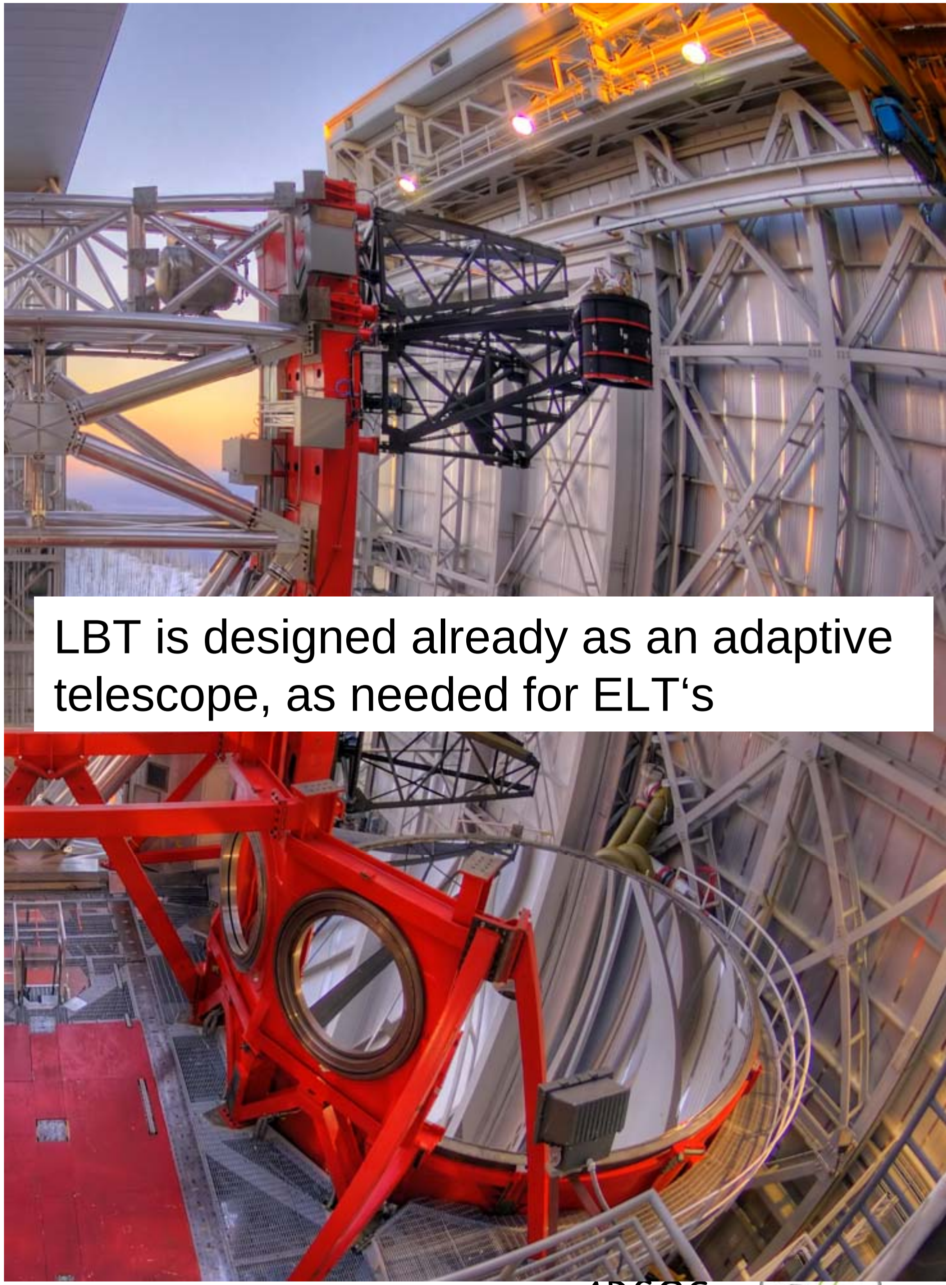


Deformable M2 unit



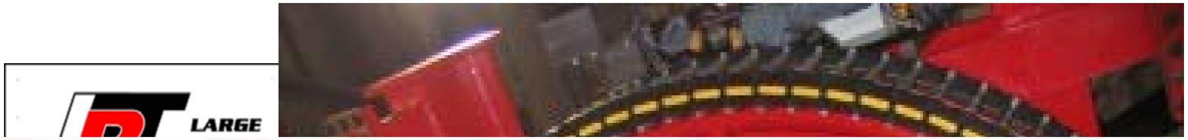


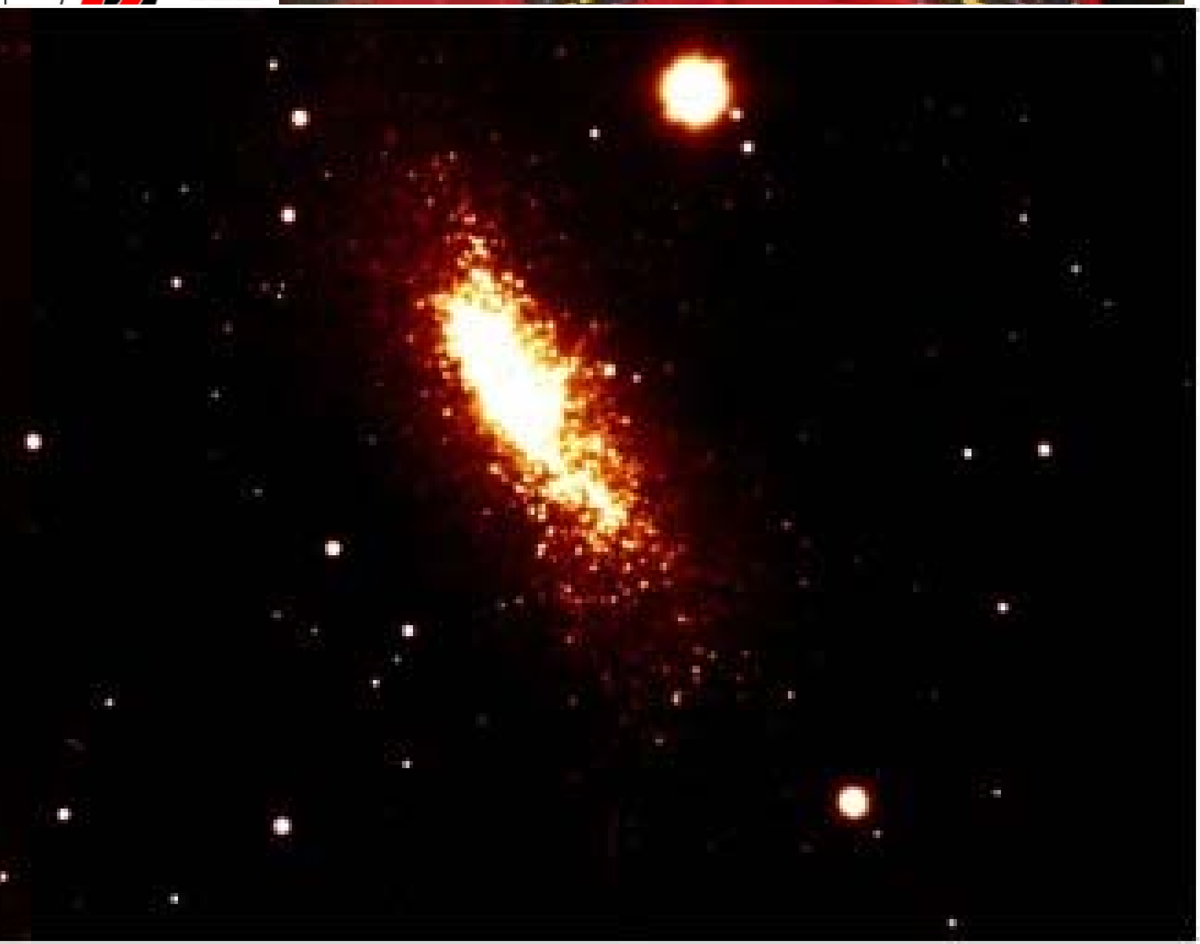
NGS Wavefront sensor



LBT is designed already as an adaptive telescope, as needed for ELT's

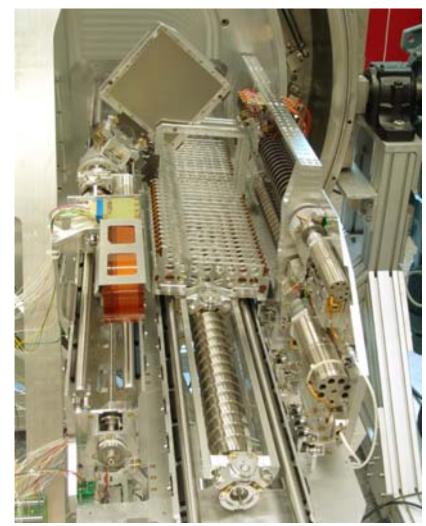
LBT Instrument Suite





LUCIFER:

- z,J,H,K bands
- Wide field and DL cameras
- 4'x4' Imaging FOV
- 4'x2' MOS FOV
- Cryo- exchangable 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

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

Strong increase of the LBT science capabilities

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...

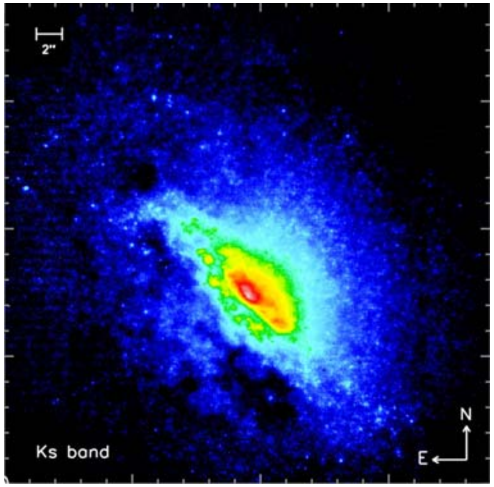
Science Case – Why ARGOS is required

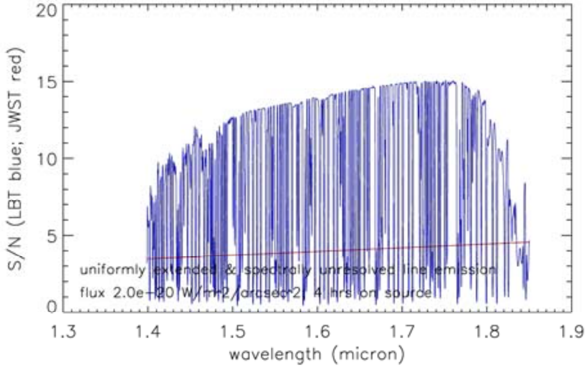
GLAO benefits

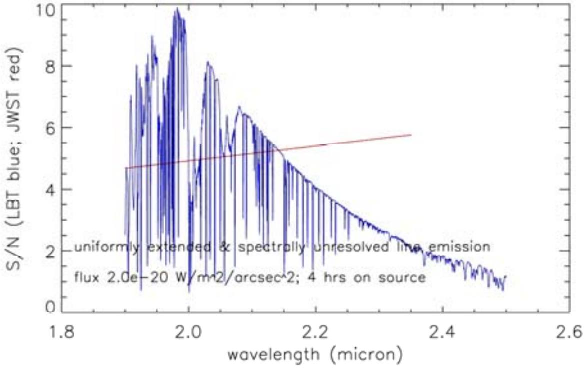
- Increased point source sensitivity
- Increased slit coupling efficiency
- Reduced crowding noise
- Enhanced spatial resolution

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

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

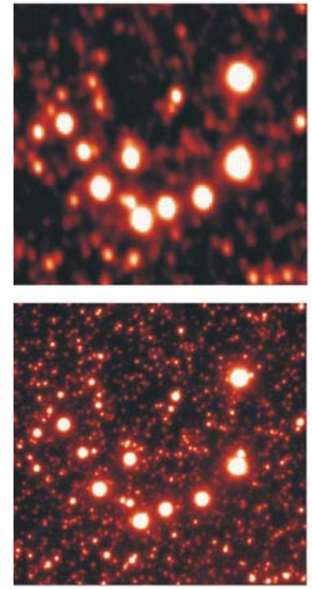




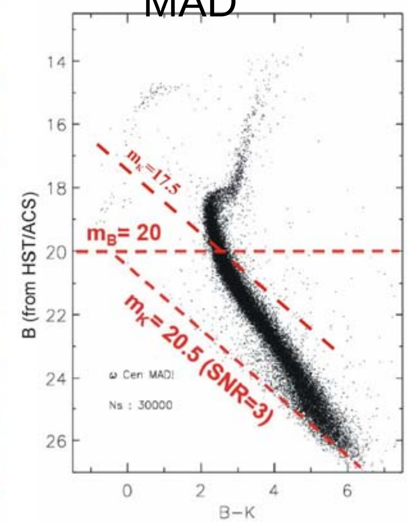


GLAO on sky

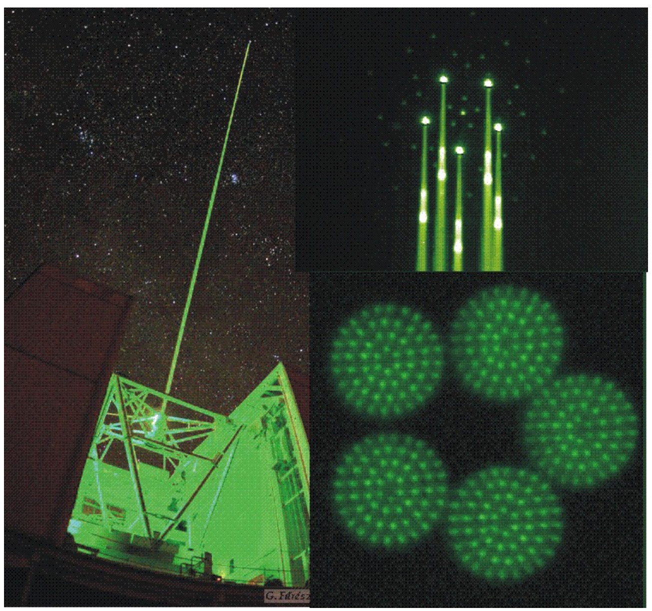
- GLAO has been demonstrated on sky already:
- MAD system: NGS
- MMT Laser AO



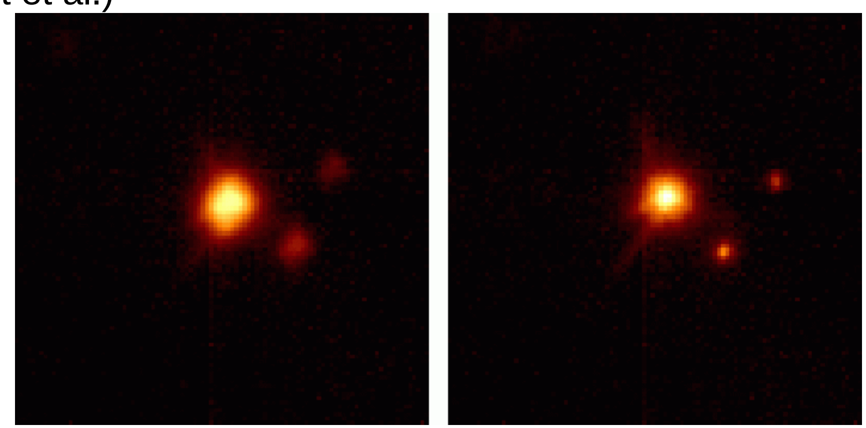
MAD



Marchetti et al.

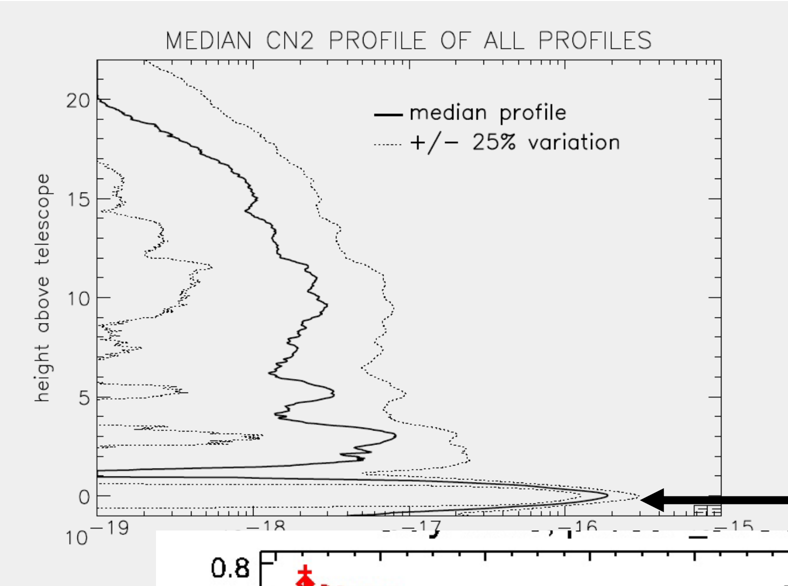


MMT Lasers
(M. Lloyd Hart et al.)



MMT GLAO images, 0.26 arcsec FWHM

GLAO Performance: Cn2 and Modelling

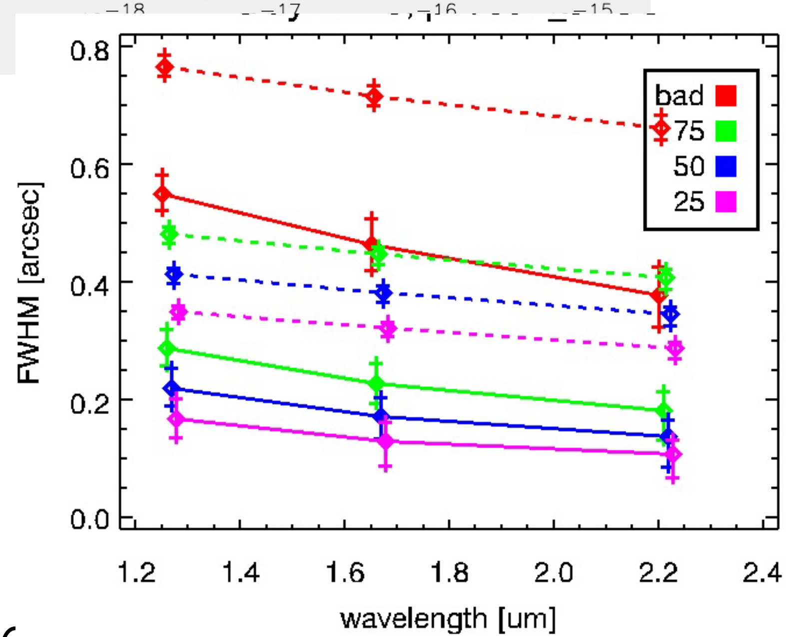


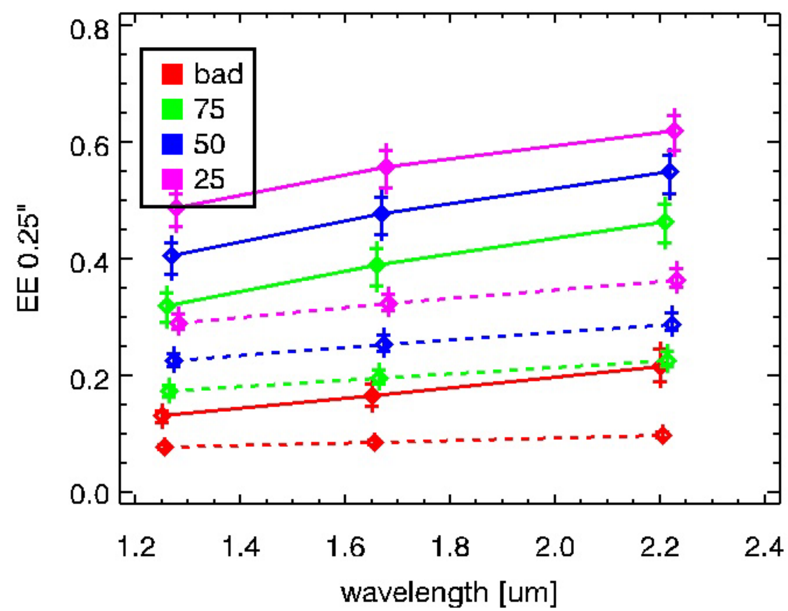
- Results from Scidar measurements
- Collection and comparison with other facilities in the area

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

Masciadri)

een!





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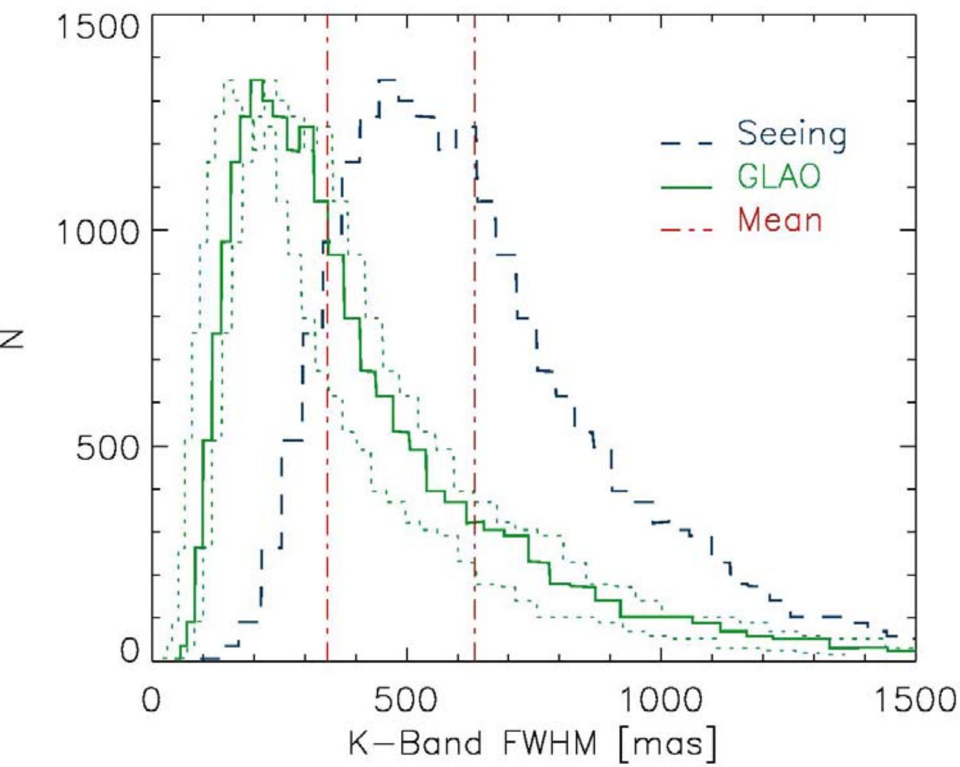
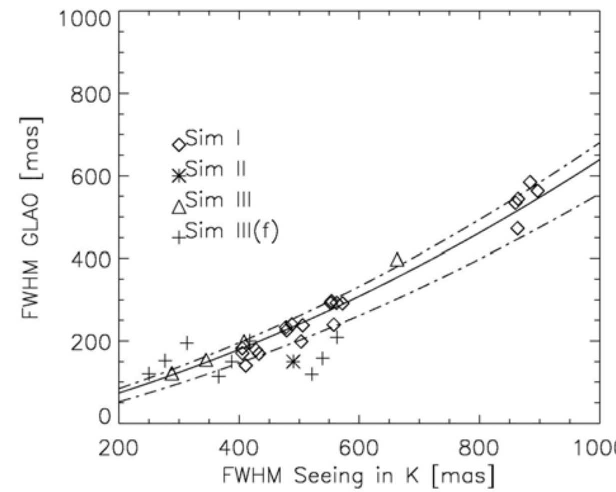
GLAO Performance





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

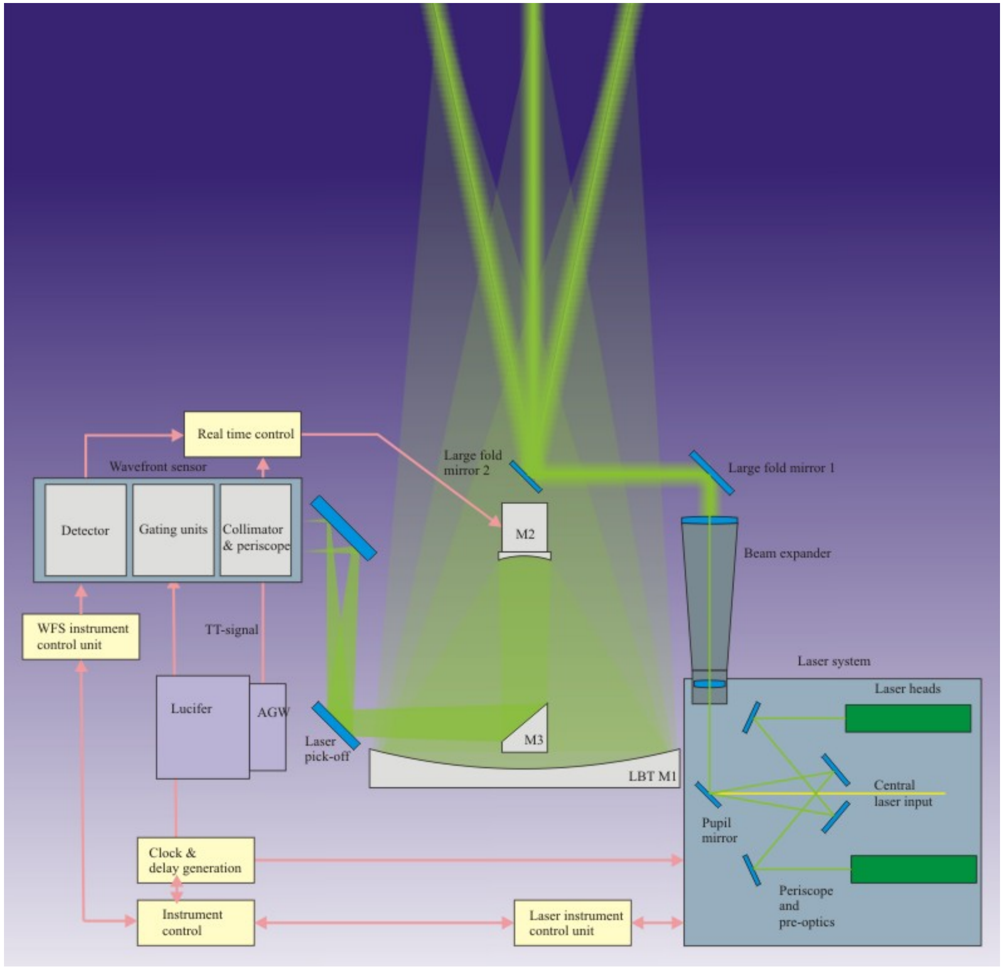
- Ensure enough photons on the detector
- Ensure large FoV subapertures
- Use lowest noise detectors
- Operate at high bandwidth
- Correct a sufficient number of modes

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

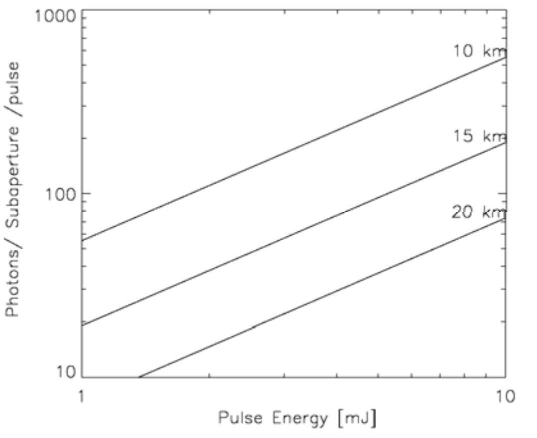


Rayleigh photon return

Photon flux calculation

$$N_{ph} = \eta_{rt} \frac{ED^2 \rho(H) \frac{d\sigma}{d\Omega} \Delta H}{N^2 \gamma H^2}$$

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

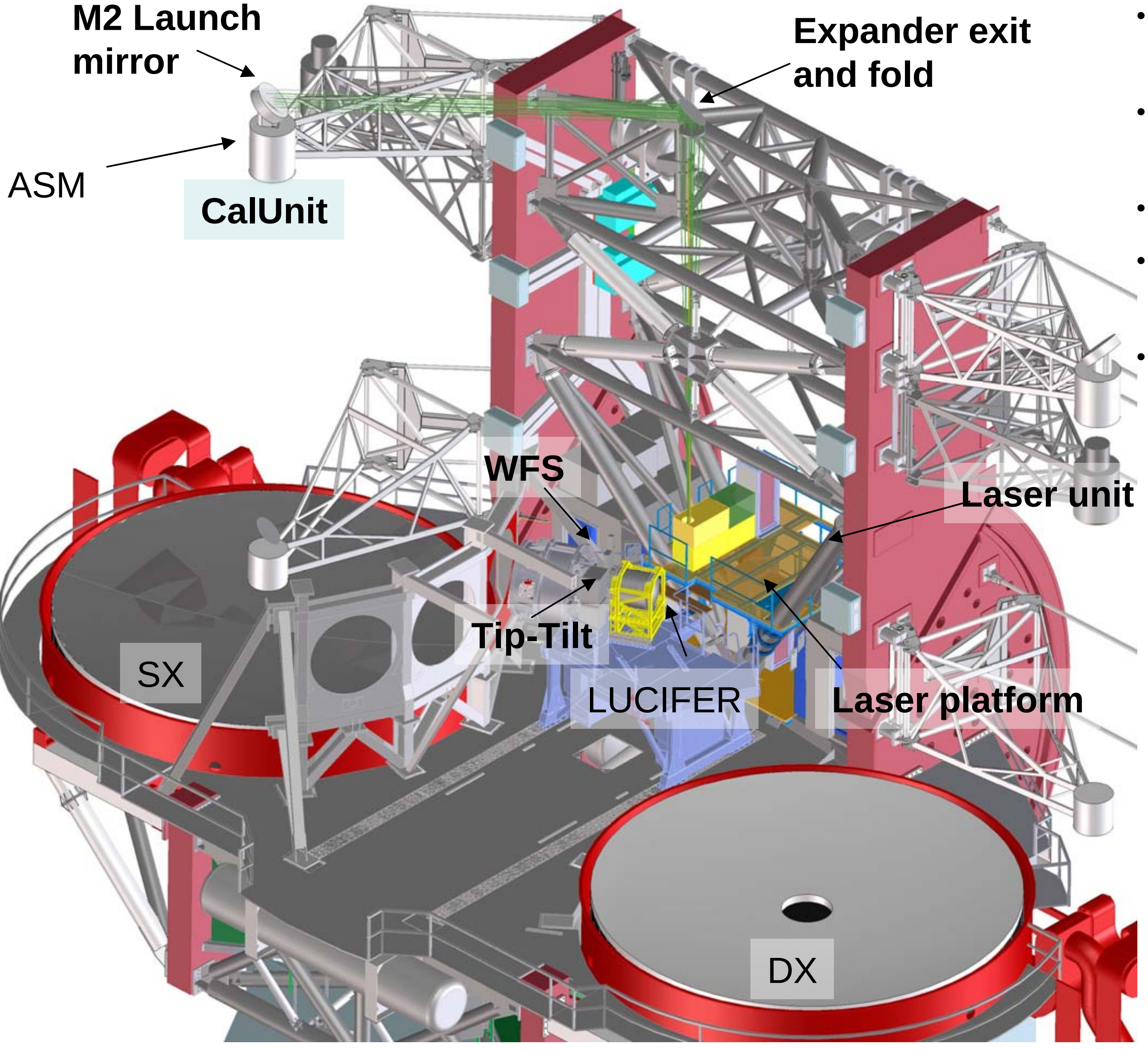


Calculated values

Rangegate [m]	eff=1	eff=0.25	eff=0.1
100	2440	609	244
200	4880	1220	488
300	7314	**1830**	731
400	9750	2440	975

→ 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 expande
- Two fold mirrors to direc 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!

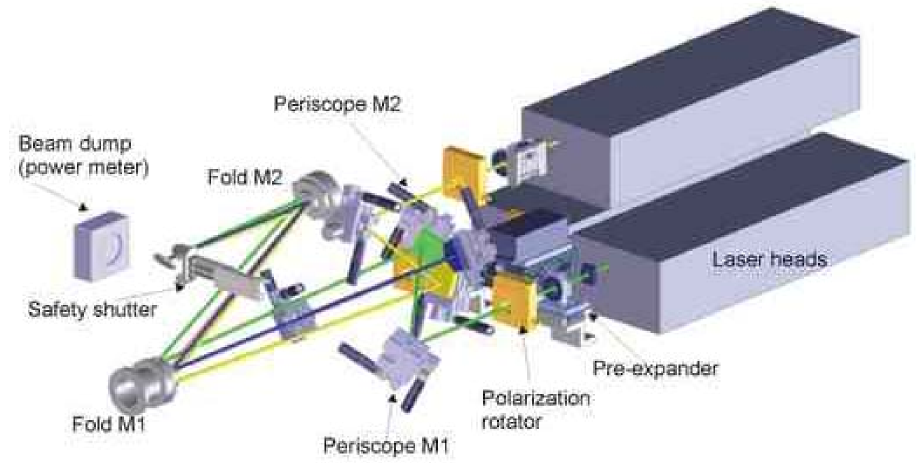
ARGOS

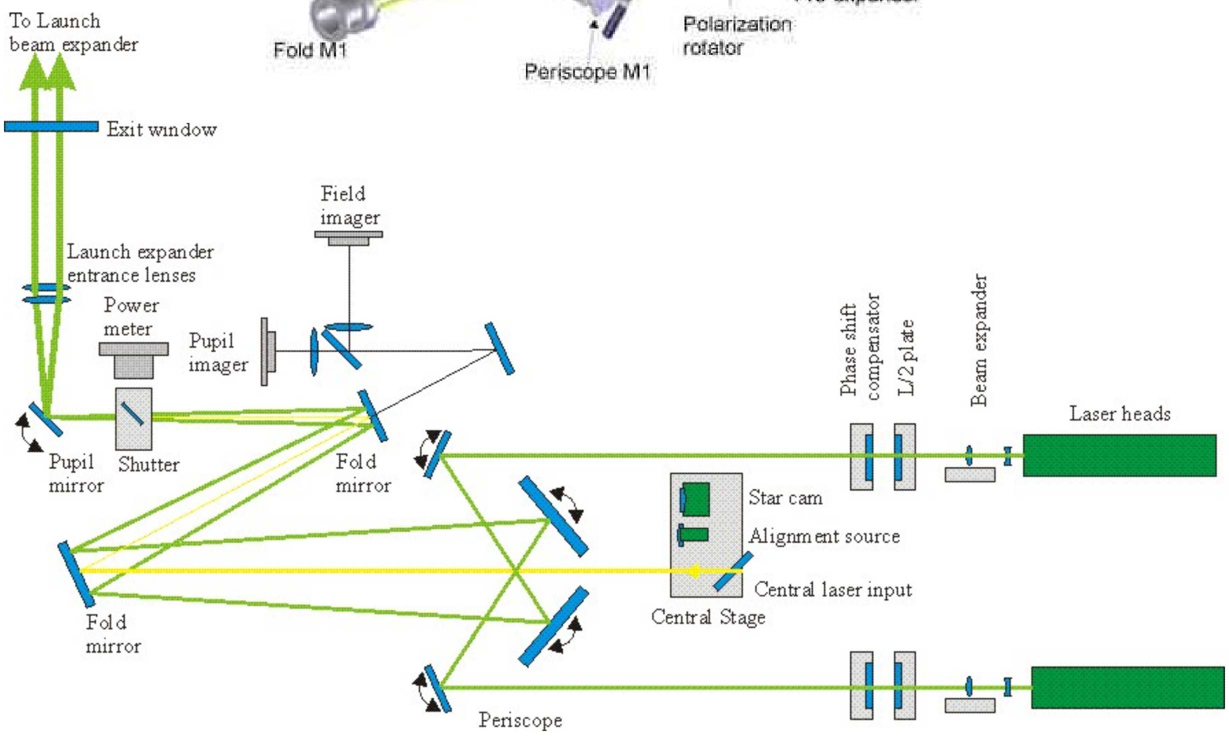
Laser system

- 3 pulsed lasers per LBT side
- 18W per Laser
- 10kHz repetition rate
- 532nm wavelength

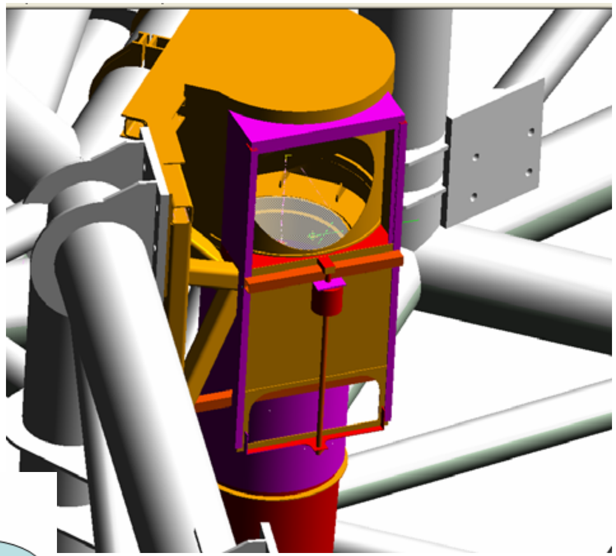
- Variable constellation diameter
- Position tracking of the beams

- Sealed enclosure
- Temperature stabilized

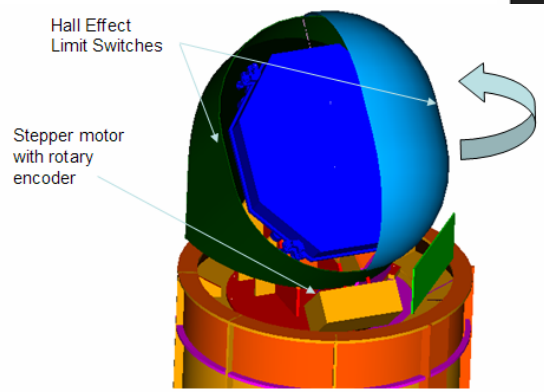


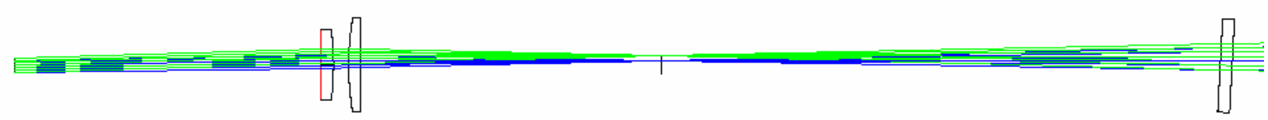


Launch system



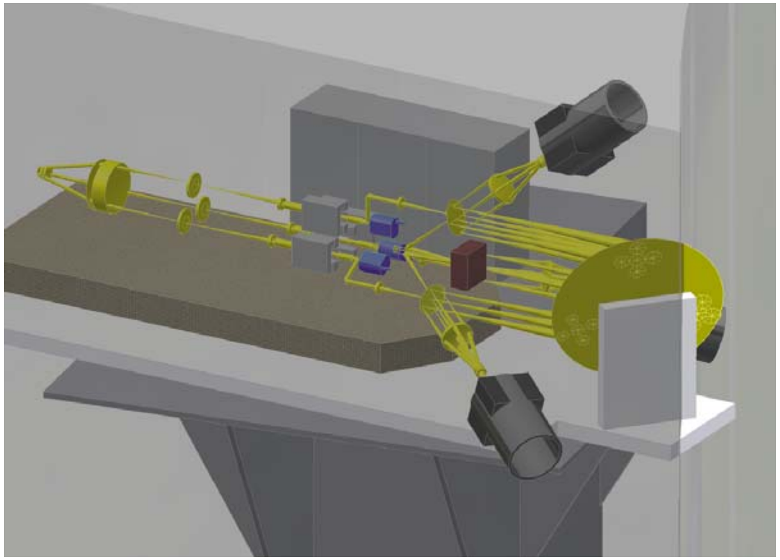
- Refractive, aspheric design 40cm clear aperture
- Launch behind M2
- Long focal length
- Uses the LBT structure
- Flat Mirrors to launch the beam
- Sealed beam tube
- Dust covers on mirrors

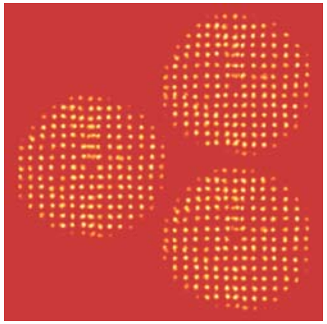


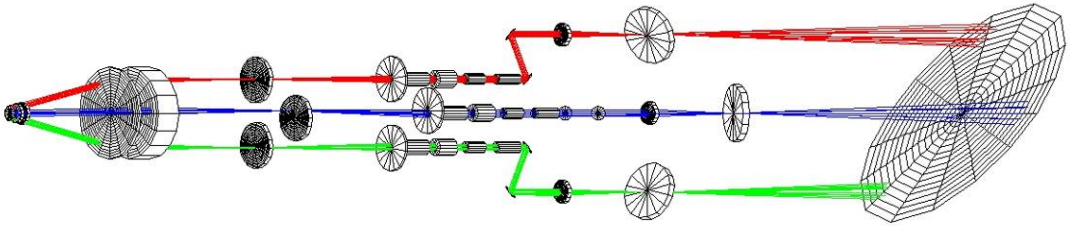


WFS Solution

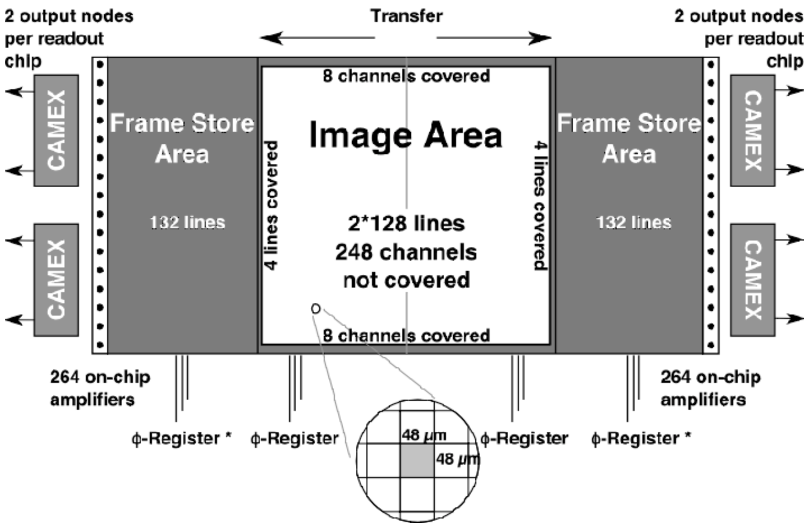
- Laser beacon light is picked in front of rotator.
- 3 guide stars are sensed individual, but with one detector
- SH-detection
- Range gate is done with Pockels cells
- Internal field stabilization
- Allows Rayleigh tomography and Sodium upgrade
- Integrated patrol cameras for guide star aquisition



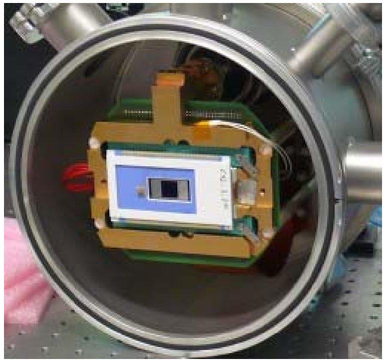


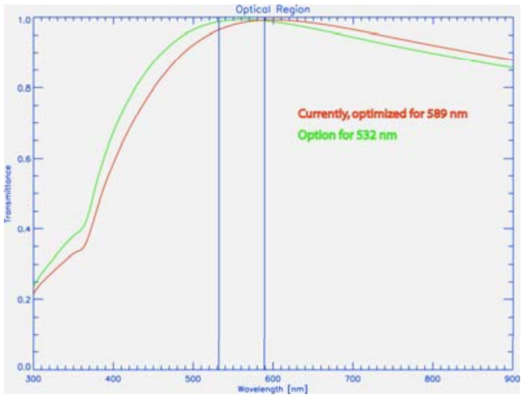


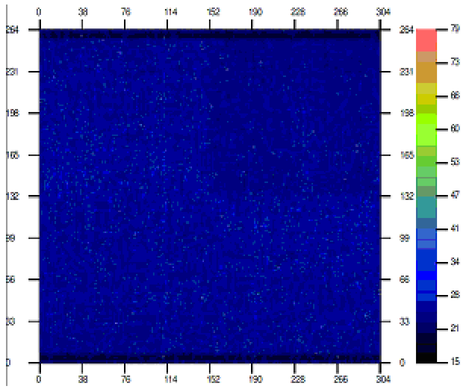
WFS detectors

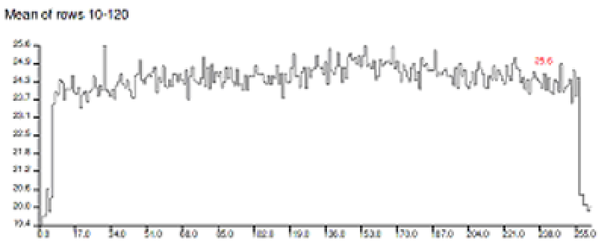


- •MPI / PnCCD
- •264x264 pixel
- •48µm pixels
- •QE~1
- •RON ~2.5e-
- •1kHz full frame

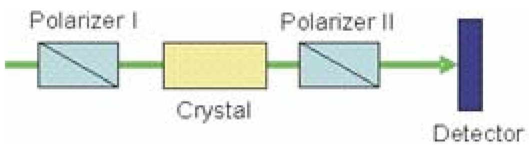


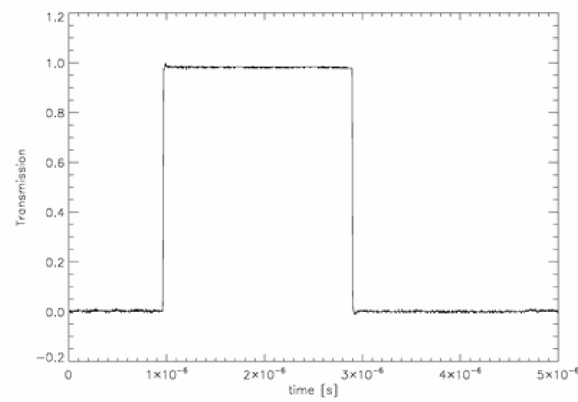




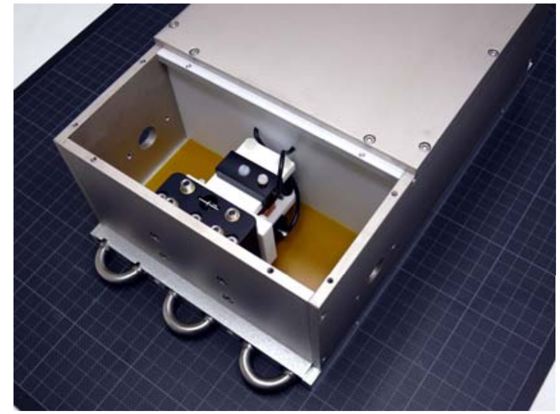


Range Gating of the laser pulses



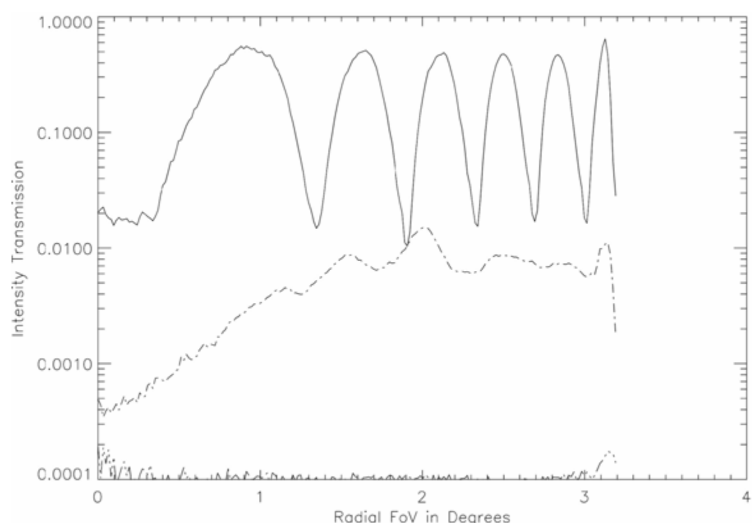


Optical transmission



BBO test cell at MPE

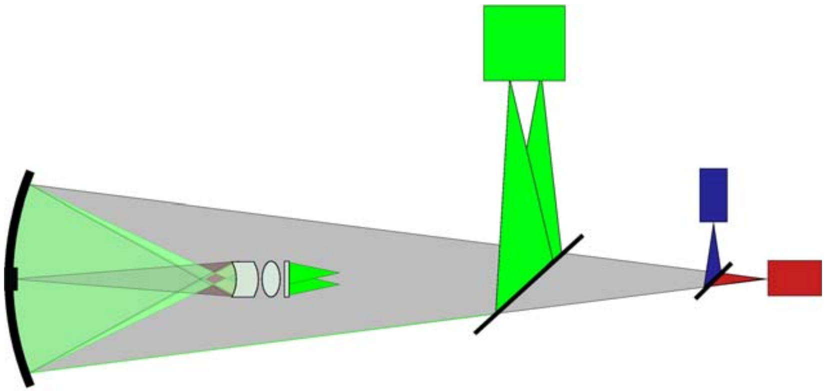
- Range gate carried out with Pockels cells in front of detector
- 10ns rise/fall time
- Wide field of view Pockels cell developed
- Suppression >10^3

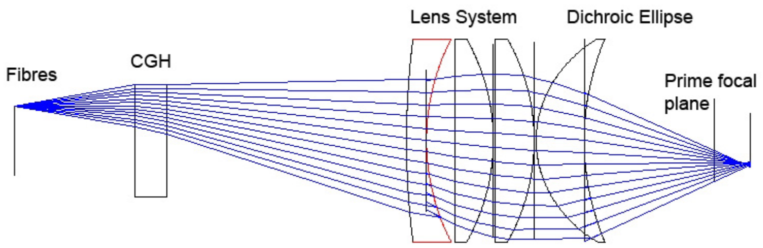


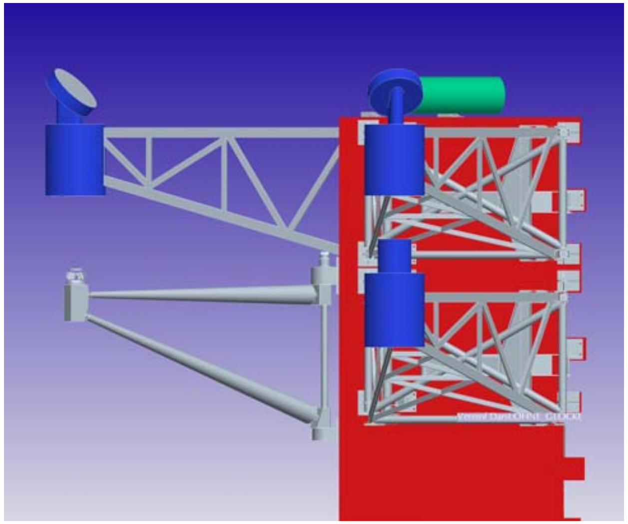
Calibration

- 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 prooves performance on the science instrument

- Poster by Christian Schwab today

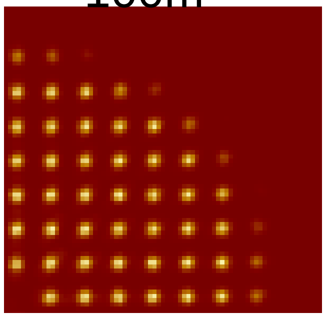


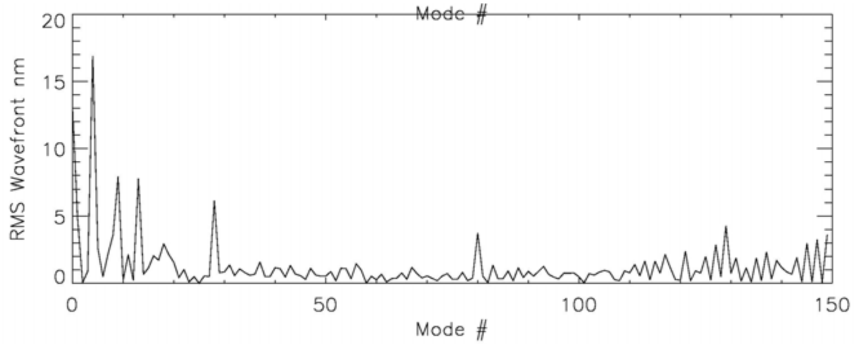




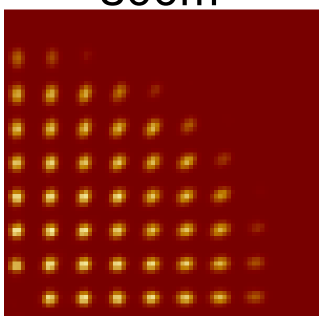
Spot elongation

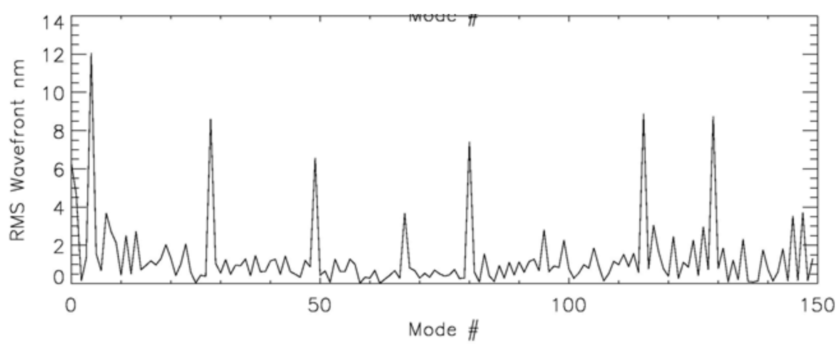
100m



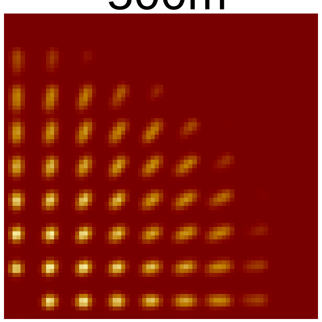


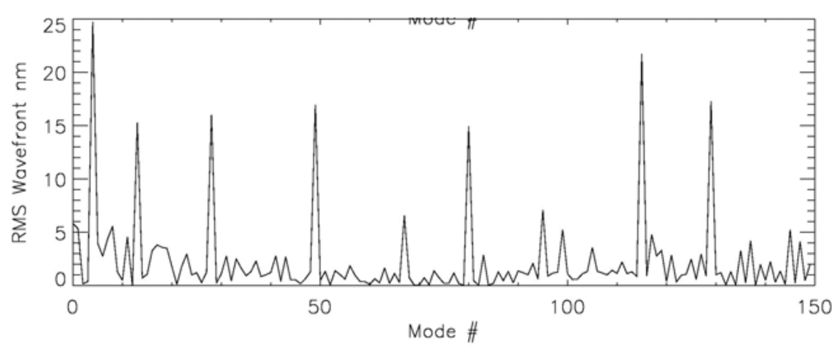
300m





500m



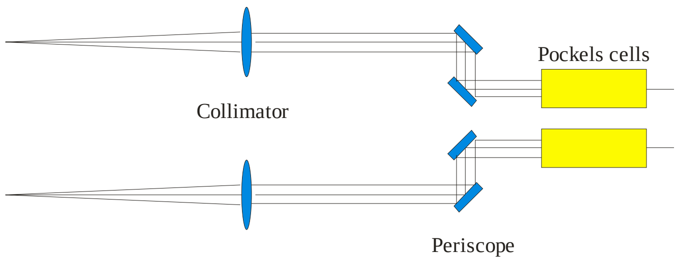


- Spots on SH get elongated
- 2“ elongation reached at ~300m range gate

- 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

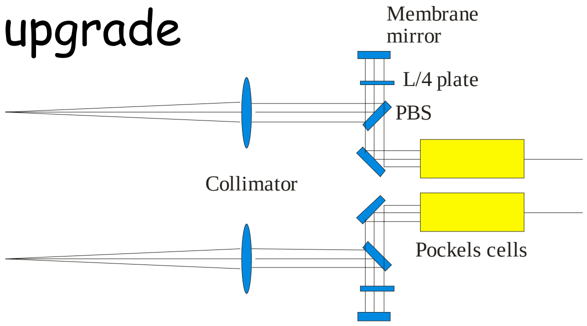
Compact refocus system

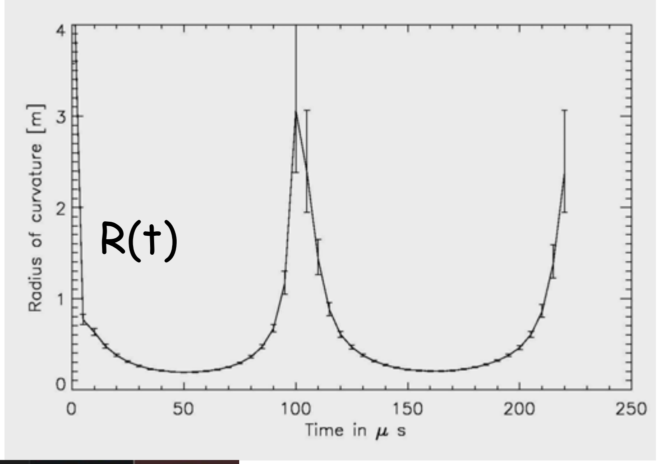
Simple gating

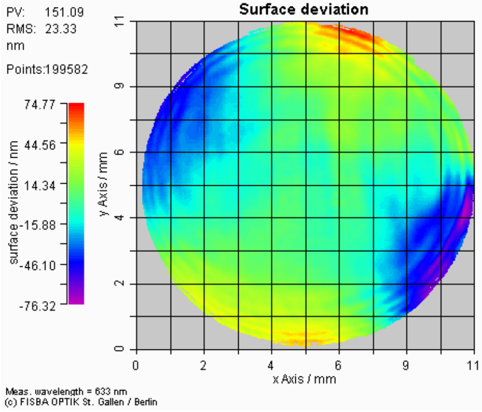


•Removes spot elongation
•Removes the need for radial / special CCDs
•Saves in laser power

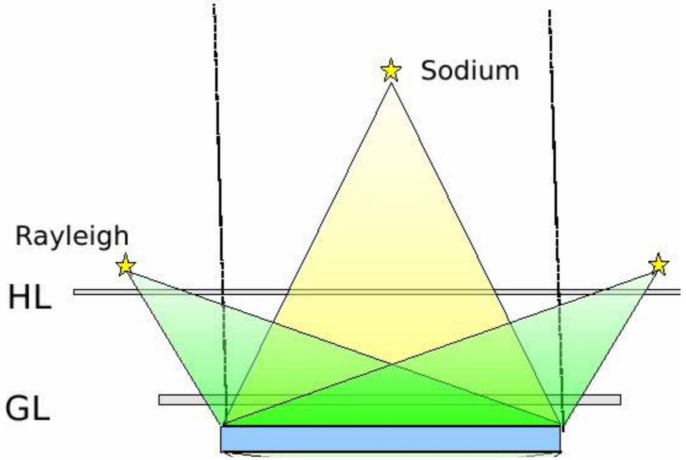
Membrane refocus upgrade

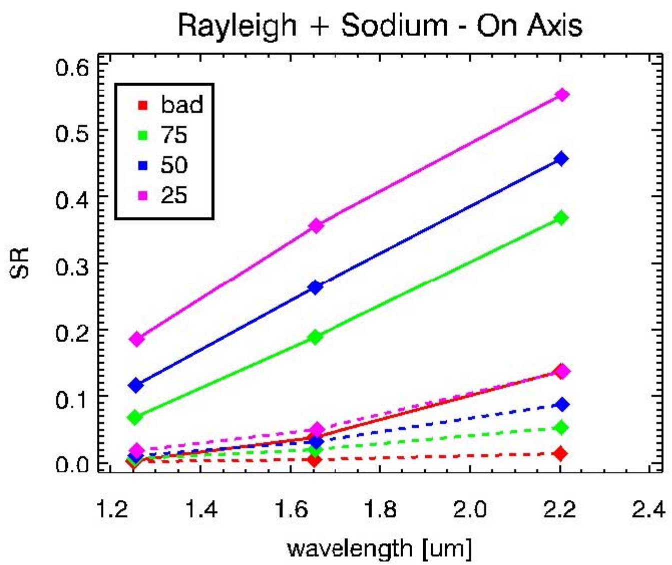






From GLAO to Diffraction Limit





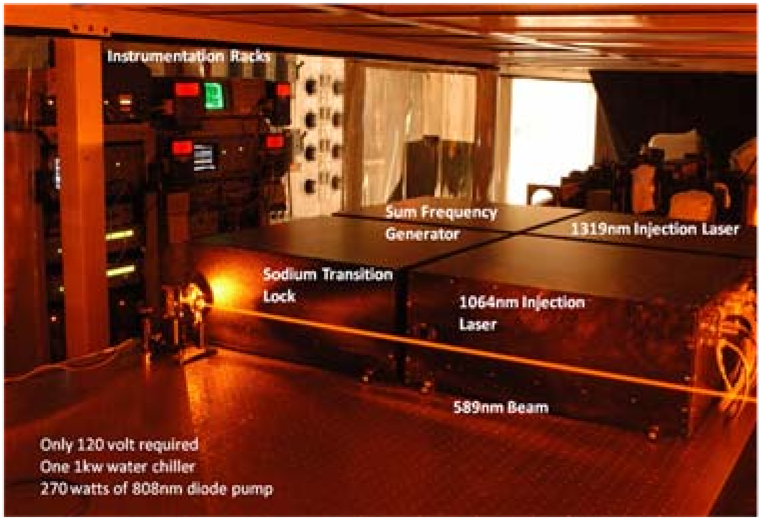
Hybrid solution I

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

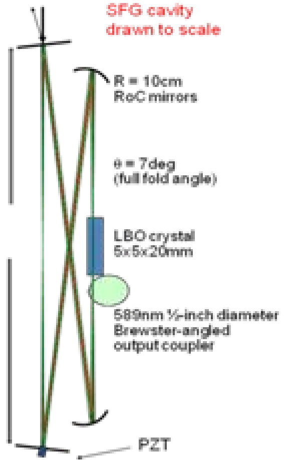
Hybrid solution II

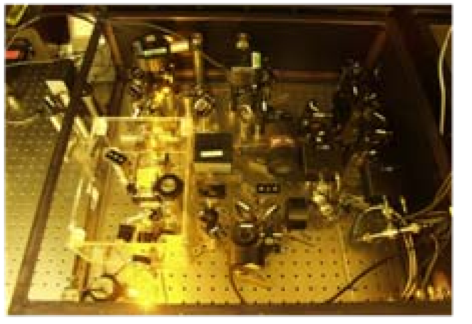
Operate Rayleigh AO together with central Sodium
-> Full DL gained
-> Only low power sodium laser needed
-> SCAO, MCAO path open
-> Breaks low order degeneragy in tomography
-> Only one TT-star needed

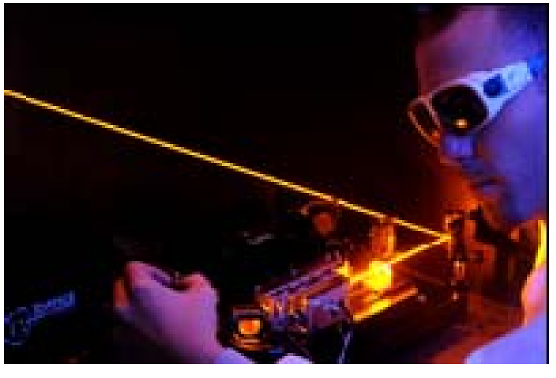
Sodium line solid state laser options



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

ARGOS