Upgrade of the ESO Laser Guide Star Facility

May 2013

Introduction

- Laser Guide Star Facility Part of Unit Telescope 4 at Paranal Observatory. Installed in 2006
- Generates a single centre-launched sodium laser guide star for client AO instruments SINFONI and NACO
- Upgrade project (PARLA), new laser source subsystem for LGSF
- Goal to support Paranal operations, more flexible laser operation
- Laser based on patented Raman fibre laser technology
- Project Start / End: Nov 2011 – Feb 2013 (start of science operations)
Laser Guide Star Facility

Main subsystems:
- Laser source
- Optical fibre injection
- Photonic crystal fibre beam relay
- Launch optical system behind telescope M2
- Safety / aircraft avoidance
System Requirements

Optical
- Power delivered to launch telescope (after relay fibre) >6 Watts (7W goal)
- Sodium D2a excitation only
- Broadened laser spectrum (110 MHz line spacing)

State Transitions
- Startup less than 60 mins / Shutdown less than 60 mins (goal 10 mins)
- Frequency Tune/Detune < 120s (goal 30s)
- IDLE to ON less than 30 mins

Lifetime/Availability:
- 3 year lifetime
- 12h operation per day average

Interfaces:
- Mechanical: laser bench and electronics cabinets
- Electrical/Electronic: LGSF control and safety systems, normal and UPS power
- Cooling: existing stabilised coolant circuit

Environmental:
- Ambient temperature stability +/- 1C
- RH 5-15% typical, air pressure 700-800mBar typical
- Gravity invariant, clean room
Laser Guide Star Facility

Laser Guide Star Facility Control Architecture

- Workstation in Control Room
- 4 x Local Control Units (VME/VX Works Systems) in Telescope Area:
  - Laser LCU
  - BRS Fibre Injection LCU
  - Launch Telescope LCU
  - Fast Jitter LCU
- Safety Interlock System
- Laser LCU TCP/IP Interface with laser local control system
Main Optical Path

Electronics Cabinet:
- Seed Laser
- Pump Laser

Laser Bench:
- Laser head
- Periscope
- Phase Modulator
- Beam Expander Unit

Parts of new laser system shown with blue border.
PARLA Bench Mechanical Layout

- Free Space Optics Mounted on Existing Optical Bench in Laser Clean Room
- Shown Below with and without Covers
Laser Tests (Europe)

Laser Stand Alone
- Output power
- Beam pointing stability (transient)
- Beam quality
- Wavelength/wavelength stability
- Local control system

Laser + Beam Relay + Fibre Coupling

Soak Tests (12h runs)

Software Tests (VLT SW Model)
- Control functionality
- State transitions
- Simulated observing cycles

![Graph showing Parla Laser Output Power at 589nm versus Raman Amplifier Set Point]

![Image of software interface for observation analysis]
Laser Spectral Optimisation

110MHz Phase modulator broadens the laser line
Overcome spectral power limitation in 27m PCF transport fibre
Figures on left show calculated line spectra for peak phase shifts of: 0, 1.44 (“3 lines”), 2.63 (“4 lines”), 3.76 (“5 lines”).
Solid curve shows overlap with sodium D2a line.
Below the measured spectrum of the beam in the installed system.
System Test Europe

- AIV Europe
- Soak tests (12h)

![System Test, Fibre Throughput 30th Oct 2012](image)

- Power at PCF Input
- PCF Fibre Output Power

![Infra-red Frequency Error](image)

- Infra-Red Frequency Error
AIV, Commissioning (Chile)

Photos courtesy Gerd Hudepohl, ESO
AIV Chile, Commissioning

Operating Hours Summary (Dec - Mar)

Cumulative hours during this period:
- Control System: 948
- Seed: 943
- Raman Amplifier: 394
- Visible: 371
Commissioning Summary

Technical tests to re-commission LGSF with Telescope / Instruments SINFONI and NACO:

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sodium D2 Line Wavelength Scan</td>
</tr>
<tr>
<td>2</td>
<td>LGS vs Pointing</td>
</tr>
<tr>
<td>3</td>
<td>NACO and SINFONI dummy OB operation, testing the representative configurations of the instruments</td>
</tr>
</tbody>
</table>

Science verification, repeat a number of existing and previously published OBs to verify system performance:

<table>
<thead>
<tr>
<th>Instr.</th>
<th>Object name</th>
<th>Description</th>
<th>Existing OB data</th>
</tr>
</thead>
<tbody>
<tr>
<td>SINFONI</td>
<td>NGC3621</td>
<td>Bulgeless Galaxy with NC</td>
<td>083.B-0279(B)</td>
</tr>
<tr>
<td></td>
<td>Centaurus A</td>
<td>AGN with central black hole</td>
<td>280.C-5005</td>
</tr>
<tr>
<td></td>
<td>Haumea</td>
<td>Solar system, trans-Neptunian object</td>
<td>087.C-0167(A)</td>
</tr>
<tr>
<td></td>
<td>(TNO136108)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NACO</td>
<td>Centaurus A</td>
<td>Active Galactic Nuclei</td>
<td>280.C-5005</td>
</tr>
<tr>
<td></td>
<td>NGC 5139</td>
<td>Omega Cen.</td>
<td>60.A-9800(J)</td>
</tr>
</tbody>
</table>
Wavelength Scan on Sky

- Wavelength of laser tuned in steps through the sodium absorption line
- 250MHz steps + 100MHz steps near D2a peak
- LGS Brightness measured on telescope guider
- Convolution of broadened laser spectrum with sodium line
- Launched polarization is not controlled
- Power on sky approx 6.4 Watts during test

PaRLa Commissioning Wavelength Scan

- 250 MHz scan, EOM 28.8%
- 100MHz scan, EOM 28.8%
LGS Equivalent Magnitude, Strehl Table

Return flux measured at different telescope elevations, SINFONI.

Equivalent V-Magnitude 12

<table>
<thead>
<tr>
<th>ALT Deg</th>
<th>Equivalent Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>85.3</td>
<td>K-band</td>
</tr>
<tr>
<td>81.2</td>
<td>K-band</td>
</tr>
<tr>
<td>80.0</td>
<td>WFS eq. mv=11.98</td>
</tr>
<tr>
<td>65.0</td>
<td>WFS eq. mv=11.83</td>
</tr>
<tr>
<td>52.5</td>
<td>WFS eq. mv =11.9</td>
</tr>
<tr>
<td>44.7</td>
<td>WFS eq. mv=12.2</td>
</tr>
</tbody>
</table>

NACO
• NGS Strehl up to 63% at 2.17 microns, LGS Strehl measured up to 42% at 2.17 microns during commissioning (18th February)
• NACO can use 14x14 WFS around 80% of time
• Air Mass up to 1.8 and in twilight
• Seeing enhanced / high order only from 0.75” Seeing to 0.12” FWHM K Band

SINFONI
• K-Band Strehl up to around 35% measured with PARLA
Science Verification: NACO, SINFONI

Reconstructed SINFONI image and spectra of the core of NGC3621. Bulgeless galaxy hosting a large black hole. CO absorption lines redward of 2.29 microns.

J,H,K band images composed in a single RGB picture, of the core of Centaurus A, a very active Radiogalaxy hosting a large Black Hole. NACO.
Laser Performance Metrics (Dec-Mar)

- Long term follow-up
- Log files
- Define Performance Metrics
- Trends over time – months / years
- First experience with fibre laser in observatory operational environment
Conclusion

- Fibre laser commissioned in Paranal Laser Guide Star Facility
- Installed in laser clean room on VLT-UT4
- Goal to support Paranal operation e.g. more flexible observing with the laser
- Completed AIV and commissioning in February 2013
- LGS-AO science operation ongoing
- First Raman fibre laser at a major observing facility.
- System in operational environment gives valuable data for future systems such as AOF.

Acknowledgements: G. Hudepohl, N. Neumeyer, Y. Al Momany