Laser Pointing Camera: a valuable tool for the LGS-AO operations

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ABSTRACT

Every observatory using LGS-AO routinely has the experience of the long time needed to bring and acquire the laser guide star in the wavefront sensor field of view. This is mostly due to the difficulty of creating LGS pointing models, because of the opto-mechanical flexures and hysteresis in the launch and receiver telescope structures.
The launch telescopes are normally sitting on the mechanical structure of the larger receiver telescope. The LGS acquisition time is even longer in case of multiple LGS systems. In this framework the optimization of the LGS systems absolute pointing accuracy is relevant to boost the time efficiency of both science and technical observations.
In this paper we describe the design and functionalities of the Laser Pointing Camera (LPC)[3], developed at OAR for the 4LGSF of the ESO Adaptive Optics Facility. The LPC allows to have a fast pointing of the multiple LGS on the AO WFS during the initial acquisition phase of the telescope preset, thus reducing considerably the overheads currently experienced in most LGS-AO systems in operation.
By recognizing via astrometric software the field stars as well as the multiple LGS, LPC is insensitive to flexures of the laser launch telescope or of the receiver telescope opto-mechanics. Moreover, LPC gives regularly the photometry and fwhm of the LGS, as well as the scattering of the uplink beams at the height of 10-15km, thus monitoring the presence and evolution of cirrus clouds. We present the first Commissioning results of the Laser Pointing Camera, obtained at the ESO VLT during the 4LGSF first Laser Guide Star Unit Commissioning, and will discuss its possible extension for the ELT operations.

Keywords: laser guide star adaptive optics, adaptive optics instruments and pathfinders

Figure 1. First light took place on the night of Wednesday 29 April 2015 and these pictures show the beam of the 4LGSF first Laser Guide Star unit being launched into the night sky.

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[3] The Laser Pointing Camera was developed by INAF-Osservatorio Astronomico di Roma in Italy and and manufactured by Astrel-Instruments.

1. INTRODUCTION

The 4LGSF is part of the Adaptive Optics Faclity. It has 4 Laser Guide Star units mounted on the centerpiece structure. 4LGSF is required to point each LGS with an absolute error of ±2.5 arcs.

Flexures hysteresis and active optics automatic adjustments of the primary-secondary of UT4, do not allow repeatable open loop pointing models with the specified error of 1" - not to mention temperature effects on the different mechanical structures.

The LPC, mounted on the top ring of UT4, uses the recognized sky stars to determine the absolute coordinates of the LGS with respect to the VLT telescope centerfield. It communicates the LGS pointing corrections to the 4LGSF control computer, wich applies them.

The pointing calculations are done while the UT4 telescope is doing active optics cycles after a pointing preset, getting ready fo the instruments. In this way the acquisition can start as soon as the VLT UT4 preset is finished, the LGS pointing requirements can be met and much less pointing calibrations are required.

Thanks to LPC, a database with LGS return flux vs ALT/AZ coordinates can be extended at each observing run, taking a measurement every two minutes, and the presence of cirrus clouds is automatically monitored for the LGS-AO user.

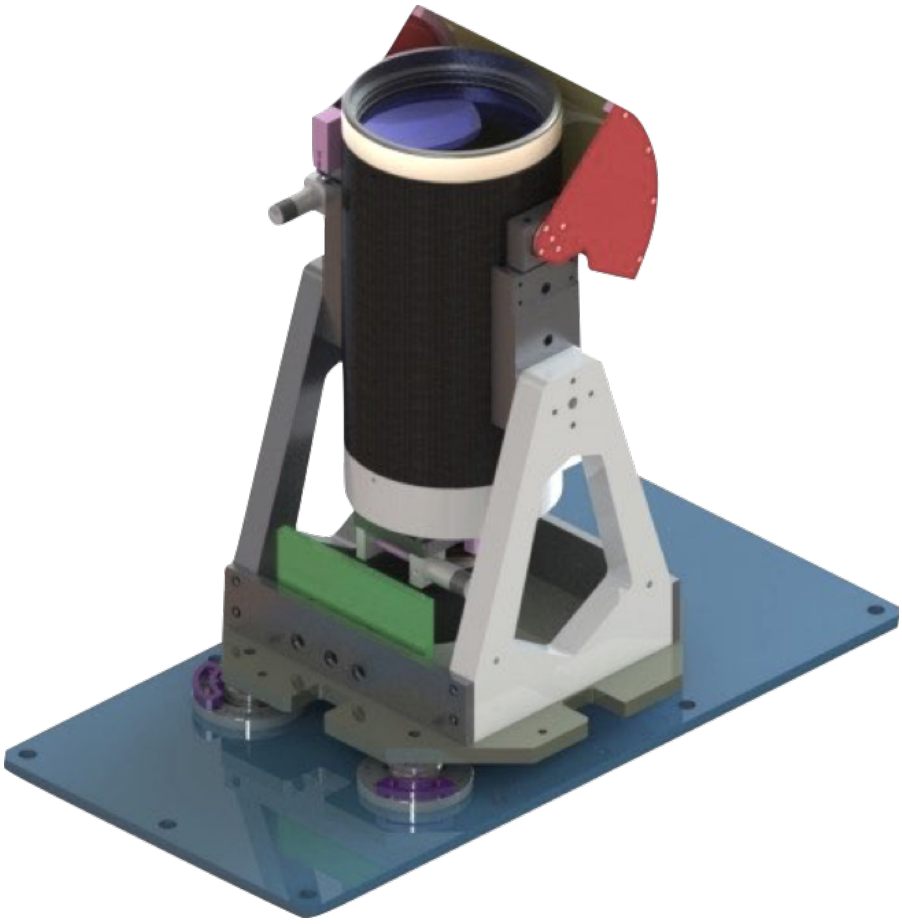

Figure 2. Assembled view of the LPC opto-mechanical concept; the cover has been removed to show the inner components.

2. LPC MAIN CHARACTERISTICS

The LPC is based on a 'smart' CCD camera, with Johnson filters, with on-board computing processor, based on Linux OS. The CCD is mounted behinda compact 15 cm aperture Maksutov telescope equipped with an image rotator. It has a field of view of ~35x25 arcmin with subarcsec resolution.

The 70x40x45cm housing protects the telescope from wind shake and dust. The total weight is 35kg. LPC does not have fans or water cooling to remove the heat generated; it uses thermal conduction with the telescope structure, instead.

LPC is thus a self-contained module, reuqiring only 24V (optionally 12V), 35W power supply and LAN Ethernet.

LPC is able to identify and derive the absolute coordinates of the LGS and the field natural stars, with 100% sky coverage; it derives the LGS relative position with respect to the UT4 optical axis, with a 3σ error ≤1 arcsec in ALT and AZ, and provides the ALT and AZ corrections to apply, to position the four LGS at their targeted positions, within 45 seconds from the user request.

LPC has been calibrated to optionally measure the LGS return flux (phot/s/m2), the LGS fwhm in arcsec and the uplink scattering intensity parameter at 15km above the observatory, in phot/s/sec/arcsec2.

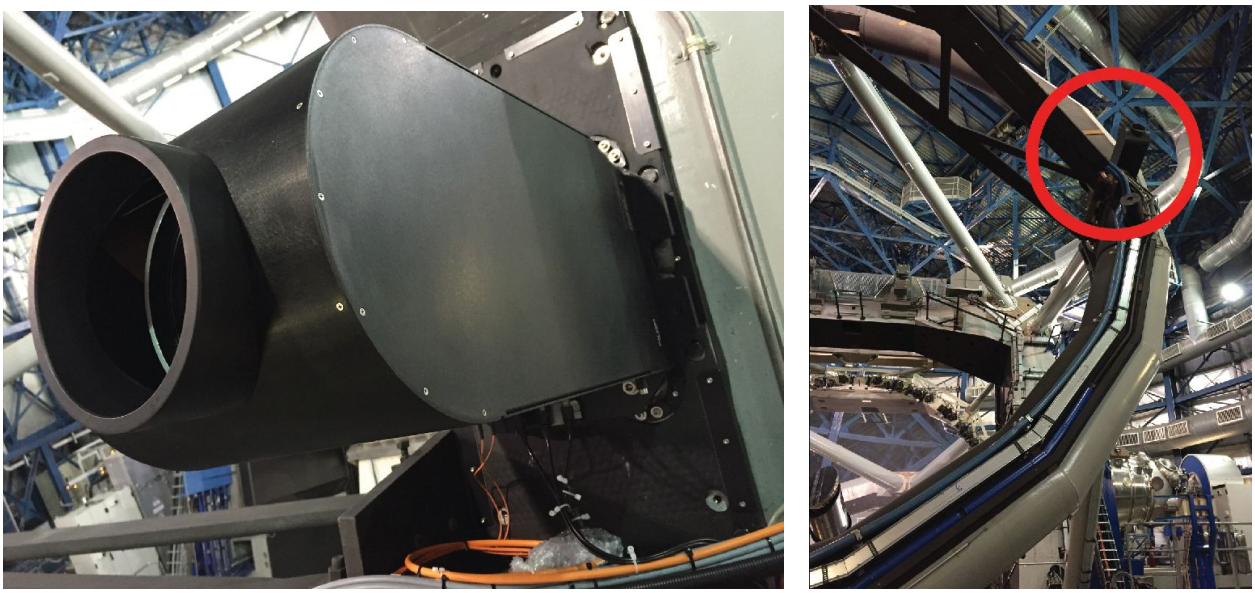

Figure 3. The LPC mounted on the top ring of VLT- UT4.

3. LPC COMMISSIONING RESULTS

LPC commissioning followed the standard ESO path for the installation and verification of new instrumentation and has been timed by the commissioning phases of the main project, the 4LGSF. LPC passed provisional acceptance tests in Garching ESO Headquarter (November 2014) and it was then delivered to Paranal for local acceptance and installation on UT4 during April 2015.

LPC commissioning started after the control software integration with the 4LGSF workstation on the night of April 24 with its alignment to UT4 optical axis and preliminary astrometry verification of plate scale, focus and sensitivity.

During the 6 following nights it was thoroughly tested using the return signal from the first of the four LGS of the new 4LGSF already activated.

Figure 4: One of the first images of the 22-watt laser being launched, taken by the Laser Pointing Camera (LPC) on the night of Wednesday 29 April 2015, shows the intense orange beam pointed at a globular cluster.

After two commissioning runs all the design requirements of LPC are fully satisfied. The main results are highlighted in the following list:

- LPC is functional on the 100% of the sky (full sky coverage), including empty or crowded star field areas.
- The average time to return the pointing correction to the 4LGSF is about 60 seconds including the exposure time, with the exception of the 47Tuc field where due to the paramount number of stars it takes about 2 minutes.
- End to end budget error for pointing correction is within 1" per axis.
- The average astrometric precision is <1 arcsec at 3 sigma.
- The photometric precision when exposing for 4 seconds the LGS using a calibrated V-band filter is better than 0.1 mag.
- The system is operative with Na return flux from 1Mphot/m2/s to 45 Mphot/m2/s.
- The passive fan-less heat dump system of the camera Peltier cooler works for a full night without overloading.
- LPC is ready to be operative from a cold start in less than 5 minutes.

Figure 5: Another LPC image shows the laser pointed close to the planet Saturn (29 April 2015).

LPC CONCLUSIONS

When completed in 2016, the Adaptive Optics Facility will see the UT4 telescope become a fully adaptive telescope providing LGS-AO corrected images for all its instruments, without the addition of adaptive modules and supplementary optics.

The concept is more far-reaching than just installing a deformable secondary mirror since the telescope instruments have also been optimised to benefit from this upgrade.

In February 2016 three further laser artificial guide stars will be installed and the 4LGSF completed. Commissioning of the 4LGSF will make full use of the LPC to calibrate the LGS pointing and focusing models.

The LPC has proven to be a very useful tool for operation of LGS-AO systems. As it operates independently of the large UT4 telescope, the overhead time for the acquisition of multiple LGS on the AO WFS is pratically zero, hidden behind the UT4 active optics initial cycles, wich last ~2minutes.

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