Analysis tools and beam relay system for the ALFA Laser

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Abstract

The ALFA project is a joint collaboration between MPIA in Heidelberg, providing the adaptive optics, and MPE in Garching, providing the laser guide star system. In this contribution we present the beam relay system and the analysis tools of the ALFA laser. As we are using a multiple mirror relay system for transporting the beam from the Coudé laboratory to the launch telescope, we have to deal with several different influences that cause the beam quality to degrade. We are using two active control loops for beam alignment and positioning. In order to get a better understanding of the physics, a number of analysis tools are mounted immediately below the launch telescope, to accurately measure the properties of the outgoing beam: Beam profile, position and angular deviation, power, polarization vector and wavefront of the laser.

Introduction

The aim of the laser guide star system is the generation of an artificial reference star for the adaptive optics, in order to increase the sky coverage of the system. For best results the Shack-Hartmann sensor of the AO system needs a sufficiently bright source to obtain centroid measurements with a good S/N ratio. So the main objectives are: How to get the brightest spot and how to get the smallest width of the spot image on the wavefront sensor. The heart of the ALFA laser facility is an argon ion pumped dye jet laser, which is installed in the Coudé lab at the Calar Alto 3.5m telescope. The laser is able to emit light at the sodium D_2 line with an output power up to 4W. For a more detailed description of the whole ALFA project see other contributions to the proceedings.[1 2 3 4] In order to create an artificial guide star in the mesospheric sodium layer, the laser beam is transported from the laser laboratory along the Coudé path of the 3.5m to a Galilean beam expander near the main mirror of the telescope, where it is finally launched (see figure (2)). Along this path, a distance of approximately 50m, the laser is subjected to the disturbing influence of the turbulent air inside the dome and other distortion sources. The appearance of the laser spot also varies under different external conditions as shown in figure (1) :

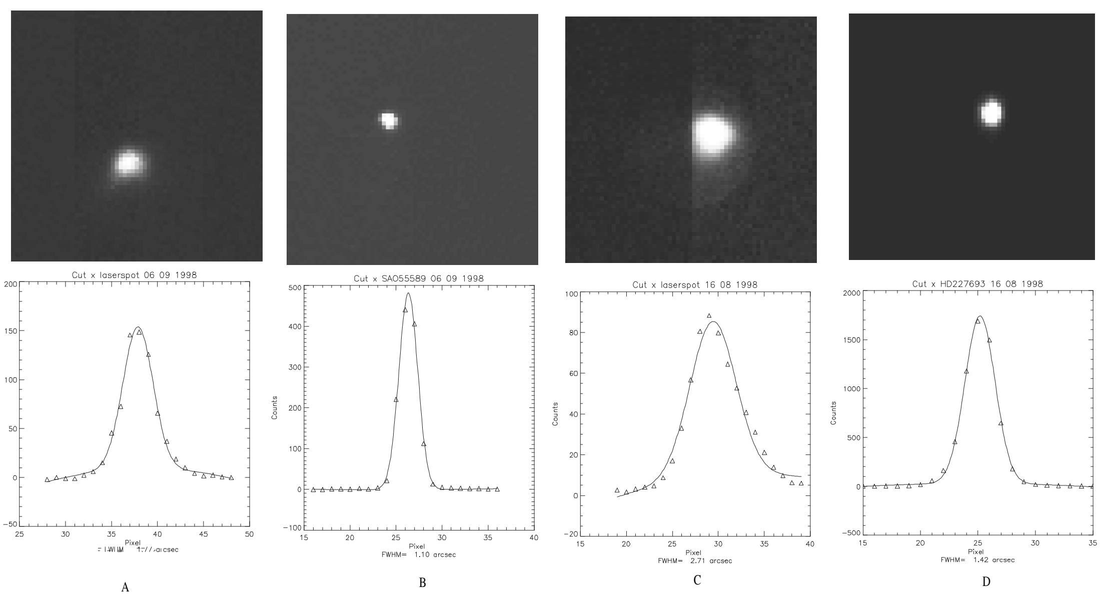

Figure 1 Laser spot and natural guide stars imaged with the wave front sensor under different conditions: A) LGS at good transparency B) NGS at the same conditions and m_v =9.4 C)LGS when shooting the laser through clouds D) NGS at the same conditions as C with m_v =9.0

One can easily see that, in comparison with the natural star, the fluorescent light from the sodium layer creates a spot at the Shack-Hartmann which may have the same integrated power as a comparable

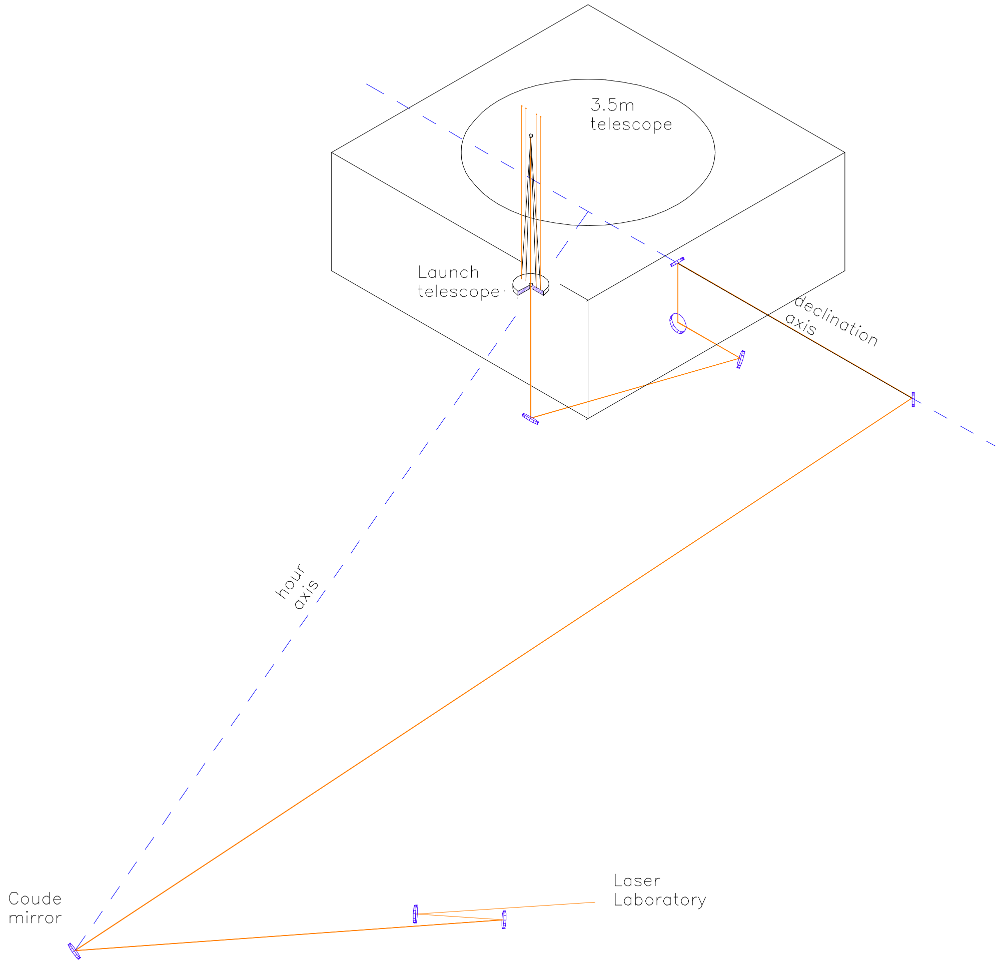

Figure 2 Laser beam path at the Calar Alto 3.5m telescope

natural guide star, but normally the size is larger than expected from seeing limitations. For a better understanding of the processes that are disturbing the laser, for fast positioning, studies of the sodium response and other experiments, an optical bench has been installed before the launch telescope where a series of instruments are fixed.

General layout of the analysis bench

Before the description of the individual components, a few words about the general layout of the system:

For the different tasks the instruments have to be fed with light from the laser beam, but without disturbing the propagation to the launch telescope and without noticeably reducing the power. For this purpose the analysis is performed on a small amount of light which is split off with a high quality, antireflection coated optical wedge plate at the center of the optical bench and the polarization detector, which is mounted at the top of the beam expander, is built as small as possible. This part of the beam feeds all instruments which are needed continuously for beam control and online measurements. Several mirrors are mounted on a linear stage and can be moved into the laser beam, to do measurements that are only needed from time to time. Because the diameter of the laser can be adapted with a pre-expander in the Coudé lab to different seeing conditions, the instruments have been designed such that they are not influenced by these changes. (The light paths of the analysis beams are shown at fig.(3))

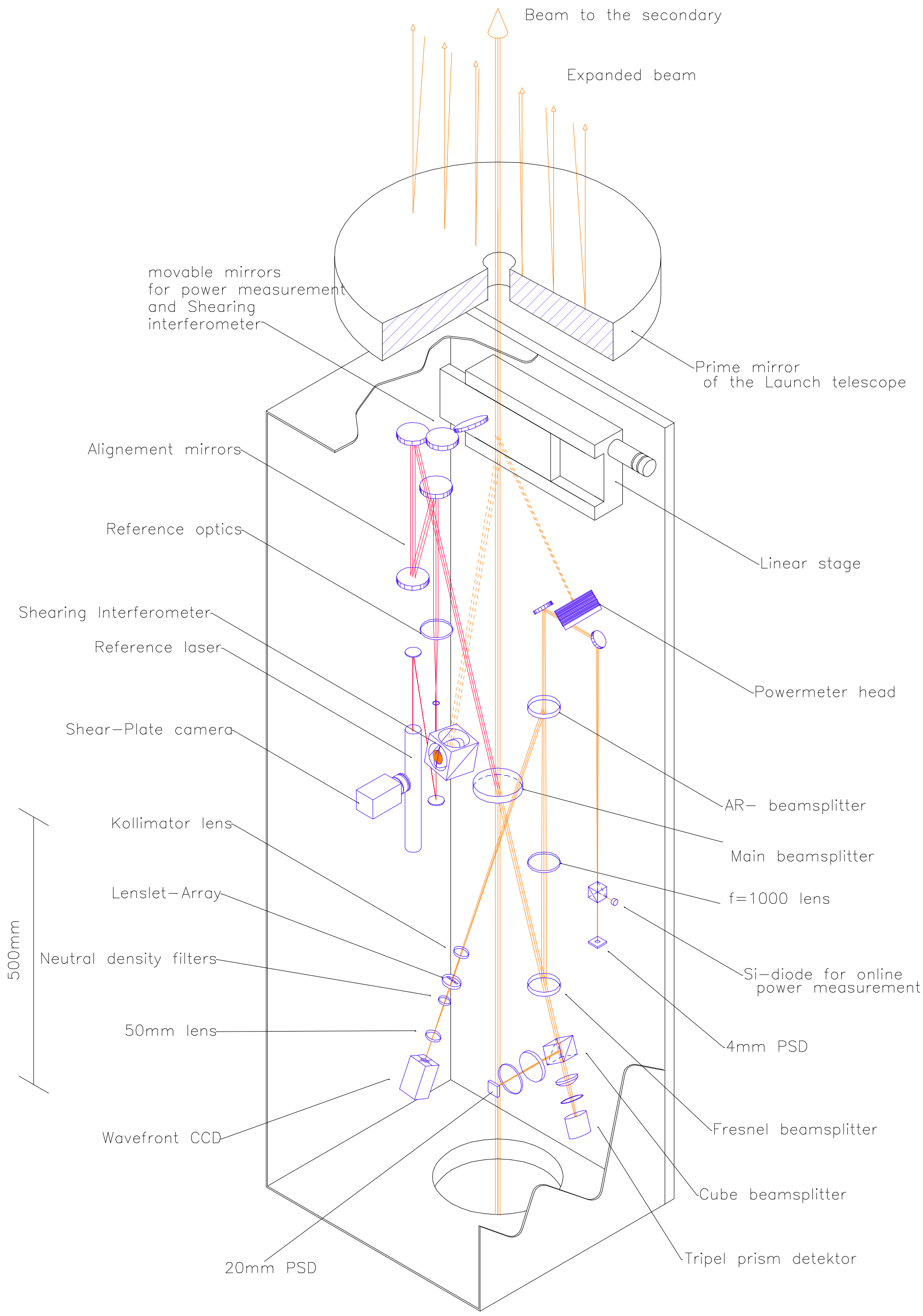

Figure 3 Optical layout of the analysis bench

1 Position measurement

Operation of the laser guide star requires the laser to remain steady on the optical axis of the launch telescope, but several different influences can affect this:

- Errors can occur when feeding the beam into the Coudé path.
- Changes of the Coudé path while the telescope is tracking.
- Turbulence in the dome may cause fast deviations of the beam position.
- Flexure in the telescope structure, instabilities of mechanical components.

To minimize beam degradation due to these effects, active control of the beam position is needed. The beam path is equipped with four fast steering mirrors to keep the laser on the optical axis. For sensing the position relative to the Coudé path, a pilot beam from the argon ion laser is monitored at the declination axis of the telescope with two PSD's (position sensitive device). To position the laser accurately on the optical axis of the launch telescope, detectors for all four degrees of freedom are installed at the analysis bench. One two dimensional PSD at the focus of an 1m focal length lens is capable of measuring angular deviations down to 0.4” . The x-y position is measured with a triple prism splitter, positioned out of the focal plane of a short focal length lens, acting rather like a quad-cell. In addition a further PSD at an 100mm focus is used for coarse alignment, in the case the laser is moved out of the field of view of the other much more sensitive detectors. To have an absolute reference, a helium-neon laser is aligned to the optical axis of the launch telescope, so the detectors can be calibrated with the signal from this light.

Measurements of the laser movement and tip-tilt measurements of the back scattering from the mesospheric sodium can be compared with the help of these tools, and a distinction between the influences of atmospheric turbulence and the turbulence in the telescope dome is possible. An example of the tip-tilt movement and the power spectrum (open control loop) is given in Fig.(4).

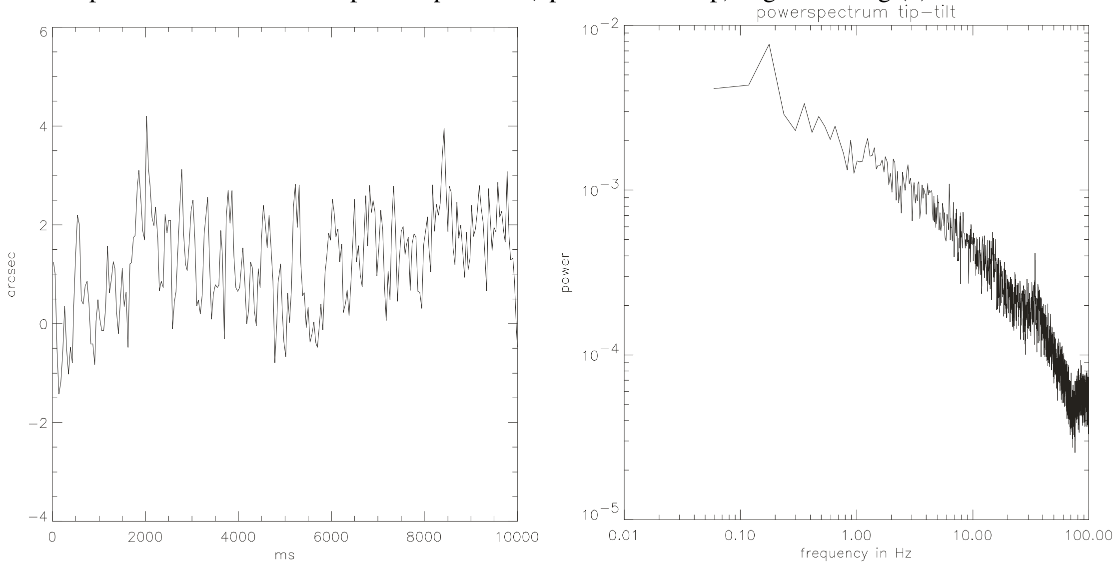

Figure 4 Jitter of the laser measured before the launch telescope.

2 Power

From the laser laboratory to the launch telescope 6 mirrors and 3 windows are installed in the telescope dome. Due to dust the mirrors surface quality tends to degrade with time, so the overall transmission of the relay system decreases. To have a monitor for this and to know the absolute power of the light propagating upward, a bolometric power meter is installed, to which the laser can be fed with the help of a dielectric, spherical mirror on the linear stage. Because this power measurement is not in use permanently an additional photo diode serves as a relative online power monitor. The typical power of the laser at the launch telescope is about 2.5W, according to an overall transmission of the relay path of 60 percent. But this number may vary from 50 percent with strong dust coverage, to 75 percent with freshly cleaned mirrors.

3 Shearing interferometer

The diameter of the laser is adapted to the actual seeing conditions with a beam expander at the laser lab. To do the collimation quickly and easily, another mirror at the linear stage can reflect the light to a shearing interferometer which is watched by a camera. In addition, the fringes indicate whether abnormal distortions are present. Pictures of some shearing interferograms are shown in Fig(5).

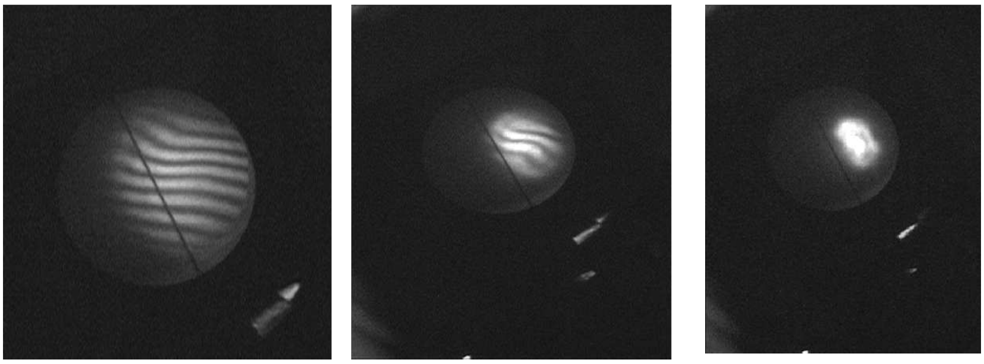

Figure 5 Change of shearing fringes while collimating the beam. Some aberrations can be recognized easily from the fringes

4 Wavefront sensing and beam profiling

For the higher orders of the wavefront distortion we have installed a Shack-Hartmann sensor at one analysis beam. The sensor consists of a lenslet array in a collimated beam of 3 to 5mm with arrays of 3x3 to 11x11 subappertures, one relay lens, one neutral density filter and a CCD camera in the focal plane. With this sensor direct measurements of the wavefront distortion can be done before the laser is finally launched. These measurements are then compared with the size and shape of the laser spot at the sodium layer.

Preliminary measurements have been done and show that sometimes there is an unexpected large distortion which reached mean values up to 0.7 λ (at 589nm). One example of wavefront gradients can be seen in Fig(6). The intensity distribution across the beam diameter, which is also an interesting parameter in propagation calculations, can be measured with the same CCD camera with better spatial resolution, when removing the lenslet array. An additional CCD camera is planed, so that the intensity profile and the wavefront can be measured at the same time.

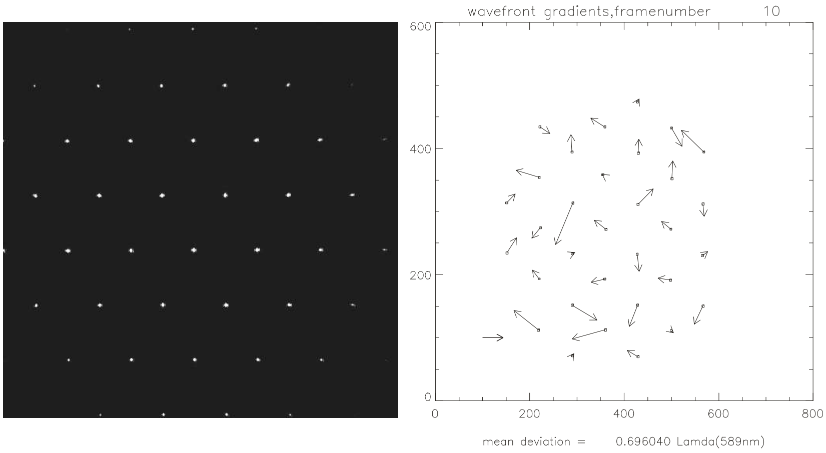

Figure 6 Example of wave front gradients at the outgoing laser measured with a Shack-Hartmann sensor

5 Polarization detection

The polarization dependence of the resonant backscattering in sodium vapor and the mesospheric sodium layer has been reported by several authors[5]. For studies on these effects and for the automatic angular control of a quarter wave plate a photo polarimeter has been constructed and installed. Two types of instruments have been tested: A division of amplitude polarimeter and one with a rotating analyzer. Both instruments are capable of determining a set of parameters that describe the complete state of polarization of any elliptically polarized light. While the advantage of the rotating version is easier calibration, the less complicated mechanics and lower sensitivity to intensity fluctuations made the division of amplitude polarimeter the choice to install at the exit of the launch telescope. First measurements of the dependence of the sodium response to the polarization have been made in September 1998, and are a subject of ongoing analysis. Further experiments will be carried out. A picture of the photo polarimeter is shown in Fig(7)

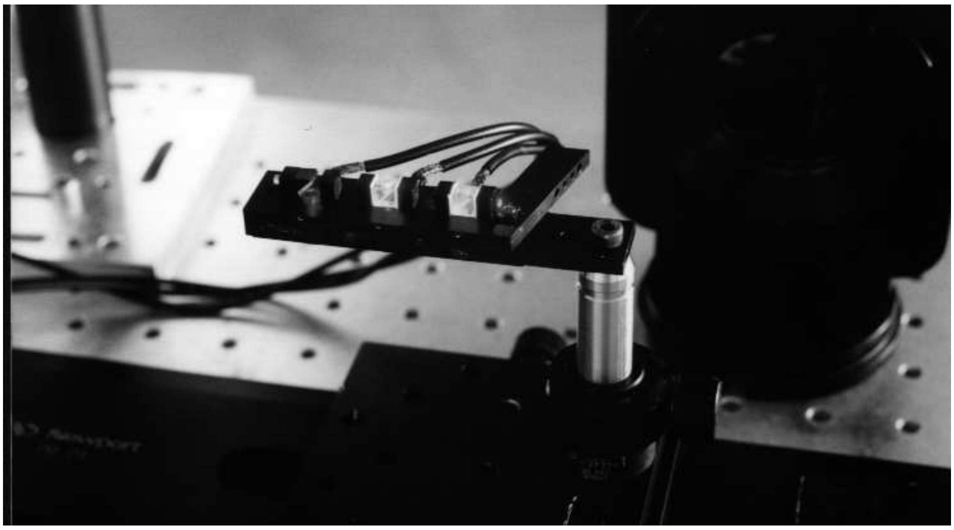

Figure 7 Division of amplitude photo polarimeter

Conclusion

The laser beam diagnostics is opening a wide field of interesting experiments on laser propagation in the atmosphere and effects of the sodium response in the mesosphere. For the operation of the laser guide star it serves as a tool to make the AO observations with the laser more efficient. Since the installation of the components in summer 1998, first measurements with the system have started. Ongoing experiments will show whether an adaptive optic system for the laser, or other steps, are needed for the most effective creation of the laser guide star for the adaptive optics.

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