MAPS, a turbulence simulator for MCAO

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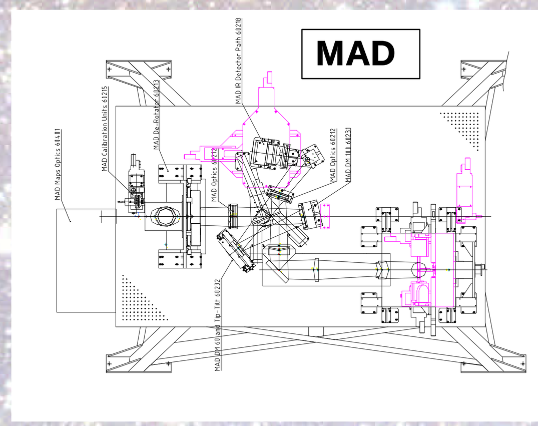
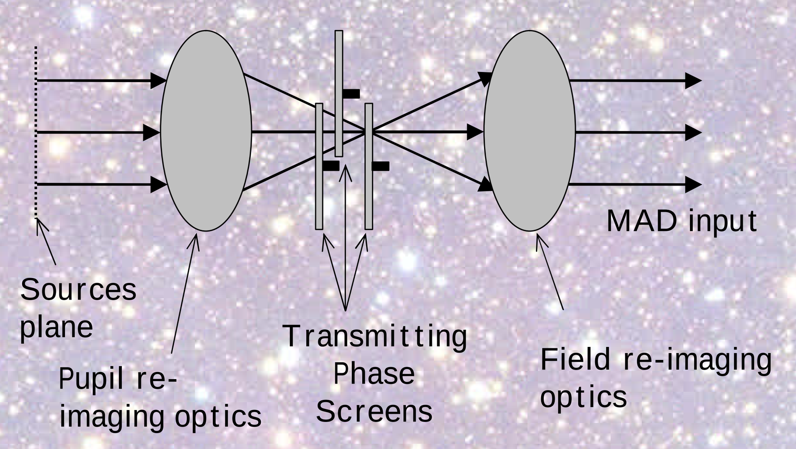
CONCEPT

The **Multi-Atmospheric Phase screens and Stars** instrument is a powerful tool that has been developed in the framework of the ESO Multi-conjugate Adaptive optics Demonstrator project (MAD). It allows emulating a 3D evolving Paranal-like atmosphere as well as up to 12 sources in a 2 arc minutes FoV, as seen at a Nasmyth focus of one of the VLT. It will be plugged in front of the entrance focus of MAD and will be used to perform advanced laboratory tests on the instrument before its shipment to Chile.





The Natural Guide Stars are simulated by visible-IR light transmitting fibres. A first group of lenses collimates the light beams from the NGSs and allows the telescope pupil to be created. Different Phase Screens are located in the collimated beams to emulate the atmospheric layers at different altitude. The PSs emulate turbulence powers according to the expected vertical Cn^2 distribution. The evolving atmosphere is emulated by rotating the PS. A second group of lenses re-images a focal plane to simulate the Nasmyth focus of a VLT.

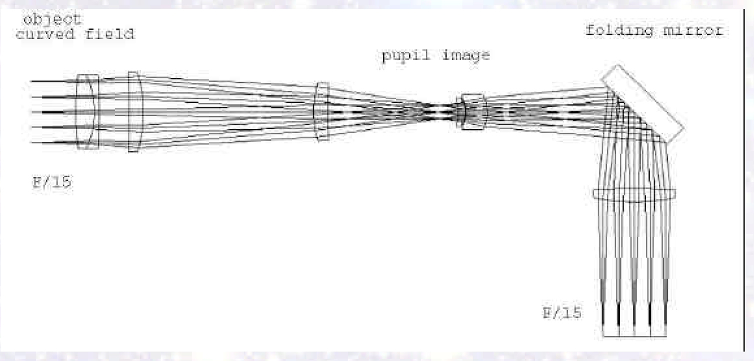
Telescope simulator	&	Atmosphere simulator
• Located at the input of MAD • Used for advanced laboratory tests • Simulates the VLT Nasmyth focus • Curved field • More than 12 sources • 4 magnitudes • Various stars asterisms • Wavelength range 0.5-2.5 µm		• Transmitting phase screens • 3 layers of turbulence • Paranal-like Cn^2 profile • Paranal-like adjustable wind speeds • 2 seeing conditions • Turbulence wavelength range 0.5-2.5 µm

DESIGN

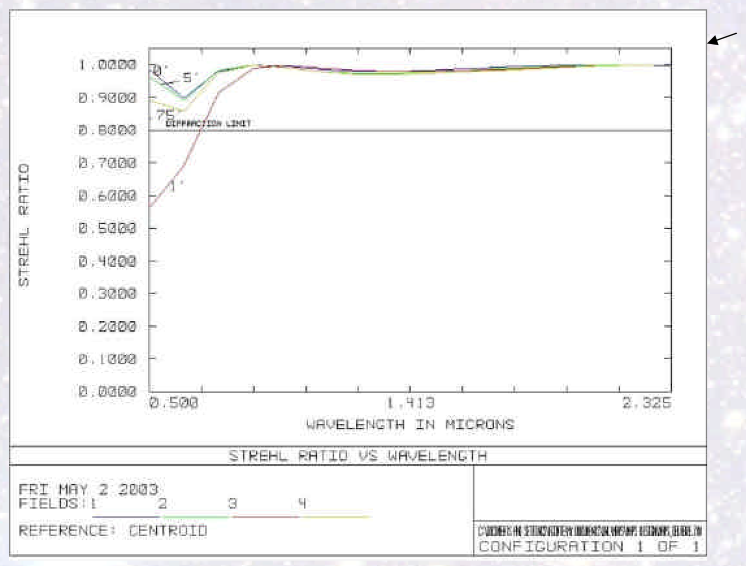
Optical design

The optics of MAPS is constituted of two different groups of lenses:

- The first group provides to collimate the beams from the artificial NGSs placed in a curve field (183 mm radius of curvature), and to create the telescope pupil;
- The second group focuses the disturbed wavefronts of the artificial NGSs on a 2 arcmin focal plane with the VLT F/15 Nasmyth focus characteristics, including the field curvature.

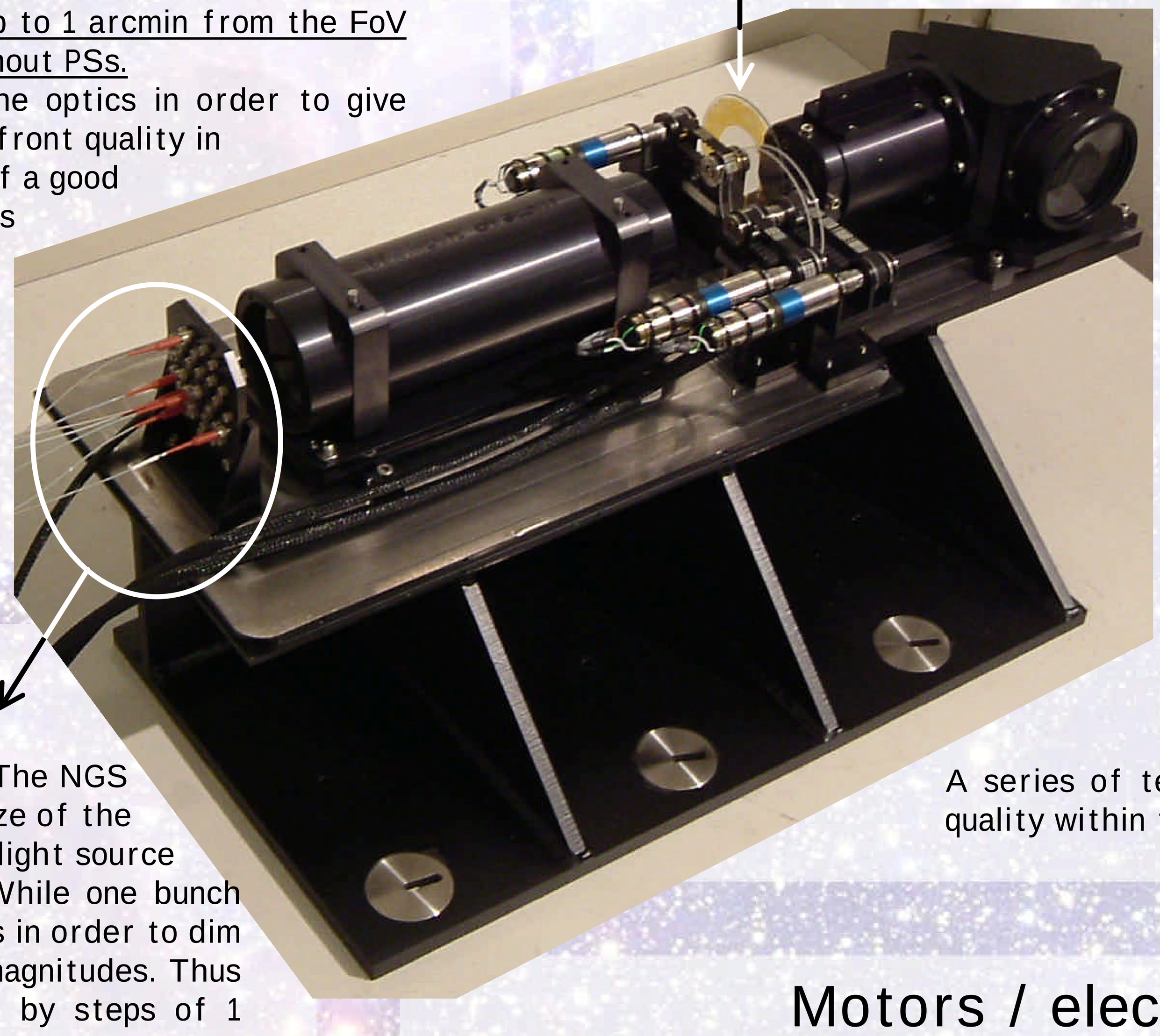


The two groups of optics are manufactured and delivered already mounted in two separate tubes to be attached to the MAPS table. As MAPS shall transfer efficiently from 0.5 to 2.5 µm, the choice of the glasses and coatings was done in order to guarantee high transmission up to IR wavelengths.



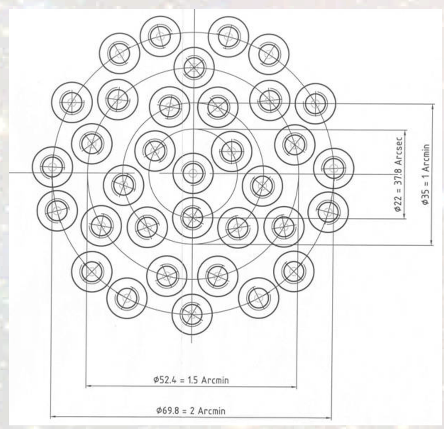
Strehl Ratio performance of MAPS optics up to 1 arcmin from the FoV centre in the spectral range 0.5-2.5 mm, without PSs.

A special care was taken when selecting the optics in order to give preference to an excellent and uniform wavefront quality in the IR range (1 to 2.5 µm) to the prejudice of a good quality in the visible. The Strehl Ration in this range is still larger than 55% over the whole FoV, whereas the SR in the IR is fairly constant and never worse than 95%.



Entrance plane

MAPS shall simulate up to 12 NGSs for correction and performance evaluation with MAD. The NGS are simulated using single-mode fibres, 9 µm core, transmitting from 0.5 to 2.5 µm. The size of the core is dimensioned to reproduce diffraction limited images of NGSs down to 0.6 µm. The light source is a halogen-tungsten lamp of 150 Watts. 36 fibres are distributed in four bunches. While one bunch faces directly the source, neutral density gelatine filters are placed in front of the others in order to dim the light entering. The filters are chosen so that they attenuate the flux of 1, 2 and 3 magnitudes. Thus MAPS permits to simulate 4 different star magnitudes at the same time, separated by steps of 1 magnitude, and the magnitude of the brightest star is determined by the dimmer of the source.



The position of the simulated NGS in the field is defined by plugging the fibres on a mask placed in the entrance focal plane of MAPS. The accuracy of positioning of the NGS will be ensured by the use of standard SMA connector for the fibres end, and their female counterpart on the mask. Those connectors are disposed on concentric rings, and each ring is adjusted in depth in order to simulate the telescope field curvature.

The mask is a metallic plate in which are mounted female SMA connectors. The choice of those standards, easy to plug and unplug connectors allows also changing quickly the configuration of the simulated asterism.

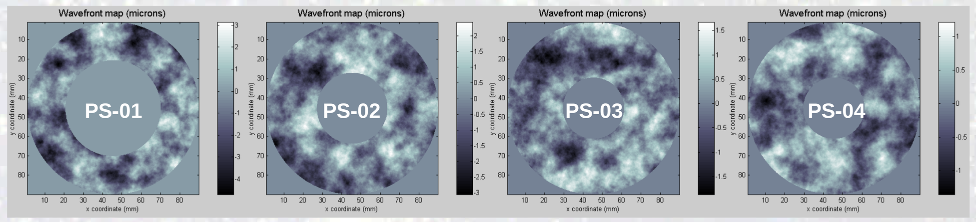
In order to simulate NGS asterisms two different solutions are adopted:
- Flexible configuration: a grid of 34 pre-defined star positions has been design for a best coverage of the whole FoV
- Real NGS targets: once the target asterisms to be observed on the sky identified, special masks will be manufactured according to the desired geometrical configuration, in order to test the system on real star asterism, and to compare later the performance with on-sky measurements.

Phase Screens

MAPS is required to have a set of four Phase Screens (PS) producing turbulence, only 3 of which will be used at any time to simulate two different seeing conditions. The PSs are optical elements capable to transmit the light. They are circular plates (100mm diameter) with a hole at the centre for fixation of the rotation axis. The PS has encoded on the surface a bi-dimensional aberration with spatial distribution typical of the atmospheric turbulence.

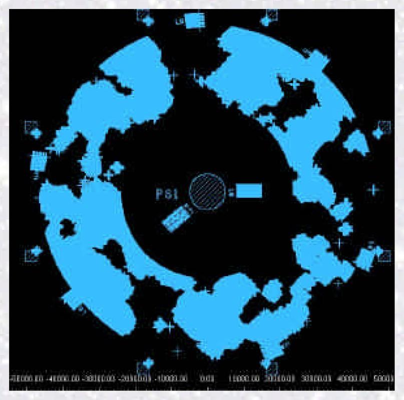
A plane wavefront passing through the PS emerges distorted accordingly to the aberrations encoded on the PS. The aberration is encoded on an annular ring centred on the PS centre, so that the wavefront shift seen through a 15mm pupil centred on the annulus is evolving when the PS is set on rotation. The speed at which this PS is set in rotation gives the value of the wind speed simulated for this altitude.

The phase screen turbulence data are produced using the invert Fourier transform of a Von Kármán spectrum. Among numerous possible random maps were kept the ones that show the smallest Peak-To-Valley (PTV) phase over their surface, while keeping the global atmospheric properties and particularly the phase variance in the pupil. This property helps for the realization of the PS as a high PTV is always hard to achieve. The size of the phase maps is 900x900 pixels[2], leading to pixels of 100 microns in the case of a ring of aberration of 90mm in diameter.



The methods to produce transmitting PS are numerous, but after a process of research and of prototyping, ESO came to an agreement with the company SILIOS Technologies for the manufacturing of several sets of PS satisfying the specifications in terms of mechanical, optical properties and of quality of the aberrations produced. The technique proposed by this company is a wet etching on glass substrate.

SILIOS manufactures the PS in its clean room facilities. The basic principle for encoding the 2^N levels of the phase map is to process N individual etching steps which either cumulate or not. The pattern of each individual etching step is defined by a photolithography process. The N patterns are realigned with an accuracy of 0.5 micron (1/200 of a pixel width). The main issues in the fabrication of the PS are linked to the accuracy of each etching depth and to the uniformity inside the wafer. The technique proposed by SILIOS provides such an accuracy.



A series of tests have been performed on a first realization of one PS and they show a product quality within the specifications.

Motors / electronics

The Phase Screens are set in rotation thanks to three Faulhaber motors equipped with reduction gear box, so that they run in their linear range although the speed of the PS themselves is quite slow, between 2 and 30 rounds per minute. Also the motors we use are equipped with a feedback sensor of the effective rotation speed of the axis.

The motors are controlled independently by three boards allowing a great accuracy in the speed of the motion. The boards are housed in the MAPS control box, and the control of the speeds is ensured by three potentiometers. Three rigid cables coming out of the back side of the control box allow placing the control at a distance of up to 1.5 meter from MAPS, and are relayed inside the covered area by more flexible cables connected to the motors.

STATUS

- Mechanics integrated
- Optics pre-aligned with dummy phase screens
- Motor system + electronics integrated and tested
- Fibers illumination system ready
- Final alignment and testing in flat configuration: July '04
- Delivery of Phase Screens: August '04
- Final testing and delivery of MAPS: August '04
- Plugging to MAD: beginning '05