1. General introduction

The AOS-0 is a complete adaptive optics system based on the ALPAO Core Engine software. It includes a large dynamic and fast deformable mirror (Hi-Speed DM69-15) and a high precision Shack-Hartman wavefront sensor manufactured by Imagine Optic.

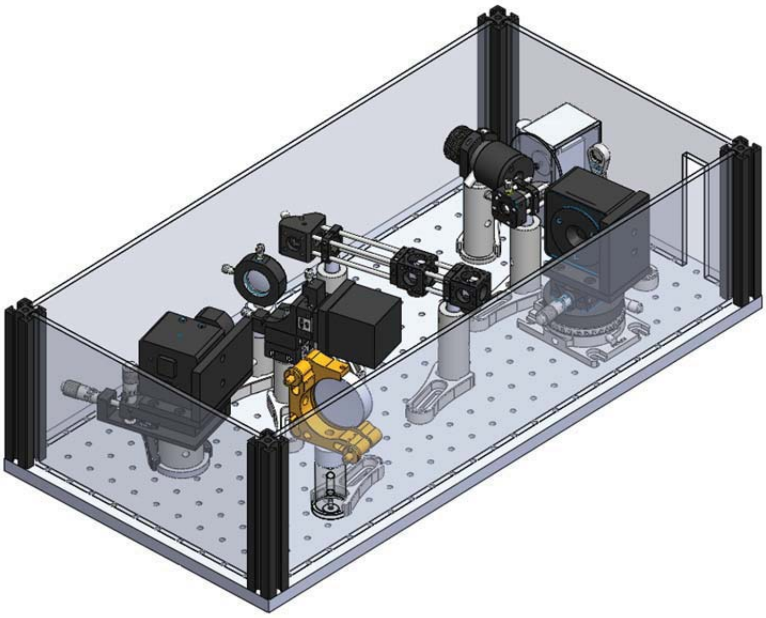


Figure 1 : The AOS-0 system

The AOS-0 system gives you all the followings:

- a ready-to-use system to learn or teach adaptive optics.
  - All components are included, even the breadboard and PC, with all drivers and software pre-installed.
  - A user-friendly graphical interface showing the synthesized information, while all of your data (for example raw images, calibration matrices) remain available all the time for deeper analysis.
  - Complete online documentation includes step-by-step tutorials.
  - Delivered pre-assembled (fragile components are detached to avoid damage during shipment).
  - All of the little details that make the difference between a do-it-yourself kit and a ready-to-run system are included, even alignment tools, cable clamps, hexagonal keys, baffles to avoid parasitic light, etc…
- a powerful open-architecture tool for research :
  - All components use standard Thorlabs® optomechanical parts. It's easy to modify, upgrade or tweak the AOS-0 system. A detailed guide to the alignment procedure and dedicated alignment tools allow you to quickly restore the system to its original state when needed.
  - Behind the graphical user interface, the ALPAO Core Engine (ACE) toolbox performs all necessary computations. All data and commands can be started from user-defined scripts.
  - The ACE toolbox runs within the standard Matlab® environment. You don't need a computer geek in order to modify the system. Using the provided samples and online documentation, you can

easily write your own version of any function. For example, you can implement your own centroid algorithm, or your own sensor-less iterative algorithm. If you can code it in Matlab®, then you can run it for real on AOS-0.

Thanks to the flexible and ergonomic architecture, it is easy to learn and test ideas to control adaptive optics. The two different strategies described next provide an example. The first strategy consists in using the Shack-Hartmann wavefront sensor.

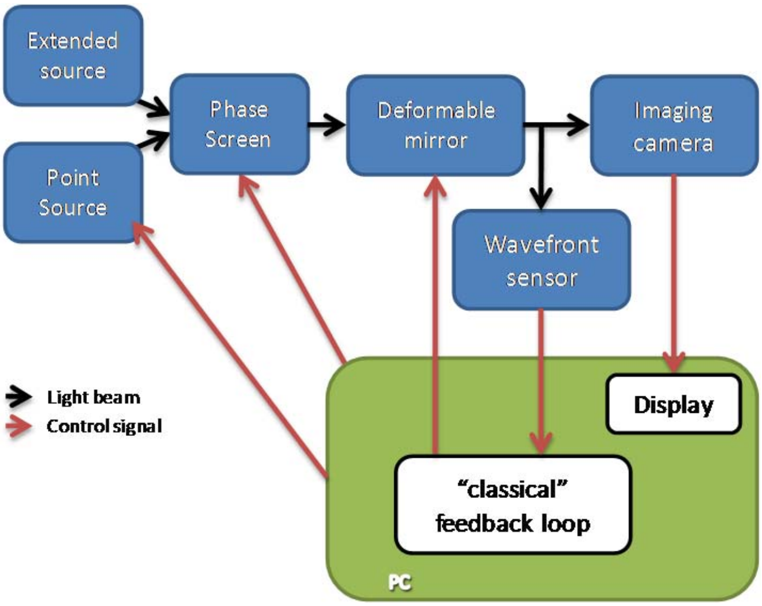


Figure 2: Classical Loop

The second strategy uses an imaging camera interfaced directly within ACE with all the data available in the Matlab® environment. Now you are ready to develop phase diversity or iterative algorithms.

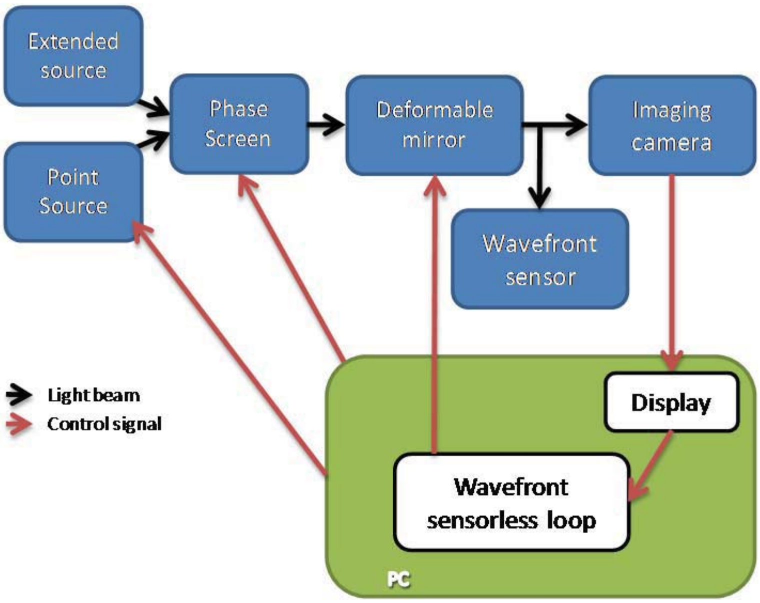


Figure 3: Loop with Signal from a Camera

The ACE is a toolbox for Matlab, allowed through an agreement with The Mathworks (producers of Matlab http://www.mathworks.com/products/connections/product_detail/product_50213.html).

Opto-electronic devices, such as the deformable mirror, wavefront sensor, and imaging camera are easily controlled through Matlab methods and properties. For example, in Matlab® type the following to quickly get the wavefront sensor information:

```
[wavefront]= wfs.GetPhase()
```

The AOS-0 is delivered with built-in example scripts making it easy to get started and the complete on-line help answers your questions to keep you using the system productively. The alignment tool and guide to alignment procedures make the alignment easy, even if you are not a specialist. Here are more examples to show you how easy it is to get started using AOS-0.

To get slopes from the wavefront sensor:

```
[sx,sy]= wfs.GetSlope() ;
quiver(sx, sy)
```

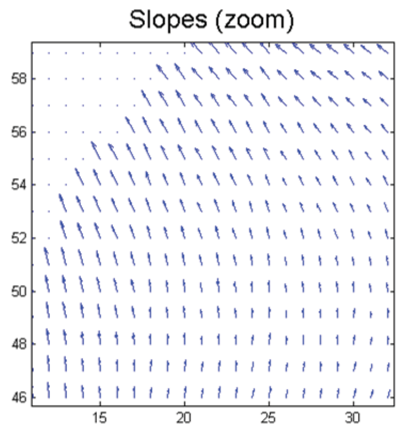


Figure 4: Enlarged View of the Slopes

To get an image from the wavefront sensor detector:

```
imWfs = wfs.GetImage() ;
imagesc(imWfs);
title('Raw Image');
```

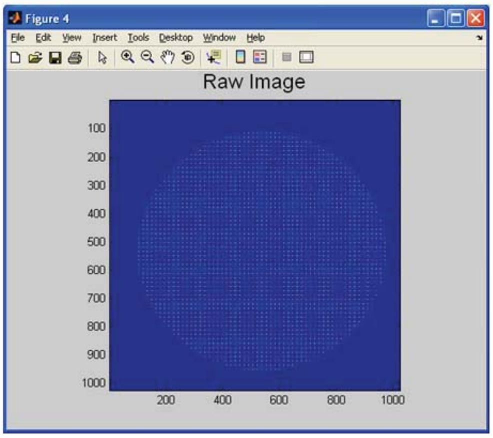


Figure 5: Raw Image Acquired by the Camera

<u>To get the wavefront measured by the wavefront sensor:</u>

```
phase = wfs.GetPhase() ;
imagesc(phase);
title('Wavefront')
colorbar;
```

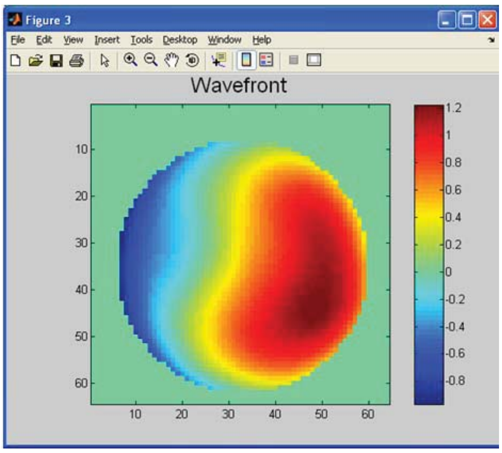


Figure 6: Reconstructed Wavefront

You operate the AOS-0 using a friendly graphical user interface.

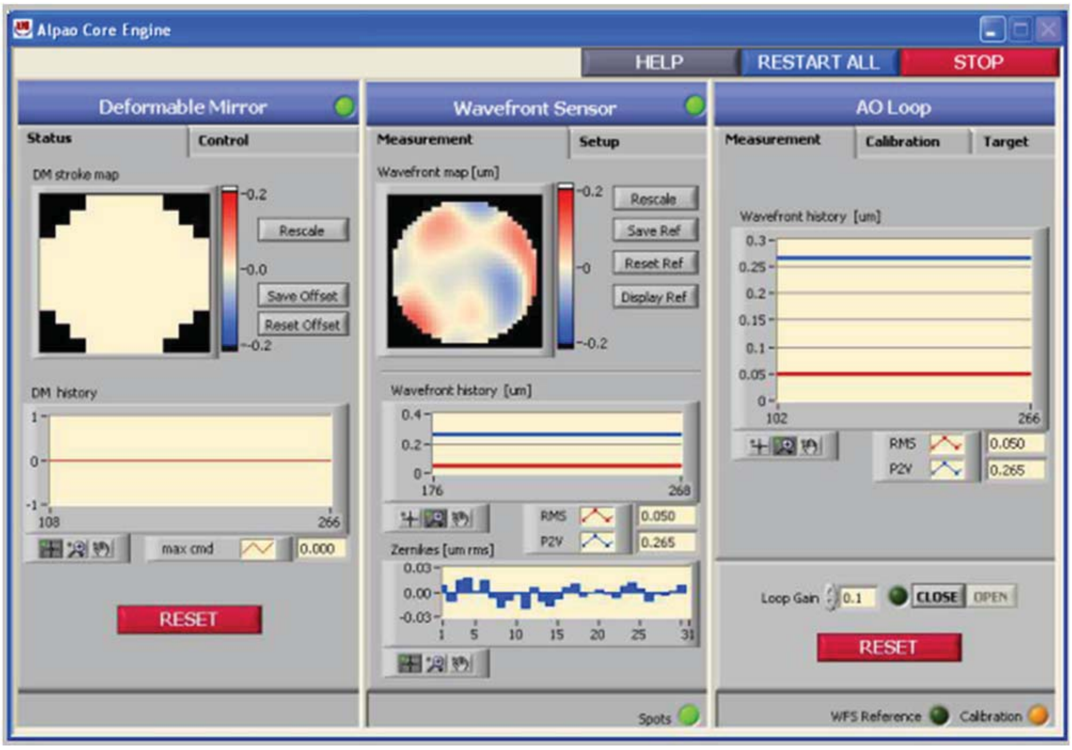


Figure 7: The AOS-0 Graphical User Interface

2. AOS-0 Main Elements

2.1. ALPAO Hi-Speed DM69-15

Description	Specifications	Units
Useful pupil diameter	10.5 +/- 0.1	mm
Actuators	69 on a square pattern	N/A
Pitch between actuators	1.5	mm
Wavefront tip/tilt stroke	+/- 60	µm
Wavefront inter-actuator stroke (PtV)	>3.0	µm
Bandwidth	> 750	Hz
Settling time (+/- 5%)	1.0	ms
Coating	Protected Silver	N/A
Non linearity errors	<3%	
Mechanical best flat (while driven)	<7	nm RMS
Dimensions (without cables)	84.6 x 74 x 53.1	mm
Operating temperature	min: 10 max 35	°C
Drive electronics		
PCI I/O Board		

2.2. Wavefront sensor (HASO4 First from Imagine Optics)

Description	Value	Units
Absolute accuracy	λ/100 RMS	N/A
Reapeatability	λ/200 RMS	N/A
Spatial resolution	32x40	sub-pupils
Pupil size	3.6 x 4.6	mm^2
Connection	USB 3.0	N/A
Single wavelength calibration	λ/100 RMS within +-50nm	N/A
Max. Acquisition frequency	100	Hz
included: HASOv3, wavefront analysis softwareFull detection area. Calibration wavelength to be confirmed when placing P.O.		

Figure 8 : Haso 4

2.3. Imaging camera specifications

Description	Specifications	Units
Size	4.7 x 3.5	Mm
Number of pixels	640 x 480	N/A
Pixel Size	7.4	µm
Frame rate	60 at 640 x 480 110 at 320 x 240 (binning)	Fps
Dynamic range	60	dB
Dimensions	44 x 44 x 56	Mm
Operating temperature	min: 10 max: 35	°C

2.4. Turbulence module

A turbulence phase screen, manufactured by ALPAO, and its rotating mechanism are provided (see figure below). This phase screen introduces time-dependent aberrations with appropriate spatial frequencies.

Description	Specifications	Units
Diameter	100	mm
Active area	83	mm
Thickness	22	mm
Phase grid	20	µm
Phase array	4096x4096	N/A

Figure 9 : Example of Phase Screen and Rotating Mount

2.5. Light sources

Two light sources are provided with AOS-0: a point-like LASER source (single mode fiber) and a source for projecting the image of an extended object.

Description	Value	Units
Wavelength	635	nm
Typical power output	2.5	mW
Fiber connectors	FC/PC	N/A
Fiber type	Single mode	N/A
Mode filter diameter	4.3	µm

The next figure shows the extended light source (the pattern projected can be changed).

Figure 10 : Light Source for an Extended Object

The spectrum of the extended light source as follows:

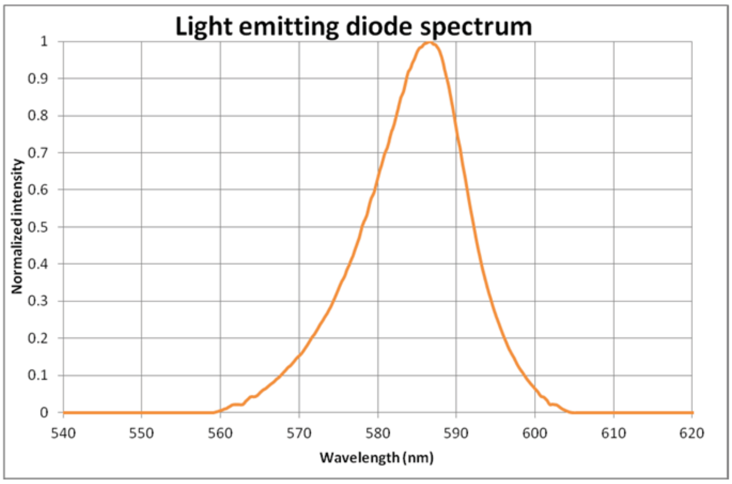


Figure 11 : Typical Spectrum of an Extended Object

3. Miscellaneous elements included

- All opto-mechanical parts including the breadboard
- A set of procedures to drive the system from Matlab® and a LabView® graphical user interface.
- A computer with pre-installed software (keyboard, mouse and screen not included)
- Microsoft Windows 7 (32 bit)

4. Adaptive Optics (AO) simulator

The AO simulator is provided with the AOS-0. The AO simulator is based on the ALPAO Core Engine (ACE) and uses the same commands and graphical user interface. It allows you to develop scripts, user interfaces and applications without requiring the optical set-up. This reduces the time needed for including adaptive optics in your instrument.

ALPAO
ADAPTIVE OPTICS

ALPAO Core Engine (ACE)
PRODUCT DATA SHEET

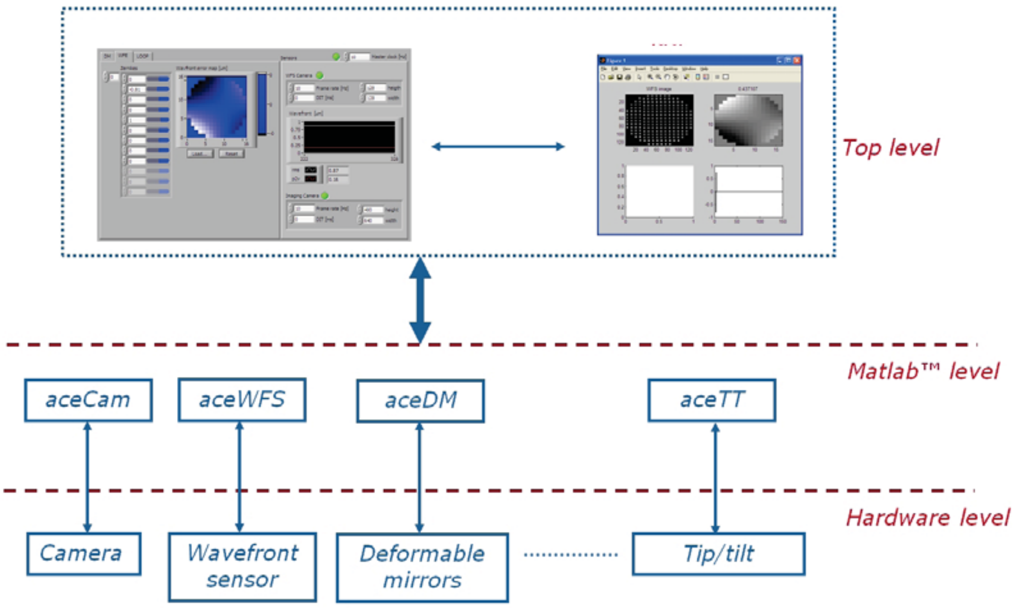
ALPAO Core Engine

ALPAO Core Engine (ACE) is a completely new software architecture for adaptive optics. Thanks to ACE, you will be able to develop instruments using adaptive optics rapidly and efficiently.

The ALPAO Core Engine (ACE) is an open, flexible and ergonomic architecture featuring unrivalled performances. This modular architecture allows users to use only the modules they need while working from MATLAB®. Performance has not been sacrificed at the expense of ease-of-use since it is possible to close the loop up to 400Hz by using ALPAO's deformable mirrors and wavefront sensors.

Moreover, flexibility means that the ACE adapts to the application. Indeed, in some applications, it is possible to dispense with a wavefront sensor and use the signal coming from a camera or a photo diode. Thanks to the ACE, you can be certain of having a system that is tailored to your application.

The ALPAO Core Engine comes with convenient built-in documentation including examples.



Recommended configuration: 4Gb of RAM, 100Mb of disk space, MATLAB® R2009b and higher versions

www.alpao.com - 3 allée de Bethléem - 38610 Gières - France - Tel: + 33 4 76 89 09 65 - Mail: contact@alpao.com

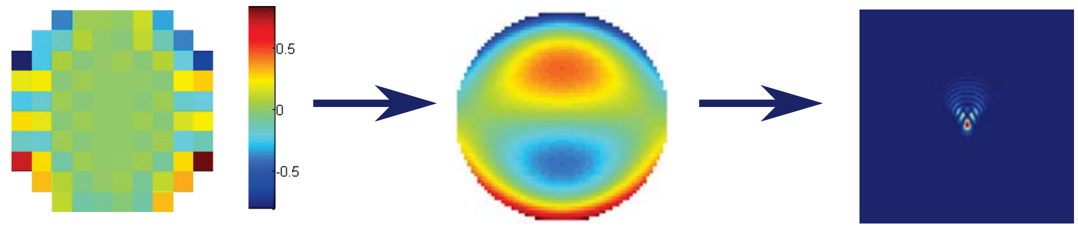
Getting AO results has never been so easy and so fast !

ALPAO Core Engine (ACE)

PRODUCT DATA SHEET

Create custom experiments

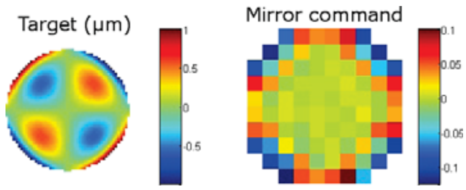
ACE is an object-oriented toolbox for MATLAB® allowing to access all the opto-electronic devices by built-in functions. Automated experiments and advanced control set-up are developed easily.



`>dm.ApplyValues(coma)` `>image(wfs.GetPhase)` `>image(cam.GetImage)`

Access to all the data in real-time

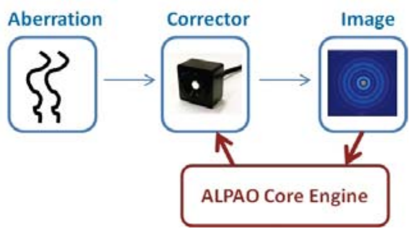
You will be able to process your data in real-time and export the results (display and values) in a wide choice of file formats (ASCII, .xls, .tif, .jpg, etc.).



Custom figure generated and exported in a graphic file.

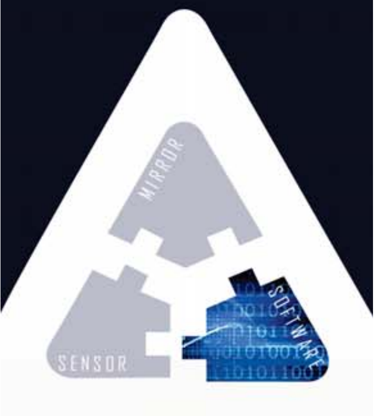
Optimize your AO system to your needs

With the ALPAO Core Engine, you can work on the wavefront sensor data or with your scientific detector. Adaptive optics without wavefront sensors and correction of non common path aberrations are easily implemented.



Build your own graphical user interface

You can use the Matlab® communication capabilities to interface your AO set-up with various softwares. For example, you can create graphical user interfaces calling ACE via Matlab®.



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