OASys

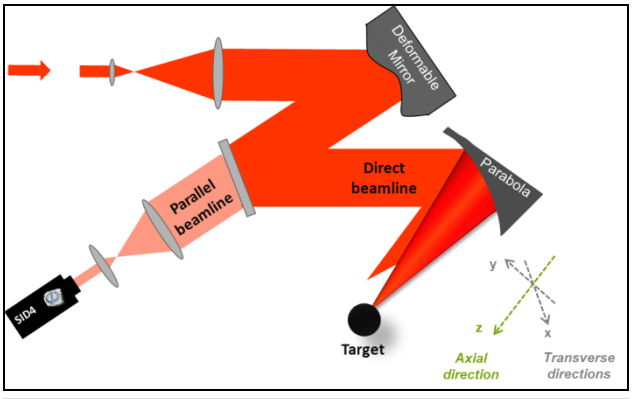

# OPTIMIZE BOTH THE FOCAL SPOT QUALITY AND POSITION

## DYNAMIC 3D POINTING

Optimizing laser-matter interactions in high power laser facilities strongly relies on the performance of the adaptive optics loop that is installed. Not only the loop should provide a **high-quality focal spot** that concentrates the light in the tiniest possible volume, but it must accurately control the **focal spot position** so that the interaction with the target can efficiently happen. Moreover, the control of the focal spot quality and position requires **stability and high repeatability** to allow comparing sets of measurements. Finally the loop should be **easy to use** for all users, even non-laser specialists.

Always offering new advanced features, Phasics leads innovation in adaptive optics for high power laser. Thanks to its unique wavefront sensing technology, the **quadri-wave lateral shearing interferometry**[1], Phasics corrects all the laser chain aberrations including the last focusing optics ones so as to obtain a focal spot of the best possible quality (Strehl ratio greater than 0.9). To optimize even more the laser-matter interaction, Phasics integrates in its solution a feature, the **3D pointing module,** that accurately positions the laser focal spot towards the target. This module prevents focusing before or after the target, or at gas jet edge. It also enables avoiding time-consuming alignment when targeting capillary.

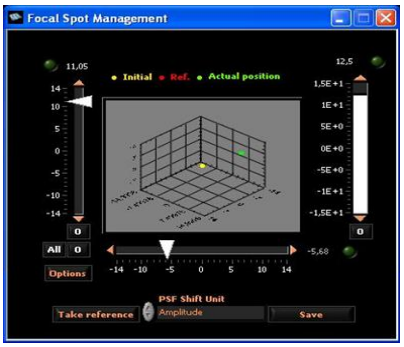
## "FOCAL SPOT POSITIONING WHILE PRESERVING ITS QUALITY"




*1. The goal of 3D pointing is to direct the laser focal spot towards the target. The directions of displacement are given using the optical axis as the z axis and perpendicular x and y axis.*

The position of the focal spot can be adjusted in any loop **by playing on the defocus and tilt** that can be additionally introduced by the deformable mirror. When considering a space basis based on the optical axis, as illustrated on figure 1, changing the tilt of the mirror results in a **transverse displacement** of the focal spot and changing the defocus of the mirror induces an **axial displacement** of the focal spot.

In Phasics' adaptive optics software solution, the required changes in tilt and defocus are combined to the reference wavefront targeted by the loop. The adaptive optics loop will converge towards this new wavefront reference that is optimizing the shape quality of the focal spot and that is managing its position. As decorrelated from other aberration values in the Zernike projection, the tilt and defocus changes do not affect the correction brought to the focal spot. Thus the **3D pointing keeps the focal spot quality intact**.




*2. In the 3D pointing module, the focal spot position shift is expressed in µm, number of PSF or wavefront amplitude.*

## "FOCAL SPOT STABILIZATION OVER TIME"

Long-term drifts of thermal origins generate tilt of the laser beam that results in unwilling displacement of the focal spot. The 3D pointing module enables a **real-time correction of the laser drift** that is not usually possible in a classical adaptive optics loop. Once the focal spot location is chosen, the corresponding tilt and defocus are added to the wavefront reference targeted by the loop. Consequently they will be part of the loop command, without any further action from the user.

## "ENOUGH DYNAMICS RANGE WITH ANY CURRENT MIRROR"

It has been proven that **less than half of the mirror voltages dynamic range is required to correct the laser aberrations**[2]. This leaves a range of displacement of more than 3 times the Airy diameter (PSF(x, y)) in the transverse direction and more than 7 times the Rayleigh length (PSF(z)) in the axial direction[3]. 3D pointing correction usually needs less than 1 PSF both in transverse and axial directions, which corresponds to 10% of the mirror dynamic range. Consequently**, any current deformable mirror offers enough dynamic range to both correct the aberrations of the laser chain and play on tilt and defocus to position the focal spot**. Besides, the tilt range required by such displacement can be **easily measured by Phasics wavefront sensor** as the sensor has a linear response for this range. Consequently, the Phasics 3D pointing module will not require any specific element and is a very affordable solution to optimize the focal spot.

| | **Dynamic**<br>*For perfect laser chain* | **Dynamic**<br>*For a laser chain of 10λ aberration* | **Sensitivity** |
|---|---|---|---|
| **Transversal shift** | 5 PSF (x,y) | > 3.5 PSF (x,y) | 1% PSF (x,y) |
| **Axial shift** | 15 PSF (z) | > 7 PSF (z) | 5% PSF (z) |

*3. These values are given for a piezoelectric deformable mirror of 48 actuators and 100 mm diameter*

### REFERENCES


[1] J. Primot et al, ONERA, " Extended Hartmann test based on the pseudoguiding property of a Hartmann mask completed by a phase chessboard", APPLIED OPTICS, Vol. 39, No. 31, November 2000

[2] B. Wattellier, J. Zou et al, LULI & PHASICS, "Comparison of Large Diameter Bimorph Mirrors for High Power Laser Applications", AOIM 2009

[3] I. Doudet et al, PHASICS, "Adaptive Optics loop implementation and optimization for petawatt laser facilities", ICUIL 2012