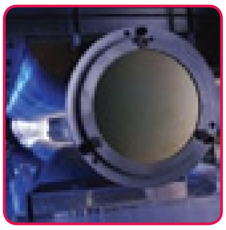
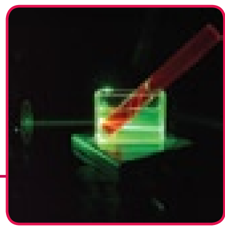
Adaptive optics inside the amplification chain and the next generation of optical fuses

High-power lasers at the forefront of technology, once considered to be purely research tools, are beginning to show their potential applications in a wide variety of scientific and industrial applications. These new applications include defense, fusion power generation, medical treatments based on proton therapy and the x-ray imaging.

Many research projects, originally performed purely to expand our understanding of the universe we live in, have unexpectedly lead to many of the technologies that have become part of our daily lives. Today's economy requires that both scientific and industrial researchers engage in projects with foreseeable commercial, or at the very least "prestige earning," applications. In the case of high-power lasers, the scientists and engineers that are developing the applications of this new generation of lasers must work quickly and efficiently to prove the value and feasibility of their work, Using adaptive optics in creative new fashions will contribute to this objective.





Currently, adaptive optics is only used in high-power lasers after amplification in order to improve final focal spot (see figure 1). While this approach has proved its utility and imposes few constraints, aberrations accumulate successively during beam amplification. Limiting the use of wavefront shaping technologies to the end of the chain has important drawbacks, the most evident of which is the inherent loss of intensity caused by the buildup of aberrations.

More importantly, using adaptive optics exclusively at the end of the chain means that users are not taking advantage of the technologies ability to help protect expensive components including crystal rods, pumps, amplifiers, stretchers and compressors. As lasers are amplified more and more, the proportionate risk to these delicate components increases as well. Manufacturing replacement components can take 6 months or more, bringing projects to a complete stop for incalculable amounts of time and devouring budgets.

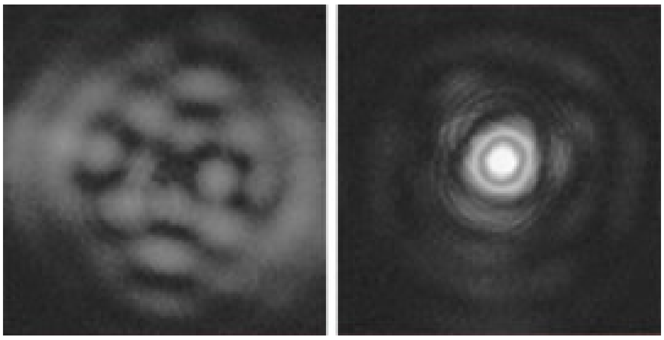


Figure 1 - A non-amplified lasers' focal spot before (left and after (right) correction using adaptive optics.

Imagine Optic's wavefront analysis and shaping technologies have proved their effectiveness post-amplification time and time again. Why?

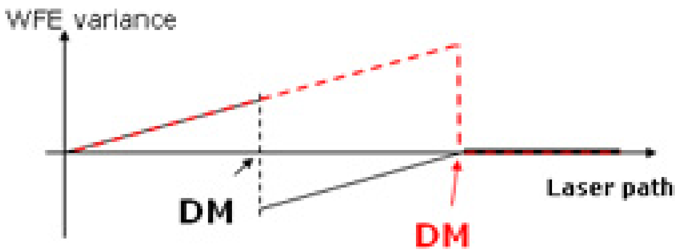
- HASO wavefront sensors go beyond the capabilities of other manufacturers' products by providing absolute measurement and simultaneous yet independent measurement of both phase and intensity.
- A wide array of proprietary and third-party active components combined with unparalleled expertise in customizing adaptive optics to individual applications.
- Unique software, including HASOv3 and CASAO, that provides the ability to move beyond rudimentary the functions offered by other manufacturers and to manipulate wide-ranging aberrations, to work seamlessly in open or closed-loop configurations, and to examine the evolution and impact of aberrations over time.

The next revolution in high-power lasers

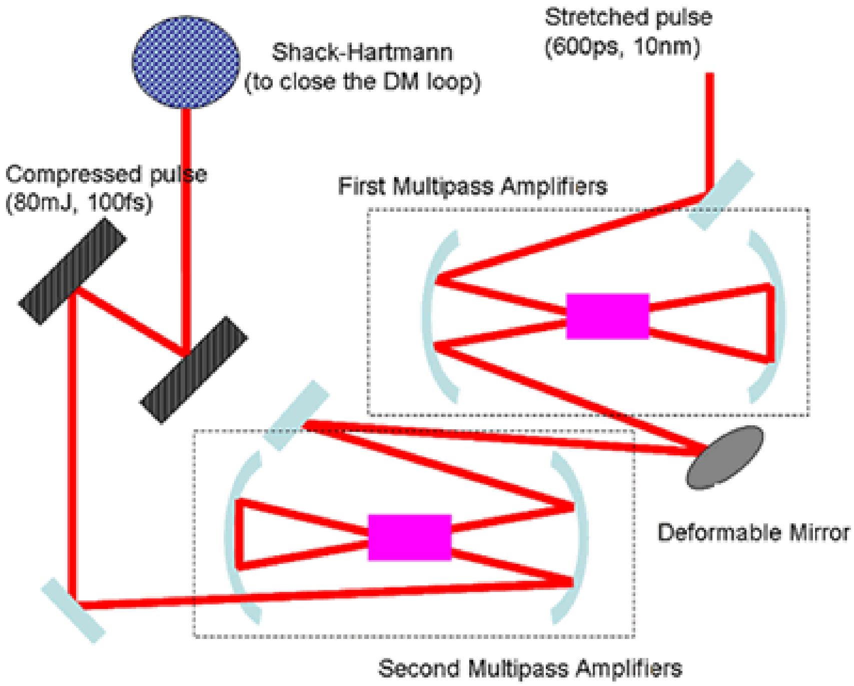
One of the keys to surpassing these new challenges is deploying adaptive optics inside the amplification chain.

As mentioned earlier, increasing power adds to the costs of building and operating a laser. Likewise, multiplying the number of amplifications increases the occurrence of variations in both phase and intensity. Whereas discrepancies in phase result in inconsistent propagation over time and space, disparities in intensity augment the risk of generating dangerous hotspots that can eventually proliferate through the chain in a cascade. Deploying adaptive optics technology at key points during amplification enables the maintenance of a homogeneous beam and provides several decisive advantages.

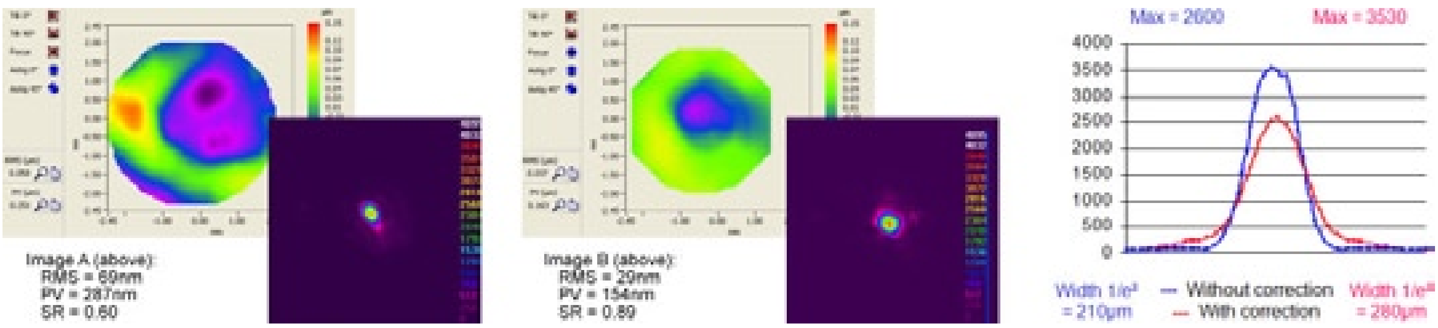
The diagram below illustrates the benefits of applying adaptive optics inside the amplification chain reduces wavefront errors and can contribute to protecting various elements used in the process, thus reducing operating costs.



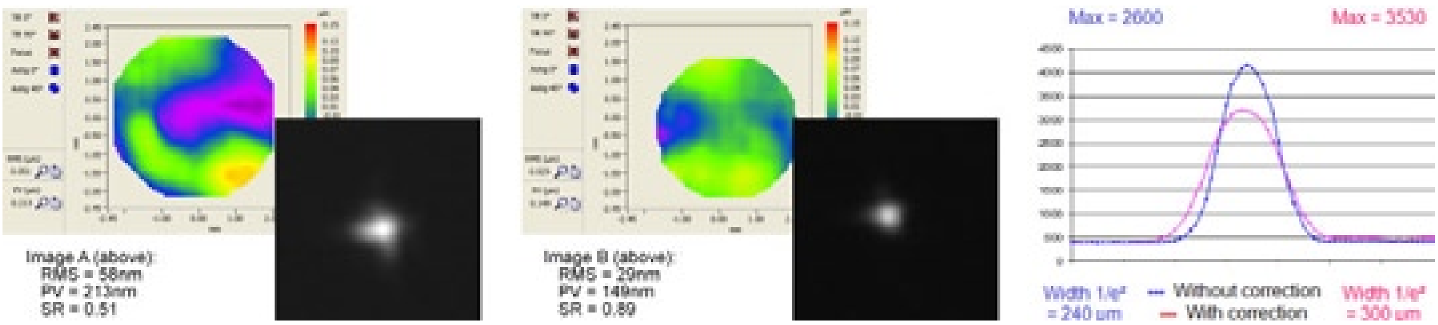
Below is a schematic of a typical deployment that demonstrates how integrating an adaptive optics loop using a HASO 32 wavefront sensor, a deformable mirror and CASAO software, in order to correct the beam's wavefront errors. After exiting the first multipass amplifier in a 10nm, 600ps stretched pulse laser, the wavefront is analyzed and aberrations are corrected before the beam enters into the second amplifier and the final compressor is configured.



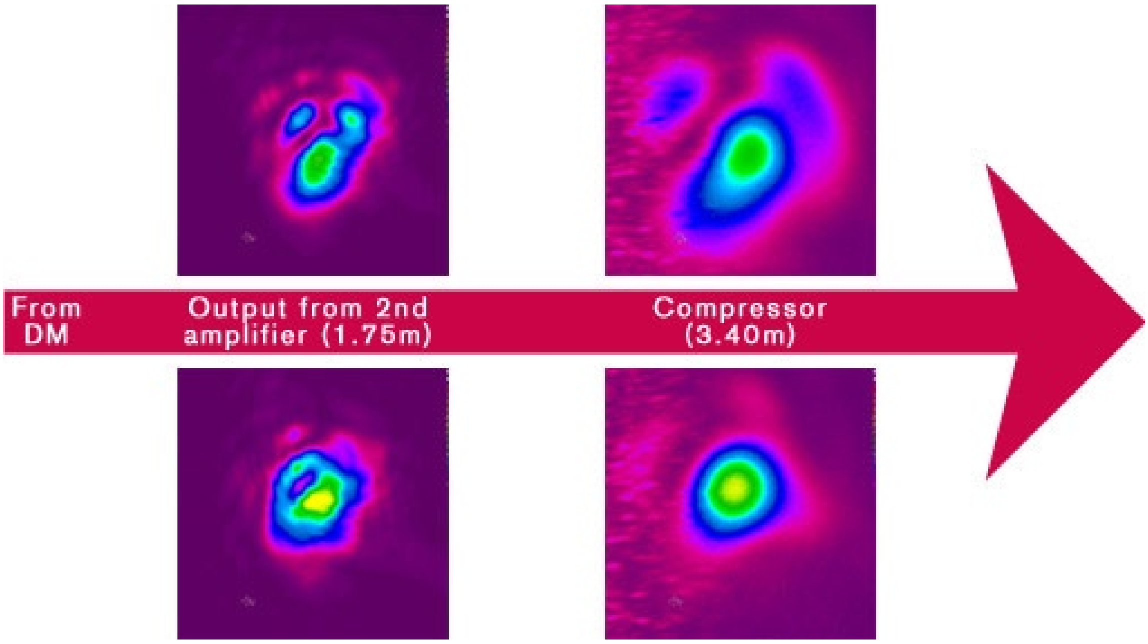
Below, image A shows the beam's uncorrected near-field focal spot and intensity profile at the exit point of the first amplifier. Image B demonstrates the same beam using adaptive optics to correct for aberrations at the same point. The graph below provides charted data on the difference in beam quality obtained.



The images below show the difference between an uncorrected beam and on that was corrected using adaptive optics inside the amplification chain. Image A shows the beam's uncorrected near-field focal spot and intensity profile at the exit point of the second amplifier. Image B demonstrates the same beam using adaptive optics to correct for aberrations inside the amplification chain between the first and second amplifier. The graph below provides charted data on these effects.



The images below show how, in our test, correcting the beam's spatial profile between the first and second amplifiers in the chain provides a homogeneous dispersion of intensity that provides two measurable advantages. First (upper images), using adaptive optics reduces the risk to sensitive beam amplification elements by eliminating the generation of unexpected hotspots. Second (lower images), the same system improves the planeness of the beam's wavefront and augments the beam's intensity by at least 10%.



Overcoming the barriers of past that impeded the deployment of adaptive optics inside the amplification chain

In the past, integrating adaptive optics inside the amplification chain, rather than at the end of the chain, faced serious technical constraints that limited its feasibility. Imagine Optic has used its 10 years of unique industry leading experience in wavefront analysis and adaptive optics to develop solutions to overcome past hurdles.

HASO wavefront sensors offer unique advantages to overcome the obstacles that many other wavefront sensors simply can't offer. HASO allows you to manage your pupil size and work with inscribed or circumscribed pupils at a variety of user-defined diameters. They equally enable you to manage and minimize the effects of parasite noise (caused by ambient light) that can interfere with measurement data. Even more, their robust measurement abilities enable you to measure even the most extreme variations in phase and intensity independently of one another yet simultaneously.

The all-new monomorph deformable mirrors that we distribute for our partner Cilas respond to the second set of challenges that inhibited adaptive optics inside the amplification chain of high power lasers. Using Cilas' monomorph technology enables us to maintain a regular and stable flux, as well as to eliminate the generation of high spatial frequencies, caused by print-through, that cause unwanted hotspots to form during beam propagation.

Finally, CASAO, the latest evolution in our adaptive optics software offer, provides key features you won't find anywhere else to answer the third challenge. One of CASAO's major advantages is that it automatically shuts down active components when it detects potentially dangerous events - a unique safety feature for high-power laser users.

As this application note demonstrates, the technologies that Imagine Optic offers today overcome many of the difficulties faced in the past that inhibited putting this technology to use in high-power laser amplification. Read on to see how the newest addition to our technology offer will provide even more advantages in this growing field.

The adaptive optics optical fuse for high-power lasers

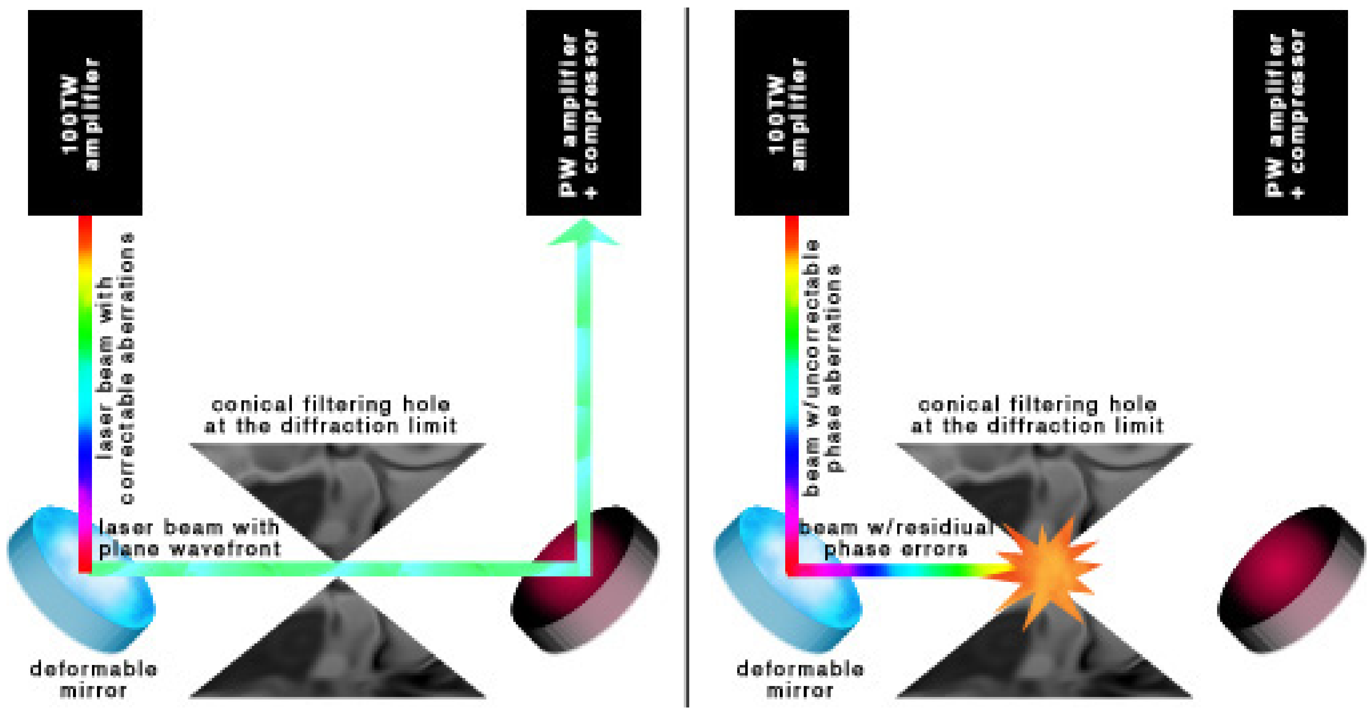
In autumn 2007, Imagine Optic filed a patent for a revolutionary optical fuse for high-power lasers. This new technology differentiates itself by incorporating the company's unique expertise in adaptive optics with low-cost consumables (specifically, the fuse element that is consumed when a problem appears). For the first time, high-power laser installations have a reliable, cost-effective means of protecting sensitive equipment.

The base principal of this new technology is simple and composed of two elements – a dielectric conical filtering aperture and an adaptive optics system functioning in a closed-loop configuration.

The two key challenges to developing the conical filtering aperture were to design an aperture small enough to be effective, all the while enabling it to function on a wide variety of beam diameters. The second was to employ the appropriate technology, in this case dielectric, that would permit the use of an optical filter within the focalization plane of a very intense laser.

The adaptive optics system used in the optical fuse equally must respond to very specific criteria in order for the ensemble to function. The deformable mirror must have enough wavefront shaping ability (dynamic range) to ensure that nearly the totality of the beam passes through the aperture while not generating high spatial frequencies that would cause the aperture to deteriorate over time. .

The diagram below illustrates the basic functional principals of this new optical fuse.



When these two elements are united, the deformable mirror corrects for lower-order aberrations whereas the conical filtering aperture takes over to eliminate higher-order aberrations. Only Imagine Optic's wavefront metrology and correction products provide the wide dynamic range and exceptional accuracy needed for this new approach to optical fuse technology to protect sensitive high-power laser installation equipment.

If you would like more information, please call +33 (0)1 64 86 15 60 or visit imagine-optic.com.