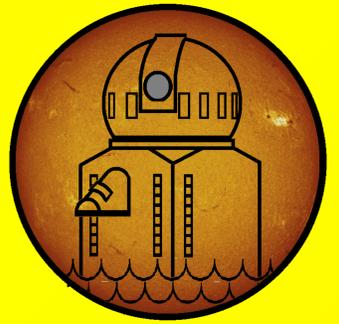




# BBSO AO-308 Adaptive Optics

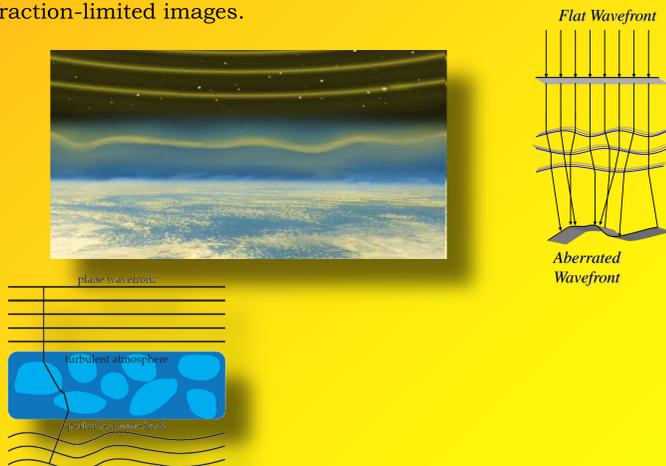


Adaptive optics (AO) is a technique that corrects in real time for image distortions caused by motions in the Earth's atmosphere. The Big Bear Solar Observatory (BBSO) New Solar Telescope (NST) depends on a state-of-the-art adaptive optics (AO) system to enable diffraction-limited imaging (0.08 arcseconds in the visible). The current NST AO incorporates a Shack-Hartmann lenslet array with 308 subapertures for measuring wavefront error. The wavefront distortion is then corrected using a deformable mirror (DM) with 357 piezoelectric actuators.

AO systems, such as AO-308 can deliver diffraction-limited images over a relatively small angle on the sky known as the isoplanatic patch. Image quality gradually deteriorates with increasing angle from the patch. The size of the patch varies with seeing conditions.

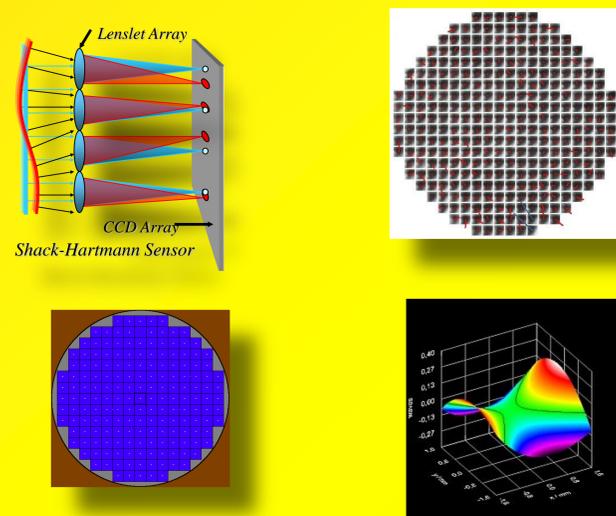
## Wavefront Distortion

Optical wavefronts traveling between the Sun and Earth are effectively flat. When propagating through the Earth's atmosphere, turbulent "bubbles" of air at differing temperatures distort the wavefronts, blurring the image. The effect is called "seeing". Telescope sites are carefully chosen for locations with good inherent seeing. Even excellent sites still limit image resolution to some fraction of an arcsecond (1/3600 of a degree). AO is required to allow larger aperture telescopes to produce diffraction-limited images.



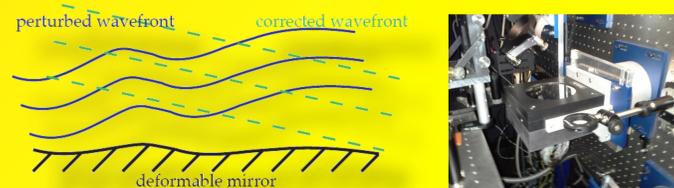
## Shack-Hartmann Wavefront Sensor

The wavefront distortion can be measured using an array of small lenses, known as a Shack-Hartmann array, placed in the telescope pupil. Each lenslet subaperture produces an identical image but offset due to the wavefront distortion. By measuring the offset in each subaperture, the wavefront shape can be reconstructed.



## The Deformable Mirror

Once the wavefront distortions are known, a deformable mirror (DM) can be used to cancel the aberration and restore the flat wavefront. The resulting image resolution is then diffraction-limited (as good as the telescope optical system is capable of delivering) instead of seeing limited. The NST AO-308 system uses a DM with 357 piezoelectric actuators that push-and-pull on a very thin 100 mm (~4") mirror.

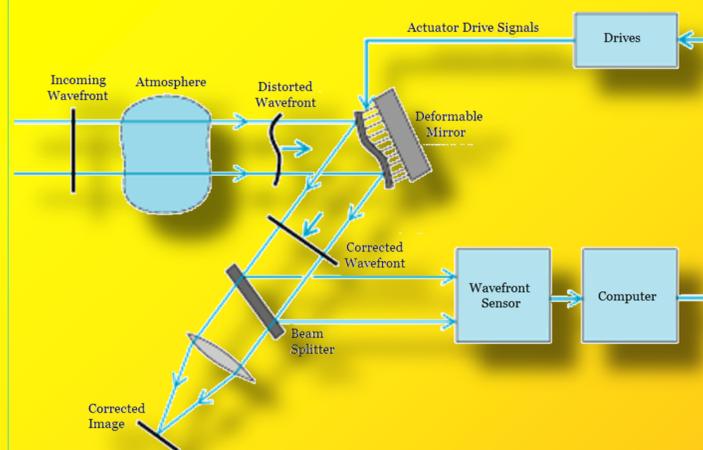


## The Servo Control Loop

The S-H lenslet array image is read by a computer which determines the wavefront distortion. The computer commands the DM to assume the same shape as the incoming wavefront but with 1/2 the amplitude. The reflected wavefront is then restored to flat once again.



The servo control computer must make corrections faster than the seeing can change (~1 kHz). The NST AO-308 system makes these corrections at about 1.9 kHz (1,900 times per second).



## Post Processing

Data are taken in quick bursts of many images. Post processing algorithms are then used to compare the images and reconstruct them using the best examples to further enhance the image quality beyond the isoplanatic patch.

