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AO-X Design:

AO-X Adaptive Optics
Installation and Operation Instructions

SBIG designed the AO-X to cover the larger CCD used in the STX-16803 but it works just as well for the rest of the STXL line. It is a new design several years in the making and represents our fourth generation of adaptive optics for amateur astronomers. This design not only increases the aperture available for larger format CCDs, but does so in a thinner design that takes up only about an inch of backfocus. Figure One illustrates the new AO-X.

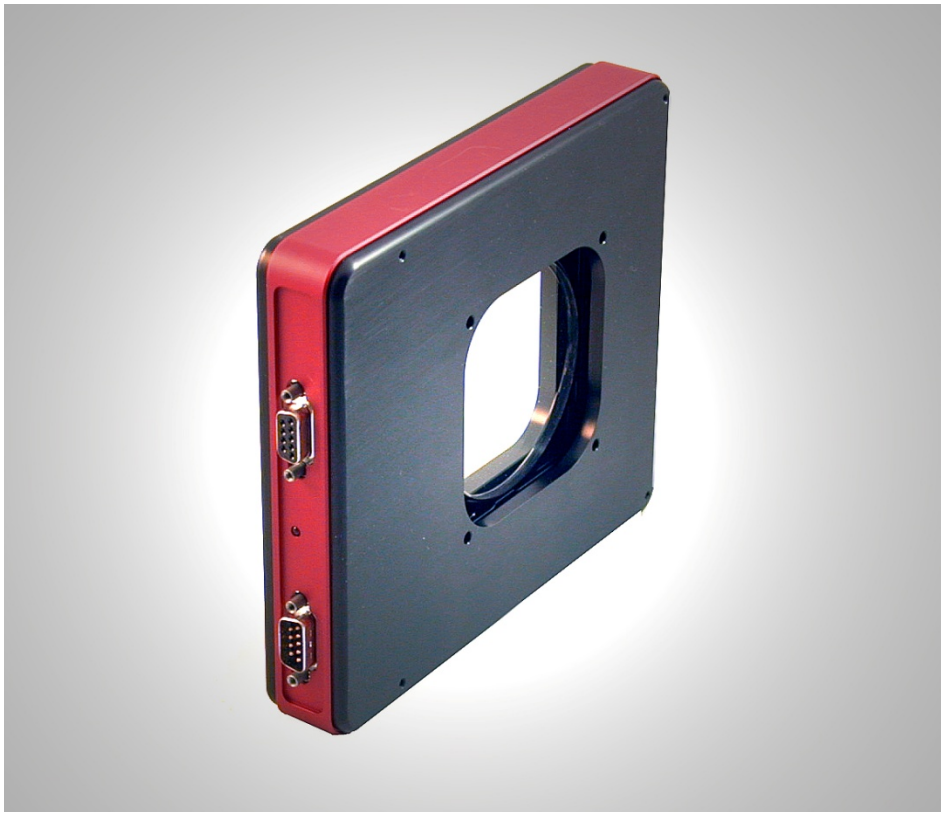

Figure One: AO-X Design Yields a Thin Package

The light passes through a 10 mm thick plane parallel BK-7 glass plate that is supported on a two axis gimbal mount. The gimbal can be tilted +/- 2.4 degrees by the action of four sets of magnets and coils around the periphery of the gimbal. The tilt in each direction produces a deflection of about +/- 144 microns in each direction, which is +/- 16 pixels using an STX-16803 or STXL-11K. This tilt has no significant focal shift, distortion, rotation, or change in magnification associated with it. The smallest move increment is $1/7^{th}$ pixel. The window has an anti- reflection coated specified to be less than 1% reflection per surface from 400 to 900 nm wavelength.

The main advantage of this new technique is that it is thin, with a body only 1.18 inches

(30.0mm) thick mechanically. Because of the thick window, the optical thickness is only 1.051 inches (26.7mm). The other advantage is that it is fast, being able to move and settle to a stop in less than 50 milliseconds. Our proprietary design has good damping, so the device moves fast, but with no overshoot.

The limited correction ability of this device, +/- 16 pixels, means that the telescope focal length must be matched to the seeing, to some extent. Our assumption is that the seeing should cause the star to hop around by no more than +/-4 pixels, which may require the use of a focal reducer for longer focal lengths. A 9 micron pixel equals one arcsecond for a 73 inch (1855 mm) focal length.

Installation and Operation:

The AO-X is designed to be bolted directly to the front of your STXL or STX camera. The steps to attaching the AO-X are as follows:

1) **Very important**: Make sure the AO-X and camera are unpowered so if a screw falls into it you do not get an electrical short.

2) Disassemble the AO-X by first removing the 4 screws that hold the front and back covers together. When separating the covers, you will find that one cover has nothing mounted to it, the "bottom" cover, and the other has all of the electronics and mechanics attached to it, the "telescope-side" cover.

3) Remove any pieces of neoprene or foam that were inserted between the window and the bottom plate during shipment. Save these in case the unit ever needs to be returned to SBIG. The foam prevents the window gimbal from hammering against its limits during shipment.

4) If you have an STX, use the four 6-32x3/16 inch (5mm) long screws provided with the AO-X to attach the bottom of the AO-X to your STX camera or filter wheel. You need to remove the four screws at the periphery of the STX front plate so the AO-X can sit flush against the face. The screws do not hold anything. Of course, you must remove the telescope adapter from the camera or filter wheel to access the tapped holes.

   If you have an STXL, the procedure is similar. You do not have the 4 screws at the periphery, so that step is unnecessary. If your STXL has the self-guided filter wheel attached then you will need to include the 4-sided square spacer that came with your AO-X between the AO-X and the filter wheel. In this case, use the longer 6-32 x 3/8 inch (10mm) screws.

5) Re-install the AO-X telescope-side plate to the bottom plate. Attach your telescope adapter and/or nosepiece to it using the 6-32 x 3/16 (5mm) screws.

6) Plug the cable from the AO-X into the I2C-AUX port on the STX. Download the latest drivers from SBIG and install them. From a software perspective the AO-X looks like a fast AO-L, so CCDOPS, Maxim, and CCDSOFT should work fine with it. If you have a

filter wheel installed connect the camera to the IIC-in port on the AO-X, and then plug the filter wheel into the IIC-OUT port on the AO-X. When connecting SBIG equipment, never-ever use a gender changer on a port. If you have a connection mismatch contact us. The 9 pin cable should be a male to female type.

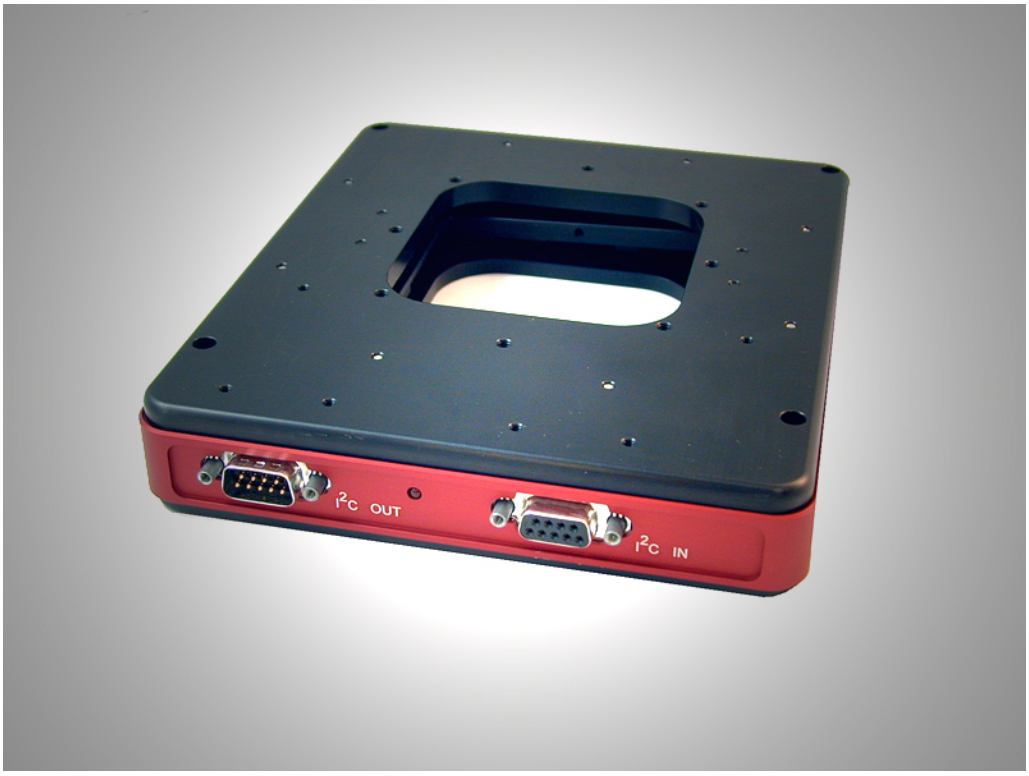

Figure Two: Telescope-Side Portion of AO-X

To try the unit out, use the EXERCISE mode in CCDOPS, under the AO menu. You can exercise the AO-X over its full range of operation using this command, with 200 milliseconds per axis, driving both axis. The full range of motion is about +/- 0.2 inch (5 mm) at the corners of the window. Bouncing a laser pointer beam off of the AO-X window and onto a white surface is a good way to see the AO-X action clearly.

If you are using the unit at a telescope with CCDOPS, please check that manual for AO operation. The technique is the same. You need to calibrate the AO-X first on a relatively bright isolated star, and then use self guiding from the AO menu to guide. Under setup, the slew rate command does nothing, and you should set the relay threshold to about 50 to 80% of full range before relay commands are employed to bring the star back to the center of the AO-X range. An aggressiveness of 10 is a good place to start, but experiment to see if tighter star images result from a lower aggressiveness of 5 or 3. On a bad night use a low aggressiveness to avoid just chasing the seeing around the chip, one frame behind its position. The AO-X should be most effective at improving the seeing on a steady, quiet night with little wind.

Operating Tips

We offer some rules of thumb here based more on experience than theory. On a night when the long exposure (> 10 second) image of a star shows a Full Width Half Maximum (FWHM) blur of 2 arcseconds, this blur is about half high speed effects beyond the reach of the AO-X, and half due to motion of the star, added in an rms sense. In other words, on a two arcsecond night you have a 1.4 arcsecond blob dancing around enough to expand the FWHM to 2 arcseconds, this second component being what we think of as the motion blur. The average rms hop is 40% of the long exposure motion blur, or, in this case, about 0.56 arcseconds. So, the rule of thumb is that the motion of the star, frame to frame, is about 30% of the FWHM, which is easily measured from a longer exposure using the crosshairs mode in CCDOPS. So, on a 3 arcsecond night you should be using a focal length under 280 inches (7100 mm) so the average hops are less than 4 pixels and therefore within the range of the AO-X. This is a very simplistic rule regarding the seeing.

Maintenance:

Window Cleaning: Use cotton swabs and isopropyl (rubbing) alcohol to clean the window if necessary. Cleaning is laborious – never re-use a cotton swab. Keep using fresh ones, and eventually all oil on the window will be removed. The AR coating on the window makes any residual oil very apparent. The coating is fairly tough, so you are unlikely to damage it with gentle pressure and a cotton swab.

Specifications

Dimensions:	6.8 x 6.1 x 1.2in (175x154x30mm)
Weight:	1 pound 15 ounces (880 grams)
Optical Backfocus:	1.051 in (26.7 mm)
Interface:	I^2C in/out