

**Santa Barbara Scientific
Seeing Monitors
SM-1xxx, SM-2xxx**

The SBS Seeing Monitor includes custom software for measuring the seeing, minute by minute, for 12 hour periods. The seeing is displayed in units of the zenith Full Width Half Maximum (FWHM) in arcseconds expected for a long exposure star image. *Please note that while the SBS Seeing Monitor program (and this manual) often refer to the SM-1 with ST-I camera, the same software will operate both the SM-1 and SM-2 models after the appropriate drivers for the cameras have been installed as described in Section 2.*



Figure One: SBS Seeing Monitor

1. Theory of operation

Most professional observatories use the Differential Image Motion Monitor (DIMM) technique to measure seeing. This technique is implemented in hardware by using a two hole mask over an 8 to 11 inch Schmidt-Cassegrain telescope aperture, and measuring the root mean square (rms) fluctuation of the spacing of the two spots seen when a bright star is imaged a little bit out of focus with a fast camera. The reason two spots are measured is that the aggregate motion of the two spots due to poor tracking or wind vibration can therefore be rejected. However, the resulting system is complicated to automate, and invariably requires an automated enclosure to house the telescope as well, running the total cost up to tens of thousands of dollars. The problem with this approach is that it completely ignores tube currents in the SCT, which are not small, nor correlated across the aperture. The SBS approach is to use a fixed single

aperture system staring at Polaris, mounted on a heavy solid pier. This way the wind motion and tracking error is gone. Polaris does move across the space of a measurement, so the linear drift of the centroid of Polaris's position is determined and corrected. We call this the SIMM technique.

An accurate seeing measurement requires exposures of 0.01 seconds or faster to freeze the seeing, and avoid errors due to the star motion being averaged over a long exposure. In the case of the SBS SM-1, the software collects 256 frames of data, each with an exposure of 0.01 second. The rms image motion is then determined. 256 frames requires about a minute of time to collect and process. A lens with a focal length of 100 mm or more is adequate for the measurement since sub-pixel accuracy is achieved with the centroid calculation. The motion of Polaris over a night is contained on the CCD with a 100 mm focal length. Over the course of a night Polaris may move in a 180 degree arc, so its motion must be considered for any long term monitoring plan.



Figure Two: Two Summed Exposures of Polaris Field – SM-1, 100 mm Lens, 10 Seconds

At the latitude of Santa Barbara, California, (35 degrees) the noise floor of an SBIG ST-I camera with a 100 mm lens is about 0.6 arcseconds FWHM. This is measured indoors at night by viewing an LED of brightness comparable to Polaris, being driven slowly in a horizontal direction. Understand that this low value will be added in an rms sense to the actual seeing at low levels. So, if an ST-I with a 100 mm lens measures 1.0 arcsecond seeing, one needs to subtract the 0.6 second measured bias from this (in an rms sense) to give the actual seeing, 0.8 arcseconds. Unless the seeing is really good you can ignore this

correction. Converting the measured seeing at the elevation of Polaris into a zenith value is done using a well-accepted formula, where the seeing at the zenith is equal to the seeing measured for Polaris divided by the airmass to the 0.6 power. Airmass is equal to 1 divided by the cosine of the quantity 90 degrees minus the latitude.

2. Installing the Drivers and Software

[a] Models with SBIG ST-i camera (SM-1xxx)

Drivers: First, install the ST-I camera drivers from the SBIG website (www.sbig.com). Go to -> SUPPORT -> SBIG ARCHIVES -> SOFTWARE DOWNLOADS -> SBIG DRIVER CHECKER (WINDOWS). As of this writing, here is a direct link:

<ftp://ftp.sbig.com/pub/SetupDriverChecker64.exe>

Install and run the Driver Checker program and this will install the latest drivers for SBIG cameras, including the ST-i.

Seeing Monitor Software: Next, to install the SM software, first create a folder on your PC named C:\SeeingMonitor. If that directory does not exist the software will fail. Then, download and unzip the folder labeled “seeingmonitorsetup.zip” (containing SeeingMonitor-Publish-051817.exe) from the SBS web site (www.sbscientific.com) and save it in a directory on your PC (could be the same directory). Go to ->SUPPORT -> SOFTWARE -> SEEING MONITOR SOFTWARE (USB). As of this writing here is a direct link: <http://www.sbscientific.com/site/assets/files/1056/seeingmonitorsetup.zip> Next, open the folder, unzip the files and double-click SBS_SM-1_STiQHY-SETUP.EXE. This will install and start the program. Find the new program in the program list (selected by clicking the START button in the lower left corner of your PC’s screen), or on your desktop, and select it to start the program. You should find a shortcut on your desktop.

[b] Models with QHY 5L-II camera (SM-2xxx)

Drivers: First install the drivers by going to the QHY web site (www.qhyccd.com), selecting Guider-Planetary Camera, then QHY-II USB2 series, and finally clicking on the QHY5L-II camera to reach the driver install menu. Follow the directions provided by QHY for driver installation and updates.

Seeing Monitor Software: Next, to install the SM software, first create a folder on your PC named C:\SeeingMonitor. If that directory does not exist the software will fail. Then, download and unzip the folder labeled SeeingMonitor-Publish-051817 from the SBS web site (www.sbscientific.com) and save it in a directory on your PC (could be the same directory). Go to ->SUPPORT -> SOFTWARE -> SEEING MONITOR SOFTWARE (USB). As of this writing here is a direct link:

<http://www.sbscientific.com/site/assets/files/1056/seeingmonitorsetup.zip> Next, open the folder and double-click SBS_SM-1_STiQHY-SETUP.EXE. This will install and start the program. Find the new program in the program list (selected by clicking the START button in the lower left corner of your PC’s screen), or on your desktop, and select it to start the program. You should find a shortcut on your desktop.

3. Menus and Commands

When first using the software, it is recommended that you begin by connecting to the camera using Maxim DL or CCDOPS for SM-1xxx models, or QHY software for SM-2 models, and verifying that the camera is working correctly. For SM-1xxx models select SBIG ST-I for the camera type. For SM-2xxx models, select QHY for the camera type. After establishing a working connection, select SHUTDOWN under the camera menu to release the USB port for other applications and then start up the SBS Seeing Monitor program.

File Menu: Under the file menu, the only commands are to save the image on the screen in SBIG format for later inspection or transmission to SBIG for troubleshooting purposes, and EXIT.

Camera Menu: Under the camera menu, you should begin by selecting ESTABLISH LINK to ST-i or QHY. This will establish a USB link to the camera. Next use TAKE EXPOSURE to capture a 0.1 second exposure and make sure a bright star is in the field of view. Polaris is readily visible in 0.1 second with a small aperture. Use FOCUS MODE to see a continuously updating display for use in positioning Polaris in the field of view.

Display Menu: The first option under the DISPLAY menu is the SETUP menu. The SETUP screen, shown in Figure Three, allows you to enter the seeing monitor lens focal length, and aperture into the program, as well as your latitude, longitude, Daylight Savings setting, and what time you want to display on the graph. There is a space to enter your times zone. The value is the offset from Greenwich Mean Time (GMT), which for the USA is typically 5 to 8 hours (8 hours in California). If daylight savings time is in effect check the Daylight Savings box. Check the GMT box if you want Greenwich Mean Time displayed on the graph, and uncheck it if you want the program to display the local time on the seeing graph. You can also set the daily start time and end time (local time only) if you want the program to run continuously for multiple nights without intervention. The start and stop time can only be entered in military time format, such as 19:15 for 7:15 PM. Only hours and minutes can be entered. This is the time when the program starts capturing Polaris data, if the sun is below -9 degrees elevation.

Latitude and Longitude are important to enter since these values are used in the calculation of solar elevation. Only enter integer values, no decimal numbers. A positive longitude is WEST of Greenwich.

You can enter a value for Polaris counts so the program can display a line on your graph that shows the measured Polaris Counts relative to this value, and therefore the atmospheric transmission. This is handy for determining, after the fact, if you had clouds or haze interfering with your night. If, for example, you enter 20,000 counts for this value and Polaris is detected with a level of 20,000 counts, it will mark a blue point at a level of 5 on the seeing graph. This is nominally the 100% value. You can customize this number for your site by seeing what level you reach on a really clean night, and adjusting the setup value accordingly. 20,000 is a good starting value for a 0.01 second exposure.

The directory to which to save files should be entered here. Note that files will always be saved to C:\SeeingMonitor\ in addition to any other folder you select. This program does not create folders – you must create them before expecting the program to save anything into them or the program will give you an error message.

Also under the DISPLAY menu is a command to display the current solar elevation, for reference, and a CROSSHAIR command so you can inspect pixel values on the image displayed on the screen. Simply slide the cursor around the image to view the values.

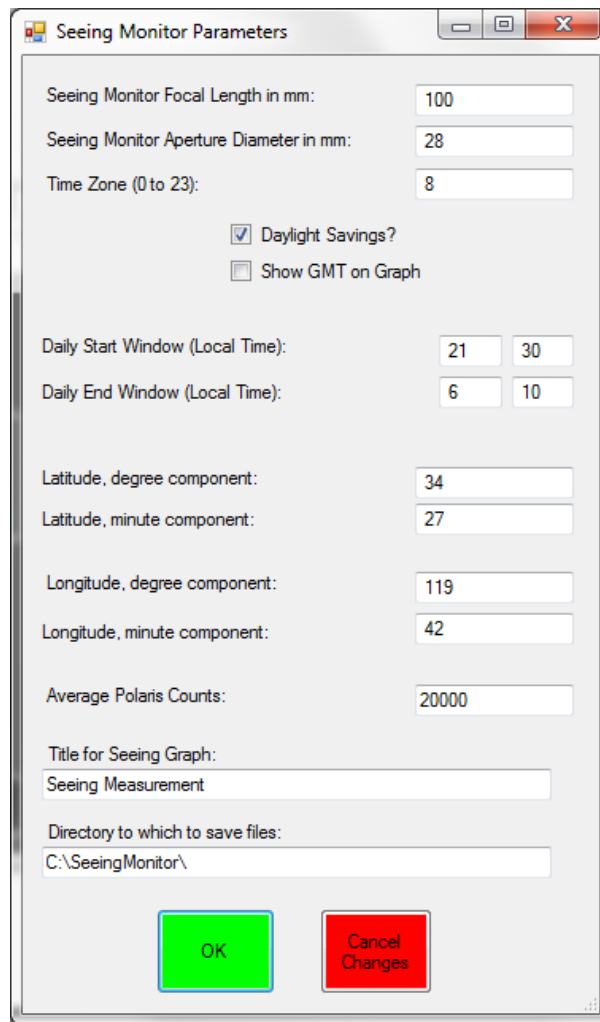


Figure Three: Setup Menu

Seeing Monitor Menu: here you can choose to immediately start logging the seeing. To start at a specific time select “Start SM,” and the program will execute for that period night after night. When logging begins, a graph displaying the zenith FWHM (full width half maximum of the star image) will pop up, with a start time which is the previous hour’s number, and that shows 12 hours of data. The length of this graph cannot be customized. The graph, and a text file logging the seeing data will be written to the C:\SeeingMonitor\ directory every 5 minutes. This seeing graph name and location never changes, so you can have an external program monitor this folder and put the image up on a web site, if you wish. Another graph image file, and text file, is saved to the directory specified on the SETUP screen, and customized with the date, so they will not be overwritten by data on subsequent nights.

Operation: The seeing monitor program requires that there be a directory on your hard drive named C:\SeeingMonitor, so please create such a directory before launching the program. The log files and setup files are all kept in this directory. When the program is launched it will try to read the SETUP parameters from C:\SeeingMonitor and, if it does not find it, it will pop up a message saying that it did not

find the file. Click SETUP under the DISPLAY menu to initialize this menu. When you click OK to exit the SETUP menu the file is automatically created and will be loaded next time the program is initialized.

Next, select ESTABLISH LINK to ST-i or QHY to link to your camera. After that it is not a bad idea to take a test image of 0.1 second length to make sure Polaris is there, and nothing got bumped. If it is, then you can launch the seeing monitor function by selecting “Start SM” (same for SM-2) to start multi-day operation with preset start and stop times. The main screen as shown in Figure Four will be displayed, along with the pop-up graph.

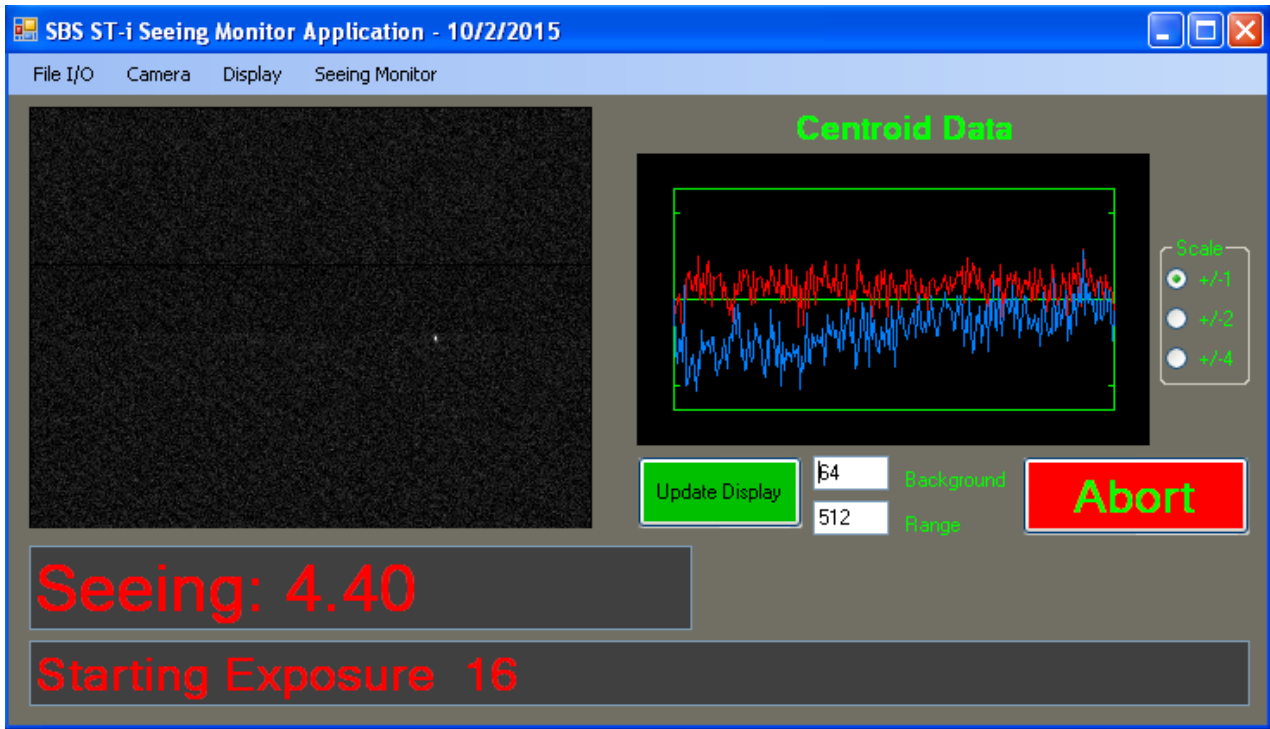


Figure Four: Main Screen

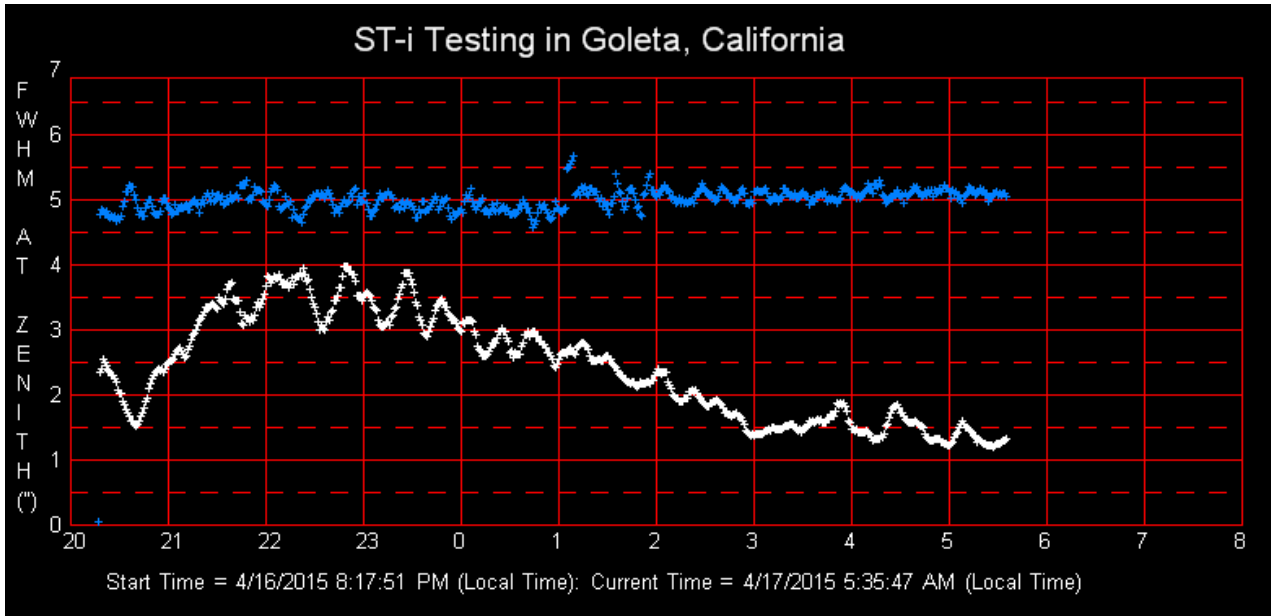


Figure Five: Seeing Graph

The ABORT button will appear. To stop the process when quitting the application just click the ABORT button one time and the process will stop in a few seconds after the exposure ends.

From Santa Barbara clear nights are often nights when winds are blowing, a hot, blustery wind off the mountains that always leads to world class bad seeing. However, some nights it subsides and we get a wind off the ocean and the seeing is great for an hour or two before the fog comes in. This graph shows such a night – the seeing became very good right before dawn. When the star is lost due to detector saturation or clouds the graph goes to zero.

4. Some helpful hints

Even when sampling at 100 times a second, when the seeing is REALLY bad the seeing monitor is probably underestimating how bad it is since the image is just a boiling blob, for example, on nights where the stars look like planets visually and the real FWHM on CCD images is in the range of 15 arcseconds. Even though the seeing monitor underestimates these terrible nights, it provides a clear indication that you will be wasting your time trying to take a high resolution image that night. It may be that nights like this are actually uncommon nationwide, but we sure get a lot of them. Please e-mail us and let us know how realistic the seeing monitor results are compared to your images.

So far in testing we have run the SM-1 for many nights, at least 1,000,000 images without a freeze or dropped frame. However, it was connected directly to a dedicated computer through a 15 foot cable without an extension. The screen saver was turned off. Of course, you have to disable any power setting that puts your computer to sleep, or the monitor. Just turn off your monitor after starting the program. We expect reliable operation with an extender, but only if it is powered on both ends since the SBIG ST-I and the QHY cameras run off USB power. The ST-I based algorithm takes a dark frame at the beginning of each series of 256 frames. The QHY approximates the dark value by looking at nearby pixels to Polaris.

Finding Best Focus Using the Latest Software¹

Alan Holmes

2/21/2018

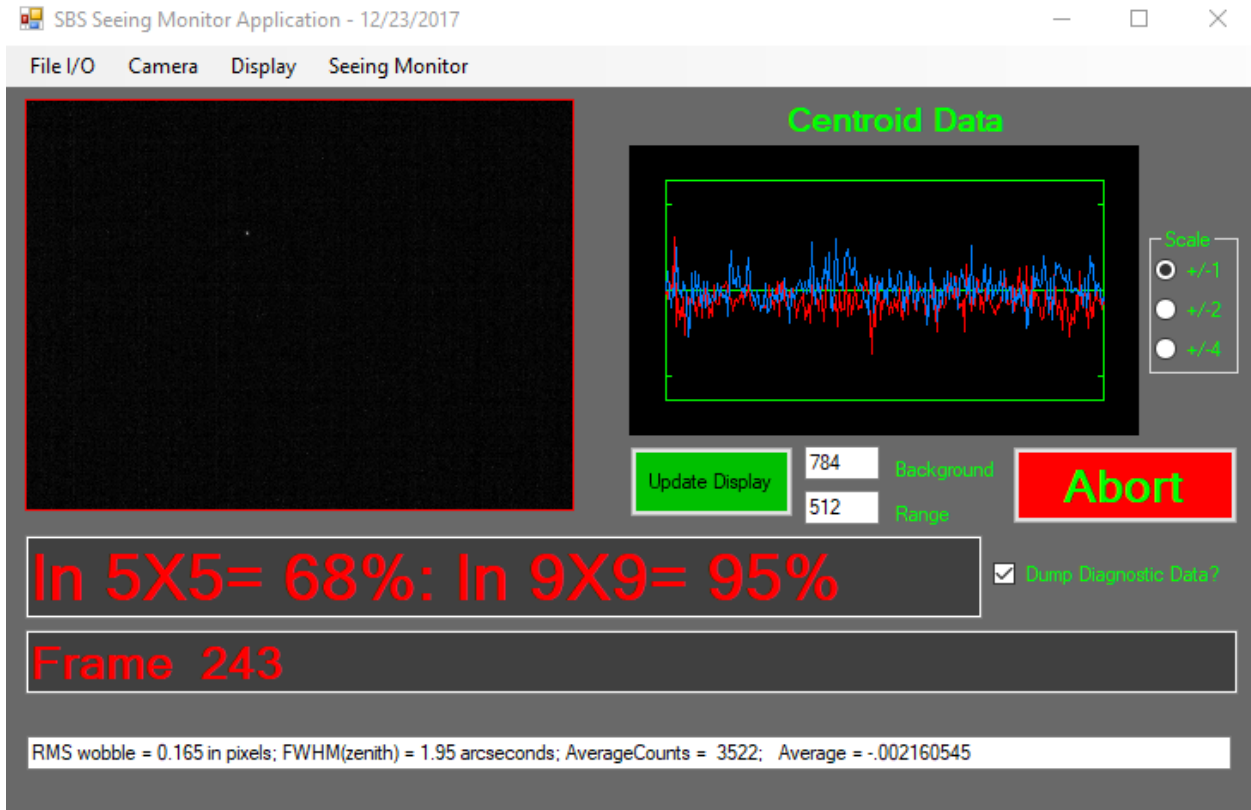
One of our users discovered that co-located multiple QHY camera-based seeing monitors would not all read the same seeing values. After a period of investigating other potential sources of the differences, such as platform vibrations and a line-of-sight over nearby air-conditioning units, it became clear that there was a real difference between seemingly identical units. I brought the best and worst performing units home to investigate this issue and discovered that the focus can affect the measured seeing. This report summarizes my measurements and conclusions, and outlines how to achieve the optimal focus with these units.

Why does focus matter? – the seeing monitor works by measuring the rms centroid motion of Polaris due to atmospheric turbulence. I use equations that relate this rms motion to the FWHM of a star at the zenith. In order to keep the costs down, we use a lens with a focal length short enough that Polaris does not rotate off the sensor during the night, in this case a 100 mm lens. An arcsecond of motion is only 0.13 pixels. However, my measurements and calculations show that this system has a noise floor when viewing Polaris of only 0.08 pixels rms, adequate for sub-arcsecond measurement. The problem is that the atmospheric turbulence is not only causing image jitter, but also scintillation, that star twinkling that is familiar to everyone. What makes sense when you think about it is that the rapid twinkling you see with your eye is not constant across large areas, but is the instantaneous brightness averaged across your 7 mm pupil. The illumination from Polaris is a patchy, uneven irradiance across the 28 mm aperture of the seeing monitor lens. So, large irradiance variations exist across the aperture. If the lens is not at the best focus, gradients across the lens will create gradients across the focused stellar image that create a centroid shift when the star image did not actually move. The situation is analogous to a Foucault test in optics, where when you slide a slit across the focused image you will see a shadow that moves one way when in front of focus, and the other direction when behind focus.

New Software: to better quantify the focus I modified the seeing monitor software to display the amount of energy from Polaris that is captured by a 5x5 pixel box (3.75 micron pixels) and a 9x9 box. My reasoning is that the smallest seeing measurement will result when the energy is most concentrated. The new screen is shown in Figure One.

1. The latest Seeing Monitor Software is SBS Seeing Monitor Application - 2/12/2018 or later, downloadable from the Santa Barbara Scientific website at <https://www.sbscientific.com/support/software>

Figure One: Screen Shot of New Software



The software now has two modes that display the included percentage of total energy in a 5x5 and 9x9 box. One is when running in Seeing Monitor mode, and the other under a new command, QHY Fine Focus Mode, under the Camera menu item. The Fine Focus mode is recommended for getting close to a good focus. To use it, first establish a link to the QHY camera, and then take an exposure of around 0.01 to 0.04 seconds. Next, using the mouse, click the image of Polaris to set the zoom region. Then, select QHY Fine Focus Mode, and the unit will repetitively show a zoomed region around the selected position. If the background and range settings are not good just type in a new number in the appropriate field and the software will start using it automatically. The included energy values shown in this mode are the average of 10 looks, so they update every 10 frames. In this mode, adjust the focus to get a nice tight star image and included energy values approaching 65% for a 5x5 box, and 90% for a 9x9 box.

Under the File I/O menu, if you stop the focus process and save the image in SBIG format, you will get an image that is 640x480 pixels in size that you can measure using CCDOPS. There is a new file save mode, Save QHY Image, that will save the raw full size QHY image data after a Take Exposure command. This data is 1280x960 pixels in size, and can also be viewed with CCDOPS (or Maxim DL, or The SKY).

When running in the seeing monitor mode the displayed included energy values are averaged over 51 looks. This may be useful to the operator if the outdoor temperature changes dramatically, or seasonally, and you suspect your focus has gone soft.

Note – in the latest version of this software, when in Fine Focus mode a pixel grid is shown. The actual field of view of the scene shown is 80x60 3.75 micron pixels, so in reality the grid spacing is 12.5x12.5 device pixels in dimension.