BWA-CAM

The BWA-CAM Laser Beam Analyzer system and software enables “real-time” laser beam measurement, analysis and monitoring of low to very high power CW and pulsed lasers. The system design is based on the international standards ISO 11146 and ISO 13694 which relate to lasers and laser related equipment and laser beam spatial metrics.

In every laser application, the laser beam profile provides valuable information for the most efficient use of the laser. By monitoring the laser beams spatial profile, circularity, centroid, astigmatism and M-squared values, you have early warning of any problems with the laser and entire beam delivery optical system. This relates to increased quality, process reliability, and reduced scrap.

The BWA-CAM is a patent pending (USPTO 12/756,476) instrument that measures the focal beam waist of a laser beam without moving parts. Prior to the advent of the BWA-CAM, all other beam waist analyzer devices have some sort of moving or spinning components which make real time measurement of a laser's M-squared impractical for on-line or real time applications.

The BWA-CAM is modular in design and can be configured for most applications and laser wavelengths. The design contains no “moving components” and provides instantaneous measurements and analysis of the laser beam and all active optical elements.

The BWA-CAM is simply placed after the laser focusing lens of the system under evaluation and adjusted until the beam waist can be seen in the primary region of interest (ROI). The smallest spot is located about midway in the series of spots (see Figure 5). Once the multiple spots, each one a spatial crossection along the beam waist, are nearly horizontal, the software automatically tracks and sizes the ROIs for accurate M-squared measurement.

The BWA-CAM can measure the laser beam waist metrics for any focal length of 75mm or more without a focus adapter. Lens systems with focal lengths < 75mm will require an optional focal length adapter which mounts into the entrance port of the BWA-CAM. The BWA-CAM can measure a laser's M-squared in well under a second. In its highest resolution condition, the system produces frame rates of more than 3 frames per second resulting in a measurement in about 333 milliseconds. This is possible through the use of an all passive optical approach to measuring the laser's beam waist. At the heart of the device is a pair of Fabry Perot etalons positioned between the laser's focusing lens and a CMOS sensor camera. The etalon pair is aligned at an angle to the incoming beam so that the light contained within the resonator oscillates and with each round trip of the focused laser beam creates a time delay and a spatial offset of the light. The distance between the etalon pair is adjustable so beam waists of a wide range of focal lengths can be measured. Figure 1 illustrates a sequential ray trace of light rays passing through a focus lens, through the Fabry-Perot etalon pair and then the resulting time delayed spatial slices of the focused laser beam landing on the CMOS sensor.

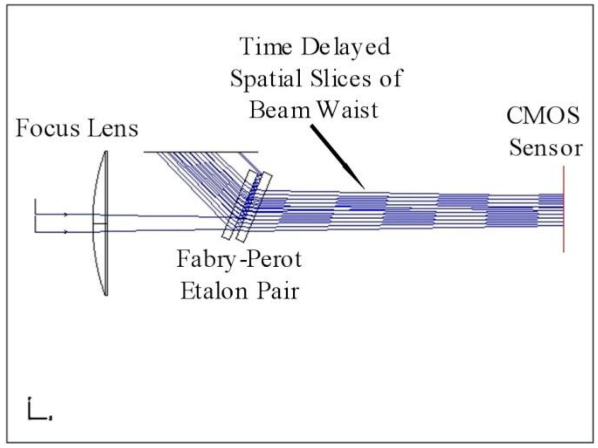

Figure 1: Basic BWA-CAM optical layout.

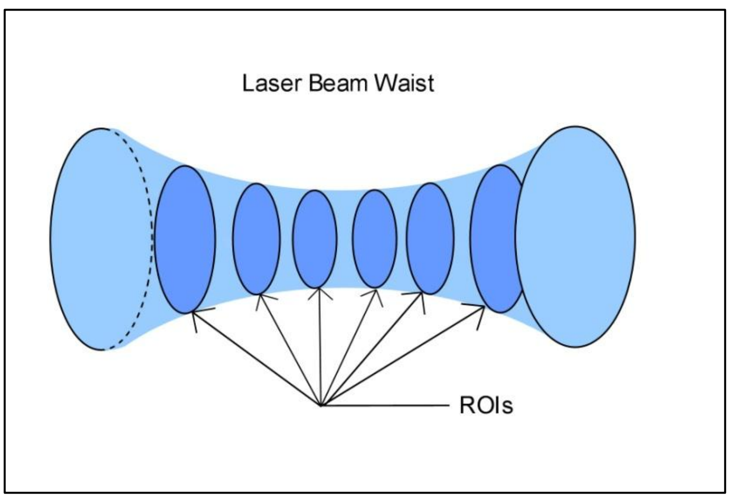

Figure 2: Graphical representation of time delayed spatial slices of the beam waist.

The BWA-CAM's software simultaneously analyzes the timed delayed spatial slices of the beam which results in a fast calculation of the laser's M-squared value. **Error! Reference source not found.** provides a graphical representation of the regions of interest (ROIs) that the software analyzes on the BWA-CAM's sensor.

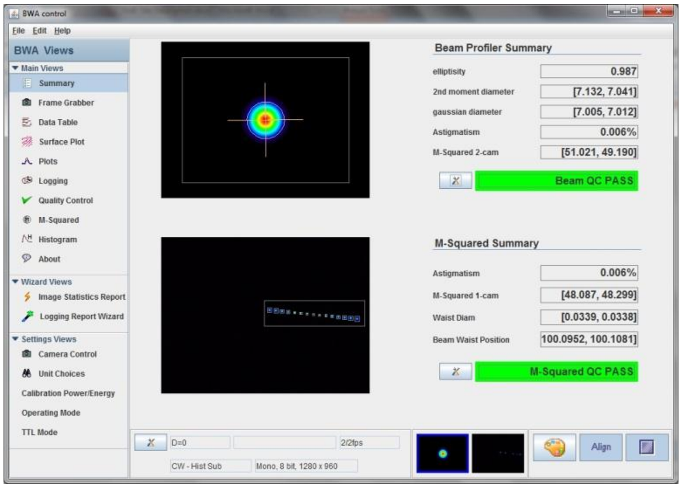

Figure 3: BWA-CAM & BA-CAM Summary Screen

Figure 3 shows a typical data summary screen for a two camera: BA-CAM and BWA-CAM setup. The top image is from the BA-CAM which measures the raw laser beam and the lower image is that of focused beam showing 15 regions of interest (ROIs). The right side of the summary provides user selected profile or M-squared data parameters. There is as well a quality control pass/fail flag that turns red should any of the user selected quality control parameters go out of range.

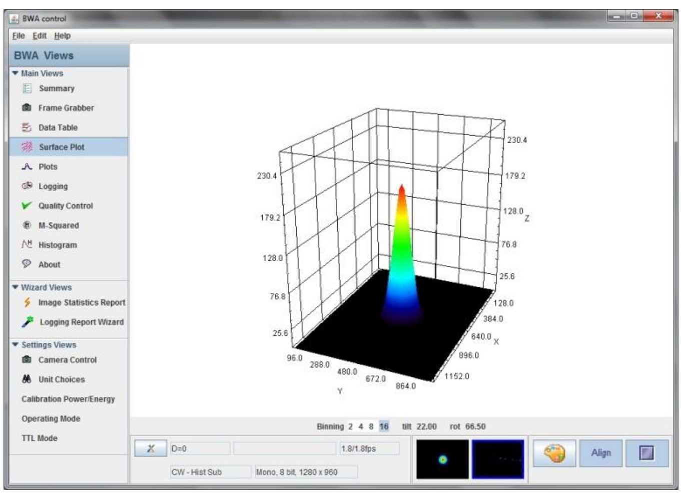

Figure 4:BA-CAM 3-D Profile plot

Figure 4 shows a 3-D, false color profile plot of the raw laser beam which is imaged on the BA-CAM. The profile can be rotated and tilted by clicking anywhere on the image and dragging.

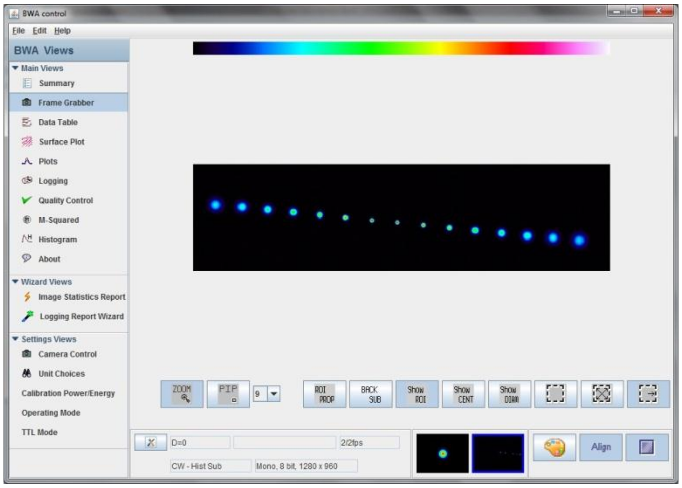

Figure 5: Zoom shot of the BWA-CAM frame grabber screen that is showing 15 regions of interest of the focused beam waist.

Figure 5 shows a screen shot of the BWA-CAM frame grabber screen in a “zoom” shot of 15 regions of interest from a focused laser beam. Here one can see the focus going in and out (left to right). All of these images are produced simultaneously and in real time on the CMOS sensor. It is these ROIs that our software analyzes spot size, divergence, astigmatism, beam waist position, Rayleigh length and of course the M-squared value.

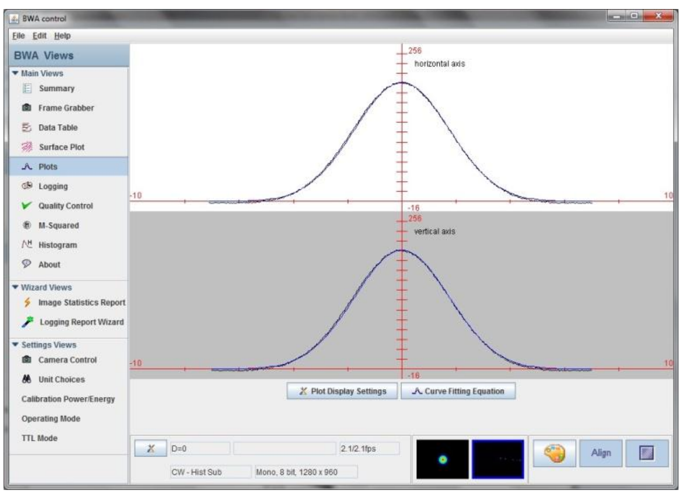

Figure 6: BA-CAM 2-D plot of raw beam profile.

Figure 6 shows a screen shot of a 2-D plot of a raw laser beam directed into a BA-CAM. The X and Y axes of the plot screen can be adjusted when the “Plot Display Settings” button is pressed to either expand or contract either or both axes. In addition, the curve fitting equation can be selected between “Gaussian”, “Super Gaussian” with mode order and “Super Donut” with its mode order.

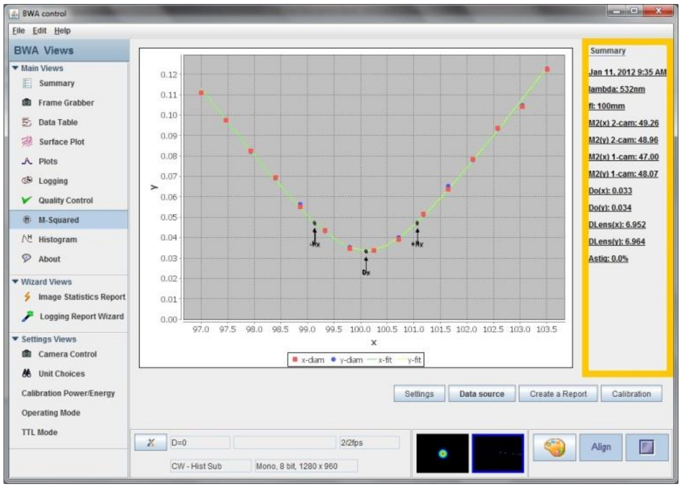

Figure 7: BWA-CAM M-squared plot screen

Figure 7 is a screen shot of the BWA-CAM's M-squared measurement. In this screen one can see the M-squared values as measured with the BA-CAM and BWA-CAM combination or the single BWA-CAM M-squared value. The X axis displays the focus position for the given focus lens used and the Y axis is the beam waist diameter value. The beam waist position and Rayleigh length tick marks are annotated for reference and the beam astigmatism and beam spot size at lens is shown in the data box to the right of the plot.

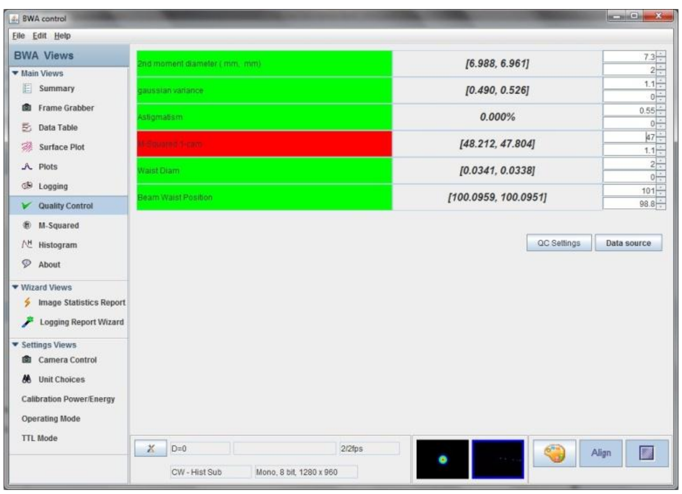

Figure 8: BA-CAM and BWA-CAM quality control settings screen

Figure 8 shows an example of laser beam profile parameters where the user can set the upper and lower limits for the user selected parameter values. If any parameter falls out of the user selected range, a flag is set where both the color of the parameter highlight turns to red from green. An optional USB output I/O interface can be sent to an interlock system to turn a system off when a value goes out of range. This is especially valuable for critical manufacturing processes where the performance of the laser and optical system must be held to a tight tolerance to avoid out of specification parts. Likewise, for very high power systems, some parameters going out of range could suggest that an optic(s) may be close to catastrophic failure and the user can stop it prior to optics self destructing under high power.

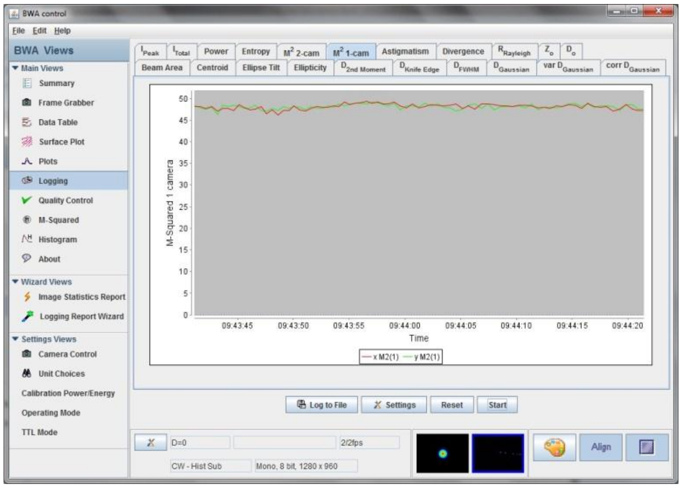

Figure 9: BA-CAM and BWA-CAM data logging screen

Figure 9 shows a data logging screen where the user can select any of the ISO 11146 and ISO 13694 laser beam parameters to track in real time. The logged data can aid the user in establishing the upper and lower limit values to set in the quality control parameter setting screen as well as simply providing the raw data for any type of measurement needed.

The BWA-CAM not only can be used with lower power lasers but high power, multi-kilowatt lasers as well. Figure 10 shows a screen shot of a BWA-CAM used with a 4 kW, CW fiber laser which had a feed fiber diameter of 200 microns and focused by a 200mm focal length objective.

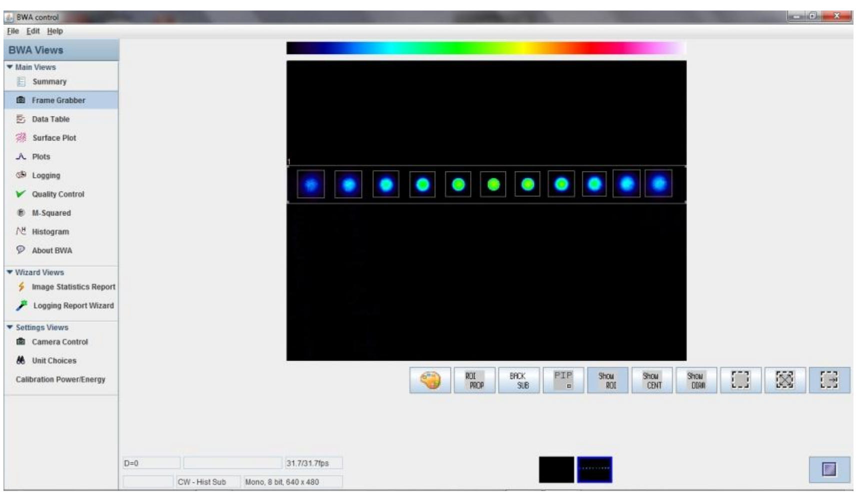

Figure 10: 4 kW CW fiber laser focused beam of a 200 micron fiber.

Not only can the BWA-CAM be used to measure critical M-squared parameters, it can be used as a diagnostic tool to help identify alignment problems with the laser, optical system or the combination of the two. Figure 11 shows a multi-kilowatt cw fiber system that has a misaligned source fiber to feed fiber. The image on the right shows a cladding mode in a 100 micron diameter feed fiber. The image on the right shows the same fiber after it was properly aligned using the BWA-CAM to tweak the adjustment to optimum alignment.

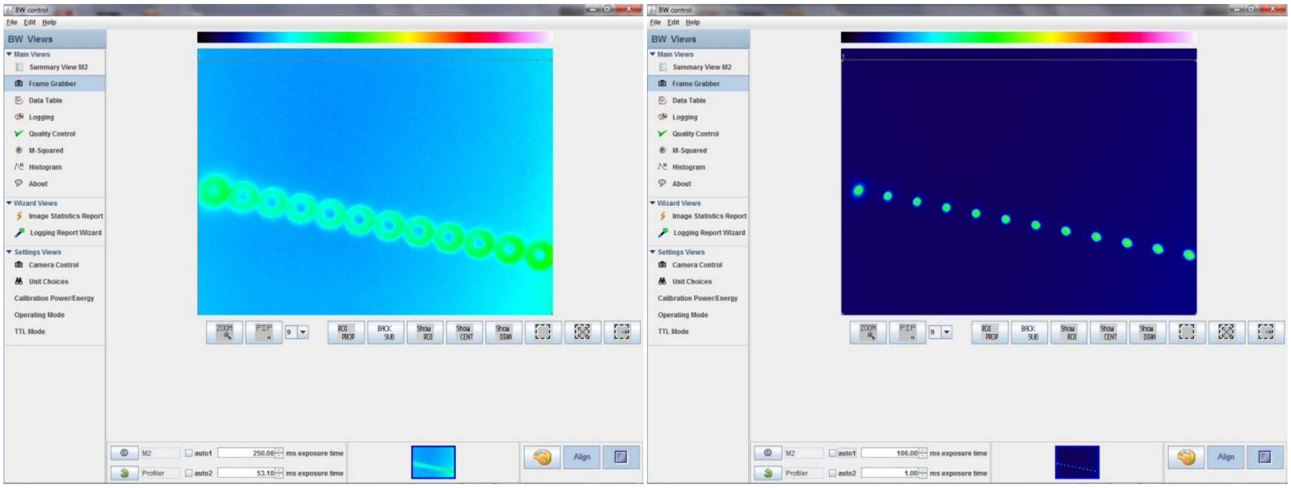

Figure 11: BWA-CAM showing that a delivery fiber is misaligned (right) to the source fiber and producing a cladding mode. The image on the right shows a properly aligned source to feed fiber of a 100um diameter feed fiber for a multi-kilowatt fiber laser.

In some cases an optical system may be "mysteriously" exhibiting a significant larger spot size than expected. Figure 12 shows such a case in a 3-axis galvo based system that utilized a 532nm fiber laser that should have focused more than 2X smaller then was being achieved in the materials being processed. The BWA-CAM clearly shows that the focused spot is manifesting severe coma which is an indication of an alignment problem with the optics of the 3-axis galvo system.

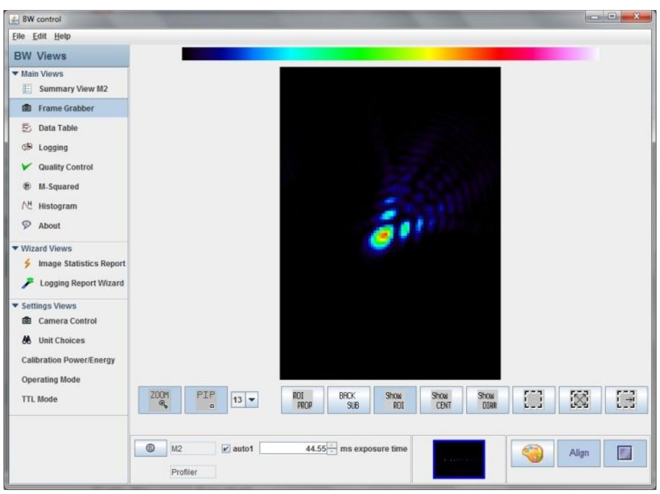

Figure 12: Zoom image of a 532nm fiber laser from a 3-Axis galvo system that is exhibiting severe coma.

Figure 13 shows another case of a 1064nm fiber laser system focused by a 3-axis galvo system where the spot size was again more than 2X out of specification. In this case the aberration seen is astigmatism that is due to misalignment of the 3-axis galvo system.

Whether it is basic laser M-squared measurement, quality control of a critical material processing application in production or trouble shooting a laser optical system, the Haas Laser Technologies' patent pending BWA-CAM is the best product on the market to achieve these tasks in a single, compact assembly and easy to use software package.

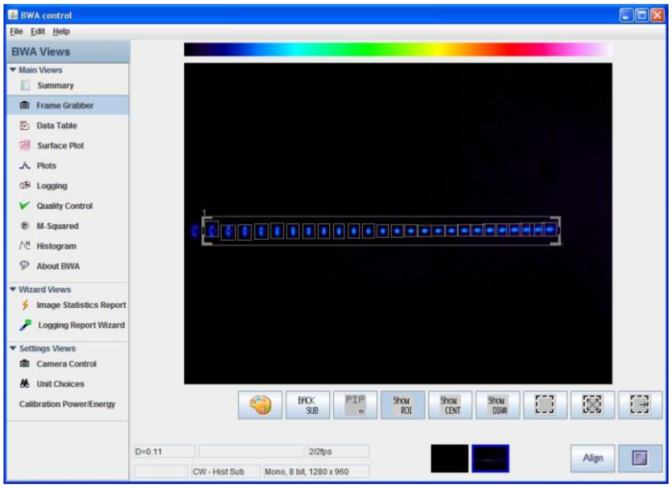

Figure 13: Pulsed, 1064nm fiber laser 3-axis galvo system exhibiting astigmatism.