The BCAM [3,4] is a simple optical instrument designed to monitor the geometry of large structures. It consists of one or two electronic cameras and one or two pairs of light sources, all integrated into a single enclosure. This enclosure mounts kinematically onto three steel balls.

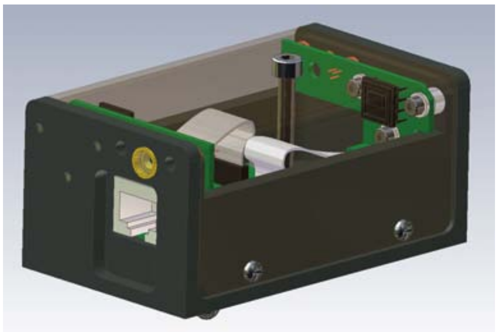

Figure 1: CAD drawing of a double ended BCAM, containing two cameras and four laser diode light sources. The enclosure is 91 mm long. The lid is shown transparent.

The word BCAM is for Brandeis CCD Angle Monitor. The cameras use CCD (charge-coupled device) image sensors and measure the bearing of light sources. The BCAM shown in Figure 1 uses red laser diodes [2] as light sources. There is no lens in front of the lasers. Instead, each laser produces a rectangular cone of light.

The camera consists of a plano-convex lens of focal length $f = 72$ mm, a 2 mm aperture, and a TC255P image sensor [1]. This sensor provides an array of 344 by 244 pixels, each pixel is 10 μm square. The field of view of each camera is approximately 30 cm by 40 cm at a range of 10 m. The optical system can be reduced to a virtual perfect thin lens and a virtual CCD [4]. The center of this virtual perfect thin lens is called the pivot point, and defines together with the center of the virtual perfect CCD the camera axis (see Figure 2).

Beneath each BCAM there are three depressions, a flat, a slot, and a cone. These allow the BCAM to sit kinematically on three quarter-inch (6.35 mm diameter) steel balls. The centers of these balls define a mount coordinate system (also called BCAM coordinates) [4]. Our calibration procedure allows us to determine the position of the camera pivot point and the direction of the camera axis, the rotation of the CCD and the position of the laser light sources in the mount coordinates. The calibration error, when added to the error in our measurement of kinematic mounts and the precision of the mounting procedure itself, gives us a total angular error of 50 μrad and translation error of 20 μm.

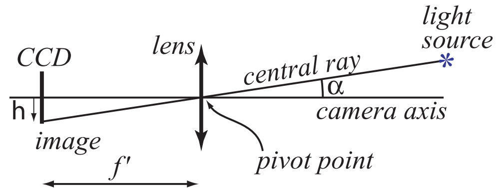

Figure 2: The measuring principle of a BCAM.

Measurement Principles A BCAM is analyzing the relative position of the center of a light spot that is projected onto the CCD. When looking at point-like sources the images need not to be in focus since the quantity of interest for the reconstruction - the center of intensity - does not change with defocus. Thus BCAMs need not be adapted to the individual source distances, which makes the technical implementation of this system easy and general. The intrinsic sensor resolution is 5 μrad, which corresponds to a center-finding precision on the CCD of 0.4 μm. This resolution can be achieved for separations between the BCAM and its source from 1 m to 20 m.

Readout System Each BCAM provides an RJ-45 socket through which the lasers and the CCDs are controlled, and the image pixels are retrieved. The RJ-45 socket is an LWDAQ Device Socket, for use with the Long-Wire Data Acquisition System 5].

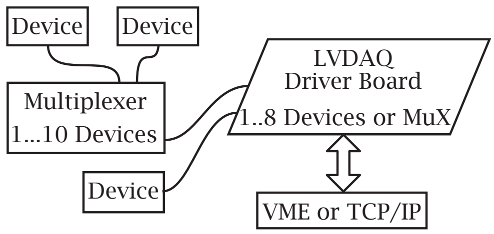

Figure 3: LWDAQ connection scheme

This DAQ system consists of a driver board that connects up to 8 devices or multiplexers. The driver board exists as VME version or as stand-alone version which is operated via TCP/IP. One type of cable (solid core twisted pair) connects to either type of element. The maximum cable length between the driver and the device is 130 m.

[1] The TC255P is made by Texas Instruments
[2] Such as the DL3147-031 by Sanyo.

[3] Hashemi et al, The BCAM Camera, ATLAS note MUON-2000-024.
[4] Daniels et al, BCAM Calibration, ATLAS note MUON-2000-026.
[5] Hashemi, LWDAQ Specification, on web site.