Bonn Shutters - ever growing?

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ABSTRACT

About ten years ago the first "Bonn Shutter" with an aperture of 110mm was developed for BUSCA, the Bonn University Simultaneous Camera. Since then smaller and larger precision exposure shutters for astronomical CCD cameras have been developed starting at a 60mm aperture for typical 4k CCDs. The largest shutter so far has an aperture of 480mm x 480mm and was built for the PanSTARRS prototype telescope and camera. An even larger system with an aperture of 600mm diameter is now being built for DECam the Dark Energy Survey camera.

Here we describe the actual developments and the procedures that are used to qualify the performance of the large format Bonn Shutters.

Keywords: Exposure shutters, wide field cameras

1. SHUTTER GROWTH

Bonn shutters of various sizes are now used at many observatories from Australia (Siding Springs) through Europe (La Palma) to the US (e.g. Kitt Peak) including Hawaii (Haleakala). The growth of the shutters is illustrated with Figures 1 and 2. Over the 10 years almost 30 devices were developed. This is best seen in Fig. 2. Interestingly the size of the largest Bonn Shutters has grown almost linearly over the past 10 years which indicates that the same is probably true for the growth of the linear size of the largest mosaic cameras.

Figure 1. A collection of shutters of various sizes and at various stages of completion together with the authors (from left: Martin Polder, Klaus Reif, Philipp Müller). The smallest shutter (top left) is 100mm, below 280mm. The door size shutter in the center is for Decam. It has a circular aperture of 600mm. At the right hand side is the base plate of a new Pan-STARRS shutter with its 480mm aperture.

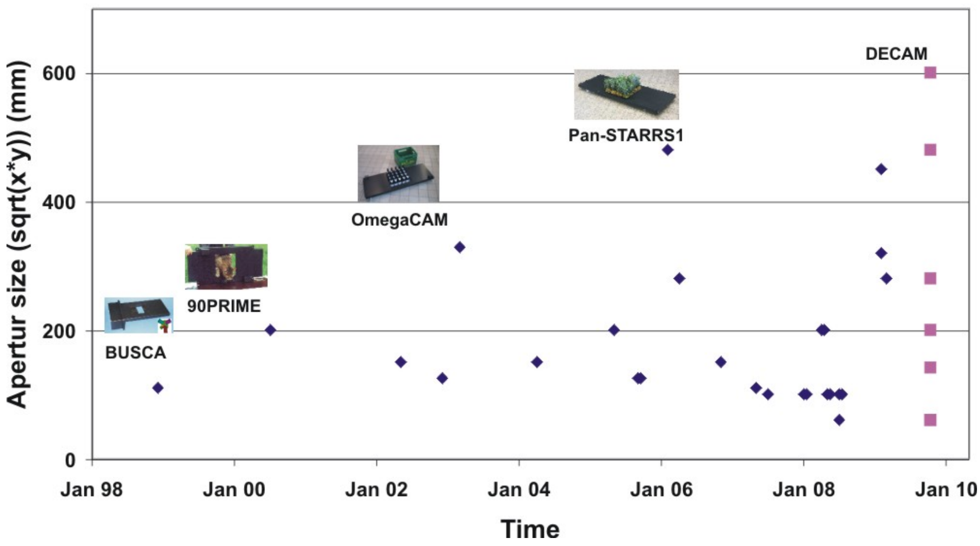

Figure 2. The diagram shows aperture sizes vs. completion dates for the Bonn Shutters that have been built for various observatories and projects (diamonds). Square symbols are for shutters that are currently manufactured.

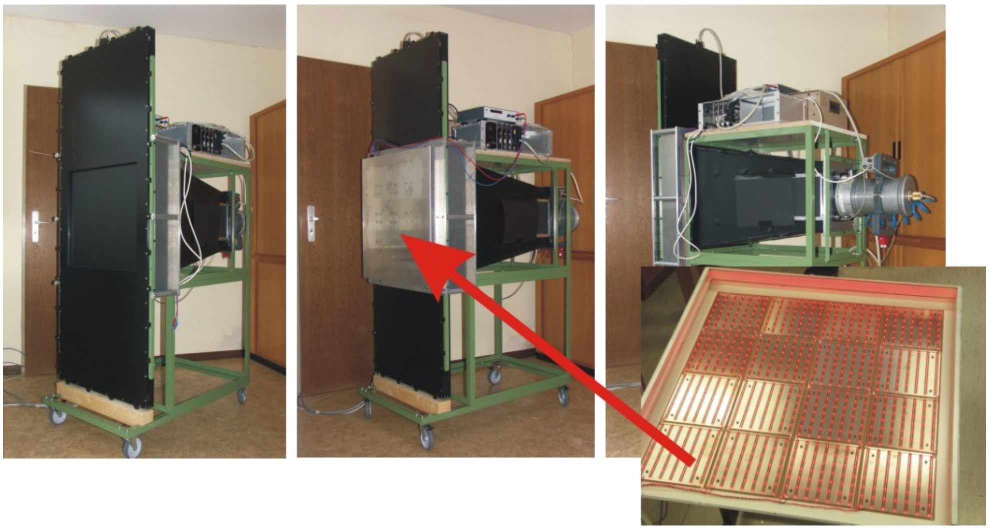

Figure 3. The shutter test stand is designed to take focussed images of the shutter aperture while the shutter is in operation. A mosaic of LED arrays serves as light source. Images are taken with one of our cryogenic astronomical CCD cameras.

2. PERFORMANCE TESTS OF LARGE FORMAT SHUTTERS.

The performance of the largest shutters (e.g. OmegaCAM, Pan-STARRS, WIYN-ODI) was carefully studied in the lab. Measurements are usually made at room temperature and in a cold chamber (-15C to -10C). Here the results for the ODI shutter are presented.

A test stand (Fig. 3) was designed such that the shutter was in the vertical orientation because this is the most demanding one: While the blades move up and down there is maximum load on the motors and maximum

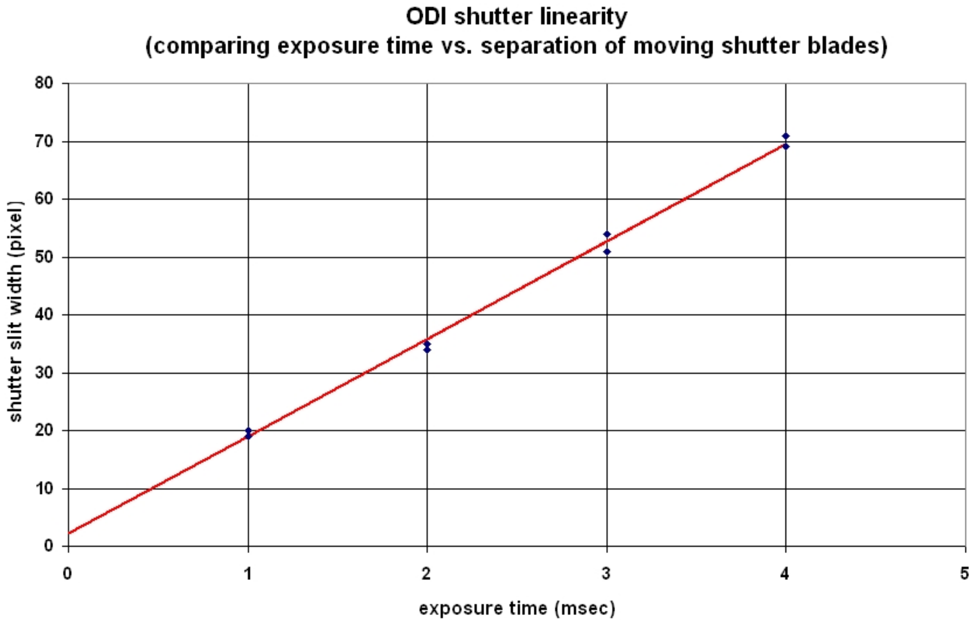

Figure 4. ODI shutter linearity at millisecond exposure times.

load difference between upward and downward motion.

The basic procedure is to take focussed images of the shutter aperture plane (linearity, homogeneity) or to just collect photons (light tightness).We use a cryogenic CCD system with or without a SLR camera lens. The aperture can be illuminated by a lightbox with a mosaic of LED arrays as a lightsource. Two diffusing screens separated by a few centimeters are mounted on top of the LEDs (not shown here).

2.1. Precision, repeatability, linearity

This is determined by how fast and how reproducible the shutter reacts on the shutter open/close signals. With a measured delay between exposure control signals and the first stepper motor step of $< 100\,msec$ this reaction time is very low. This can be demonstrated e.g. via linearity measurements at very short exposure times (few msec) where those errors would produce a measurable scatter of the separation of the shutter blades i.e. of the width of the slit while moving at constant speed.

The width of the moving slit was determined by taking flash images with a normal digital camera during shutter operation for exposure times from 1msec to 4msec. On the digital images the slit width was measured (see Fig. 4). The scatter w.r.t. the lin. regression line shows that the exposure accuracy is of the order of $200\,\mu$s.

2.2. Homogeneity

We have investigated non-homogeneities at very short exposure times were they are easy to detect. We adopted a procedure commonly used at telescopes: Flat field exposures taken with the exposure time in question (0.1sec) are compared with (i.e. divided by) frames of significantly longer (50x) exposure times which serve as reference. "Flat fields" means focussed images of the shutter aperture plane taken with one of our astronomical CCD systems (see previous section). In all cases the deviations from homogeneity stay within 1% (at 0.1sec). This corresponds to an absolute timing accuracy of 1msec (see Fig. 5).

2.3. Light tightness.

The shutter blades and the shutter body are not in close contact. Instead inside the shutter body we have light trap stuctures which force the light to many reflections at black painted or anodized surfaces. The test stand

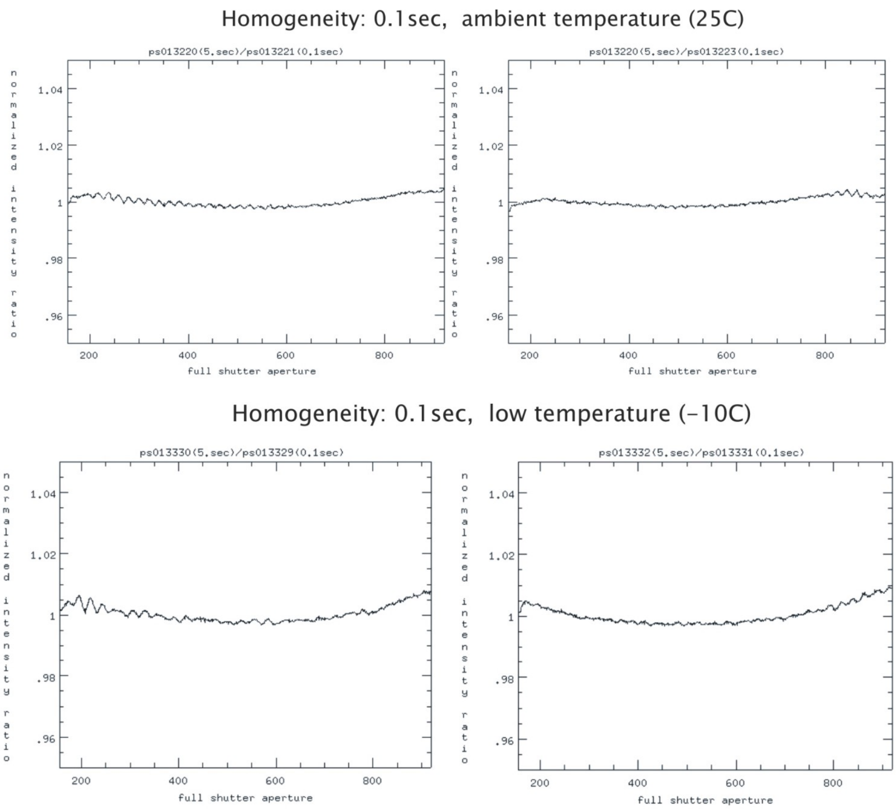

Figure 5. Shutter exposure homogeneity at 0.1 sec exposure time measured for both movement directions (left: up, right: down) at ambient temperature and at -10C. The abscissa covers the complete width of the shutter aperture (450mm). The diagrams show a ±5% range on the y-axis.

was used as shown in Fig. 3 (left). It was placed in the lab at normal illumination (all lights on) with the shutter facing a large white screen at a distanc of about 1m. The camera lens was removed from the CCD dewar.

In these conditions a 1msec exposure led to about $7000\,e^{-}$/pixel. In a 1h dark image (ODI shutter closed but the CCD camera shutter open) we find $< 100\,e^{-}$/pixel, i.e. $< 3\,10^{-2}\,e^{-}$/sec/pixel

Table 1. Test results of the WIYN-ODI Shutter (450mmx450mm).

Minimum exposure time	1 msec
Exposure time error	200 μsec
Exposure inhomogeneity	$< 1\,msec$
Dead time	0.85 sec
Light tightness	$< 3\ 10^{-2}$phot/sec/pix at room light

3. COMPACT SHUTTERS.

In parallel to our large shutter developments we saw a growing number of requests for "small" aperture shutters. With new types of tiny high torque stepper motors an overall flat 100mm aperture shutter with a total thickness of only 23mm was developed The principle of operation and the performance are the same as for the other Bonn

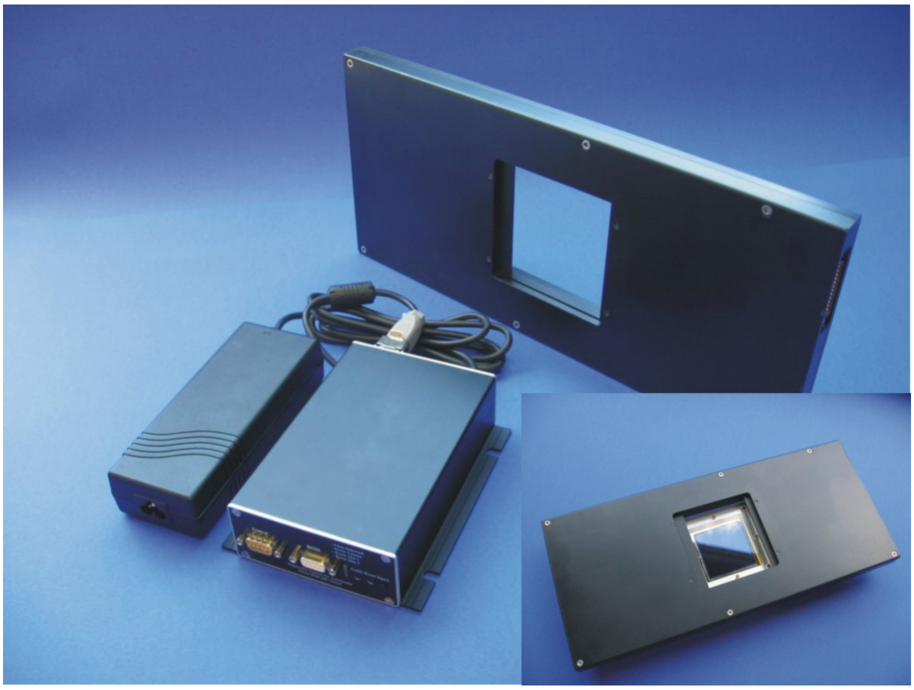

Figure 6. A compact 100mm aperture shutter. Lower right: 100mm shutter with a 4k×4k 15μ CCD.

Shutters. At the same time the shutter control unit was redesigned to make it also compact and light weight. This compact control electronics is now standard also for the largest shutters.

4. SUMMARY

Bonn shutters that have been tested so far show similar performance parameters, independent from their physical size. Up to an aperture size of 480mm×480mm (PanSTARRS) the exposure time errors are not larger than 200 μsec and exposure inhomogeneities are below 1 msec.

5. LINKS

BUSCA online report: `http://www.astro.uni-bonn.de/~ccd/busca/ca_newsletter/`
Bonn Shutter homepage: `http://www.astro.uni-bonn.de/~ccd/shutters/`