Bonn Shutters - ever growing?

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Abstract

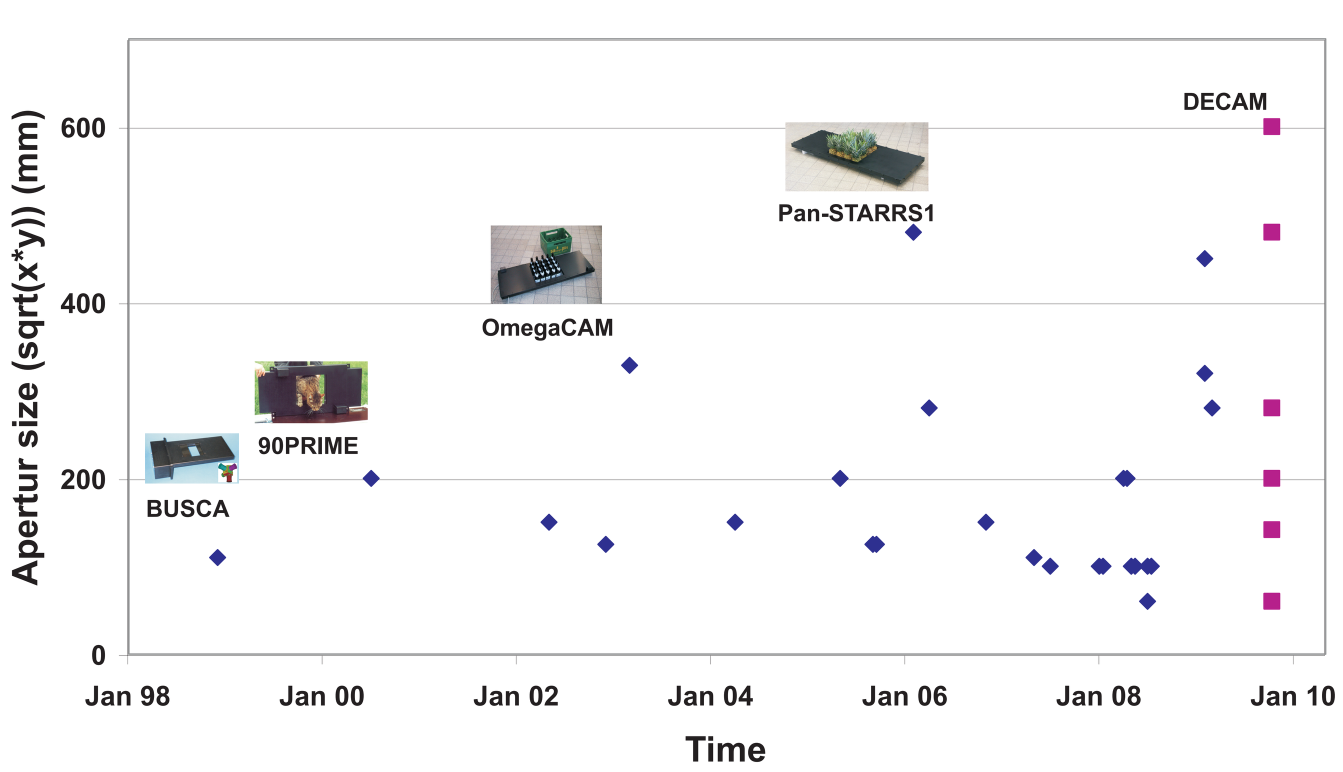
About ten years ago the first "Bonn Shutter" with an aperture of 110mm was developed for BUSCA, the Bonn University Simultaneous Camera. Since then smaller and larger precision exposure shutters for astronomical CCD cameras have been developed starting at a 60mm aperture for typical 4k CCDs. The largest shutter sofar 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 beeing 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.

What's there

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..

Shutter Growth

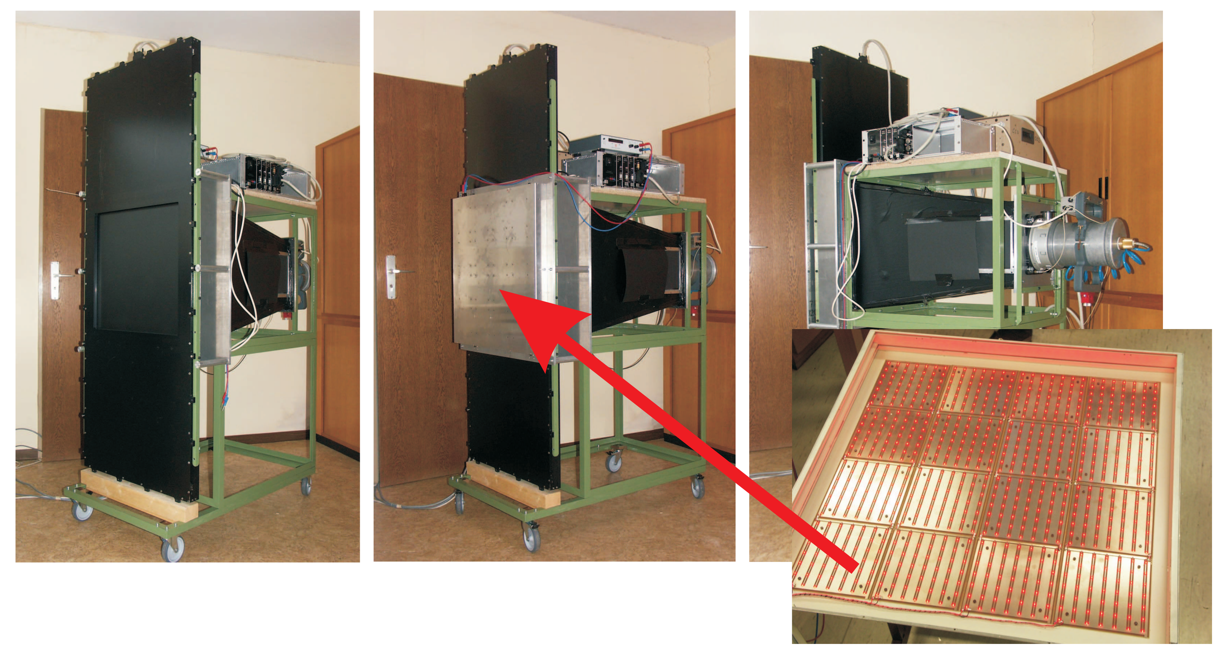


The diagram shows aperture sizes vs. completion dates for the Bonn Shutters that have been built for various observatories and projects (diamonds). Square symbols are for shutters that are currently manufactured. The size of the largest Bonn Shutters has grown almost linearly over the past 10 years.

Performance tests of large format shutters

The performance of the largest shutters (e.g. OmegaCAM, Pan-STARRS, WIYN-ODI) was carrefully 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 discussed.

Test equipment

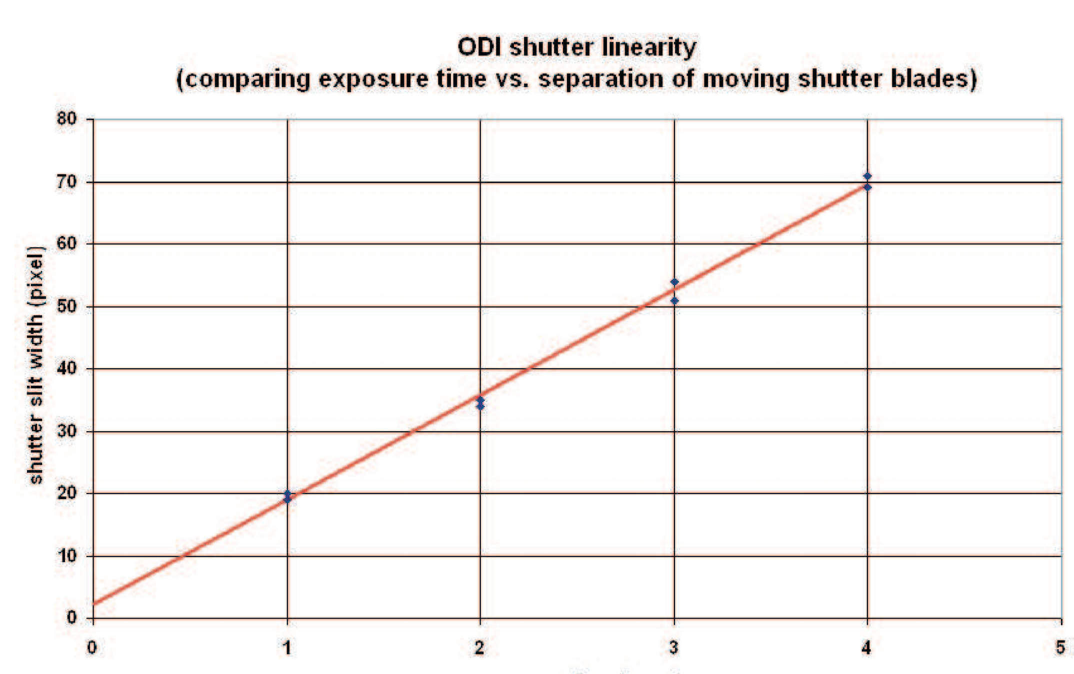


A test stand was designed such that the shutter was in the vertical orientation because this is the most demanding one: While the blades move up and down there is maximum load on the motors and maximum load difference between upward and downward motion.

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).

Precision/repeatability/linearity

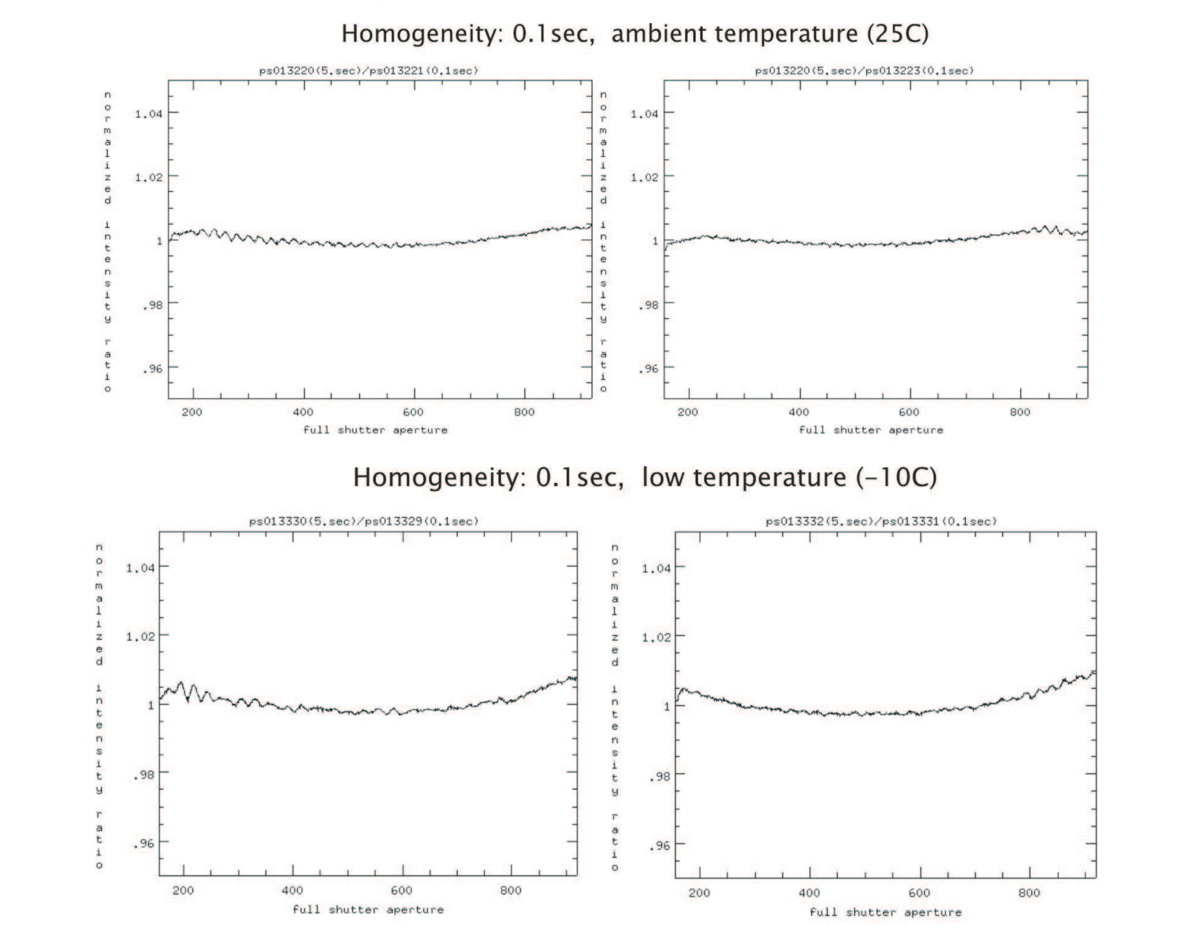
This is determined by how fast and how reproducible the shutter reacts on the shutter open/close signals. With a measured delay between exposure control signals and the first stepper motor step of <100µs this reaction time is very low. This can be demonstrated e.g. via linearity measurements at very 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 diagram). The scatter w.r.t. the lin. regression line shows that the **exposure accuracy is of the order of 200µs**.

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" in this case are focussed images of the shutter aperture plane taken with one of our astronomical CCD systems (see section on "Test equipment").



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. In all cases the deviations from homogeneity stay within 1% (at 0.1sec). This corresponds to an absolute timing accuracy of 1msec.

Light tightness

The shutter blades and the shutter body are not in close cantact. 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 was used as shown in the picture. 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 **$7000e^-$/pixel**.
In a **1h dark image** (ODI shutter closed but the CCD camera shutter open) we find **<$100e^-$/pixel**, i.e. **<3 $10^{-2}e^-$/sec/pixel**

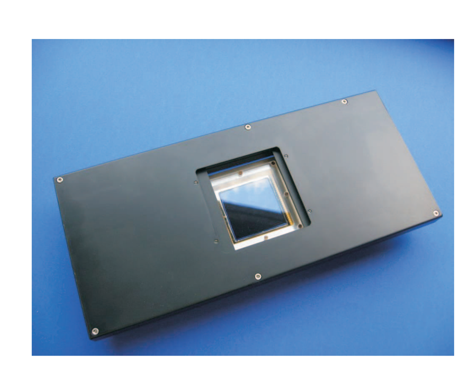
Test results of the WIYN-ODI Shutter (450mmx450mm):

Minimum exposure time:	1msec
Exposure time error:	200µs
Exposure inhomogeneity:	<1msec
Dead time:	0.85sec
Light tightness:	<3 10-2 phot/s/pixel at room light

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 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.

100mm shutter with old and new electronics



100mm shutter with a 4kx4k 15µ CCD.

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