SNDICE: a Direct Illumination Calibration Experiment for MegaCam

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CFHT

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The SNLS calibration highlighted systematics errors related to instrument modelisation (cf N. Regnault poster). And because of the increasing of the number of SNeIa detected and studied, these uncertainties will become more and more dominant. Moreover, all the future surveys are trying to develop calibration procdures competeting with standard stars based calibration : such new calibrations implie precise modelisations of atmospheric absorption and instrument response function. SNDICE is a first attemp to study such an instrument modelisation and monitoring. It will be installed at Fall 2007. We aim to be able to calibrate the instrument with an accuracy of 0,5 % and to monitore it with a relative precision of 0,05 %.

General overview

SNDICE principles

We aims to modelise a detailed response of the instrument (CFHT primary mirror + MegaPrime) and to monitore the parameters of this modelisation.

SNDICE will be composed of a calibrated light source and calibrated detectors. We'll use a calibration bench developped in Paris to transfer calibration from photodiodes delivered by standard institutes (NIST, Gigahertz Optik) to the sources and detectors that will be installed at CFHT.

LEDs are now sufficiently powerfull to be used for such an application. And they have all the required feautures : stability of the emitted light, easy to controle, point like sources. Their spectrum width ($\Delta\lambda/\lambda \approx 7\%$) implies that we'll need around 20 LEDs to cover Megacam bandwidth (from 300 to 1000 nm) and will avoid to deal with fringing problems.

The power of the LEDs allows to perform all the calibration measurements during daytime with very short integration time. There will be several procedures that could be performed at different time scales : extensive calibration (few hours moreless once a month) and fast monitoring (few minutes each day).

Megacam instrumental calibration device

The SNDICE will operate in a direct illumination setup, where the calibrated light source illuminates the primary mirror (see below). The reflected light then gets to the camera and the photodiodes. The angular size of the emitted beam is calculated to cover the whole field.

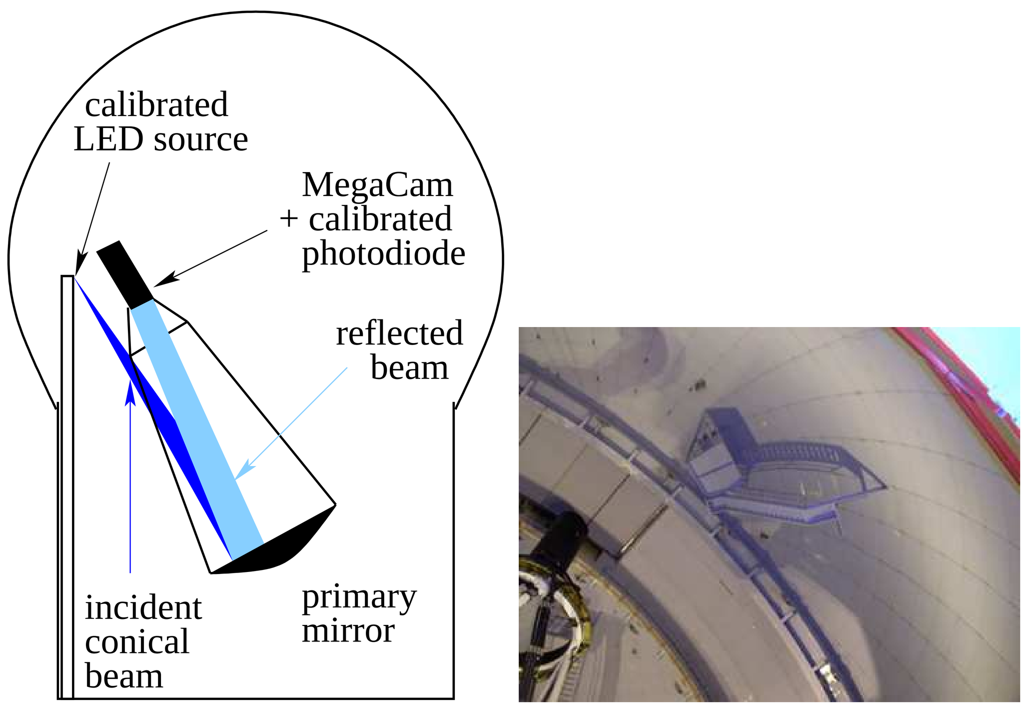

Figure 1: Inside the CFHT dome: the LED source will be attached to this platform.

The LED source will be in a fixed position on the CFHT dome (see picture), with a support mechanism allowing angular movement in both directions to explore the full space of positioning parameters.

The photodiodes will be Cooled Large Area Photodiodes (CLAPs) due to the distance to the source and the low level of noise required. Since the LED source will be calibrated absolutely, the photodiodes are an independent measurement of the stability of the source. They are not needed theoretically for absolute calibration of the instrumental response of the camera. However, they will enable us to monitor closely the stability of the calibration system and the stability of the telescope optics, especially the deposition of dust. To do this, we can place CLAPs in three different positions (see below).

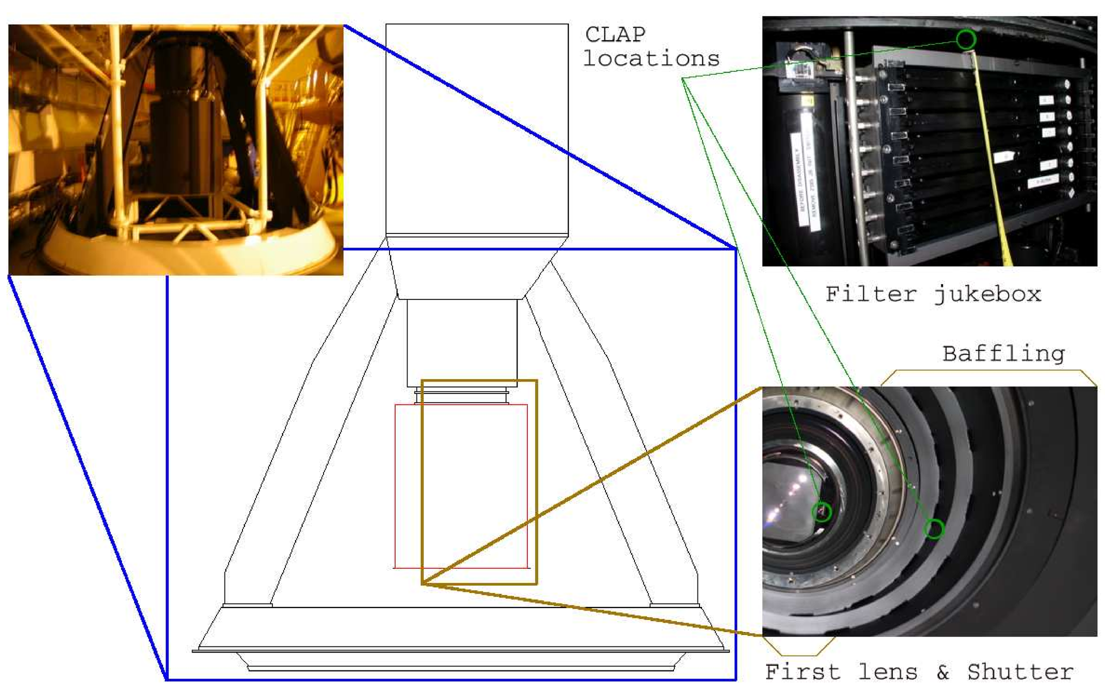

Figure 2: Three proposed positions for CLAPs: inside the baffling, behind the first lens using the same light path as the guiding (on the side of the shutter), and between the filter jukebox and the MegaCam cryostat, right next to the cryostat opening.

SNDICE Elements

LED source

Since the width of an LED spectrum is approximately $\Delta\lambda/\lambda \approx 7\%$, the LED source in SNDICE will include at least 20 LEDs in order to cover the whole spectral range of MegaCam. In particular, LEDs with spectra at the edge of the filters will allow us to monitor closely any evolution in the bandpass of the filters.

The LED source module will define a conical beam from each LED, and include a guiding system to measure its position relative to the camera. To insure the stability of the illumination, each LED will be current-controlled. The module will also include an off-axis photodiode to monitor each LED individually. The electronic card will include a feedback loop based on this measurement to correct any fluctuation in the luminous intensity.

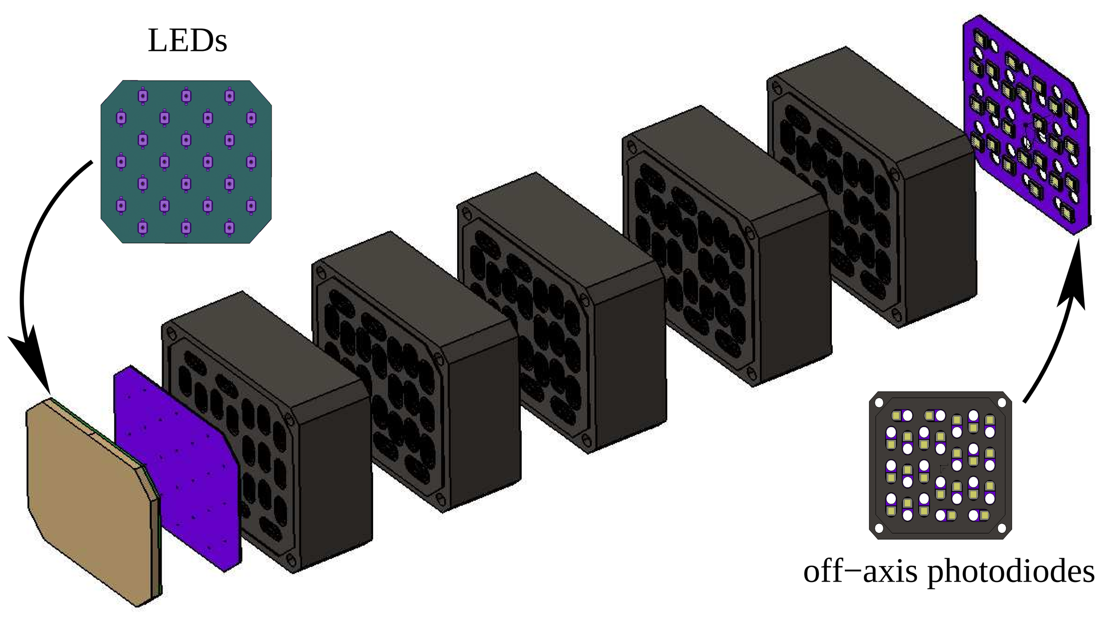

Figure 3: Design of the LEDs module with the LED plane, first mask, baffling and end mask with monitoring off-axis photodiodes.

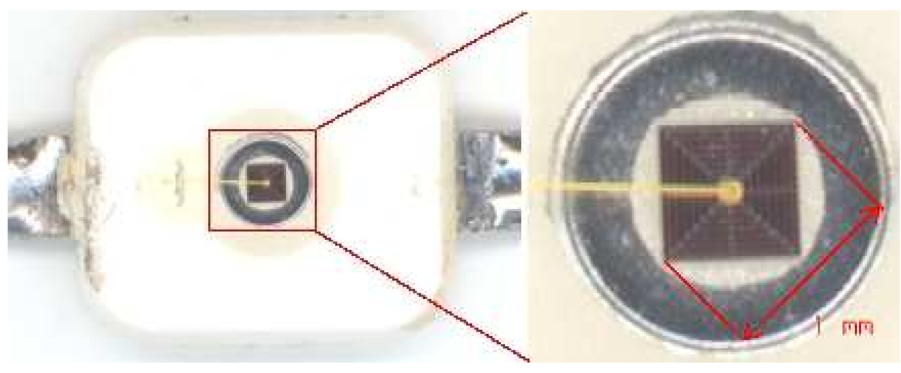

Figure 4: A Golden Dragon OSRAM LED, with a zoom on the photoemitting 'dice' (dark square, in center). The golden wire is one of the electrodes.

Cooled Large Area Photodiode

To adapt the space available close to the camera, the photodiode modules will be separated into three elements : the CLAP itself, a front-end box as thin as possible (a.k.a. 'pancake' box) for the amplification of the signal, and a back-end box for digitization and signal acquisition (common to all CLAPs).

Figure 5: The Hamamatsu S3477 photodiode (including a Peltier cooler).

The measurement of the CLAP currents will be done with an integrated circuit designed at LPNHE for this purpose (the 'Low Current Amplifier' ASIC), which includes a 1 GΩ current amplifier stage and a dual gain amplifier stage (gain 3 and gain 96).

Calibration

3D Calibration bench

Preliminary calibration on a test bench is critical for the accuracy goals. We will calibrate both the CLAPs and the LED source on the bench, using the movement along the three axes. Currently the range of distances available is 1 to 2.5 meters (see picture). We plan to extend this to a 13.5 m range to match the focal length of the telescope.

Figure 6: Test bench inside a black box for 3D calibration of the LED source.

LEDs light studies

The main concerns regarding the use of LEDs as calibration sources were the attainable intensity of the beam, and its stability.

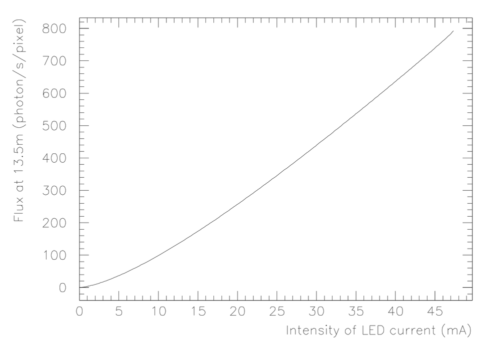

Figure 7: Flux in photons/s/pixel expected on MegaCam as a function of the current in a Golden Dragon LED (based on test bench measurements on a photodiode). The current in a Golden Dragon can go up to 300 mA, giving then 20,000 photon/s/pixel.

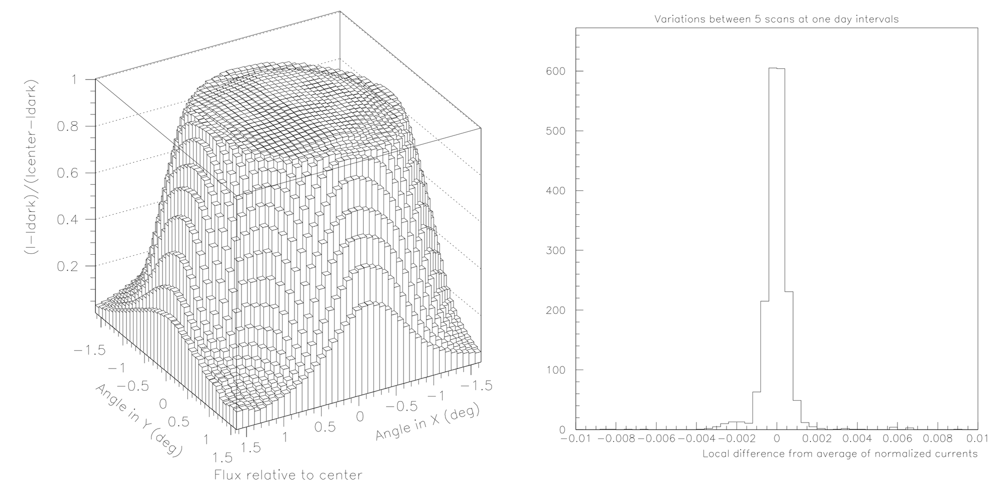

Figure 8: Map of the luminous field (relative to center) of an Agilent LED in the first prototype of LED source (left). Stability of the field map: local difference from average of five scans taken at one-day intervals (right).

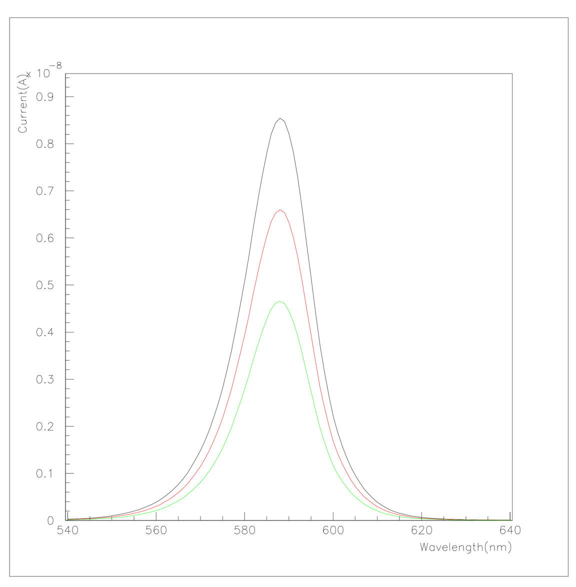

Figure 9: Spectrum of an orange Golden Dragon LED for three different LED currents.

Cooled photodiode sensitivity and readout noise

We have measured the dark current on the S3477 Hamamatsu CLAP, and found it decreasing exponentially with temperature as expected. At lab temperature (22 °C), the cooling power of the Peltier module allows to cool the photodiode down to -15 °C. With additional refrigeration, we got down to -23.5 °C, and measured a dark current of 50 fA. Extensive tests have been conducted on the low current amplifier ASIC, including the calibration of the electrical constants and noise spectrum measurements. We are now working on the integration of the current amplifier stage with the voltage amplifier stage.