Status of the CCOB–NB

Camera Calibration Optical Bench – Narrow Beam

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Outline

CCOB Narrow Beam concept and implementation

Light throughput measurement

Optics aligment constants

Conclusions

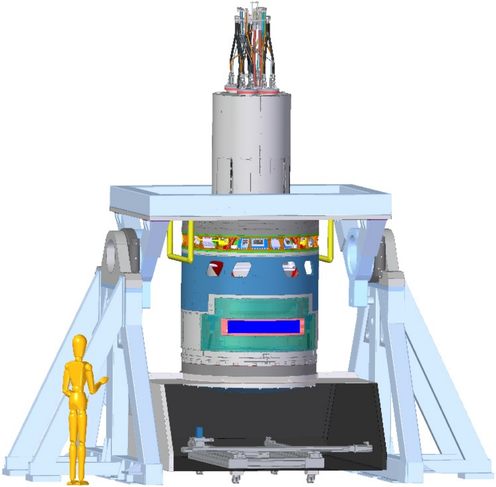
CCOB–NB, what for?

- Commissioning of the integrated camera (LCA-283-F)
  - precise measurement of the **optical throughput**
  - determination of the **optics alignment/tilt**
  - mapping of the **baffle** between L1 and L2

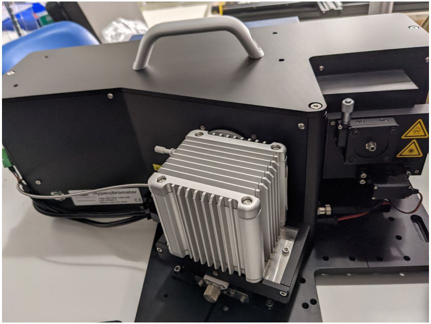
- The Camera Calibration Optical Bench Narrow Beam (CCOB-NB) is a calibrated and (X,Y)+(Θ, Φ) positionable pencil beam monochromatic light source.
  - allows the illumination of the focal plane through the full optical system from a variety of incident angles in the 6 spectral bands
  - 2.5 mm wide monochromatic beam ($\delta\lambda \sim 1$ nm)
  - from 300 nm to 1100 nm

In–operation schema

Designed and built at LPSC, delivered to SLAC in Summer 2021



Hardware



- ‘hyperchromator” from Mountain Photonics with high speed shutter
- big XY table, goniometer, rotative stand, moving arm for NIST diode

Current state

New dark tent updates

Darkened the CCOB-NB XY stage area

CCD mounted on adjustable Z point within tent

Light source + target now darkened

Room for so much **dark** activities!

- CCOB-NB beam profiling in X, Y, Z
- Testing of full run plan in XY+Θϕ
- Pinhole filter blank testing with pinhole mounted at fixed Z
- Uniform illuminator beam profiling

Work lead by Andrew Bradshaw @ SLAC

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Throughput measurement

– Goal: verify the full light throughput of the integrated camera, including filters

– "The full LSST beam input on the camera at L1 is an annulus approximately 0.6 meters in diameter subtending angles between 14 to 26 degrees from the optical axis."

– Narrow beam configurations to sample that pupil:

  - high fidelity: choose a single Focal Plane location, using 15 wavelengths in each of the 6 bands and 100 aperture spots.
  - full scan: use 9 wavelengths per band and 10 aperture spots for one location per raft

  $\rightarrow$ $\sim$20000 images or 1 week of data taking

– Configurations are being prepared just now through raytracing simulations (A. Rasmussen)

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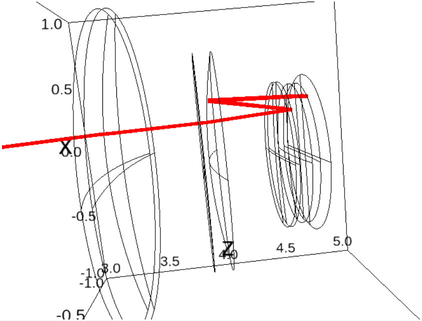
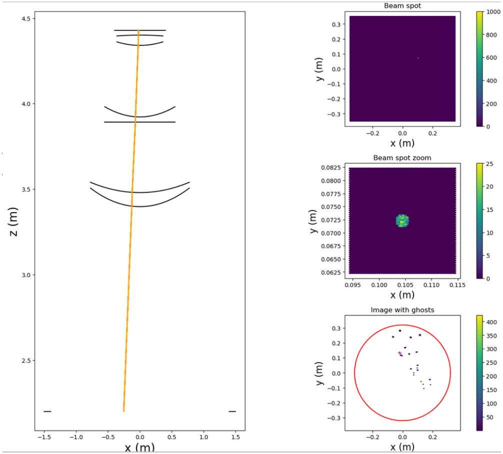
Optics alignment

- The position and orientation of each optical element is measured by the metrology team with respect to a few reference points of the camera structure.
- The goal is to verify metrology by using the position of secondary images produced by the reflections on optical surfaces of a thin light beam.

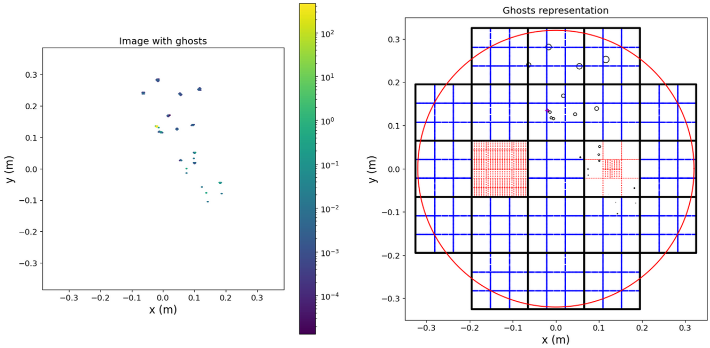


"ghosts" package

- Built as a Batoid plugin: ghosts simulation and analysis [github:bregeon/ghosts]
- example: beam at an angle to spread seconday images all over
  - geometry with no filter, 1 main spot + 20 ghosts spots

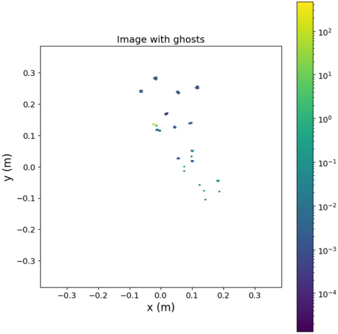


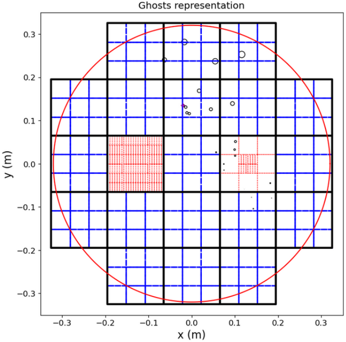
“ghosts” representation



- ghosts are characterized by their position, diameter and flux
- simple algorithm based on the truth of the simulation
- DM has a peak finder algorithm that can be tuned for ghosts images

“ghosts” representation

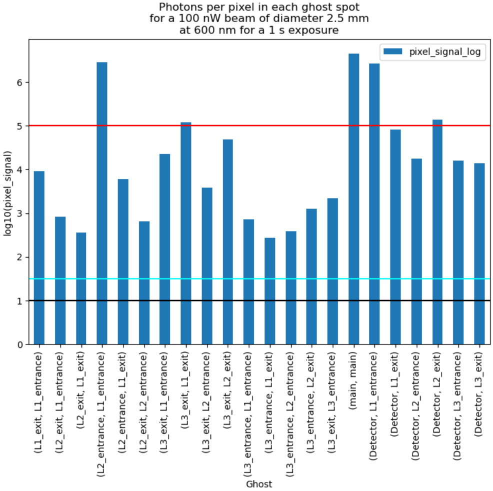




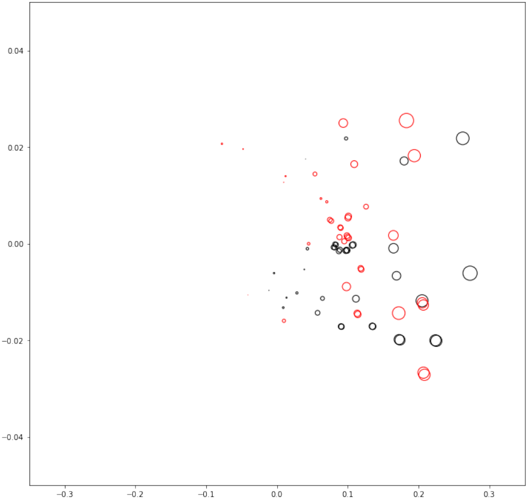
	beam_id	geom_id	index	name	pos_x	std_x	pos_y	std_y	width_x	width_y	radius	radius_err	flux	surface	n_pixels	pixel_signal
0	0	0	0	(L1_exit, L1_entrance)	0.056498	0.000271	0.026311	0.000271	0.001066	0.001088	0.000538	1.096830e-05	0.301186	0.910748	8197	9.433834e+03
1	0	0	1	(L2_exit, L1_entrance)	0.017302	0.000894	0.168538	0.000894	0.003523	0.003537	0.001765	7.046005e-06	0.277805	9.785781	88072	8.098324e+02
2	0	0	2	(L2_exit, L1_exit)	-0.016875	0.001376	0.281373	0.001376	0.005421	0.005473	0.002724	2.618720e-05	0.289259	23.303916	209735	3.540867e+02
3	0	0	3	(L2_entrance, L1_entrance)	0.121685	0.000010	-0.059080	0.000010	0.000040	0.000041	0.000020	3.666263e-08	0.289259	0.001287	12	6.409390e+06
4	0	0	4	(L2_entrance, L1_exit)	0.100468	0.000345	0.018343	0.000345	0.001359	0.001379	0.000684	9.837642e-06	0.301186	1.471606	13244	5.838411e+03
5	0	0	5	(L2_exit, L2_entrance)	-0.062959	0.001049	0.239891	0.001049	0.004133	0.004244	0.002094	5.506202e-05	0.301186	13.778513	124007	6.235682e+02
6	0	0	6	(L3_exit, L1_entrance)	0.142590	0.000172	-0.104178	0.000172	0.000682	0.000703	0.000346	1.063578e-05	0.256238	0.376619	3390	1.940856e+04
7	0	0	7	(L3_exit, L1_exit)	0.184959	0.000056	-0.079549	0.000056	0.000219	0.000227	0.000112	4.084139e-06	0.266804	0.039150	352	1.944048e+05
8	0	0	8	(L3_exit, L2_entrance)	0.099324	0.000412	0.032529	0.000412	0.001622	0.001622	0.000811	2.386852e-07	0.277805	2.066674	18600	3.834587e+03
9	0	0	9	(L3_exit, L2_exit)	0.074802	0.000109	-0.014935	0.000109	0.000425	0.000413	0.000209	5.984739e-06	0.289259	0.137695	1239	5.992662e+04

“ghosts” fluxes

- the thin beam is powerful: 10e9 photons per second, but is equipped with a high speed shutter (down to $\sim$20 ms)
- main spot will be highly saturated, so as a couple of ghosts



Ghosts images visualization



- 2 series of ghosts images for the same incident beam (just 10 cm off–axis)
- 2 randomized camera geometries

Distance between “ghosts” maps

- start from 2 lists of beam spots parameters
- consider statistical error on spots positions and diameters
- compute distance for each ghost spot to all neighbors, to find the nearest neighbor and associate 2 spots
  - might not find the correct one?
- compute a pure Euclidean distance between the 2 series of spots
  - similar to a bare χ^2
- also tried to add scaled spot diameter as additional parameter
  - does not seem to be really necessary

Distance formula

ghost spot $g_{r,i}$ has parameters $[x_{r,i}, dx_{r,i}, y_{r,i}, dy_{r,i}, rad_{r,i}, drad_{r,i}, p_{r,i}]$ for position in x and y with uncertainties dx and dy, radius rad and uncertainty $drad$ and intensity.

the 2D Euclidean distance between 2 ghosts spots is defined as:

$$d(g_{r,j}, g_{s,i}) = \sqrt{(x_{s,i} - x_{r,j})^2 + (y_{s,j} - y_{r,j})^2}$$

and the associated error is:

$$\sigma_d(g_{r,j}, g_{s,i}) = \sqrt{(dx^2_{s,i} + dy^2_{s,i}) + (dx^2_{r,j} + dy^2_{r,j})}$$

with the distances spot to spot between the 2 lists $(g_{r,j1..m}, g_{s,i1..n})$, one can them associate each spot in the S_s set with the closest spot in the S_r set.

we note g_{r,k_i} the closest ghost spot in S_r to the ghost spot $g_{s,i}$ in S_s.

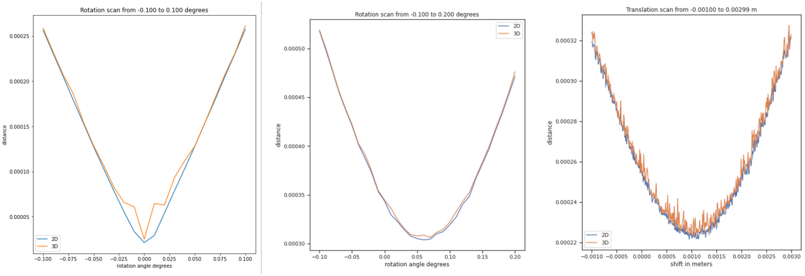
the reduced distance between 2 sets of ghosts spots may then be defined as follow:

$$L = \frac{\sqrt{\sum_{i=1}^{n} \frac{d(g_{s,i}, g_{r,k_i})^2}{\sigma_d(g_{s,i}, g_{r,k_i})^2}}}{n}$$

if 2 sets of beam spots are the same $L = 0$, and if they are really close then L should be small.

Distance behavior

– a few tests with simple 10 cm off–axis beam
  - left: rotating L2 around X with all optics aligned
  - center: rotating L2 around Y with L2 misaligned around X
  - right: shifting L2 along X with many optics misaligned



→ distance seems to be well behaved. . .

Todo list

- Some more work to be done on the distance (add flux?)
- Strategy for the real data analysis
  - build a large data base of simulations
  - run some kind of MCMC to find the best match, based on the distance between to sets of ghosts

  $\rightarrow$ need to develop software
- Verify that the geometry used in my simulation matches current metrology
- Prepare data taking configurations
- Prepare data reduction: from images to ghosts with the DM stack

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- CCOB–NB designed and built at LPSC, sent and received at SLAC in Summer 2021 (after a long journey)
- Characterize the optical throughput of filter (and the whole optical system)
- Determine optics alignment constants through ghosts images analysis
  - current focus [`github:bregeon/ghosts`]
  - getting ready for data taking at SLAC in Spring 2023
  - and on the summit when the camera is reassembled there!

L’équipe CCOB-NB du LPSC

- Marc Marton (SDI, conception mécanique, montage)
- Emmanuel Tourba (Electronique, câbleur)
- Eric Lagorio (Electronique)
- Myriam Migliore (Pôle Accélérateur et SI)
- Guillaume Dargaud (Contrôle Commande)
- Valérie Favre (administration)
- Nicolas Andres (stagiaire M1 2019)
- Aurélien Barrau
- Johan Bregeon
- Cécile Renault

Merci à tous !

Links

- Confluence page: CCOB Thin Beam
- Confluence page: CCOB Thin Beam Hyperchromator
- [github:bregeon/ghosts]