Status of the CCOB–NB

Camera Calibration Optical Bench – Narrow Beam

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Overview

CCOB Narrow Beam concept and implementation

- goals
- implementation
- tests

Optical alignment through ghosts images analysis

- simulations
- analysis
- data taking?

Conclusions and path forward

Outline

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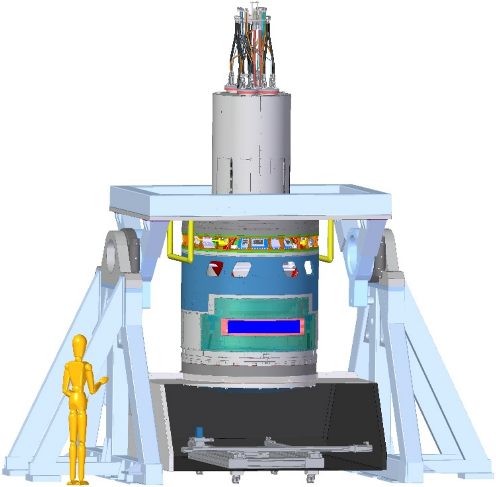
CCOB–NB, what for?

- Commissioning of the integrated camera
  - precise measurement of the **optical throughput**
  - determination of the **optics alignment/tilt**

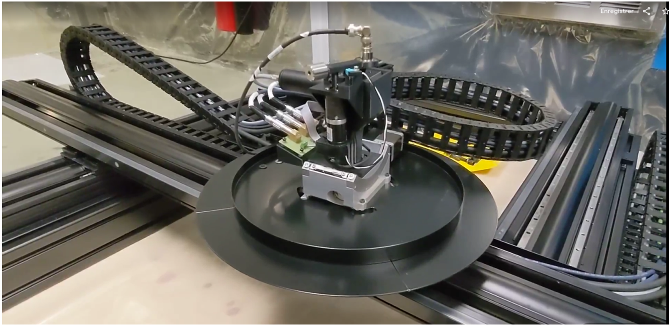
- The Camera Calibration Optical Bench Narrow Beam (CCOB-NB) is a calibrated and (X,Y)+(Θ, Φ) positionable pencil beam monochromatic light source.
  - allows the illumination of the focal plane through the full optical system from a variety of incident angles in the 6 spectral bands
  - 2.5 mm wide monochromatic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

In–operation view

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

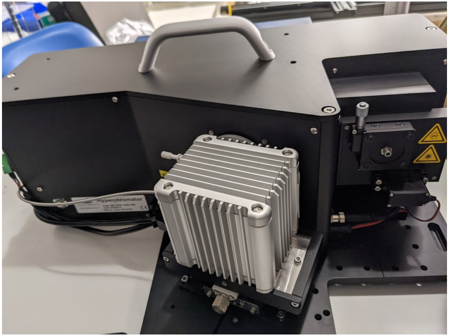


Hardware — table



- black painted XY table with footprint 3000$\times$3100 mm
- goniometer, rotative stand, moving arm for NIST diode
- cable guides for full exploration of the phase space

Hardware — source



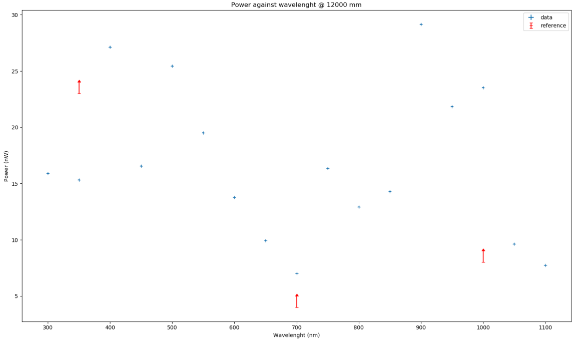
- “hyperchromator” from Mountain Photonics: plasma source + 2 gratings to select wavelength
- multimode 200μm output fiber
- optical collimated solution with off-axis parabolic mirror
- stable high speed shutter

Hardware — CC and measurements

- Keithley Picoammeter coupled to NIST diode to measure absolute light flux
- High resolution camera to measure beam shape
- Ocean Optics spectrometer
- *Everything* remote controlled from a laptop through USB and network
  - XY and Θ|Φ stands, Picoammeter, NIST diode, camera and spectrometer readouts
  - command line scriptable interface

Tests and performance

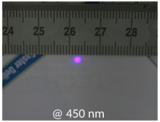
– power requirements satisfied on the full spectrum for $\sim$ 1 nm wavelength width

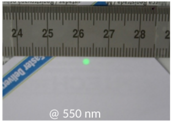


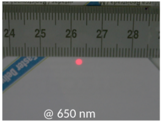
Wavelength (nm)	Power (nW)	Required power (nW)
415	34	23 @ 415 nm
600	20	4 @ 300 nm
900	10	8 @ 1000 nm

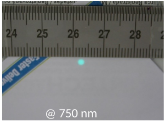
Tests and performance

– 2.5 mm wide circular beam at 1.2 m distance, on the full frequency range

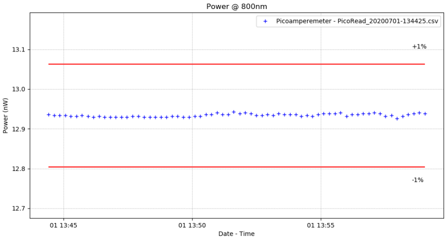






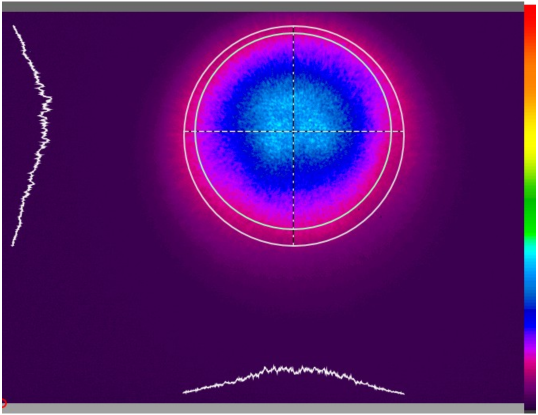


– great stability of the light source and shutter



Tests and performance — shape

– symmetric beam shape



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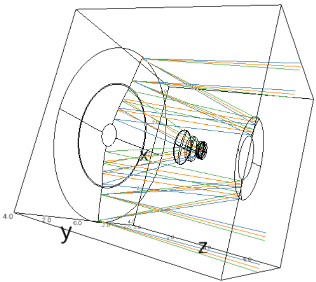
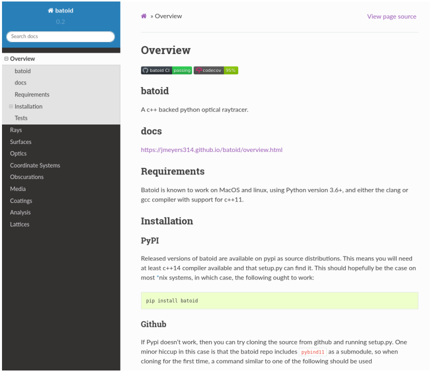
Ray tracing simulation software

– Using Batoid [github:jmeyers314/batoid]





Overview

batoid

A c++ backed python optical raytracer.

docs

https://jmeyers314.github.io/batoid/overview.html

Requirements

Batoid is known to work on MacOS and linux, using Python version 3.6+, and either the clang or gcc compiler with support for c++11.

Installation

PyPI

Released versions of batoid are available on pypi as source distributions. This means you will need at least c++14 compiler available and that setup.py can find it. This should hopefully be the case on most *nix systems, in which case, the following ought to work:

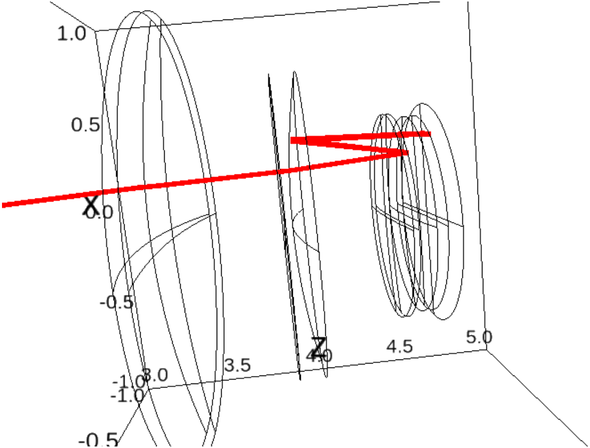
```
pip install batoid
```

Github

If Pypi doesn't work, then you can try cloning the source from github and running setup.py. One minor hiccup in this case is that the batoid repo includes `pybind11` as a submodule, so when cloning for the first time, a command similar to one of the following should be used

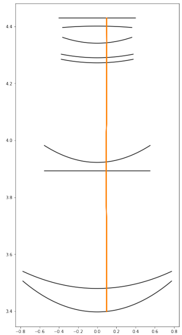
CCOB setup simulation

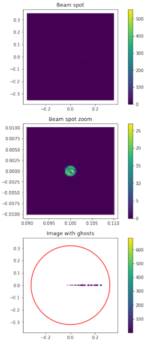
– Remove mirrors and adapt coating to get light reflection

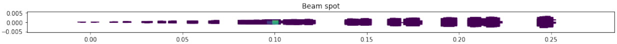


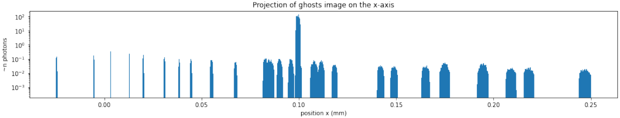
“ghosts” package

- Built as a Batoid plugin: ghosts simulation and analysis [github:bregeon/ghosts]
- example: beam 10 cm off the x–axis



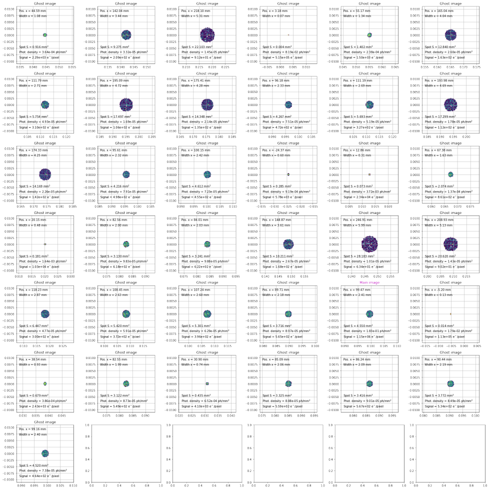






“ghosts”: map

– 36 ghosts images of different size and brightness!



“ghosts”: randomized optics

– Functions to move and tilt optics

Ghosts image analysis

– ghosts absolute position, size and intensity

– ghosts relative positions, sizes and intensity

→ data saved in pandas and serialized to parquet files

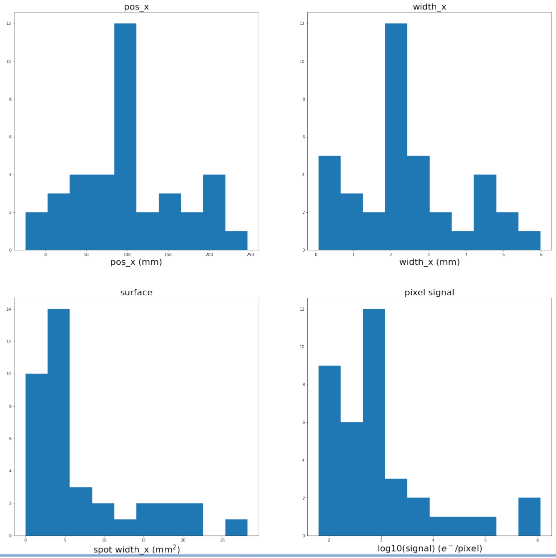
In [10]:

```python
from ghosts.analysis import make_data_frame
data_frame_1 = make_data_frame(spots_data)
data_frame_1.sort_values(by=['name'])
```

Out[10]:

	config	n_photons	beam_x	beam_y	beam_theta	beam_phi	index	name	pos_x	width_x	surface	pixel_signal
33	0	1000	0.1	0.0	0.0	0.0	33	(Detector, Filter_entrance)	-5.180695e-07	0.002087	3.419645	5.134283e+02
34	0	1000	0.1	0.0	0.0	0.0	34	(Detector, Filter_exit)	-5.250468e-07	0.002115	3.512375	5.204845e+02
29	0	1000	0.1	0.0	0.0	0.0	29	(Detector, L1_entrance)	3.065462e-08	0.000123	0.011970	1.247851e+05
30	0	1000	0.1	0.0	0.0	0.0	30	(Detector, L1_exit)	-2.349178e-07	0.000946	0.703138	2.211958e+03
31	0	1000	0.1	0.0	0.0	0.0	31	(Detector, L2_entrance)	-5.028983e-07	0.002026	3.222307	5.025719e+02
32	0	1000	0.1	0.0	0.0	0.0	32	(Detector, L2_exit)	-1.885446e-07	0.000760	0.452938	3.722838e+03
35	0	1000	0.1	0.0	0.0	0.0	35	(Detector, L3_entrance)	-5.500511e-07	0.002216	3.854855	4.937970e+02
36	0	1000	0.1	0.0	0.0	0.0	36	(Detector, L3_exit)	-6.035585e-07	0.002432	4.641336	4.270329e+02
10	0	1000	0.1	0.0	0.0	0.0	10	(Filter_entrance, L1_entrance)	-6.766032e-07	0.002726	5.832723	3.010159e+02
11	0	1000	0.1	0.0	0.0	0.0	11	(Filter_entrance, L1_exit)	-1.180802e-06	0.004757	17.764713	1.029083e+02
12	0	1000	0.1	0.0	0.0	0.0	12	(Filter_entrance, L2_entrance)	-1.057515e-06	0.004260	14.248464	1.335945e+02
13	0	1000	0.1	0.0	0.0	0.0	13	(Filter_entrance, L2_exit)	-5.815582e-07	0.002343	4.309119	4.599556e+02
14	0	1000	0.1	0.0	0.0	0.0	14	(Filter_exit, Filter_entrance)	-6.095641e-07	0.002456	4.734159	4.186601e+02
6	0	1000	0.1	0.0	0.0	0.0	6	(Filter_exit, L1_entrance)	-6.802227e-07	0.002740	5.895293	2.860273e+02
7	0	1000	0.1	0.0	0.0	0.0	7	(Filter_exit, L1_exit)	-1.187576e-06	0.004784	17.969128	9.770883e+01
8	0	1000	0.1	0.0	0.0	0.0	8	(Filter_exit, L2_entrance)	-1.064046e-06	0.004287	14.424998	1.267339e+02
9	0	1000	0.1	0.0	0.0	0.0	9	(Filter_exit, L2_exit)	[illegible]	[illegible]	[illegible]	[illegible]

Ghosts image analysis example

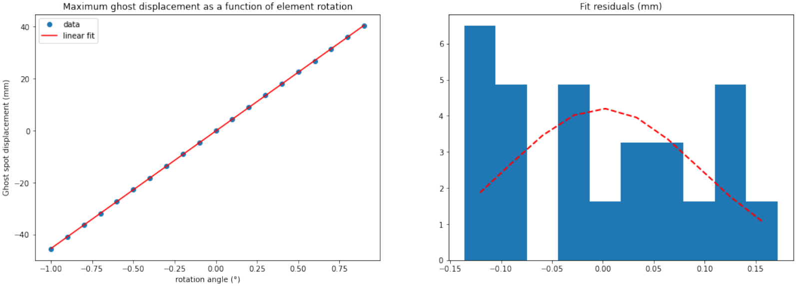


Simulation and analysis

– Scan on L2 rotation with fix beam at 10 cm off the x–axis

– Check the position of the ghost image furthest from the main

$\rightarrow$ linearity for small angles!



Todo list

- Upgrade analysis to 2D
- Implement a basic CCD response: pixel, noise etc...
- Use realistic wavelength dependent reflectivity
- Gather information about realistic range of positions/rotations from mechanical engineers
- Full image analysis: find spots and characterize these properly
- Define a strategy for the real data analysis
  - build a big model from a large set of simulations
  - setup a kind of MCMC trying to fit a simulation to the data
  - find most informative ghosts to build an iterative procedure to find all alignment constants "one by one"
  - revive analytic fit from Barrau and Baumont
- Need to think about real camera data handling (large volume)

Data taking

- Data taking shall happen at SLAC in Spring 2022 and on the mountain likely in 2023
- Need to define an efficient procedure for data taking
  - requires to have chosen an analysis strategy
  - balance between data taking time, data volume, achievable precision on constants

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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`]
  - needed to define data taking at SLAC in Spring 2022
  - and on the mountain, at some point

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]