Emittance measurements for SOLEIL–II

Pinhole camera prelimary measurements and faced issues

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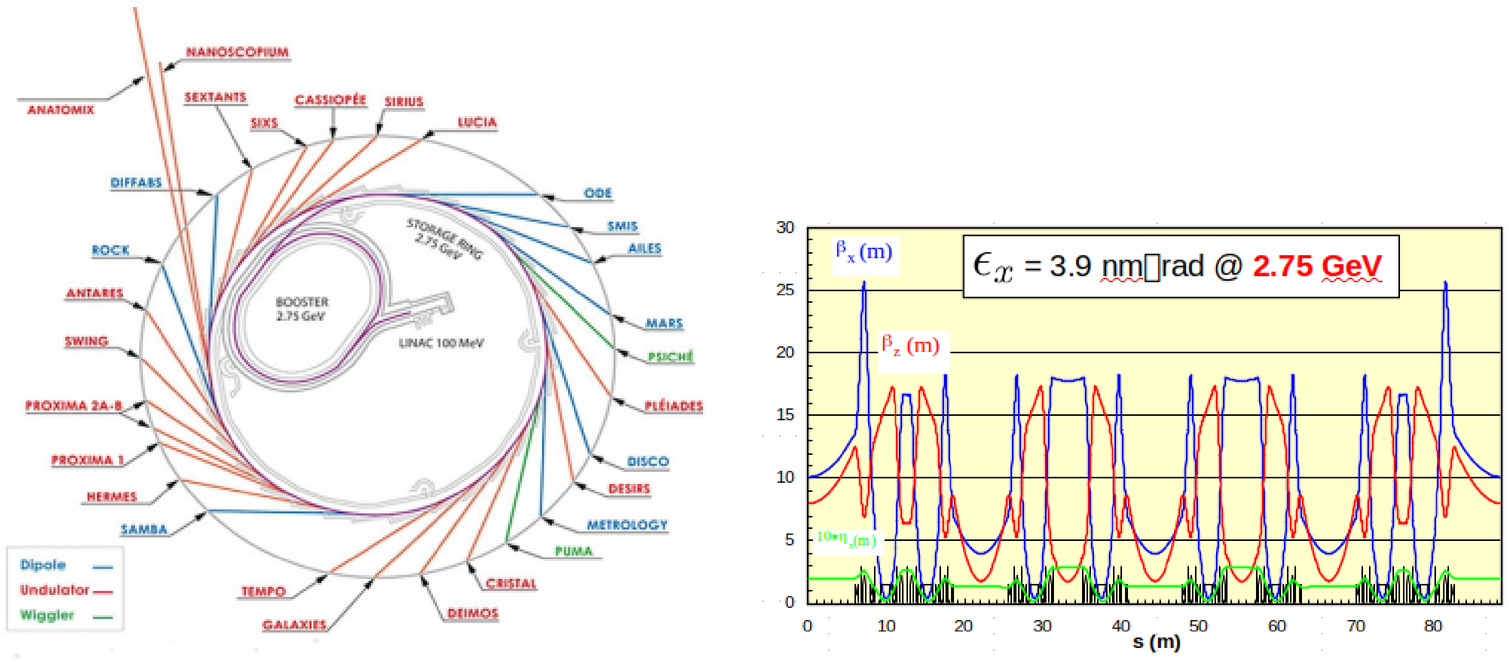
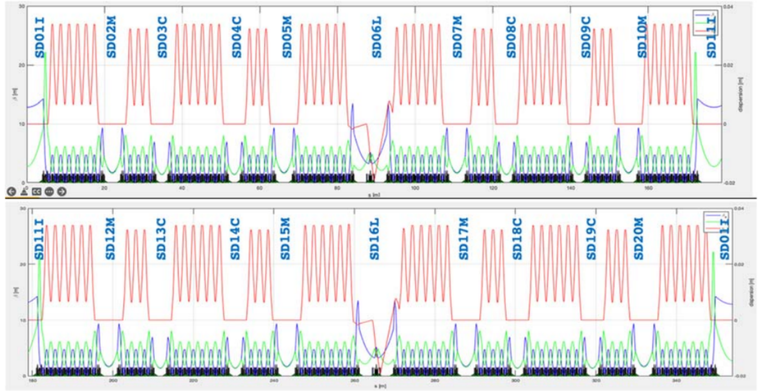
SOLEIL present storage ring

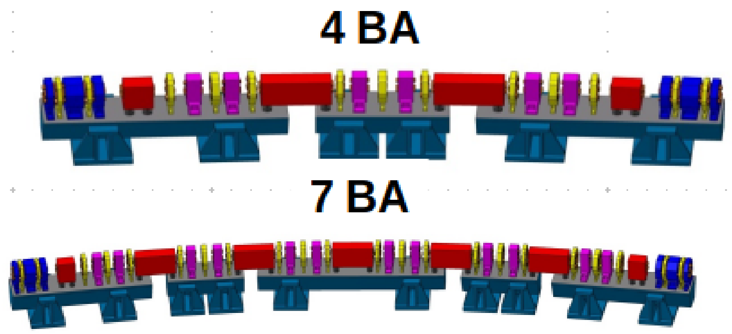


SOLEIL present storage ring

- Storage ring: 354 m circumference
- Lattice: DBA + distributed dispersion
- ϵ_x=3.9 nm.rad ; ϵ_y=40 pm.rad
- 29 beamlines

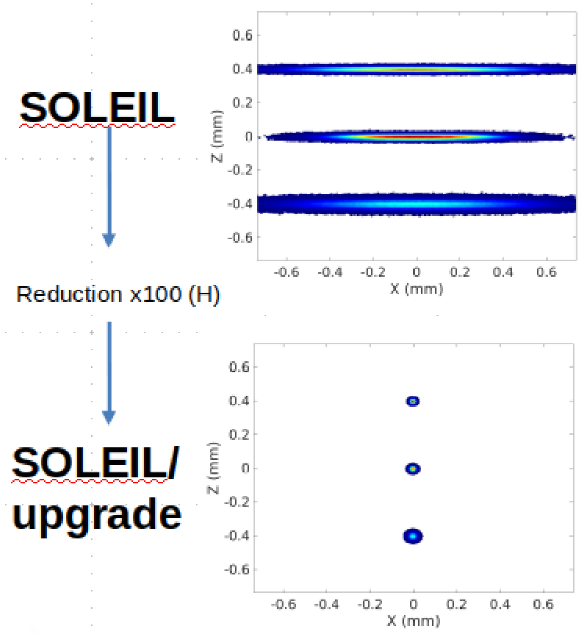
SOLEIL–II (project) storage ring





Non standard 7BA/4BA CDR lattice

SOLEIL–Upgrade lattice



- Lattice: non–standard 7 DBA + 4 DBA
- ϵ_x=84.4 pm.rad ; ϵ_y=25.3 pm.rad

Beam sizes and emittances for SOLEIL–II

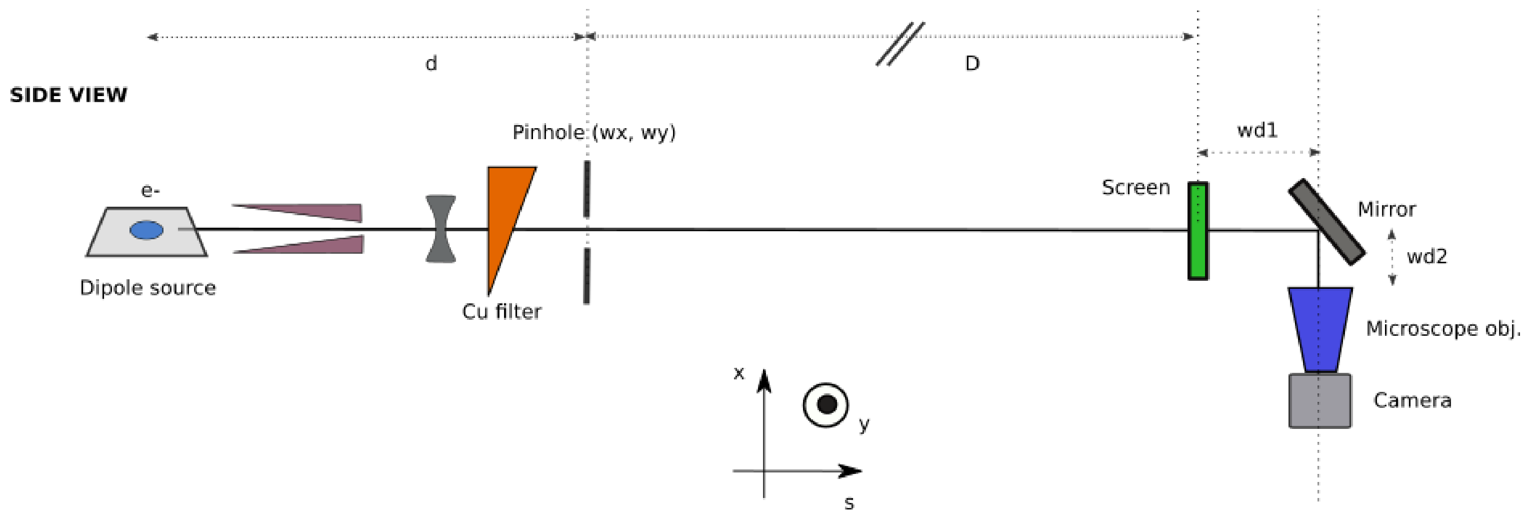
- SOLEIL vs. SOLEIL-II parameters:

Machine	SOLEIL	SOLEIL–II Nominal / Machine tuning
ϵ_x (pm.rad)	4000	84.4 / 90
ϵ_y (pm.rad)	40	25.3 / 1
σ_x in dipoles (μm–RMS)	45–75	7 / 6.6–7.5
σ_y in dipoles (μm–RMS)	25	12.4 / 2.4–18.3

- Specifications for $\epsilon_{x,y}$ ($\sigma_{x,y}$) measurement:
  - $\epsilon_{x,y}$ measurement with sub–pm resolution
    $\rightarrow$ $\sigma_{x,y}$ measurement with sub–μm resolution
  - $\epsilon_{x,y}$ (nominal) measurement at $>$100 Hz repetition rate
  - High reliability for $\epsilon_{x,y}$ (nominal) measurement

Strategy for emittances measurements

- Development of 2 types of diagnostics beamlines, both based on dipole SR analysis:
  - Two (similar) X-ray range beamlines:
    - SR source: high–field (3 T) dipoles
    - Technique: Pinhole camera imaging with $\approx 1\ \mu$m–RMS resolution
  - One near–UV / visible beamline:
    - SR source: low–field (0.6 T) dipole
    - Technique: Polarized imaging with $\approx 5\ \mu$m–RMS resolution (??)



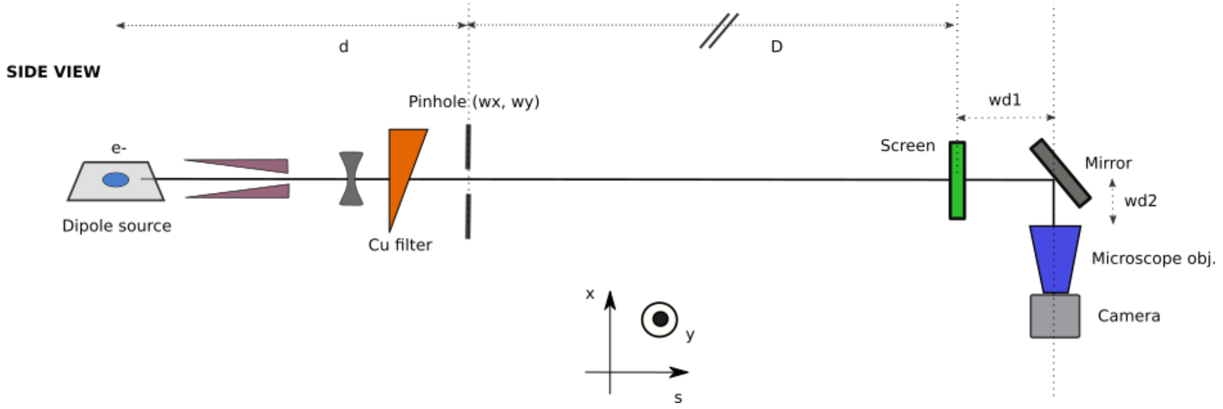
- Principle:
  - Image source point with a pinhole onto a scintillator
  - Image scintillator onto a camera using a microscope objective
  - Deconvolve beam size on scintillator (image plane) from PSF (relying on SRW)
  - Retrieve beam size at source point (relying on accurate measurement of beamline magnification)
  - Retrieve emittances at source point (relying on accurate modeling of optical functions)

X–ray range beamlines >> Principle

	SOLEIL		SOLEIL-II
Parameter	PHC-C02	PHC-C16	PHC-C08 and PHC-C18 >> nominal / low-coupling mode
sigma_x at source (µm-rms)	**45**	**62**	**7.1 / 7.2**
sigma_y at source (µm-rms)	**24**	**21**	**12.4 / 2.5**
d (m)	4338	4335	2505
D (m)	5730	5716	12495
Pinhole Magnification (-)	1.32	1.32	4.99
X-imager magnification (-)	2.2	2.55	9
X-imager resolution (pixel)	1	1	2
Camera pixel size (µm)	7.4	7.4	7.4
Resolution at image (scintillator) (µm-rms)	**3.36**	**2.90**	**1.64**
Resolution at source (µm-rms)	**2.55**	**2.2**	**0.33**
Adding sensitivity criteria: **>> Minimum measurable beam size at source (µm-rms)**	**25**	**29**	**2.5**
Using a Voigt function for PSF deconvolution: **>> Minimum measurable beam size at source (µm-rms)**	**~7**	**~7**	**~ 1**

- Difficult point = PSF deconvolution... → Let's test it on SOLEIL present storage ring...

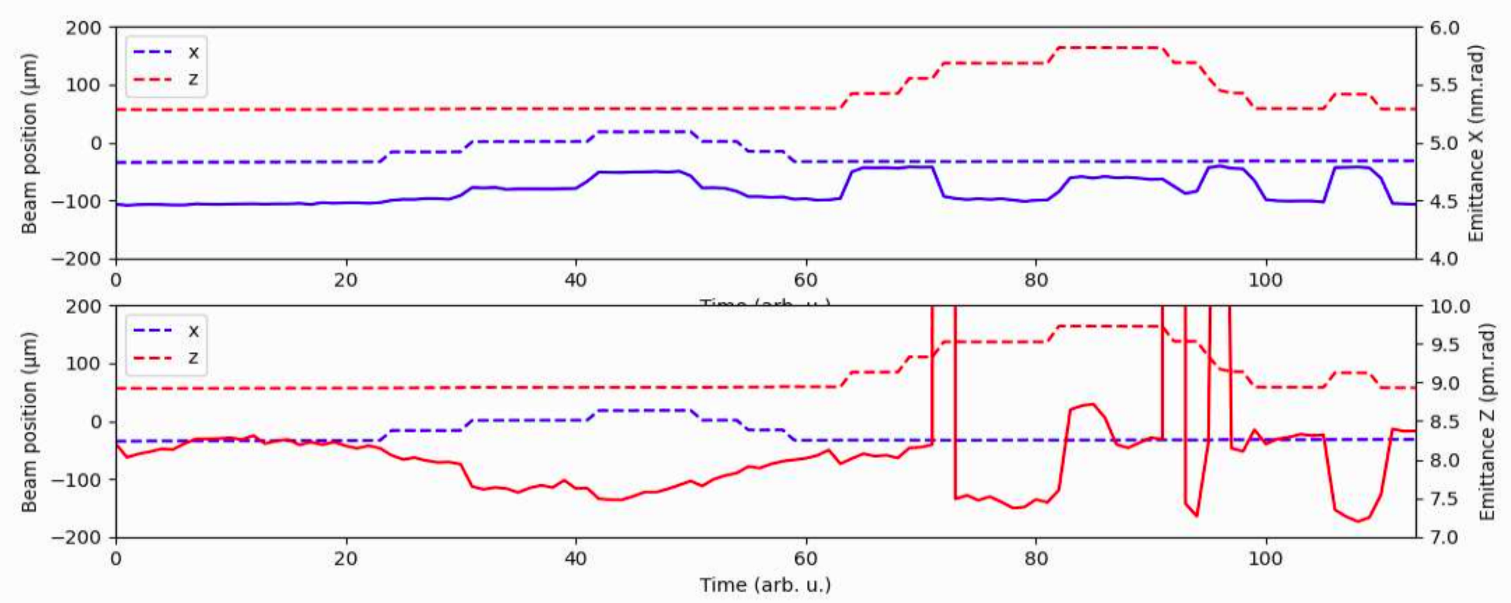
Experimental setup @ SOLEIL



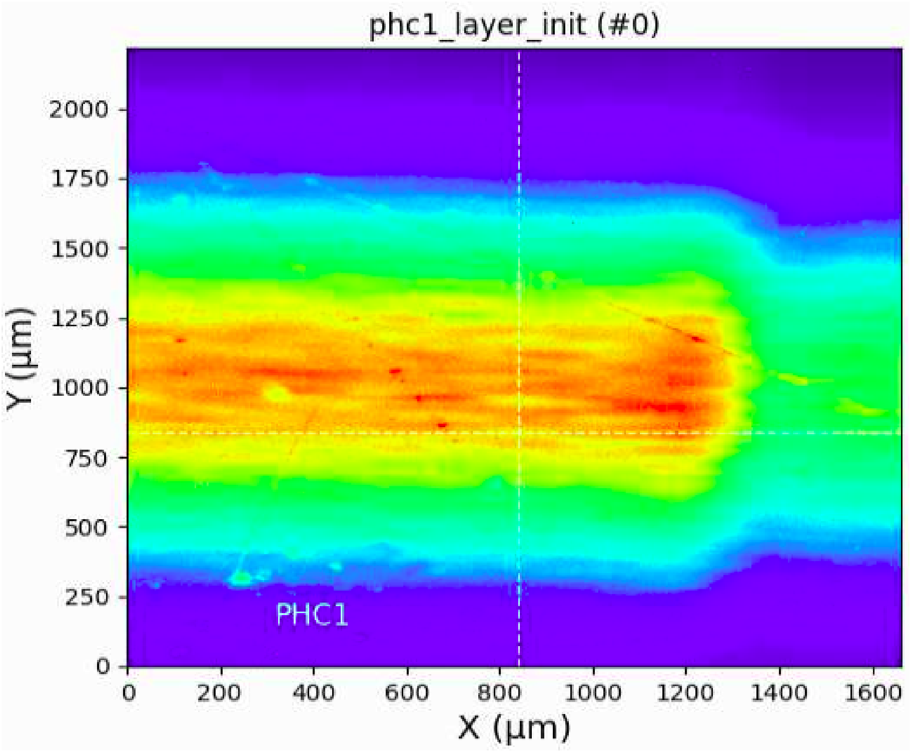
- Machine settings:
  - Specific cycling to obtain a symmetric machine
  - Minimum coupling to reach minimum ϵ_y
  - $I < 10$ mA to :
    - operate with BbB feedback OFF
    - limit the power density on the scintillator when pinhole and copper absorber are removed
  - Reached emittances: $\epsilon_x \approx 5$ nm.rad ; $\epsilon_y \approx 8$ pm.rad
- PHC1 settings = “standard”:
  - Pinhole size: 15 x 10 μm, Copper attenuator thickness: 1 mm
  - Exposure time: few hundreds of ms

First observation

- Emittance dependency to beam displacements at source point by $\approx$ 20-50 μm:
  - $\approx$ nm.rad variations in H plane i.e. $>$10$\%$
  - $\approx$ few pm.rad variations in V plane i.e. $>$10$\%$
  - Never seen before !!!

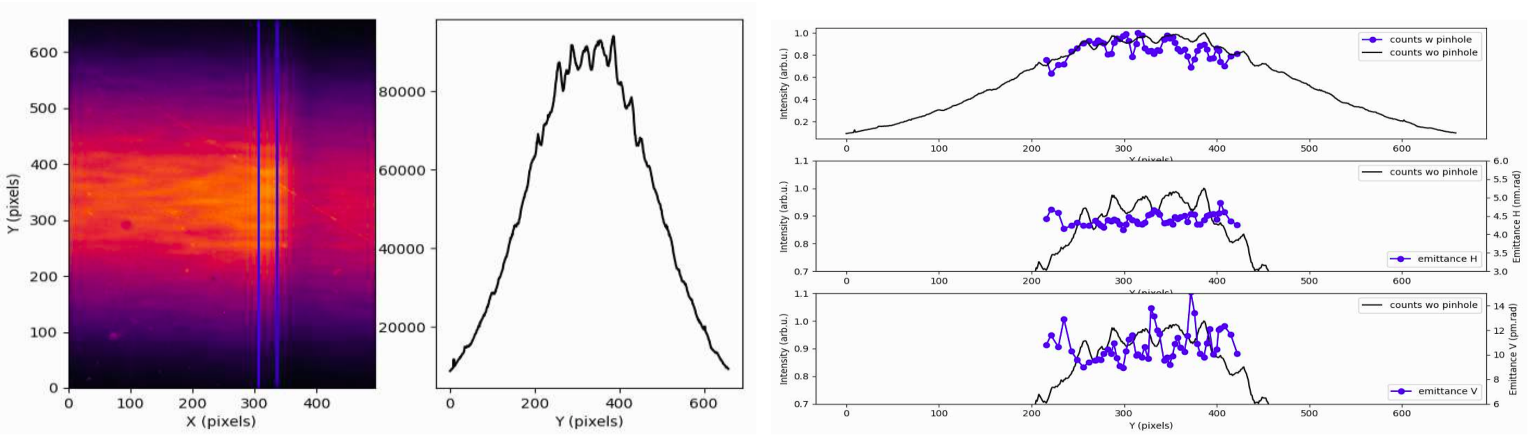


First finding



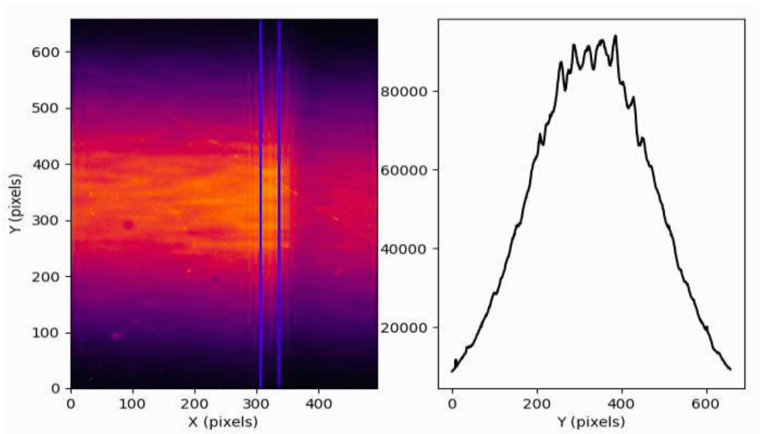
- Once the pinhole removed >> SR layer appears “filamented” ??!!

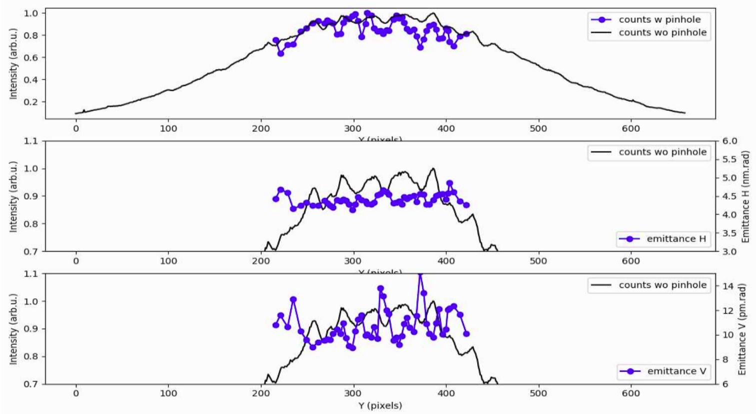
First finding



- Performing emittance measurements versus pinhole block in Y....
- ... Emittance seems correlated to the filament structure

First finding

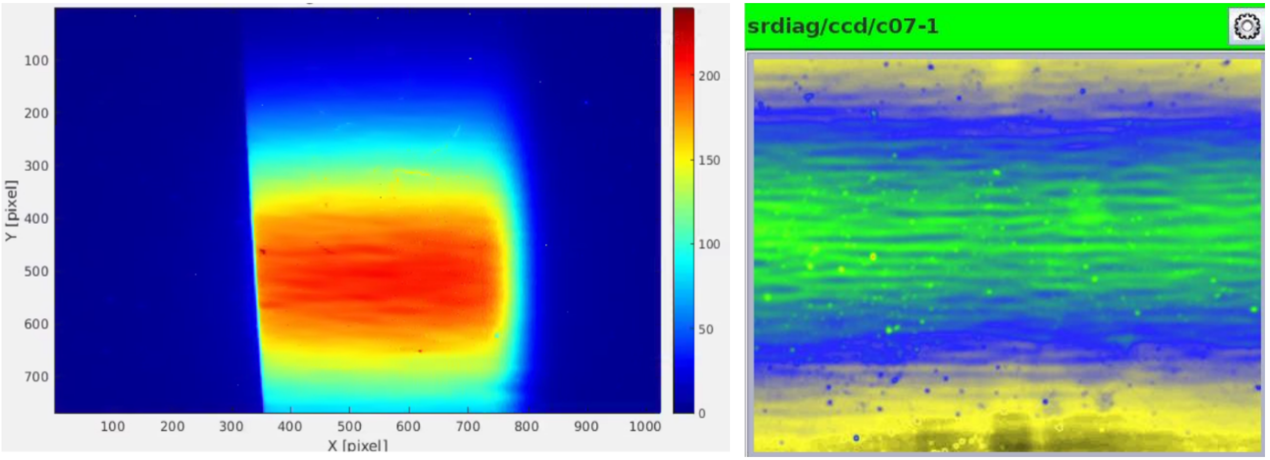




- Performing emittance measurements versus pinhole block in Y....
- ... Emittance seems correlated to the filament structure

  $\rightarrow$ But where are these filaments coming from ???

Are these filaments specific to SOLEIL ?

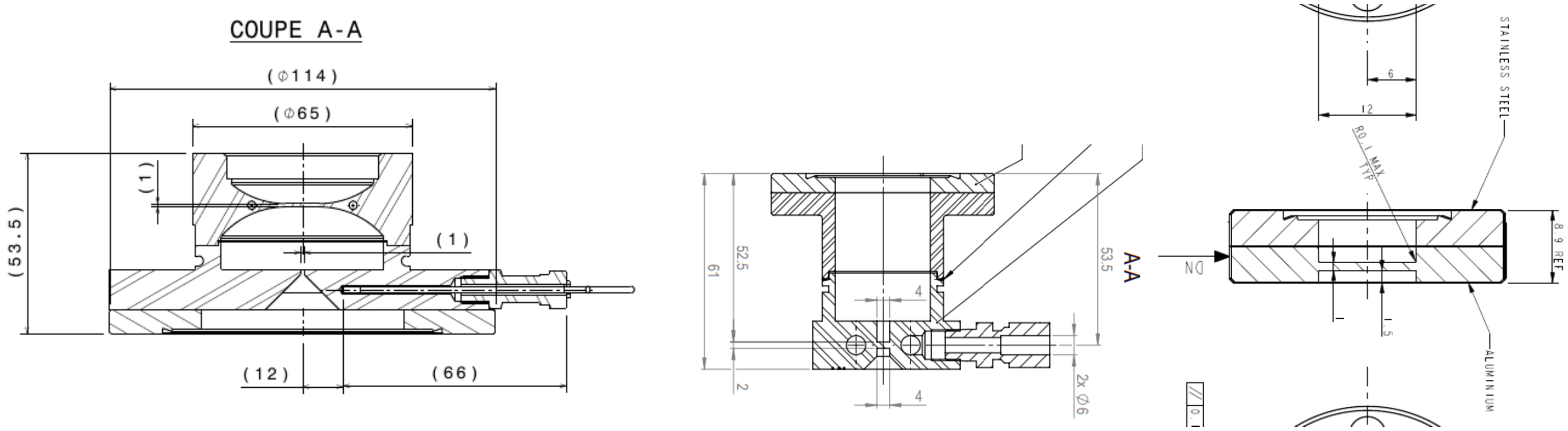


SR pattern recorded without pinhole at (left) Diamond Light source and (right) ESRF-EBS at minimum vertical emittance. Courtesy L. Bobb, N. Vitoratou and F. Ewald.

- NO !
- Same filaments observed at Diamond Light Source and ESRF-EBS...

Filaments / Al UHV window correlation....

- After quite some tests (especally bumps) $\rightarrow$ Filaments seem to be due to the Al UHV window



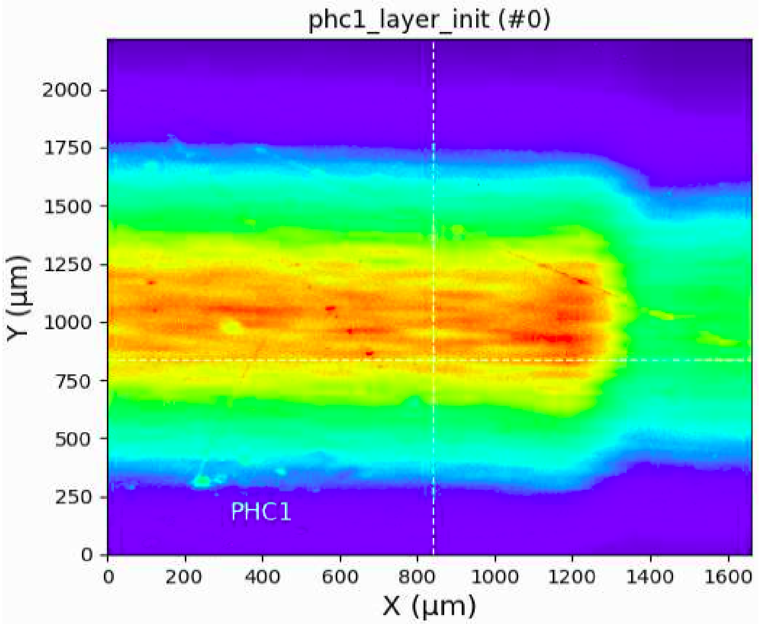
Aluminium UHV windows of (from left to right) SOLEIL, ESRF, DLS.

- BUT:
  - It can not be a simple transmission issue due to some bulk impurities
    $\rightarrow$ Windows are all nearly "pure" or melted with similar Z materials
  - It can't be neither a diffraction effect
    $\rightarrow$ Filaments are too small even for small angle diffraction

Al window → phase contrast imaging ?

- After quite some discussions with many SOLEIL beamline scientists...

(CRISTAL, PSYCHE, ANATOMIX, METROLOGY)



→ We might be simply making phase contrast imaging of our Al window...

Al window → phase contrast imaging ?

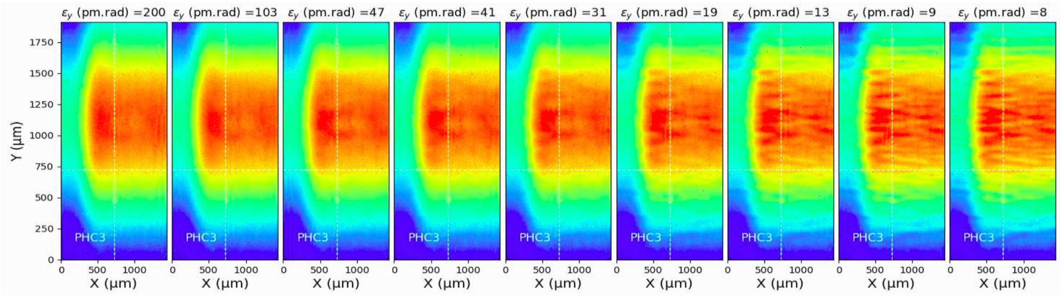
- And indeed: our (at least at SOLEIL) Al window surface is just ... “crap”

Picture of the Aluminium UHV window of SOLEIL.

Al window $\rightarrow$ phase contrast imaging ?

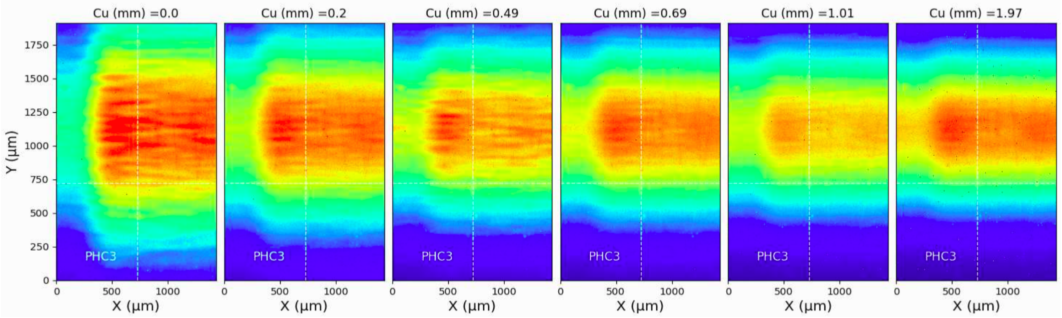
- Additionnal tests to confort this track:
  - Filamentation versus ϵ_y: the smaller ϵ_y $\rightarrow$ the more pronounced the filaments

(= matching with a more vertically coherent beam)



  - Filamentation versus Cu thickness: the thicker Cu $\rightarrow$ the more blurred the filaments

(= matching with a softer X-ray beam, coherence reduced)



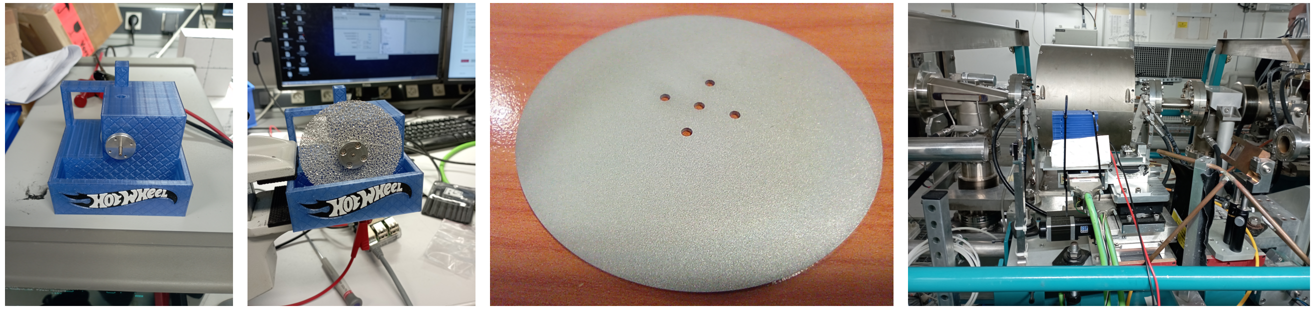
$\rightarrow$ Both tests in good agreement with phase contrast theory

How to get rid of these filaments ?

- “Parasitic” phase contrast imaging from UHV windows
  = a well known issue on several beamlines
- Solutions “known” from several beamlines:
  - (1) A decoherer = random / rotating structure to blur the phase interferences
    $\rightarrow$ 1 k€
  - (2) A high quality ($<$nm surface polish) diamond window
    $\rightarrow$ 25 k€
- Solution “not yet explored”:
  - (3) Why not a high quality surface Al window ?
    $\rightarrow$ 15 k€

(1) Tests of a decoherer

- Experimental setup:
  - A wheel
  - Several types of Al disks: foam or plane with different levels of roughness

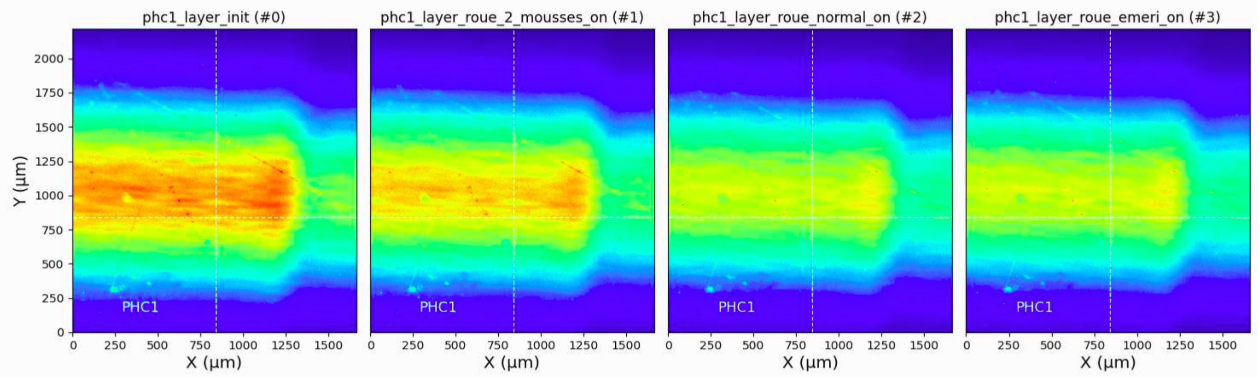


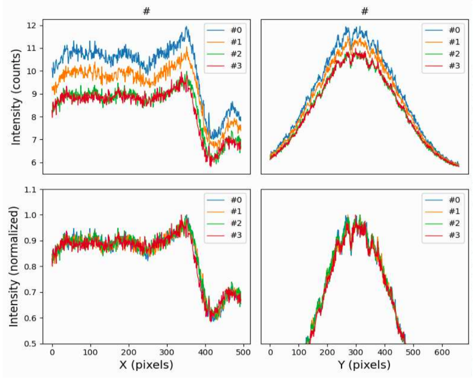
From left to right: wheel, foam disk, plane disk, wheel installed.

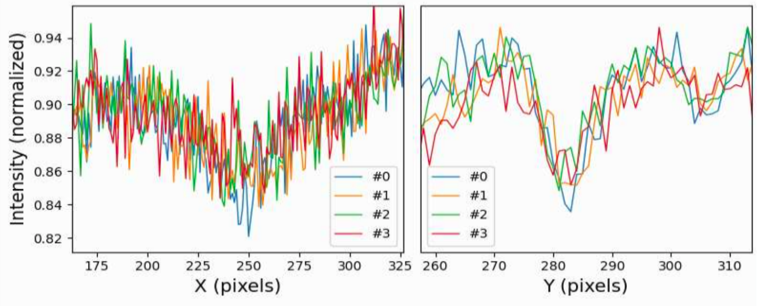
  - Wheel installed instead of pinhole, i.e. just downstream Al window

(1) Tests of a decoherer

- Experimental results:







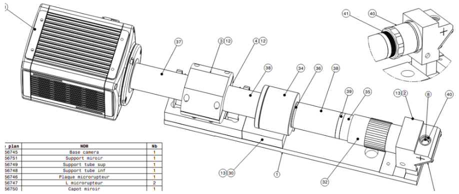
→ As predicted by Metrology beamline scientist: “it’s not enough...”

(3) Test of Al plates with different surface qualities

- Before moving to an expensive Diamond window....
- We will test the effect of more finely polished Al plates on filaments
- Test bench = Metrology beamline → beginning July ?
  - Same SR source (a 1.7 T dipole)
  - Same distance UHV window – Scintillator + Imager (=6.1 m)
  - Possible insertion of various types of windows / plates

    ... including a diamond window



From left to right: beamline metrology, X-imager on its stand, X-imager, X-imager drawing.

Conclusion

- Willing to test our PHCs towards low vertical emittance measurements....
- ... We faced an unexpected issue:
  - SR filamentation in the image plane
  - A filamentation strongly pertubating the emittance measurement
- This filamentation was found to result from... phase contrast imaging of our Al window
- Possible solutions:
  - A decoherer → tested → not efficient enough
  - A higly polished Al window → to be tested
  - A high quality diamond window → it's THE solution on beamlines

    ...though expensive, we might endup with it...
- Many thanks to:
  - F. Ewald, L. Bobb and N. Vitoratou for offering their time to make dedicated measurements and helping us solving this issue.

→ QUESTIONS ???