SESAME

4 May 2021

Report on ML slope error

BEATS - BEAmline for Tomography at SESAME

Summary

Raytracing of the BEATS beamline Three-Pole-Wiggler and Double Multilayer Monochromator. Two 500mm-long plane mirrors with modified surface slope error and PreMLayer reflectivity are considered for the DMM. A W/B4C stripe with 100 MLs and (graded) d-spacing of 3 nm is considered at beam energy of 45 keV. Beam profiles at the sample position are shown for 0.1, 0.2, 0.25, 0.3, 0.35, 0.4 and 0.5 μrad mirror slope error. The quality of the flat field is affected already for slope errors > 0.25 μrad.

SESAME Doc:	BEATS_ML_slope_error	
Version:	Ver 5.1	
Last modified:	`10:13 on 4 May 2021`	
Prepared by:	**Checked by:**	**Approved by:**
G. Iori	J.R. Herrera	

Version history:

Ver 1.0	BEATS TDR
Ver 2.0	Changed substrate size based on feedback from CM and companies
Ver 3.0	Feedback CM, RB, JRH and RM
Ver 4.0	Increased ML length to 500mm; W/B4C stripe d-spacing: 3nm Added substrate slope error simulations
Ver 5.0	Checked by JRH

Contents

0.1 Resources

- BEATS raytracing codes can be found on GitHub here.
- Figures (e.g. beam profiles) are stored here.

0.2 Beamline layout

See beamline drawing and beamline functional layout attached.

1 X-ray source - Three Pole Wiggler (3PW)

1.1 Wiggler plots

The magnetic field profile of the BEATS 3PW is shown in Figure 1.
Figure 2 shows the electron beam trajectory.
Figure 3 shows the expected 3PW flux spectrum.

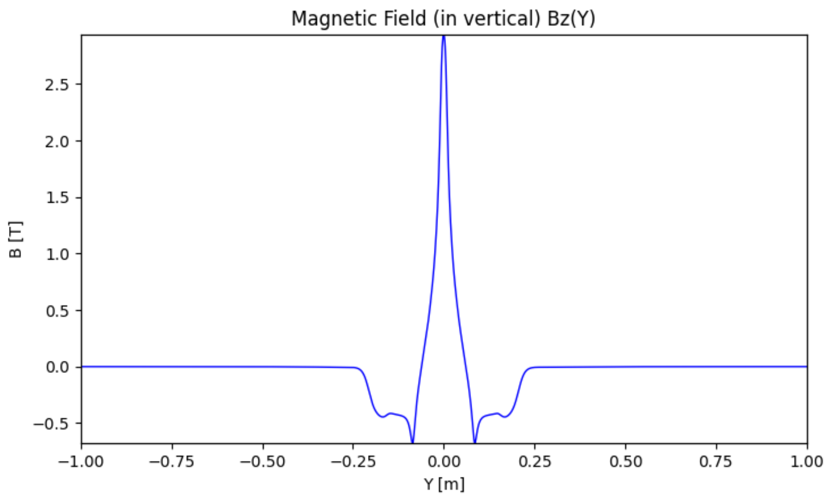


Figure 1: BEATS 3PW magnetic field profile.

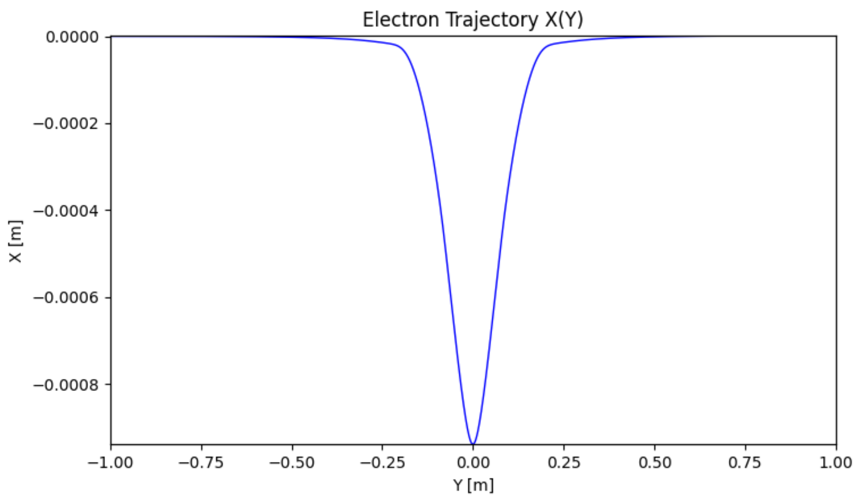


Figure 2: BEATS 3PW electron beam trajectory.

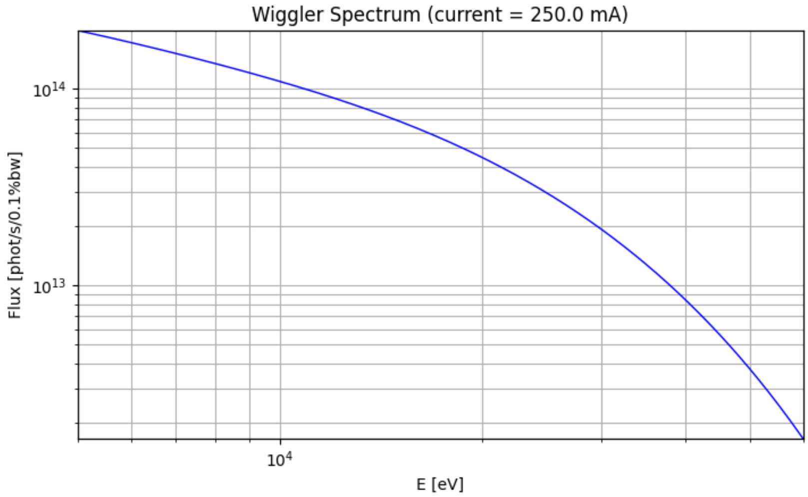


Figure 3: BEATS 3PW spectrum.

1.2 Source size and divergence

Figure 4 shows the BEATS source size. The source has an offset of almost 1mm. Plots of the horizontal and vertical photon source size and divergence are shown in 5.

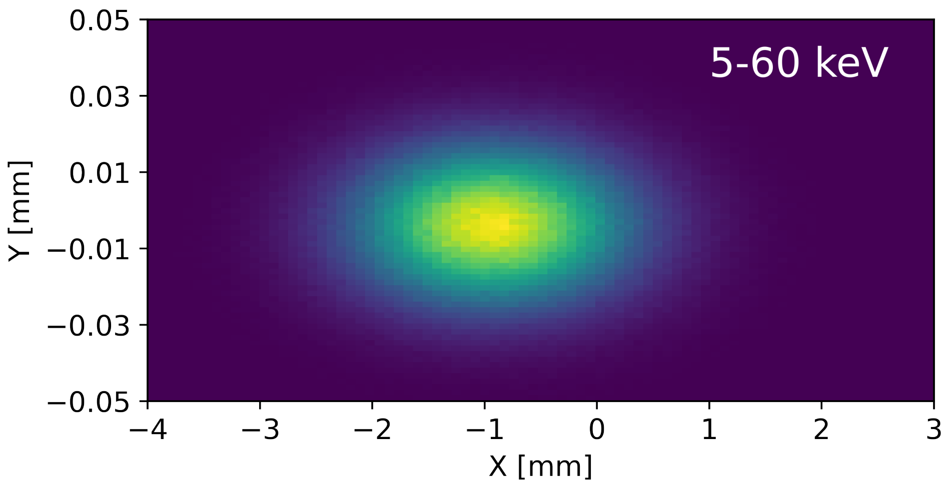


Figure 4: BEATS 3PW photon source snapshot.

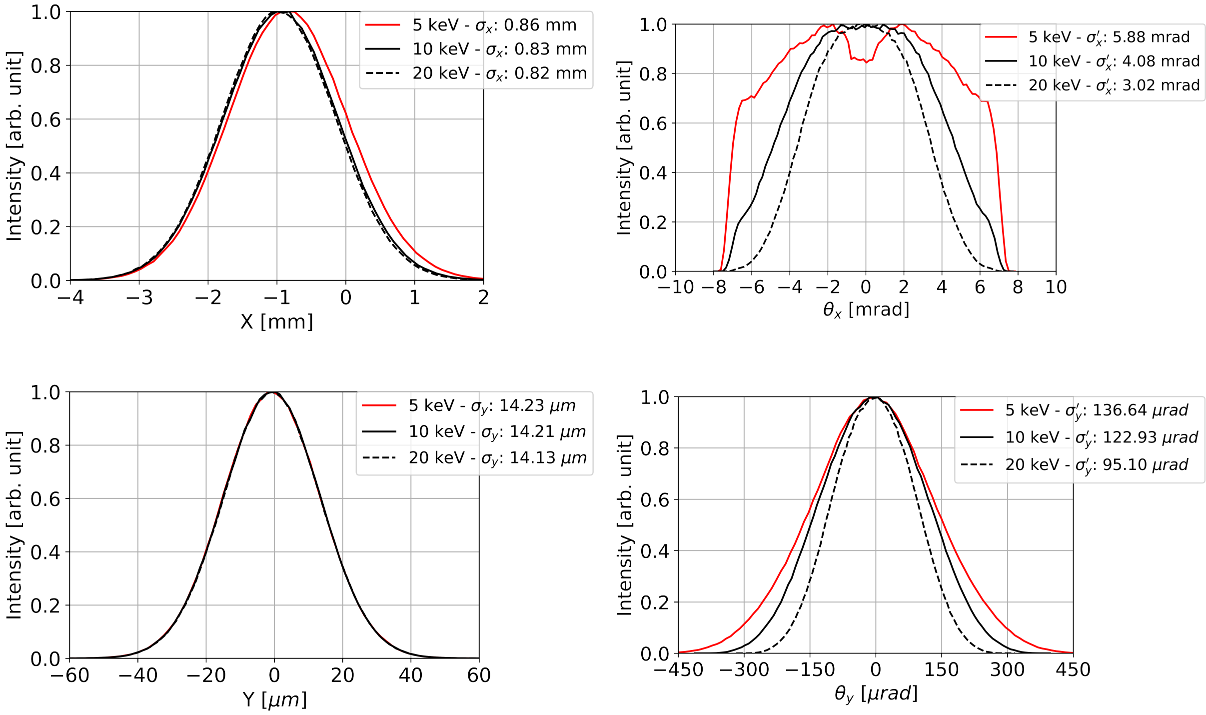


Figure 5: Photon source size and divergence of the BEATS 3PW at 5, 10 and 20 keV.

2 Double Multilayer Monochromator (DMM)

Deflection	Vertical
Distance from source (1st ML)	15.165 m
Beamline aperture	1.8 mrad × 0.4 mrad (Hor. × Ver.)
Beam size @ 1st mirror	29 mm × 6 mm (Hor. × Ver.)
Working energy	8 – 50 [keV]
ML length	500 mm
Distance between MLs	510 mm
Offset (variable)	Min. 4.2 – Max. 16.0 [mm]
Theta (Bragg angle)	-0.5 to +2.5 [deg]
Bragg resolution	0.5 µrad
Input beam power on 1st mirror	133 W

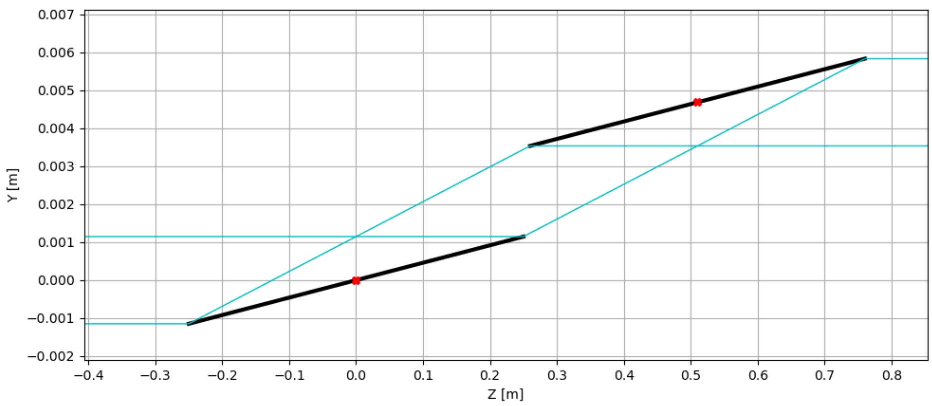


Figure 6: d-spacing: 3 nm; E: 45 keV; Grazing: 0.263 deg; offset: 4.68 mm.

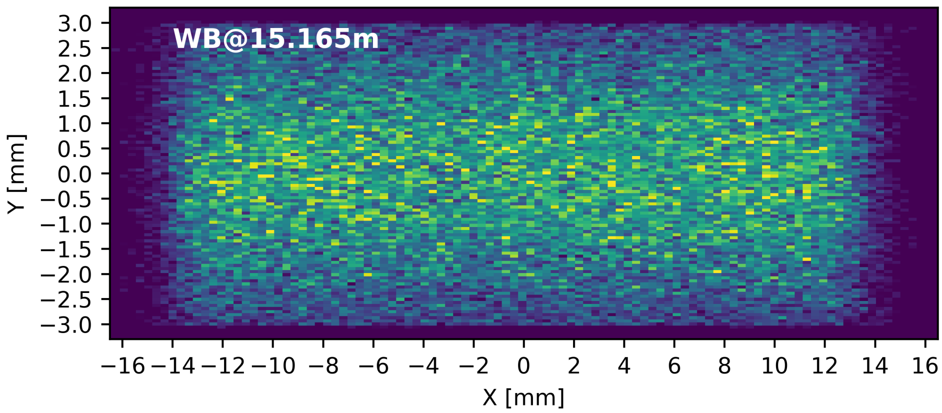


Figure 7: White beam (5-60 keV) snapshot at 15.165 m from source (center position of ML1).

2.1 Substrates

The ML length was increased to 500 mm. A drawing of the proposed substrate size is attached. The substrate size and optical quality (tentative) are reported in Table 1.

Substrate dimension	500 mm $\times$ 70 mm $\times$ 60 mm (see drawing attached)
Coated area	500 mm $\times$ 25 mm (2 stripes)
Surface roughness	$<$ 0.3 nm rms
Slope error along Z (beam direction)	$\leq$ 0.3 μrad rms
Slope error along X (perpendicular to the beam)	$<$ 20 μrad rms

Table 1: BEATS DMM substrates.

2.2 ML coatings

Following the increase in ML length to 500 mm the d-spacing of the high-energy stripe is changed back from 2.5 nm to 3.0 nm. This gives approx. +50% int. reflectivity (dE/E increases from 2.3% to 3.2%). Thanks to the increased mirror length, the useful vertical part of the beam is intercepted even at minimum grazing and even with a d-spacing of 3.0 nm. Coating specs of the two ML stripes are given in Table 2.

	STRIPE 1 $[W/B_4C]_{100} - d3.0nm$	**STRIPE 2** $[Ru/B_4C]_{65} - d4.0nm$
Materials	W/B4C	Ru/B4C
d-spacing [nm]	3.0	4.0
d-spacing gradient along Z (O.A. 500 mm)	3.297 % (0.00659 % / mm)	
N. bilayers	100	65
Duty cycle γ	0.5	0.5
Energies [keV]	20 – 50	8 - 22
dE/E	3.2 %	3.1 %
Coated area	480 (500) mm $\times$ 25 mm	
Theta (Bragg angle) [deg]	0.23 – 0.59	0.41 - 1.00

Table 2: BEATS multilayer coatings.

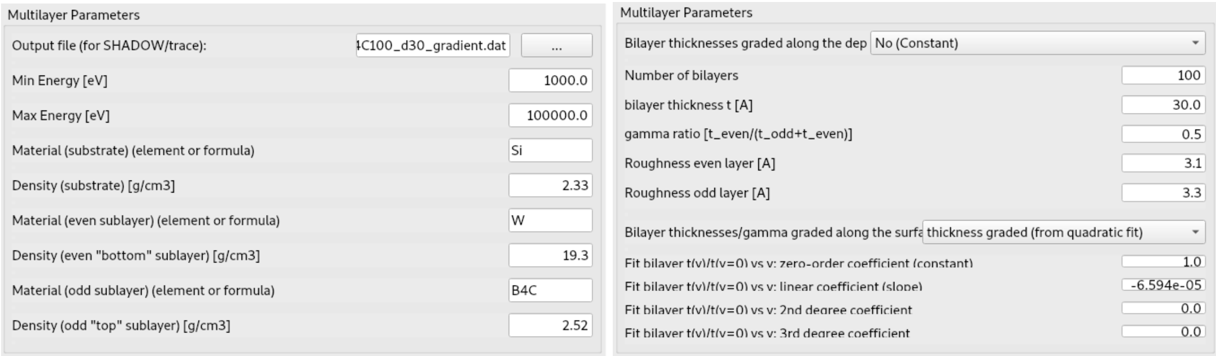


Figure 9: PreMLayer widget settings in Shadow.

2.3 Raytracing

The double-bounce DMM is modelled with two Shadow Plane Mirror widgets in series (Figure 8). ML reflectivity is modelled with a Shadow PreMLayer widget as shown in Figure 9. The mirror surface error is is simulated with external splines with varying slope error (0.1, 0.2, 0.25, 0.3, 0.35, 0.4 and 0.5 μrad RMS) along the beam axis (Z). Modified surfaces (10) are generated with the Shadow PreProcessor - Height Profile Simulator widget. The slope error perpendicular to the beam axis (X) is kept constant at 20 μrad RMS, and fractal profiles are chosen.

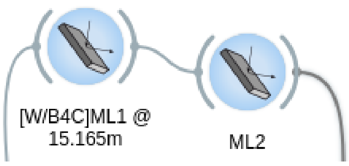


Figure 8: Double Multilayer Monochromator in Oasys Shadow.

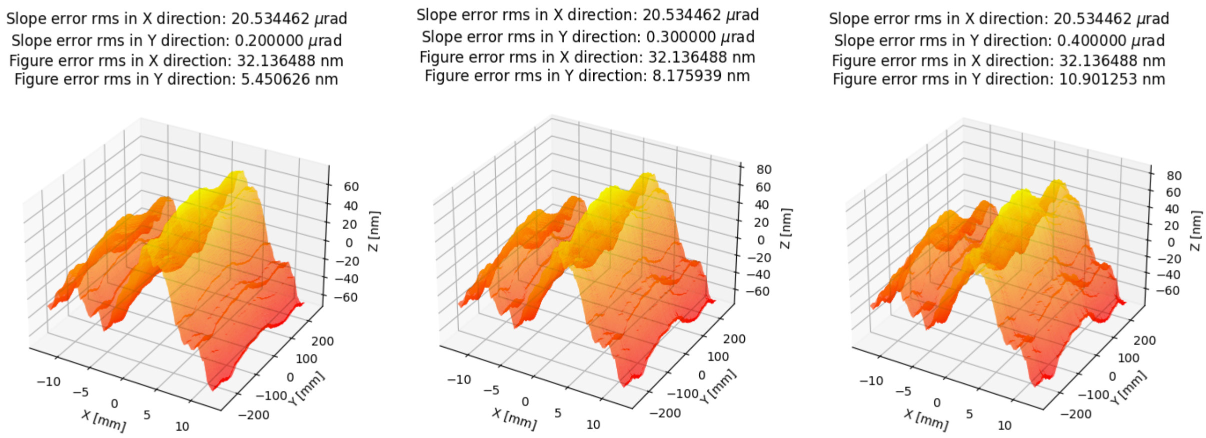


Figure 10: Modified mirror surfaces. In this figure the Y-axis corresponds to the beam path and the X-axis is perpendicular to the beam.

2.4 Substrates slope error

Flat field snapshots at the sample position (42m from source) for different ML slope errors are shown below. W/B4C coatings with d-spacing of 3.0 nm on coated areas of 500 mm x 25 mm are considered. The DMM is set to an energy of 45 keV (theta: 0.274 deg). 16×10^6 rays are used for the Monte Carlo simulation.

2.4.1 0.1 urad

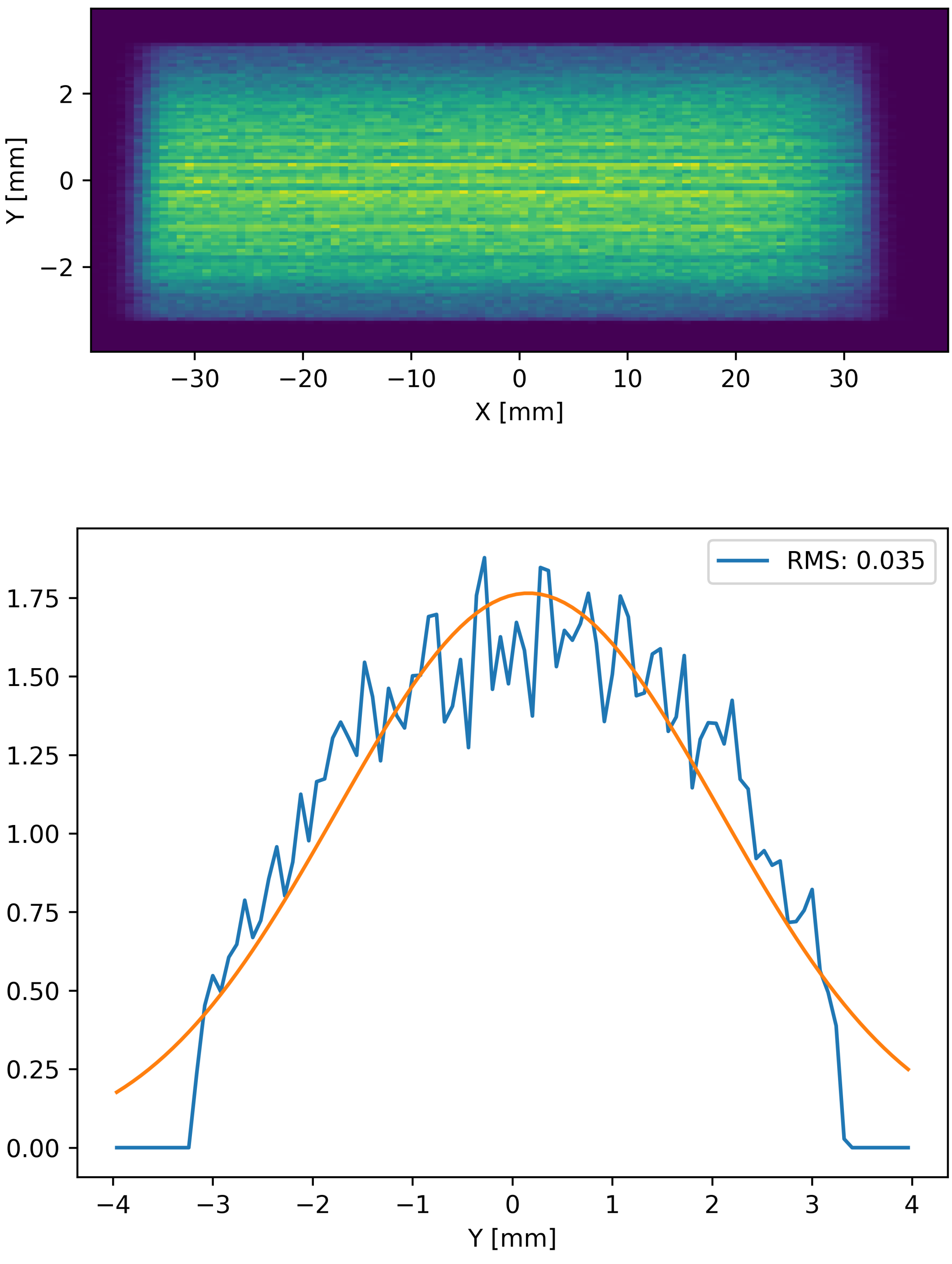
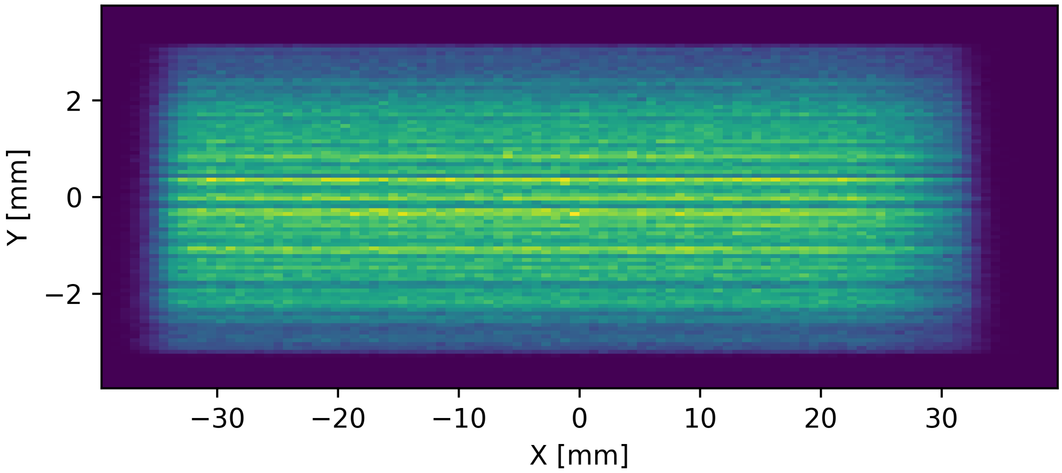


Figure 11: 0.1 urad

2.4.2 0.2 urad



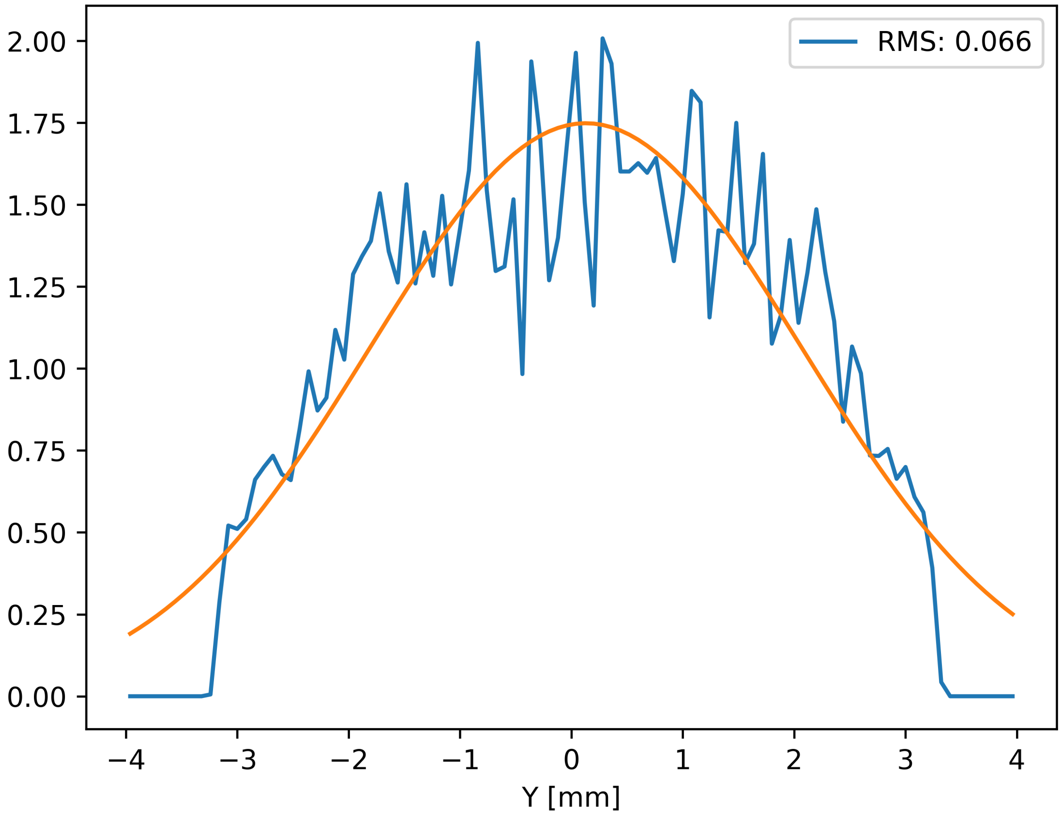
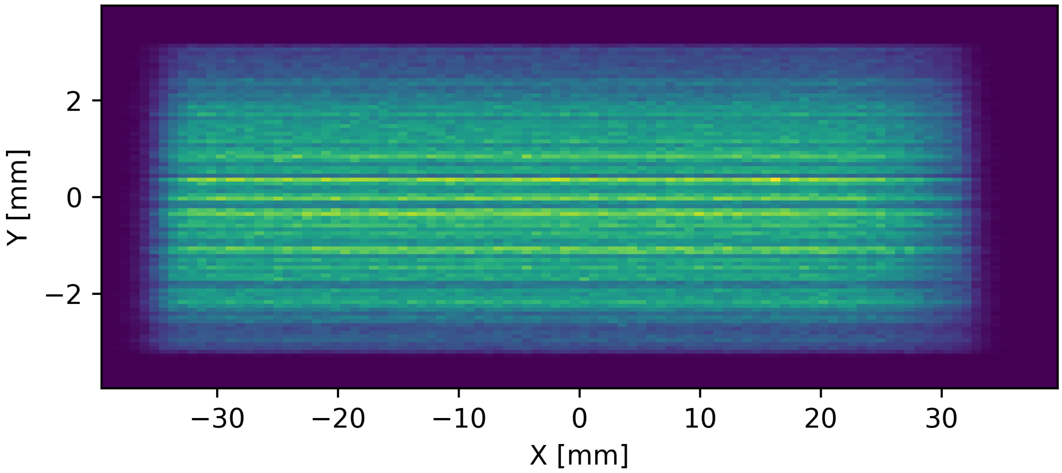


Figure 12: 0.2 urad

2.4.3 0.25 urad



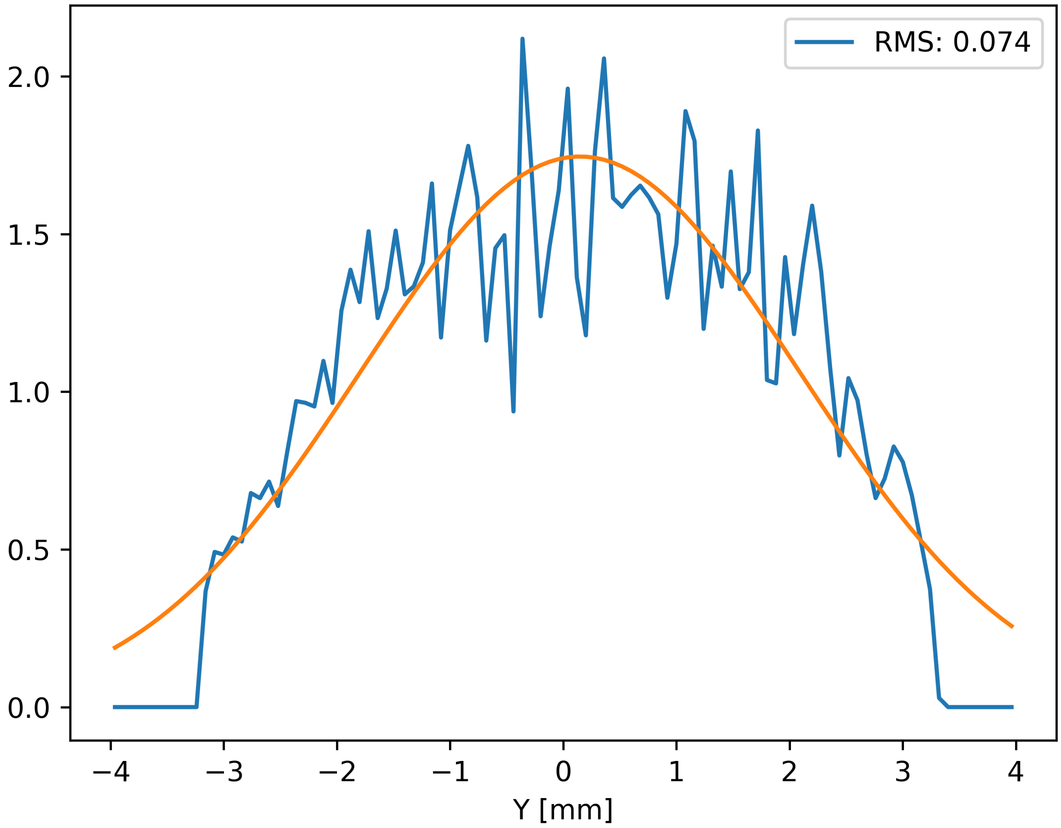
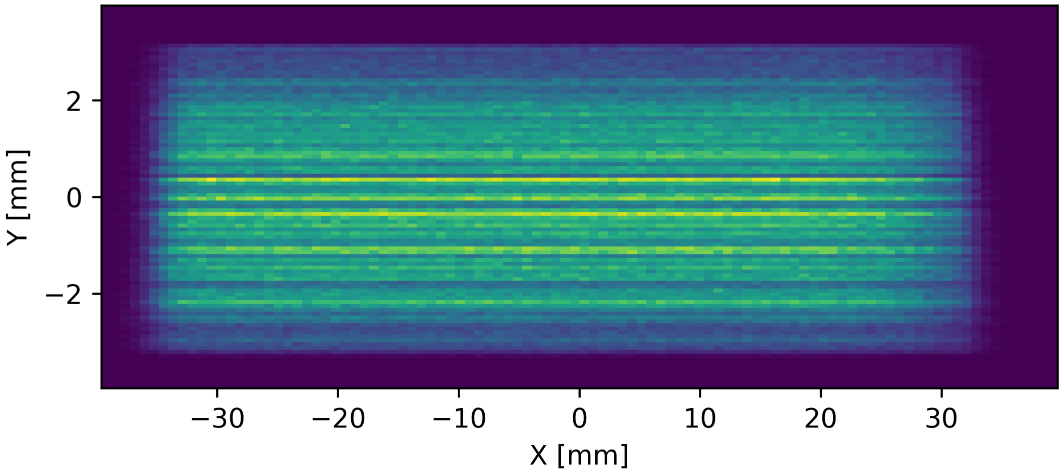


Figure 13: 0.25 urad

2.4.4 0.3 urad



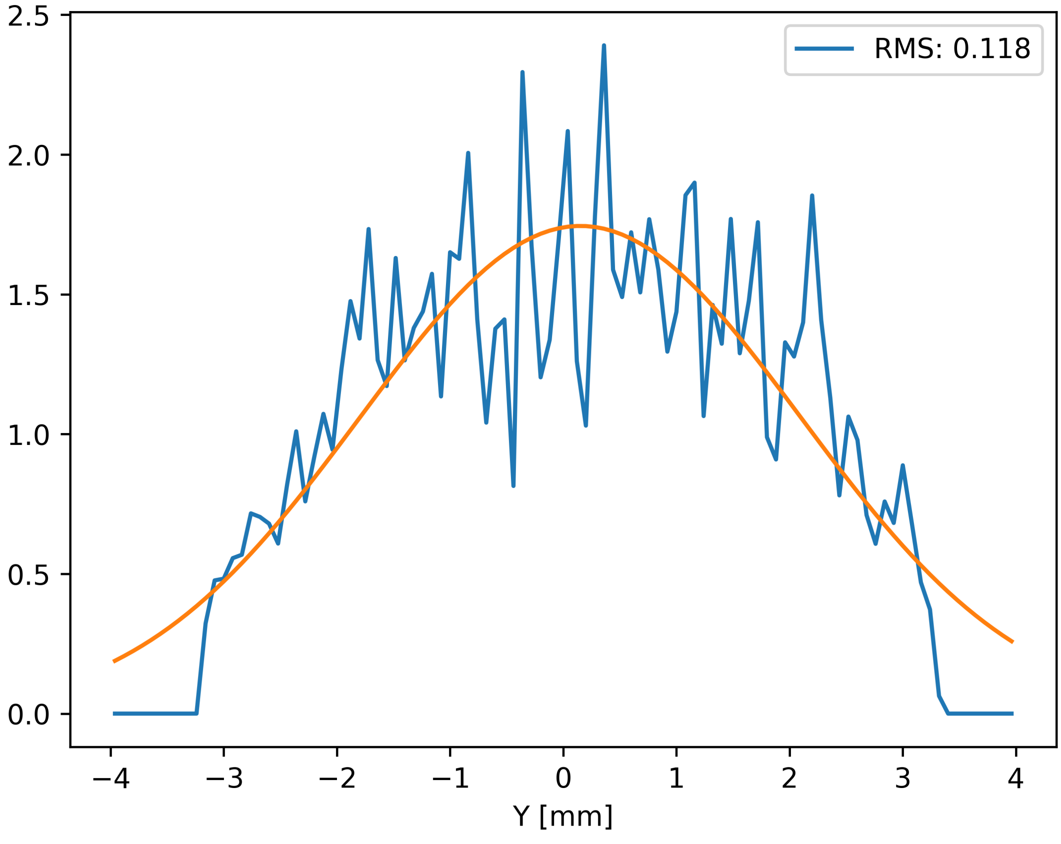


Figure 14: 0.3 urad

2.4.5 0.35 urad

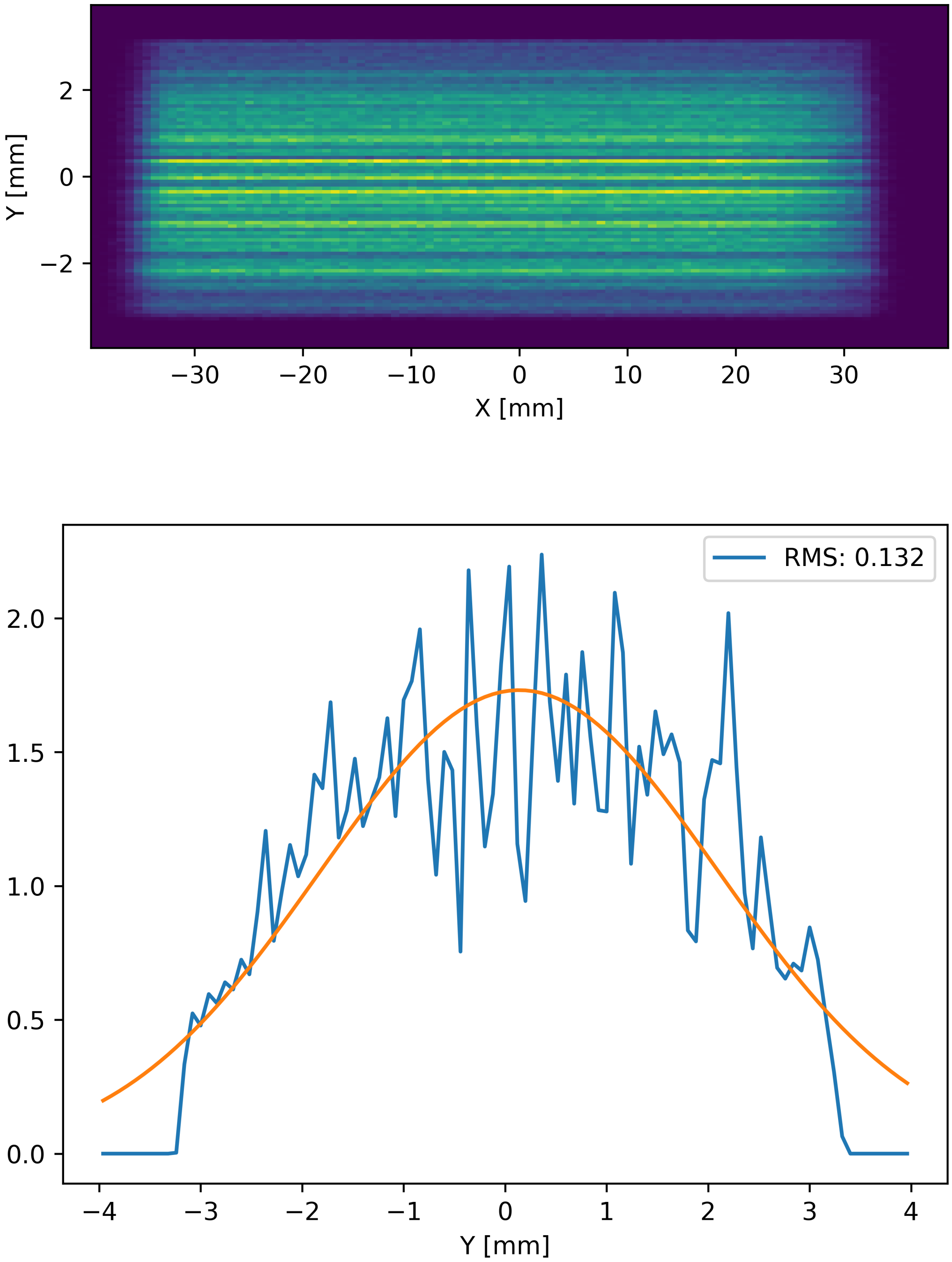


Figure 15: 0.35 urad

2.4.6 0.4 urad

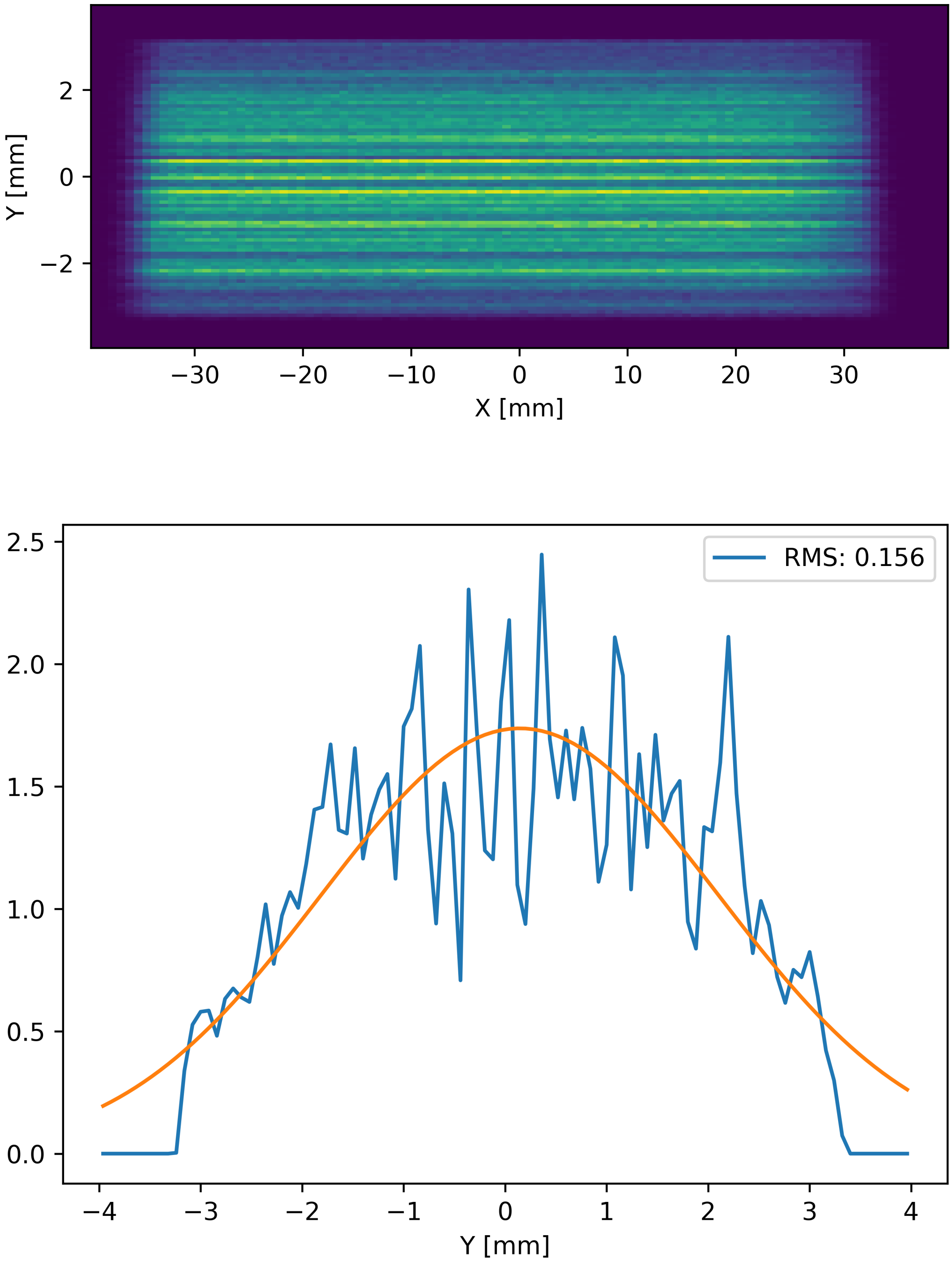
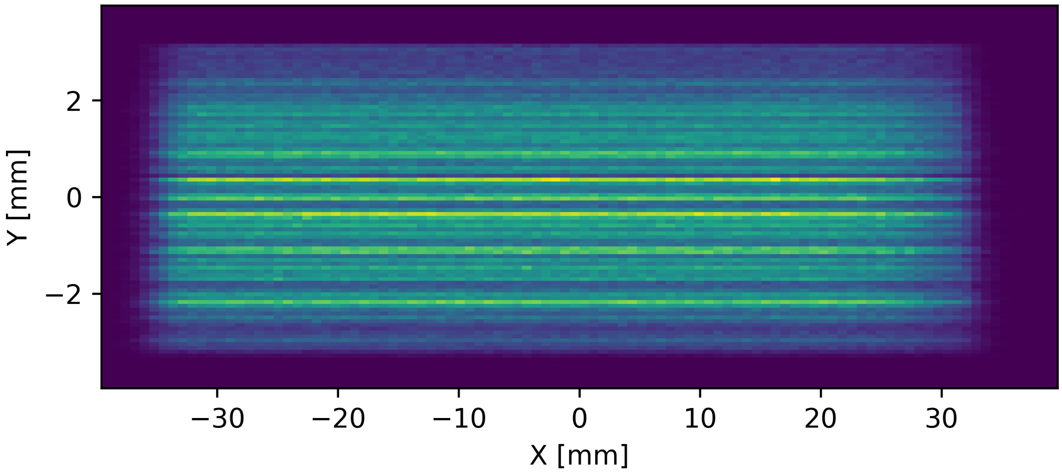


Figure 16: 0.4 urad

2.4.7 0.5 urad



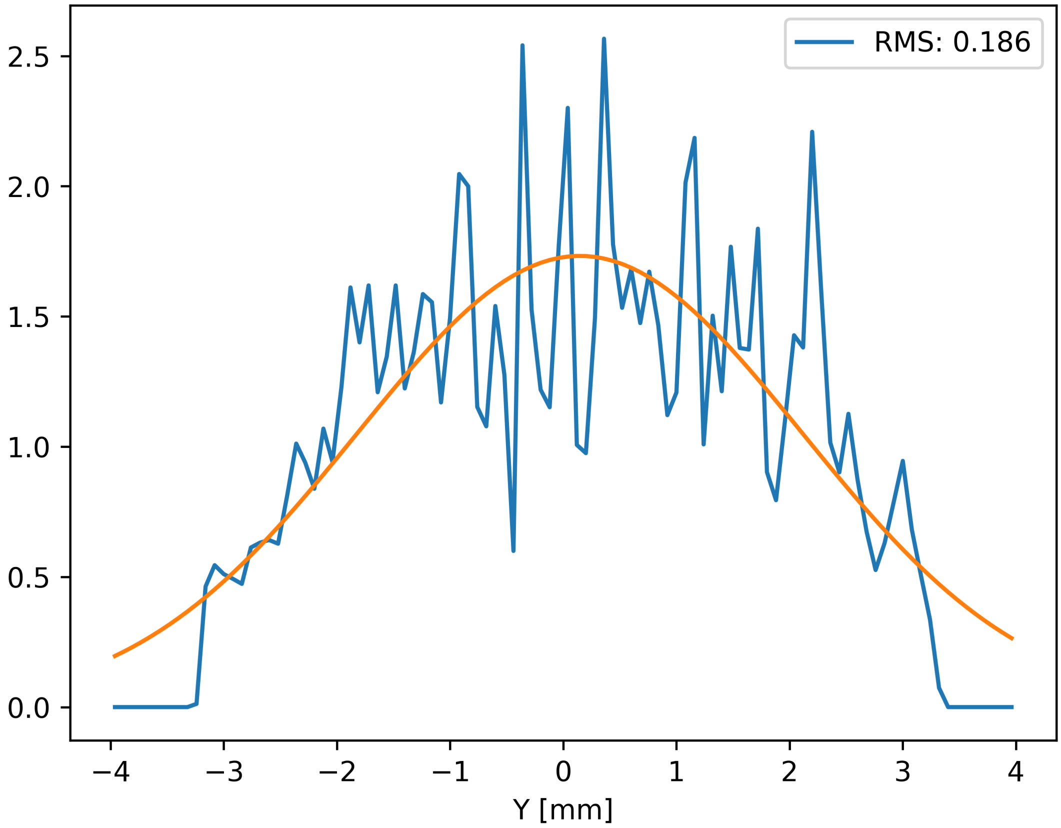


Figure 17: 0.5 urad

2.5 Thermal stability

The thermal stability of ML1 should be verified with FEA simulations considering the white beam colliding with the mirror at the maximum Bragg angle allowed by the Bragg stage motorization (34.9 mrad). The thermal stability of the cooled mask in front of the ML1 profile shall be also verified.

The power density profile at 15.165 m from source is shown in Figure 18. Raw data can be found in the power profiles source.

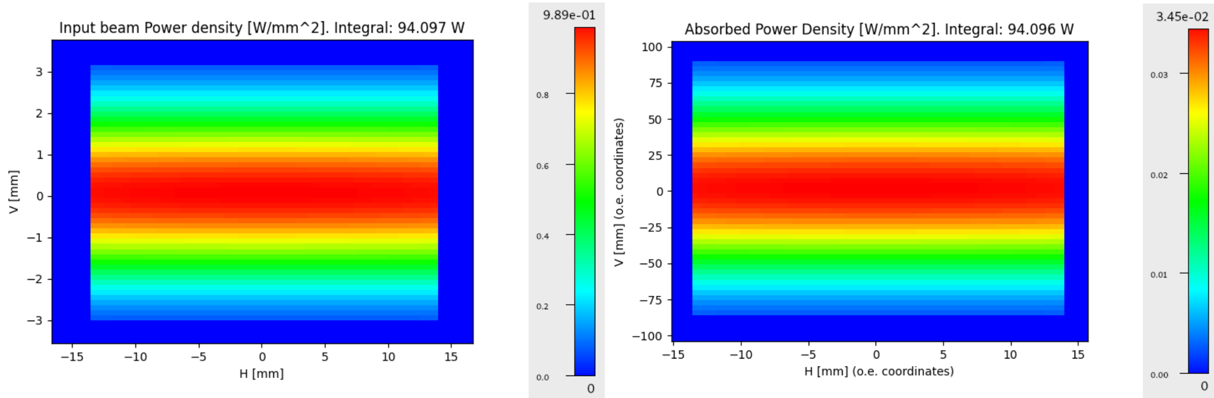


Figure 18: Power density profile at 15.165 m from source (center position of ML1). (LEFT) Input beam. (RIGHT) Absorbed by substrate at maximum grazing (2 deg); reflectivity neglected.