Two APS Upgrade Beamlines and Their Expected Performance at the MBA APS

Ruben Reininger

X-ray Science Division

Outline

- Ray tracings and its limitations
- Hybrid method
- RIXS beamline: Figure errors
- ISN beamline: Flux gain
- Summary

What can SHADOW do?

Source

x_i	x_i'
y_i	y_i'
z_i	z_i'
$h\nu_i$	Pol_i
OP_i	F_i

OE Element

Mirrors
Crystals
Gratings
Multilayers
Transfocator

Figure Errors
Slits
Apertures
Mirror Size

"Image"

x_i	x_i'
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z_i	z_i'
$h\nu_i$	Pol_i
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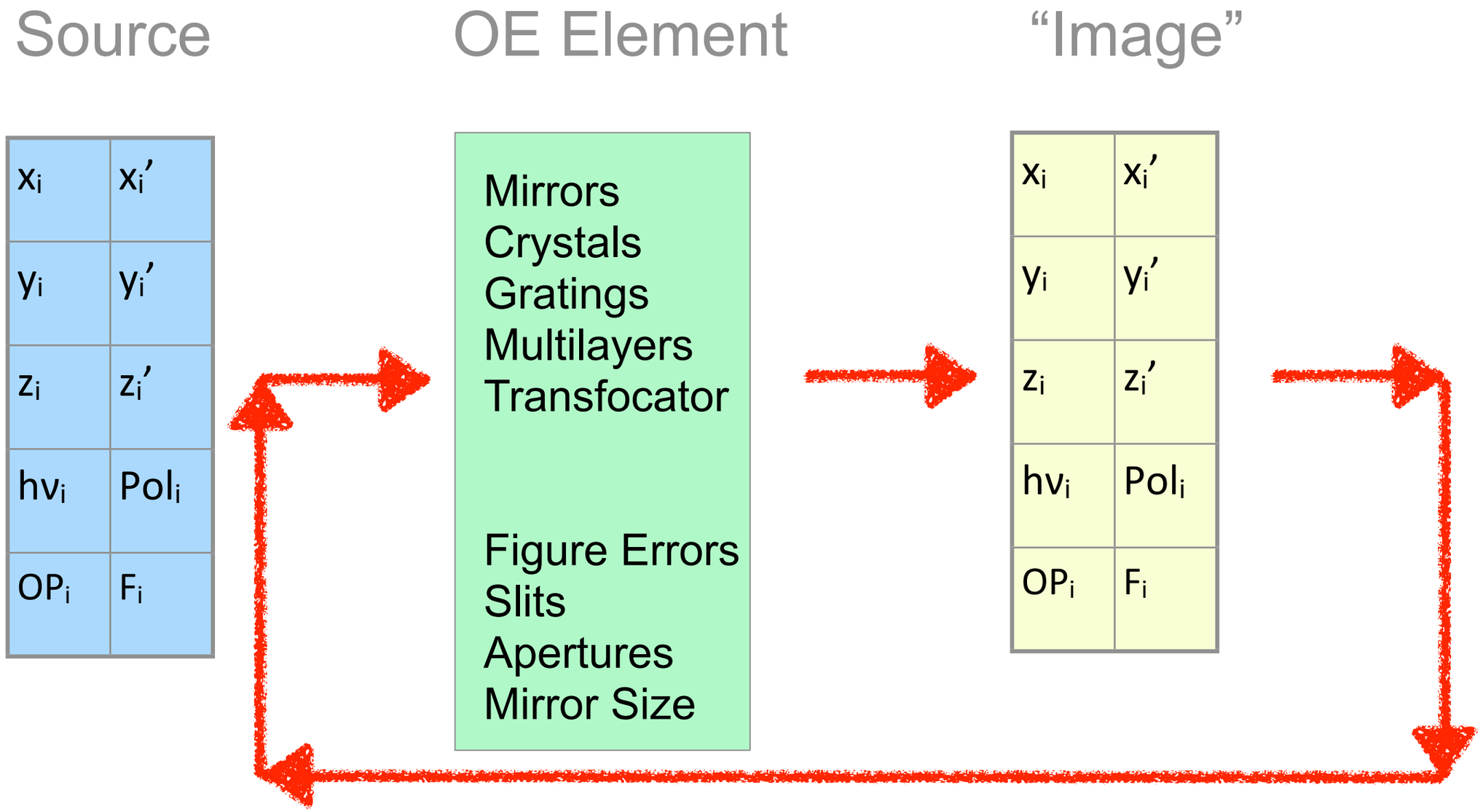
i=1,N
N limited by computer memory

What can SHADOW do?



i=1,N
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What SHADOW can't do

Source

x_i	x_i'
y_i	y_i'
z_i	z_i'
$h\nu_i$	Pol_i
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OE Element

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i=1,N
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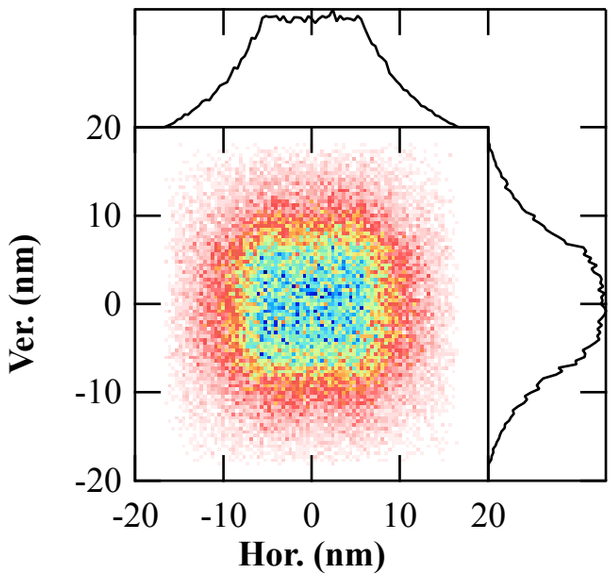
Hybrid: Ray Tracing+Wave Propagation

Fast tool to iterate in beamline simulations
Tested results on SRW

Ray Tracings

ISN

trans:2.2x10^{-4} SDx:6.4 nm SDy:6.6nm



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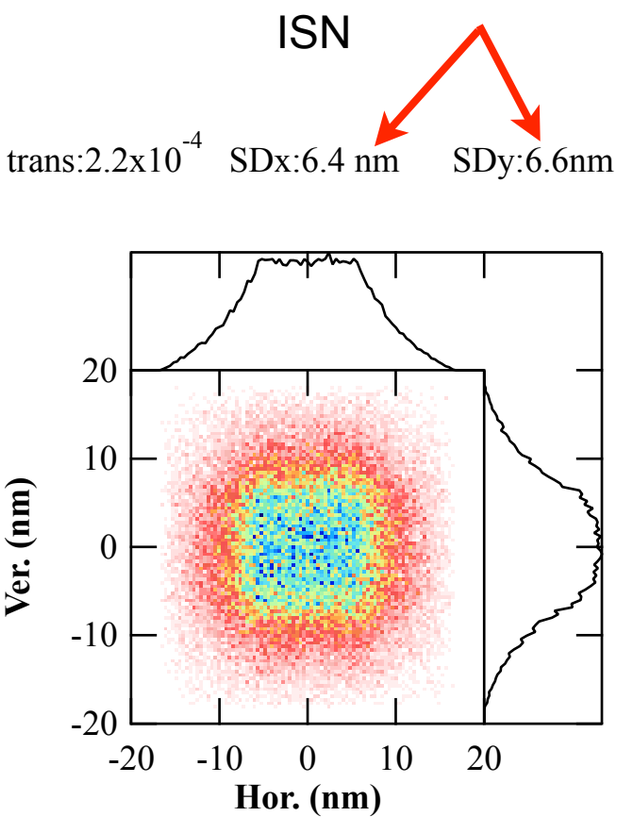

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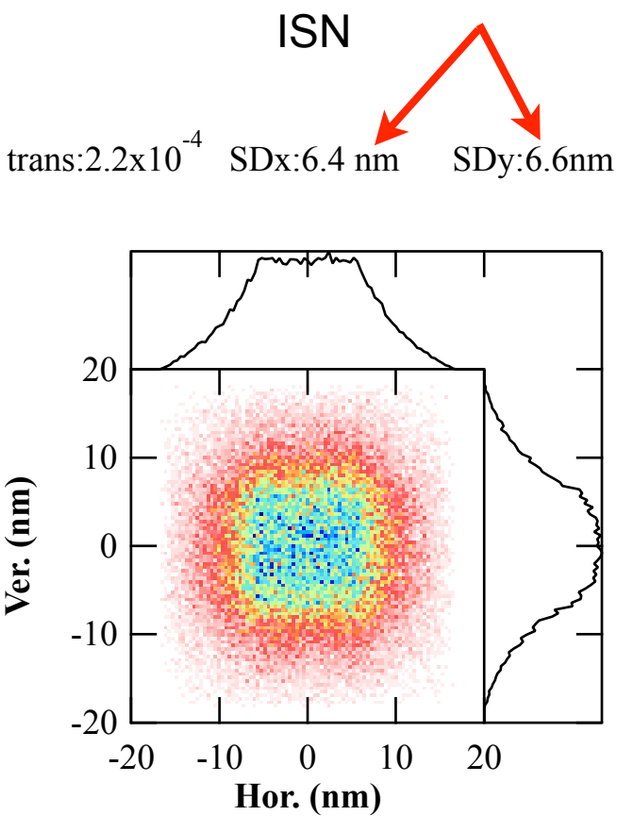

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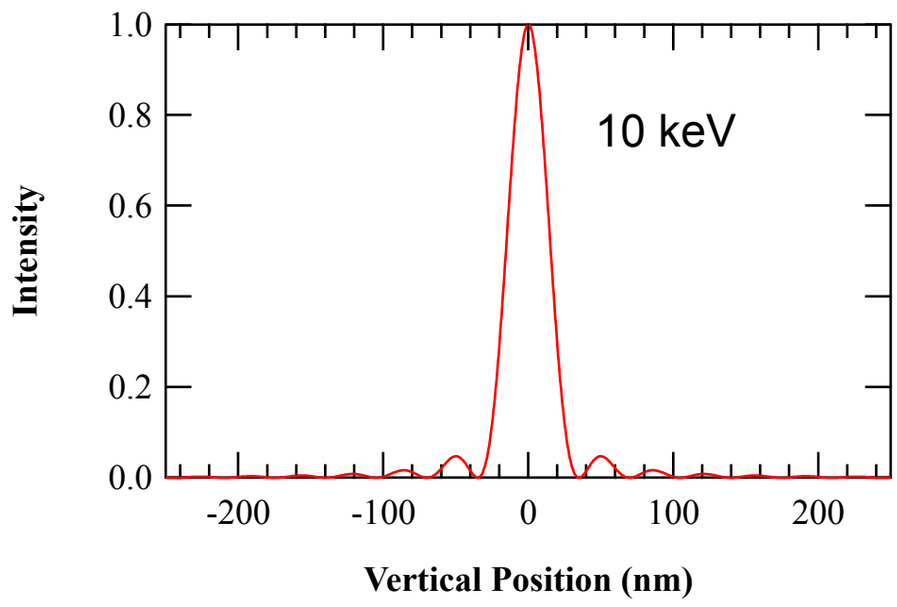

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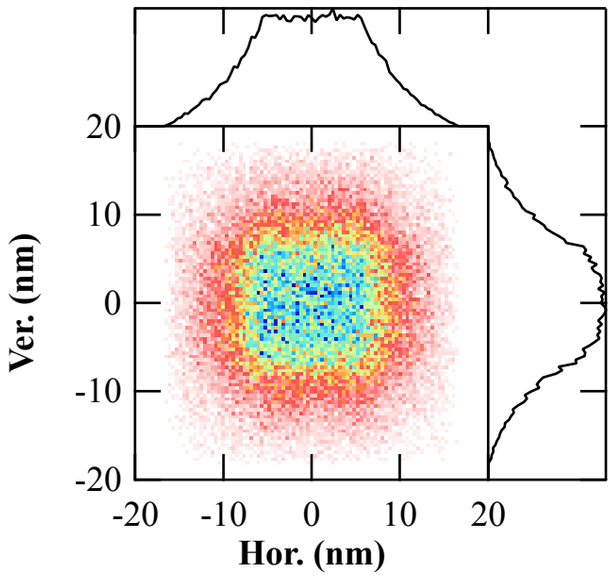
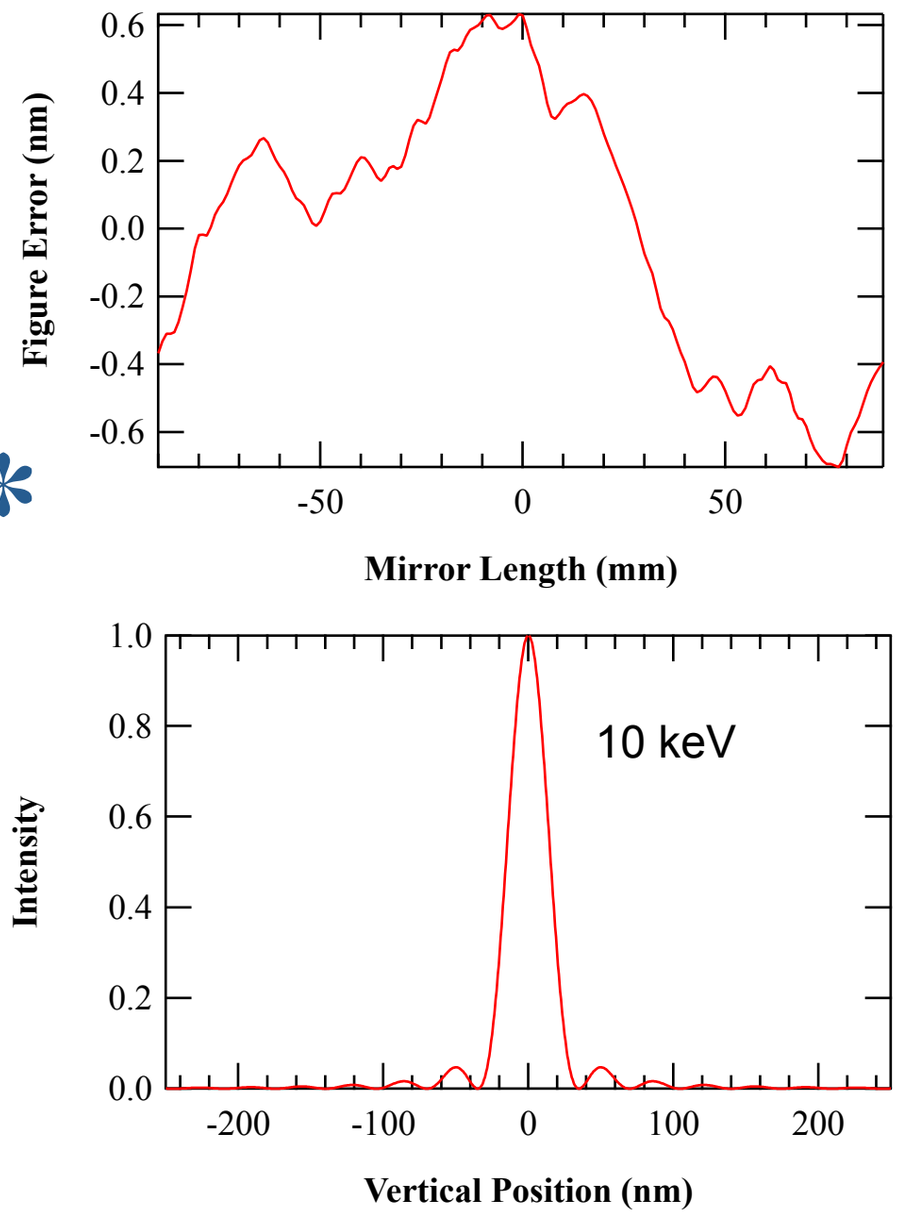


RMS Height: 0.4 nm
RMS Slope: 0.035 µrad



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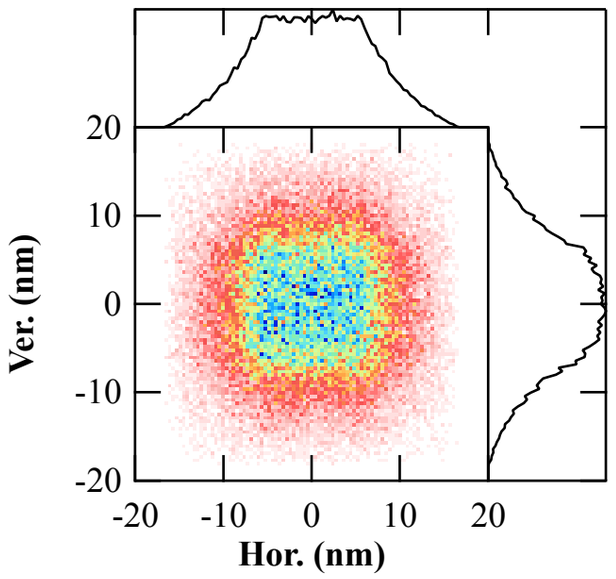

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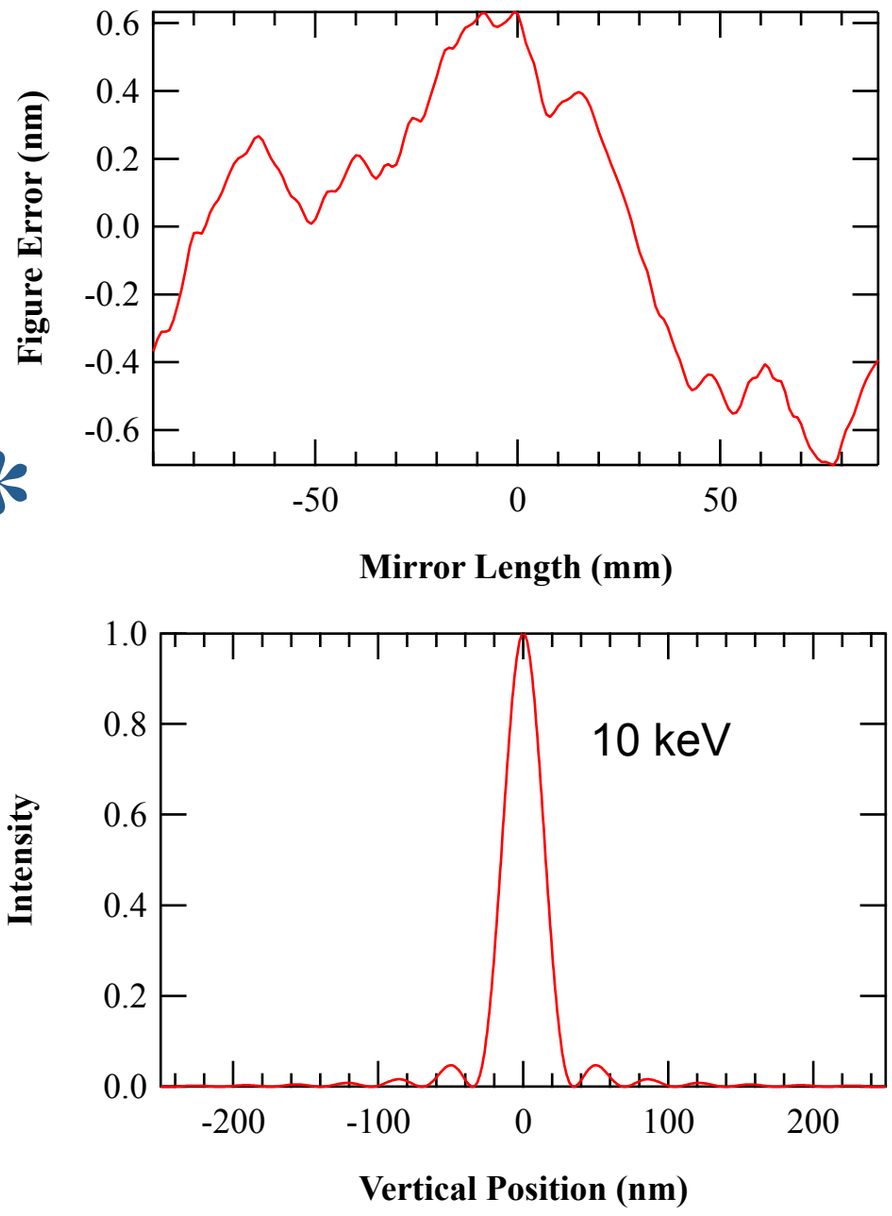
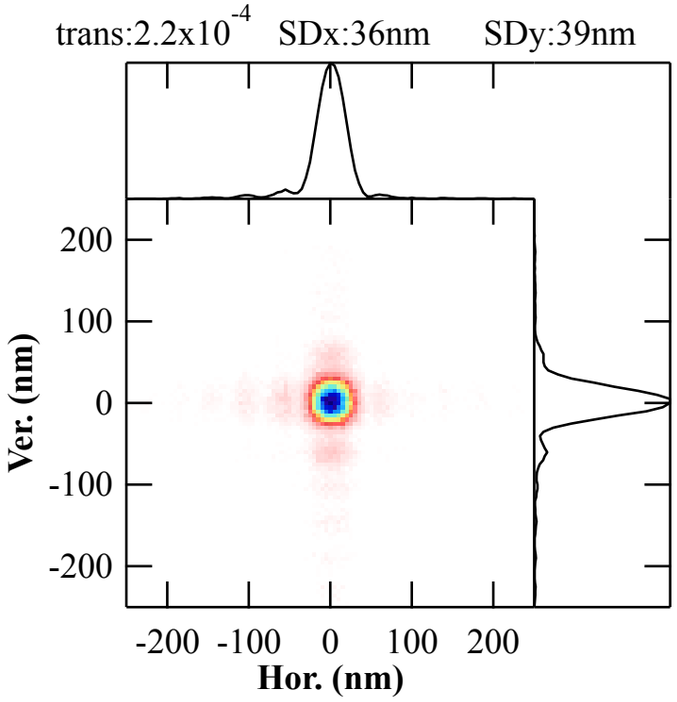


trans:2.2x10^{-4} SDx:36nm SDy:39nm



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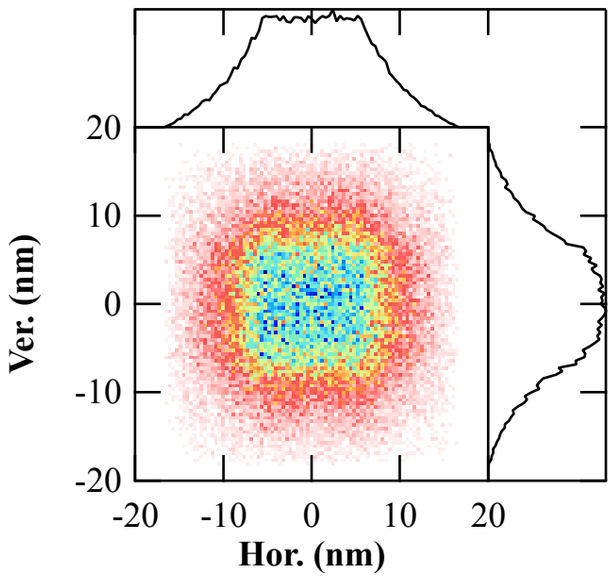

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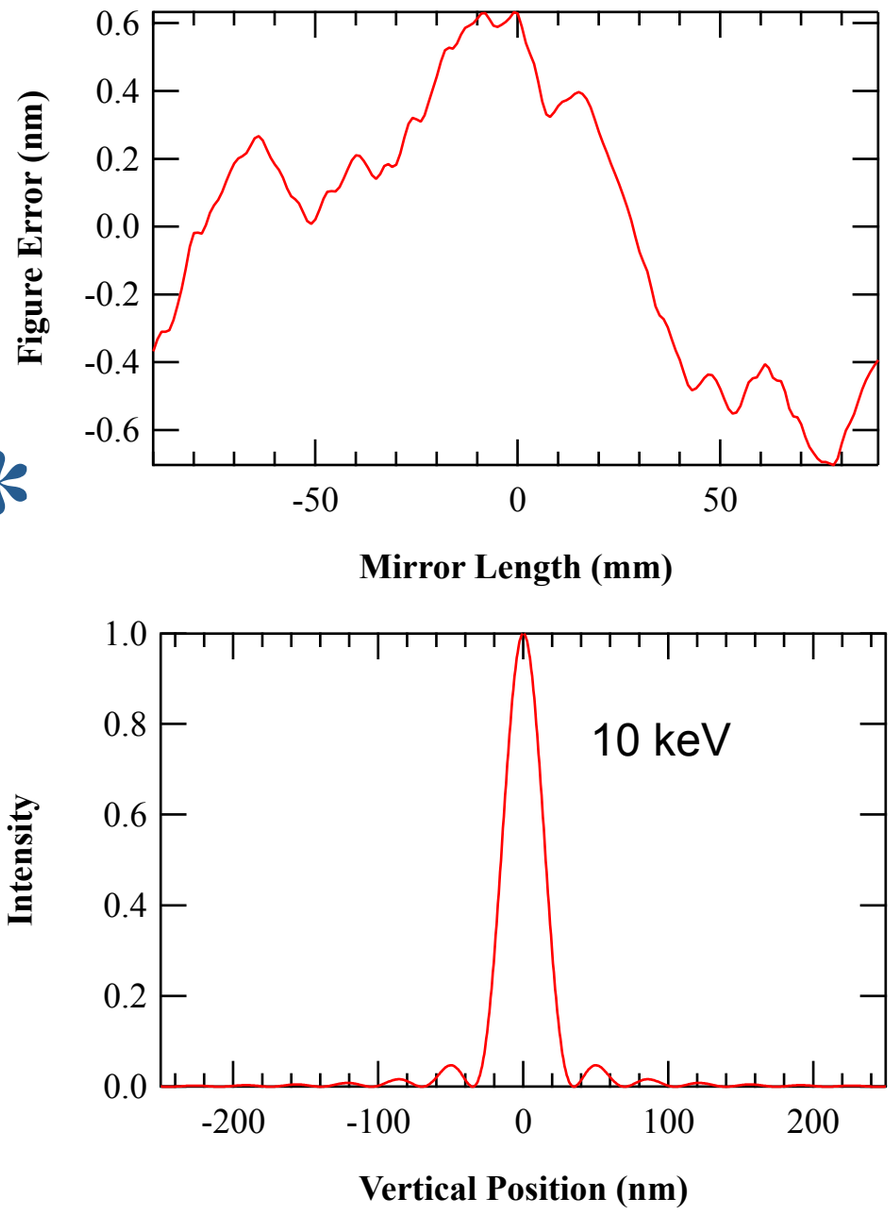

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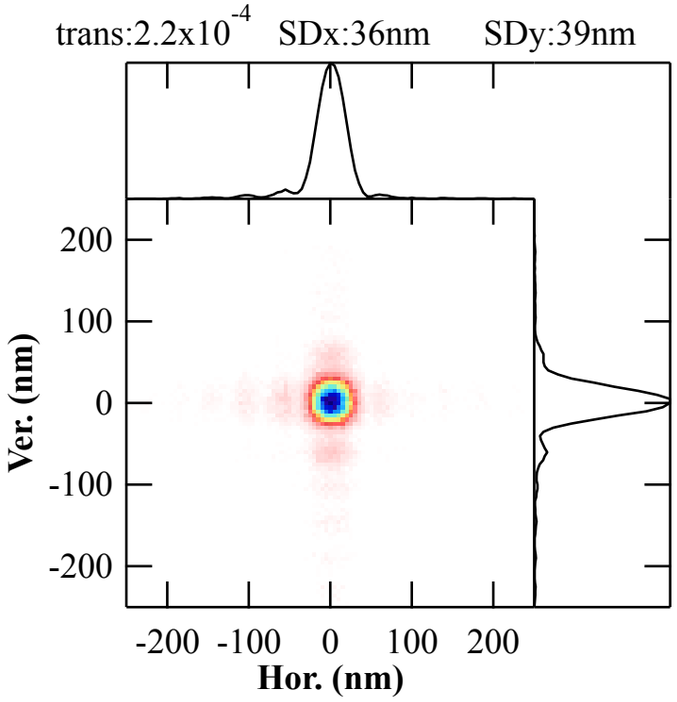


FWHM:
Horizontal 40 nm
Vertical 41 nm

Electron parameters APS, MBA

Performance Characteristics of APS Multibend Achromat Lattice

Michael Borland, Accelerator Systems Division
CVS revision 1.2: Tue Jul 30 20:19:01 CDT 2013.

Quantity	Symbol	Range	Units
Horizontal beta function	β_x	1-4	m
Horizontal dispersion function	η_x	< 3	mm
Horizontal beam size	σ_x	5 - 17	μm
Horizontal beam divergence	$\sigma_{x'}$	3 - 9	μrad
Horizontal size-divergence product	$\sigma_x\sigma_{x'}$	30 - 73	pm
Vertical beta function	β_y	1-4	m
Vertical dispersion function	η_y	0	mm
Vertical beam size	σ_y	2 - 13	μm
Vertical beam divergence	$\sigma_{y'}$	1 - 6	μrad
Vertical size-divergence product	$\sigma_y\sigma_{y'}$	6 - 40	pm

43 Hor
5.6 Ver

Ele			
	APS	MBA	
σ_x	276	14.8	µm
σ_y	11.6	4.3	µm
σ'_x	11.6	5.0	µrad
σ'_y	3.7	1.7	µrad
ε_x	3200	74	pmrad
ε_y	42	7.4	pmrad

Photon parameters APS, MBA

Photon RIXS	Electron			Total			
Energy: 11.2 keV, (4.8 m device)		**APS**	**MBA**		**APS**	**MBA**	
σ_r = 5.2	σ_x	276	14.8	Σ_x	276	15.6	μm
	σ_y	11.6	4.3	Σ_y	12.7	6.8	μm
σ_ρ = 3.4	σ'_x	11.6	5.0	Σ'_x	12.0	6.0	μrad
	σ'_y	3.7	1.7	Σ'_y	5.0	3.8	μrad

$$\sigma_r \approx \frac{1}{2\pi}\sqrt{2L\lambda}$$

$$\sigma_\rho \approx \sqrt{\frac{\lambda}{2L}}$$

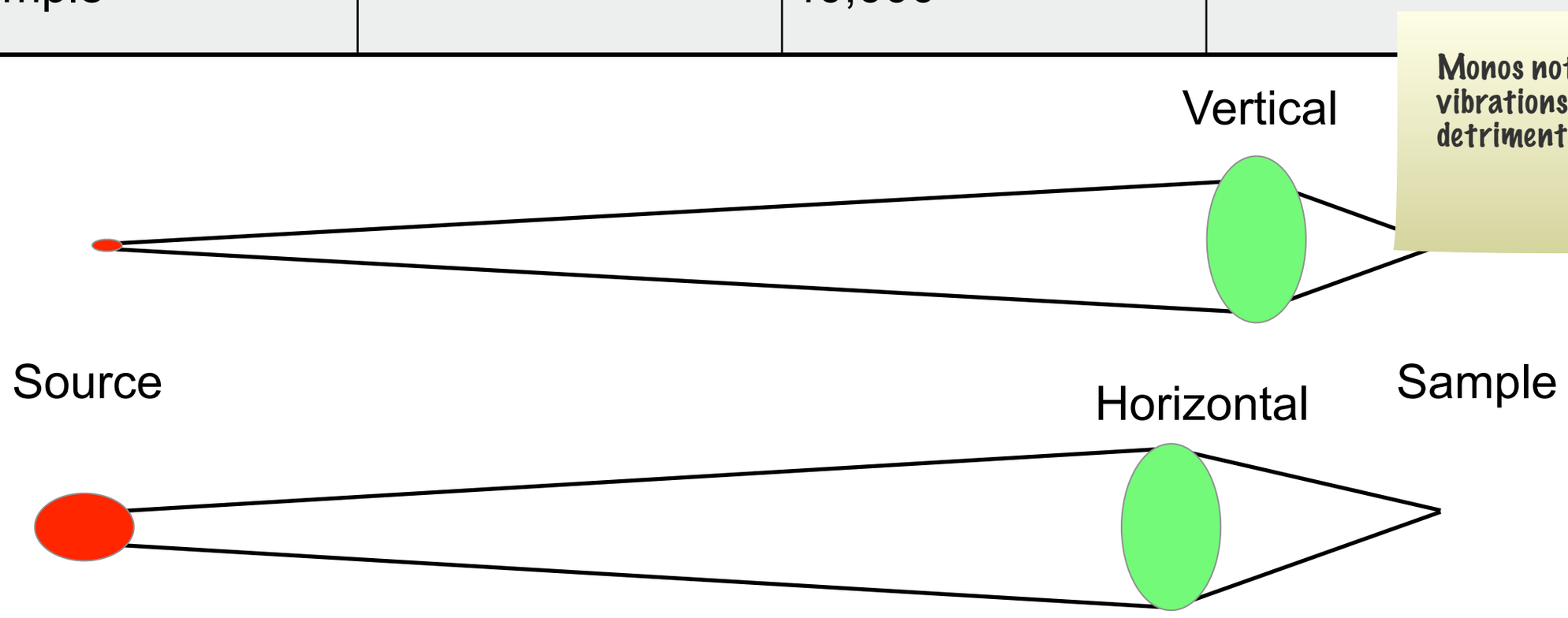
For resonant energy

$$\Sigma_{x,y} \approx \sqrt{\sigma_{x,y}^2 + \sigma_r^2}$$

$$\Sigma'_{x,y} \approx \sqrt{\sigma'^2_{x,y} + \sigma_\rho^2}$$

RIXS: Optics considered in hybrid simulations

Element	Length	Distance from source (mm)	Incidence angle (mrad)
Elliptical cylinder Hor. Focusing	320 mm	39,120	3
Elliptical cylinder Ver. focusing	320 mm	39,440	3
Sample		40,000	



Monos not included but vibrations could be detrimental

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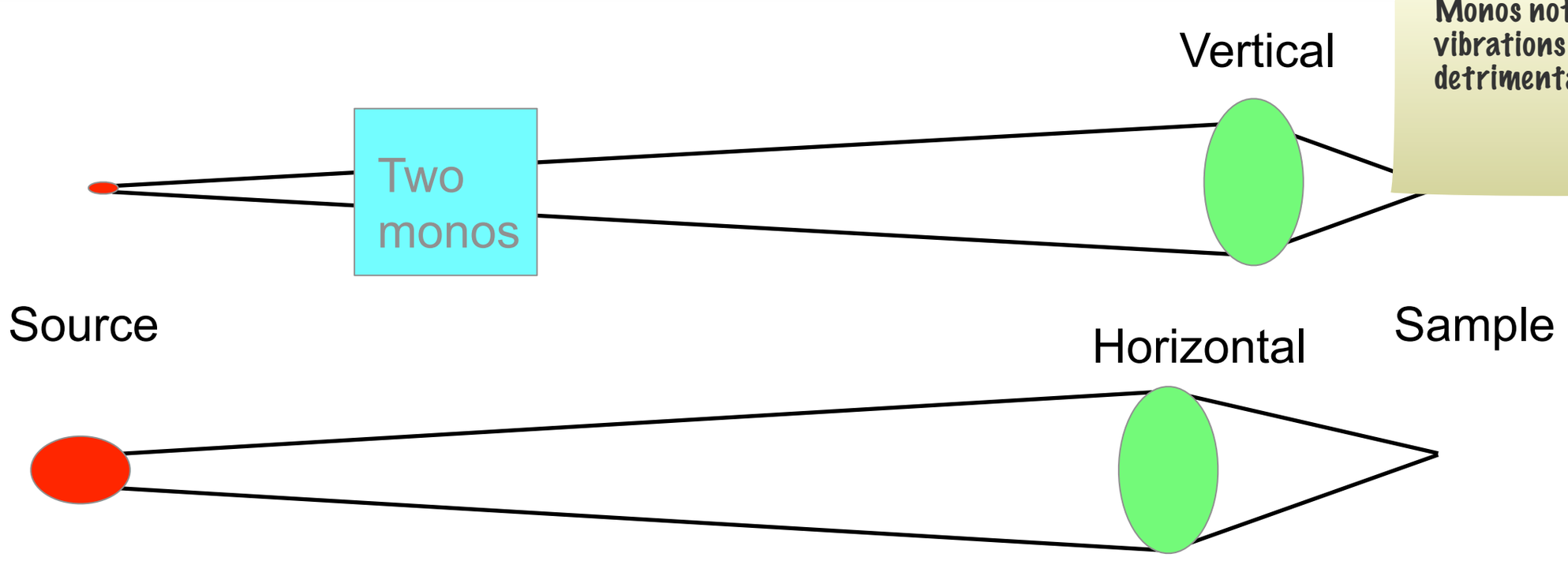
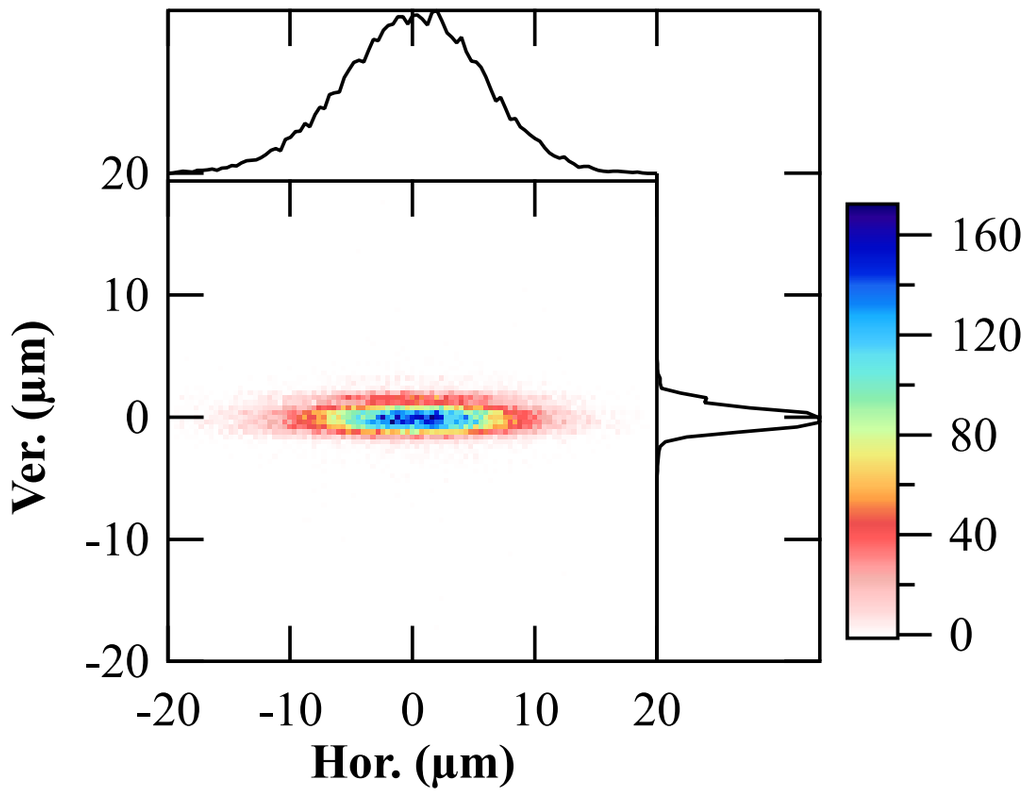


Monos not included but vibrations could be detrimental

APS vs MBA

APS: Hybrid @ sample

Trans: 0.61 SDx:5.7 μm SDy:1.0 μm
Hor RMS 1.0 μrad, Ver RMS 1.0 μrad



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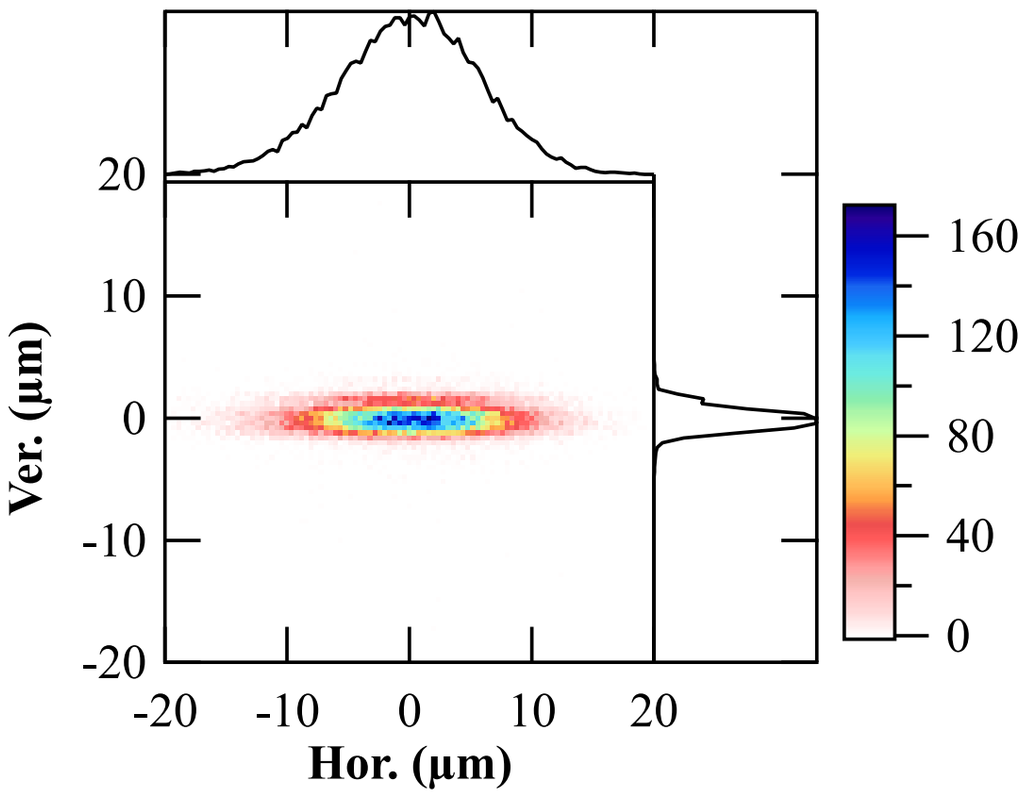
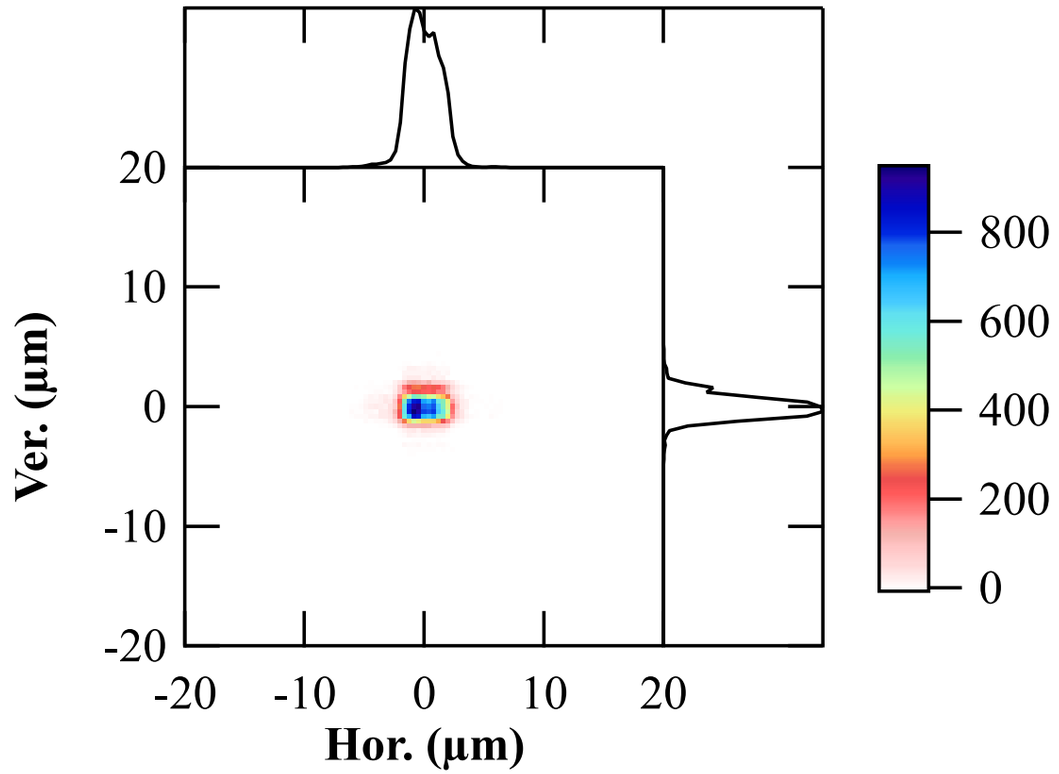


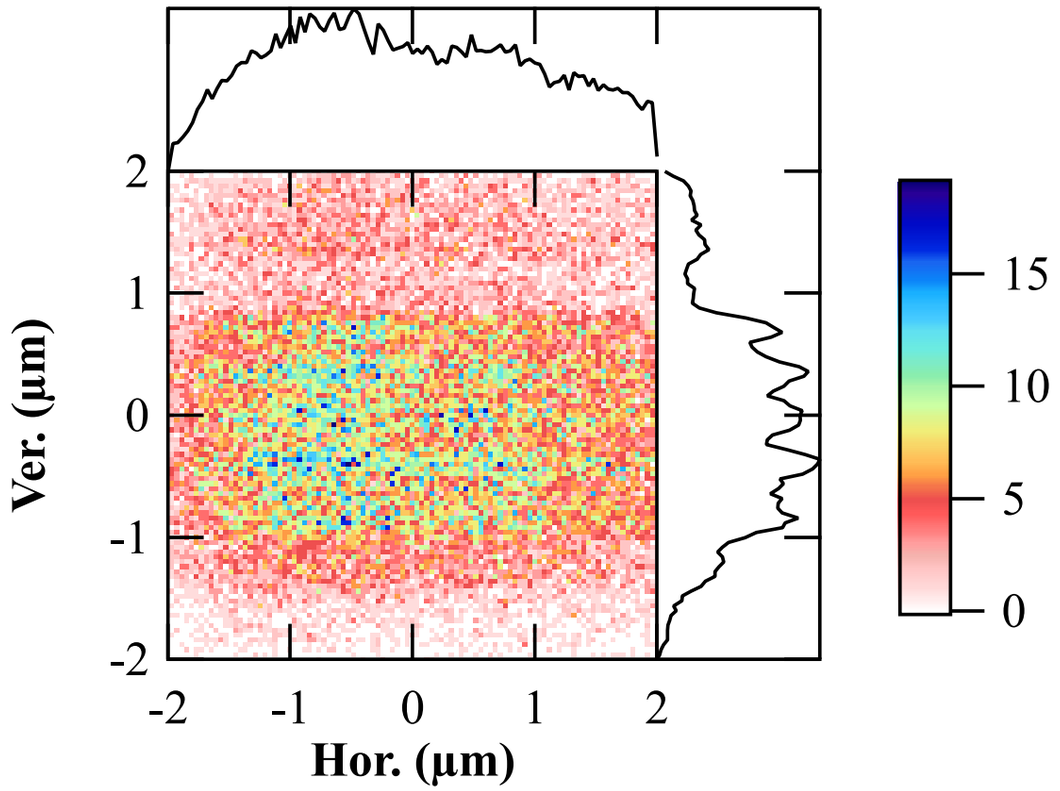
MBA: Hybrid sample

Trans: 0.96 SDx:1.5 μm SDy:1.0 μm
Hor RMS 1.0 μrad, Ver RMS 1.0 μrad



Slope errors with MBA

Trans:0.82 SDx:1.0 μm SDy:0.83 μm
Hor RMS 1.0 μrad, Ver RMS 1.0 μrad



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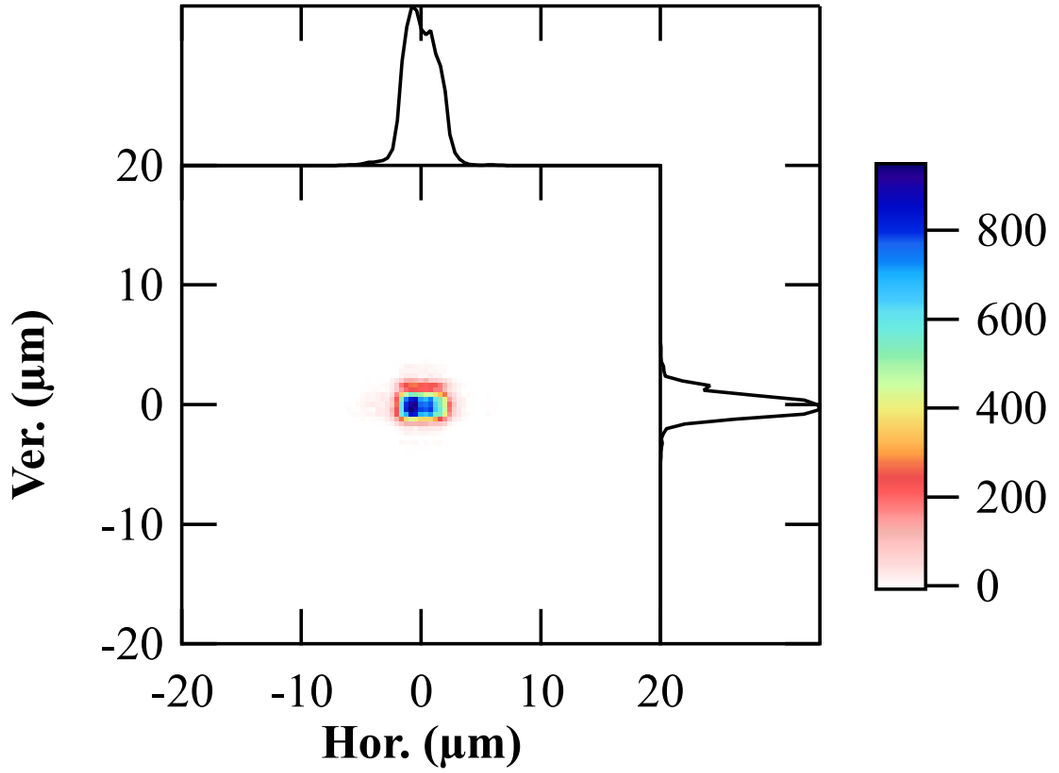

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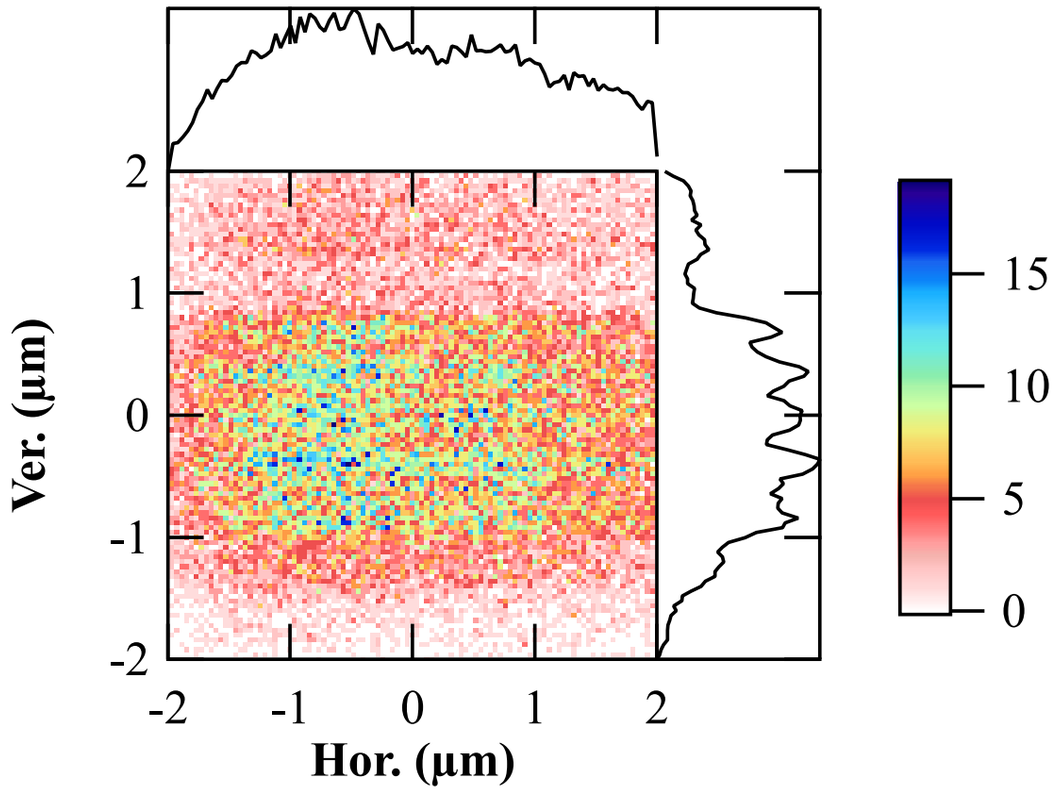
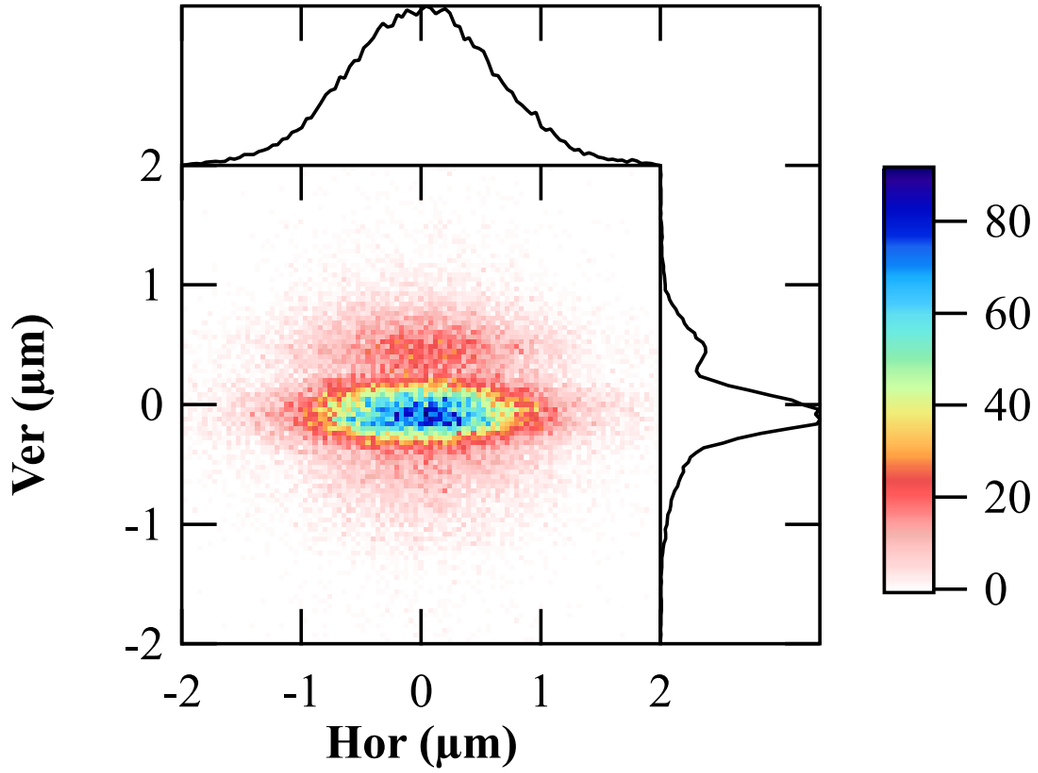
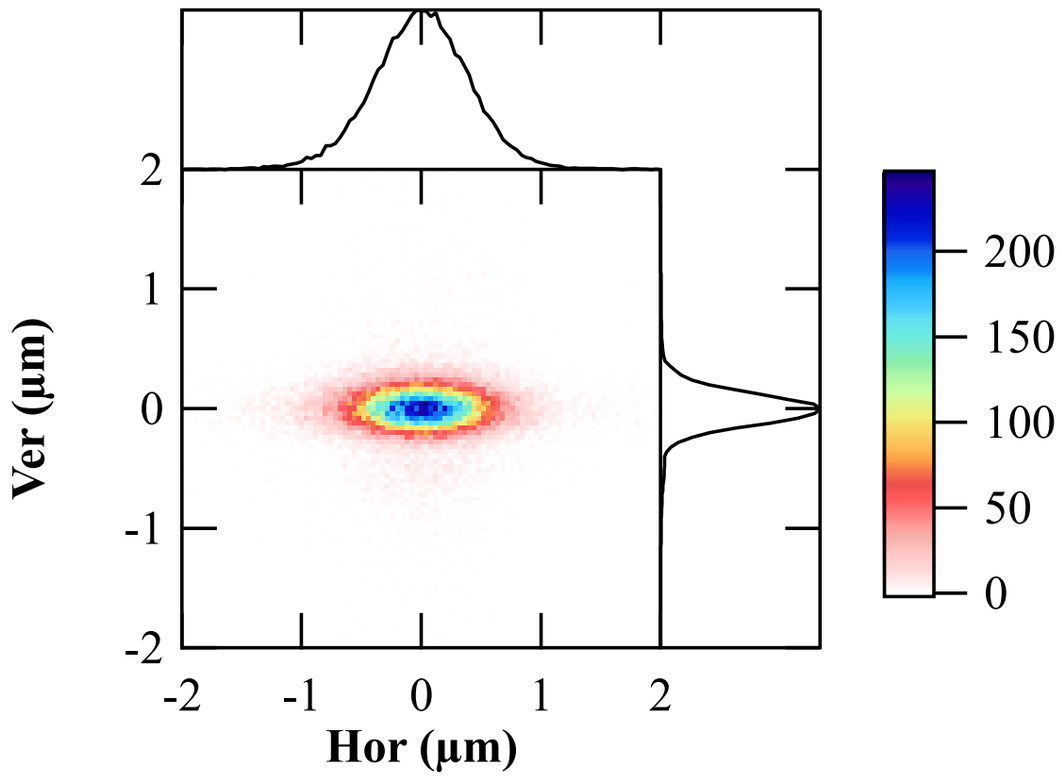


Trans: 0.96 SDx:0.63 μm SDy:0.41 μm
Hor RMS 0.45 μrad, Ver RMS 0.45 μrad

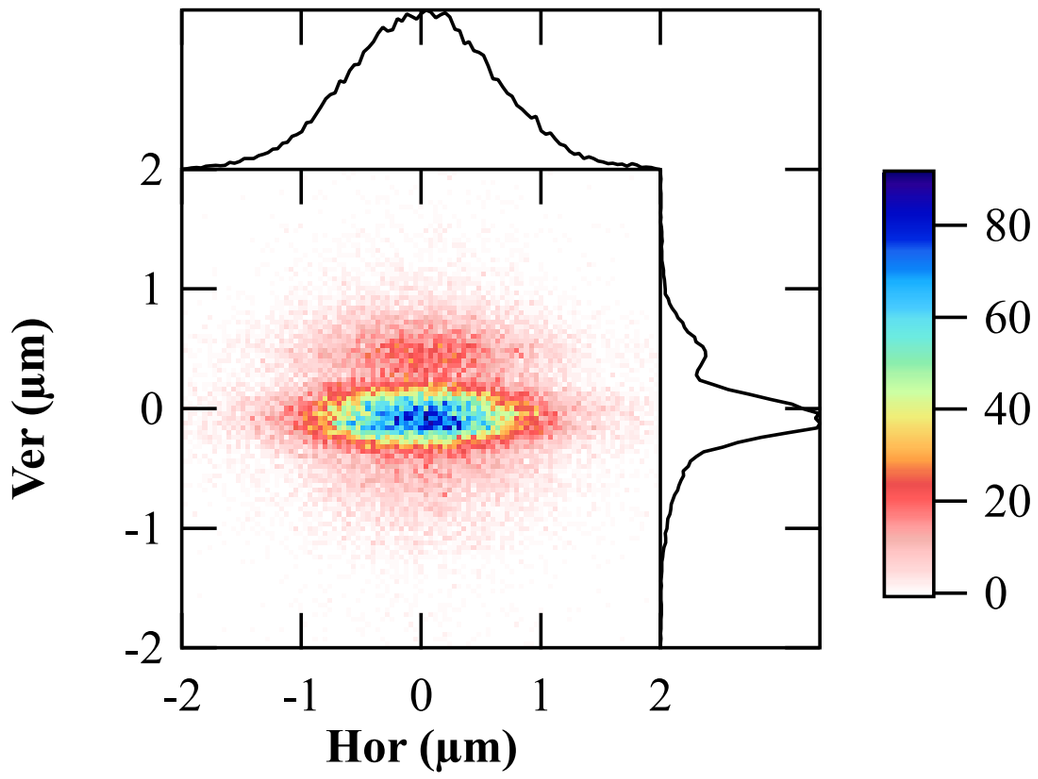


Slope errors with MBA

Trans: 0.96 SDx:0.42 μm SDy:0.20 μm
Hor RMS 0.15 μrad, Ver RMS 0.15 μrad



Trans: 0.96 SDx:0.63 μm SDy:0.41 μm
Hor RMS 0.45 μrad, Ver RMS 0.45 μrad



Slope errors with MBA

Trans: 0.96 SDx:0.42 µm SDy:0.20 µm
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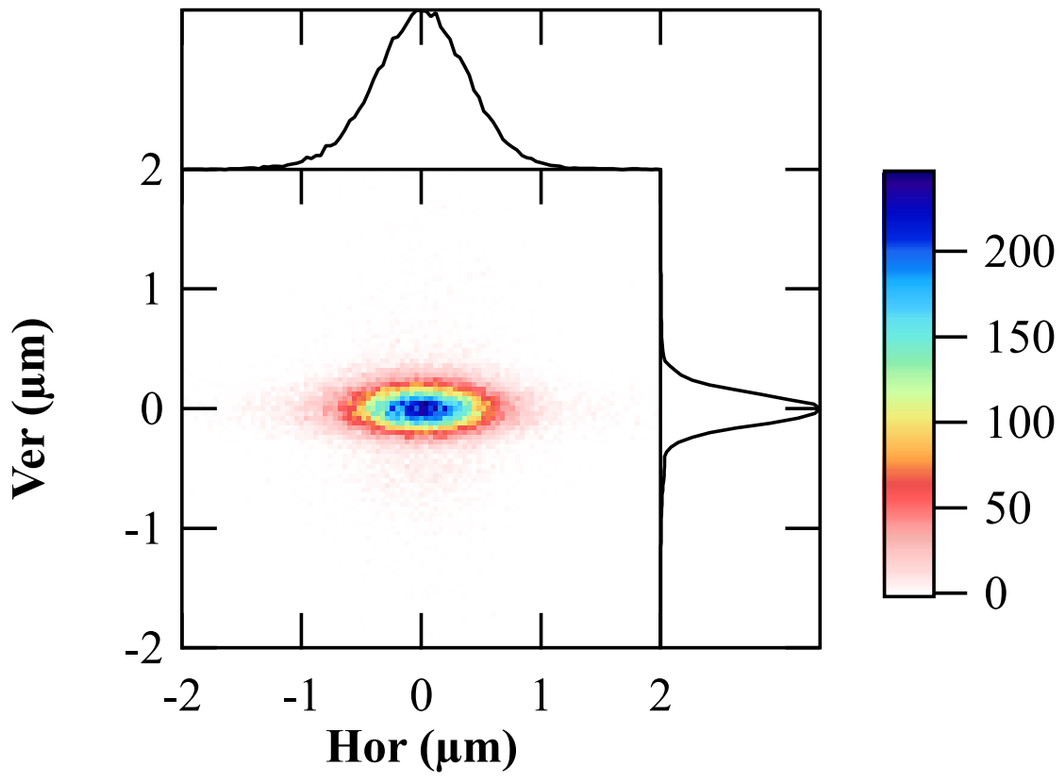
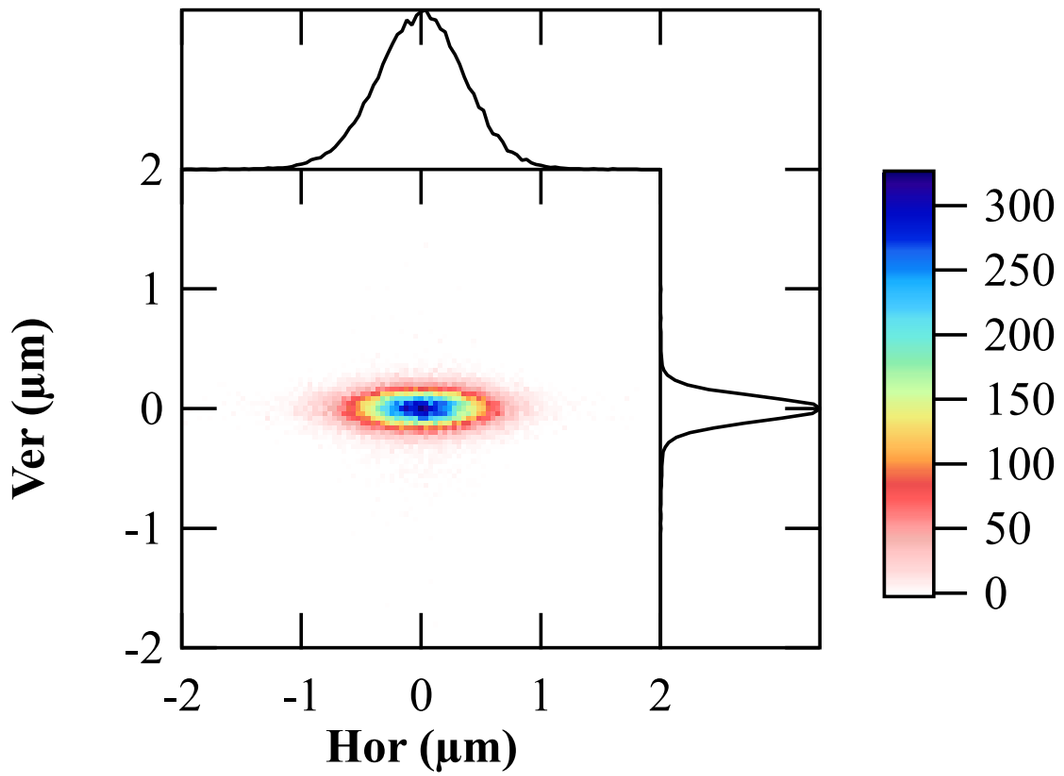


Trans: 0.96 SDx:0.38 µm SDy:0.16 µm
Hor RMS 0.05 µrad, Ver RMS 0.05 µrad



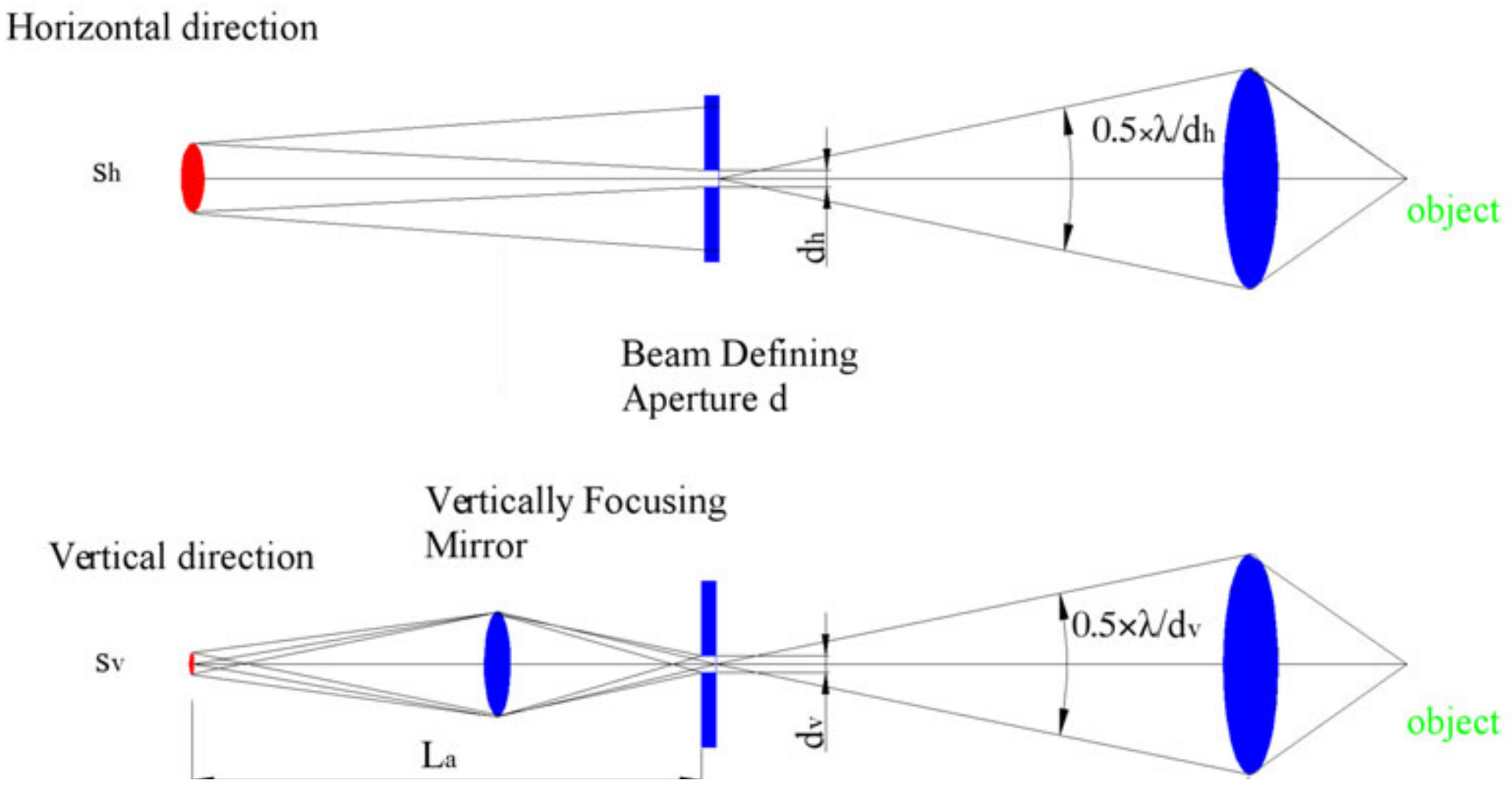
Along vertical diff. 100 nm

ISN Beamline

10 keV
2.4 m device

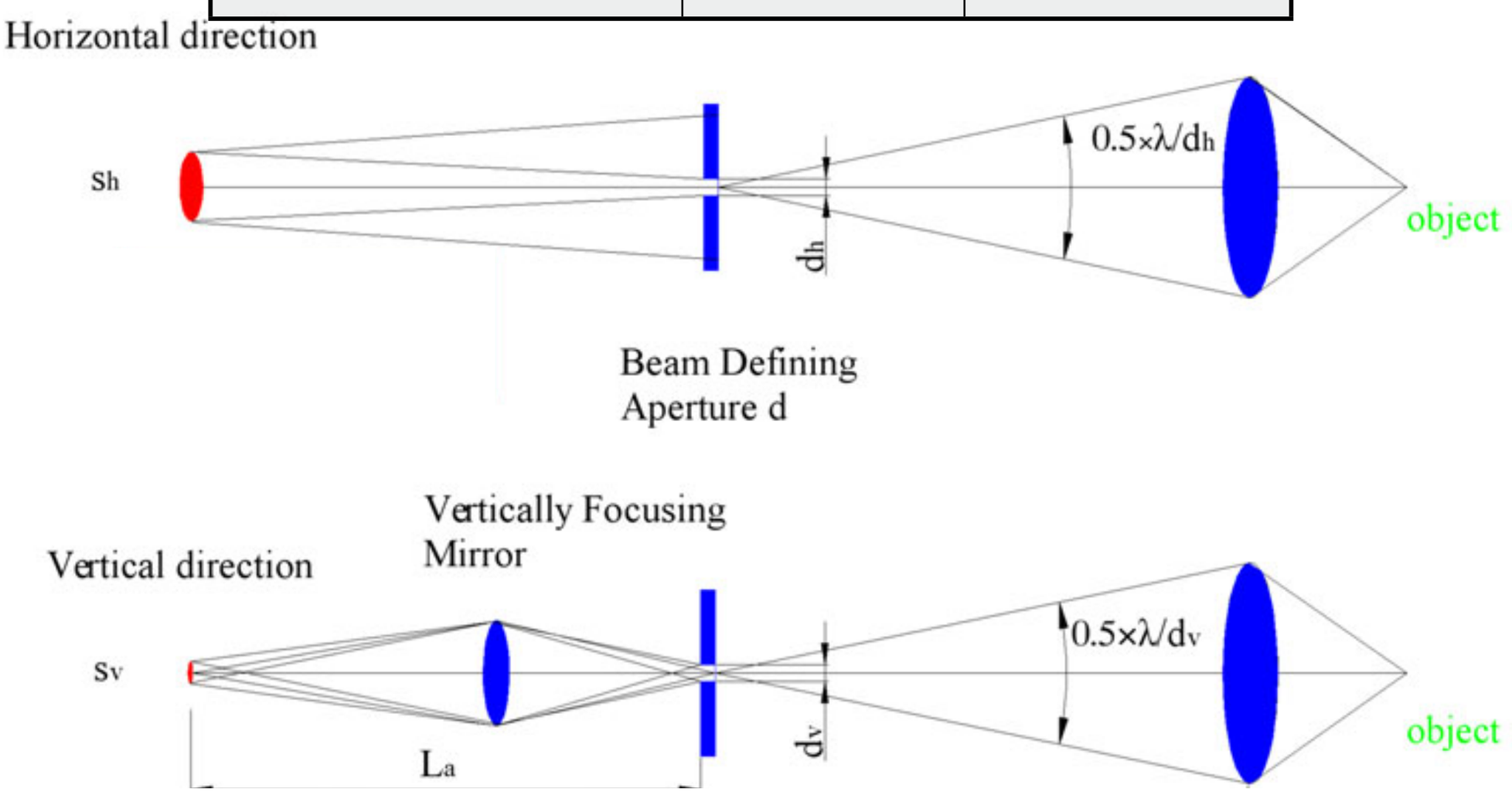
	APS	MBA	
Σ_x	276	15.8	μm
Σ_y	12.7	7.0	μm
Σ'_x	12.0	6.0	μrad
Σ'_y	5.0	3.8	μrad

35 horizontal
2.4 vertical



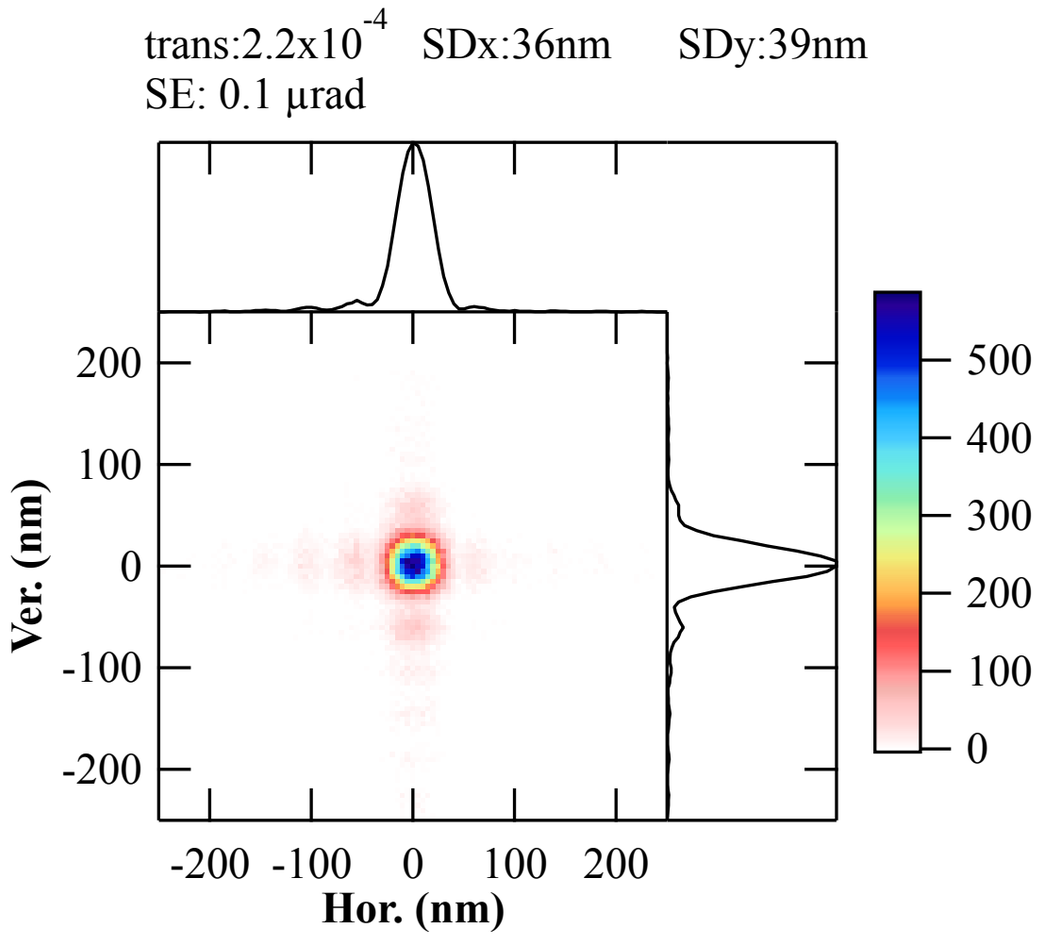
ISN Beamline

Element	Size	Distance from source (mm)
Elliptical cyl. Vert. Focusing	360×2 mm^2	35300
Aperture	11×4 μm^2 (h×v)	42200
Elliptical cyl. Vert. Focusing	180 mm	71820
Elliptical cyl. Hor. Focusing	60 mm	71940
Sample		72000



APS vs MBA

APS: Hybrid @ sample

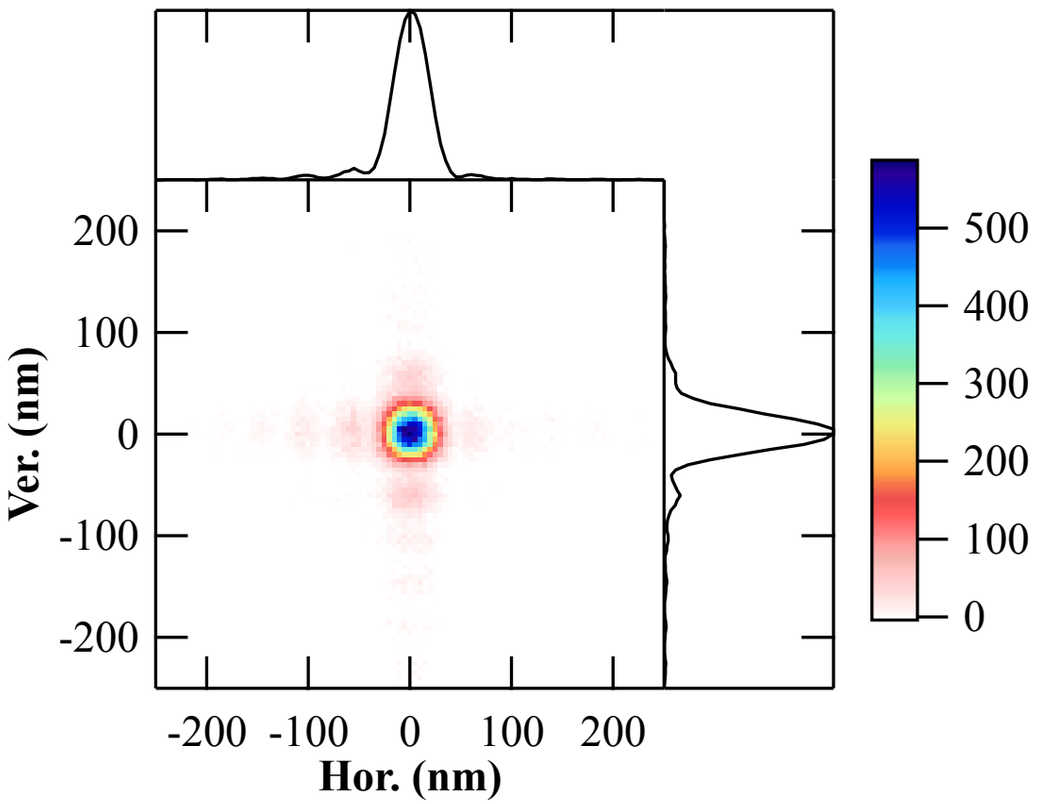


APS vs MBA

No horizontal aperture

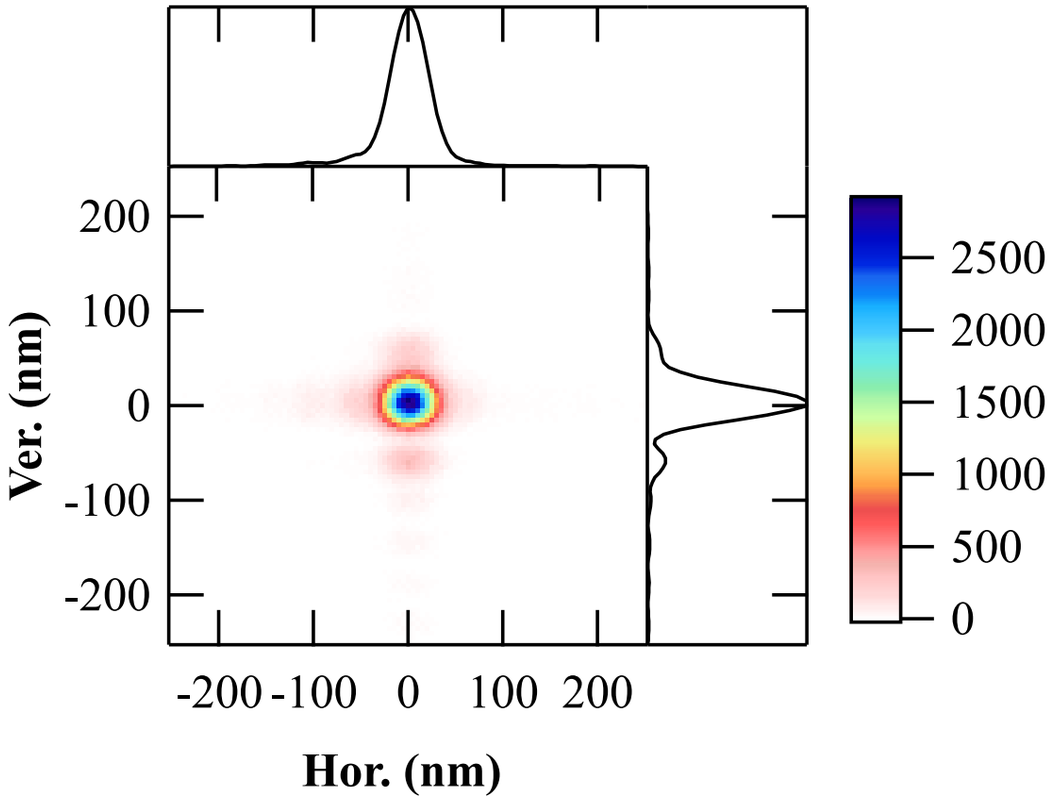
APS: Hybrid @ sample

trans:2.2x10^{-4} SDx:36nm SDy:39nm
SE: 0.1 µrad



MBA: Hybrid @ sample

Trans: 3.2e-2 SDx:38 µm SDy:41 µm
SE: 0.1 µrad



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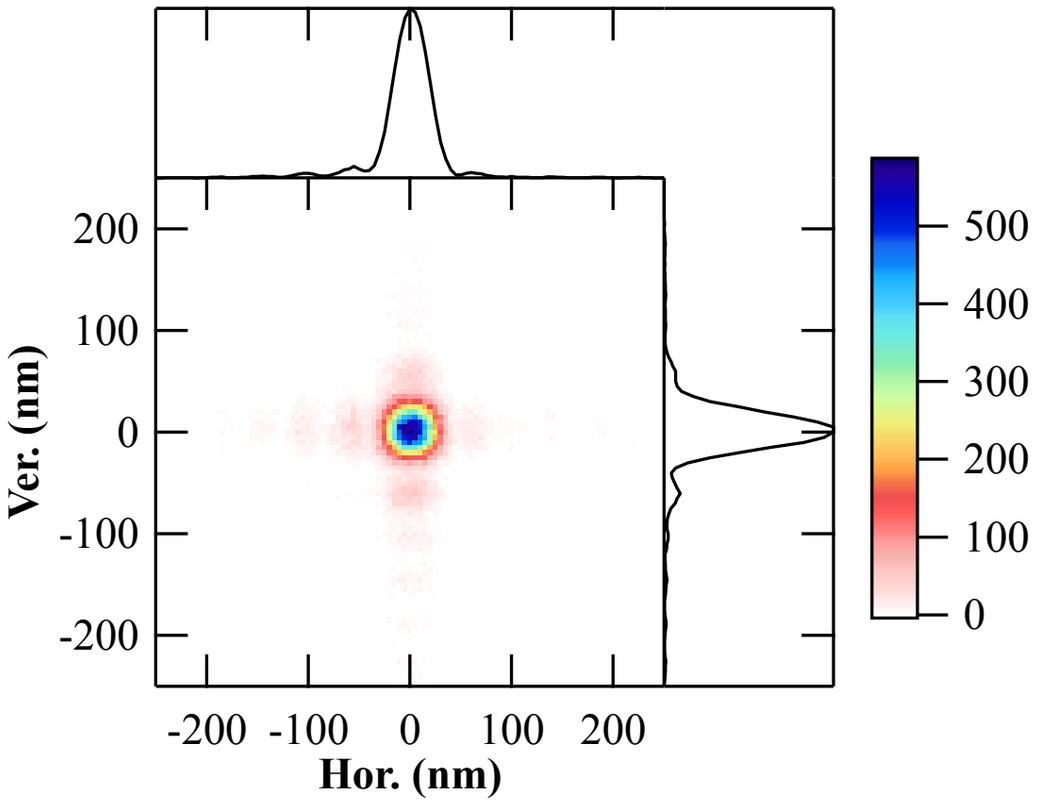

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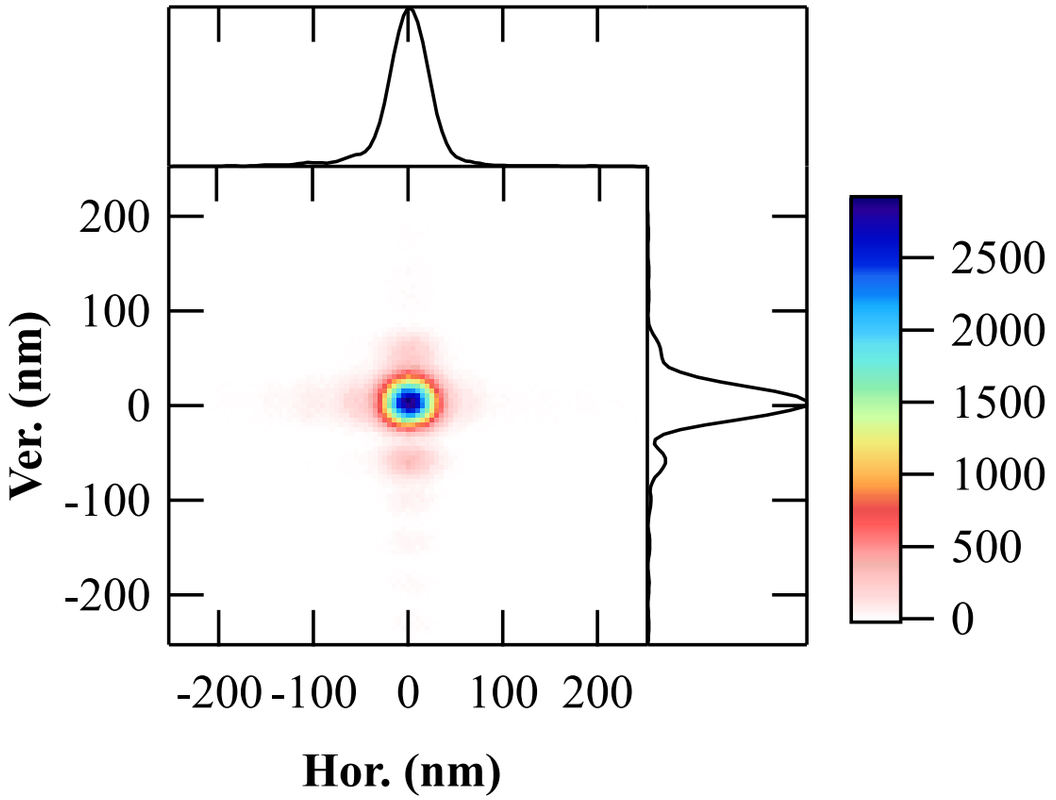
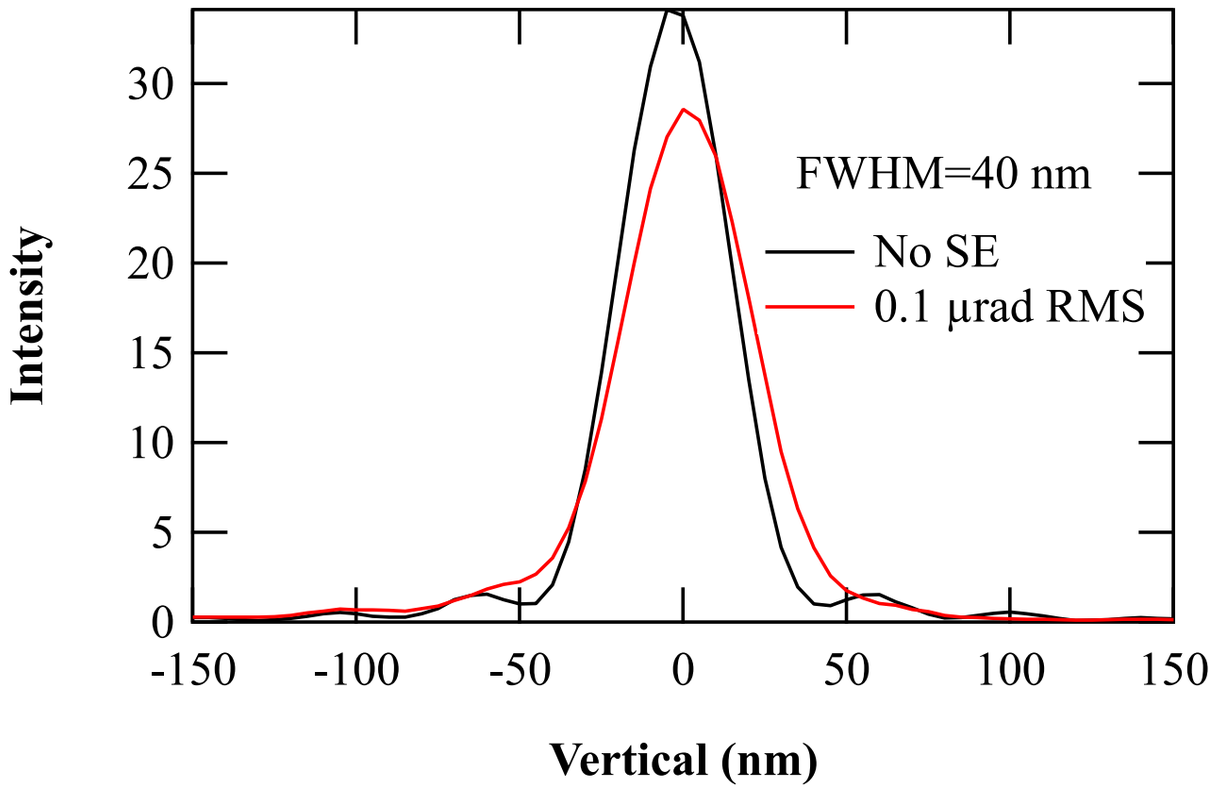


Beamline needs to be optimized for MBA

Slope errors with MBA



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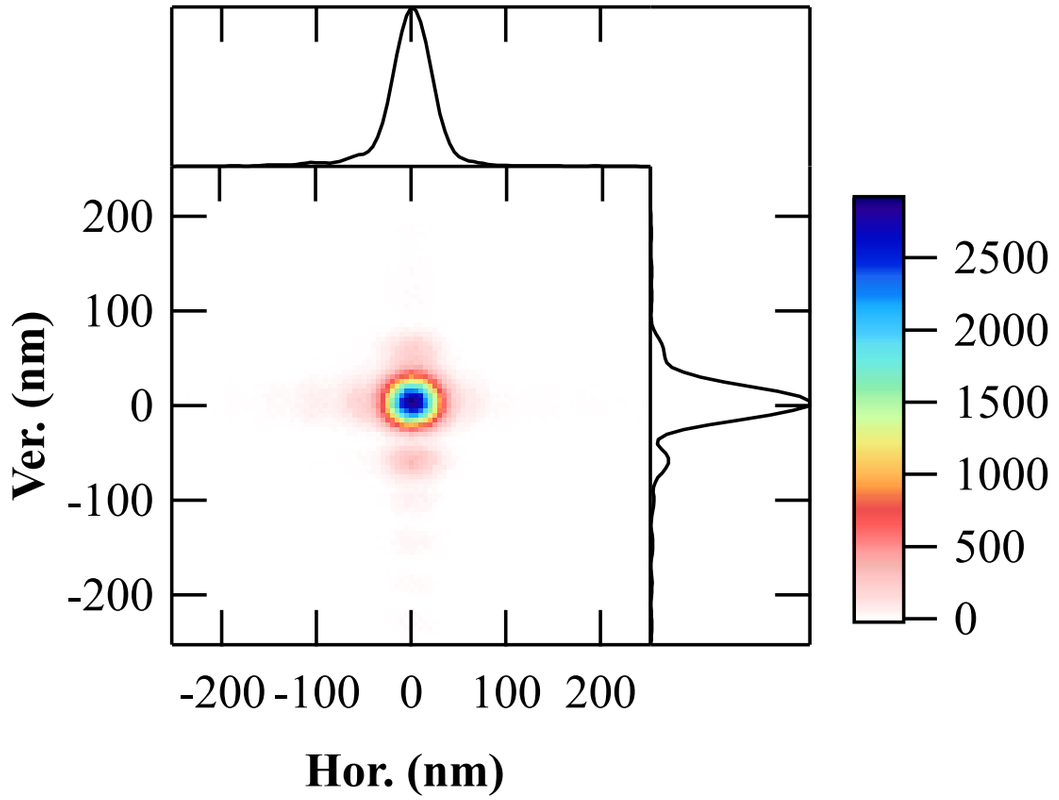
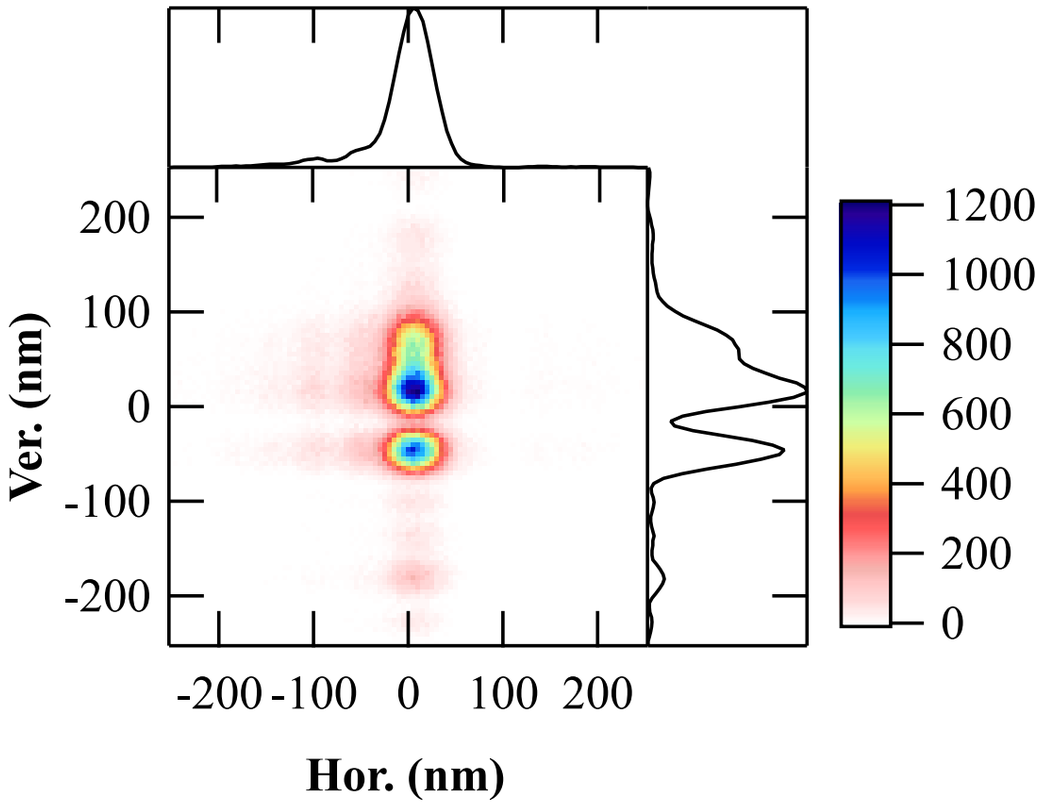
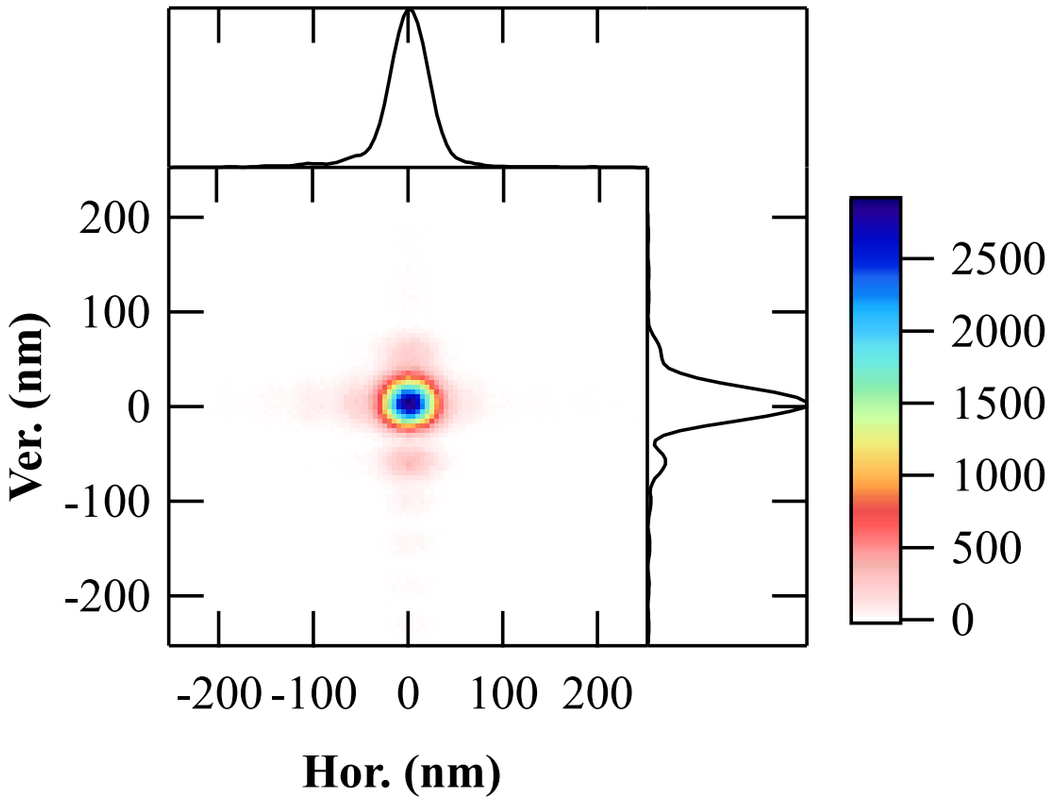


Slope errors with MBA

Trans: 3.0e-2 SDx:44 µrad SDy:69 µrad
SE: 0.4 µrad



Trans: 3.2e-2 SDx:38 µm SDy:41 µm
SE: 0.1 µrad



Summary

- For demanding beamlines, “state of the art” optics are required
- Can we standardize optics?
- New tool to asses beamline performance. Will incorporate into SHADOW.
- Working on tracking coherence
- Lahsen Assoufid will be covering many more issues Oct. 10

Thanks:
Xianbo Shi
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Lahsen Assoufid
Joerg Maser
Thomas Gog
Diego Casa