New Achievements in OAM beam characterisation using the Hartmann wavefront sensor and KAOS

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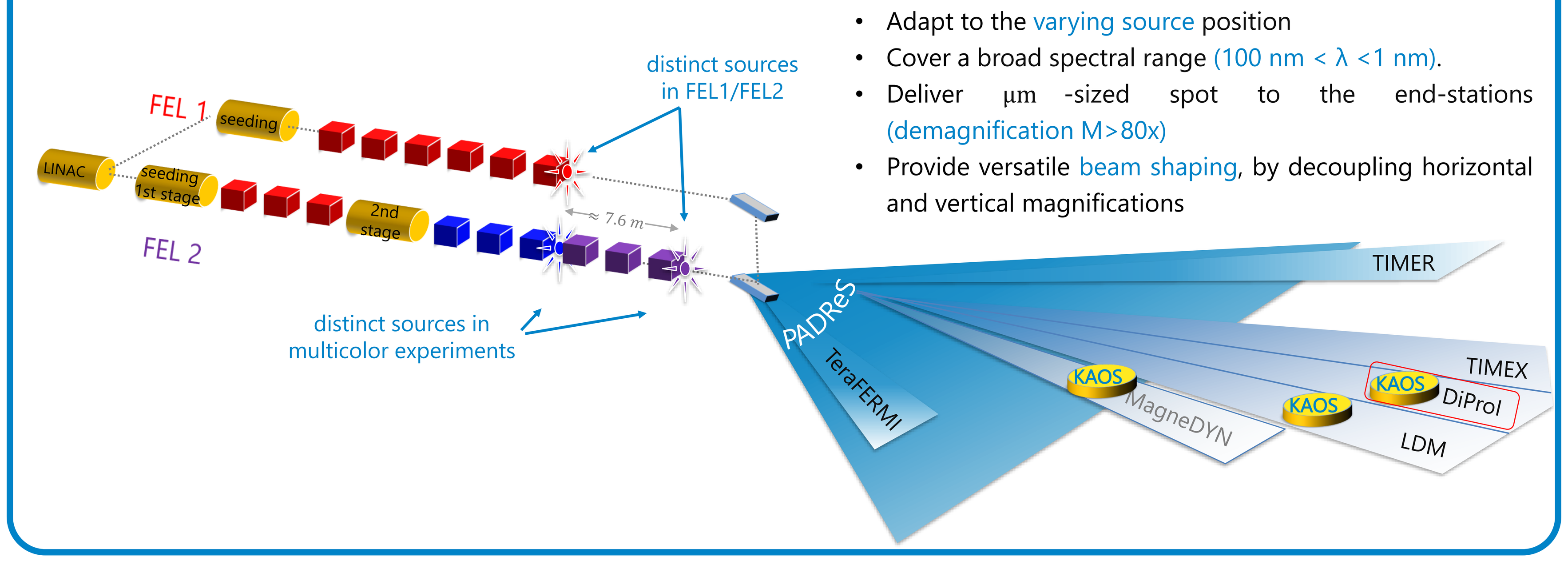
PADReS — Photon Analysis Delivery and Reduction System

Light beams carrying Orbital Angular Momentum (OAM) are sparking new developments in several fields like the excitation of chiral magnetic phenomena, both in the static and dynamic regime, enhanced imaging and novel light-matter interaction. The creation and characterisation of OAM beams is by itself a challenging task and thus a separate field of study.

At FERMI we can create an OAM beam either by tailoring the emission process on the undulator side, or, in most cases, by coupling a spiral zone plate in tandem with the KAOS active optic system. To provide a robust and reproducible workflow to our users we leverage on the use of a Hartmann wfs both for optics tuning and beam characterization. In particular, to operate KAOS in the so-called near-collimation mode and to provide an independent characterisation of beam helicity and topological charge characterisation after creating a structured beam. In this poster, we will present our latest achievements in operating the KAOS system out of nominal configuration and in the beam characterisation workflow while powering up the OAM research community.

FERMI light source

FERMI: "the" seeded free electron laser

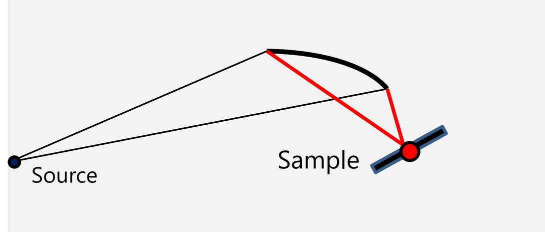


KAOS is conceived to...

- Adapt to the varying source position
- Cover a broad spectral range (100 nm < λ <1 nm).
- Deliver μm -sized spot to the end-stations (demagnification M>80x)
- Provide versatile beam shaping, by decoupling horizontal and vertical magnifications

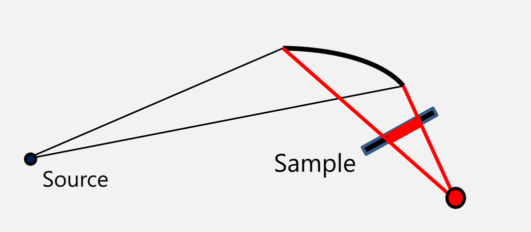
KAOS operation modes

Focusing



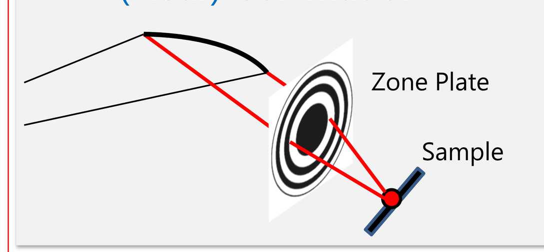
- Maximum fluence
- Spot size: $\approx 3\times 4\ \mu m^2 - 10\times 13\ \mu m^2$ FWHM (depending on the λ)
- Wavefront optimization: REQUIRED

Beam Shaping



- Adjustable fluence and spot size
- Spot size: $20\times 20\ \mu m^2 - 500\times 500\ \mu m^2$ FWHM
- Wavefront optimization: OPTIONAL

(Near) Collimation

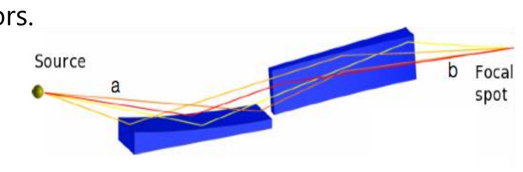


- Near-plane wavefront
- Can illuminate auxiliary optics (e.g. Fresnel and spiral zone plates)
- Not a standard configuration!
- Wavefront optimization: REQUIRED

K-B mirror system

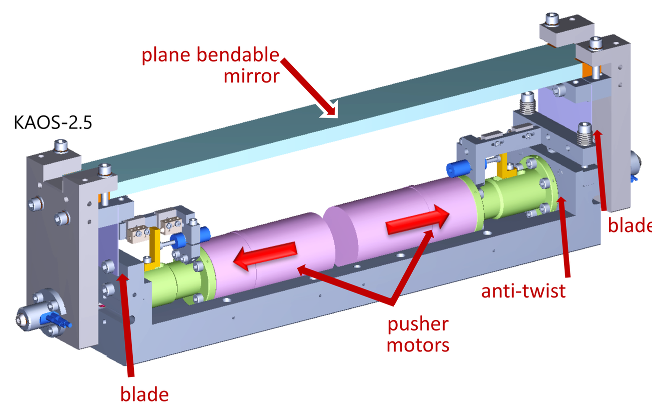
The K-B, in general

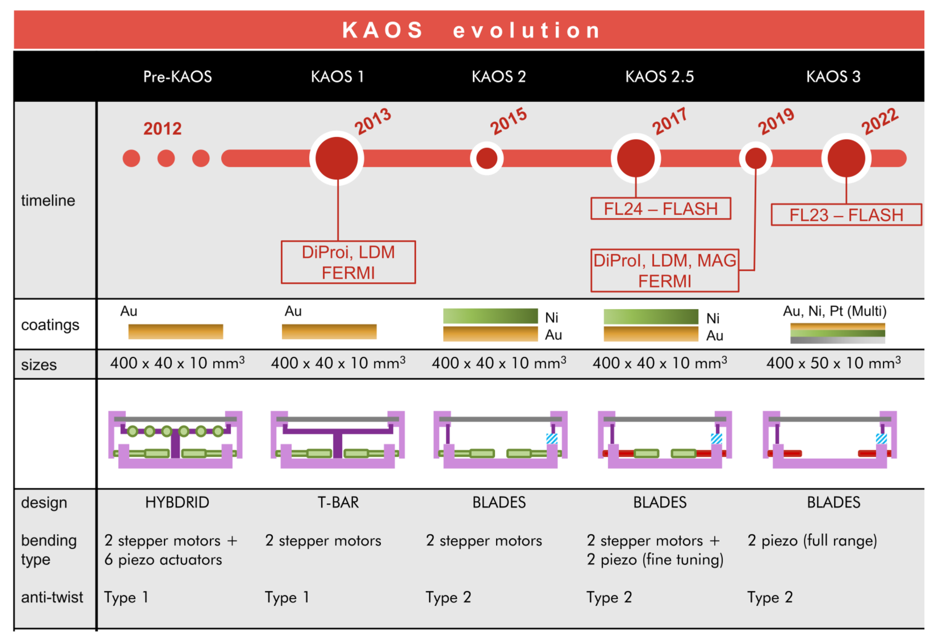
it consists of a two curved mirrors focusing the radiation separately in the two directions. The solution is cheaper and more versatile than realizing bulk mirrors.



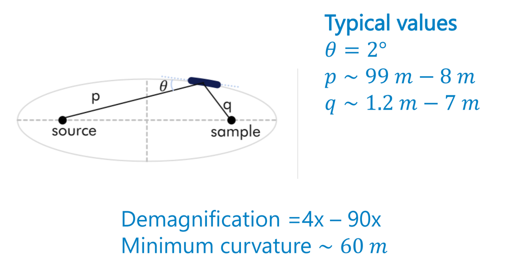
The design

is based on the leaf-spring bending mechanism of Howells et al. [see 1]: two pusher motors induce a curvature in the substrate (fused-silica), approximating the elliptical profile up to the third order ⟹ Astigmatism and coma can be corrected [1].



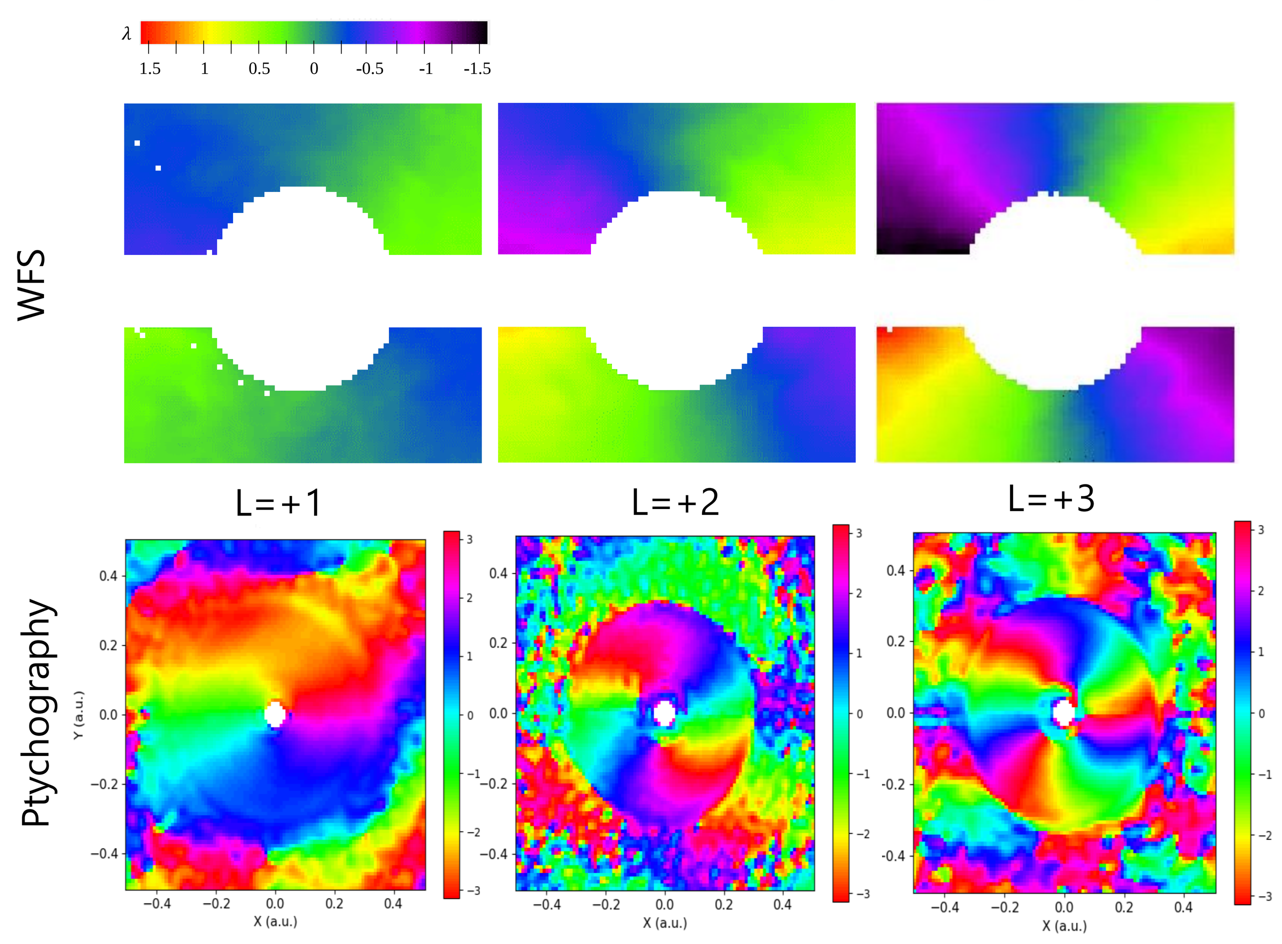


Action!



[1] L. Raimondi & al., J. Sync. Rad, 2019, doi: 10.1107/S1600577519007938

WFS vs. Ptychography

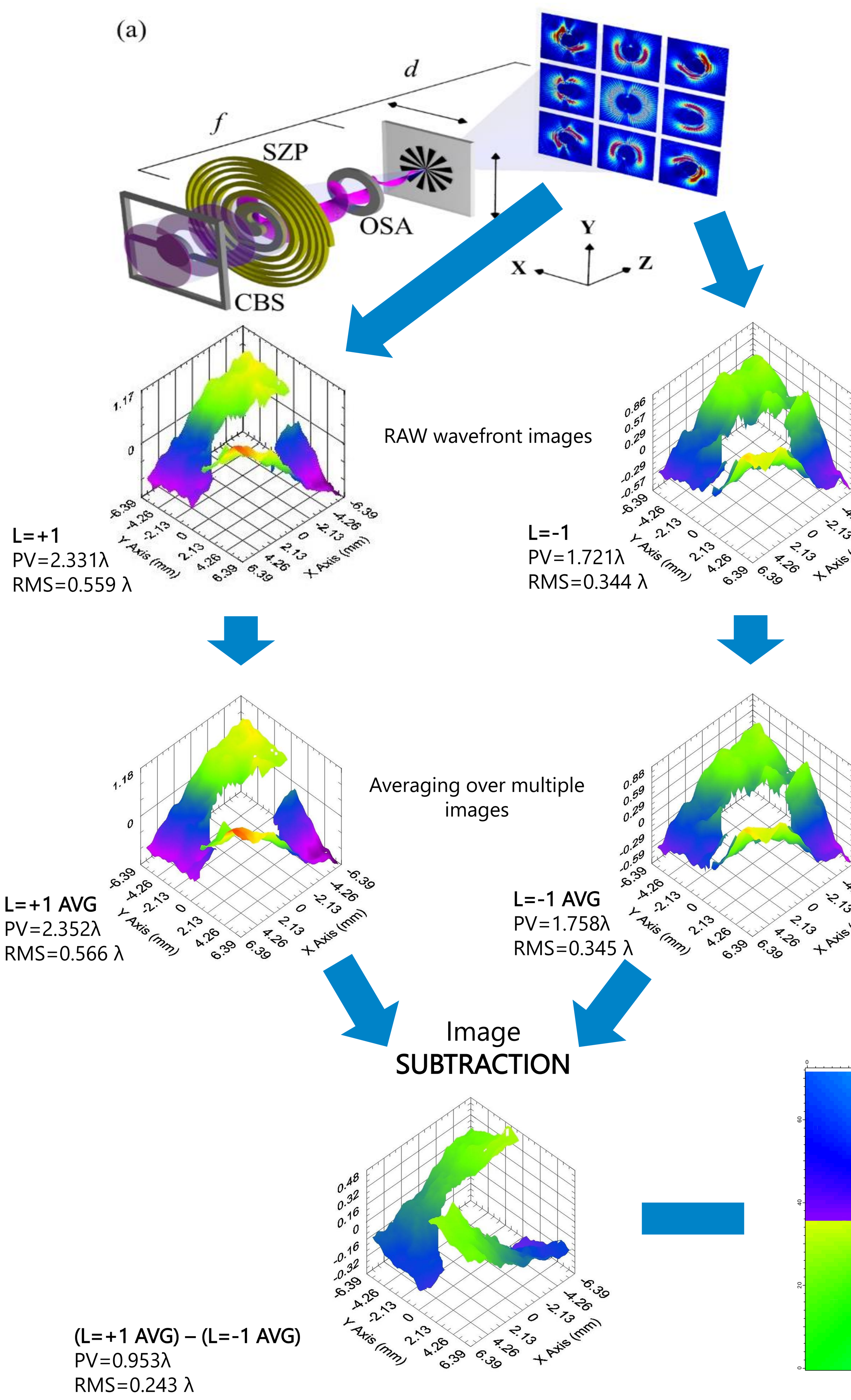


Ptychography is a powerful metrological tool to characterise wavefronts in a single-shot fashion at FEL. With WFS we provide independent characterisation of the beam topological charge. Both techniques return results in good agreement.

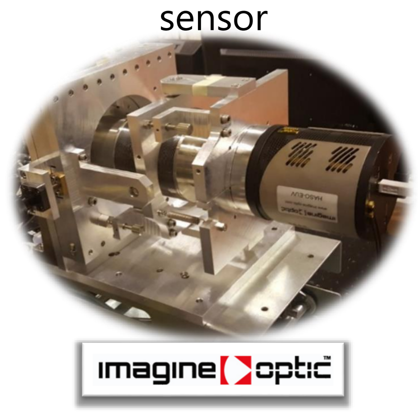
Conclusions

- Independent characterisation of OAM with WFS and Ptychography in good agreement
- Further operation study of KB system to be performed for better KAOS optimization
- WFS beam characterization is reliable and already serves the research community

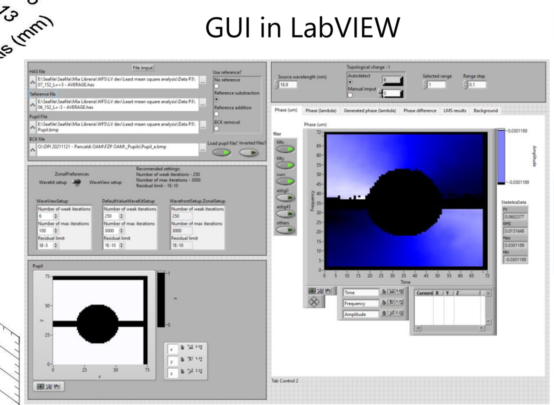
OAM wavefront measurement



Hartmann wavefront sensor

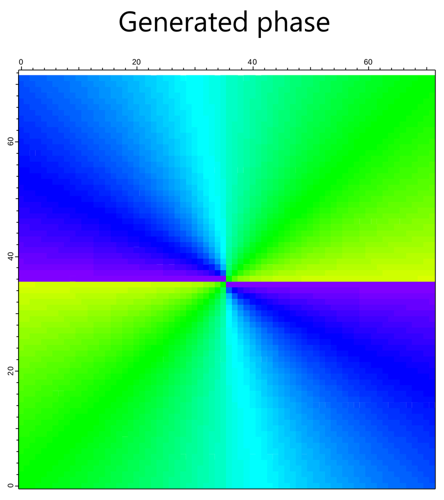


GUI in LabVIEW



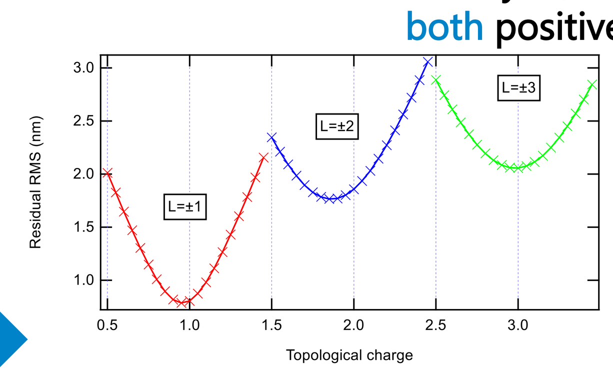
By subtracting two images with the same absolute integer value, we supress the background contribution and are left with "pure" OAM.

Generated phase



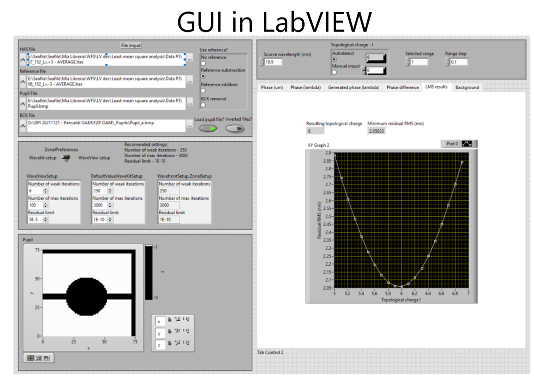
$$f(\varphi,\theta) = 2\pi \cdot L \cdot \theta$$

For such analysis, we need to obtain measurements for both positive and negative OAM values!



We perform the least square fit of the mathematically generated phase with L ranging from L-0.5 to L+0.5 with a step of 0.1 while looking for minimized RMS of a residual.

GUI in LabVIEW



By MINIMIZING THE RMS OF THE RESIDUAL WAVEFRONT we determine the OAM value of the measured beam.

PRELIMINARY RESULTS!

L	L (fit)	RMS (nm)	RMS (λ) ≈
1	0.95	0.769	λ/25
2	1.85	1.717	λ/11
3	3	2.058	λ/7

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