Wavefront Measurement using Beams with Orbital Angular Momentum: Preliminary Investigations

Dustin Posor[1,2], Jonas B. Ohland[1,2], Vincent Bagnoud[2,3]

[1]*Institute for nuclear physics, Technische Universität Darmstadt, Darmstadt, Germany;*
[2]*GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany;* [3]*Helmholtz-Institut Jena, Jena, Germany*

Motivation

Many laser-plasma experiments rely on a well-defined intensity distribution in the focal plane. As this property is directly linked to the wavefront (WF) of the laser beam in the nearfield (NF), WF measurement and control is crucial for the operation of modern high-intensity laser systems. WF measurement is often performed in the NF, which comes with **two complications**:

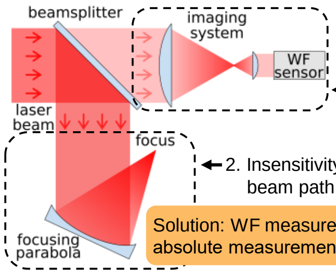

Fig. 1: Exemplary beam path for laser-plasma experiments with WF measurement in NF

1. Biased measurement by aberrations introduced in the separated beam path
2. Insensitivity to the aberrations of the beam path after the sampling position

Solution: WF measurement in the farfield (FF) yields absolute measurement of the system's aberrations.

One option to do WF measurement in the FF: Phase retrieval [1]. But it's rather impractical (complicated data acquisition and evaluation).

➡ Novel approach to WF measurement in the FF: **Adding an orbital angular momentum (OAM) to the beam** yields ring-shaped intensity distribution in the FF, whose **shape is highly sensitive** to the underlying aberrations [2]. It is then analyzed algorithmically [3].

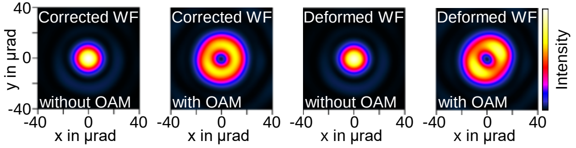

Fig. 2: Foci with/without OAM and with corrected/deformed WF [4]

Functional Principle

Characterization of focus distribution

After FF intensity measurement, the focus is characterized this way:

1. Find path of highest intensity around center
2. Get intensity over angle data
3. FFT
4. Save real and imag. parts of Fourier components (FC) 1, 2 and 3

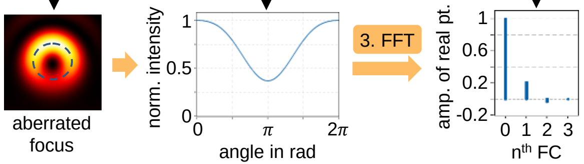

Fig. 3: Characterization of the focus intensity distribution

The **FC can be used as a measure of the aberration amplitudes** (AA) of the azimuthal aberrations: Coma, astigmatism & trefoil (in the Zernike sense).

Iterative approximation algorithm

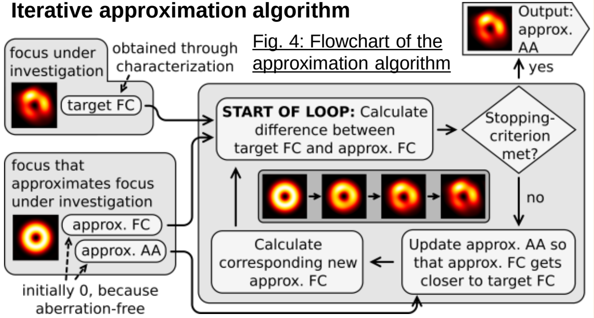

Fig. 4: Flowchart of the approximation algorithm

Simulation Results

We conducted first tests on the performance of this method by applying it to simulated aberrated foci. This way, the input AA could be compared with the approximated ones so that the limits of this approach can be better understood.

Ranges in which the AA of the simulated foci have been randomly selected: ±100 mλ and ±200 mλ

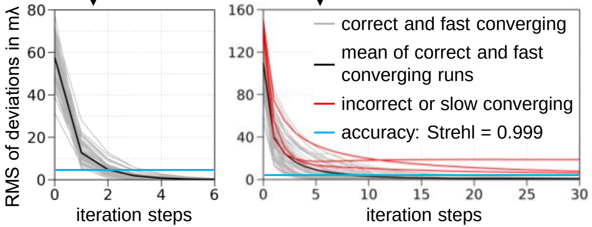

Fig. 5: RMS of the deviations between AA of simulated foci and AA of iteratively approximated foci

Conclusion & Outlook

- Beams with OAM can, in principle, be used for WF measurement.
- As the measurement is conducted in the FF and is rather uncomplicated, this method appears to be a possible valuable addition to current WF sensing techniques.
- Tests with simulated data show accurate convergence (and faster than phase retrieval) when the foci under investigation contain AA in the range of ±100 mλ (of coma, astigmatism and trefoil).
- Next step: Adjusting the algorithms to be used with real data.

[1] - [4] References on the next slide