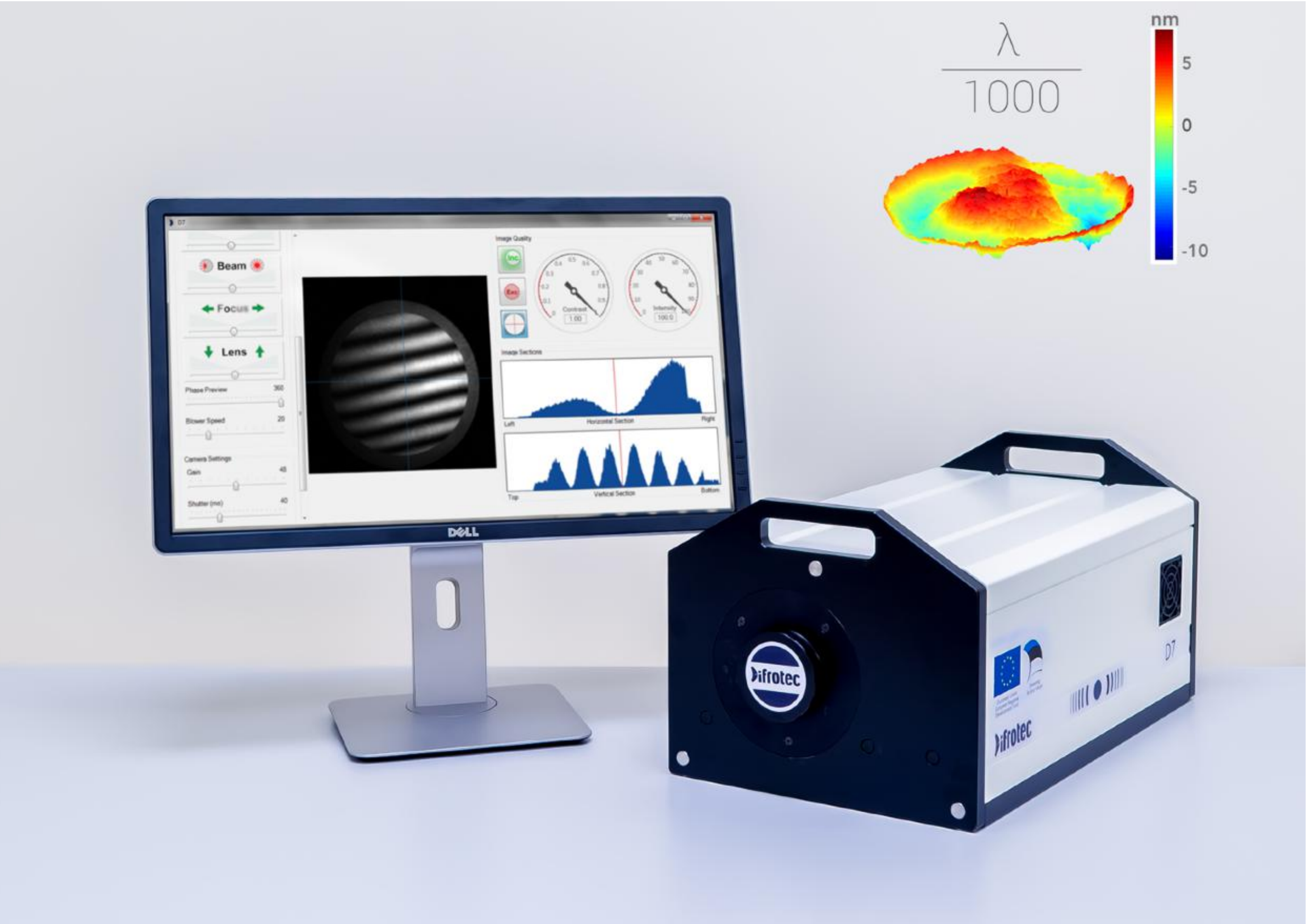
Difrotec Product & Services

Ultra high accuracy interferometry & custom optical solutions



Content

Overview

Interferometry is the first optical metrology method when obtaining the surface map with high precision. Difrotec launched a breakthrough innovation in interferometric measurements. A compact, user-friendly, reliable interferometer with accuracy greatly advancing the state-of-the-arts.

Test optics in their precision machined mounts

Interferometer D7

Difrotec's interferometer D7 being the flagship of accuracy on interferometry market is an instrument which measures the form of optical surfaces and wavefronts. Difference between the measured and real forms is below 0.6 nm. It is the D7's accuracy value.

D7 is a standalone hardware that comes along with a fringe patterns processing software, DifroMetric.

$$\frac{\lambda}{1000}$$

D7 is compact, reliable, and easy to use

World record!

The interferometer D7 provides a world record accuracy 0.6 nm or 6 Ångström with an excellent repeatability

Technology

D7 is phase shifting common path point diffraction interferometer (PSPDI). While the common Fizeau interferometers require reference optics, generating additional errors and masking surface details, D7 produces perfect reference – wavefront diffracted from a pinhole (sub-wavelength aperture in a thin metal film). D7 is patent pending.

Benefits

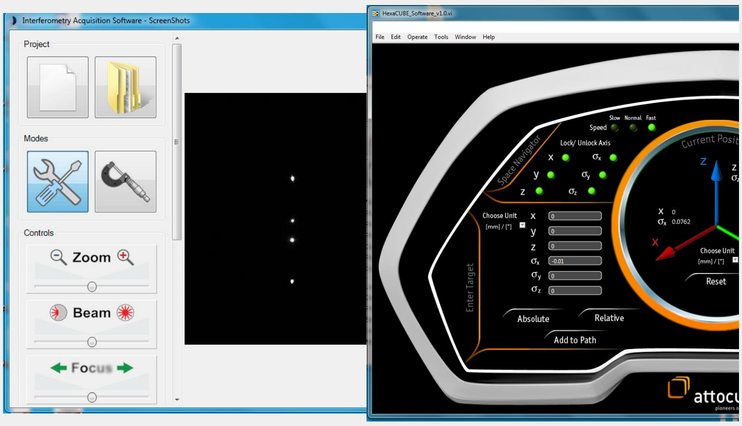
Advantages	Benefits
Ideal reference: no propagating error from using physical references	- Saving time because no need to change a large number of references; - Saving cost because no need to buy expensive reference kit
100 times higher accuracy over standard performance transmission spheres used in Fizeau interferometers	- Saving time & cost because intermediate instruments or additional methods to improve accuracy are not required
The D7 inspects more of the surface features than other interferometers	- Saving cost due to better revealing manufacturing mistakes before installation and launch of optical systems
Stability and robustness	- Saving time because excellent repeatability provides results which do not need continuous proof; - Saving cost because D7 does not require special environment conditions
Wide range of applications	- Saving time & cost due to compact and simple set-up for using in a lab or on factory floor (in-situ) with vertical and horizontal orientation
No retrace errors	- Saving time & cost due to simplified set-ups when measuring asphere and freeforms

Measurements

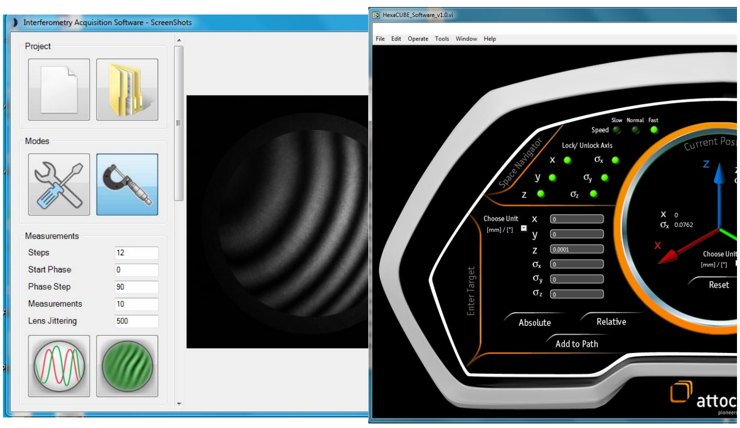
Measuring an optics with D7 can be done is 3 simple steps

1 Put the test part on the holder

2 Align the test part using software interface



3 Tune the fringes and click measurement button

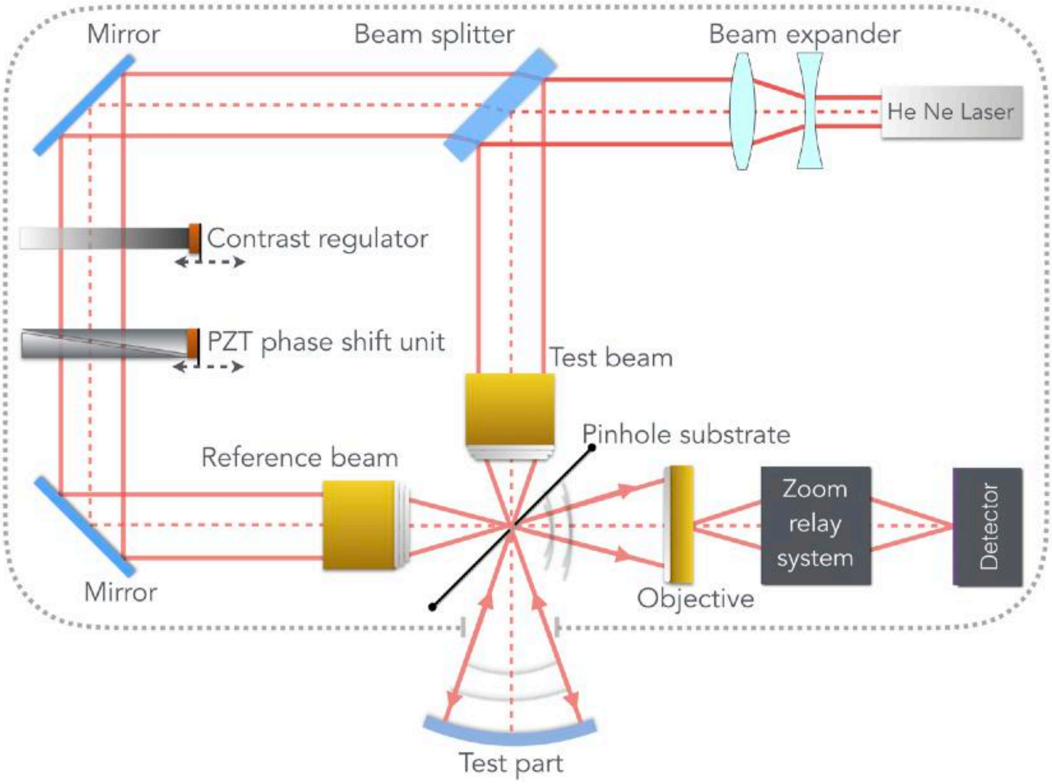


Specifications

Performance	
Accuracy:	≤0.6 nm (λ/1000)
Wavefront RMS repeatability:	≤0.23 nm (λ/2800)
Acquisition time:	10 milliseconds
Optical	
System clear numerical aperture (NA):	0.6 (F# 0.83)
System imaging numerical aperture (NA):	0.55 (F# 0.91)
Image zoom system:	4× optical zoom controlled by software interface
Imaging:	Coherent (no diffuser glass) with artifacts removal option
CCD camera:	0.5k × 0.5k (optional: 1k x 1k, 2k x 2k or 5k x 5k)
Height resolution:	λ/8000
Pixels depth (digitization):	12 bits
Exposure time:	40 μs minimum
Sensor pixel resolution:	500 × 500 on ≥50 mm diameter part
Focus control:	Motorized & controlled through software interface
Optical focus range:	± 2 meters
Illumination	
Laser type and wavelength:	Stabilized He-Ne, 632.8 nm
Laser power:	2 mW (higher power available on demand)
Polarization:	Adjustable test surface properties
Coherence:	≥100m
System	
Data acquisition:	Phase shifting interferometry (PSI) or Static
PSI method:	PZT electronic phase shifting
Alignment range:	± 2.5 deg.
Alignment type:	Dual spot
Alignment reticle:	Computer generated

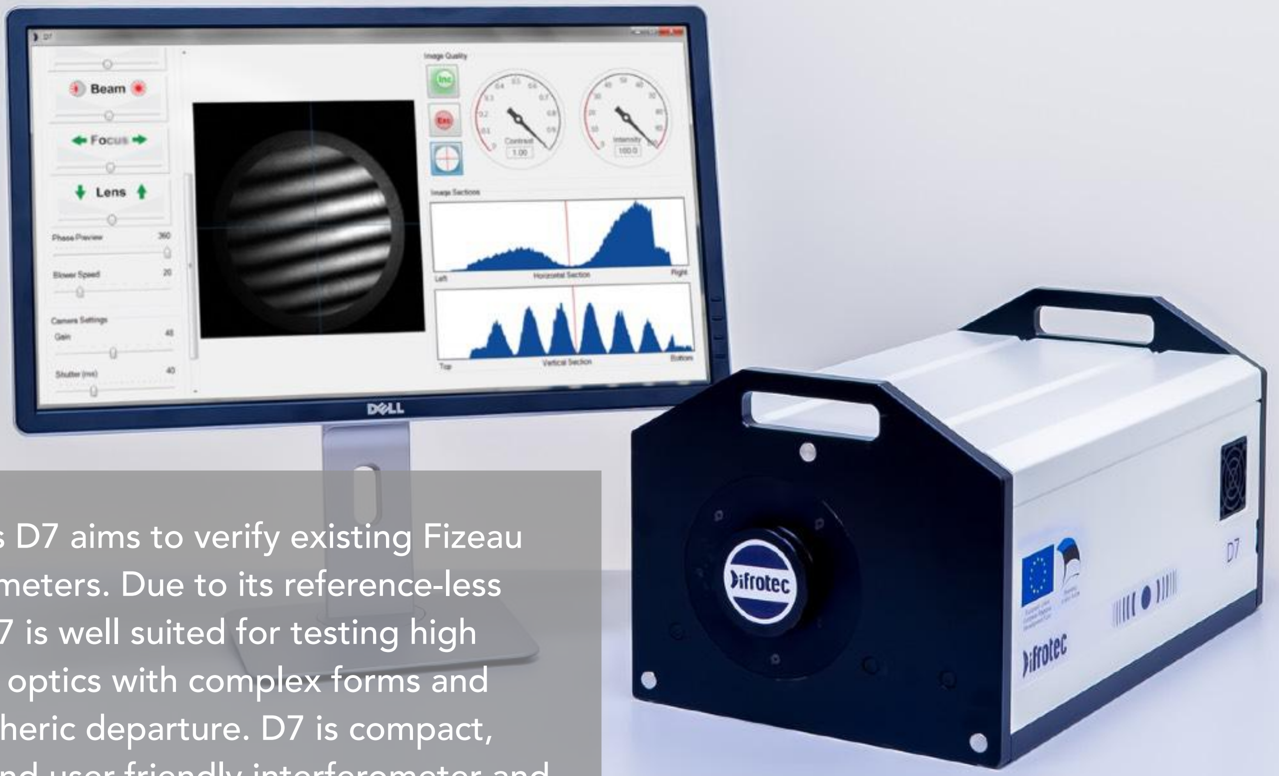
D7 has no physical reference optics

Working principle of D7 (specific schematic withheld)



Two-beam phase shifting point diffraction interferometer provides a major advantage over other schemes by availing two independently steerable beams. Here, the test beam and reference beam are perpendicular to each other, where the intensity of the reference can be regulated. Concave shapes can be measured directly, whereas other kinds of optics are measured using a non-precise accessory. Please refer to our website, www.difrotec.com and brochure for detailed configurations.

Applications



Difrotec's D7 aims to verify existing Fizeau interferometers. Due to its reference-less design D7 is well suited for testing high precision optics with complex forms and large aspheric departure. D7 is compact, reliable and user-friendly interferometer and equally excellent to measure common optics.

D7

Wavefront Quality

- Projection lenses
- Telescopes
- Microscopes
- Photo lenses

Optical Surface Quality

- Spheric
- Flats
- Corner cubes
- Aspheres
- Freeforms
- Reference optics

Radius of Curvature

- Combining long distance sensors with the highest focusing accuracy provided by D7 gives ppm RoC accuracy

Image Quality

- Validate the resolving capacity of your optics before deployment.

Application cases

Measurement cases with D7

D7 found a significant difference between two identical lenses and predicted a reduction of resolution by 3 times. Being able to validate the image quality from orbit is crucial for the mission.

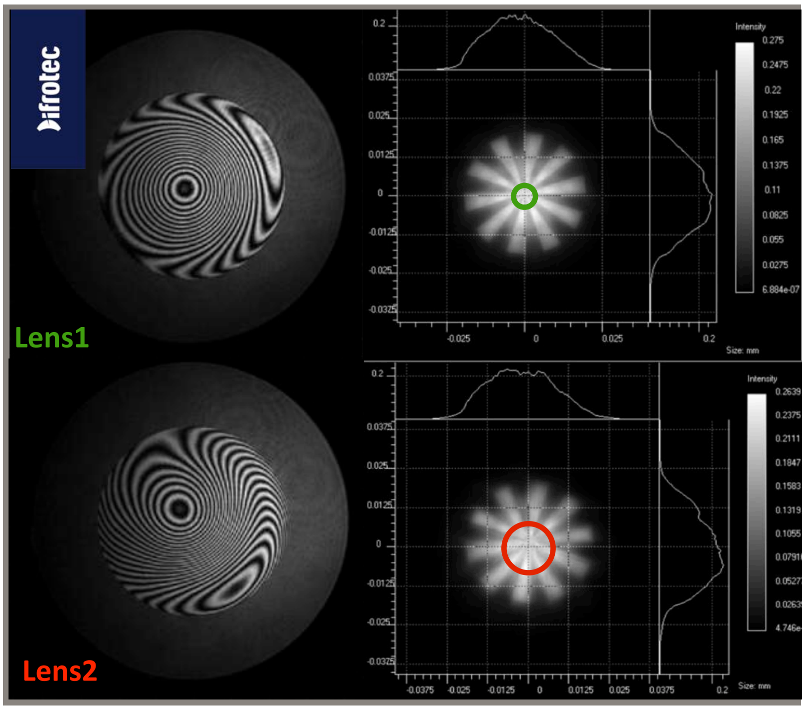
image: Taavi Torim

1. Validating image quality of a space camera

Difrotec tested two lenses for Tartu Observatory, Lens 1 & Lens 2, for space satellite Student Earth Orbiter (ESEO). Department of Space Technology wanted to verify if the lenses were on par with the given specification so as to render the highest quality image after being launched 520 km into space.

D7 found that two supposedly identical lenses were quite different in terms of wavefront quality, and the image resolution was 3 times worse. D7 distinguished the quality difference between lenses having wavefront aberrations 3 λ with accuracy λ/1000. Lens1 resolves 20 meters per pixel, whereas Lens2 60 meters per pixel from the working distance of 520 km.

It helped Tartu Observatory to choose and fine tune the satellite camera assembly before an expensive launch.

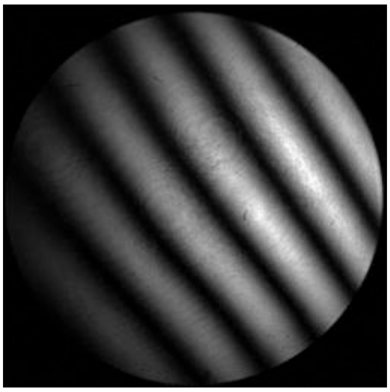


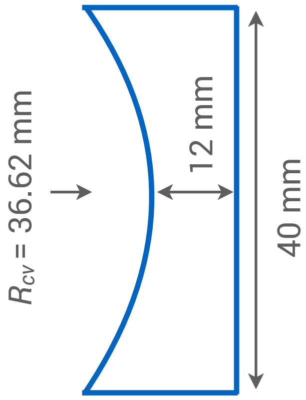
Fringe patterns and simulated Siemens star help determine image resolution for optics.

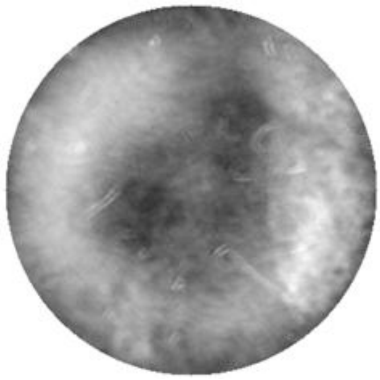
2. Revealing optics machining residue

Optical surfaces are machined to a certain shape by various methods such as pitch polishing and lapping. They leave residue that affect the performance of produced optics. Commonly, when residue heights do not exceed several nanometers, residues are not seen from the surface map provided by a Fizeau interferometer. D7 investigates deep and reveals shape forming technology.

Shape formed by lapping

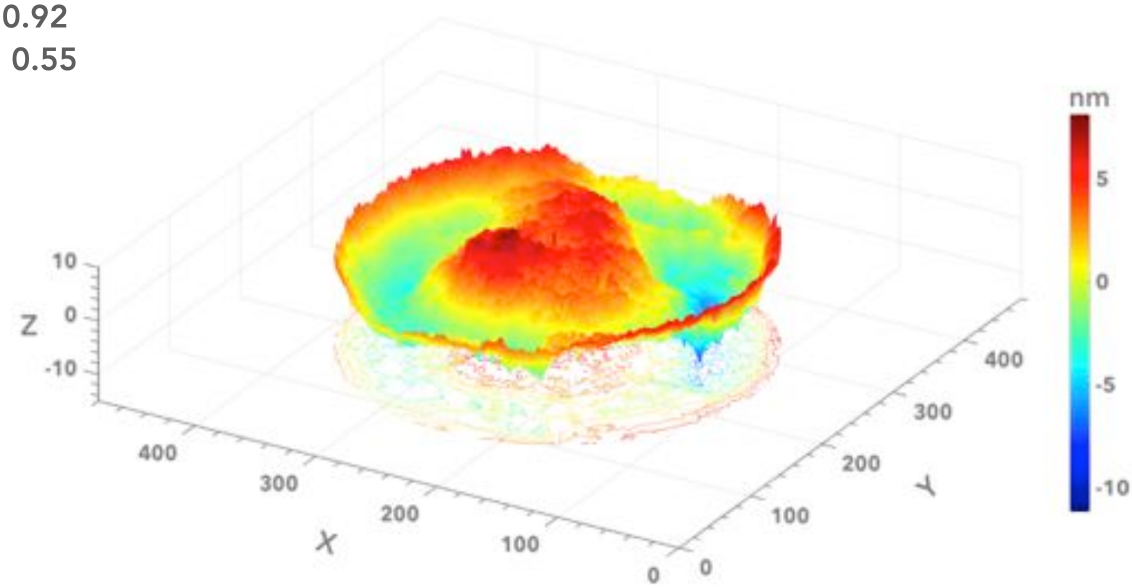






Surface form of an optics machined by using **lapping method**

Peak to Valley = 20.44 nm
RMS = 3.48 nm
R# = 0.92
NA = 0.55

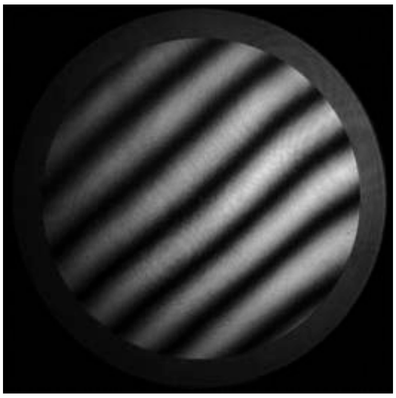


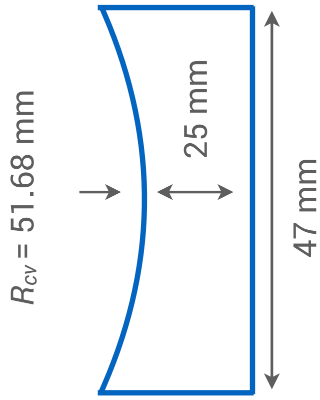
A typical pattern of lapping residues contains smoothed random irregular features.

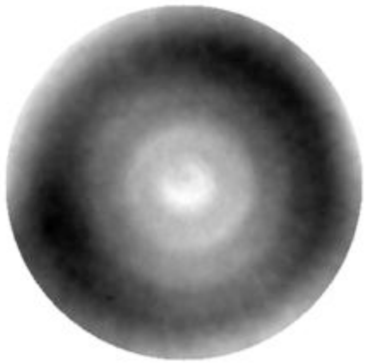
Shape formed by pitch polishing

Pitch polishing is often used to shape optics. This is done in multiple steps, where the accuracy of the CNC lathe is successively increasing. A cutter head with diamond finishes the surface. The turning motion of the lathe and the contact approach repeats the defects during the finishing giving rise to ring like structures on the form.

Surface 1

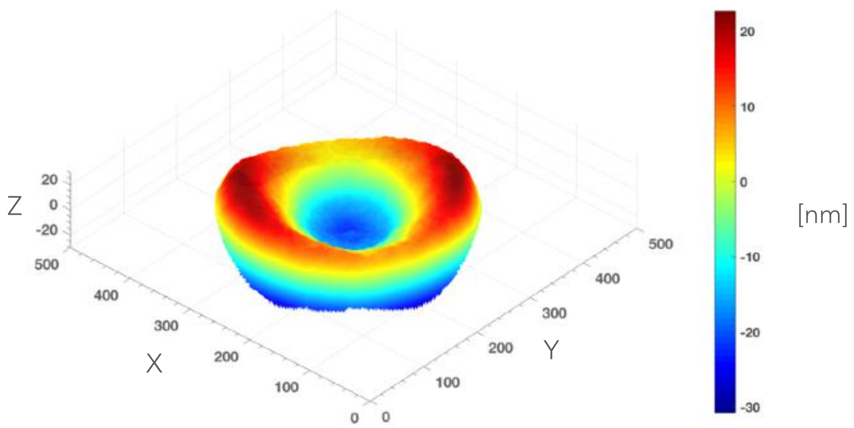






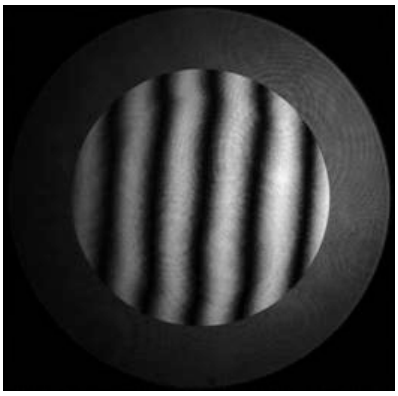
Peak to Valley = 38.93 nm
RMS = 8.18 nm
R# = 1.1
NA = 0.45

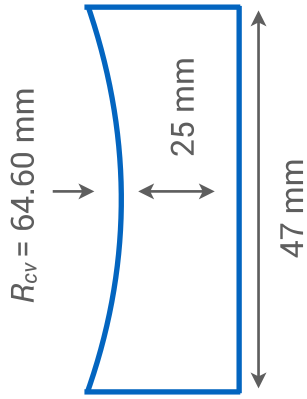
Circular ring like structures on the surface form indicate that the optics is machined by using **pitch polishing.**

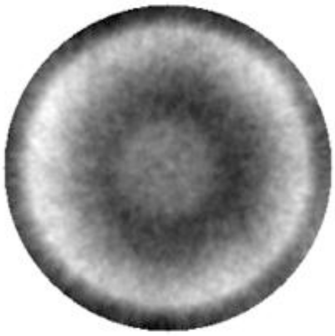


Features residue from pitch polishing machining process appears as shallow circular patterns which contribute to aberration but cannot be always clearly seen using standard Fizeau interferometers.

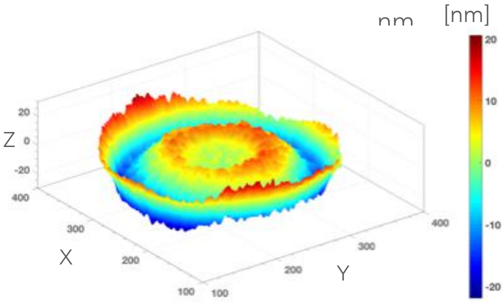
Surface 2







Circular ring like structures on the surface form

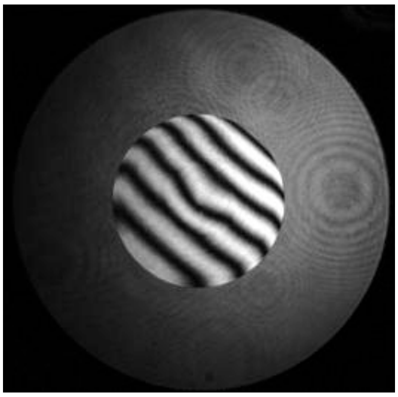


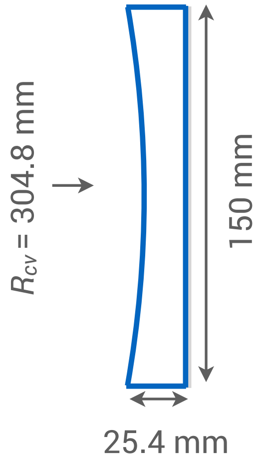
Features residue from pitch polishing contribute to aberration.

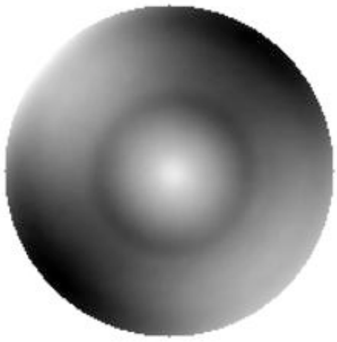
Peak to Valley = 42.49 nm
RMS = 8.26 nm
R# = 1.37
NA = 0.36

Aluminum coated spherical mirror

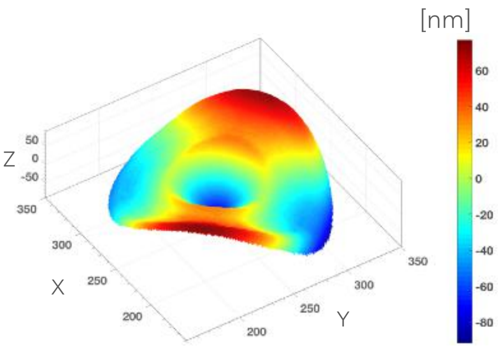
D7 is similarly effective in revealing the features residue from machining in mirrors.







Circular ring like structures on the surface form



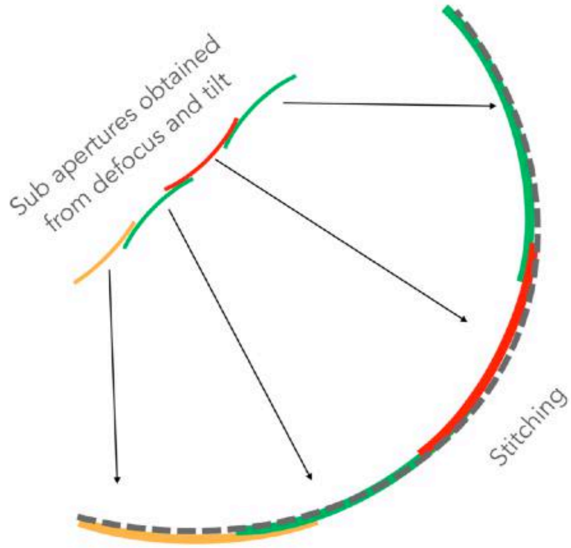
Features residue from pitch polishing contribute to the aberration.

Peak to Valley = 168.4 nm
RMS = 34.15 nm
R# = 2
NA = 0.25

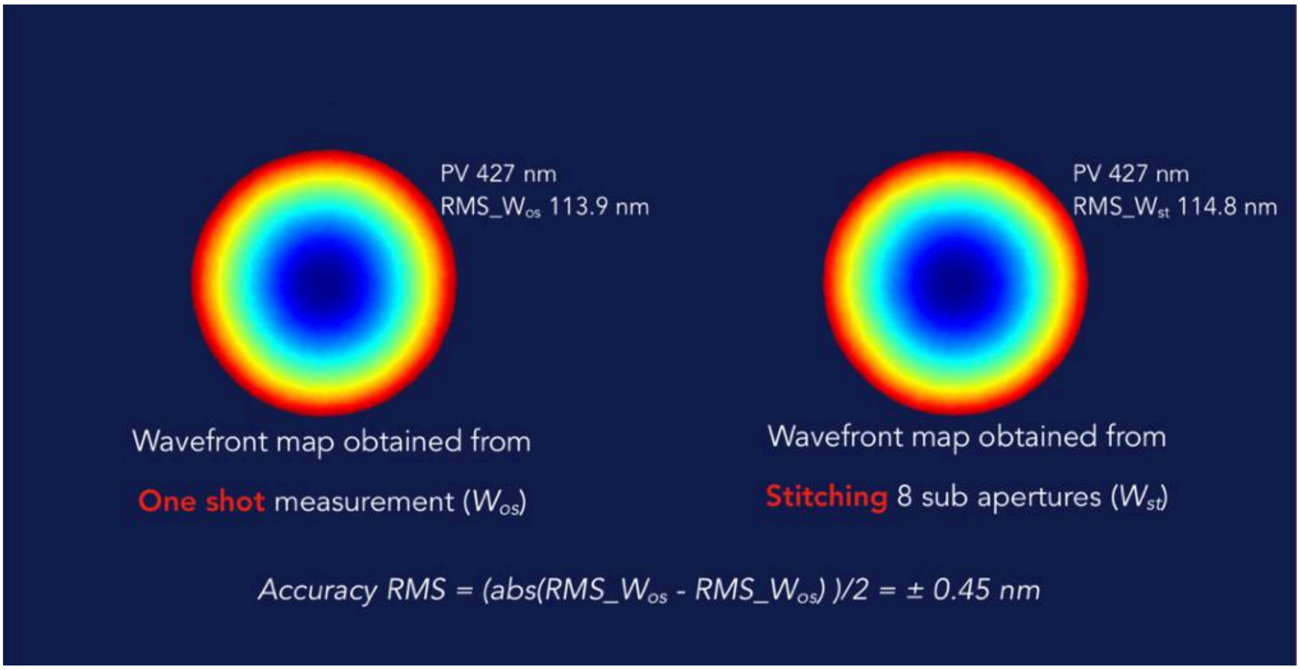
Stitching

Over sized optics and aspheres

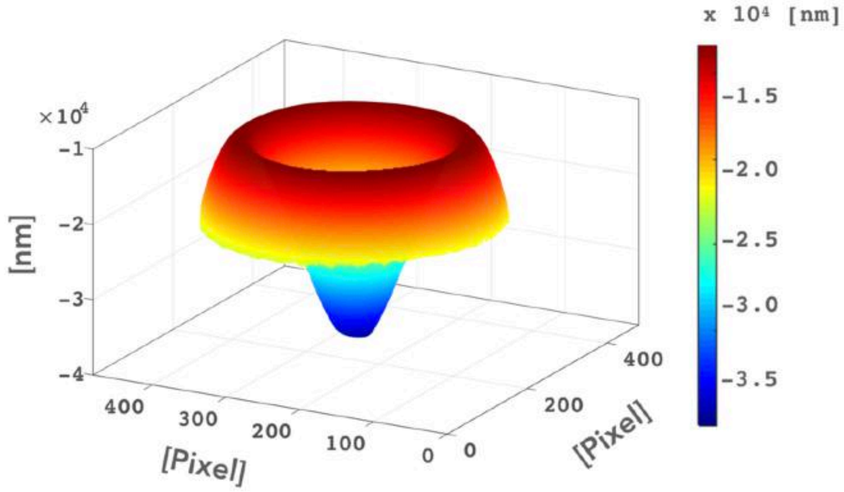
- Large spherical concave of R# ≥ 0.9 can be directly measured by putting D7 farther away.
- Optics with larger aperture require accessories.
- **For aspheres and freeform we use high accuracy sub aperture stitching (SAS)**
  - D7 has greater accuracy reserve to match overlays.
  - Easier to align and no retrace errors preserve accuracy throughout stitching.



Testing the reliability of stitching



Asphere concave stitched



Ø = 50 mm

Peak to Valley = 26841.1 nm

RMS = 6675.8 nm

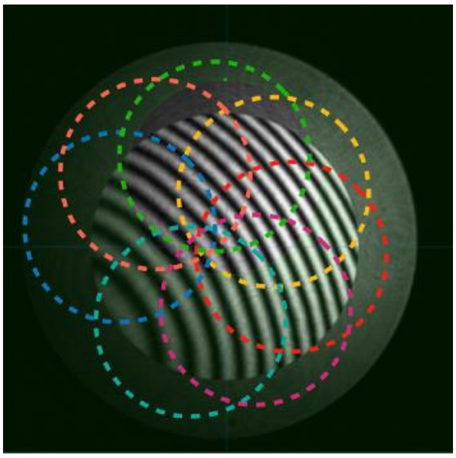
R# = 1.372

NA = 0.36

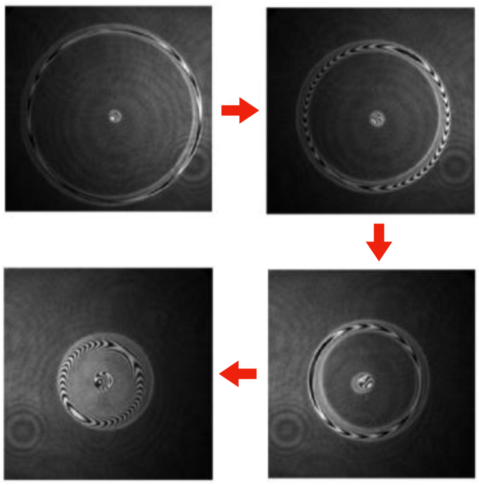
Rc (apex)= 68.6 mm

Stitching

Our algorithm does not involve stage parameters or any special scanning procedure as long as there is an overlap of over 50% between successive sub-apertures. This means, sub-apertures can be obtained by z-axis scanning, lateral scanning, radial scanning or **linear scanning (for longer slabs)**.



Fringes are captured by rotating the test part at a certain angle around optical axis to provide sufficient overlay.



Fringes are captured by z-axis scanning, i.e. changing defocus to measure above asphere.

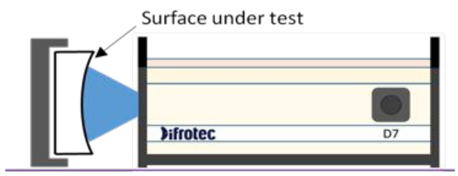
Services

Optical testing

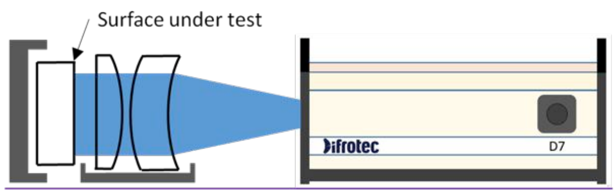
Type of optics

Concave optics
D7 can measure them directly (without accessories) out of the box.

Configuration



Flat surface
Flats can be measured with a beam converging accessory DA-1. The impact of accessory is calibrated and eliminated on-line during measurements.

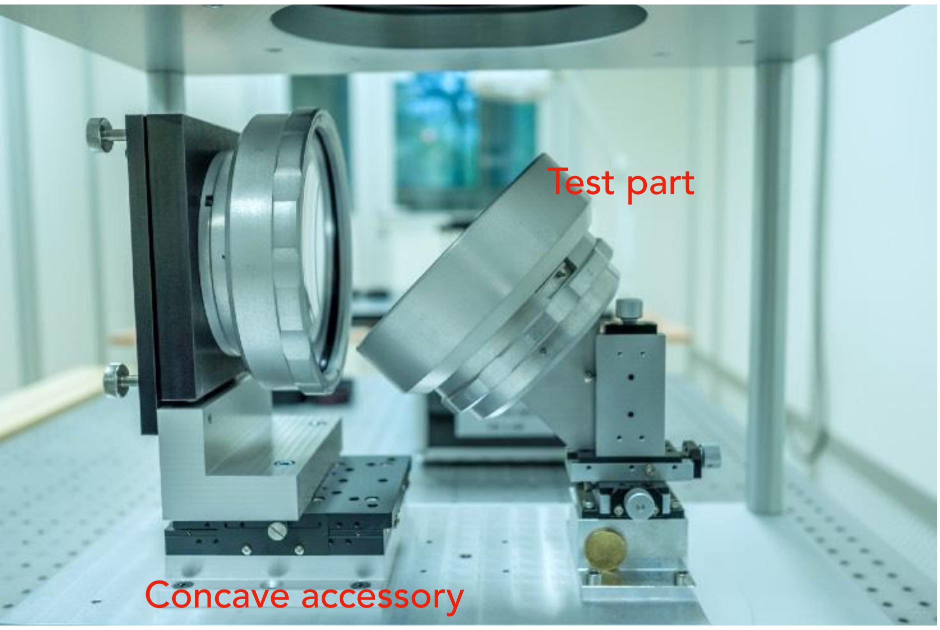


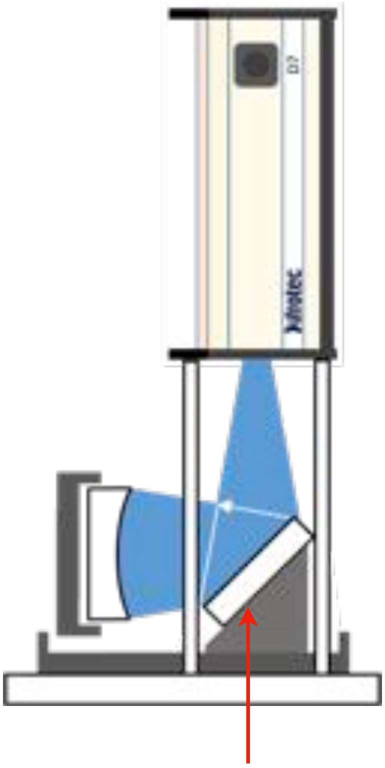
Type of optics

Configuration

Flat surfaces

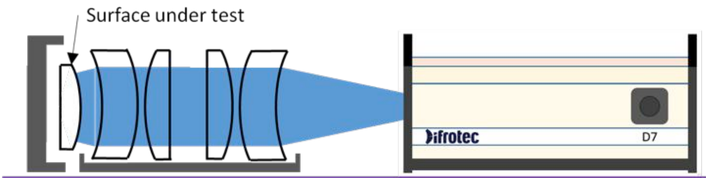
Flats can be measured in a semi direct fashion.





Convex surfaces

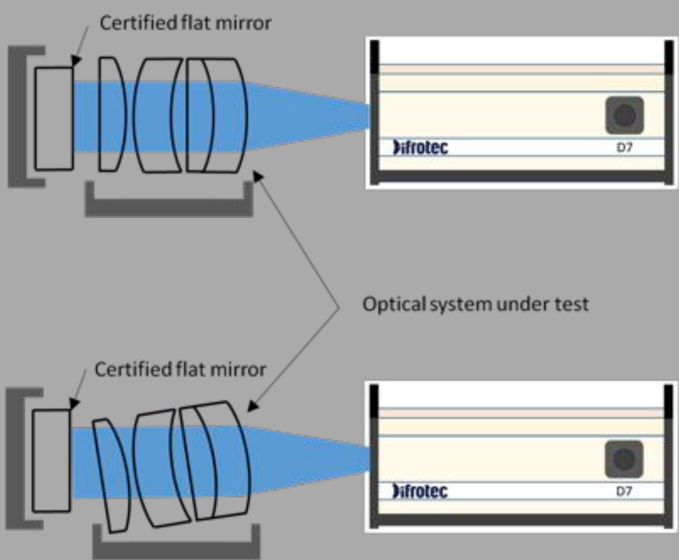
Convex optical surfaces can be measured with a beam converging accessory DA-1



Wavefront quality

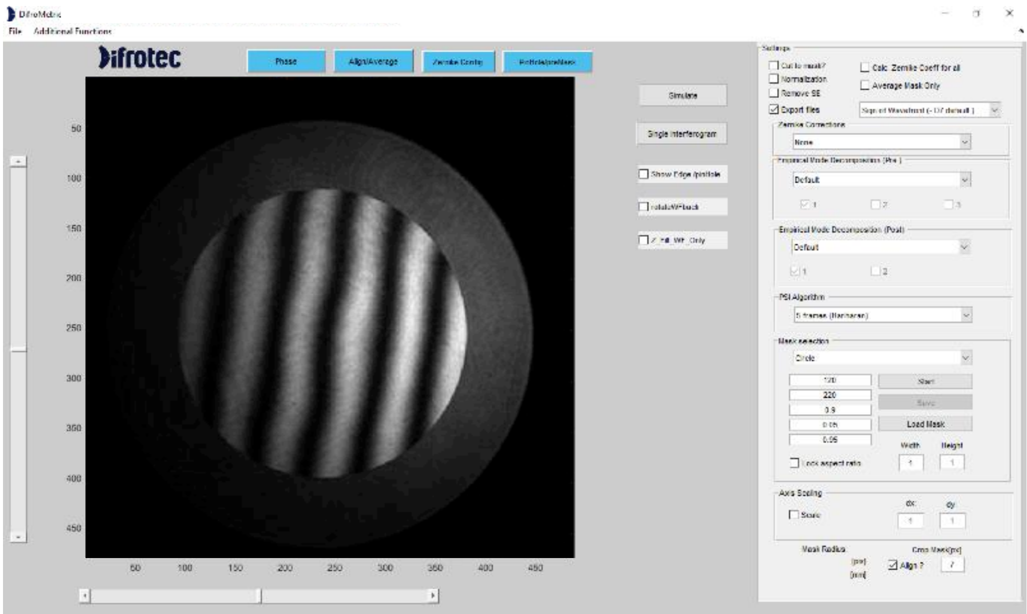
Testing wavefront transmitted from optical system

*Unlike in the case of transmission spheres, effect of accessory is canceled by design of D7 and has no influence on the measured wavefront of the test part.



DifroMetric

DifroMetric is feature rich fringe analysis software made by Difrotec. DifroMetric is OS/platform independent and can take and produce most of the data formats common in the field of interferometry. Processing steps are automated, which saves time while analyzing thousands of interferograms.



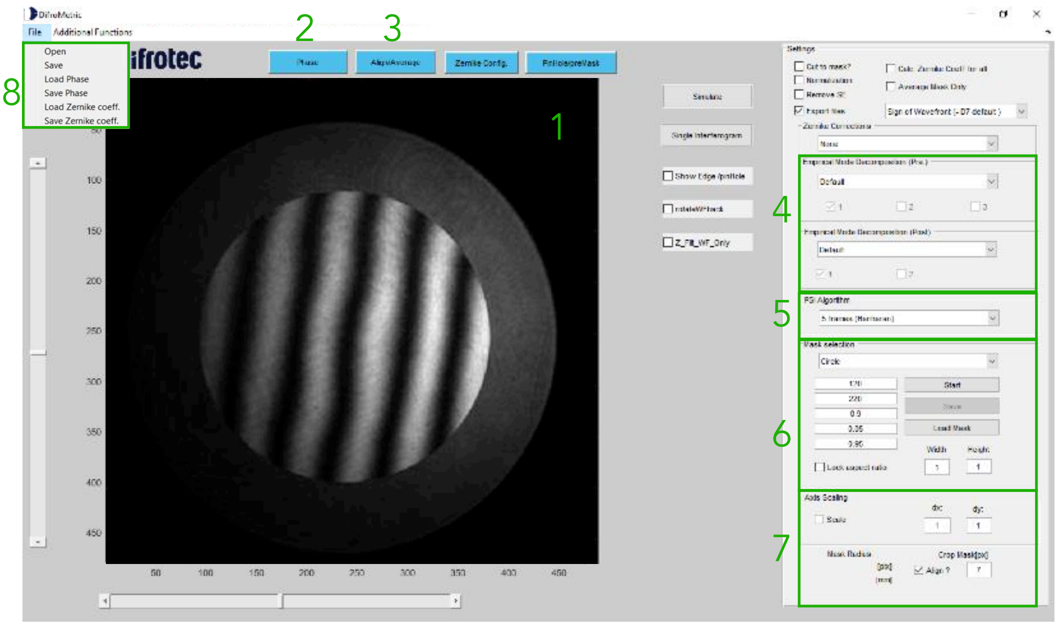
Main functions

1. Fringe pattern and wavefront image processing
2. Circular, elliptical, rectangular and custom mask generating
3. Wavefront computation based on vibration resistant methods of phase retrieval
4. Zernike fitting of measured wavefronts
5. Intelligent averaging wavefronts to damp spare reflections effects (SRE)
6. Intelligent averaging wavefronts to eliminate system error of the interferometer
7. Wavefront arithmetics — developing
8. Sub-apertures lattice arrangement — developing
9. Sub-aperture wavefronts smart stitching — developing
10. Processing benchmark data of the interferometer performance

Each function contains default and user settings, and offers custom combination of numerous opportunities of interferometric data analysis

Various additional functions including fringe pattern normalization, loading/saving settings, Zernike coefficients and diagrams, tracking actual phase error, et al.

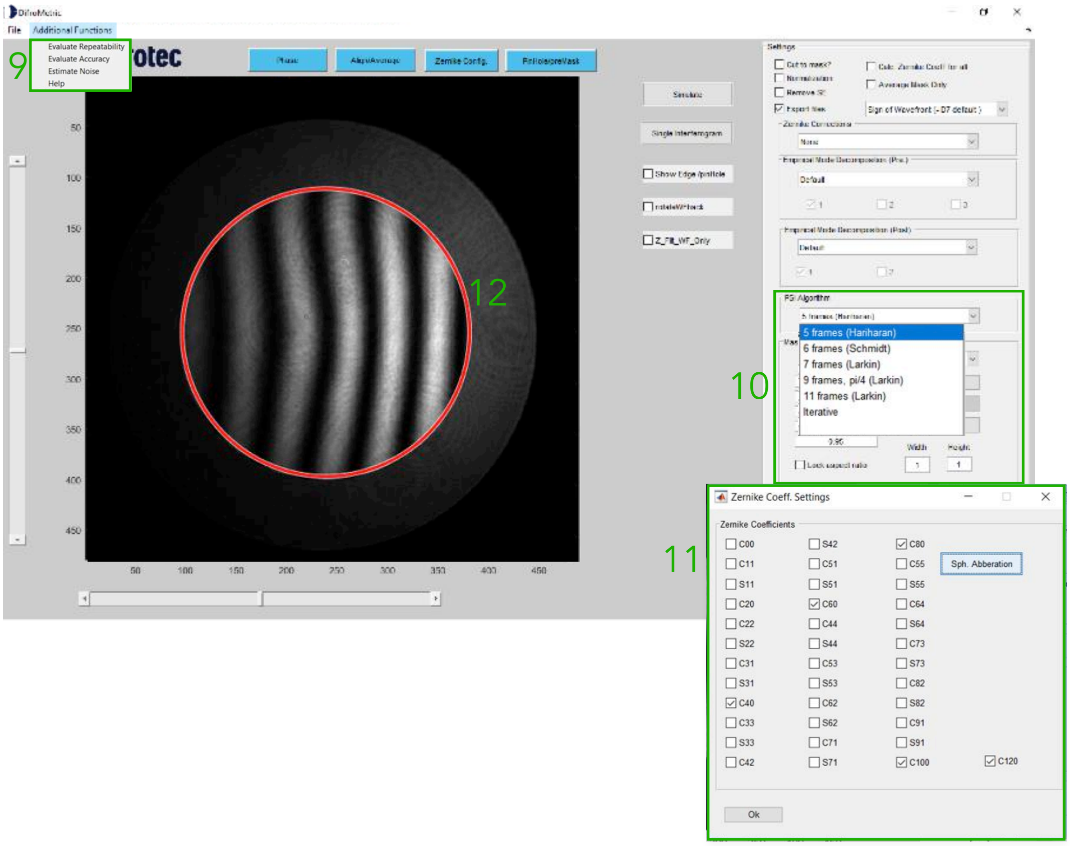
Main Window



Features (base options)

1. Fringe pattern window
2. Phase button — launches phase retrieval procedure
3. Intelligent averaging button — runs system error elimination procedure
4. Image processing options
5. Selection of phase retrieval method
6. Setting mask type and parameters
7. Intelligent averaging parameters
8. Drop-down file menu — allows to open necessary sets of phase shifting frames, open/ save retrieved wavefronts and their Zernike fitting

More built in options

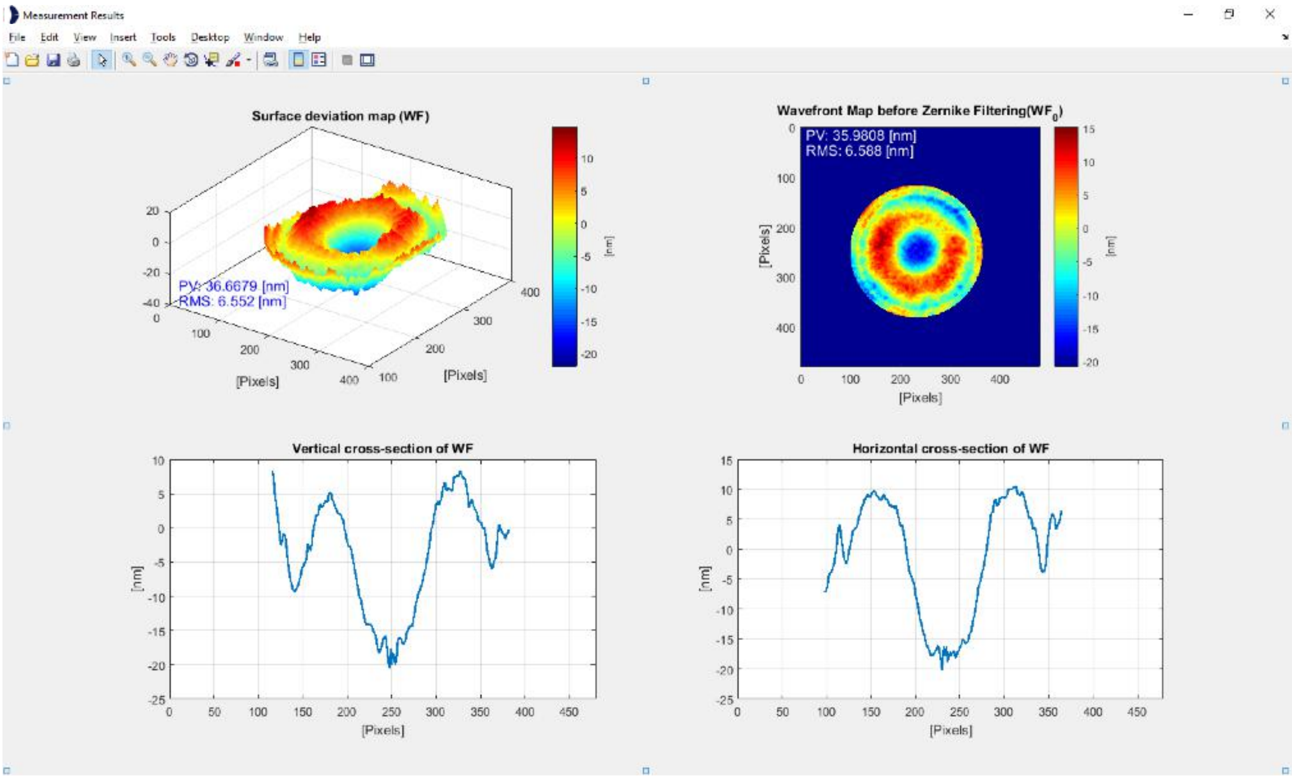


Features (additional options)

9. Drop-down additional options menu of the pre-installed interferometer performance auto-testing
10. Selecting Phase Retrieval method
11. Settings for Zernike fitting
    a. User can manually set the combinations
    b. User can also perform a reverse Zernike correction

12. Loading the mask
    a. Circular
    b. Elliptical
    c. Rectangular

Displaying results



- Surface deviation map
- Cross sections in x and y axes
- Zernike coefficients in *.csv format
- Result images in *.fits format (can be customised to other formats)
- Intermediate, as well as averaged results are automatically saved

Contacts

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