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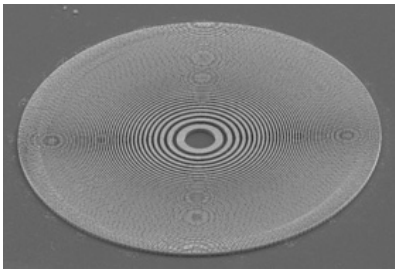
XRnanotech

Nanoscale diffractive optics
with Swiss precision

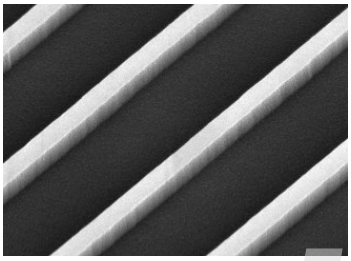
XRnanotech Product Brochure

Fresnel Zone Plates



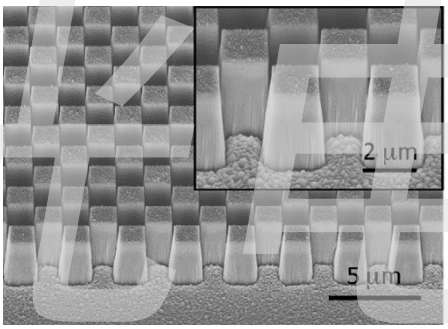
- High aspect ratio Fresnel zone plates
- Best achievable resolution
- Great efficiency across a wide energy range
- Outstanding freedom of material choices (Au, Ni, Si, SiO_2, Ir, Cr, Diamond)

Gratings and Beam Splitters



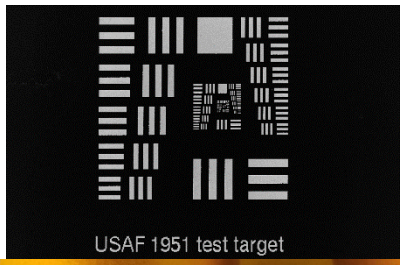
Diamond Optics

Resolution Test Samples



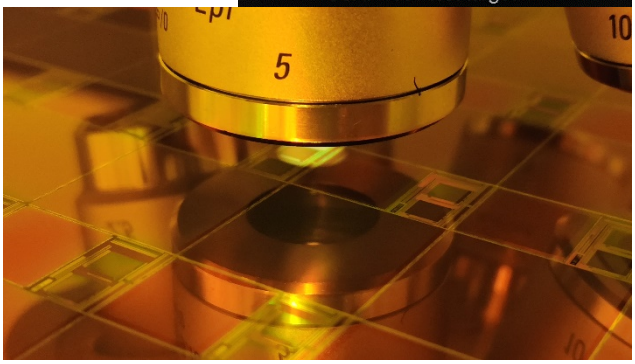
- Nanostructured resolution test patterns
- 3D resolution test patters for tomography
- Micro-CT test standards

3D Nanostructures



Phase Contrast Imaging

Hartmann Wavefront Plates



Foundry Services

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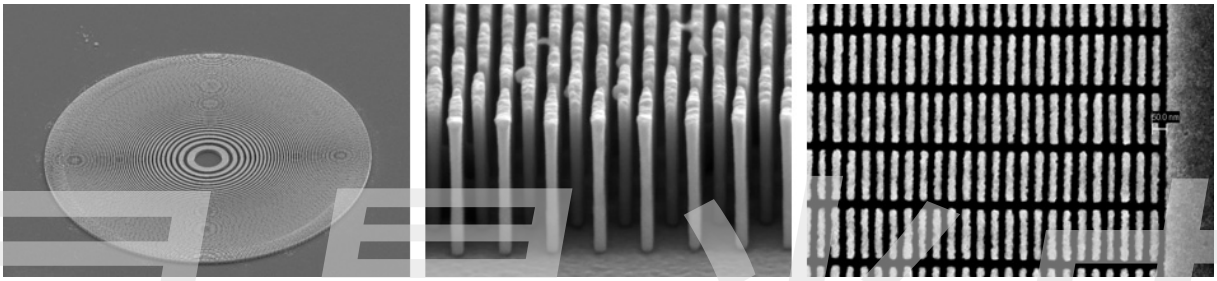
Fresnel Zone Plates

Description:

- High aspect ratio Fresnel zone plates
- Best achievable resolution
- Great efficiency available across a wide energy range (50 eV – 20 keV)
- Outstanding freedom of material choices (Au, Ni, Si, SiO_2, Ir, Cr, Diamond)

Example:



Electroplated gold zone plate for multi-keV X-rays with 50 nm wide and 500 nm high structures (left and center). Nickel zone plate for soft X-rays with 25 nm outermost zone width (right).

Specifications:

Parameter	Typical value	Achievable limits
ΔRn [nm]	50-100	<10
D [µm]	100 - 500	>4500
N	1000-3000	>30000
Aspect Ratio	10	>30

Publications:

1. S. Gorelick et al. *Direct e-beam writing of dense and high aspect ratio nanostructures in thick layers of PMMA for electroplating* Nanotechnology 21 (2010) p. 295303
2. S. Gorelick et al. *Direct e-beam writing of high aspect ratio nanostructures in PMMA: a tool for diffractive x-ray optics fabrication* Microelectronic Engineering 87 (2010) p. 1052
3. S. Gorelick et al. *High efficiency Fresnel zone plates for hard X-rays by 100 keV e-beam lithography and electroplating* Journal of Synchrotron Radiation 18 (2011) p. 442
4. K. Jefimovs et al. *Beamshaping Condenser Lenses for Full-Field Transmission X-ray Microscopy* Journal of Synchrotron Radiation 15 (2008) p. 106

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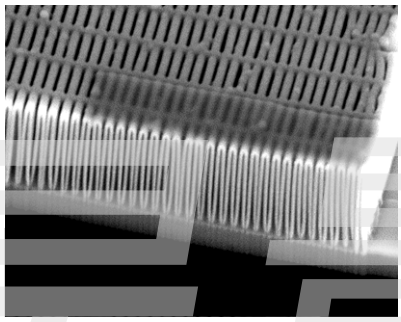
Ultra-high Resolution Zone Plates

Description:

- Ultra-high aspect ratio Fresnel zone plates
- World-record achievable resolution
- Based on the Ir-line-doubling technique
- Material: Ir

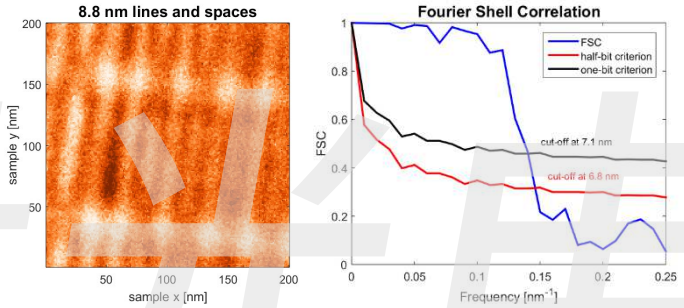
Example:

Ultra-high aspect ratio Fresnel zone plate



FIB cross-section of 25 nm wide, 550 nm high Ir

World-record resolution: 7nm



Specifications:

Parameter	Typical value	Achievable limits
ΔRn [nm]	25-50	<10
D [µm]	100 - 250	>2500
N	1000-3000	>30000
Aspect Ratio	20	>30

Publications:

1. B. Rösner et al. Exploiting atomic layer deposition for fabricating sub-10 nm X-ray lenses Microelectronic Engineering 191 (2018) p. 91
2. B. Rösner et al. 7 nm spatial resolution in soft x-ray microscopy Microscopy and Microanalysis 24 (2018) p. 270
3. K. Jefimovs et al. A zone doubling technique to produce ultra-high resolution x-ray optics Physical Review Letters 99 (2007) p. 264801
4. J. Vila-Comamala et al. Advanced Thin Film Technology for Ultrahigh Resolution X-Ray Microscopy Ultramicroscopy 109 (2009) p. 1360

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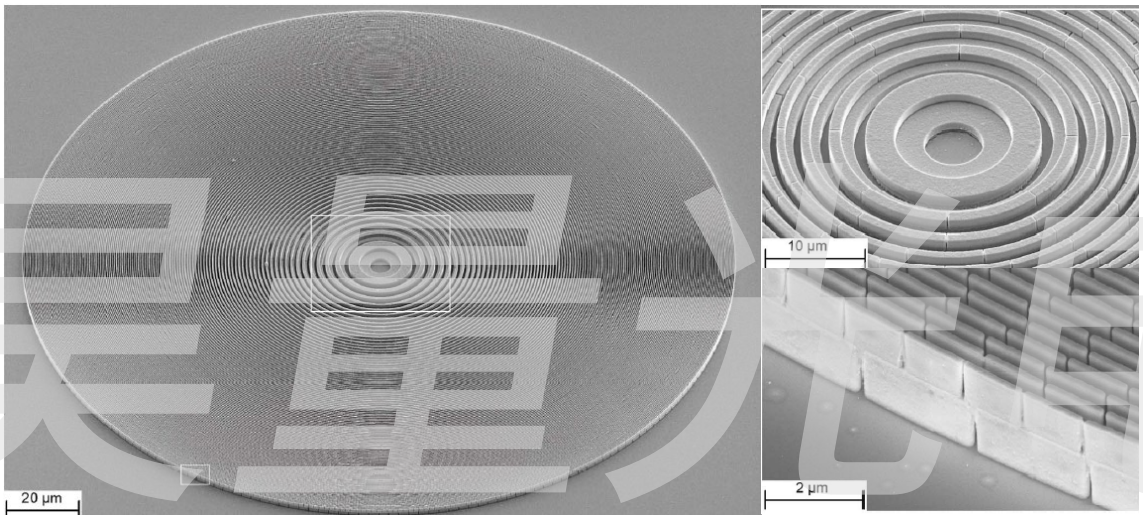
High-Efficiency Zone Plates

Description:

- High efficiency due to material choice (Au, Ni, Si, SiO_2, Ir, Cr, Diamond)
- Optimized phase shift and low absorption
- Blazed optics overcome limitations of binary optics

Example:



A three-level nickel zone plate with 200 µm diameter and effective 200 nm smallest zone width

Publications:

1. P. Karvinen et al. Kinoform diffractive lenses for efficient nano-focusing of hard X-rays Optics Express 22 (2014) p. 16676
2. I. Mohacsi et al. High efficiency X-ray nanofocusing by multilevel zone plates Journal of Synchrotron Radiation 21 (2014) p. 497
3. I. Mohacsi et al. Fabrication and characterization of high efficiency double-sided blazed X-ray optics Optics Letters 41 (2016) p. 281

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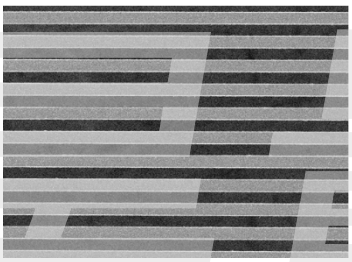
Gratings And Beam Splitters

Description:

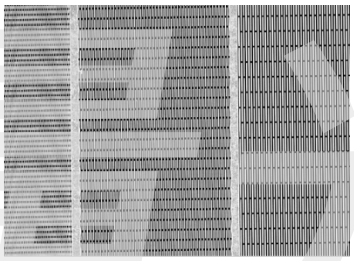
- Diffractive gratings on thin membranes or silicon wafers
- Different use cases:
  - Beam splitting
  - Grating interferometry
  - Phase contrast imaging
  - Wavefront sensing
- Wide range of material choices (Si, Au, Ni, SiO_2, Ir, Cr, Diamond)

Example:

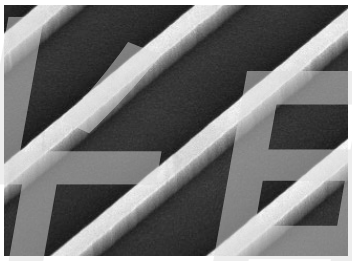
Si grating (p=1800 nm)



Au grating (p=100-200 nm)



SiO_2 grating (p=500nm)



Specifications:

- Gratings can be designed according to customers' needs using various fabrication approaches.

Publications:

1. S. Marathe et al. *Development of synchrotron pink beam x-ray grating interferometer at the Diamond Light source I13-2 beamline* Developments in X-Ray Tomography XII 11113 (2019) p. 1111319
2. C. David et al. *Differential phase-contrast imaging using a grating interferometer* Applied Physics Letters 81 (2002) p. 3287
3. F. Pfeiffer et al. *Phase retrieval and differential phase-contrast imaging with low-brilliance X-ray sources* Nature Physics 2 (2006) p. 258
4. I. Zanette et al. *Two-Dimensional X-ray Grating Interferometer* Physical Review Letters 105 (2010) p. 248102
5. Y. Kayser et al. *Wavefront metrology measurements at SACLA by means of x-ray grating interferometry* Optics Express 22 (2014) p. 9004
6. S. Rutishauser et al. *Exploring the wavefront of hard x-ray free electron laser radiation* Nature Communications 3 (2012), p. 947

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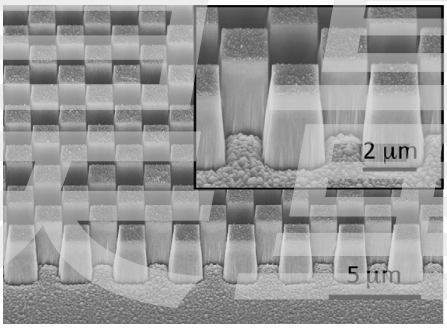
Diamond Optics

Description:

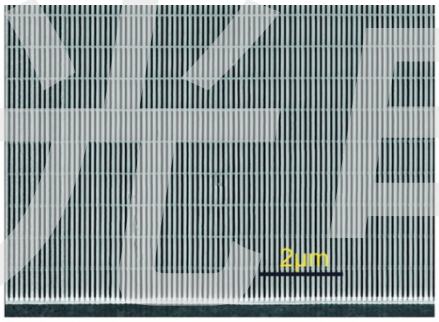
- Designed for high heat load applications
- Different use cases:
  - Diamond zone plates
  - Diamond gratings for spectral monitoring
  - Split-and-delay schemes for ultra-fast pump-probe experiments
  - Wavefront sensing
- Diamond optics allowing for peak power densities in the focal spot of $4x10^{17}$ W/cm^2
- Combinable with the Ir-line-doubling technique

Example:

Diamond checkerboard grating



Diamond grating (pitch:150 nm, height: 1200 nm)



Specifications:

Parameter	Typical value	Achievable limits
Pulse Energy	1.2 mJ @ 8 keV	N.A.
FZP: ΔRn [nm]	100	50
FZP: D [µm]	100-250	>2500
Grating: Area	1 mm x 1 mm	3 mm x 3 mm

Publications:

1. C. David et al. *Nanofocusing of hard X-ray free electron laser pulses using diamond based Fresnel zone plates* Scientific Reports 1 (2011) p. 57
2. M. Makita et al. *Diamond diffraction gratings for experiments with intense hard x-rays* Microelectronic Engineering 176 (2017) p. 75
3. N. Kujala et al. *Characterizing transmissive diamond gratings as beam splitter for hard X-ray single-shot spectrometer of European XFEL* Journal of Synchrotron Radiation 26 (2019) p. 70

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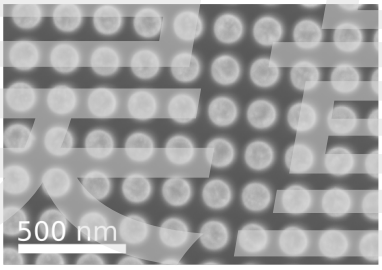
EUV, XUV and Soft X-ray Gratings

Description:

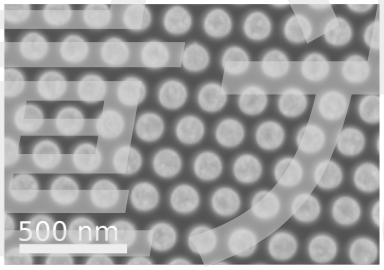
- Diffractive gratings on thin membranes
- 1D gratings
  - Lines
- 2D Gratings
  - Squares/ Checkerboards
  - Circles
  - Circles in hexagonal array
- For use in spectroscopy, EUV lithography and other applications
- Wide range of materials (Cr, Si, Au, Ni, SiO_2, Ir, Diamond)

Example:

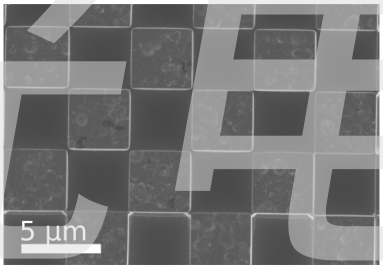
Au grating of circles



Au hexagonal grating of circles



Au checkerboard grating



Specifications and parameters:

Parameter	Typical value
Grating area	Typical 1 x 1 mm, 2 x 2 mm, up to 3 x 3 mm possible
Typical grating periods	100 nm – 10.000 nm
Material	e.g. Cr/Au/SiO_2 on 100 nm Si_3N_4
Typical carrier size	3 x 3 mm or 6 x 6 mm

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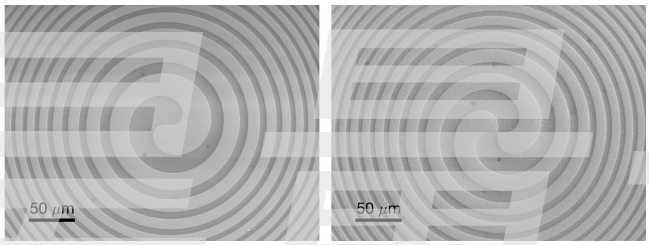
Custom Design Optics

Description:

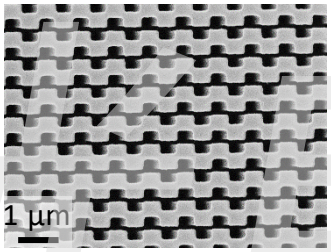
- Designed to enable unique applications at synchrotrons and XFELs
- Different use cases:
  - Focusing
  - Beam splitting
  - Generating beams with orbital angular momentum
- Wide range of material choices (Au, Ni, Si, SiO_2, Ir, Cr, Diamond)

Example:

Spiral zone plate



Multi-focus zone plate



Specifications:

- Optics can be designed according to customers' needs.
- Please get in contact with us.

Publications:

1. F. Döring et al. *Multifocus off-axis zone plates for x-ray free-electron laser experiments* Optica 7 (8) p. 1007
2. P. R. Ribič et al. *Extreme-Ultraviolet Vortices at a Free-Electron Laser* Phys. Rev. X 8.3 (2018)
3. B. Rösner et al. *High resolution beam profiling of X-ray free electron laser radiation by polymer imprint development* Optics express 25 (24), p. 30686

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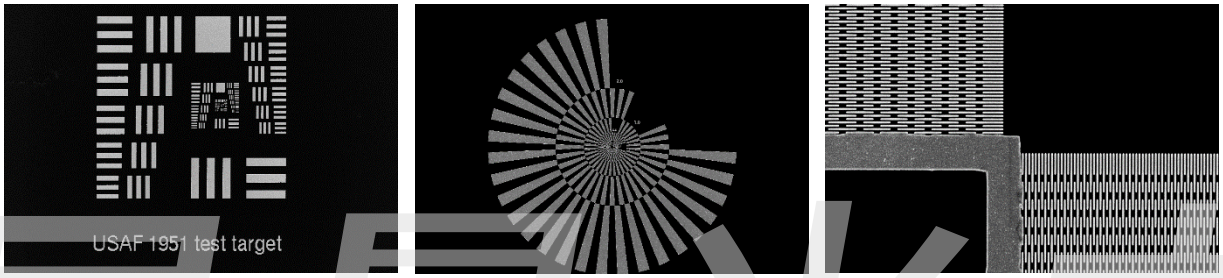
2D Resolution Test Samples

Description:

- Different standard resolution test patterns
- Material choices: Au, SiO_2
- Customizable according to customers' needs

Example:



USAF 1951 test target in nm | Siemens stars | 50 nm Lines and spaces

Specifications:

Parameter	Typical value	Achievable limits
Smallest features [nm]	50	15
Area	1 mm x 1 mm	3 mm x 3 mm
Aspect Ratio	10	>30

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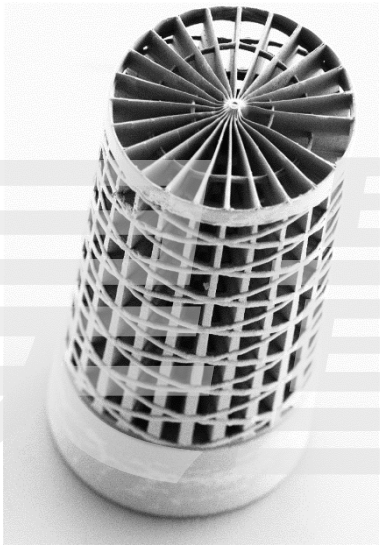
3D Resolution Test Samples

Description:

- Different standard resolution test patterns
- Material choices: Polymer e.g. $C_{14}H_{18}O_7$, with ρ=1.2g/cm^3
- Customizable according to customers' needs

Example:



3D Siemens Stars

Tomography test pattern

Specifications:

Parameter	Value
Smallest features [nm]	<200
Diameter [µm]	100
Height of structures [µm]	200
Overall height [µm]	250

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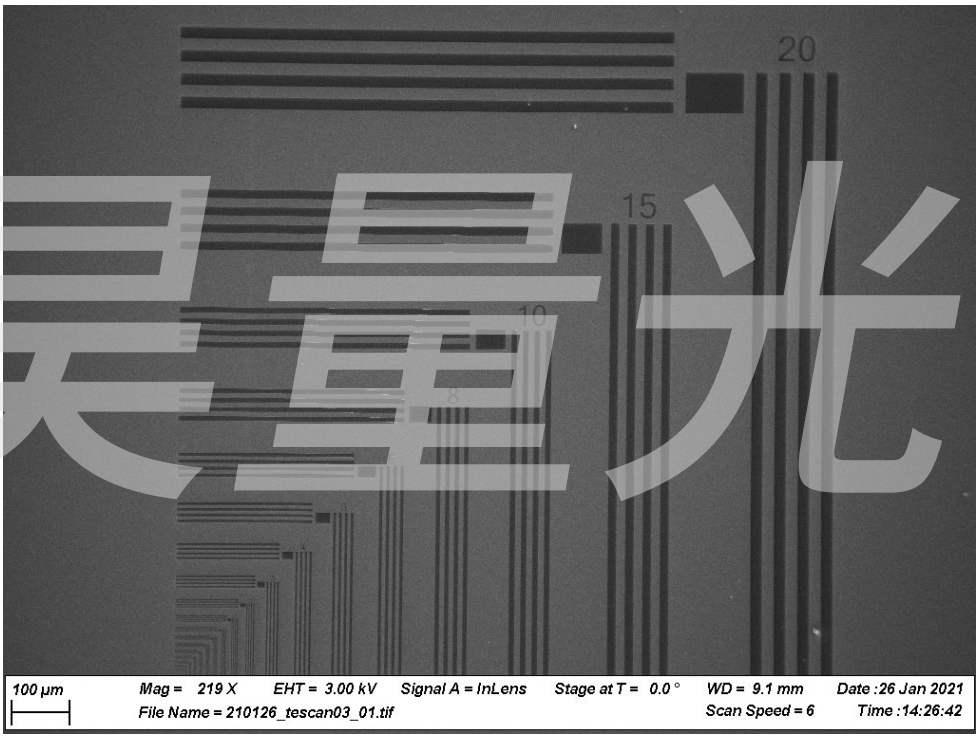
Micro-CT Test Targets

Description:

- Test targets for resolution tests and calibration
- Lines and spaces test pattern, Siemens stars and more
- Material choices: Au, Si, SiO_2, Polymer
- Customizable according to customers' needs

Example:



Specifications:

Parameter	Typical value	Achievable limits
Smallest features [nm]	200	50
Area	1 mm x 1 mm	50 mm x 50 mm
Aspect Ratio	10	>30

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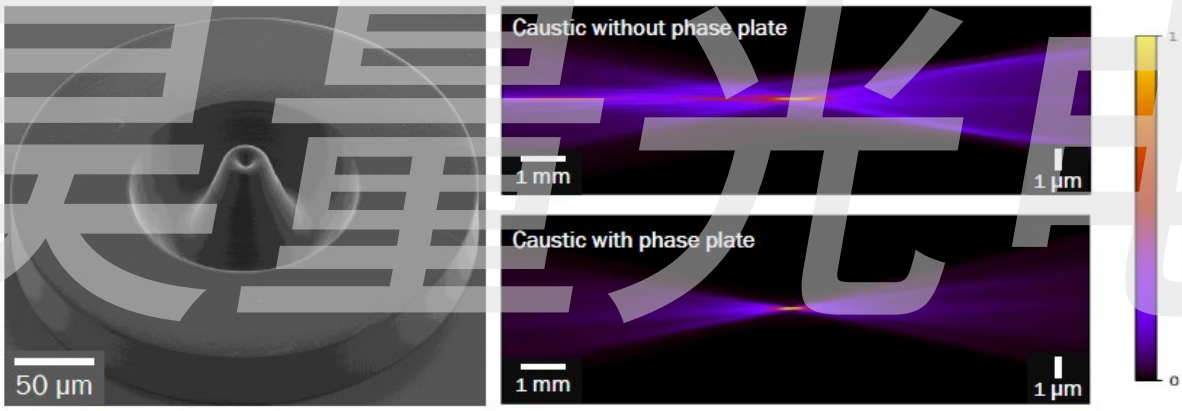
3D Nanostructures

Description:

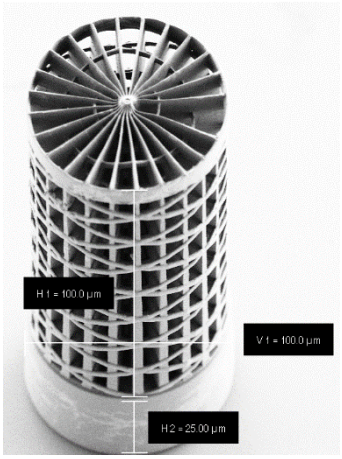
- 3D nanoprinting allows unique nanostructures
- Material: Polymer (C14 H18 O7, density: 1.2 g/cm^3)
- Custom design structures are possible
- Possible applications:
  - Phase corrector plates for Be CRLs
  - 3D Siemens stars as resolution test patterns in tomography
  - Kinoform lenses and lens arrays

Example:

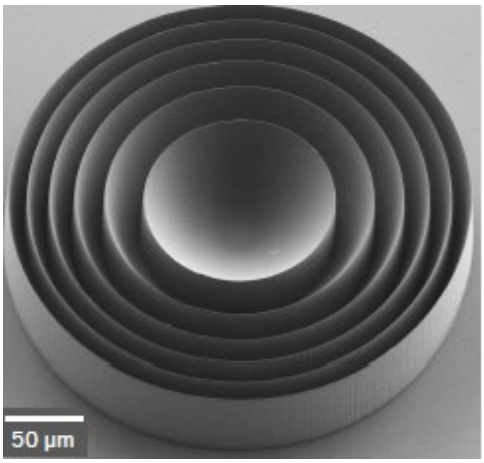
Phase corrector plates for Be CRLs



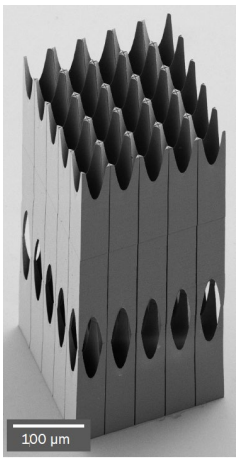
3D Siemens star



Kinoform lens



Lens array



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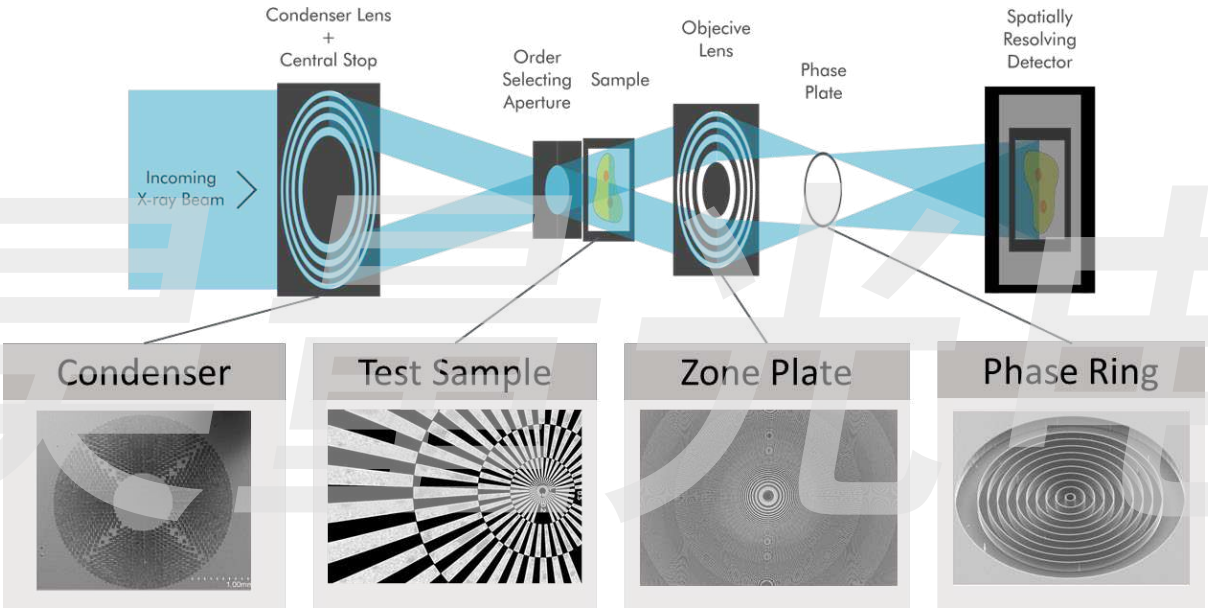
Zernike Phase Contrast

Description:

- Full field transmission X-ray microscopy optics
- Combinations of beam shaping condensers, Fresnel zone plates and Zernike phase rings
- Material choices: Au, Ir

Example:



Publications:

1. I. Vartiainen et al. *Halo suppression in full field X-ray Zernike phase contrast microscopy* Optics Letters 39 (2014) p. 1601
2. M. Stampanoni et al. *Hard X-ray 3D phase-contrast nanoimaging* Physical Review B 81 (2010) p. 140105
3. I. Vartiainen et al. *Artifact characterization and reduction in scanning X-ray Zernike phase contrast microscopy* Optics Express 23 (2015) p. 13278
4. I. Vartiainen et al. *Zernike X-ray Ptychography* Optics Letters 41 (2016) p. 721
5. M. Storm et al. *The Diamond I13 full-field transmission X-ray microscope: a Zernike phase-contrast setup for material sciences* Powder Diffraction (2020) p. 1

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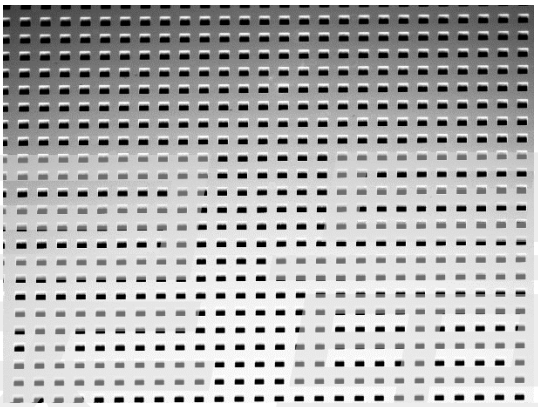
Hartmann Wavefront Sensor Plates

Description:

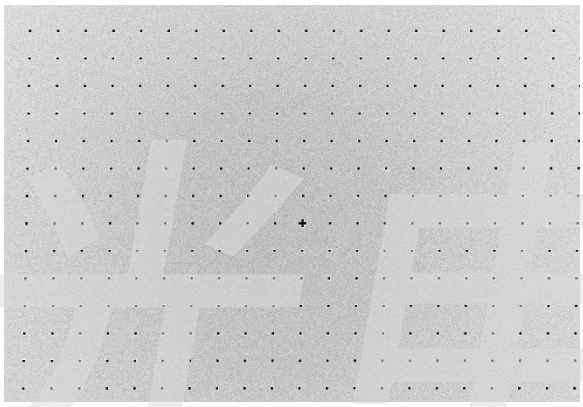
- 2D arrays of holes for wavefront sensing
- Etched into silicon using deep reactive ion etching technology
- Possibilities for high-Z materials (Au, W)

Example:

2D silicon holes (pitch: 25 μm, holes: 12.5 μm)



2D silicon holes (pitch: 30 μm, holes: 3 μm)



Specifications:

Parameter	Typical value	Achievable limits
Material	Si membrane 10 μm	Si, Au, W
Aspect ratio	10	>30
Area	Membranes: 4.5 mm x 4.5 mm	> 10 mm x 10 mm

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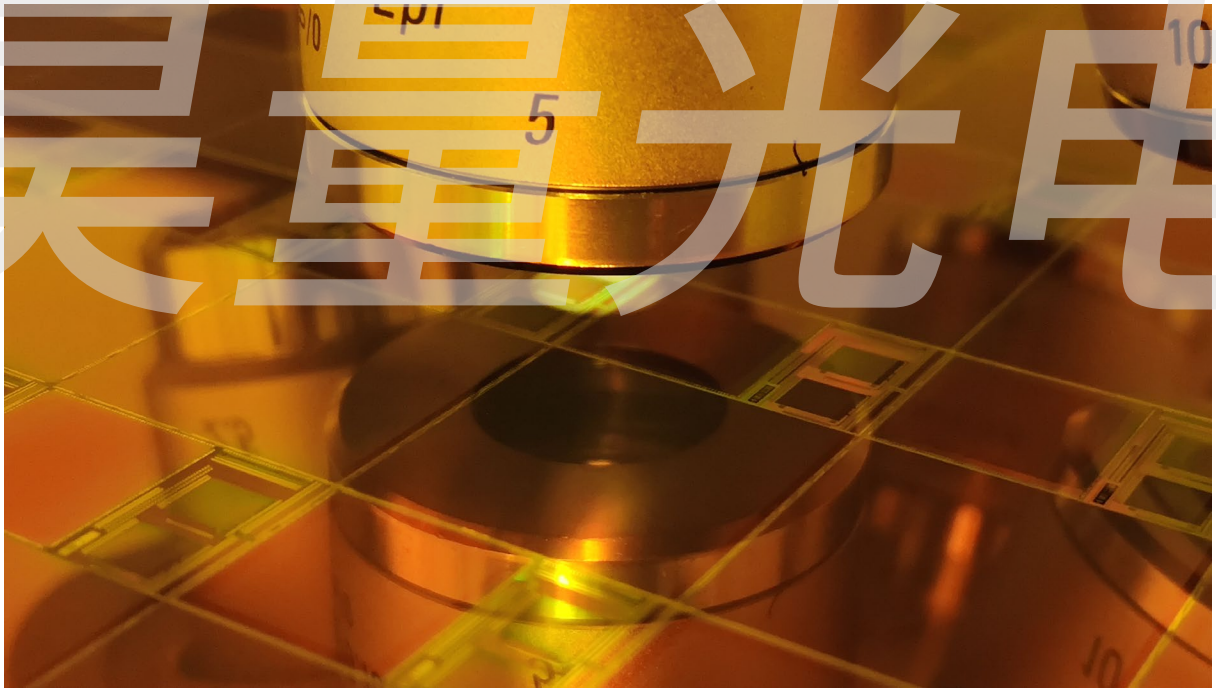

Contact us now for more information

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