X-RAY PHASE-SENSITIVE IMAGING TECHNIQUE BASED ON A BILENS INTERFEROMETER

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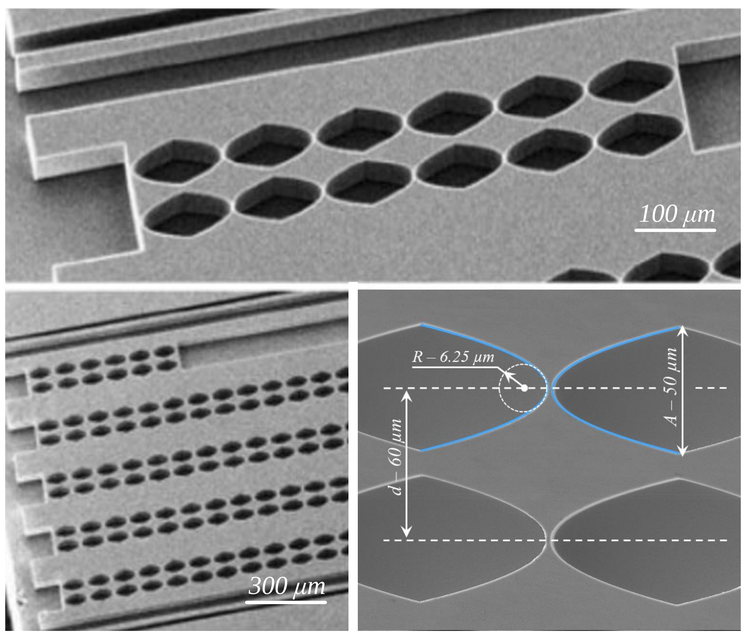
DESIGN OF BILENS

SEM IMAGE OF THE BILENS INTERFEROMETER



The bilens interferometer [1] consists of two identical, parallel, planar compound refractive lenses separated transversally by a distance d. Each lens focuses the beam at a distance z_f:

$$z_f = f/(1 - f/z_0),$$
$$f = R/2N\delta$$

where f is the lens focal length and z_0 is the source-to-bilens distance, R is the radius of curvature of one parabolic surface, N is the number of individual lenses, δ is the decrement of refraction index. Five interferometers were manufactured on the same Si chip in order to cover a range of X-ray energies *from 10 to 50 keV*.

PHASE-SENSITIVE IMAGING

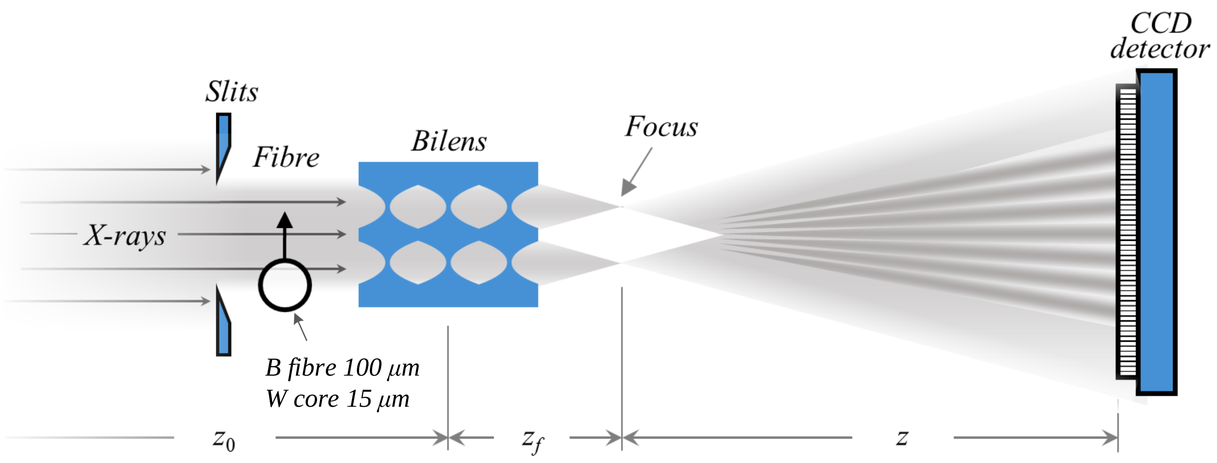
The bilens generates two coherent beams which recombines producing an interference pattern with a fringe spacing ranging from tens of nanometers to tens of micrometers, depending on the distance to observation plane.

As in the case of a classical interferometer, one can easily insert a sample in one of the beams while they are separated. The sample leads to a certain phase shift (delay) of the incident beam shifting the interference fringes.

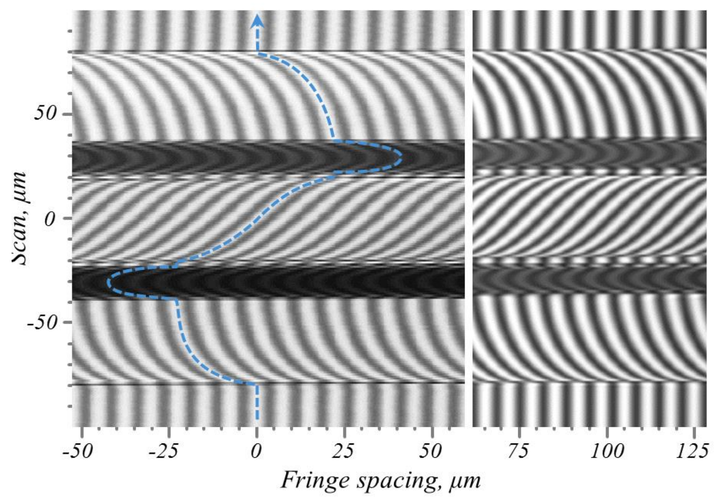
To reconstruct the phase profile of the object, it is necessary to analyze the shifts of the interference fringes recorded during the scanning of the sample in the direction perpendicular to the optical axis [2].

EXPERIMENT

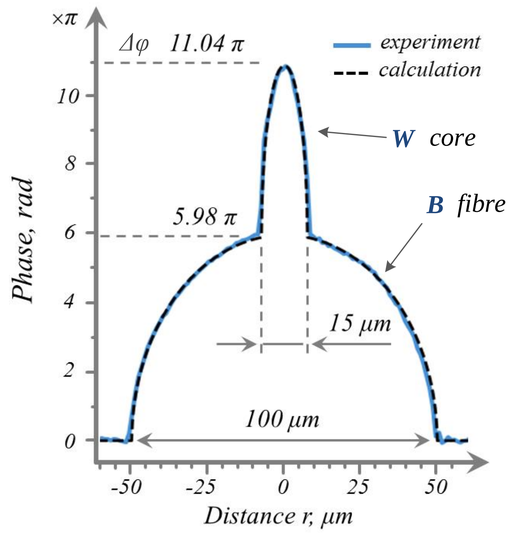
SCHEMATIC LAYOUT FOR X-RAY PHASE-CONTRAST IMAGING TECHNIQUE



EXPERIMENTAL AND SIMULATED SCANS



PHASE RECONSTRUCTION



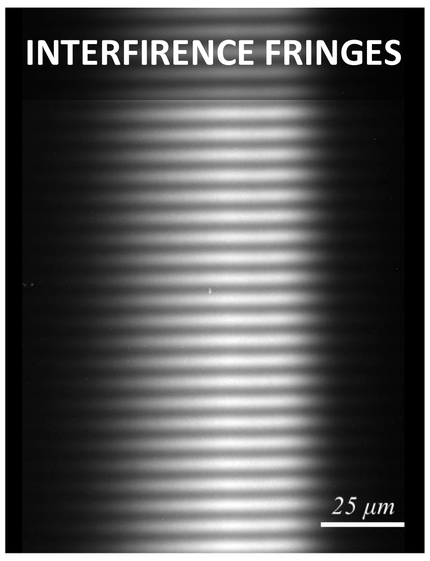
PARAMETERS AND ESTIMATIONS

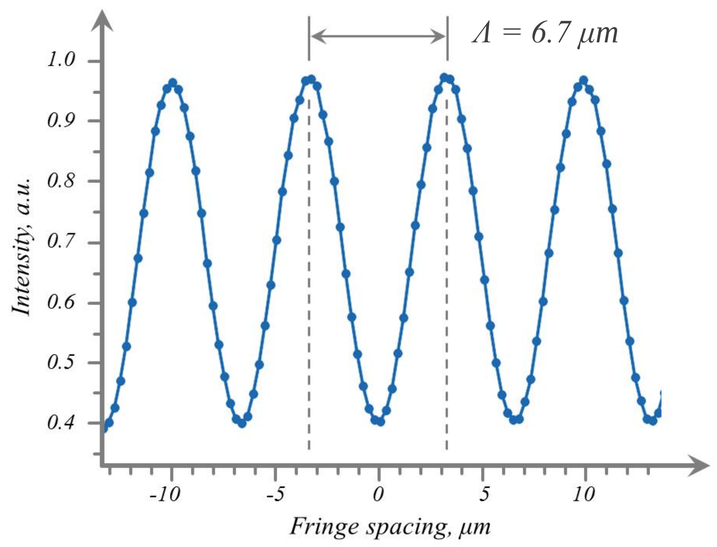
Energy: *12.0 keV*

$z_0 = 56$ m $z = 3.9$ m
$z_f = 36$ mm $d = 60$ μm

$$\Lambda = \lambda z / d = 6.72\ \mu m$$

INTERFIRENCE FRINGES





$$\delta = \lambda \Delta\varphi / 2\pi t$$

where t is a thickness of a material

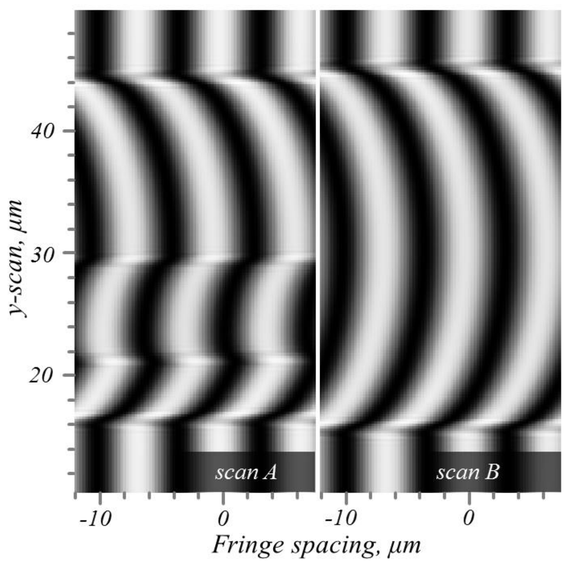
For energy of *12.0 keV*:

$\delta_B = 3.1 \pm 0.05\ 10^{-6}$
$\delta_W = 2.0 \pm 0.07\ 10^{-5}$

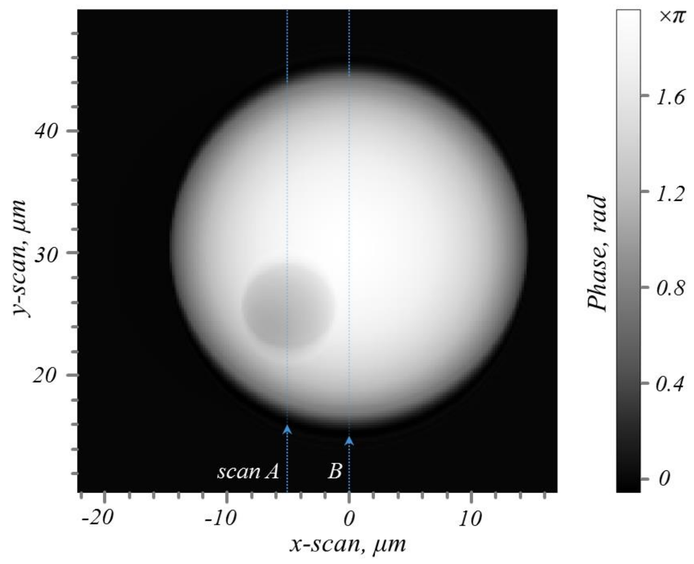
Correspond to the theoretical values!

SIMULATION OF 2D SCAN REGIME

SIMULATED SCANS



2D PHASE RECONSTRUCTION



THE SIMULATED LAYOUT completely coincide with the experimental conditions.

SAMPLE is a silicon sphere with a diameter of $30\ \mu m$, having a spherical cavity of an $8\ \mu m$ diameter placed out of the sample center.

THE SCAN STEPS in both directions across and along the bilens system *were 200 nm*.

OUTLOOK

- The phase-sensitive imaging technique using the bilens interferometer allows studying the weakly absorbing samples.
- The sample can be placed in the focal plane of the lenses. In this case, the small size of the focused beams provides extremely high phase and spatial resolution.
- The bilens interferometer makes possible to study the samples with sizes smaller and larger than the distance between separated beams.
- The proposed phase-contrast imaging concept can be extended by use of the multilens interferometers [3].
- The approach can be realized with X-ray radiation in a wide energy range, especially at the hard X-rays (>30 keV), where the use of other phase-contrast techniques are problematic.

REFERENCES

[1] Snigirev, A., et al. "X-ray nanointerferometer based on si refractive bilenses." Physical review letters 103.6 (2009): 064801.

[2] Zverev, D., et al. "X-ray phase-sensitive imaging using a bilens interferometer based on refractive optics" Optics express 28.15 (2020): 21856-21868.

[3] Snigirev, A., et al. "X-ray multilens interferometer based on Si refractive lenses." Optics express 22.21 (2014): 25842-25852.

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