Nanometer-accurate fringe metrology using a Fresnel zone plate

Chulmin Joo
Carl G. Chen
Paul T. Konkola
G. S. Pati
Ralf K. Heilmann
Mark L. Schattenburg

Massachussets Institute of Technology

Erik H. Anderson
Alexander Liddle

Lawrence Berkeley National Laboratory

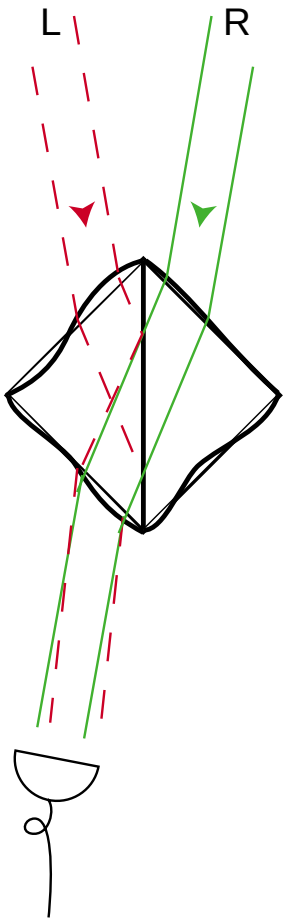
Motivation

Accurate intereference fringe metrology is needed for a precise stitching of subsequent scans (Refer to 10B4).

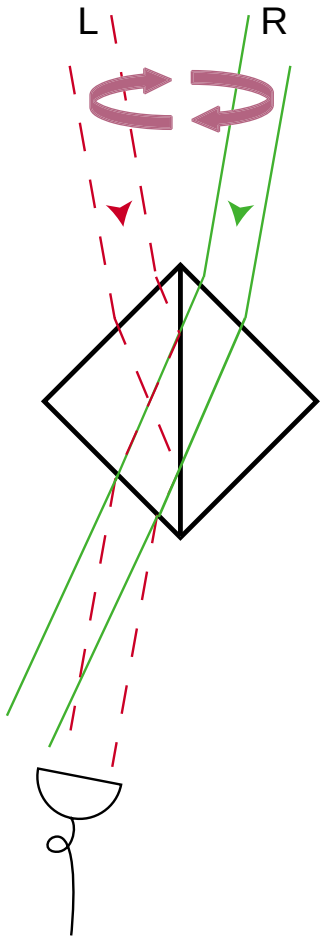
Interference fringe metrology for a wide range of periods is needed (Refer to PG7).

Motivation

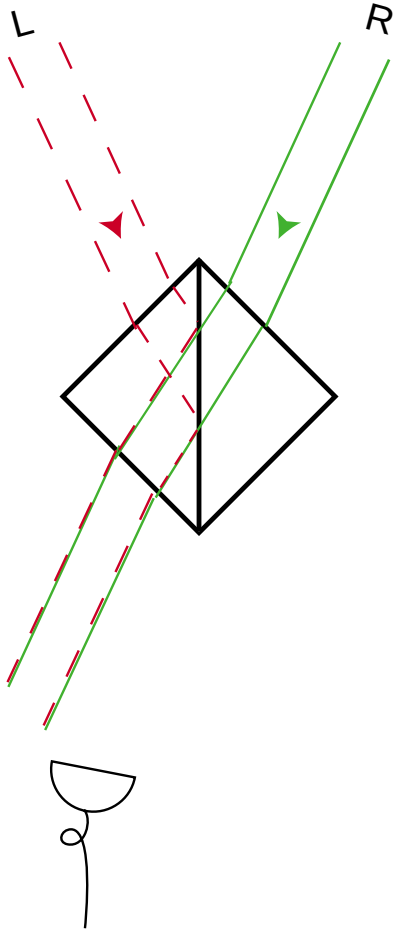
Limitations of Beamsplitter Scheme



(a) Distorted beamsplitter



(b) Rotating beams

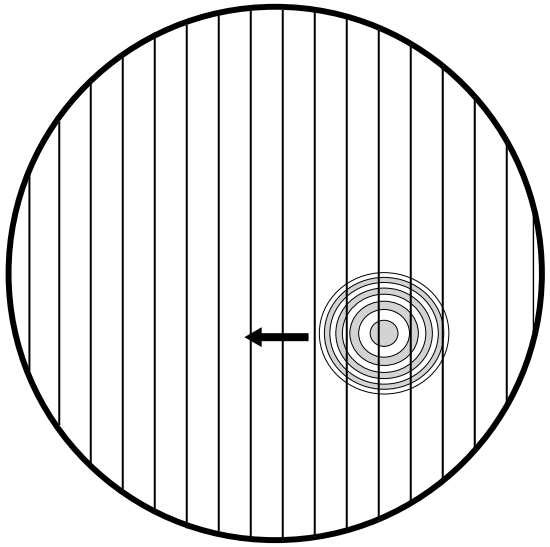


(c) Change of incident angles

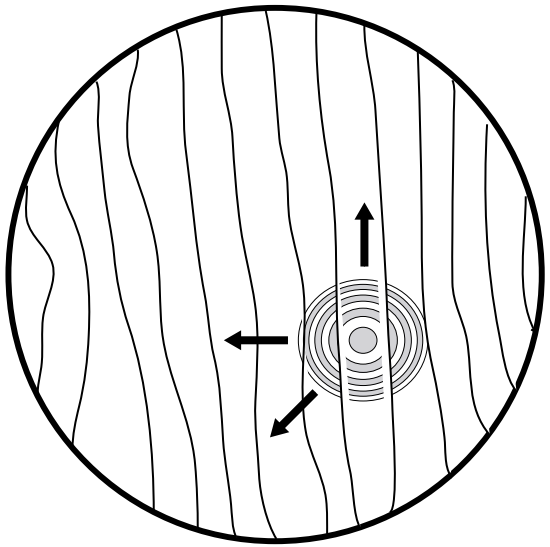
Motivation

Zone plates:

(1) Have a wide range of spatial frequencies
(2) Have high accuracy
(3) Are very small

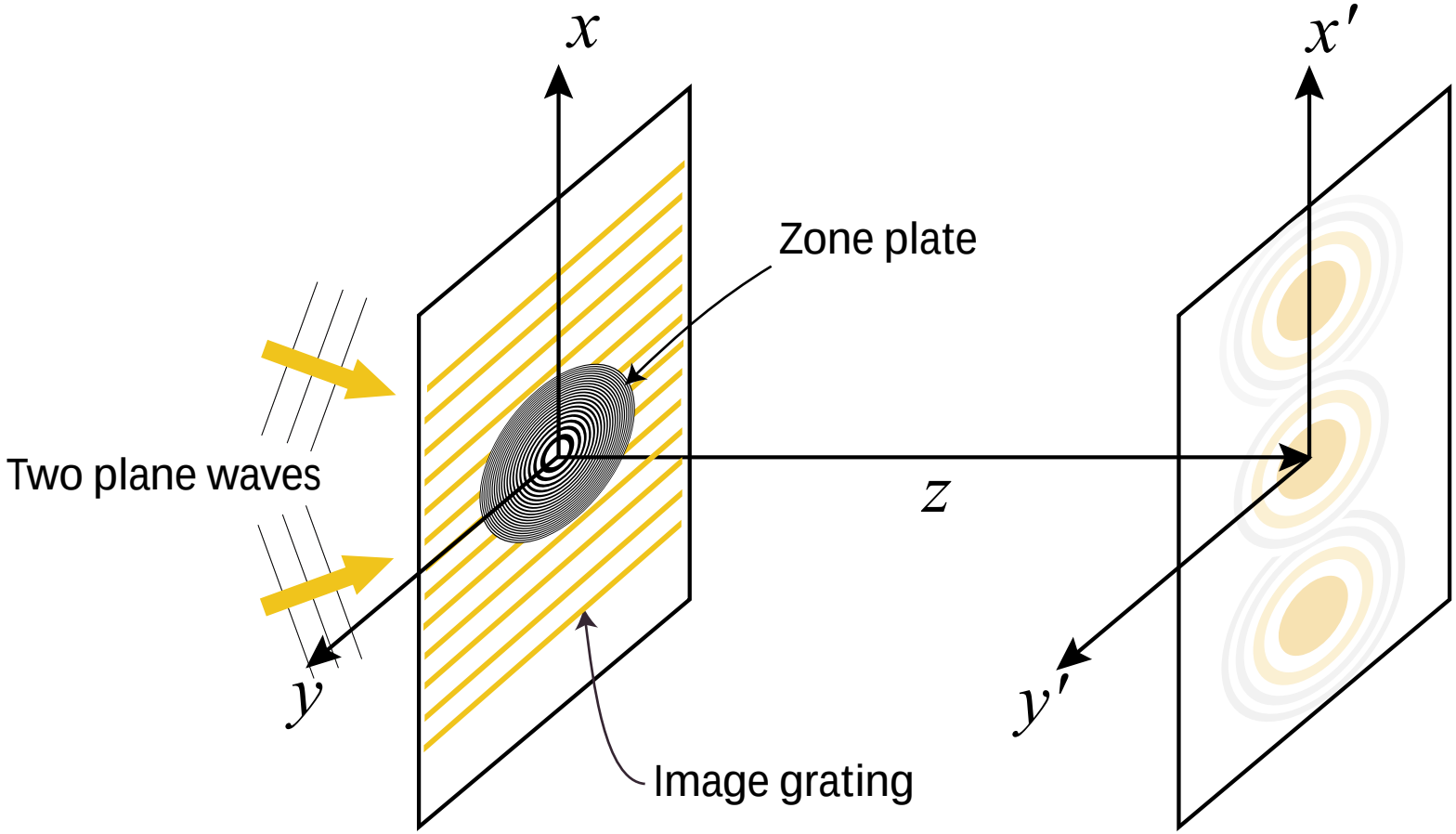


(a) Fringe period measurement



(b) Fringe mapping

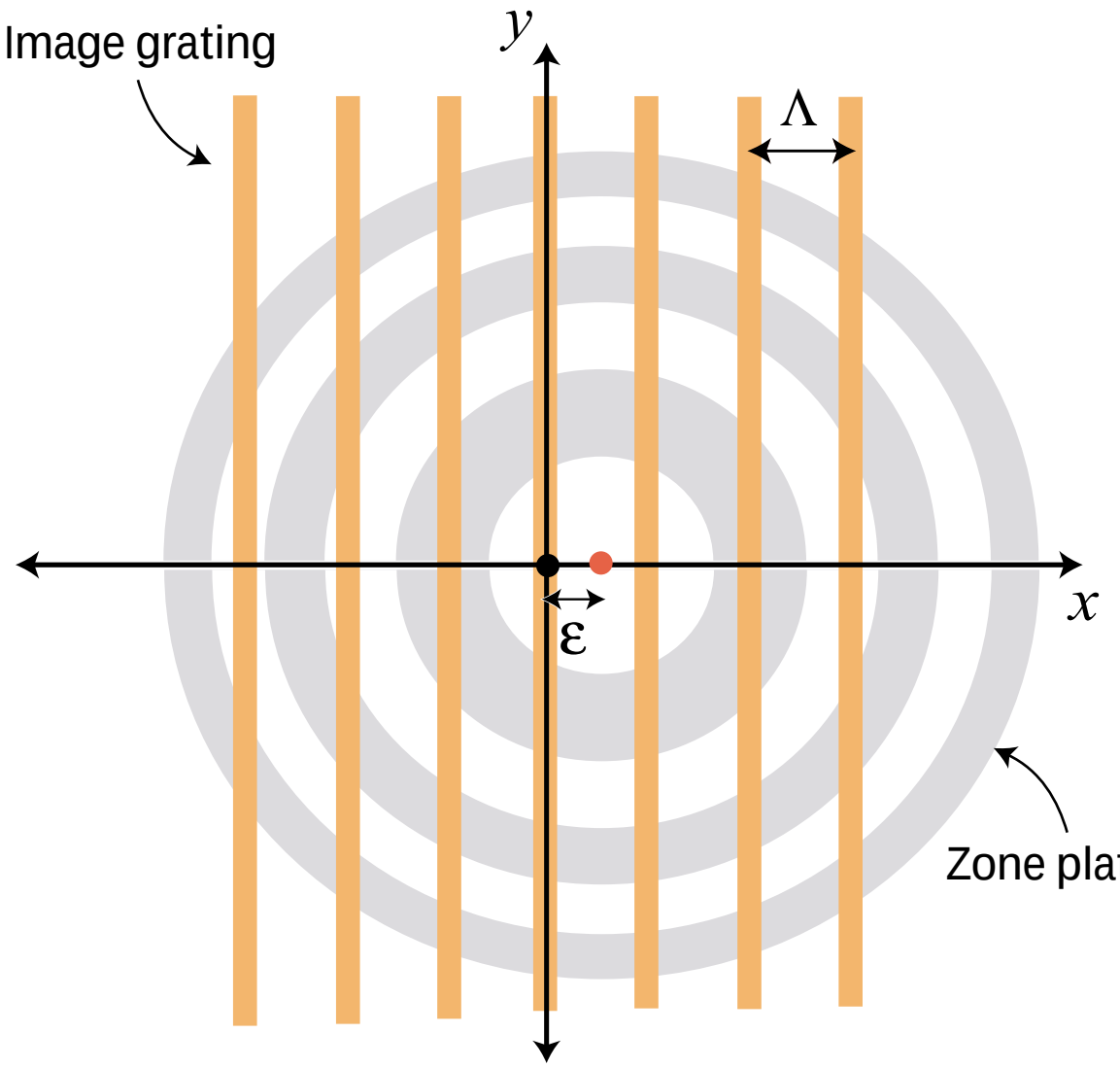
Diffraction of Two Plane Waves by Zone Plate



Superposition between
image grating and zone plate

Far field diffraction pattern

Image Grating



Fringe Intensity

$$I(x, y) = 2 + 2\cos\frac{2\pi}{\Lambda}x$$

Irradiances

x-y Plane

$$I(x, y) = [\ 2 + 2\cos\frac{2\pi}{\Lambda}x\ ]\ |f(x-\varepsilon, y)|^2$$

$f(x, y)$: Transmittance of zone plate centered at the origin

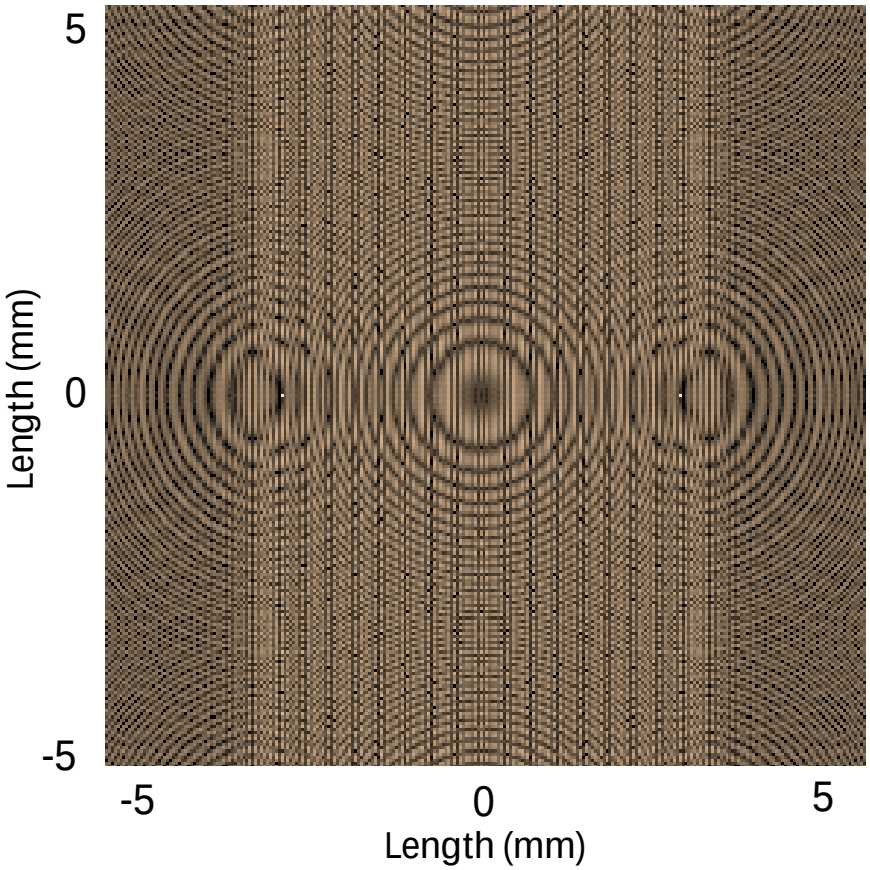
x'-y' Plane

$$I(x', y') = g_1(x', y') + g_2(x', y') + 2\, g_1(x', y') g_2(x', y') \cos\frac{2\pi}{\Lambda}\varepsilon$$

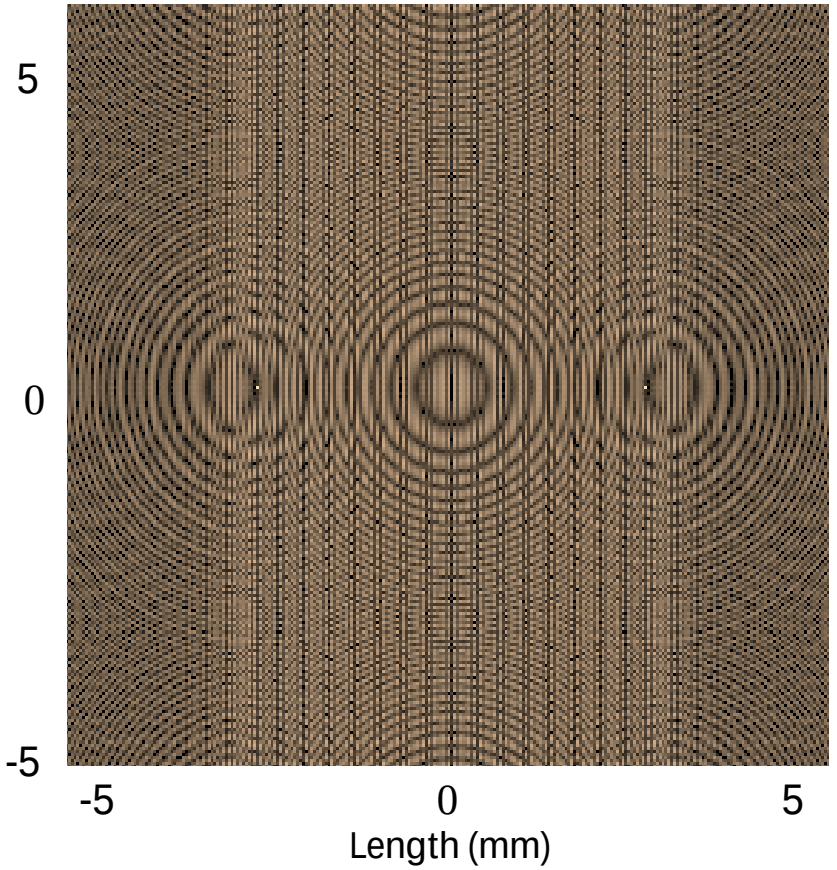
$g_1(x', y')$, $g_2(x', y')$ } Diffraction pattern of zone plate

Simulation

Diameter of innermost zone / Image grating period = 10

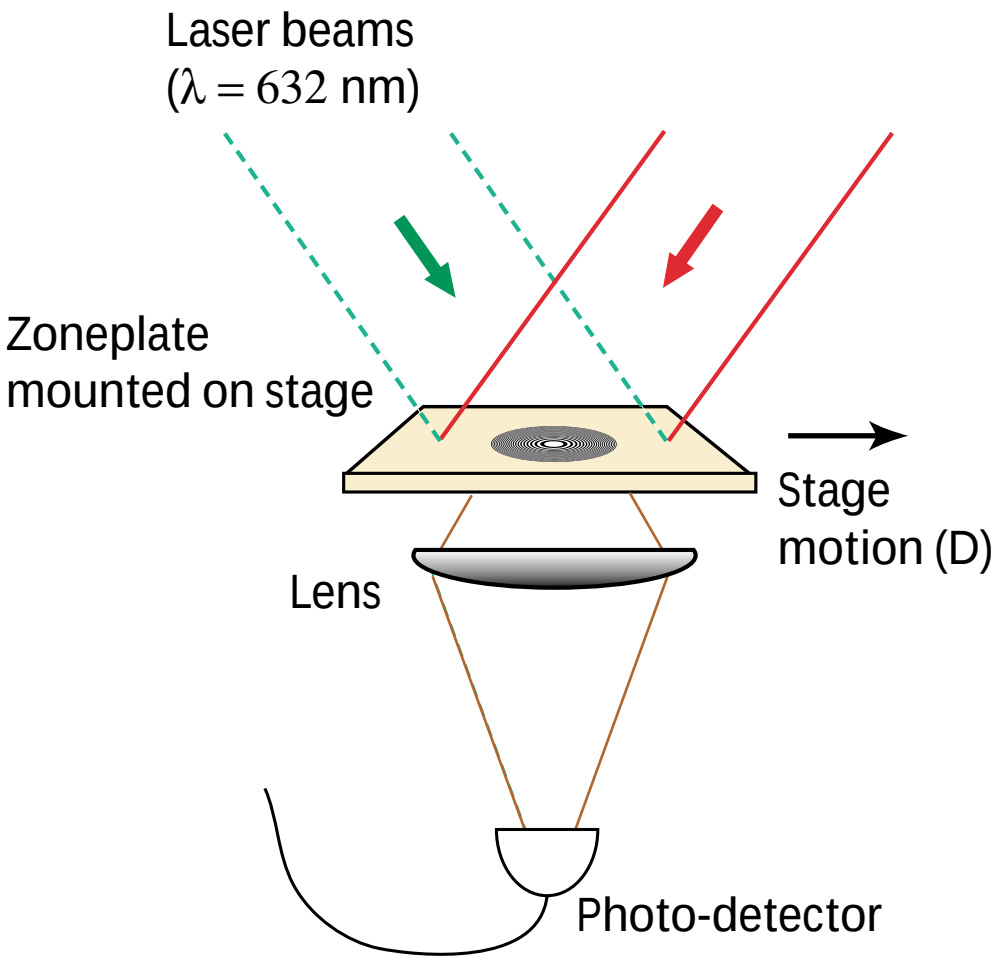


(a) In Phase

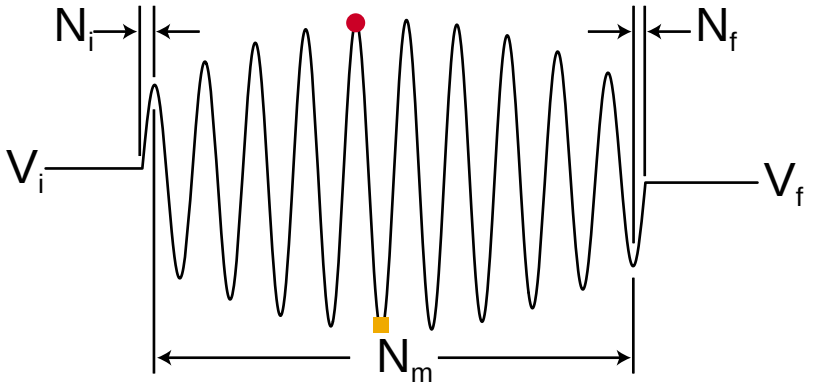


(b) Out of Phase

Interference Fringe Period Metrology



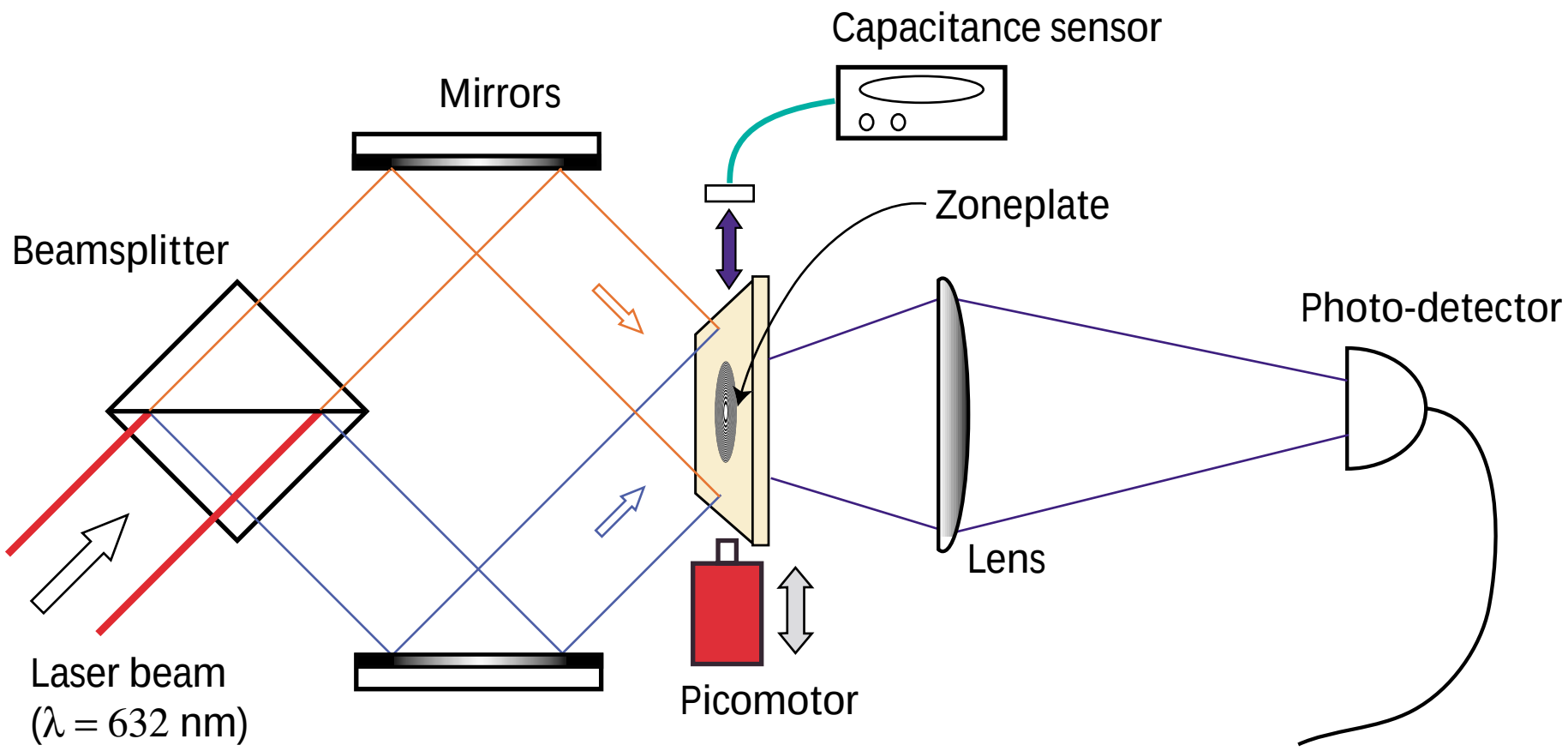
Signal Detected as Stage Moves



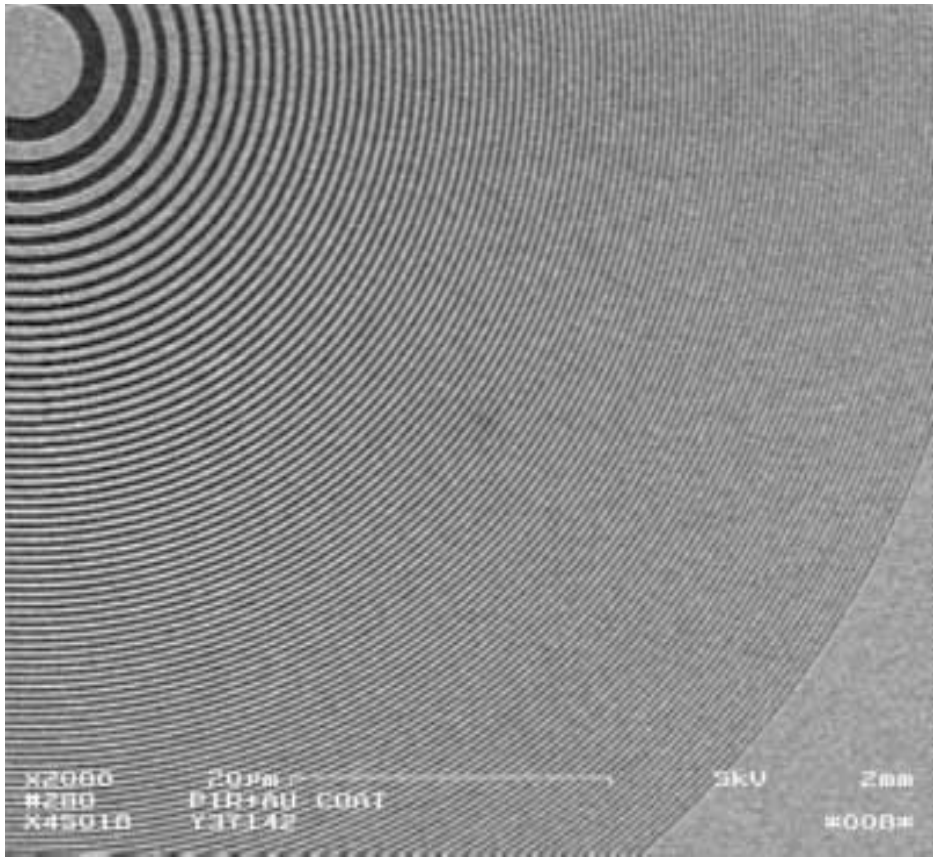
$$N = N_i + N_m + N_f$$

Grating period = D/N

Interference Fringe Period Metrology



Interference Fringe Period Metrology



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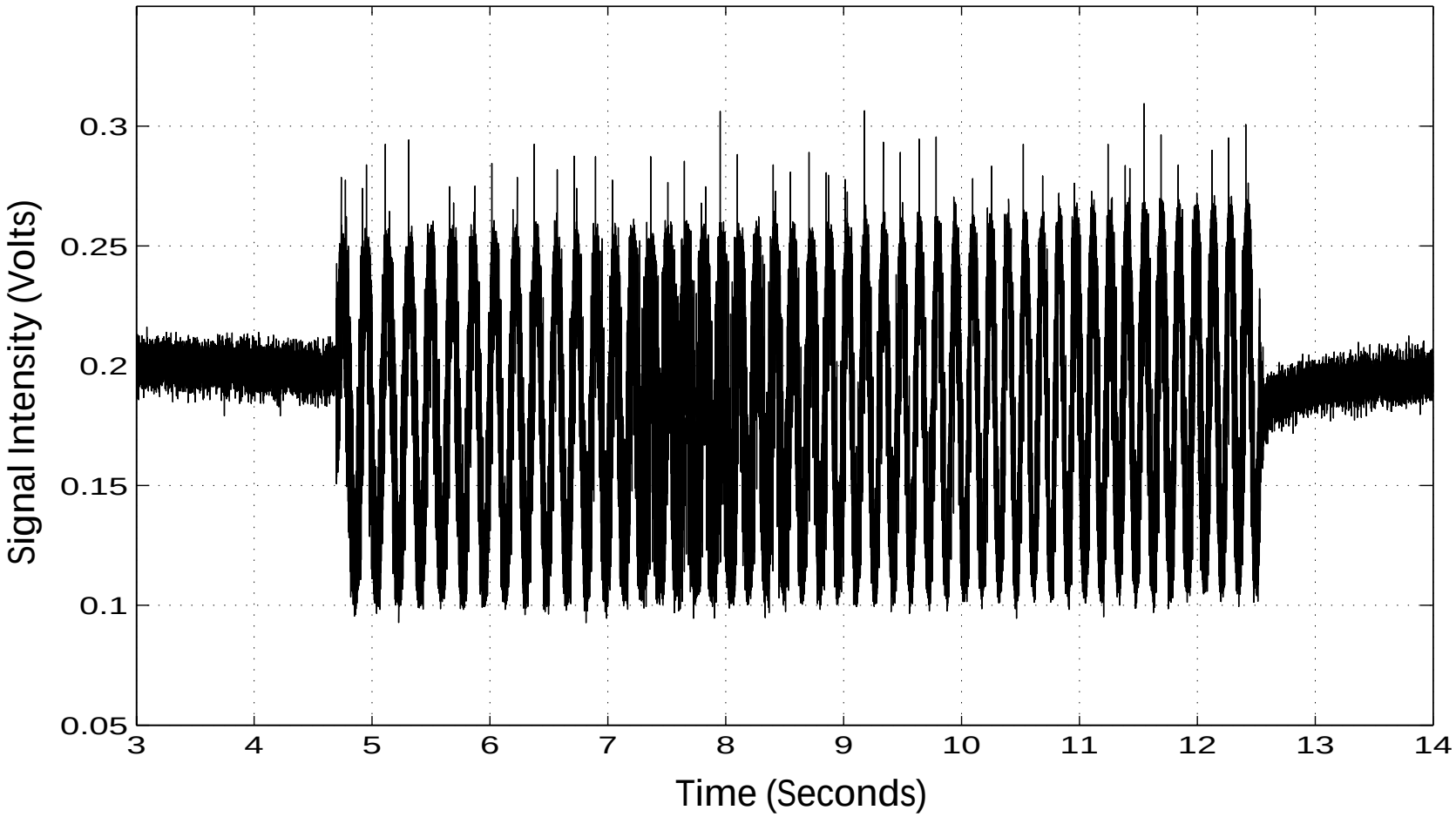
Number of zones: 200

Diameter: 127 μm

minimum zone width: 207 nm

Interference Fringe Period Metrology

Angle of Incidence: 20 degrees (f_s = 5 kHz)



Interference Fringe Period Metrology

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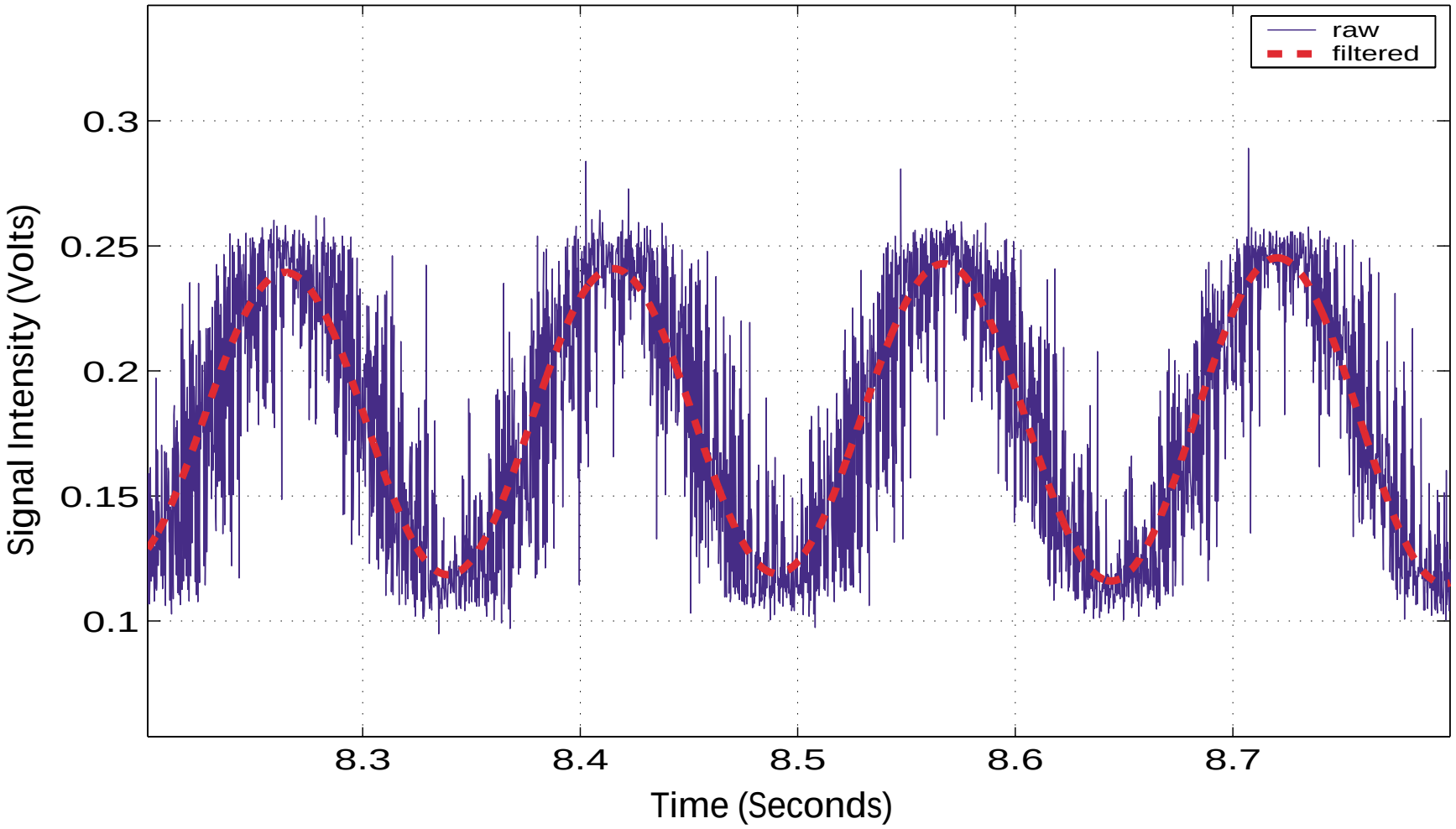

Interference Fringe Period Metrology

Protractor angular resolution: 1 degree
Number of measurements: 30

Angle of Incidence: 20 degrees

- Measured period: 911.8 ± 1.1 nm
- Predicted period: 923.9 ± 44.3 nm

Angle of Incidence: 35 degrees

- Measured period: 541.1 ± 0.9 nm
- Predicted period: 550.9 ± 13.7 nm

Error Sources

Uncertainty in angle measurement

± 44.3 nm	for 20 degrees
± 13.7 nm	for 35 degrees

Inaccuracy in displacement sensor

± 0.3 nm	for 20 degrees
± 0.2 nm	for 35 degrees

Cosine errors in alignment

Interference fringe drift due to the change of refractive index

Vibrations

Acoustics

Conclusions

Demontrated *in-situ* interference fringe metrology using a zone plate.

Correctly controlled error sources should allow sub-nanometer characterization of interference fringes.

Study on signal contrast variation with a period of fringes is undergoing.