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Sphere choice in Mirau interferometric microsphere assisted profilometry

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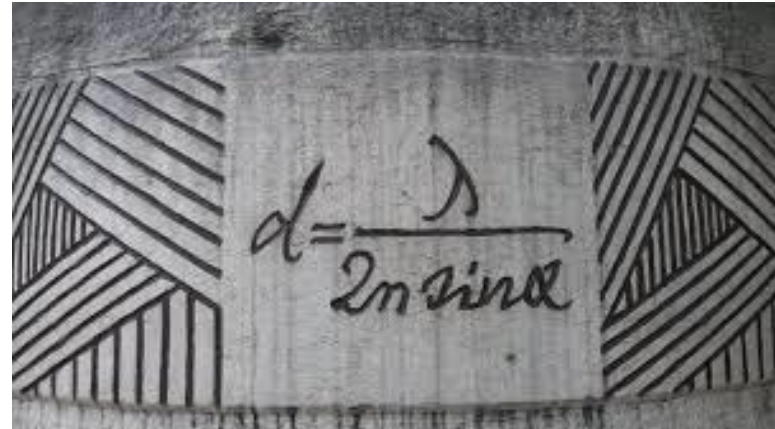
- 1. Microsphere-assisted microscopy**
- 2. Mirau interferometric configuration**
- 3. Linnik interferometric configuration**

Microsphere assisted microscopy

Classical microscopy : limited by diffraction (~ 200 nm, visible)



In 1873, Ernst Abbe :



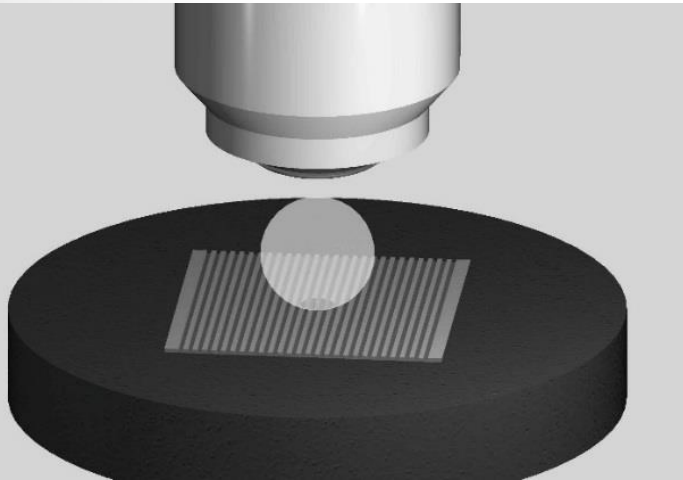
How to enhancement the resolution ?

Label free technique ?

Full-field imaging ?

Microsphere assisted microscopy

A glass μ -sphere
on a Si grating

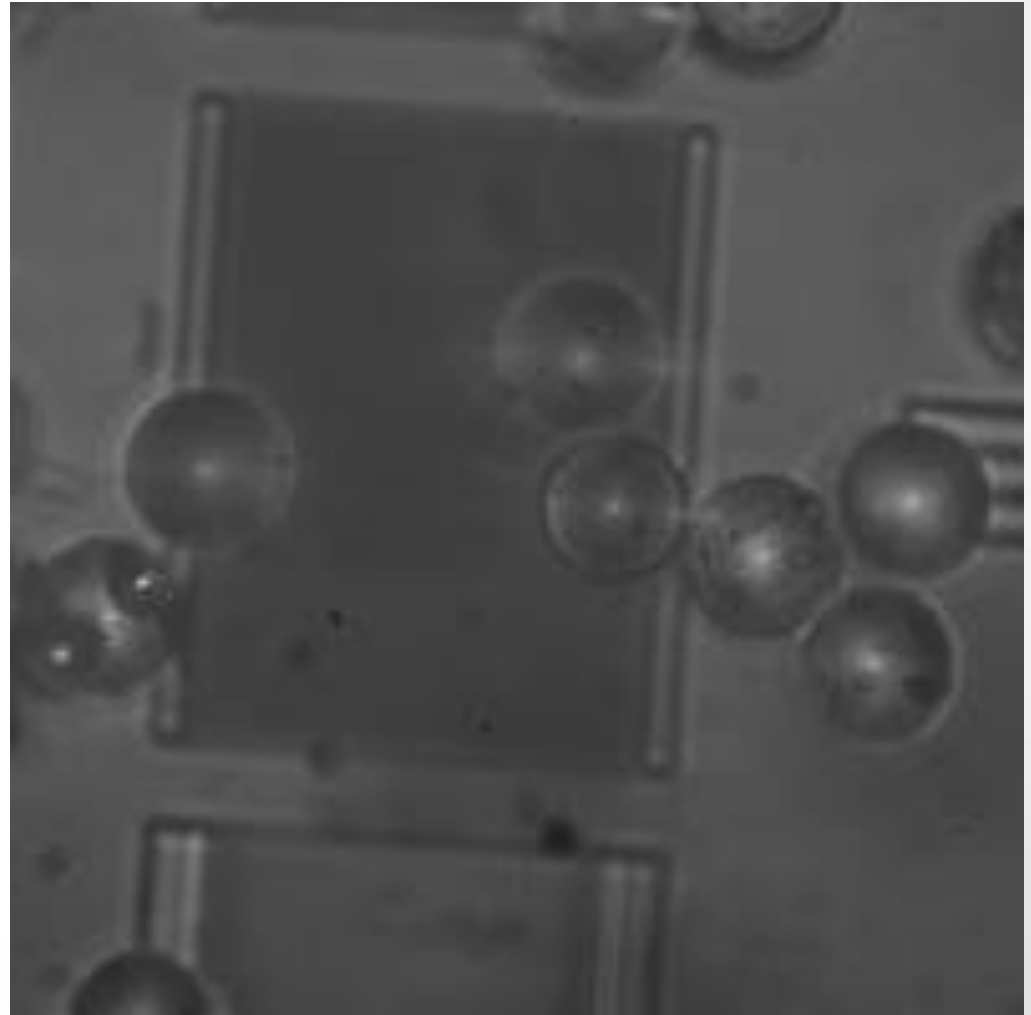


The microsphere behaves
as a lens

Resolution :

100 nm in air

50 nm in immersion

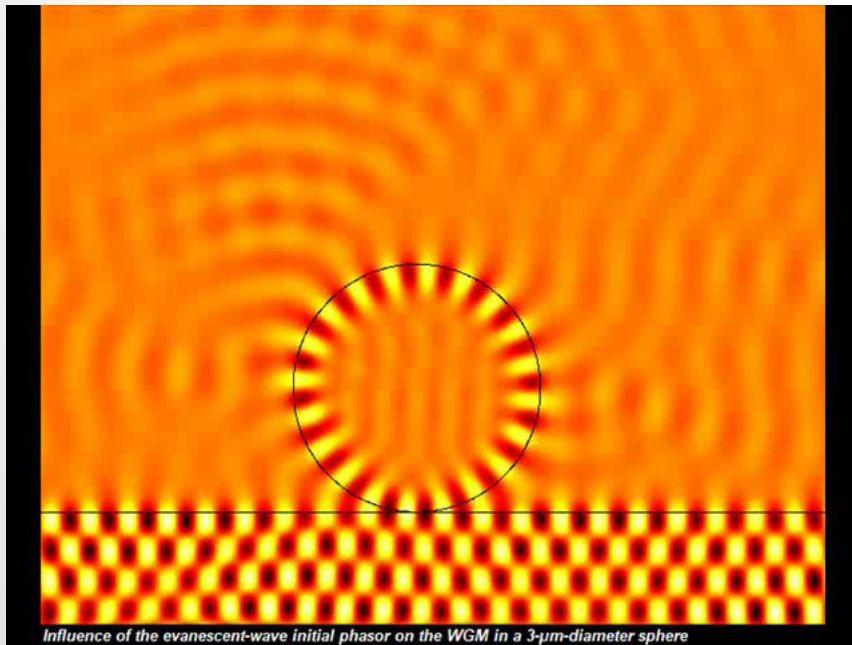


[Perrin, Label-Free Super-Resol. Micro., Springer, 2019]

Microsphere assisted microscopy

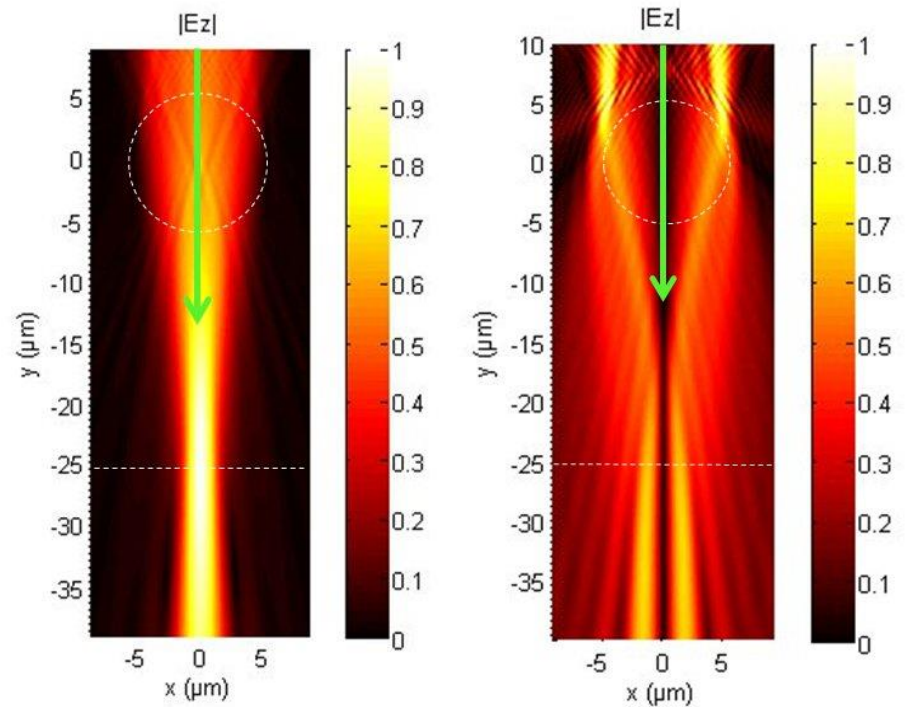
A meso-scale phenomenon

Evanescent waves
conversion in far field



[Boudoukha, MDPI Photonics, 2021]

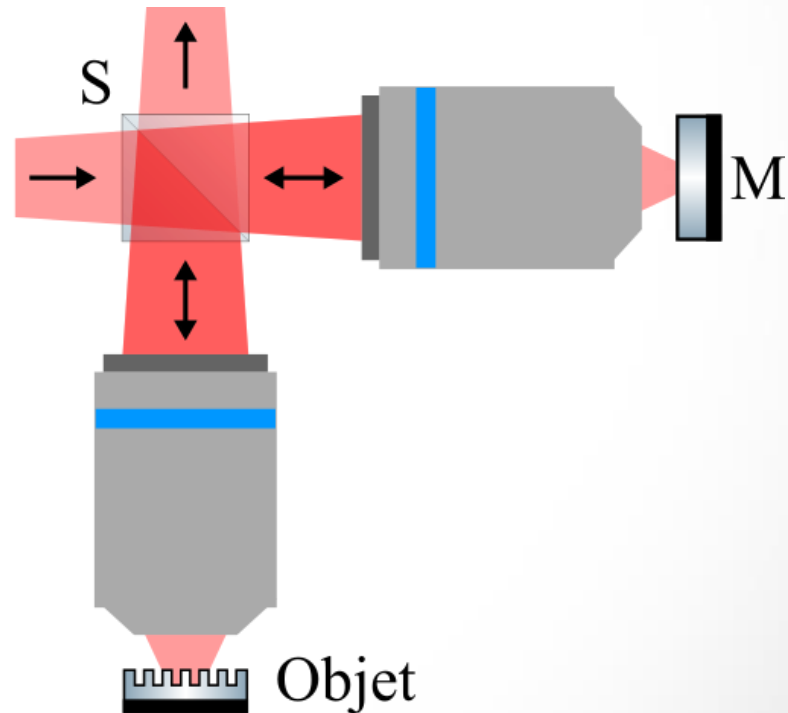
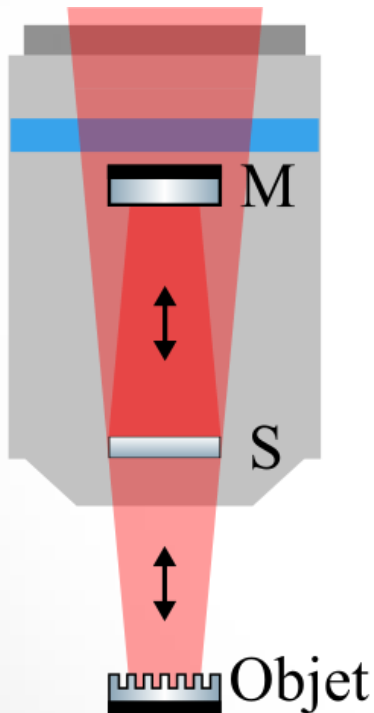
2 pt sources virtual image simulation
in-phase sources Out-of-phase sources



[Kassamakov, Lecler *et al.*, Sci. Rep.7, 3683, 2017]

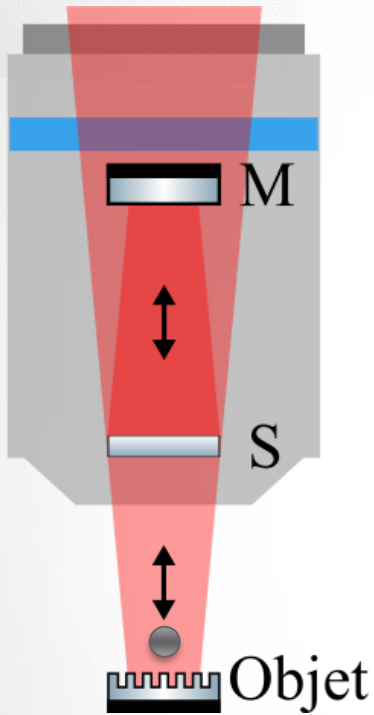
Interferometric configuration

Mirau versus Linnik configuration



To measure phase and deduce profile

Mirau configuration



Sodalime glass sphere
 $\text{Ø} = 6 \mu\text{m}$ ($n = 1.5$)

$\lambda_0 = 600 \text{ nm}$, x50 (ON = 0.55), in air

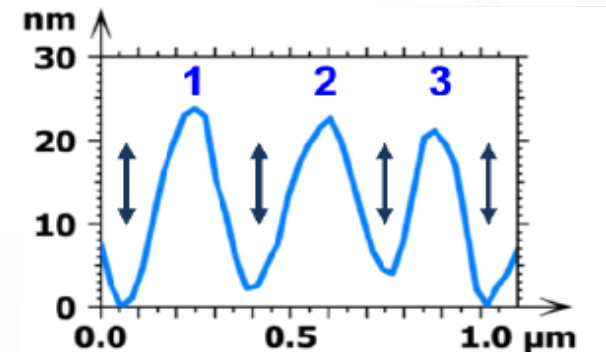
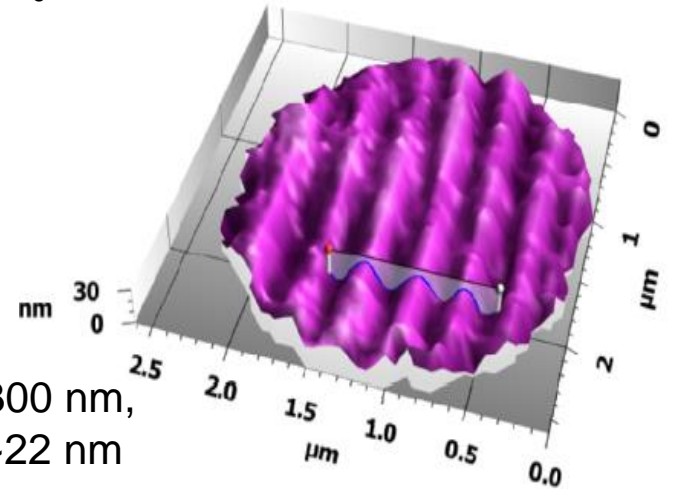
Melamine formaldehyde sphere
 $\text{Ø} = 11 \mu\text{m}$ ($n = 1.68$)

$\lambda_0 = 600 \text{ nm}$, x50 (ON = 0.55), in air

~~$\text{Ø} = 20 \mu\text{m}$ ($n = 1.5$)~~

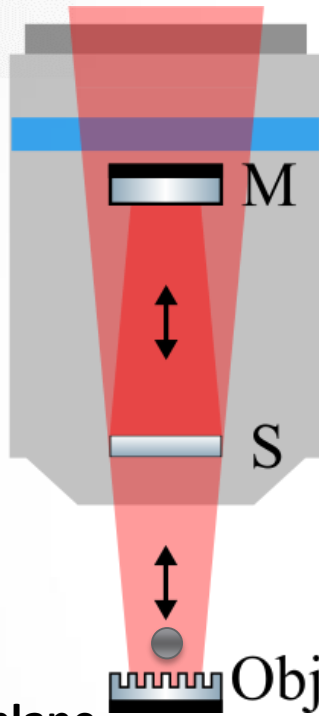
Currently only for small sphere
 ($R < 15 \mu\text{m}$)

Blu-Ray :
 period of 300 nm,
 height of ~22 nm



[Kassamakov et al., Sci. Rep.7, 3683, 2017]

Mirau configuration



.....
Coherence plane

Image plane

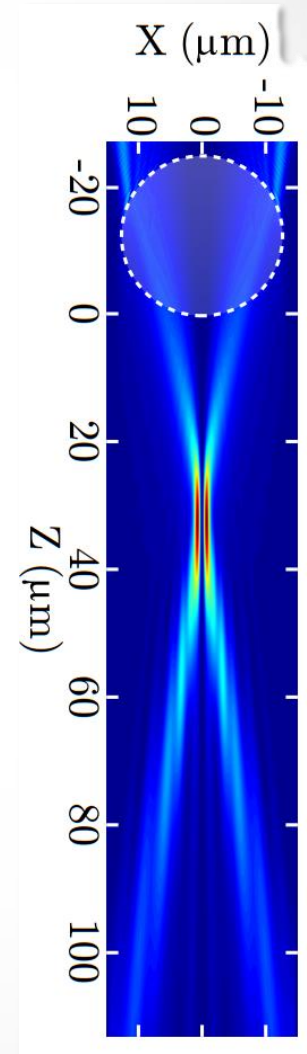
Coherence length

μ -sphere depth of field

Linear displacement

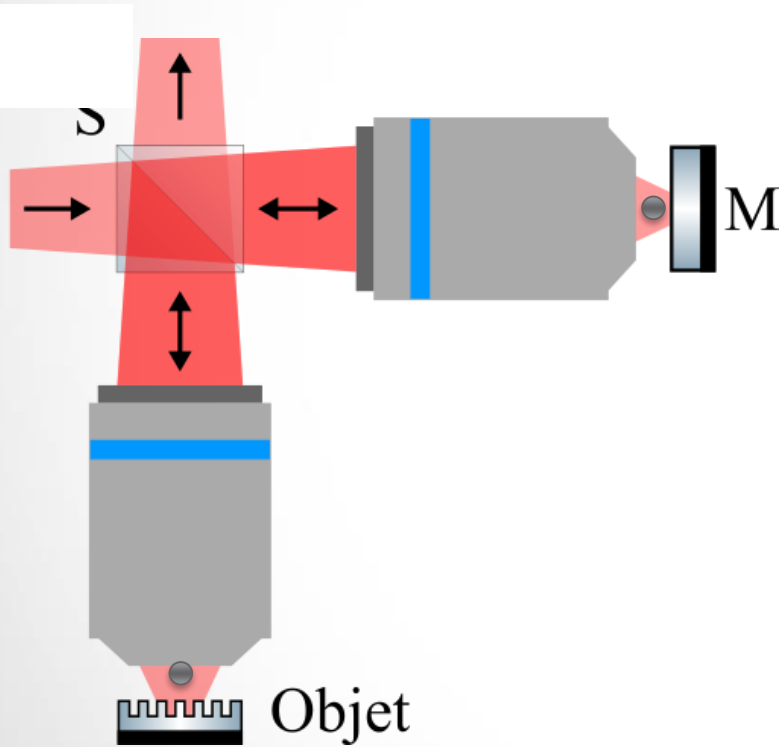
Exponential displacement

μ -sphere depth of field



Virtual image simulation

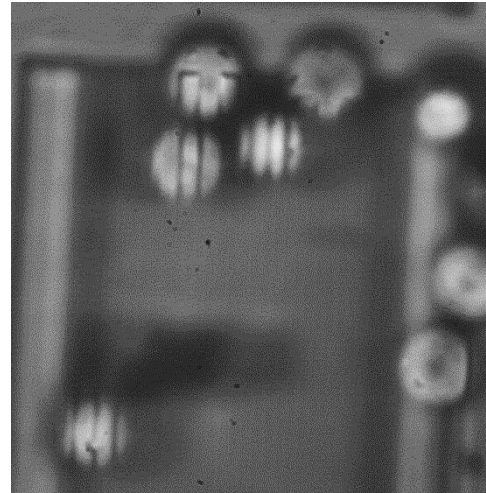
Linnik configuration



Linnik configuration in white light
with 50x objectives (ON = 0.85)

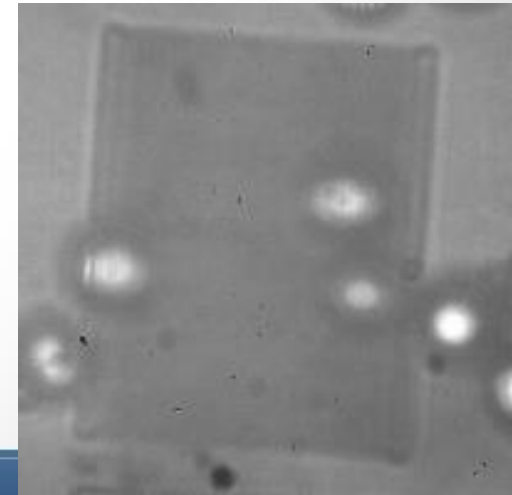
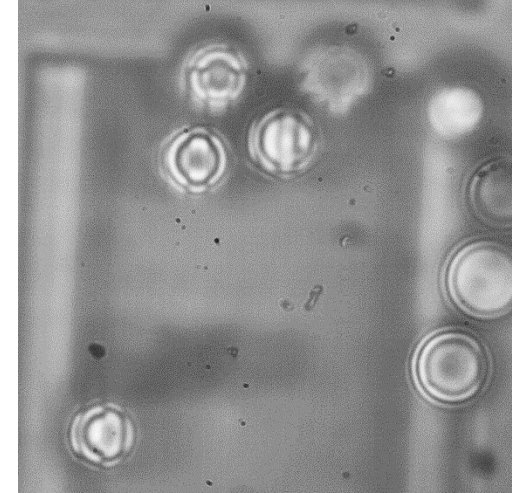
[S. Perrin et al., Applied Optics 56 (2017)]

Linnik without
fringes



Resolution standard:
Si gratings
Period = 3 μm

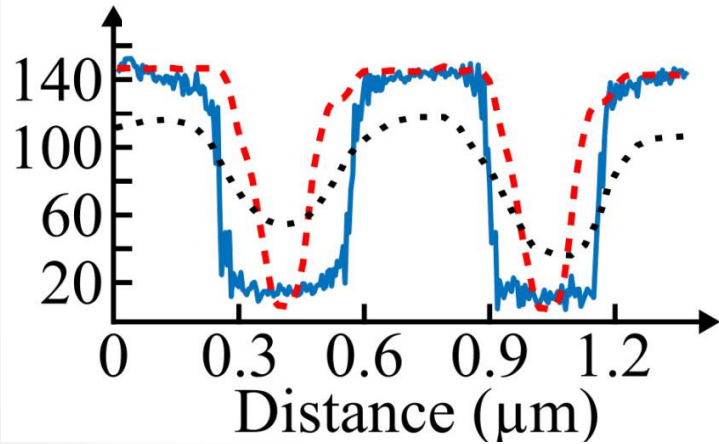
Linnik with
fringes



Linnik with sphere compensation in the ref. arm

24 μm glass sphere

Si Grating period: 600 nm

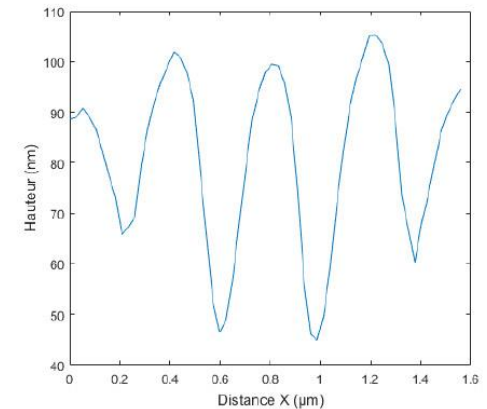
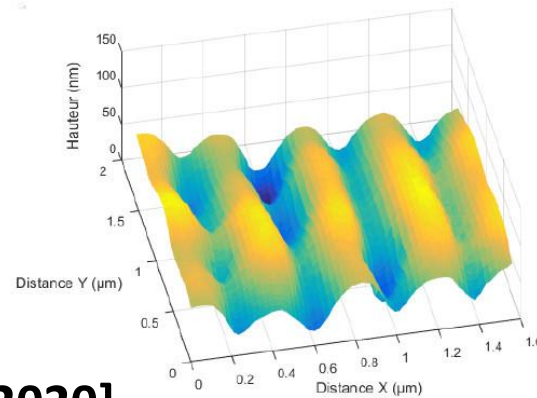


AFM

Microsphere – Non Compensated

Microsphere - Compensated

Si Grating period: 400 nm



[Perrin, Physical Review Applied, 2020]

Conclusion

- **Optical, label free, full field 2D super-resolution ($\lambda/5 \sim 100$ nm)**
 - A **meso-scale** phenomenon
- **Measuring phase for profile reconstruction**
 - In **Mirau** configuration for **sphere < 15 μm**
 - In **Linnik** configuration to **compensate sphere aberrations**

Thank you for your attention!

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