High accuracy assessment of the spatial frequency constancy of the grating scale of a displacement sensor

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OUTLINE

- Gratings made by Step & Repeat : Problems
- A very sensitive measurement technique: 1 pm on the period
- The stitching errors
- The lens system aberrations
- Conclusion

Grating manufacturing by microelectronic technologies

Interests

- Submicron period
- Long length (300 mm), large size
- High productivity
- High reproducibility
- Open, standard processes

Problems

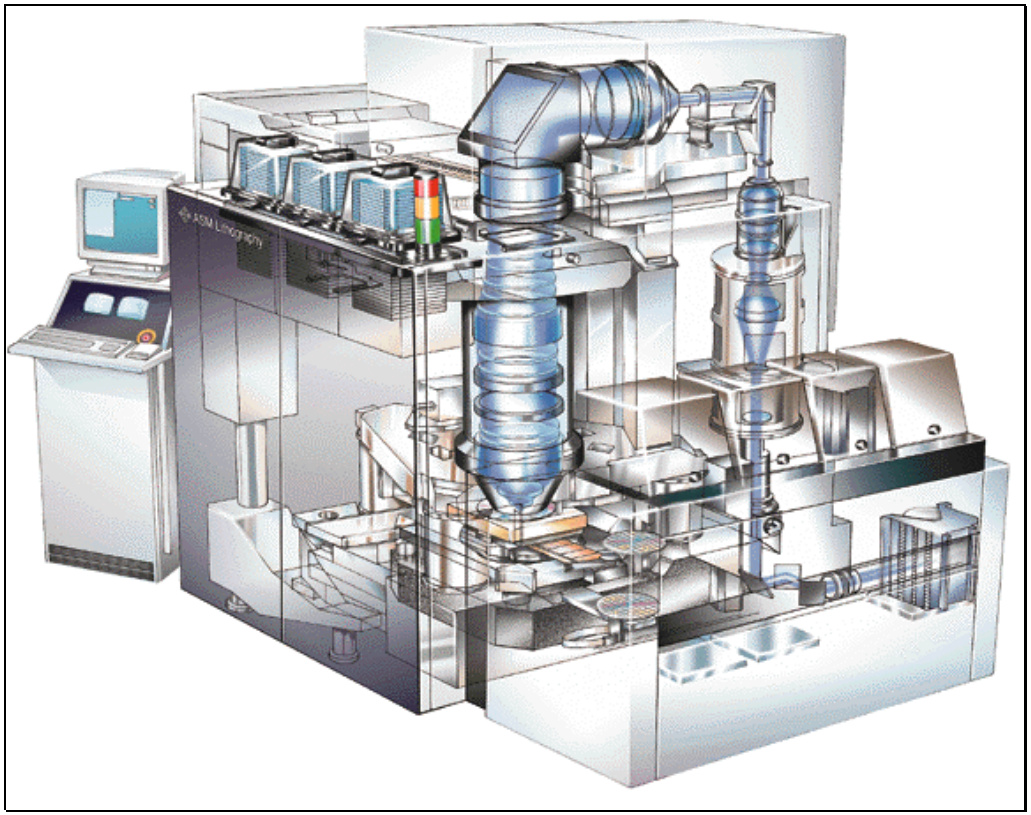
All concentrated in the Step & Repeat camera

- Stitching errors
- Field distorsion

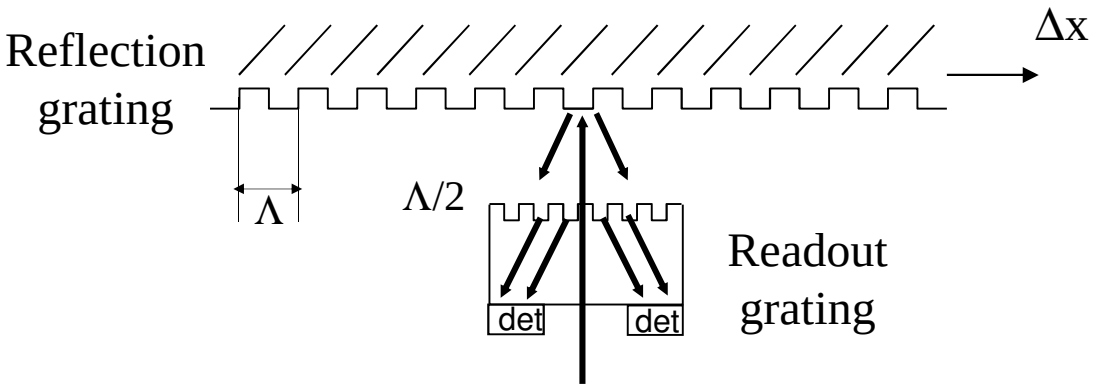
Assessment of a ASML PAS 5500

- I-Line (365 nm)
- Wafer scale 1µm period grating

ASML Stepper
PAS 5500



Very sensitive characterization of grating spatial frequency

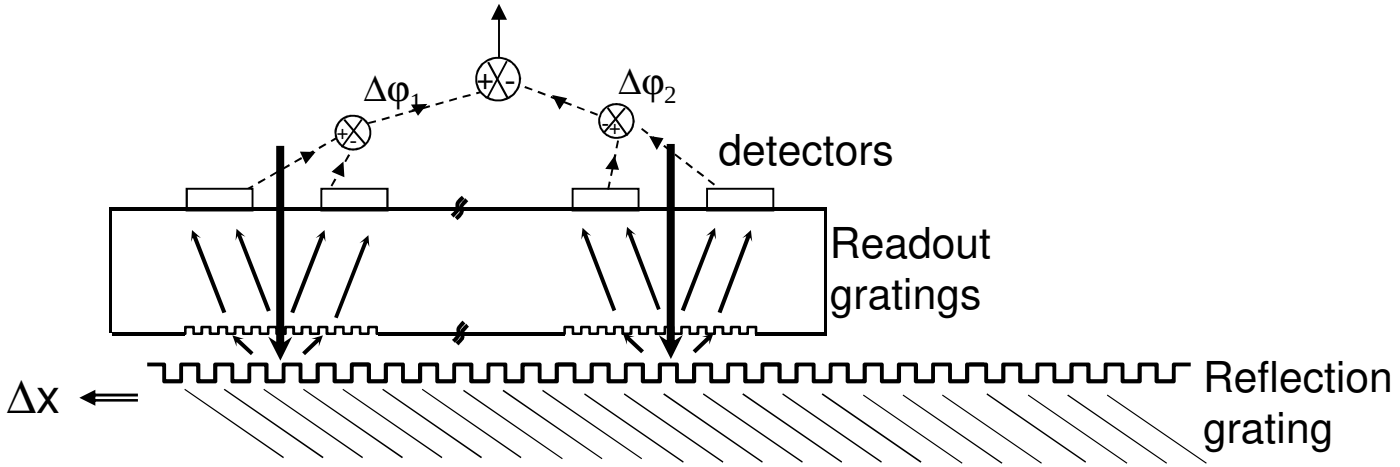


$$\Delta\varphi = 2\, K_g(x)\, \Delta x$$

$$K_g(x) = 2\pi/\Lambda(x)$$

- **Diffractive interferometric scheme**
- **Counts the number of periods over displacement ΔX**
- **Nanometric resolution**

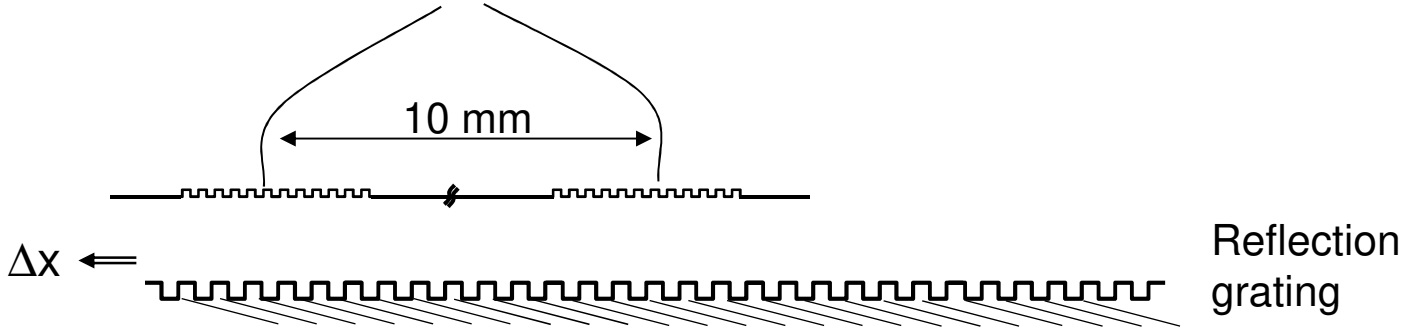
Two such sensors...



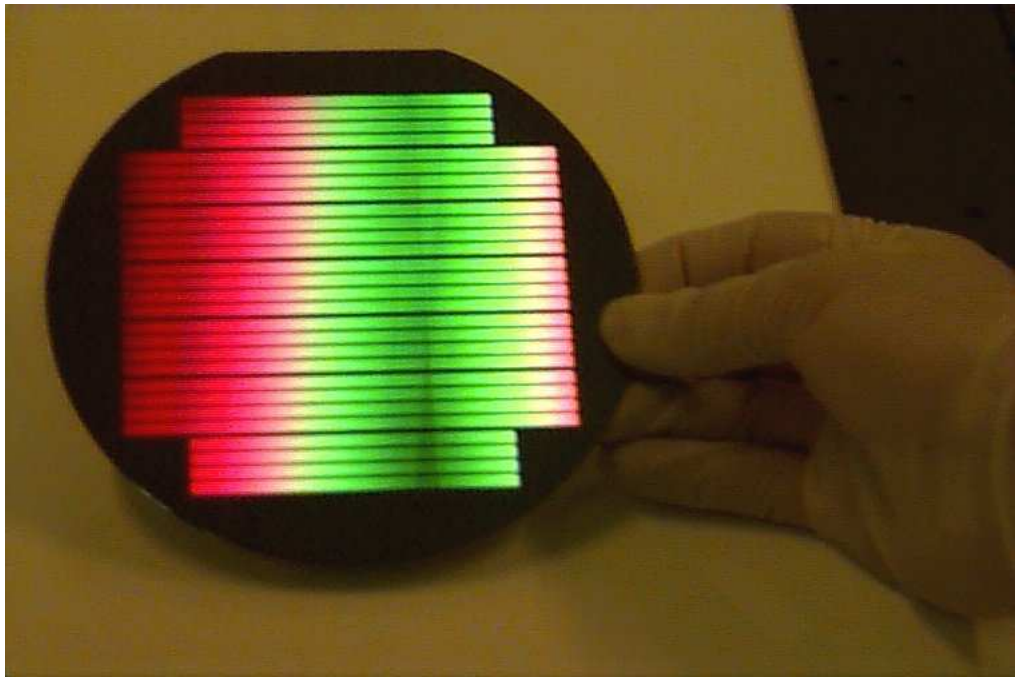
$$\frac{d}{dx}(\Delta\varphi_1 - \Delta\varphi_2) = K_g(x+L) - K_g(x)$$

…measure the variation of the grating spatial frequency

$$\Delta\varphi = 1^\circ \Rightarrow \delta\Lambda \approx 1\text{pm}$$



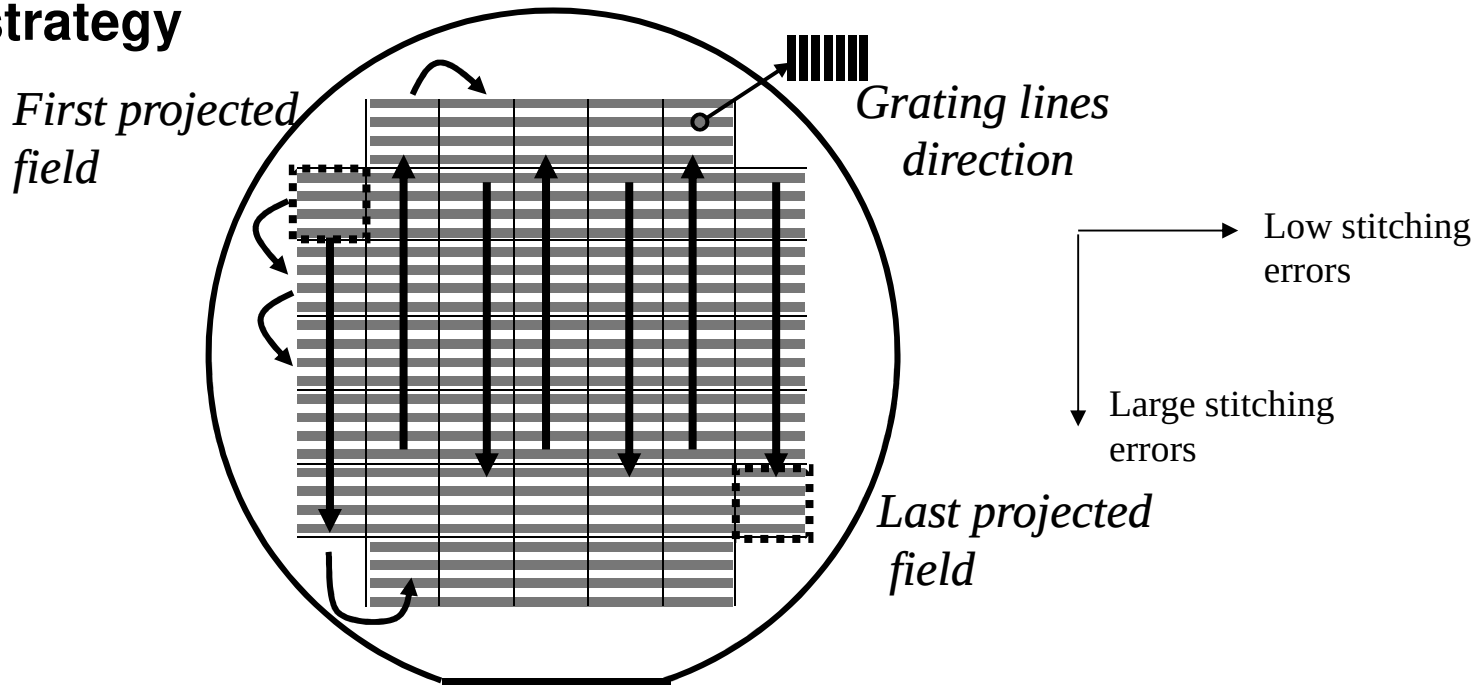
Grating wafer



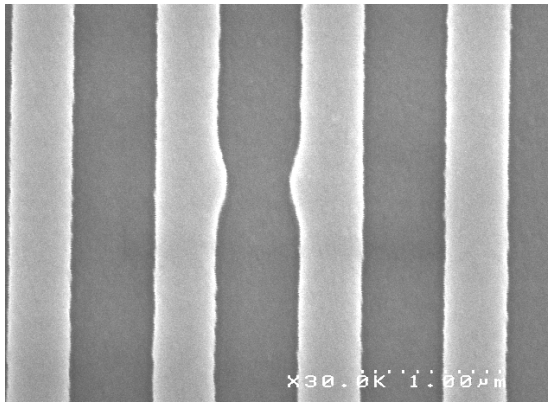
- 6 inches
- Λ = 1 µm
- Stepped, etched, metal coated
- Field size 16x16 mm

Stitching errors

- **Printing strategy**

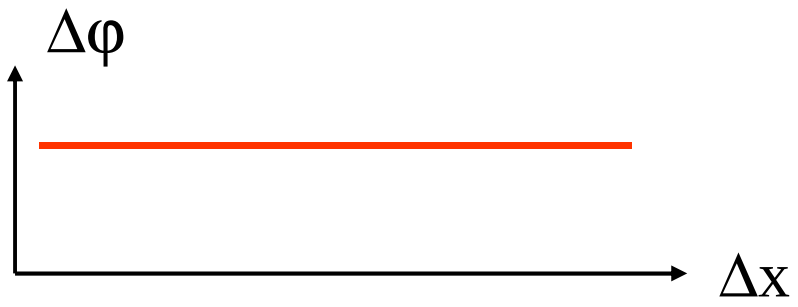


- **Matrice-tenon joint**
  < 10 nm error

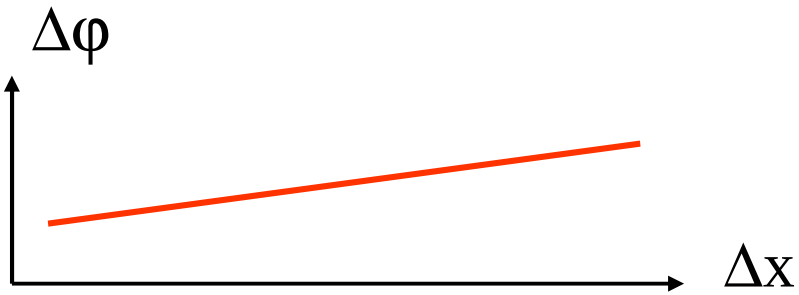


Field distortion

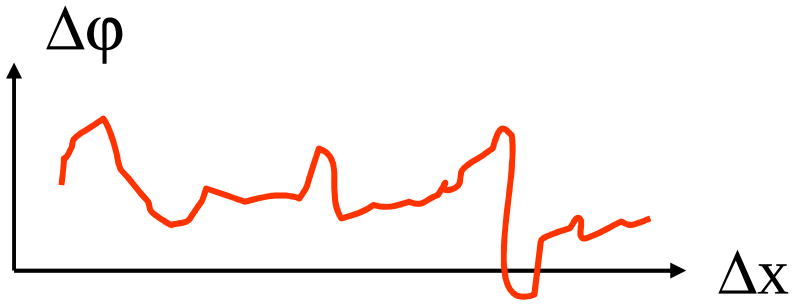
- Constant period grating



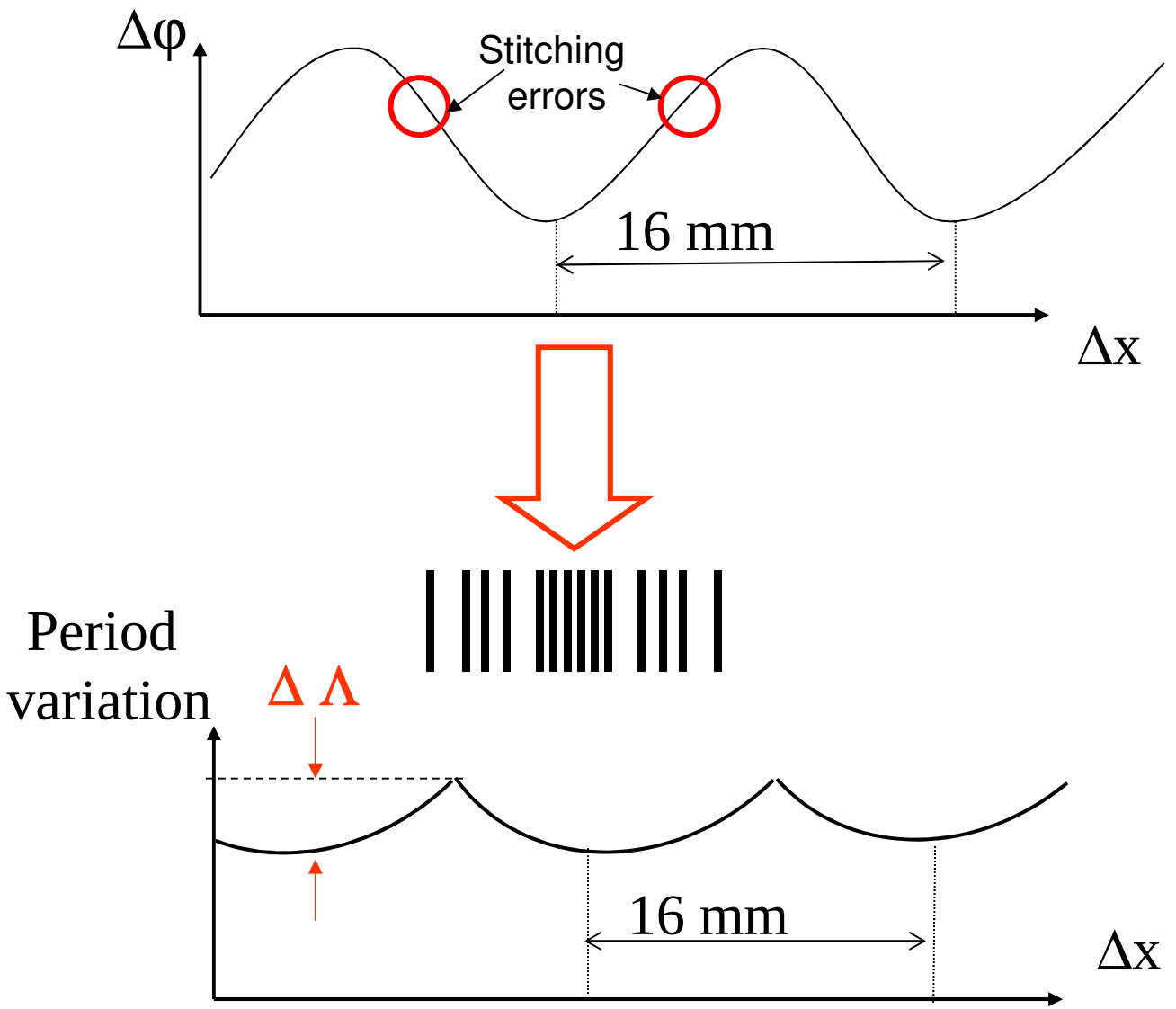
- Linearly chirped grating



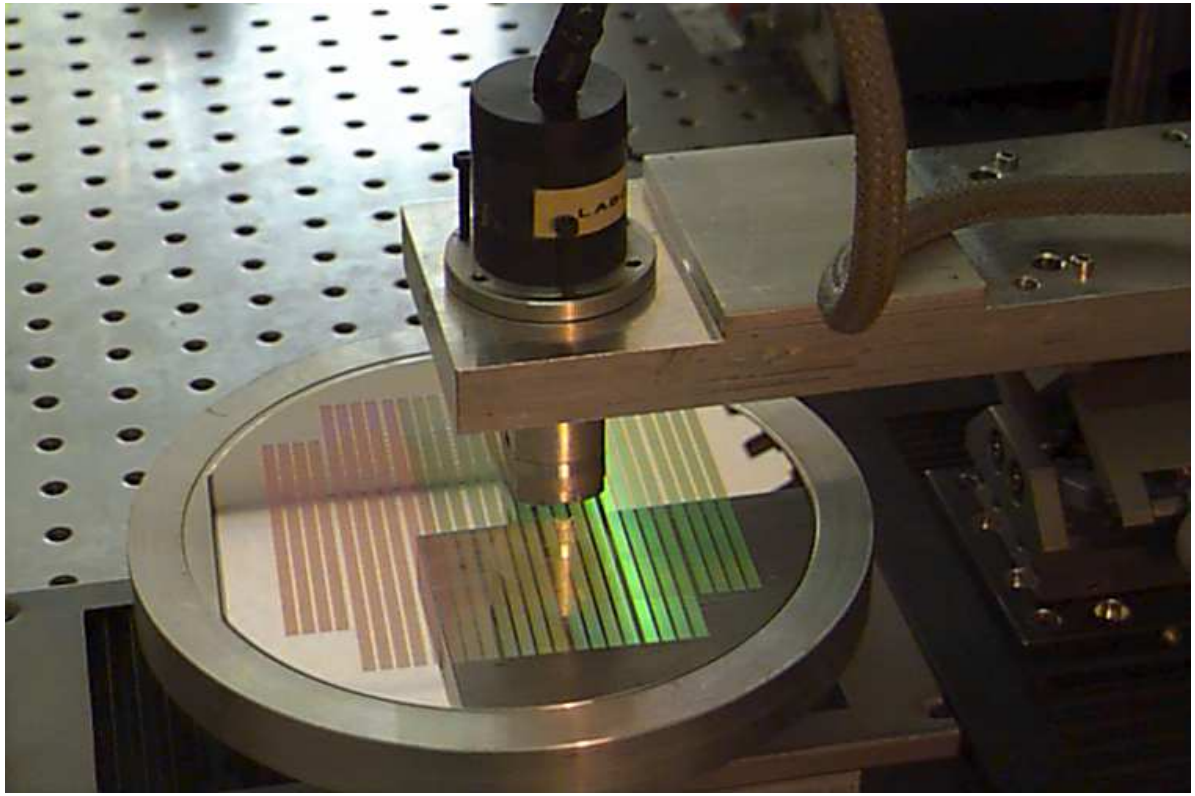
- Ruled grating



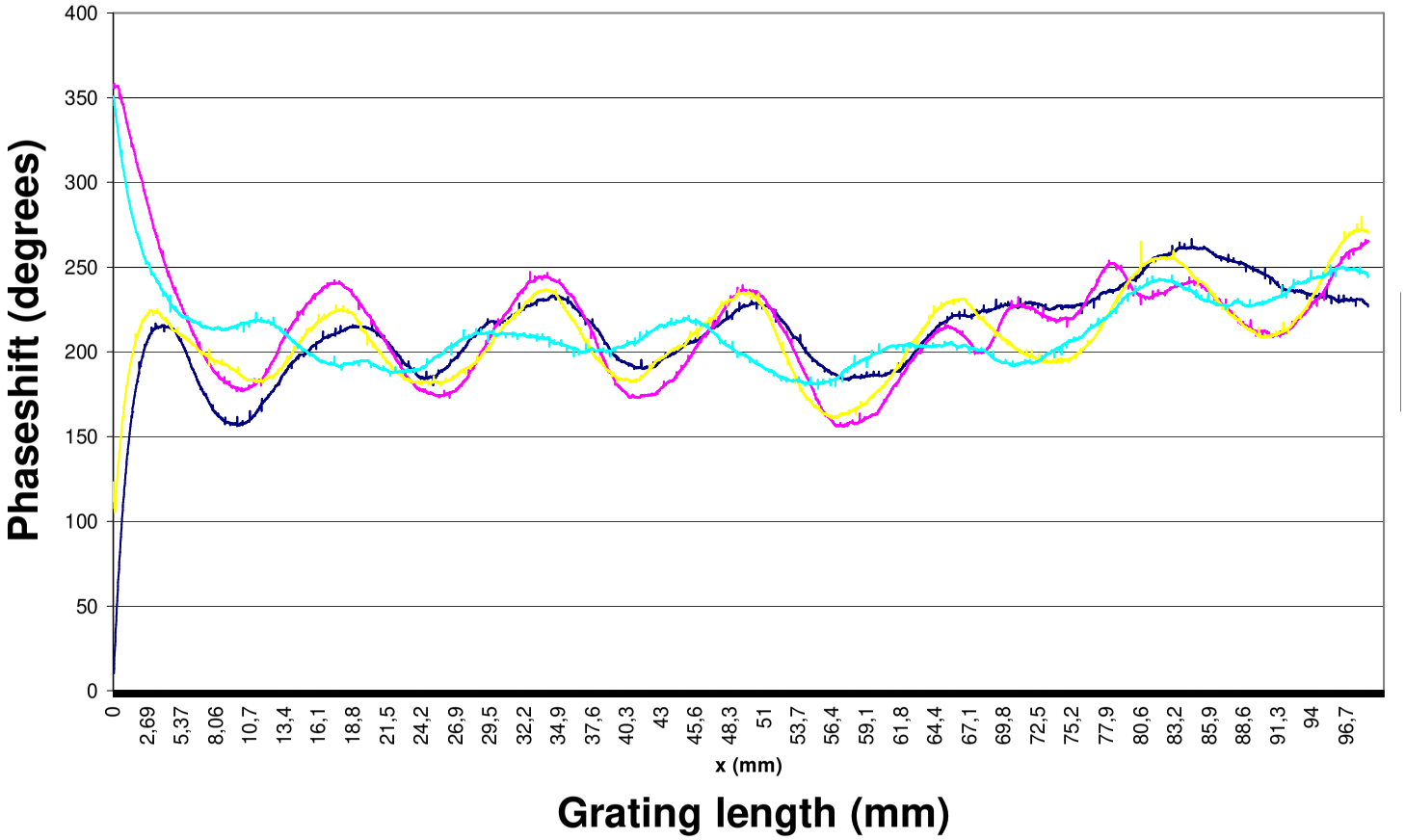
Step & Repeat grating



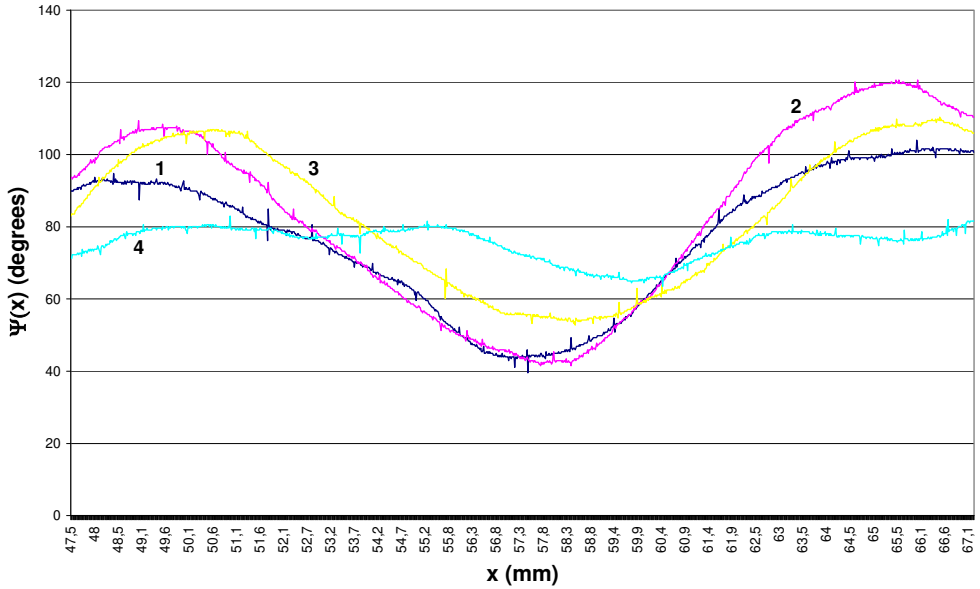
Scanning of the double read head over a 100 mm grating



Scanning of the double read head over a 100 mm grating



Plot of the phaseshift measured on the 4 grating tracks of the same field

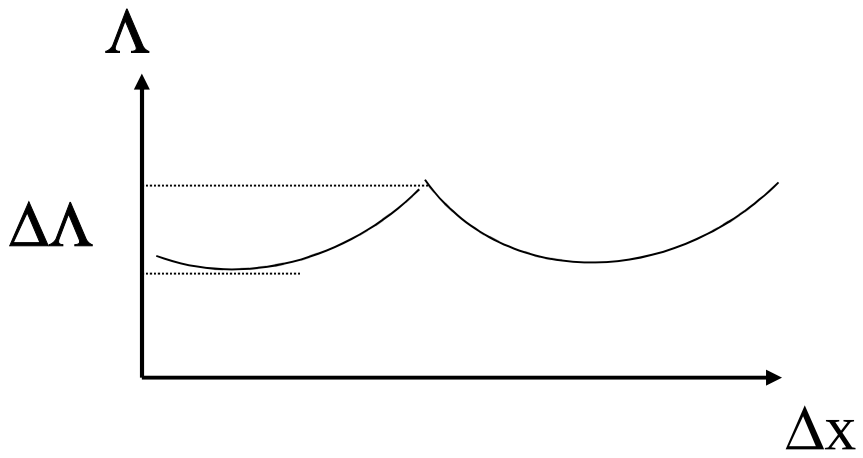


Best fit parameter $\Delta\Lambda$ for each grating track

Grating tracks	$\Delta\Lambda$ (nm)
1	0.012
2	0.021
3	0.018
4	0.007

How good, How bad ?

- **Stitching errors < 10 nm**
- $\Delta\Lambda$



$\Delta\Lambda_{\text{PAS 5500}}$ **< 20 pm !**

Conclusion

- **Grating scale of displacement sensors**
  Error: maximum of 500 nm per 16 mm
  Can be corrected by choice of nominal Λ_0
  100 ppb accuracy possible

- **Spectroscopy grating**
  «Lambda by 5» grating in the visible
  «Lambda by 15» grating at 1550 nm

- **Not bad !**

- **Predistortion ?**
  => Perfect gratings !