Fast Tunable Blazed MEMS Gratings and the Use of X-Ray Diffraction for Early Failure Detection

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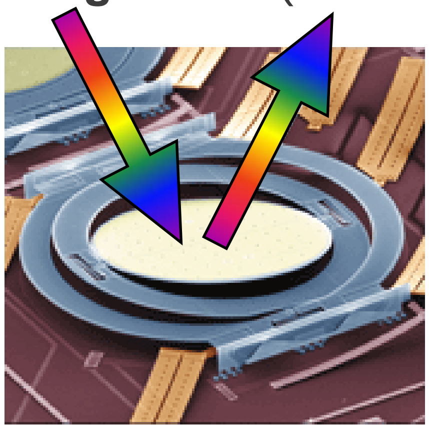
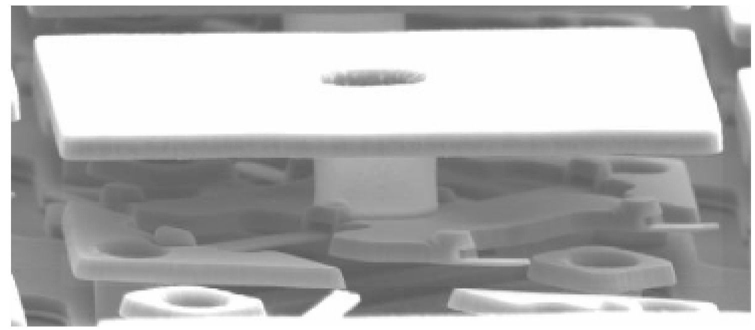
6th ESA Round Table, 8-12 October 2007

Optical MEMS to deflect light

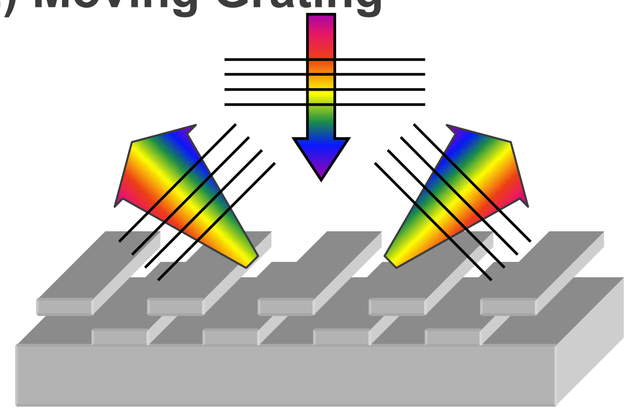
(1) Moving Mirror (Lucent Techology)



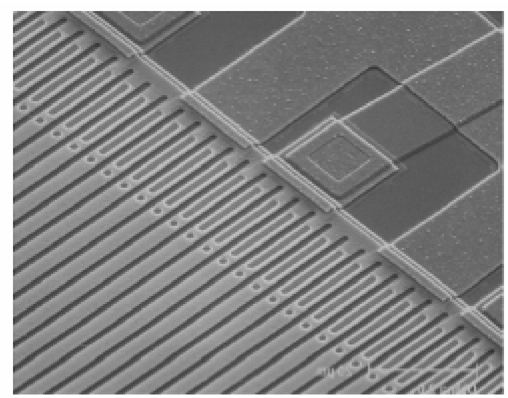
DLP™ (Texas Instruments)



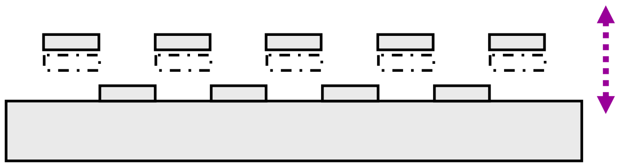
(2) Moving Grating



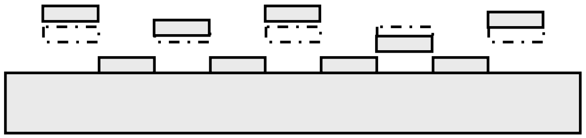
GLV™ (Silicon Light Machines)



Two families of PDMG's: 1^{st} Family – Piano Gratings



or



Technique: Spatial light modulator

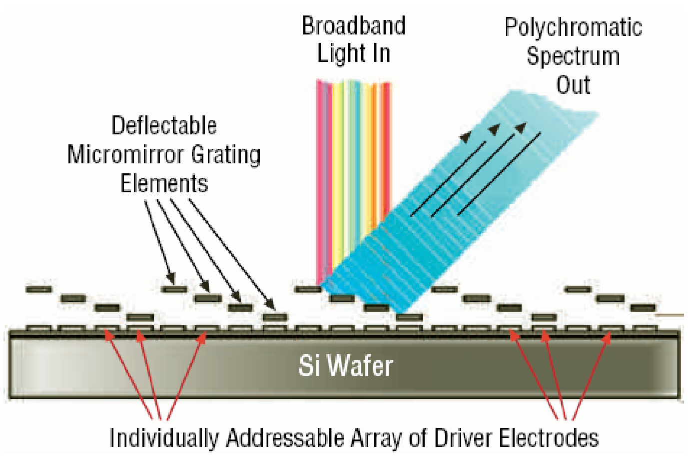
Technique: sampled grating

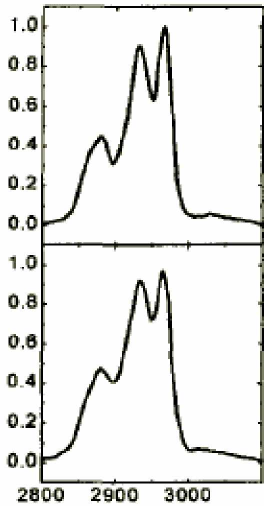
Piano Gratings can be used as

(A) switchable pixels

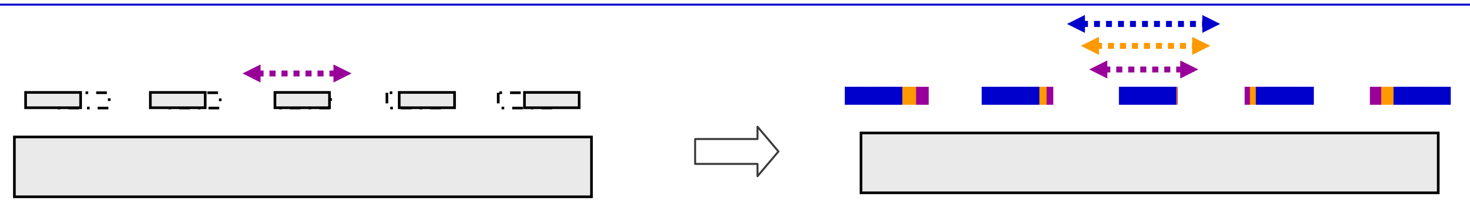
(B) to make synthetic spectra

Spectroscopy (PolyChromix)





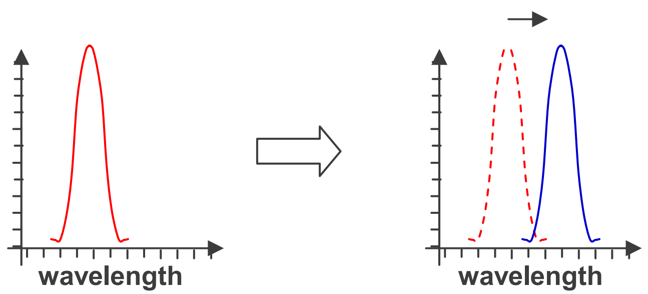
2nd family of PDMG's – Accordion Gratings



Accordion Gratings

Technique: grating stretching

Advantage: continuous tuning possible

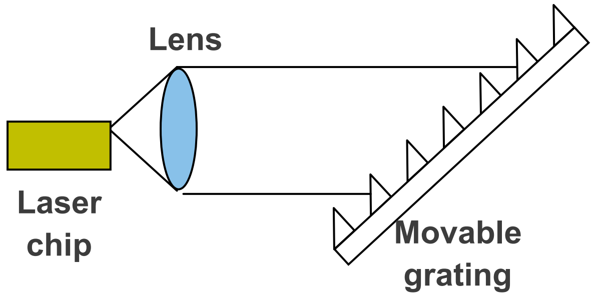


Applications:

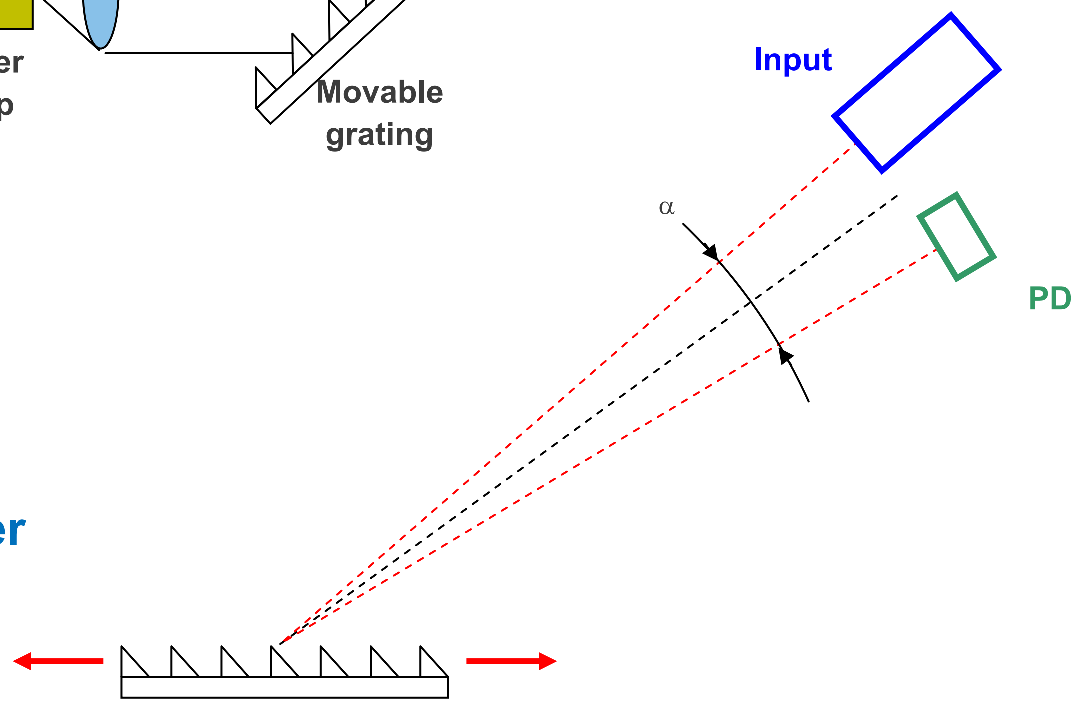
- Tunable filters
- External Cavity Lasers
- Spectrometers

Basic applications concepts

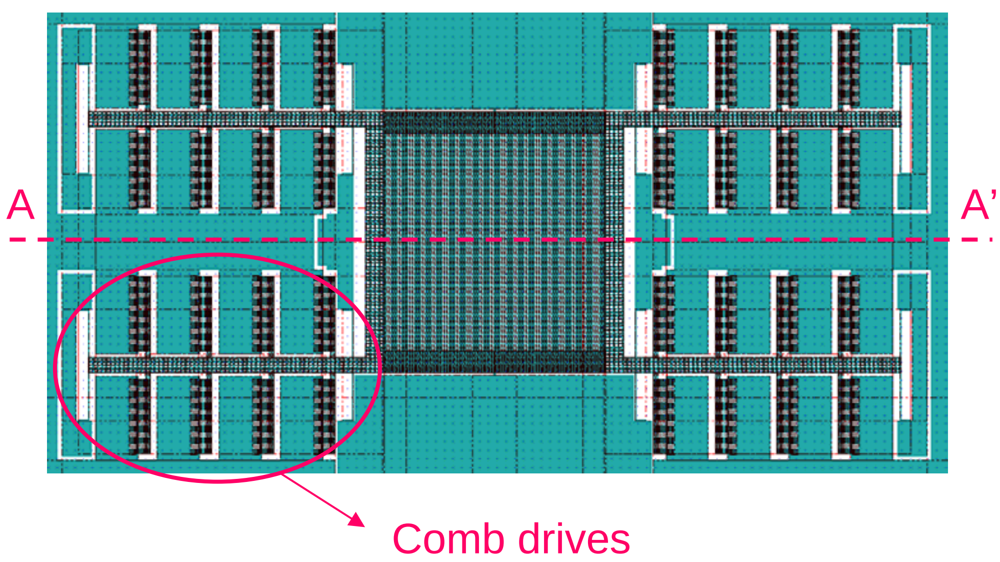
Tunable laser

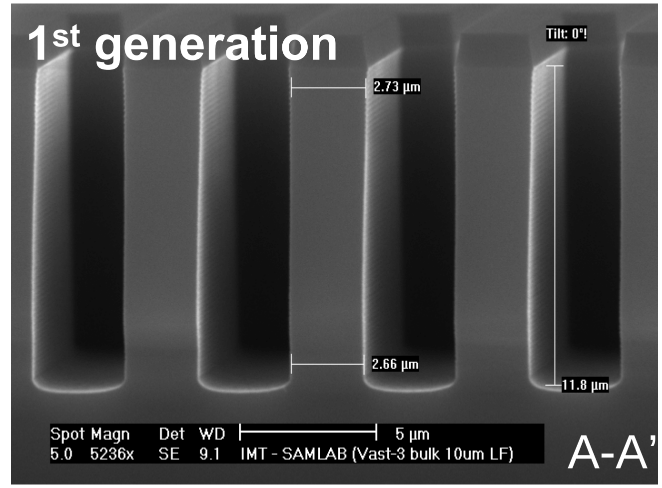


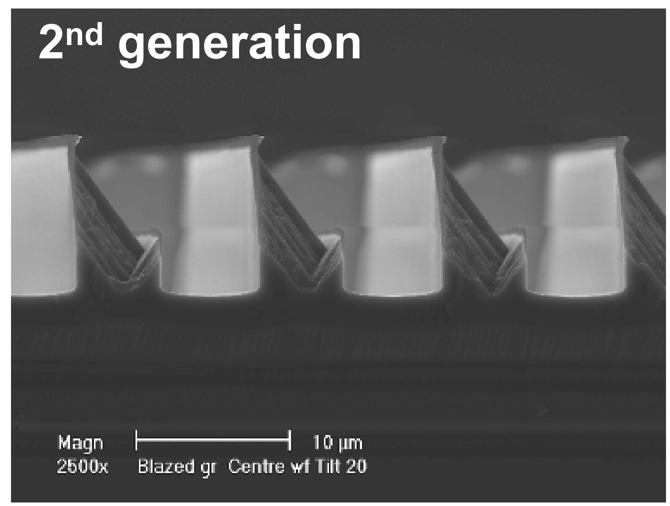
Grating Spectrometer



Blazed movable gratings



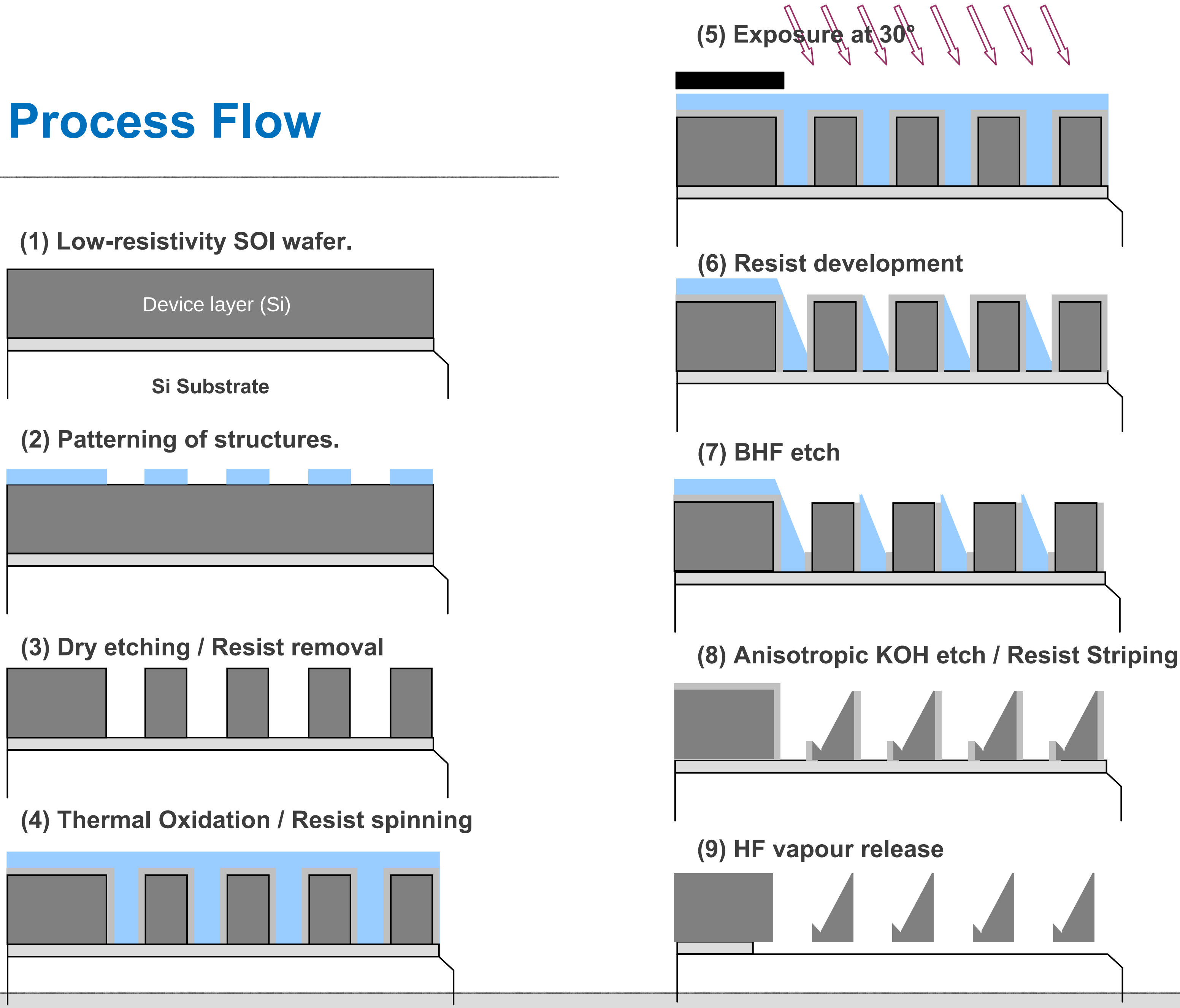




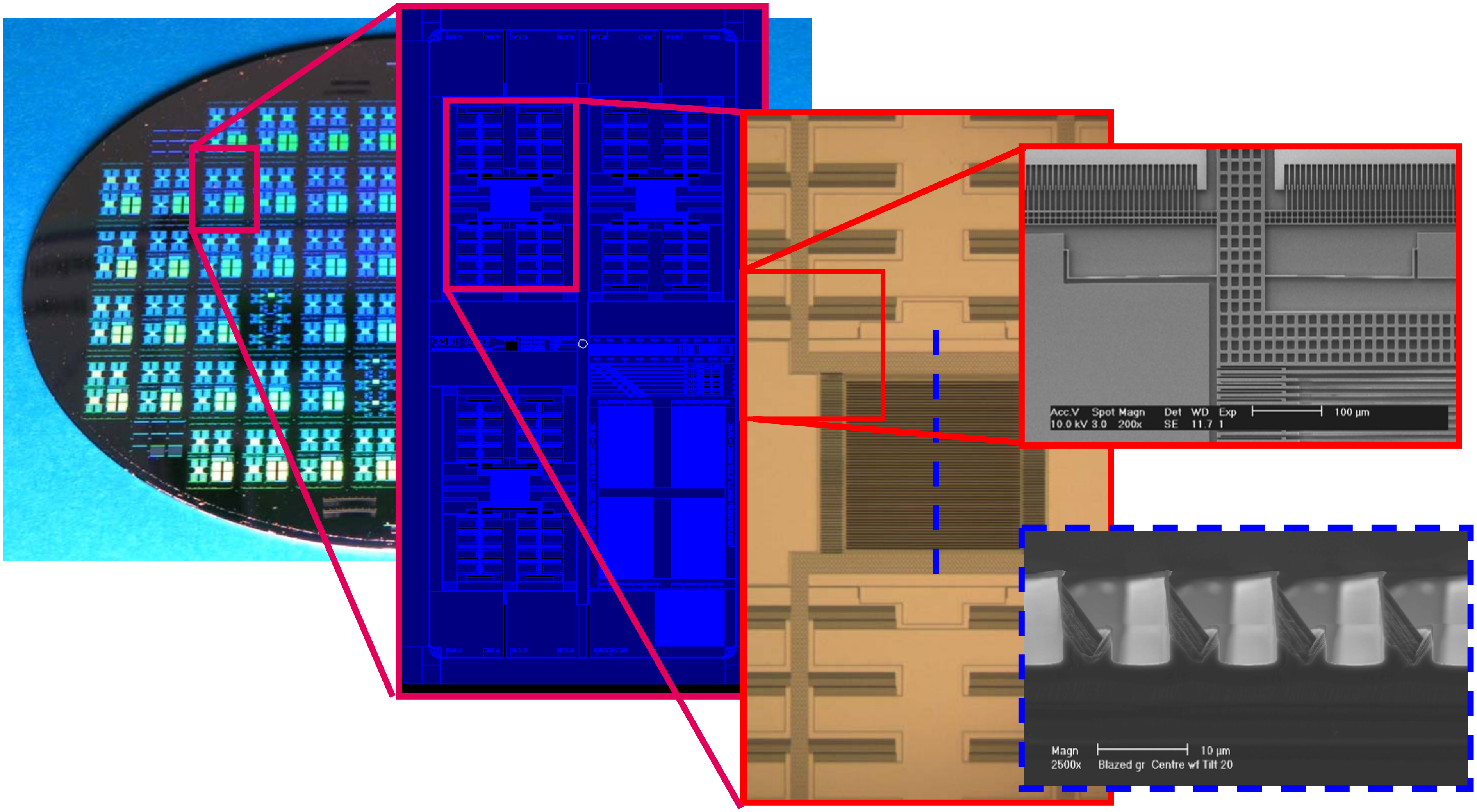
Grating properties

- 1mm x 1mm
- Period 12 µm
- *Blazed* (54.74°,Littrow condition)
- Maximum tuning: 6%
- For λ = 700 nm ⇔ 28th diffraction order!

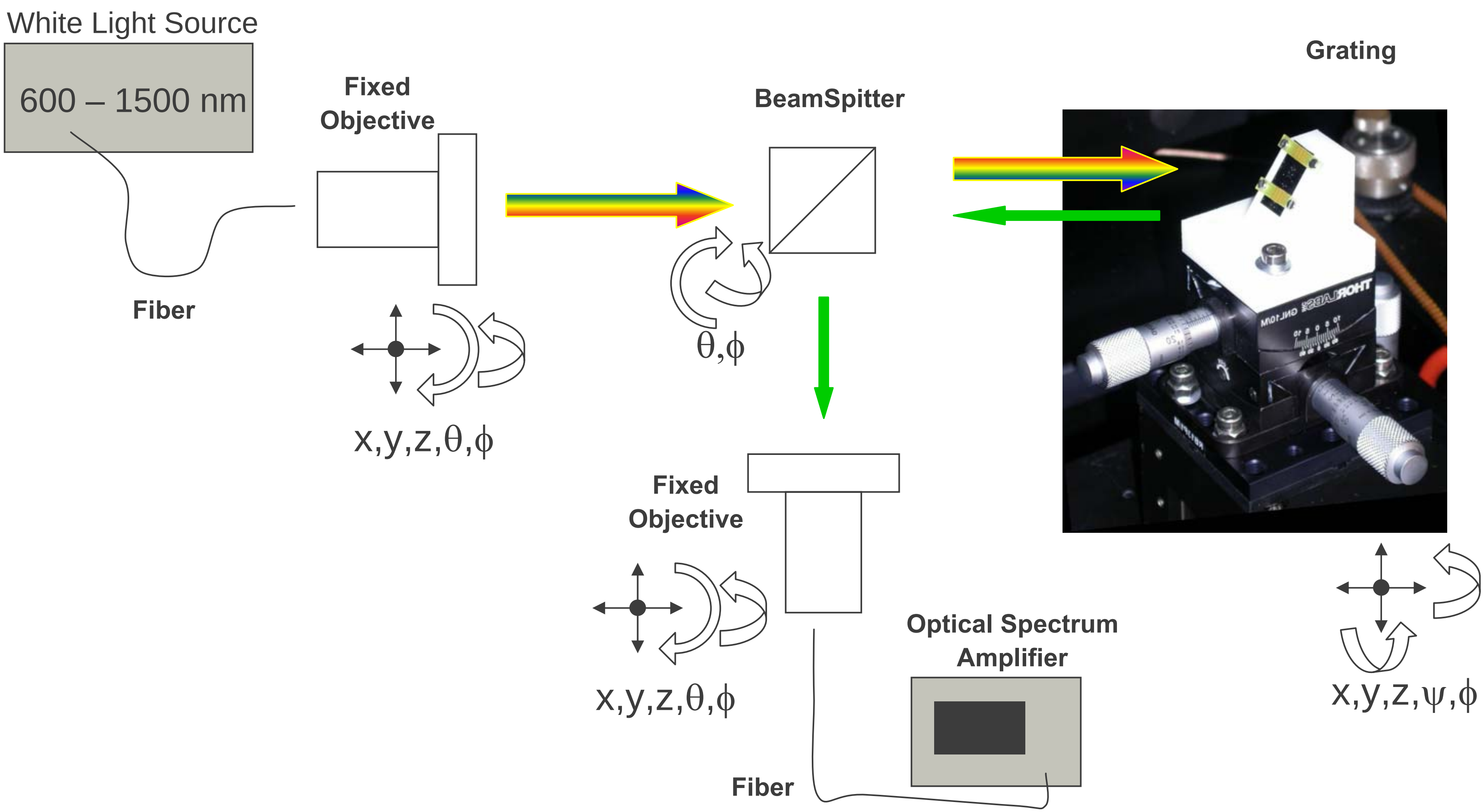
Process Flow



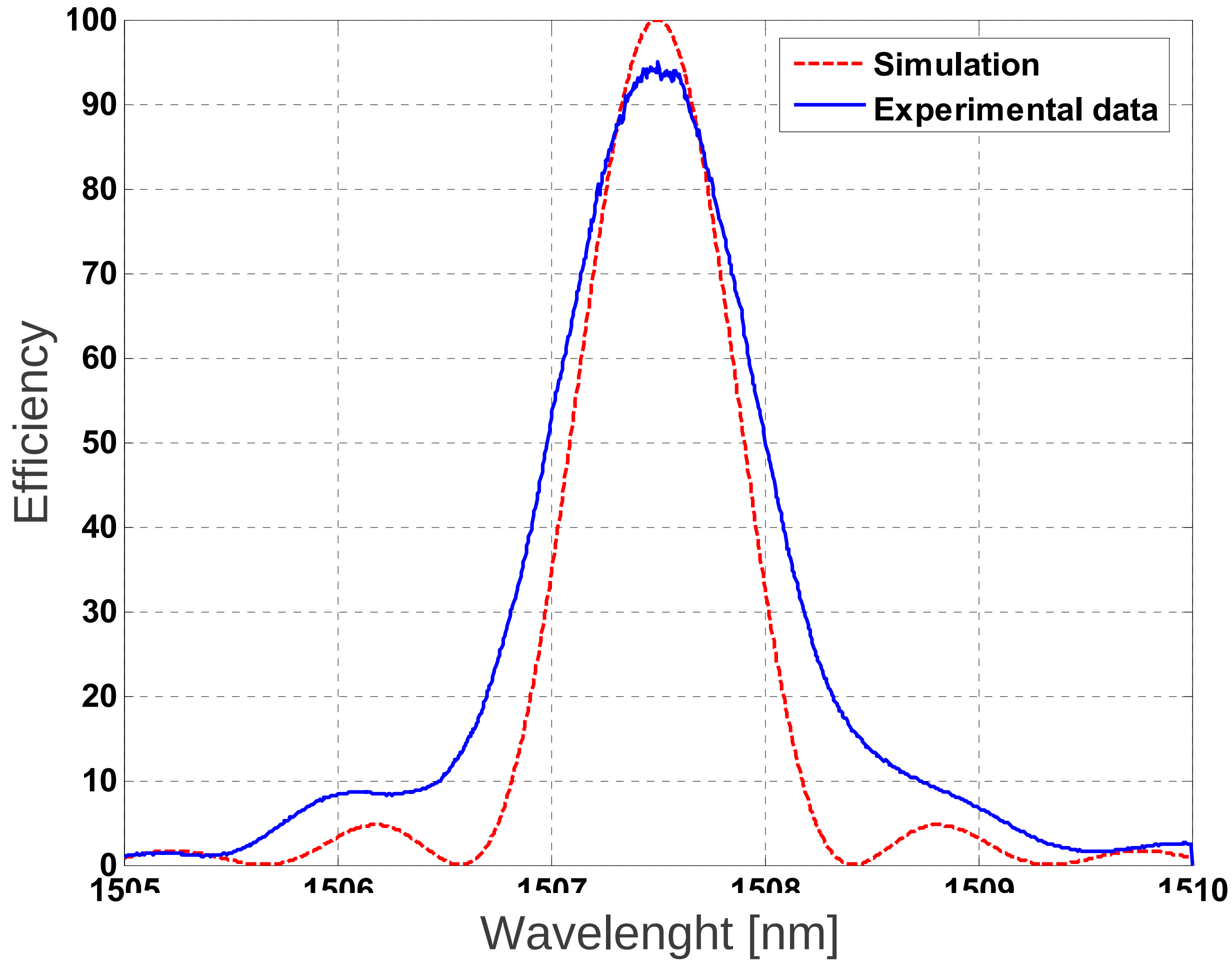
Blazed movable gratings



Optical Characterization setup

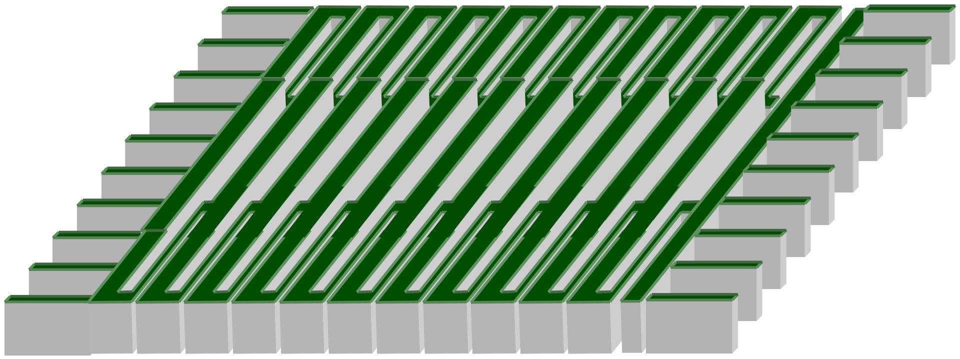


Optical performances

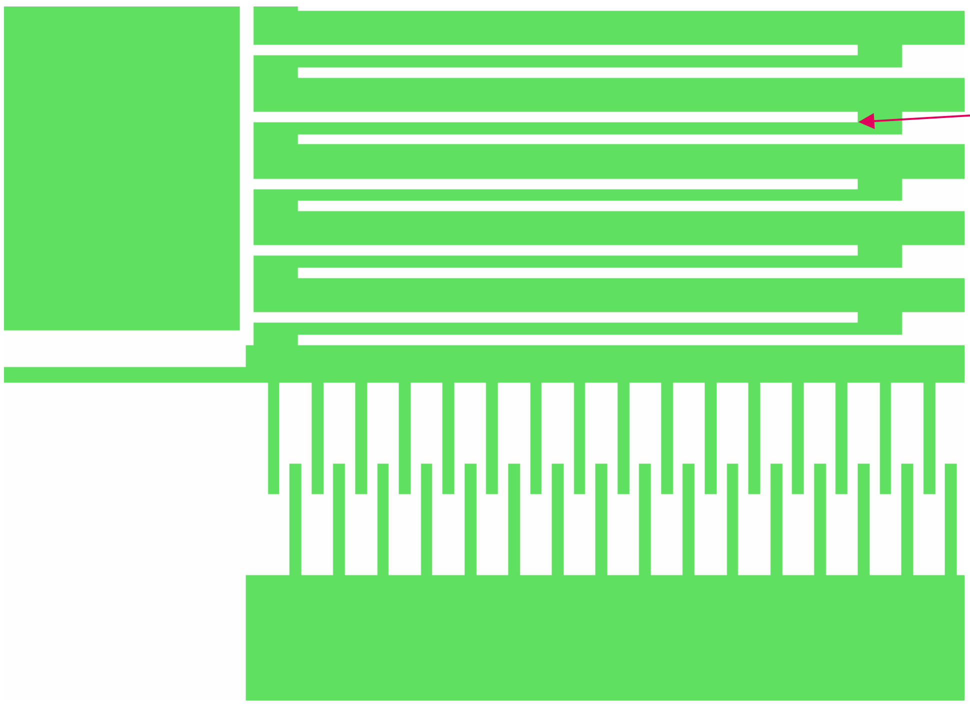


Design Challenges

1. Free standing grating
   - rigid enough to be held
   - but flexible enough to be actuated
2. Springs need to be identical
3. Diffracting beams - distortion free
   - in-plane bending
   - out-of-plane buckling
   - rotation
4. High quality optical surfaces



Spring & comb actuator design



- **Accordion springs**
  - leaf hinges
  - only flexible element
  - prevents beam rotation
  - prevents beam buckling
- **Maximum ideal displacement:**
  - 6 µm at each comb

Early Failure Detection

Lifetime of MEMS devices is correlated to aging, where aging is related to defects in the crystal lattice.

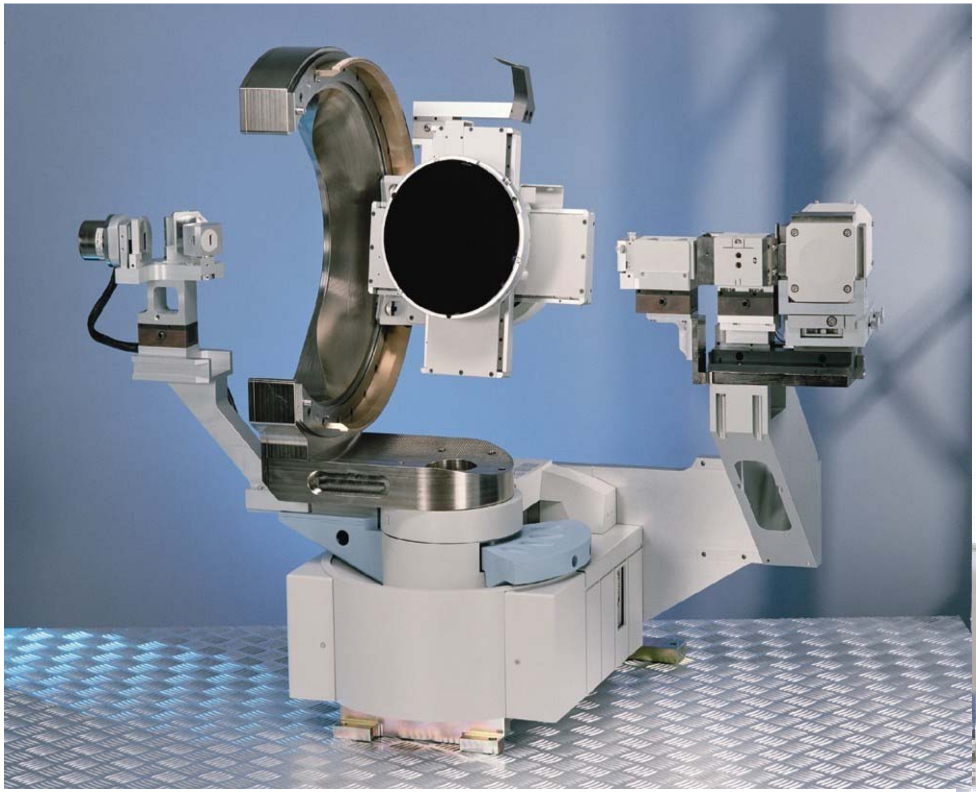
Defects induce stress

Stress can be determined from strain measurements (Hooke's law)

HRXRD Techniques:

1) **Measurement of peak shape (rocking curve)**
2) **Reciprocal Space Mapping (RSM)**
3) **TDA (Triple crystal diffractometry)**

Study of Crystalline Imperfection in Si Microstructures and its correlation to mechanical properties and Aging



High Resolution X-Ray Techniques

HRXRD Techniques:

Strain measurement

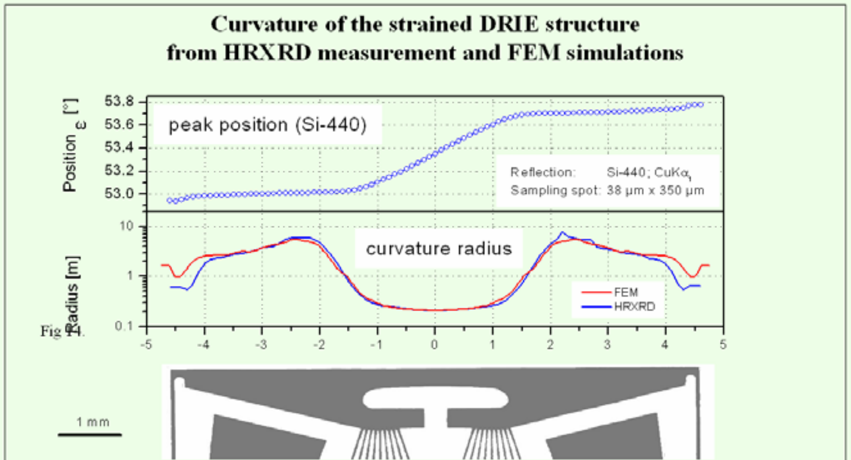


Fig 14. Comparison of the curvature (measured by X-ray diffraction and modelled by FEM)

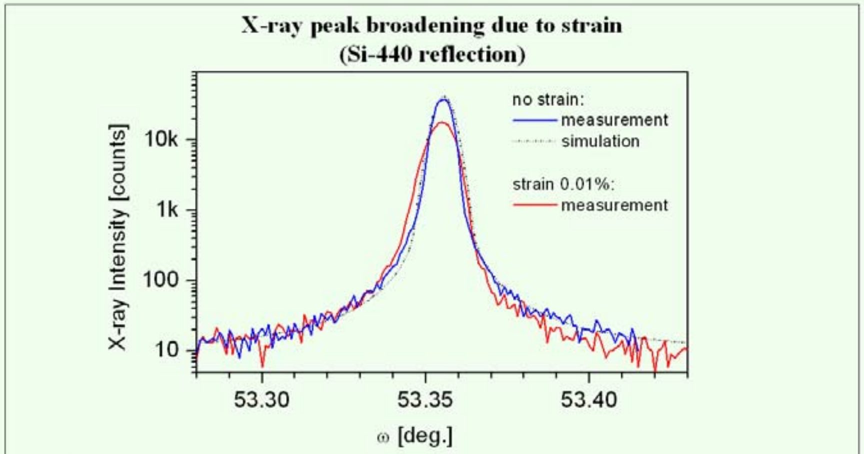
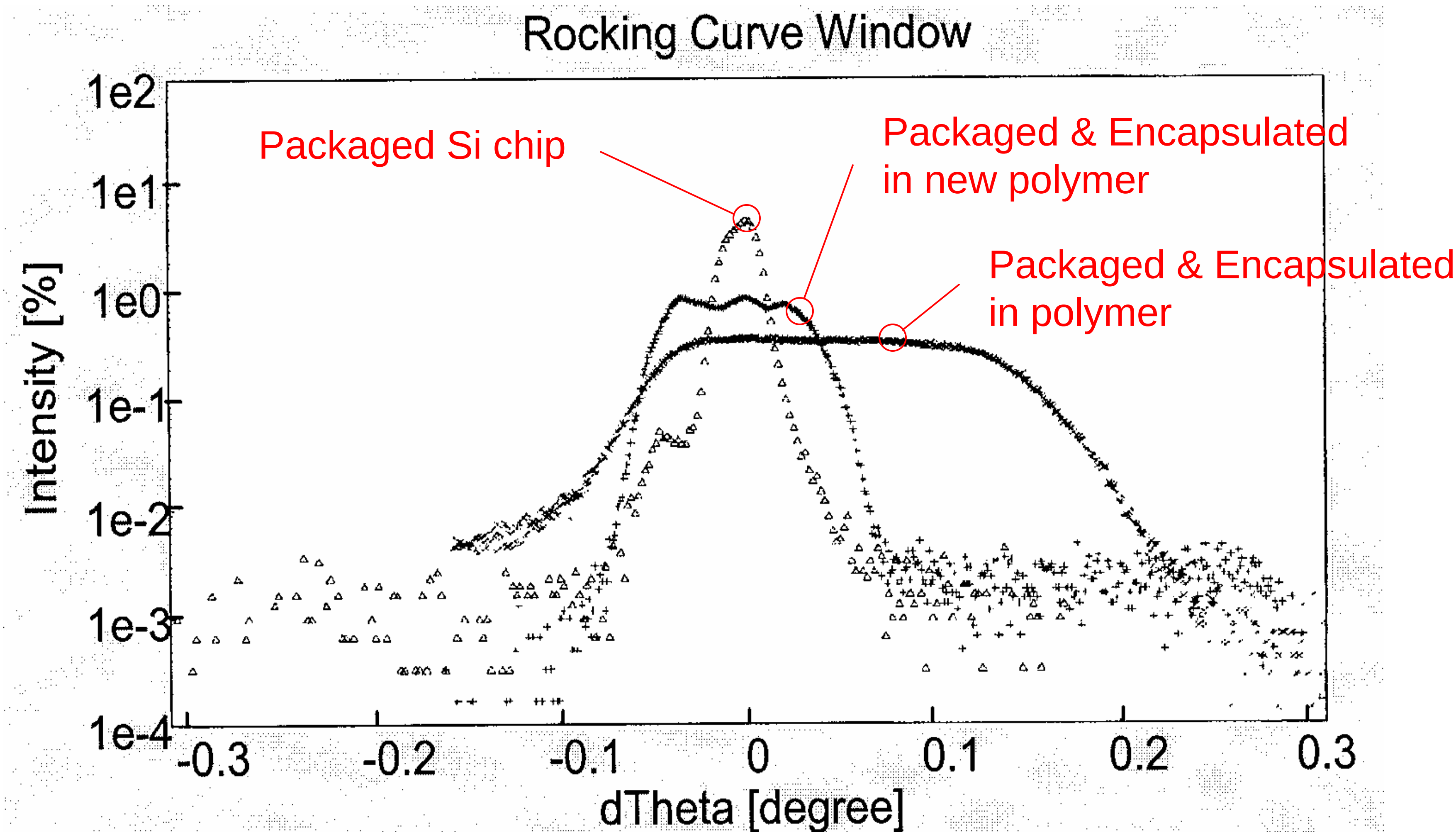


Fig 13. Symmetric X-ray rocking curves of the (440) peak of (110) Si surface. The measurements were done on the DRIE structure after introducing a normal strain of 0.01% (red curve).

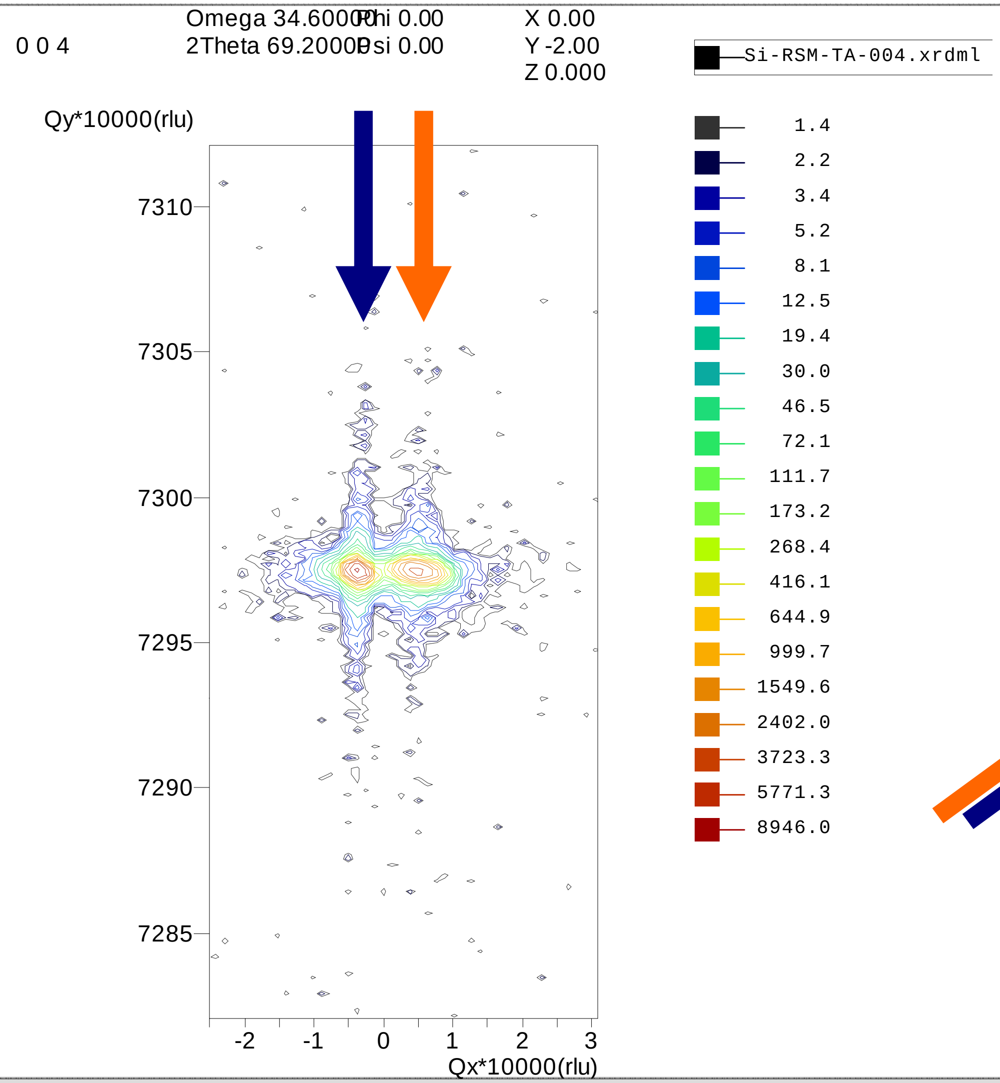
- Traveling peak technique (curvature)

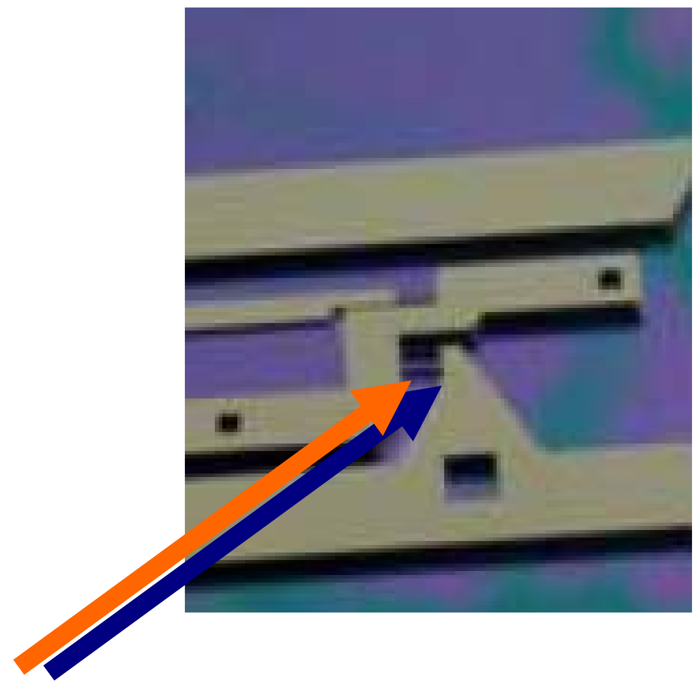
– Rocking curve (peak shape and width)
– Peak broadening due to a multitude of different lattice constants

Example: Encapsulation problem



Si STRUCTURE
RSM on 004 (small and large parts exposed)

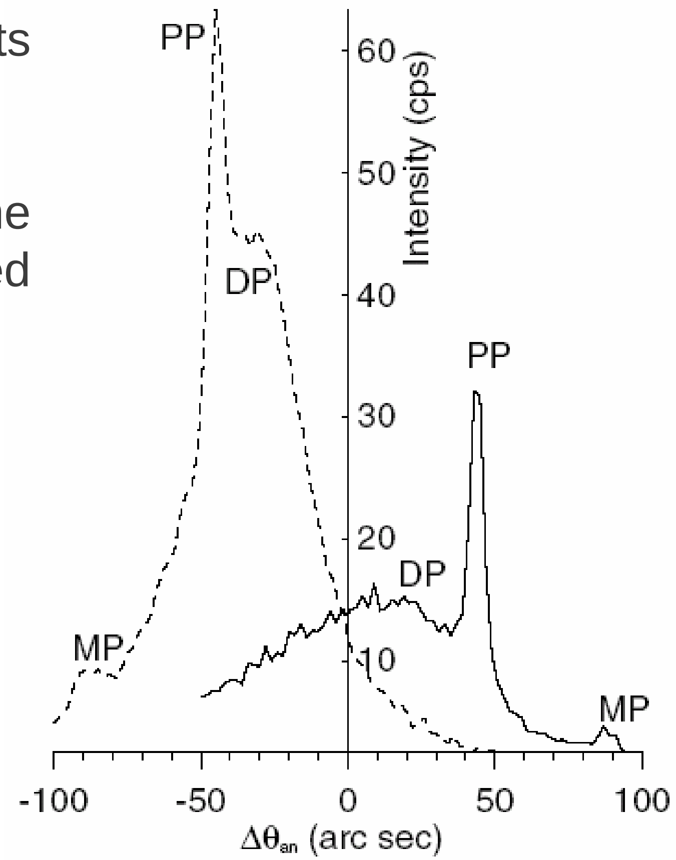




3) TCD (Tripple crystal diffractometry)

Study of diffused scattering due to the defects of the crystal lattice

Separation of the elastic component of the scattered intensity (Bragg) from the diffused one.



TCD spectra for θ = +45 arc s (full curve) and θ = −45 arc s (broken curve).

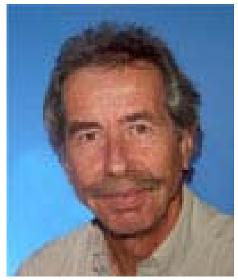
MP, main peak
PP, pseudo peak
DP, diffuse peak.

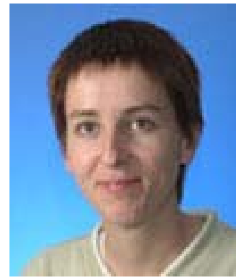
Conclusion

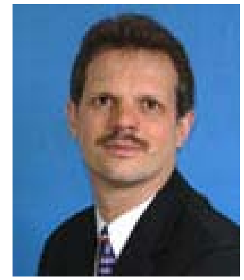
- Deformable MEMS accordion grating with electrostatic actuation
- High blaze angle → high order → high resolution with a “small” number of grooves
- Wide tuning range
- Applicable to VIS, near IR and mid IR
- Soft HRXRD to determin strain → stress → defects → aging → failure

Thanks to…

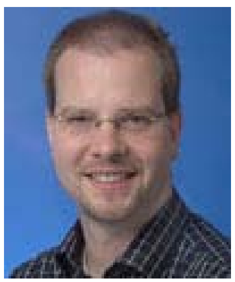

P. Niedermann

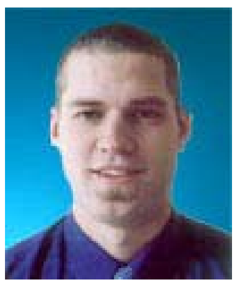

J.-P. Morel


A.-C. Pliska

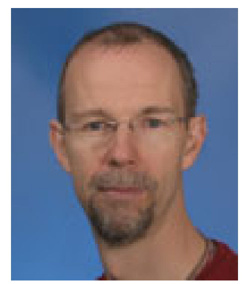

A. Hoogerwerf

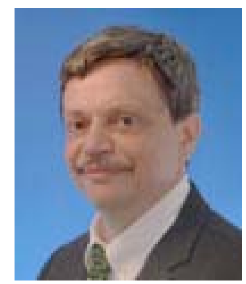

M. Tormen


T. Overstolz


R. Lockhart


C. Ketterer


R. Stanley


A. Dommann

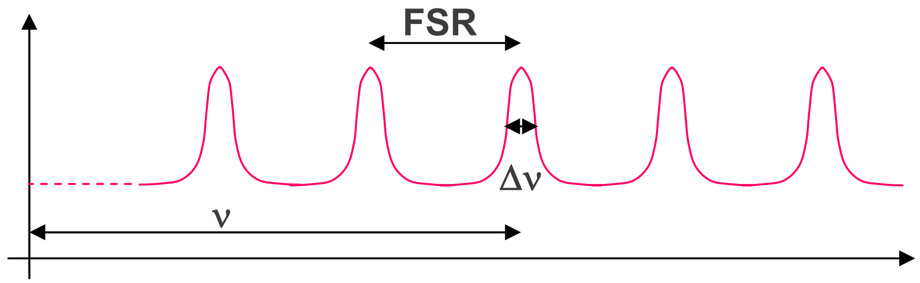
Fabrication was carried out at COMLAB, the joined facility between CSEM and IMT

Thank you for your attention.

$$Resolving\ \ Power \equiv Q \equiv \frac{\nu}{\Delta\nu}$$

$$Finesse \equiv \frac{FSR}{\Delta\nu}$$

where FSR is the Free Spectral Range



For a grating:

$$Resolving\ \ Power = m \cdot N$$

$$Finesse = N$$

where m is the diffraction order, N the number of grating teeth.

In order to have high Finesse and high Q → high m and high N are required

Color scheme

CSEM-Blue RGB 0-112-188	**Light Blue** RGB 136-193-233	**Dark Grey** RGB 90-87-70
	Red RGB 225-0-90	**Light Grey** RGB 196-196-186
	Olive Green RGB 193-191-0	