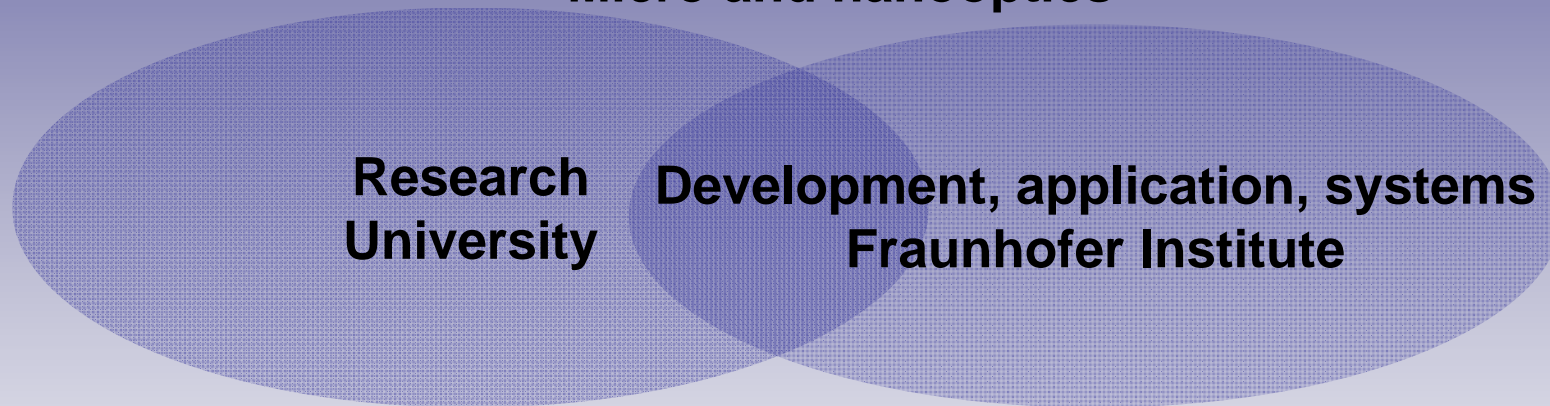


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Friedrich-Schiller University- Jena, Jena, Germany,
and Fraunhofer-Institute, Jena, Germany

Micro and nanooptics



DOE

Gratings (**dispersive**, coupler/combiner, mirrors)

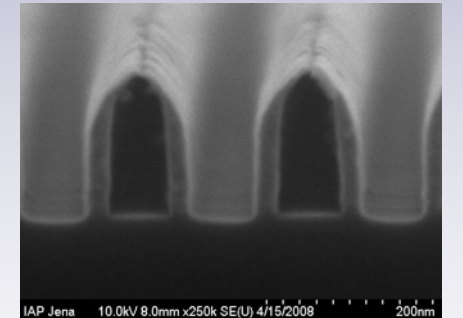
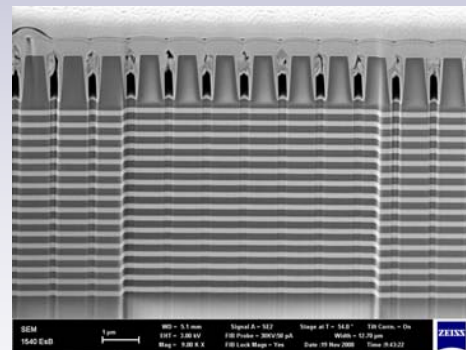
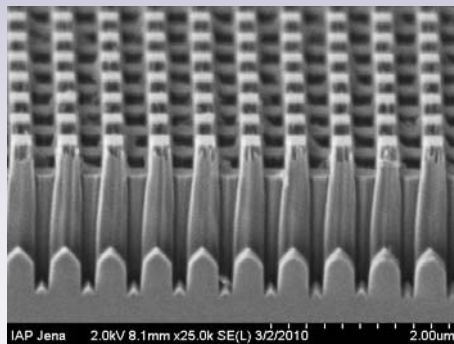
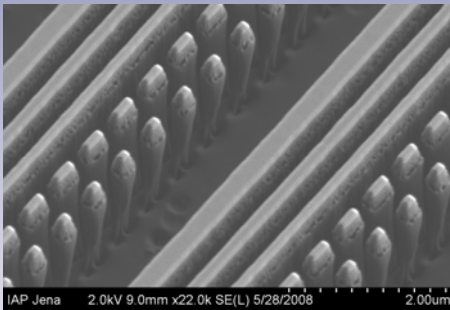
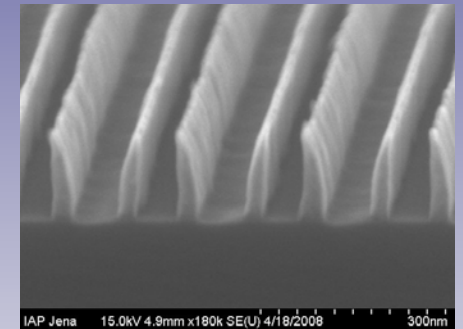
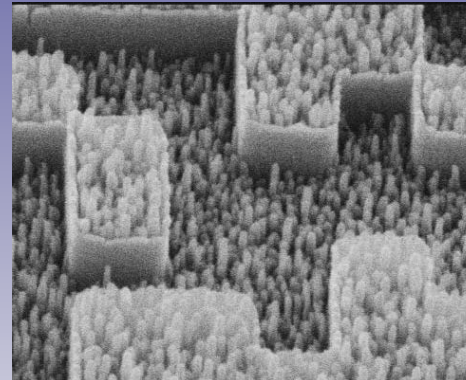
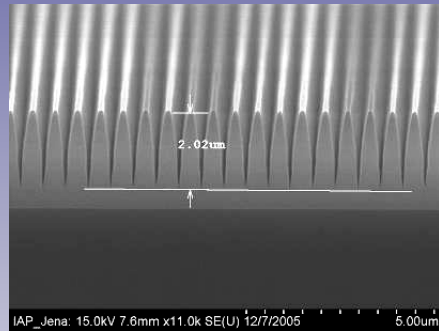
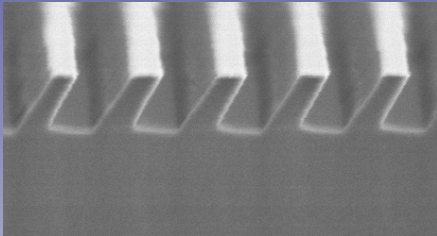
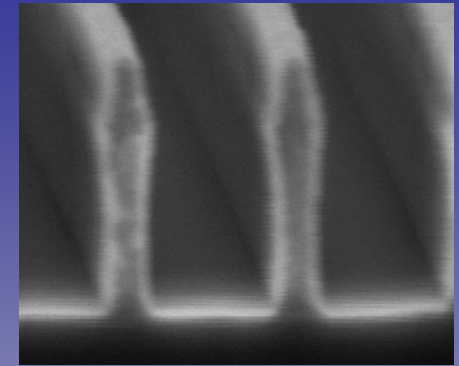
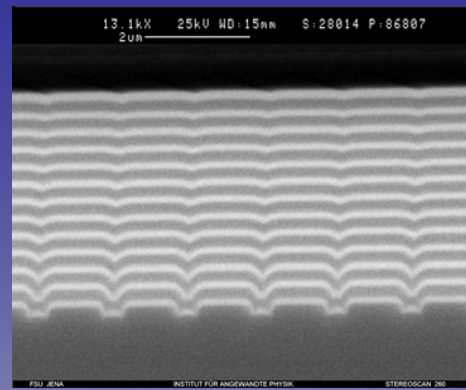
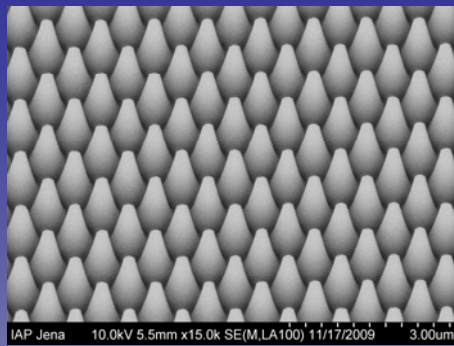
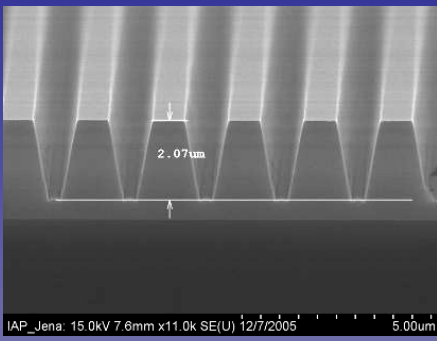
Wave guide optics

Effective media

Polarization, birefringence

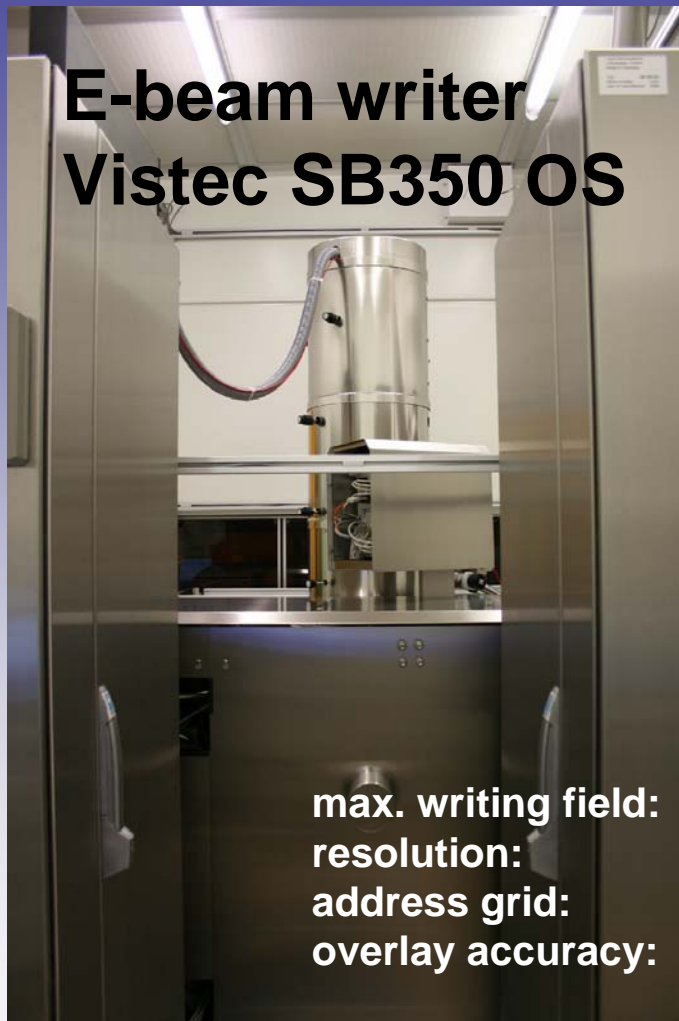
Plasmonics

Metamaterials

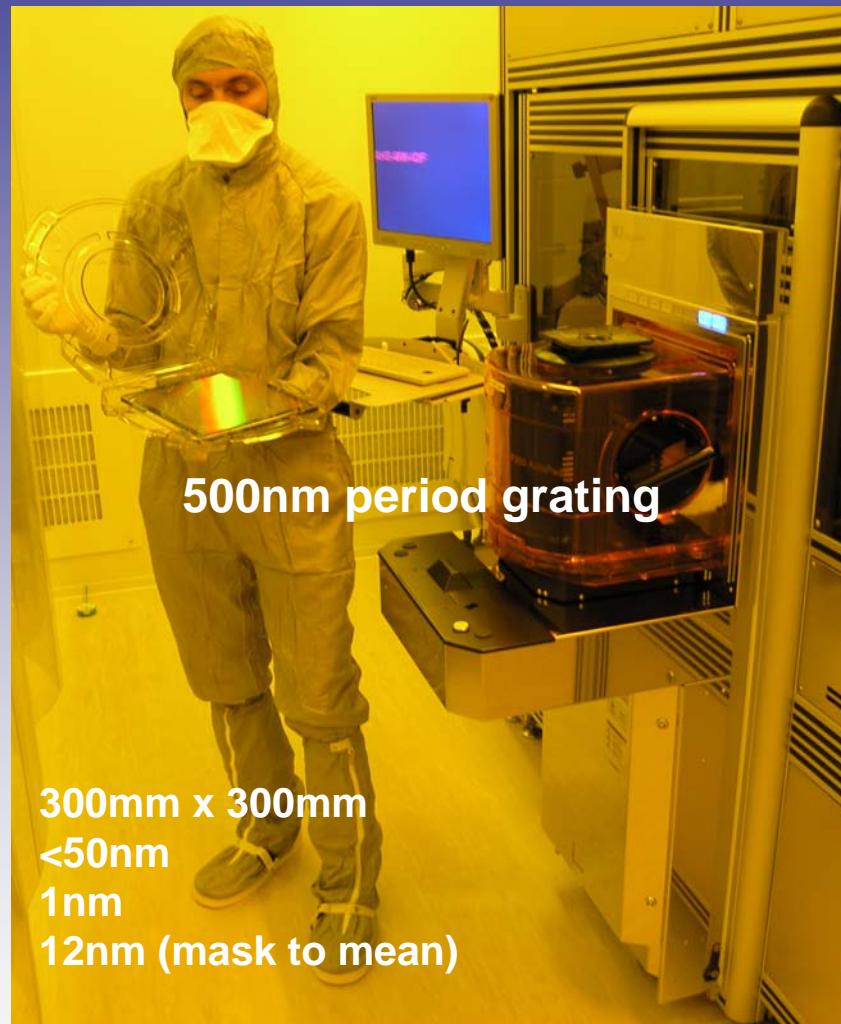


Our technology

E-beam writer Vistec SB350 OS



max. writing field:
resolution:
address grid:
overlay accuracy:

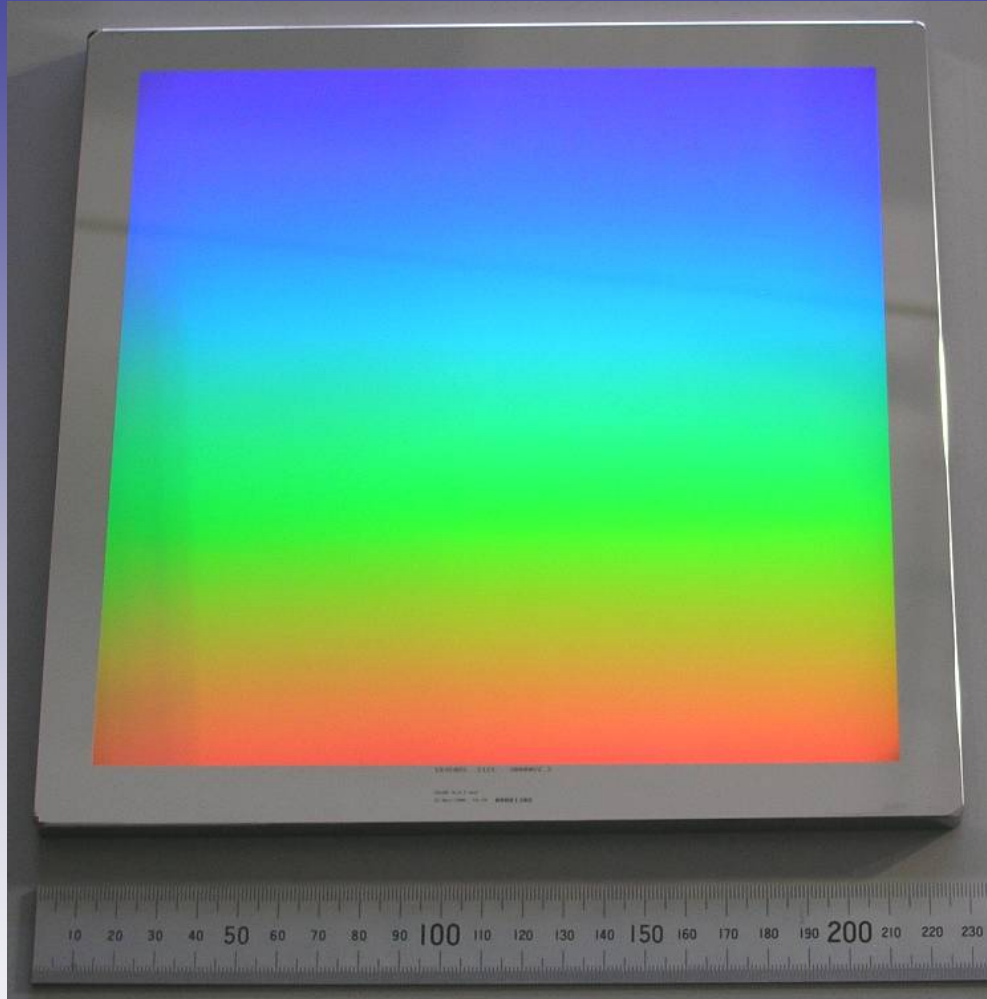


500nm period grating

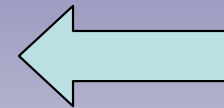
300mm x 300mm
<50nm
1nm
12nm (mask to mean)

etching tools
IBE
RIBE
RIE
ICP RIE

Grating sizes



200mm x 200mm grating,
230mm x 230mm substrate
1 μ m period



Sizes available

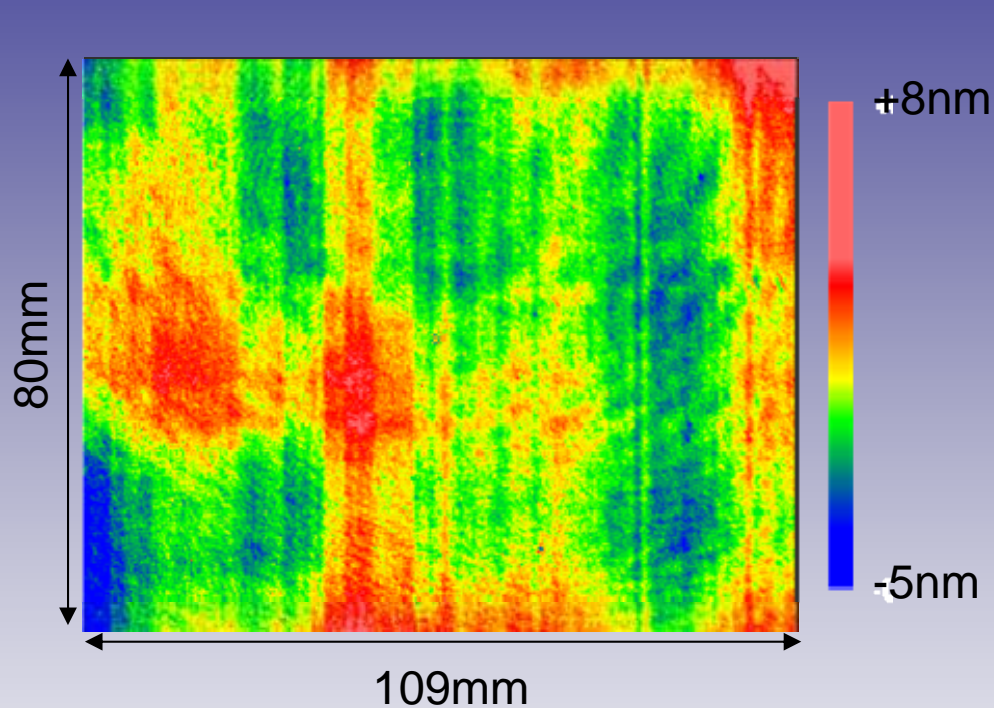
6" x 6"

9" x 9"

12" x 4"

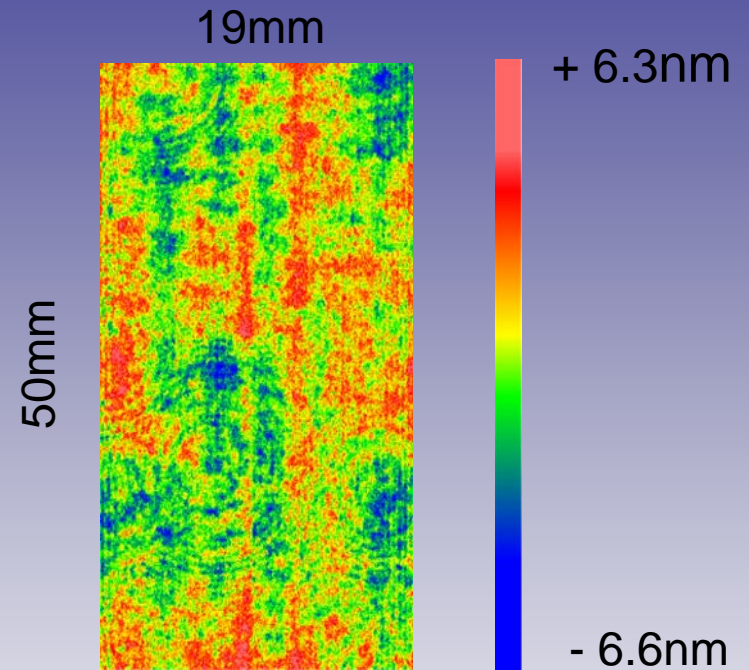
(20" x 20")

Reflective wave-front measurement (1 μm period grating + technology, Littrow-Mount)



	wavefront	placement
PV	12.8nm	<10.3 nm
rms	2.7nm	<2.2 nm

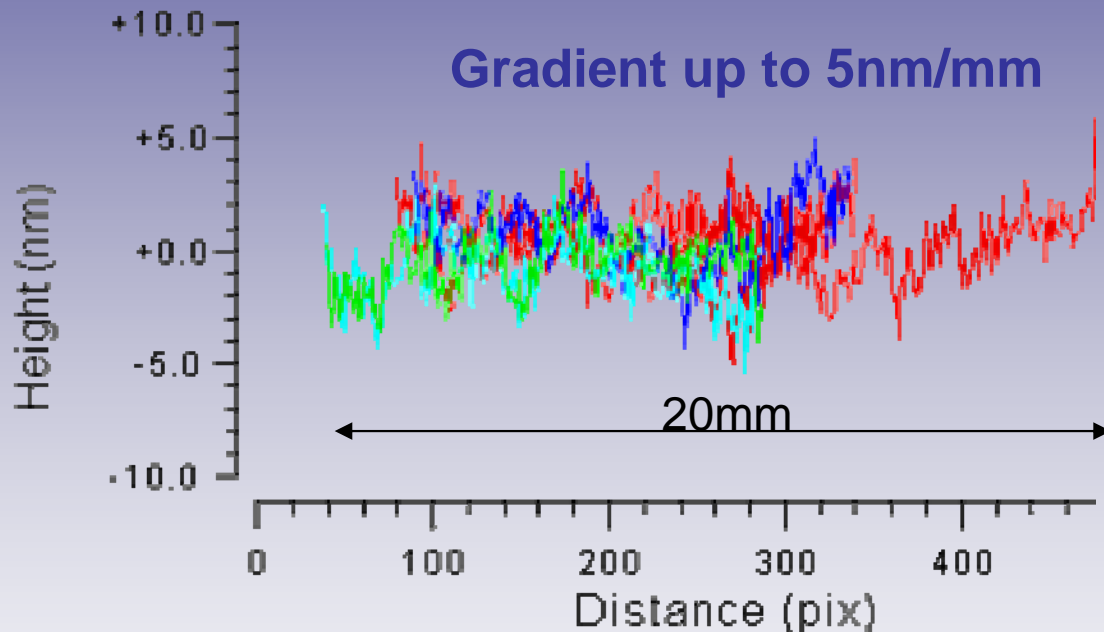
grating wave front gradient up to 5nm/mm



	wavefront	placement
PV	12.8nm	<10.3 nm
rms	1.4nm	<1.1 nm

period uniformity < 40pm

Wavefront gradient caused by the grating



Grating line quality width variation

line width variation

6" mask blank

Resist FEP 171

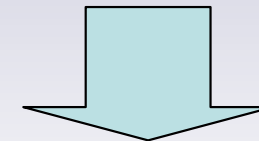
120mm x 120mm: ± 5 nm

100mm x 100mm: ± 3 nm

line edge roughness

depending on writing strategy

6 – 10nm



Uniformity of diffraction efficiency

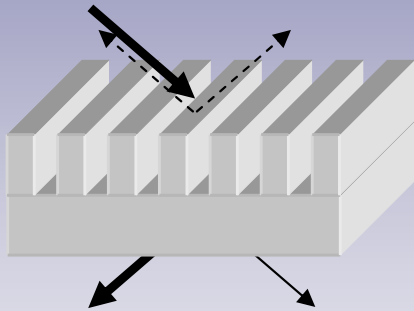
Depends on

- design tolerances
- technology applied

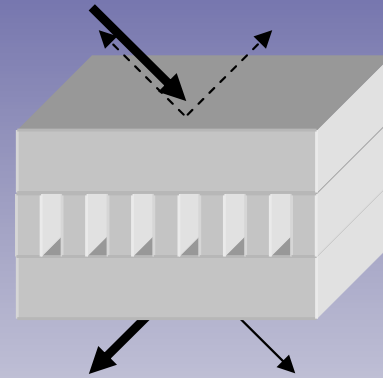
Transmission gratings

2 ways for anti reflection (AR)

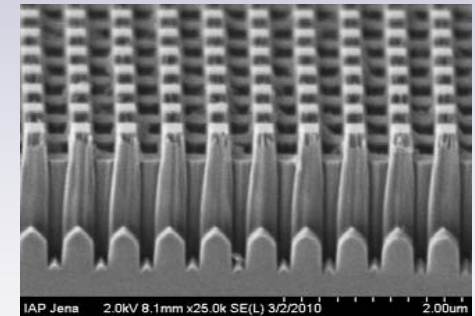
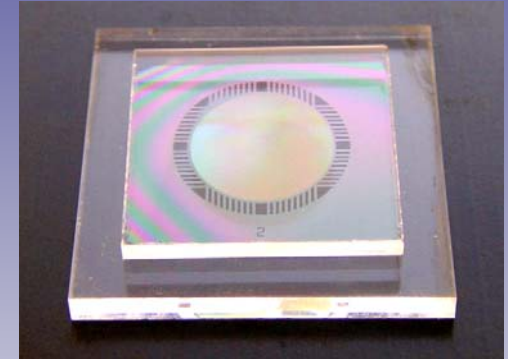
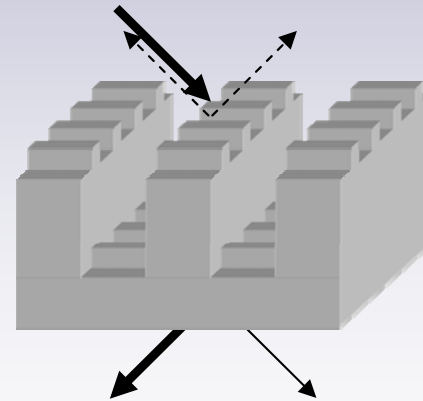
Small periods
→ Fresnel reflection



Fabry-Perot effect
embedding



Moth Eye effect
effective medium grating

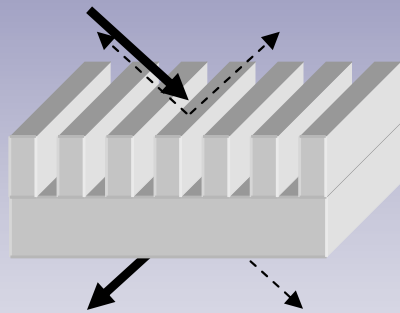


Transmission gratings

2 ways for anti reflection (AR)

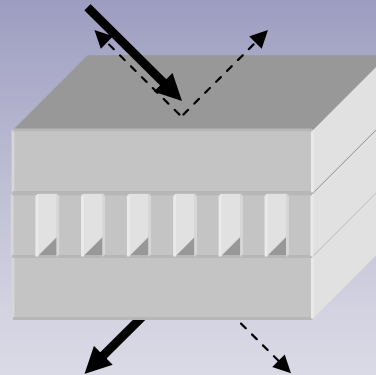
$\lambda = 1040\text{nm}$, period = 600nm, Littrow angle 62.5°

Classical grating



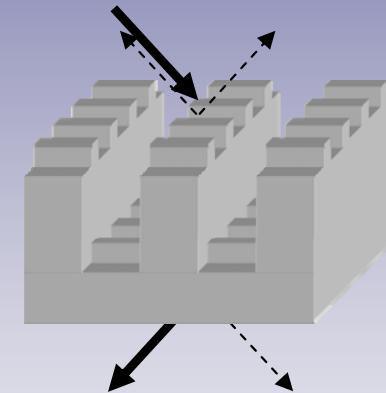
TE-Efficiency
design 93%
not fabricated

AR by Fabry Perot



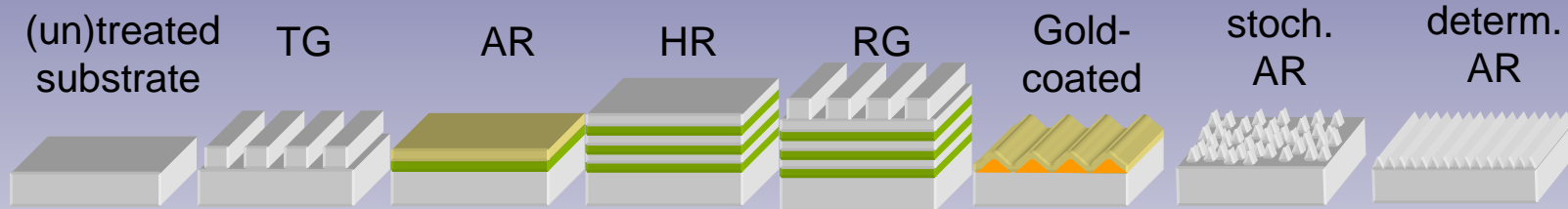
TE-Efficiency
design 100%
measured 98%

AR by effective media



TE-Efficiency
design > 99%
measured 97%

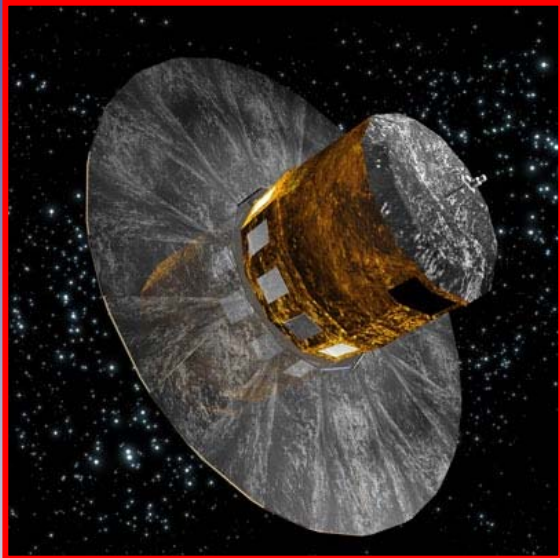
Damage



170ns	360	250				0.65		
8ns	80 (200)	35	27		10			
8ps (IAP)	3.3 (5.5)	1.62	1.73	2.2	0.7		5.5	6.5
150fs		1.5						

0% damage probability [J/cm²]

Spectrometer grating for the Gaia mission of European Space Agency

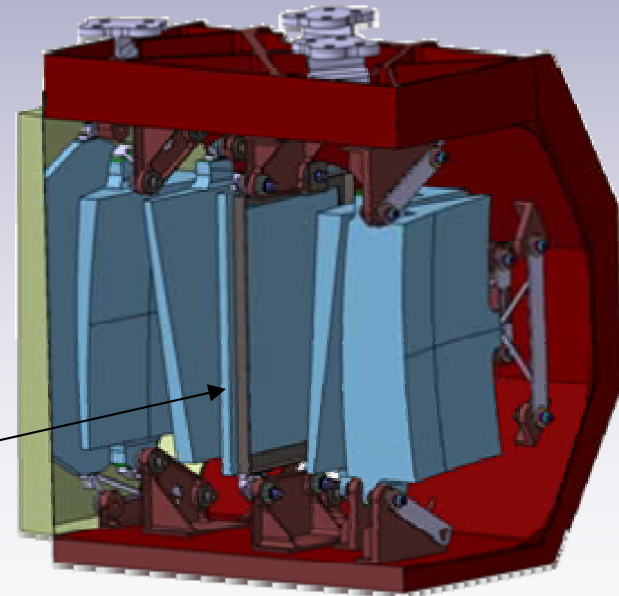


Gaia (Dec. 2011)
- 1E9 Stars
- Magnitude: 22.5-20

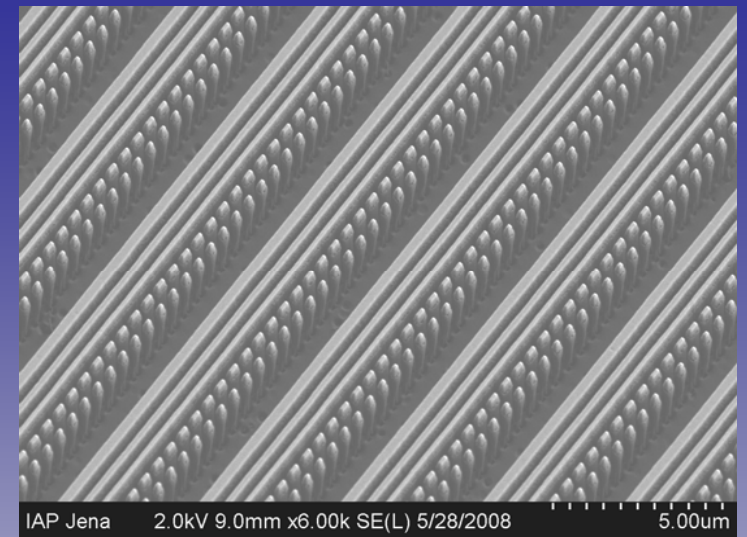
Distance measurement by read shift measurement

Radial Velocity Spectrometer
Spektral range: 847-874 nm

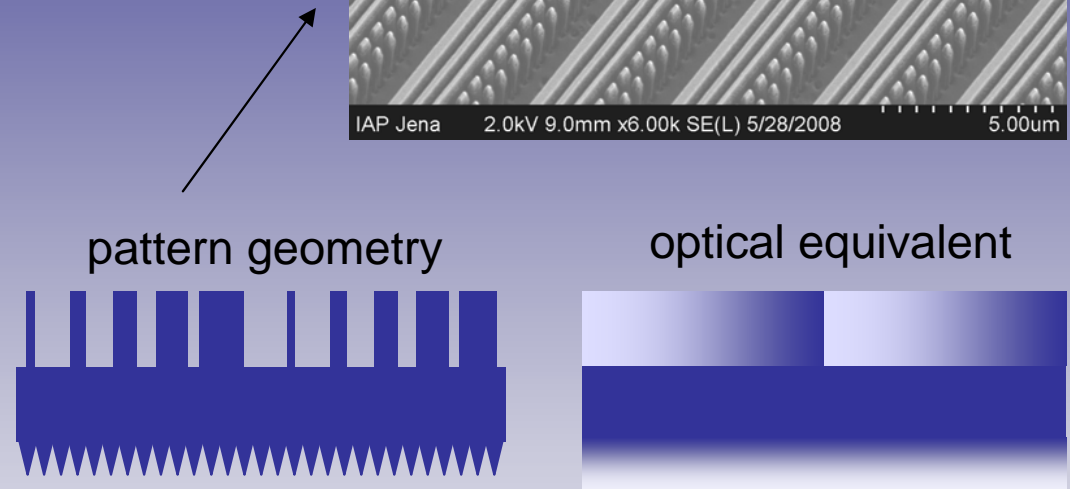
Grating



Results for the Gaia grating

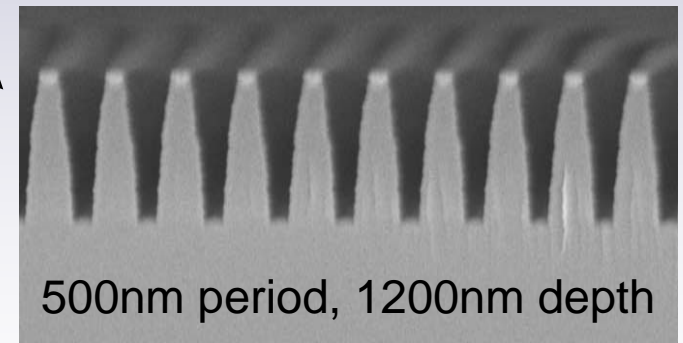


period:	3310nm
wavelength:	850nm
TE, TM efficiency:	>83%
Polarization sensitivity:	< 5%
back side reflectivity	<0.3%

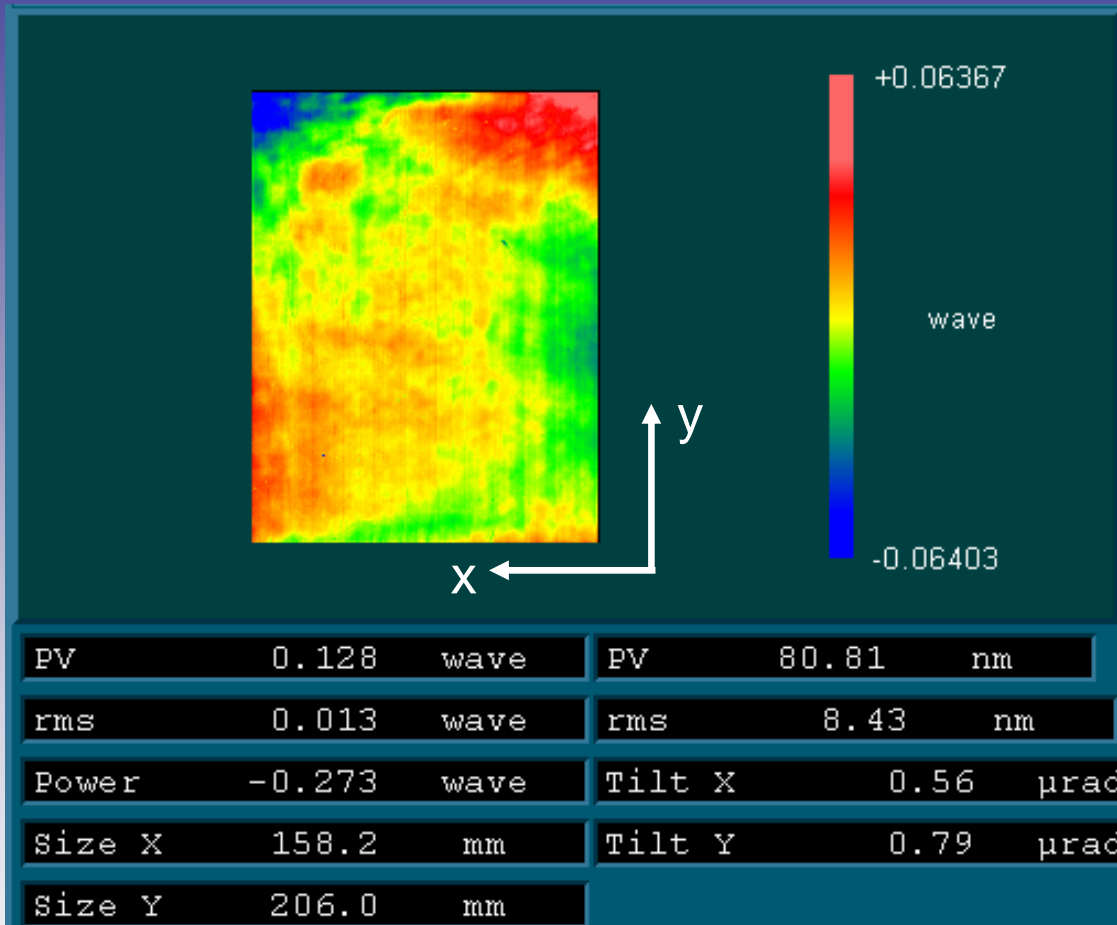


e-beam writing time for 210mm x 155mm

- diffraction grating: 36 -75 h (depends on design)
- AR-Grating: 10 h



Wave-Front Full Grating Area 155mm x 205mm



1st diffraction order
transmitted wave-front
(tilt, defocus removed)

P-V: 81nm
RMS: 8.4nm
RMS: < 5nm (on quality area)

grating area:

wave front on Ø60mm < 5nm

