Inband EUV Open Frame Resist Exposer TEUVL

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Task

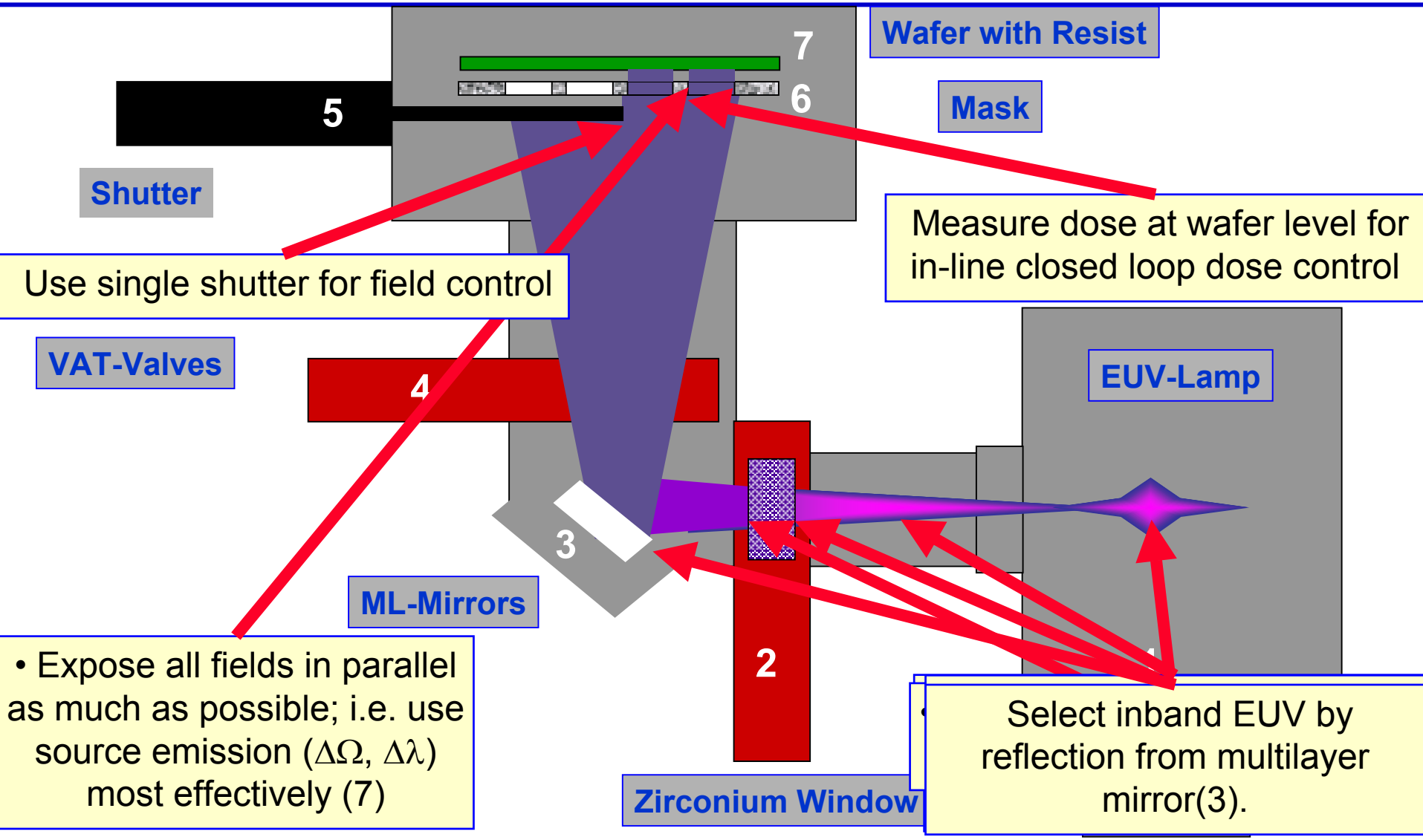
AIXUV EUV-Technology

In-House resist Exposure supplementing research at BESSY II beamline for the development of EUV resists with features:

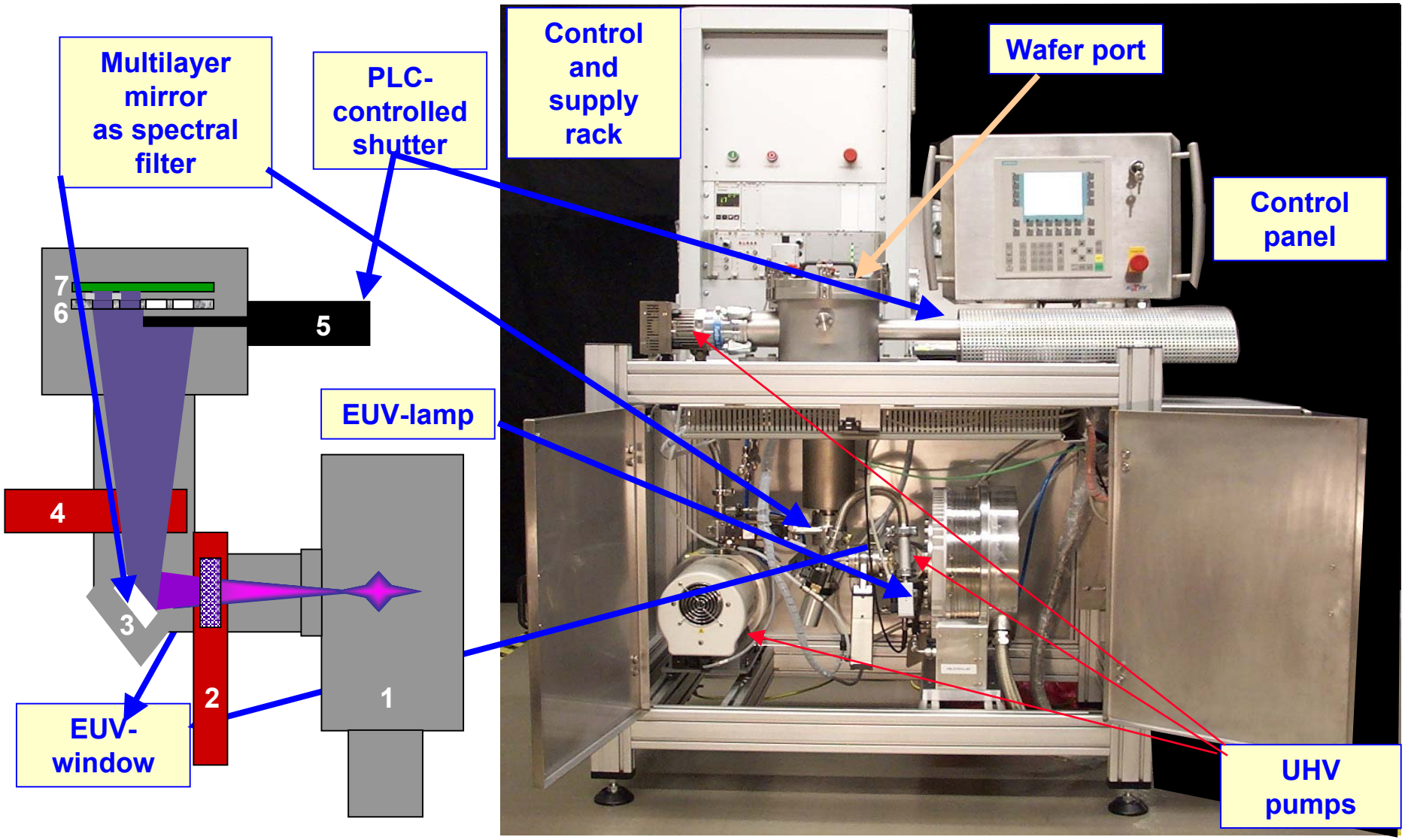
- Only expose with nearly in-band EUV radiation
- 20 fields of 5 mm diameter for dose-contrast curve
- Exposing with pre-set doses
- Results should be comparable with beamline
- Homogeneous illumination of the individual fields
- Clean vacuum in exposing volume (outgasing)
- Compact, affordable device
- Stability, Reliability for >> 100 Wafers
- Clean-Room compatible
- Less than 2 hours for 20 fields
- Load-Locking

- Spectral Filter
- Field Shutters
- In-Line Dose Control
- Calibration of Doses
- Open Beam
- UHV-compatible
- Discharge Lamp
- Discharge Lamp
- Steel housing, Open
- Parallel exposure
- 3 chambers

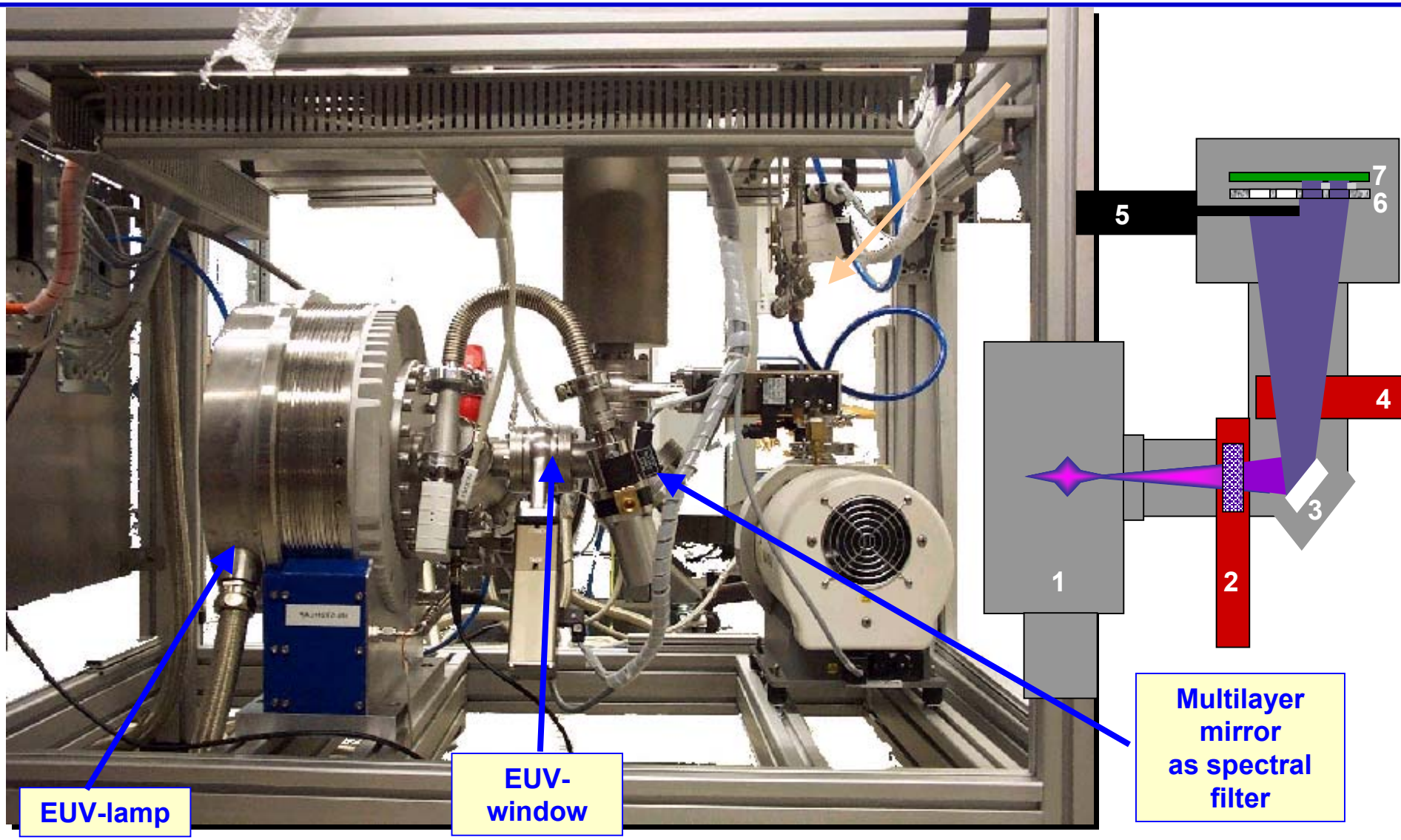
Concept of Resist Exposer



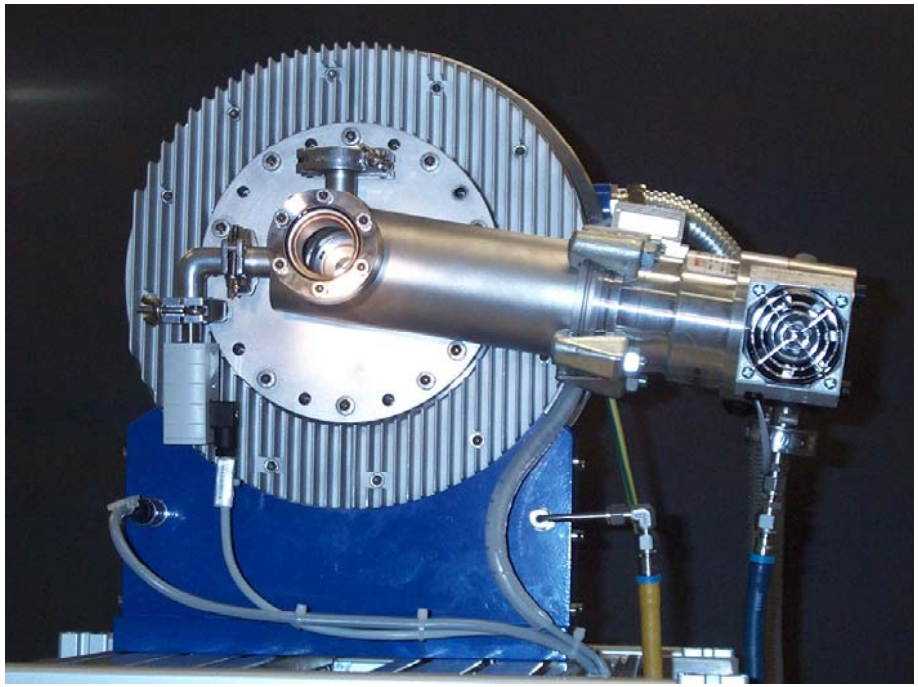
Components of TEUVL



Source integrated



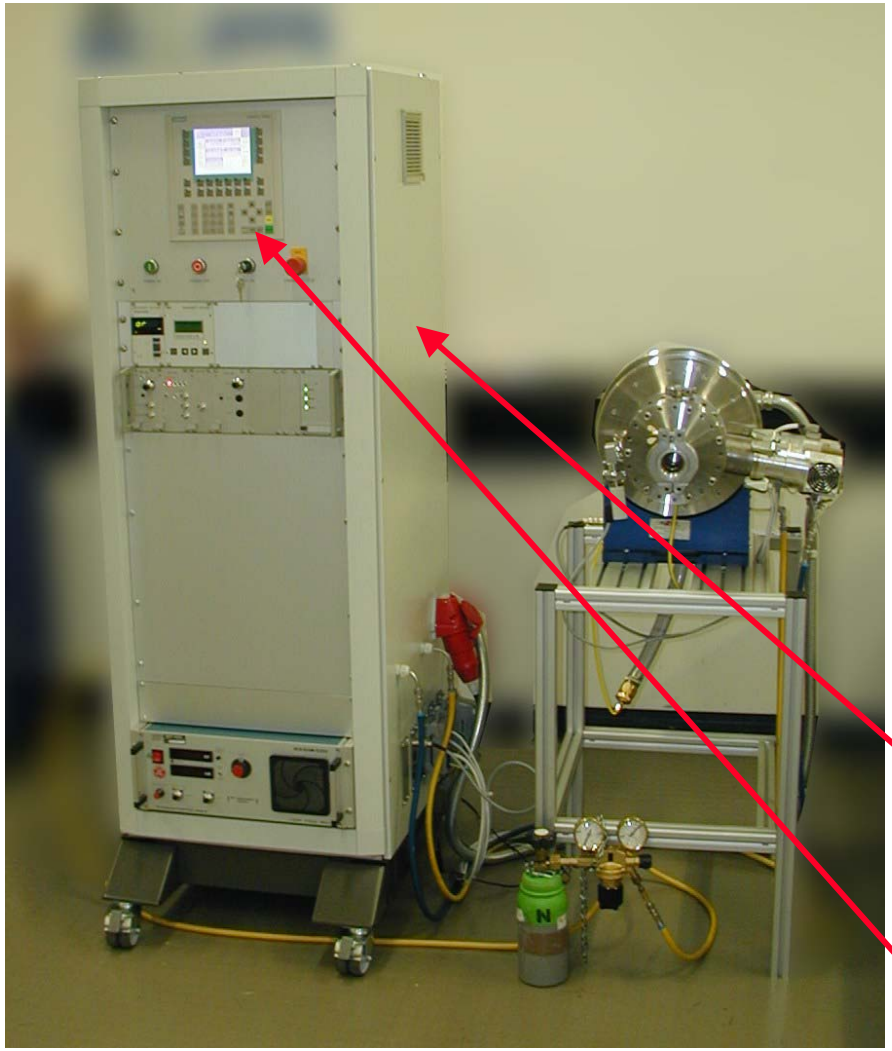
“EUV-Lamp” as Source



EUV Lamp Head:

- 2 J electrical input per pulse
- 0,5 mJ/sr/2% bw. EUV emission
- <= 500 µm FWHM diameter
- Permanent operation 4w/7d/24h
- Expected MTBF ≅ $4*10^7$ Pulses, i.e. > 2.000 hours, i.e. 2 MJ inband radiation
- Flexible head orientation
- . spectral characteristics from narrow to quasi-cw available
- all gaseous “targets” can be used
- environmentally sealed

EUV-Lamp System as Basis of Development: Exposer is Add-On



- 50, 100, 250 Hz reprate
- 150, 300, 750 mW/inband/2π sr
- CE certificate
- User-friendly control
- Remote maintenance interface (Telephone line)
- At site installation and training

Exposer control supplements PLC

Exposer control supplements user-interface

Source features

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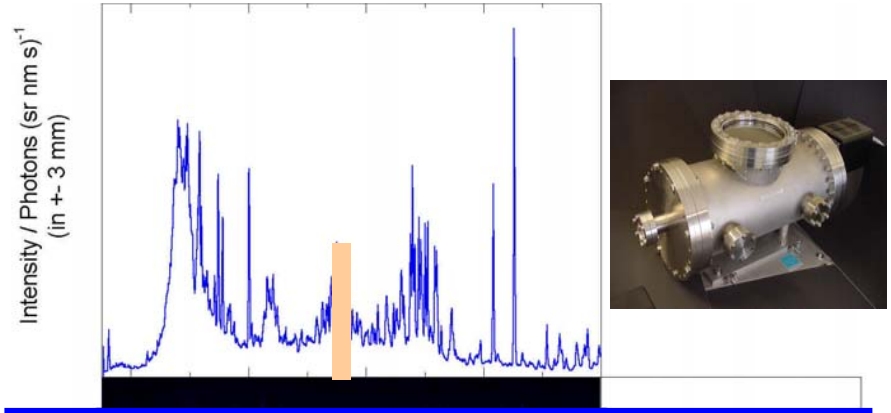
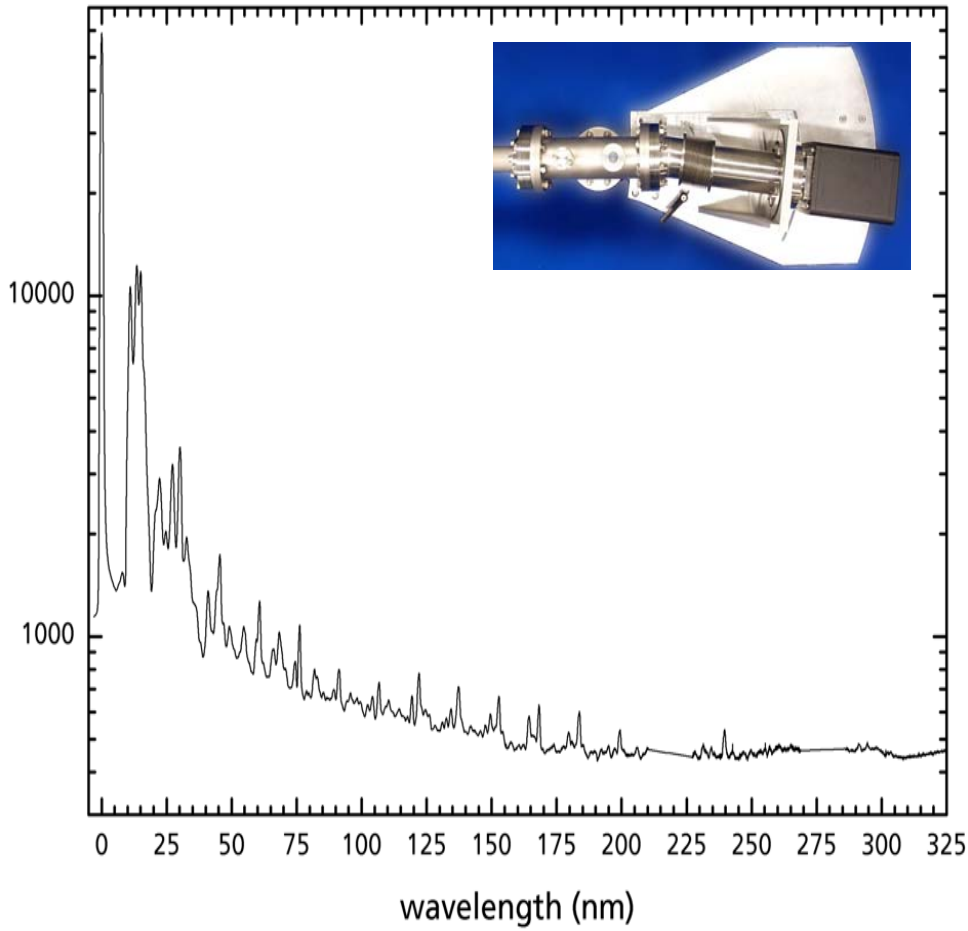
EUV-Emission and Source Size



Flux distribution based on preliminary calibration of E-TGS-1000

EUV-ib.	25 mW/sr
EUV tot (10-20 nm) ≅	10* EUV ib
VUV (20-150 nm) ≅	60*EUV-ib
UV (150-328 nm) ≅	22*EUV-ib

Out-of band



Measured with E-Spec and E-TGS-1.000

JENOPTIK JENA Mikrotechnik

Spectral filter of out of band radiation

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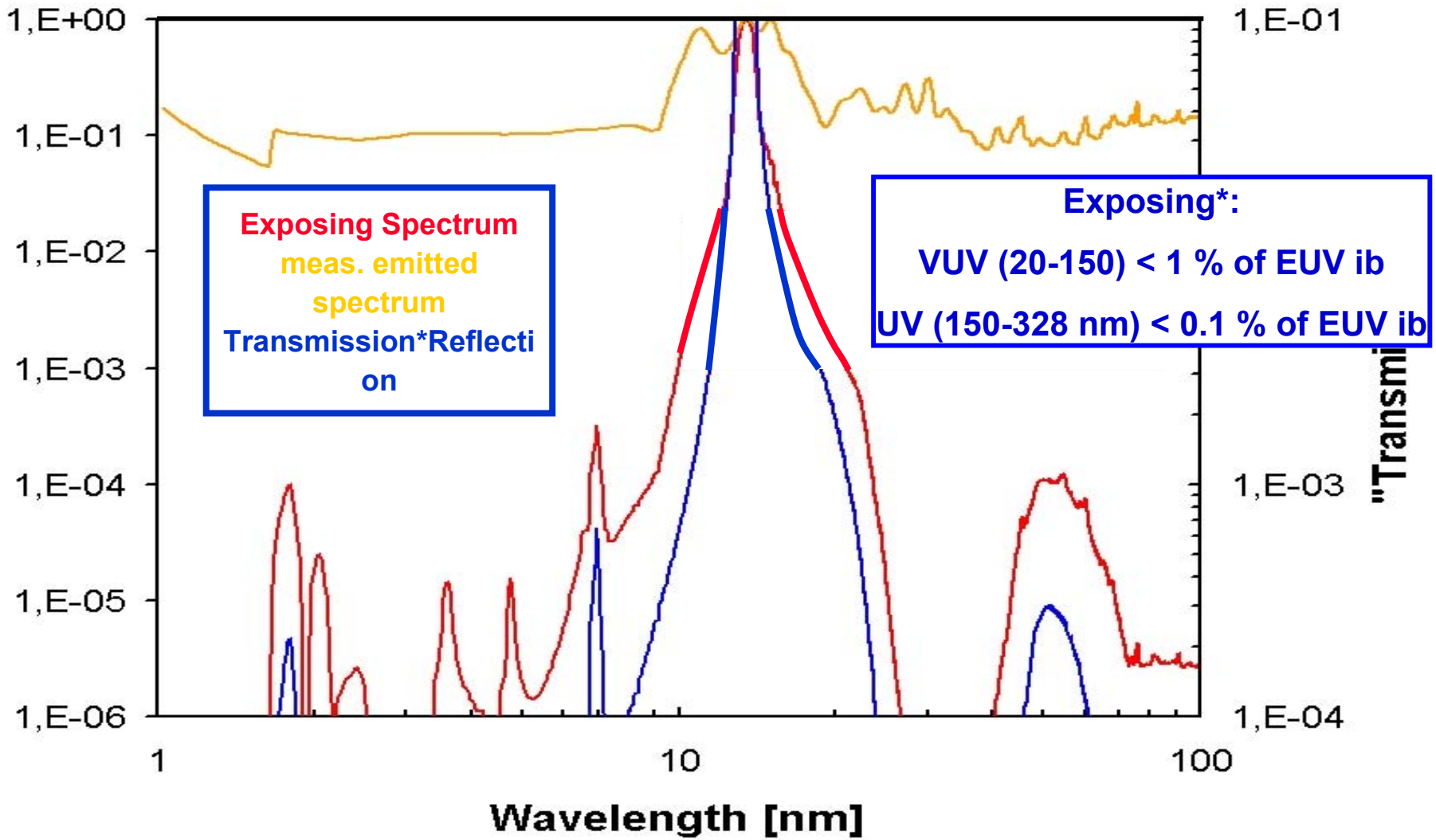
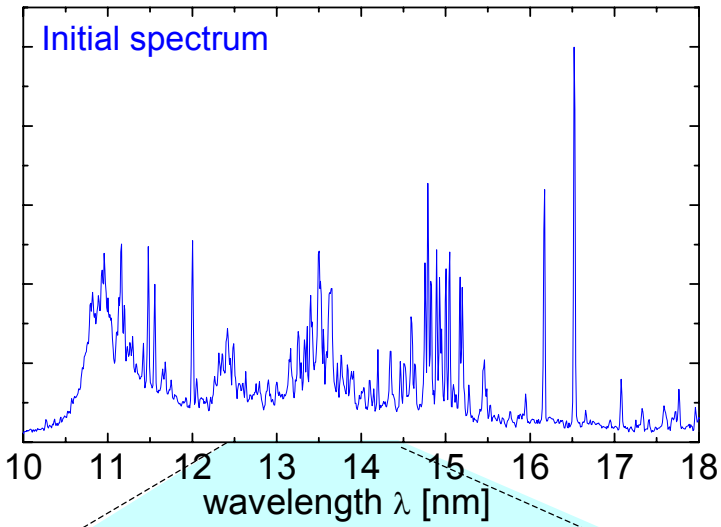
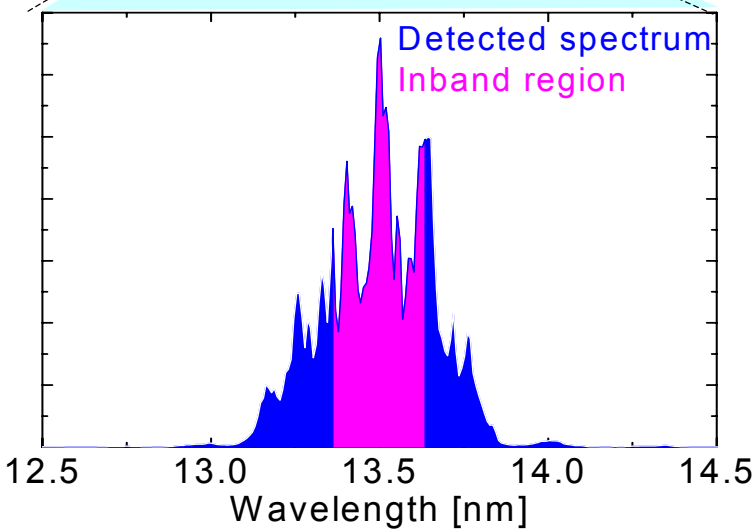
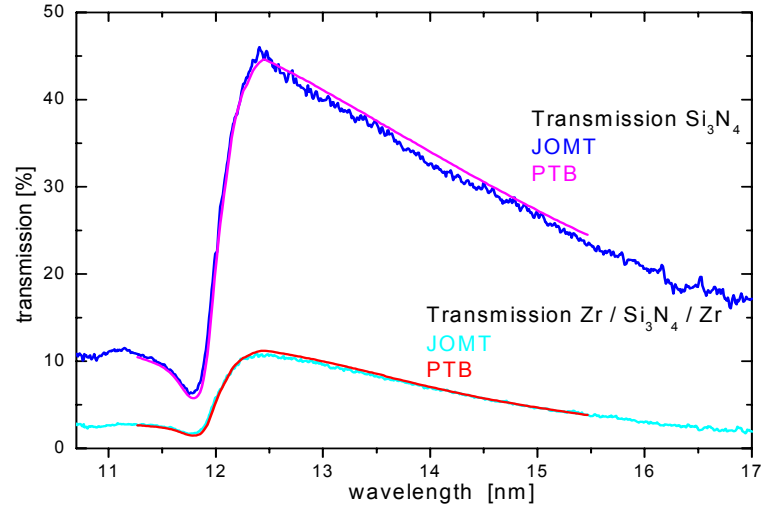


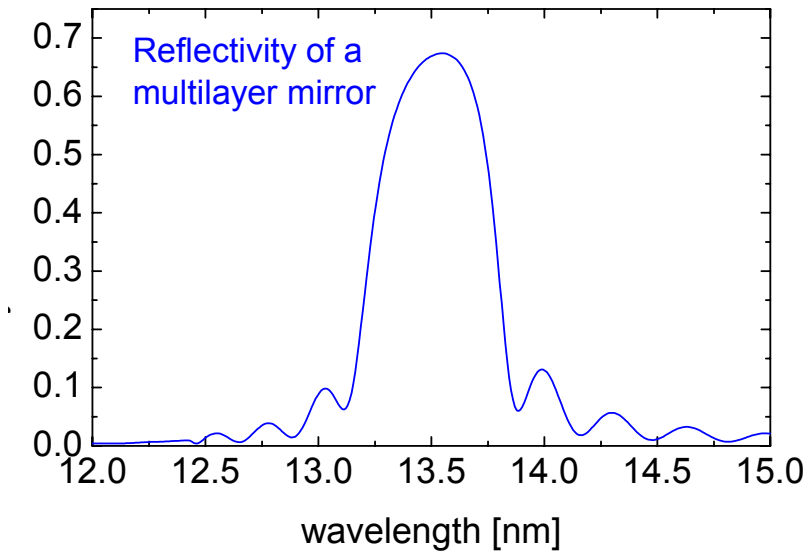
Flux distribution based on preliminary calibration of E-TGS-1000 and CCD-Camera (Princton)

EUV-inband selection:
Filter transmission + Multilayer reflectance



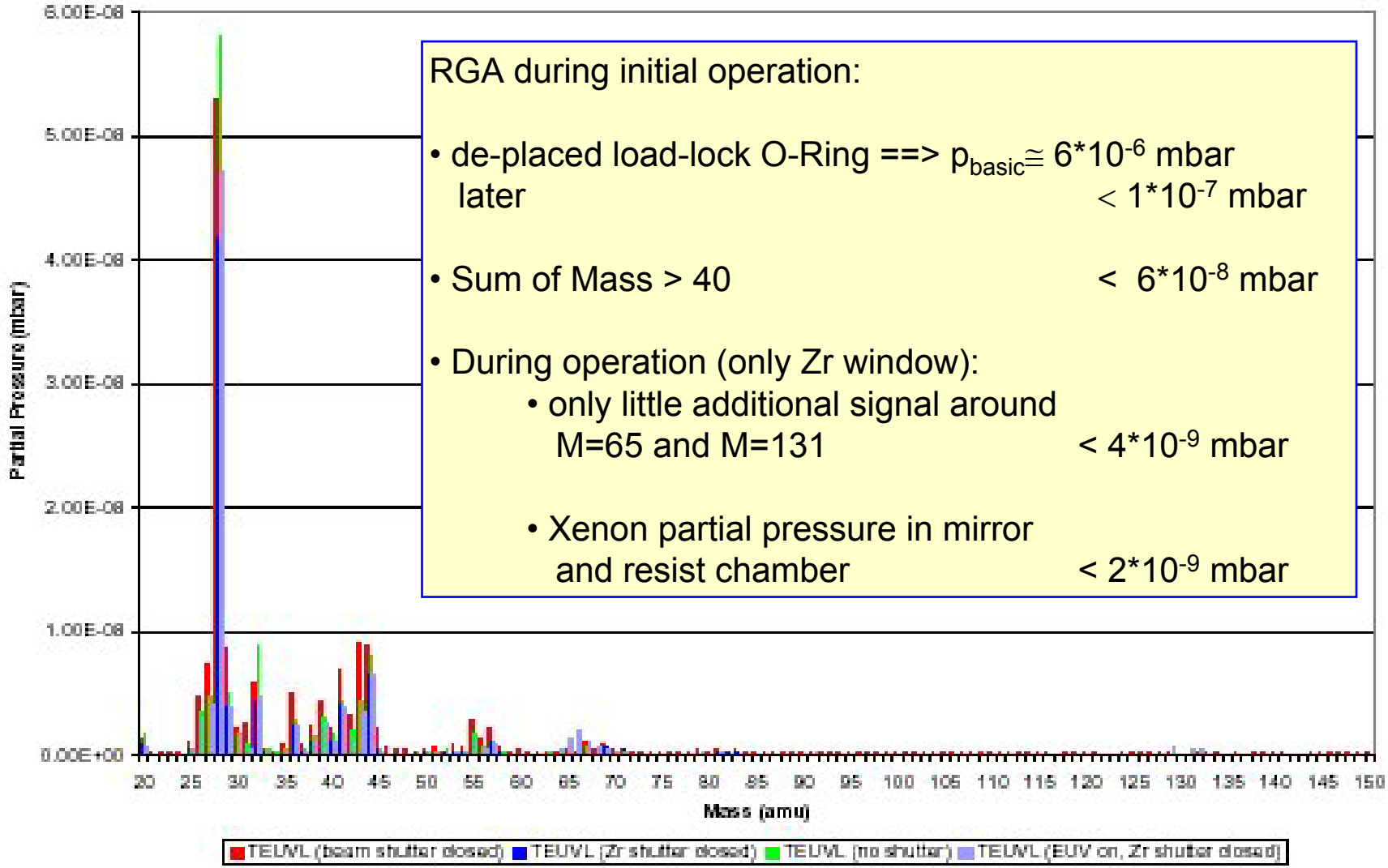






Based on source spectroscopy and internal components calibration at JENOPTIK Mikrotechnik

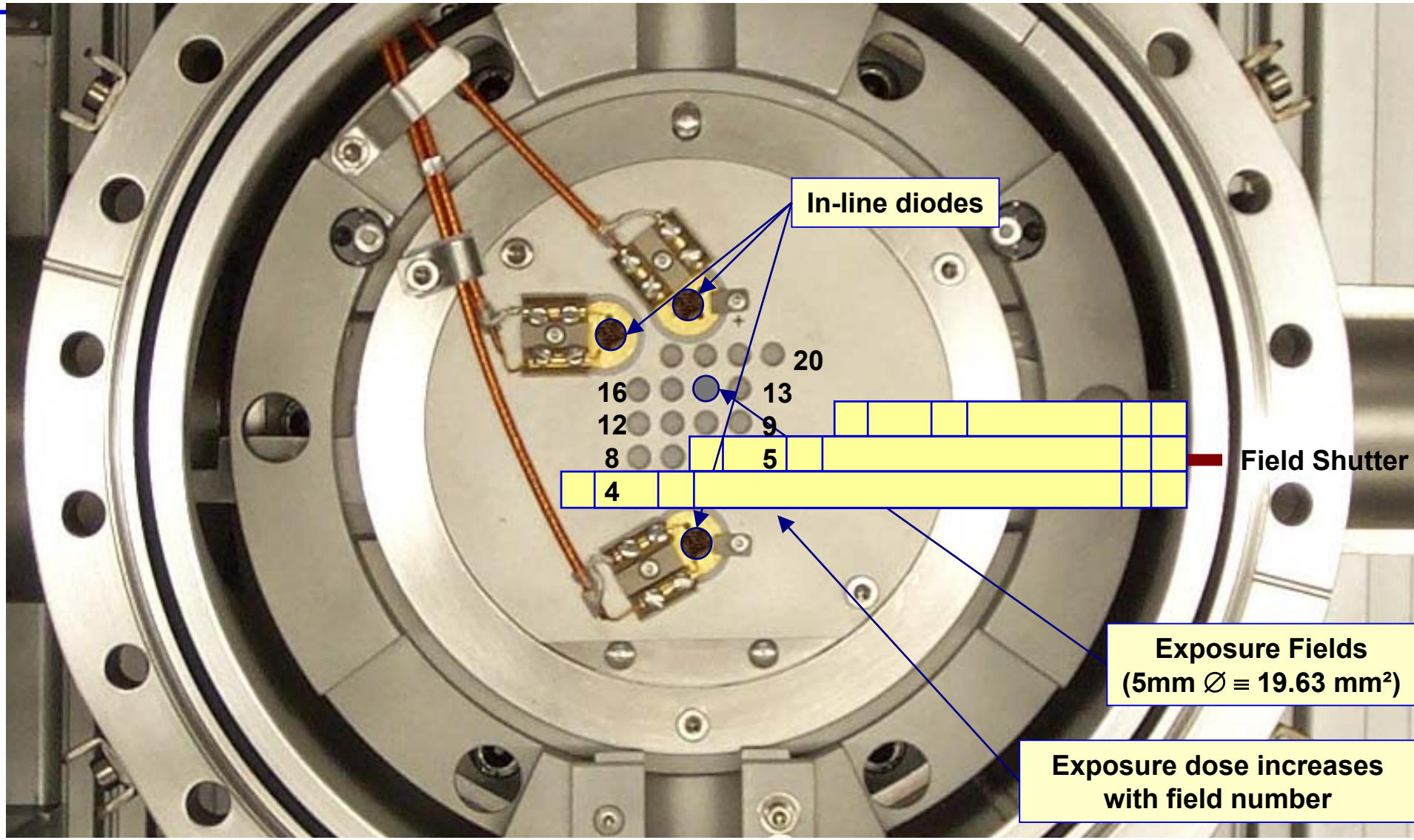
Residual Gas Analysis



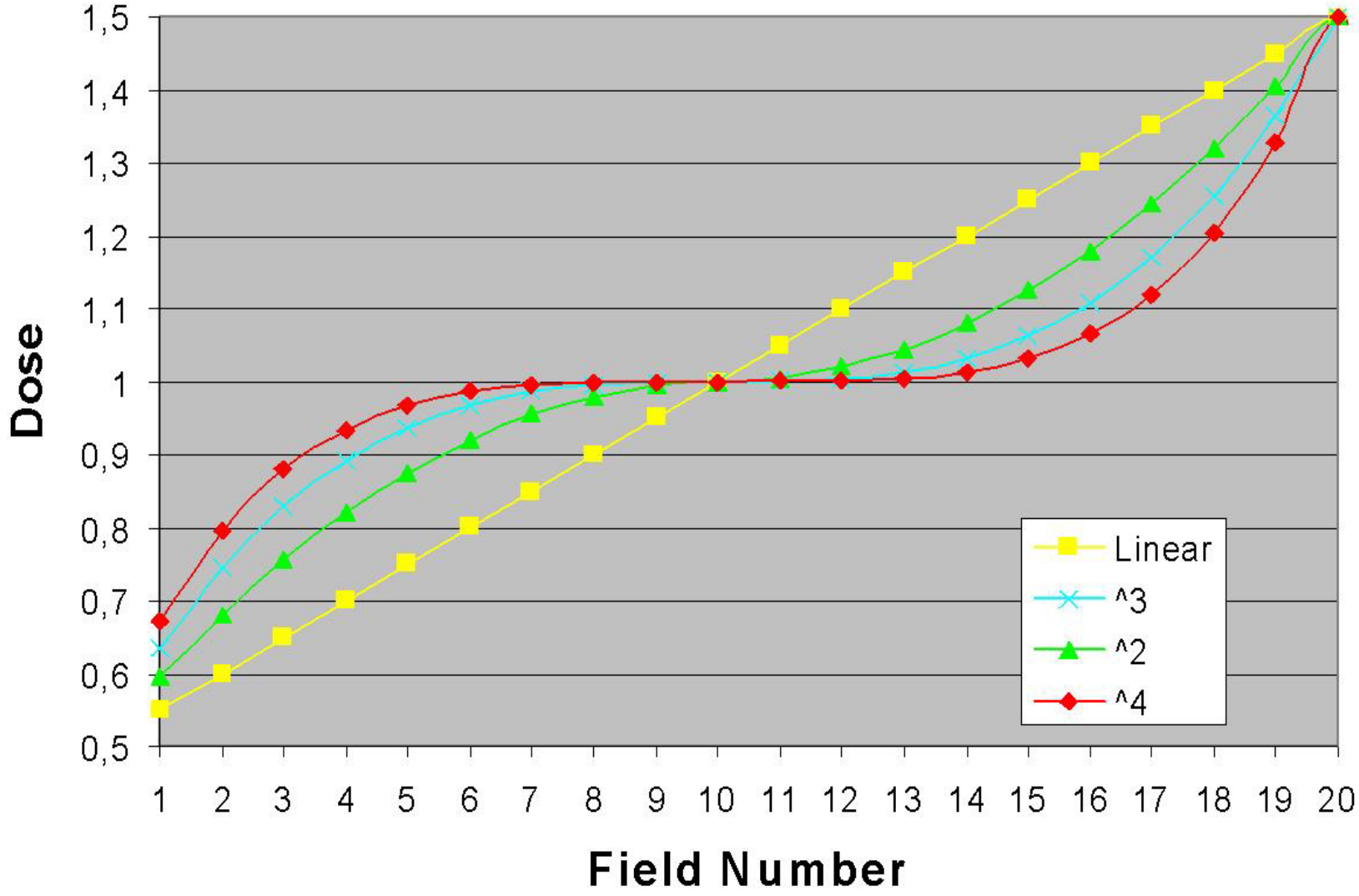
RGA during initial operation:

- de-placed load-lock O-Ring ==> $p_{basic} \cong 6*10^{-6}$ mbar
  later $< 1*10^{-7}$ mbar
- Sum of Mass > 40 $< 6*10^{-8}$ mbar
- During operation (only Zr window):
  - only little additional signal around M=65 and M=131 $< 4*10^{-9}$ mbar
  - Xenon partial pressure in mirror and resist chamber $< 2*10^{-9}$ mbar

Field Mask with 3 in-line diodes for flux/dose determination



Parameterized Dose Distribution



TEUVL: Single Pulse Homogeneity: Single Pulse

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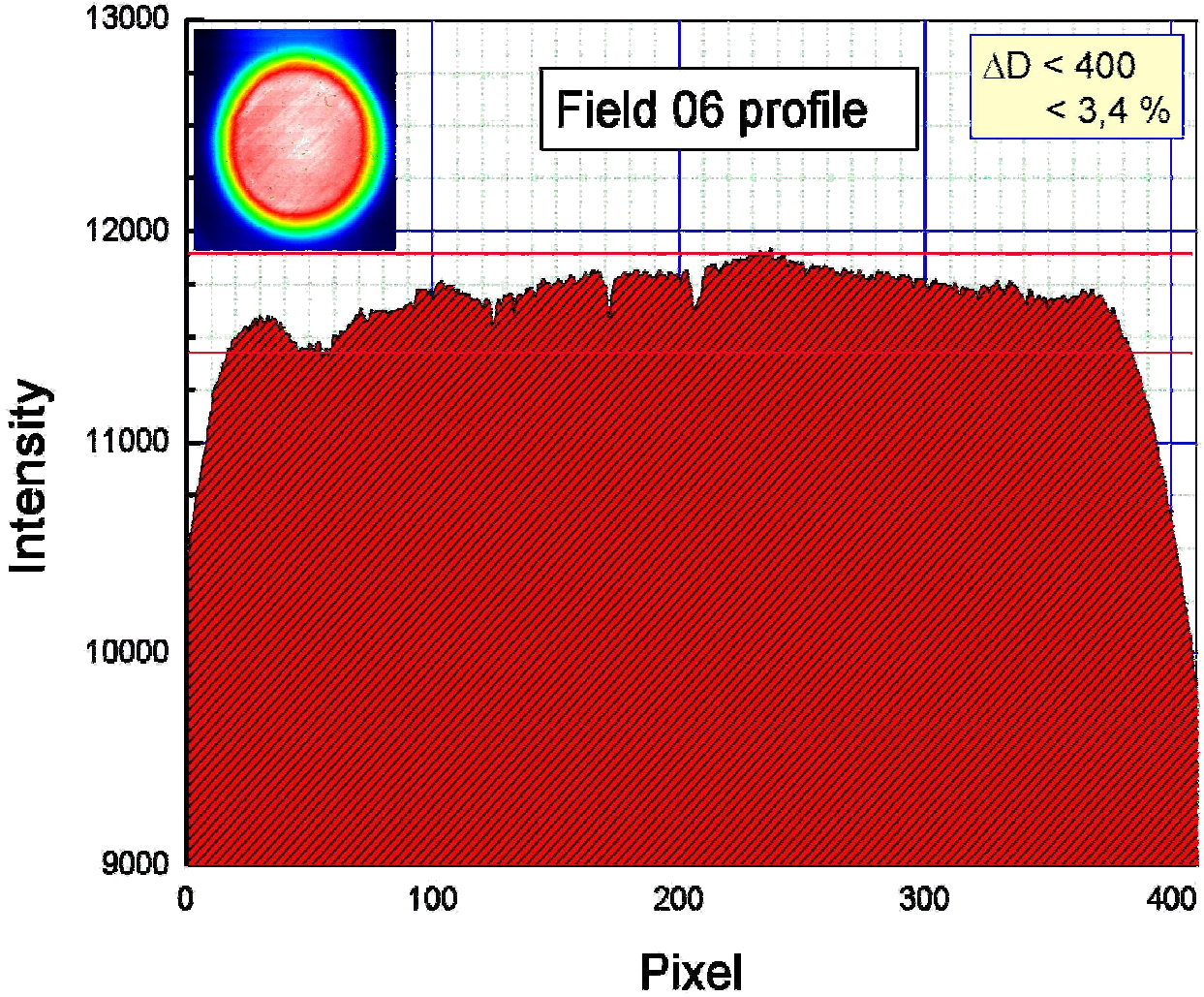
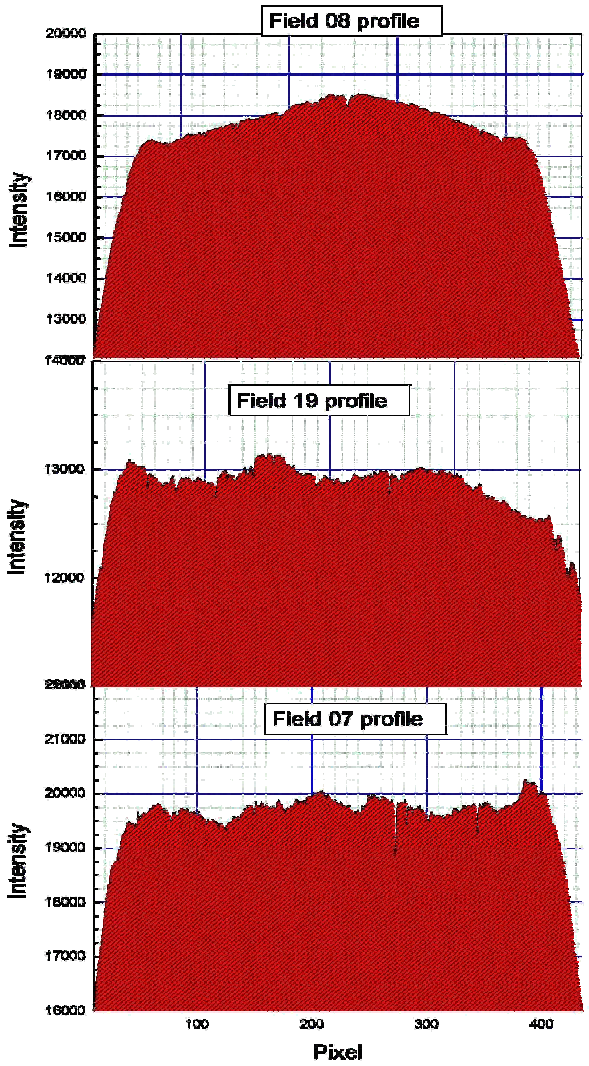
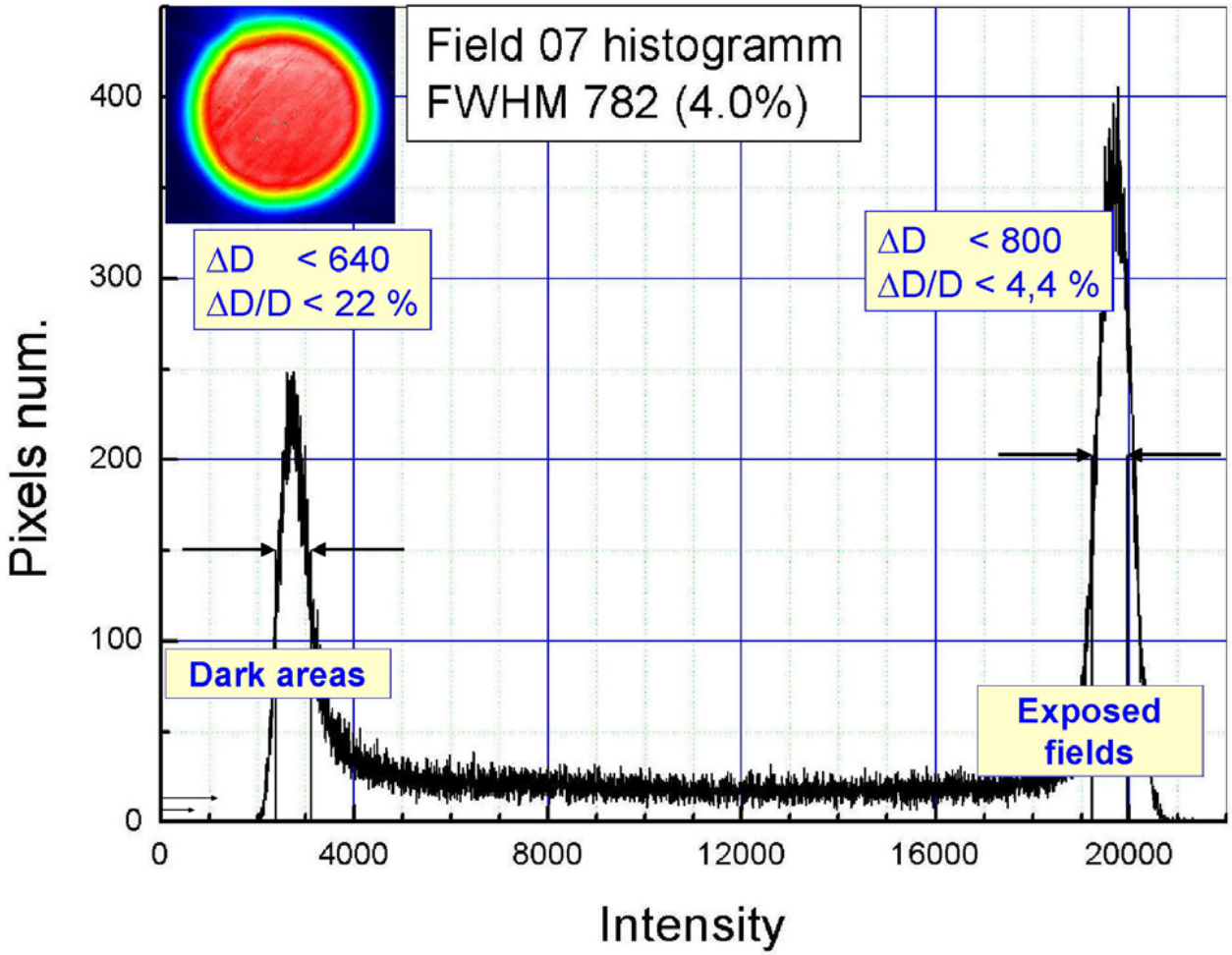
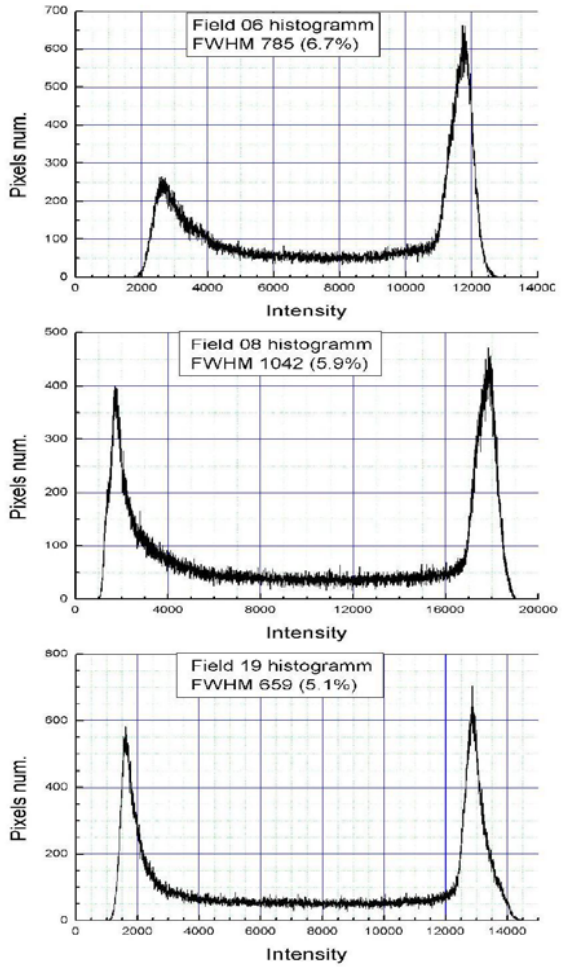




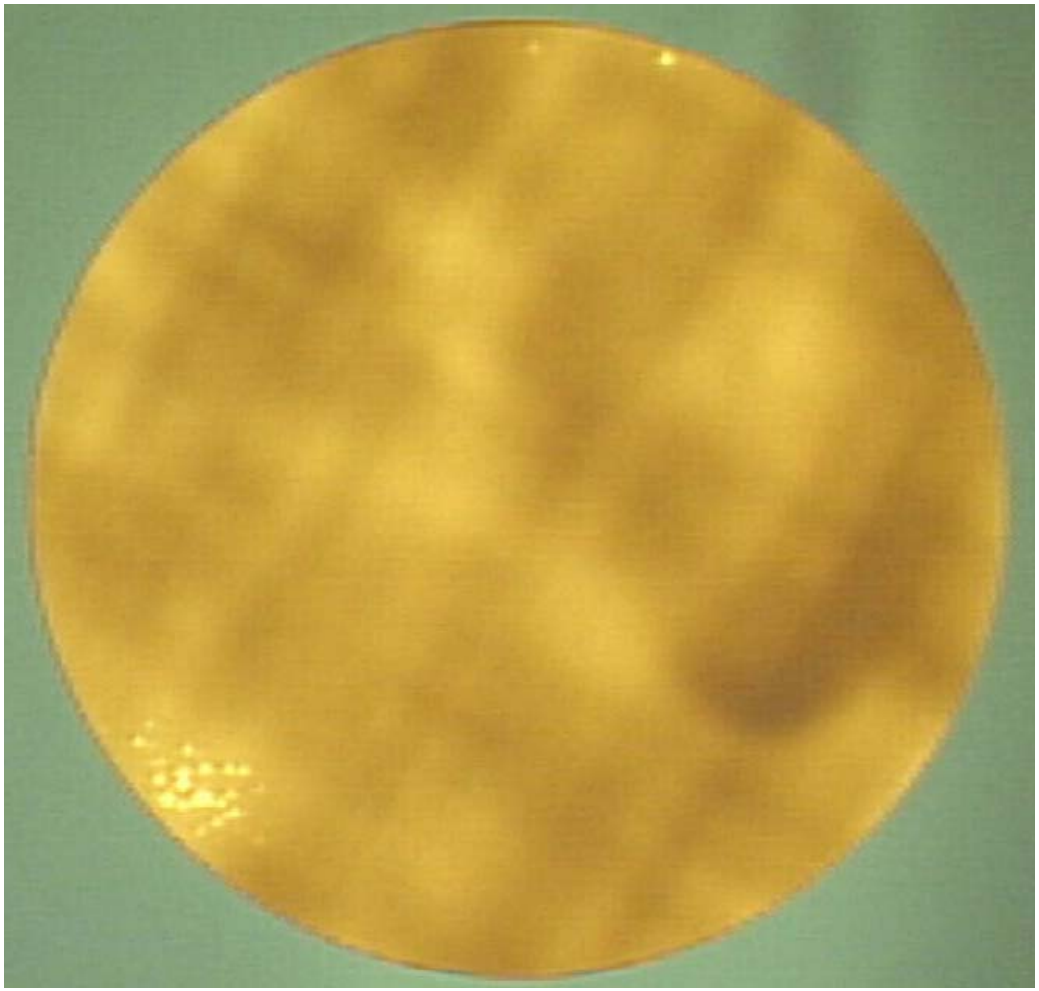
TEUVL: Single Pulse Homogeneity: Single Pulse Photon Statistics





Fluctuation of single pulse exposure is lower than fluctuations in dark fields

Homogeneity in Print



5 mm

Field with nearly Dose to Clear for steep and sensitive resist shows 1 % fluctuations due to support mesh on Zirconium window

EUV Resist Exposer System

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System has been shipped and installed at INFINEON Erlangen in October 2002

EUV-inband Resist Exposure TEUVL

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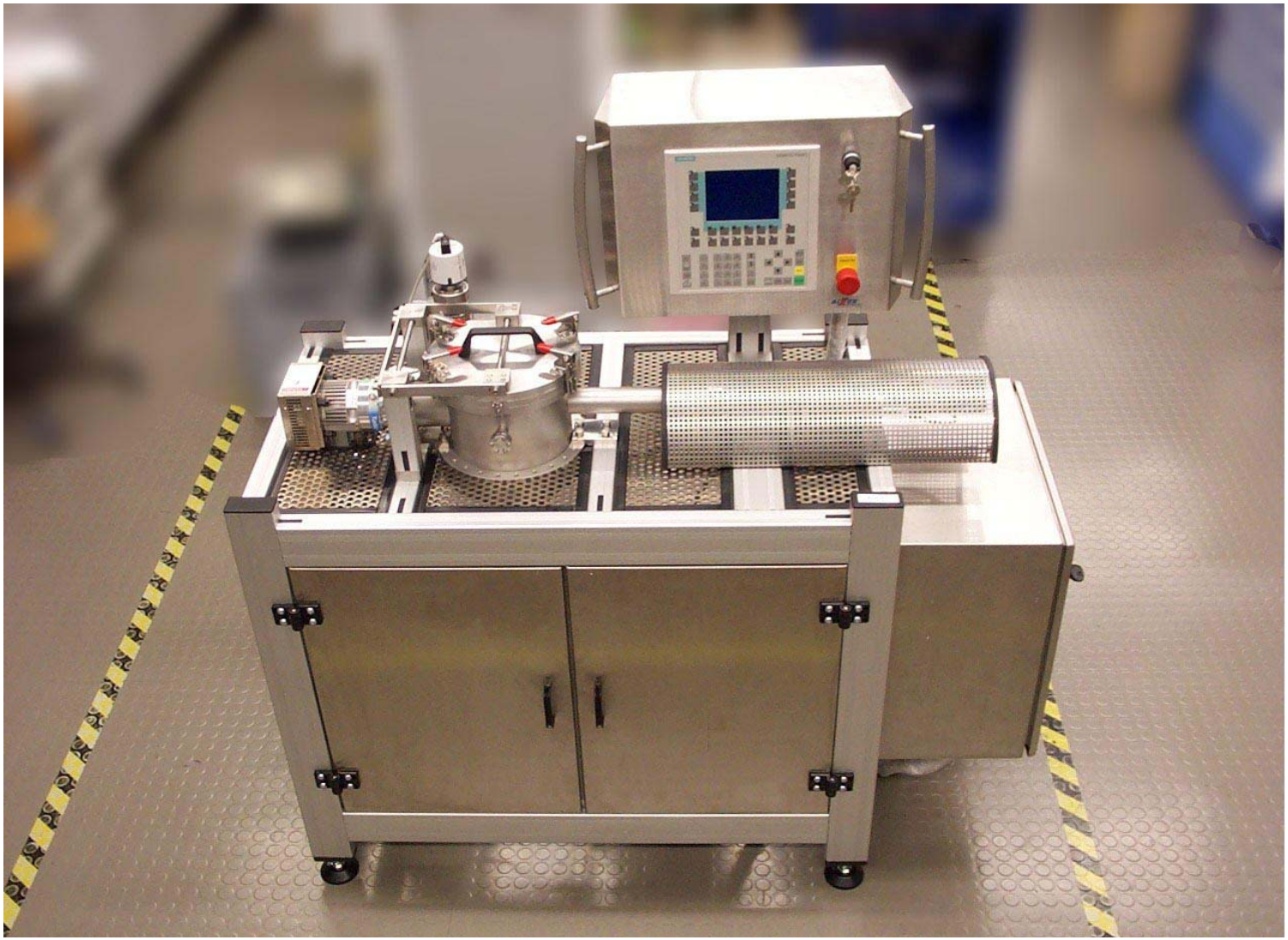
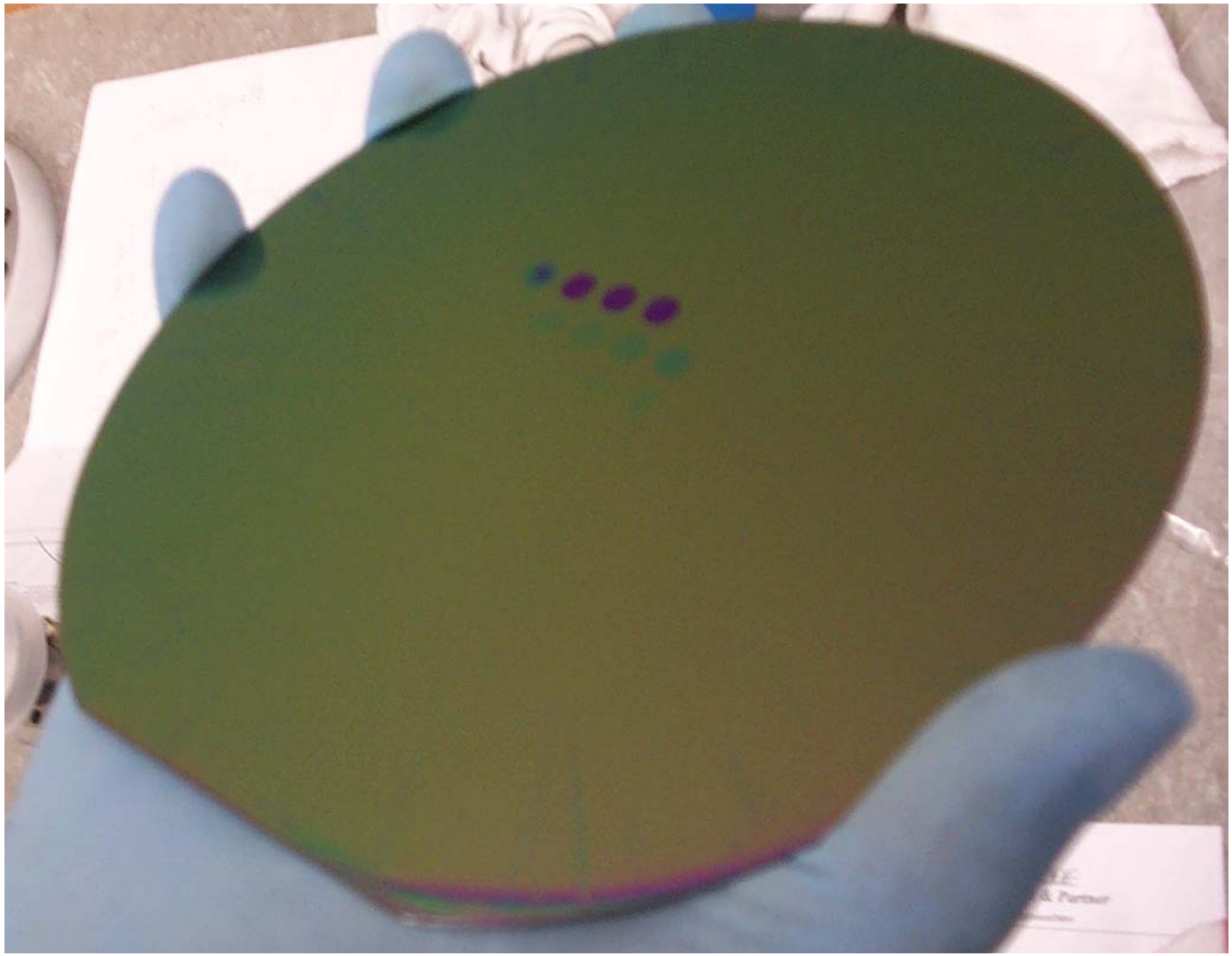
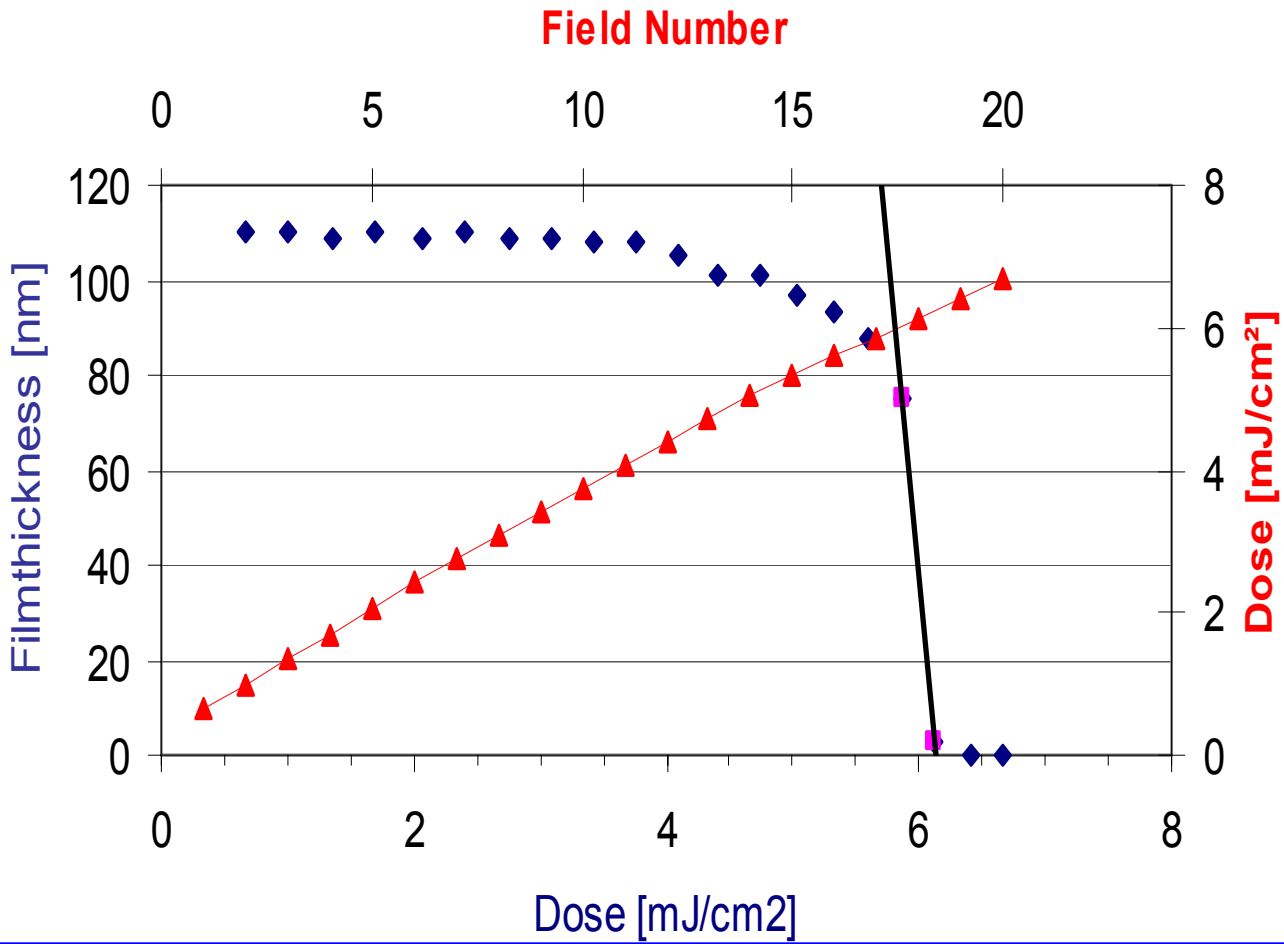


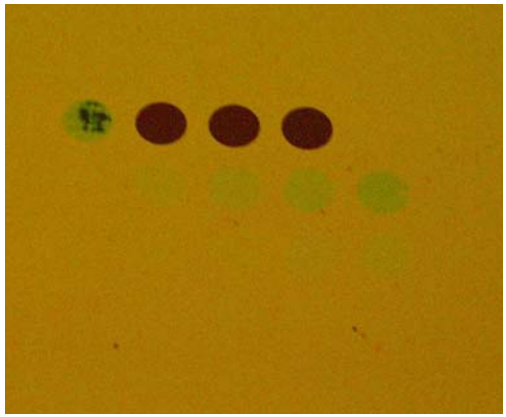
Wafer Loading at EUV - Resist Exposer

Gray-Scale EUV-exposed fields on Wafer



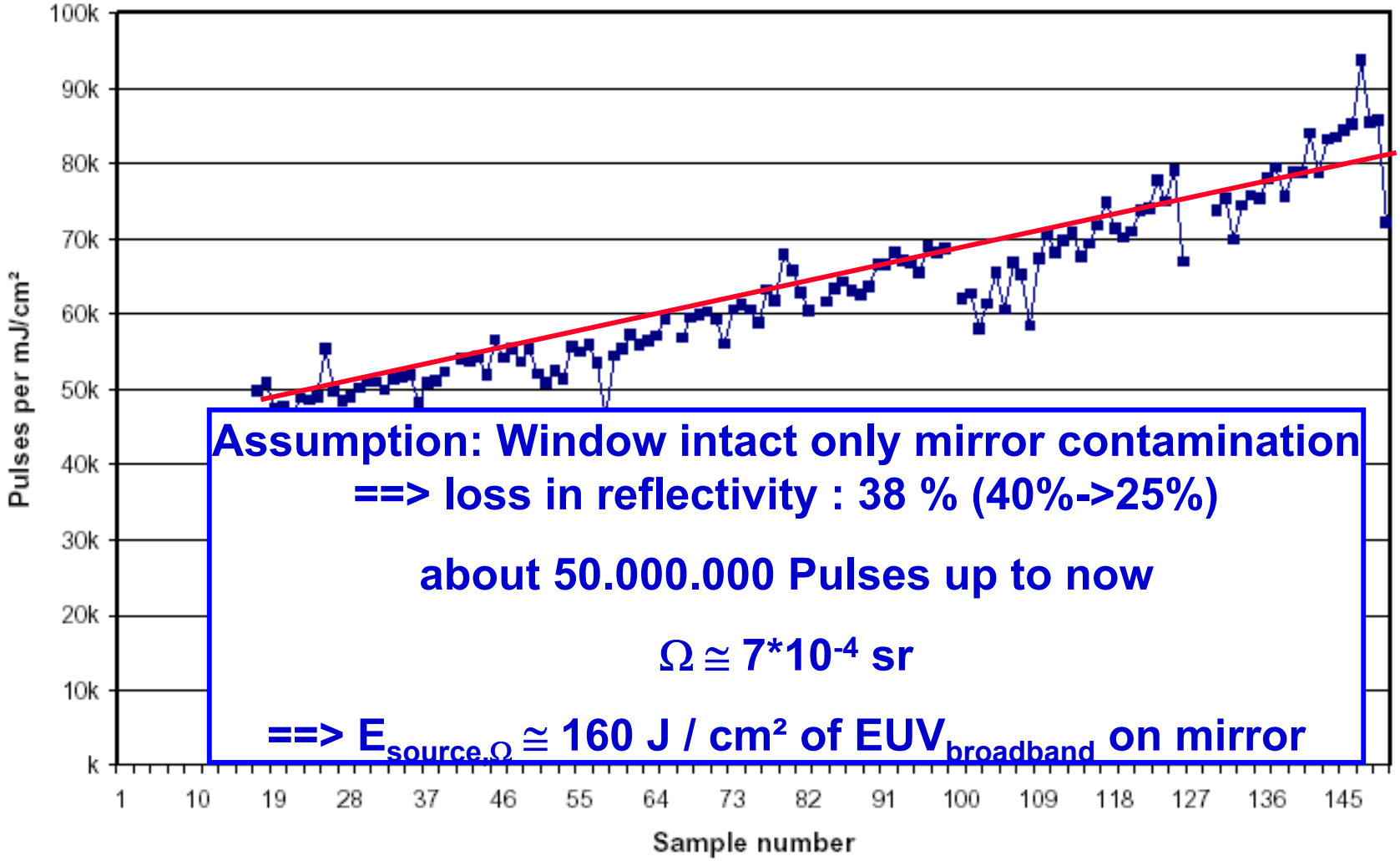
First Result: EUV Dose-Contrast Curve





With calibrated, feed-back dose measurements reliable contrast curves are obtained within less than 1 hour for 5 mJ/cm² resists.

Mirror and Window Contamination ?
Exposure history



Assumption: Window intact only mirror contamination

==> loss in reflectivity : 38 % (40%->25%)

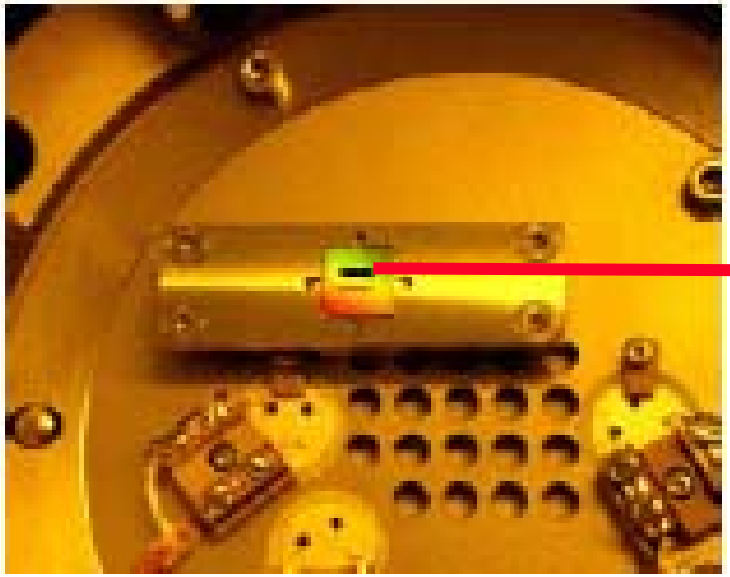
about 50.000.000 Pulses up to now

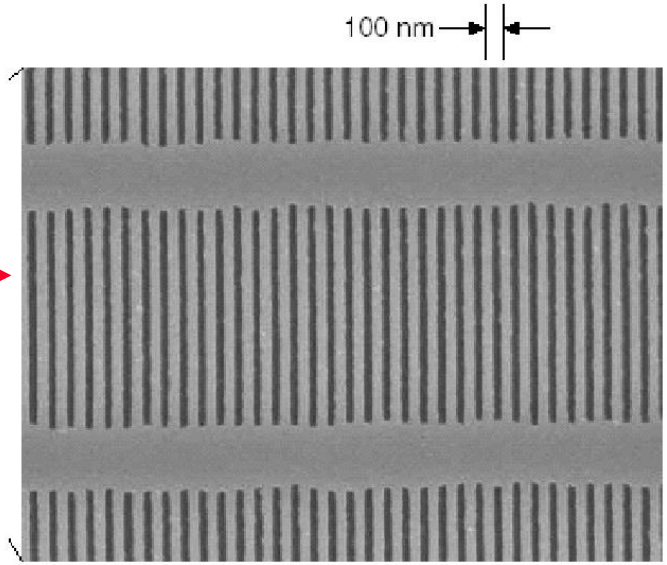
$\Omega \cong 7*10^{-4}$ sr

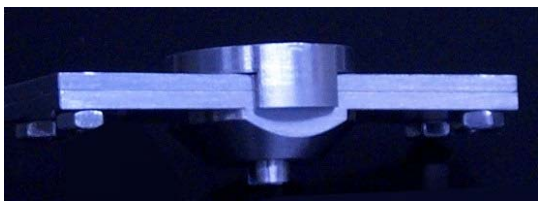
==> $E_{source,\Omega} \cong 160$ J / cm² of $EUV_{broadband}$ on mirror

Structuring possible with contact mask

Contact Mask insert available



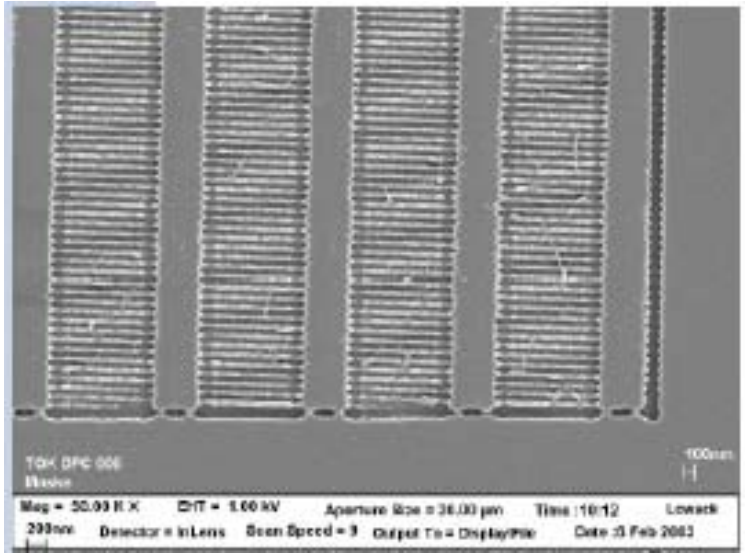


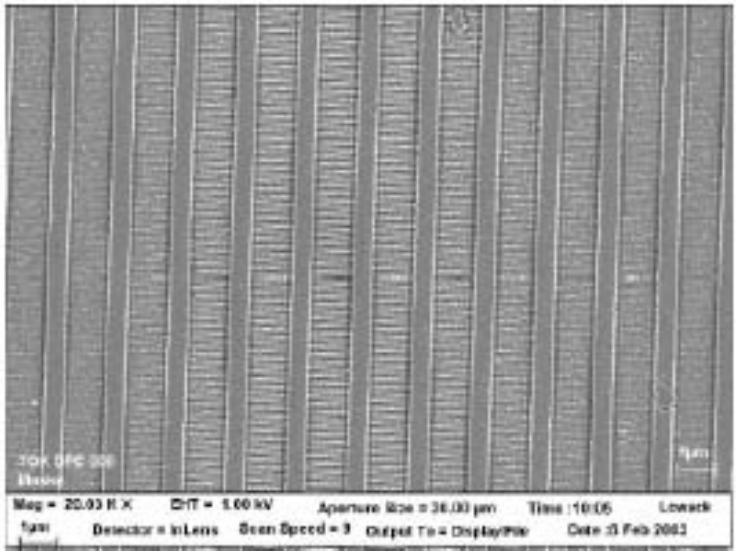


Down to 50 nm L/S

Customer Specific Masks can be supplied
(Elbows, Freestanding lines etc. from 500 nm down to 50 nm sizes).

Contact Exposures of 50 nm lines and spaces





- Feasibility of proximity printing with TEUVL and mask insert demonstrated
- 50 nm lines and spaces observed
- Stability of better than 50 nm was achieved over 50 minutes exposure
- Distance control difficult (physical limit)

$$N_f = \frac{1}{2\pi}\frac{k\,a^2}{L} = \frac{a^2}{\lambda\,L}$$

$N_f \cong 0{,}5$ for 100 nm resist and D=0

Thank You

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