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Fraunhofer Institut Lasertechnik

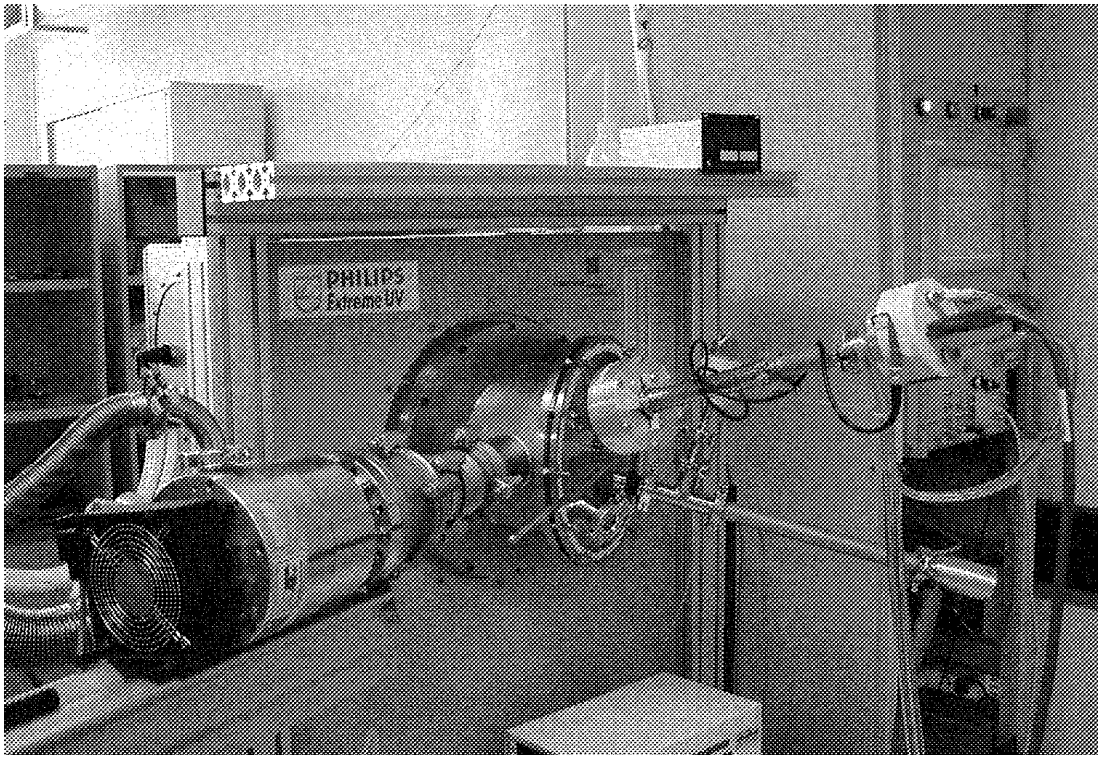
Philips Extreme UV:

a Joint Venture Between Philips and Fraunhofer Institute

Hollow Cathode Triggered Pinch Plasma Source for EUV Lithography

J. Pankert

Picture of sources

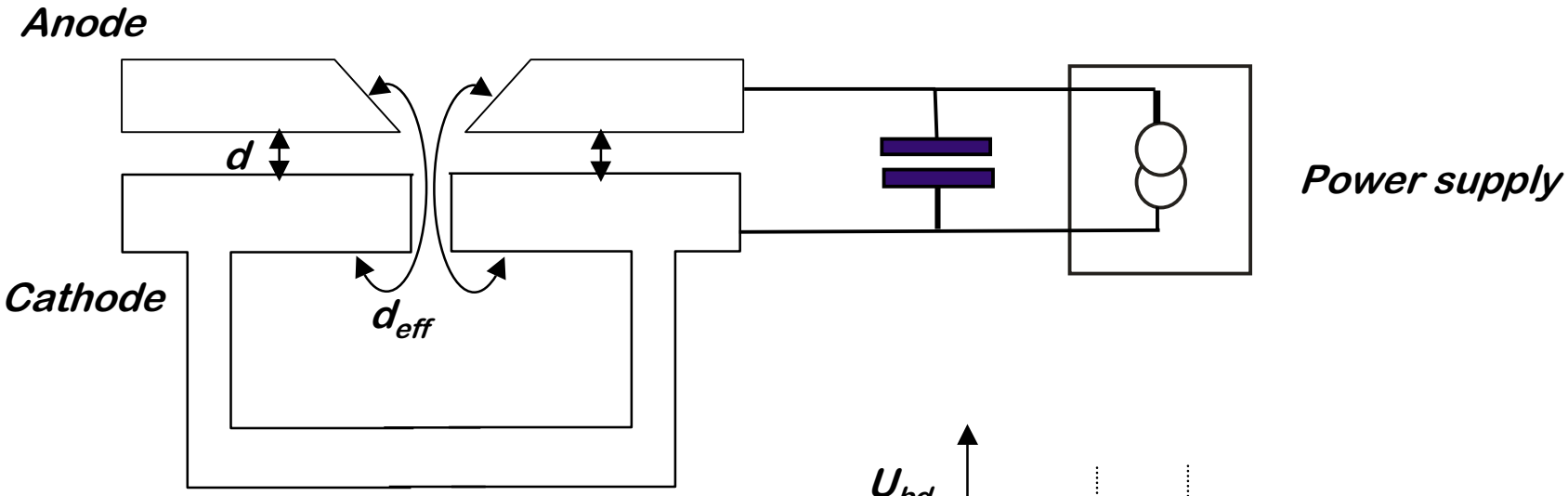


- Four high power sources with control functionality
- Two special purpose, low power sources

Outline

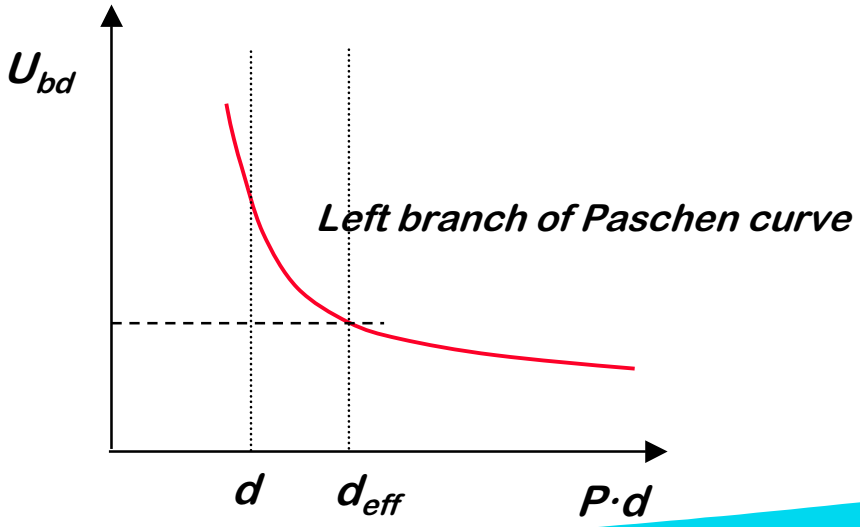
- Concept of the source
- Power scaling and stability
- Pinch size
- Spectral purity
- Roadmap

Concept of source: Principle of operation



- self breakdown mode
- low inductance design (few nH)
- pulses of few J

Phases of discharge:
- *ignition*
- *pinch phase*

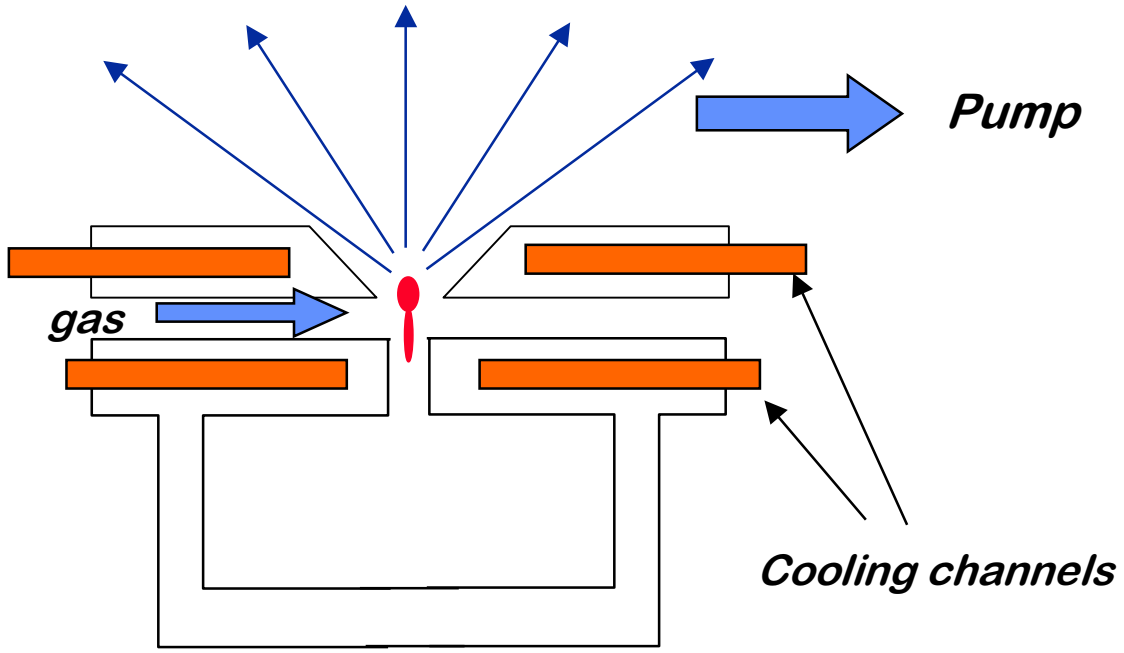


General design properties

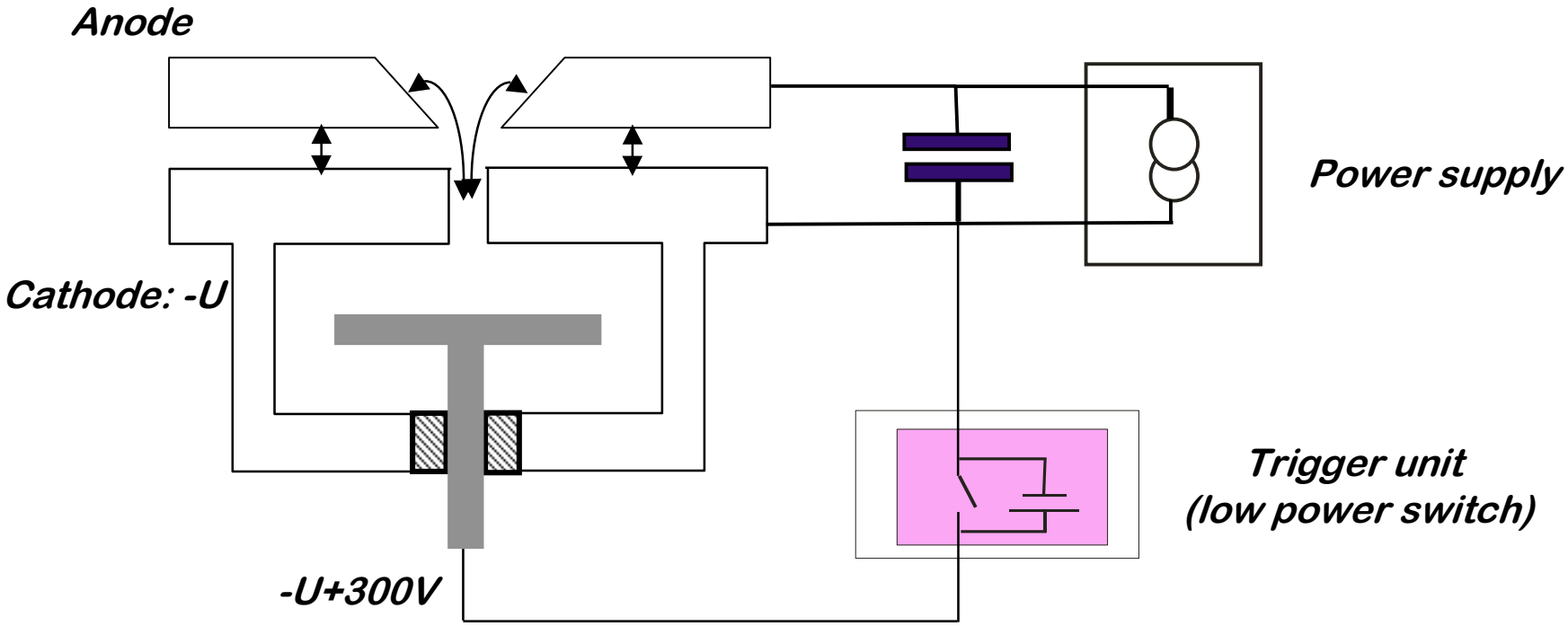
- Background pressure:
10^{-3}- 10^{-4} mbar

- Source opening:
up to π sr

- All metallic materials

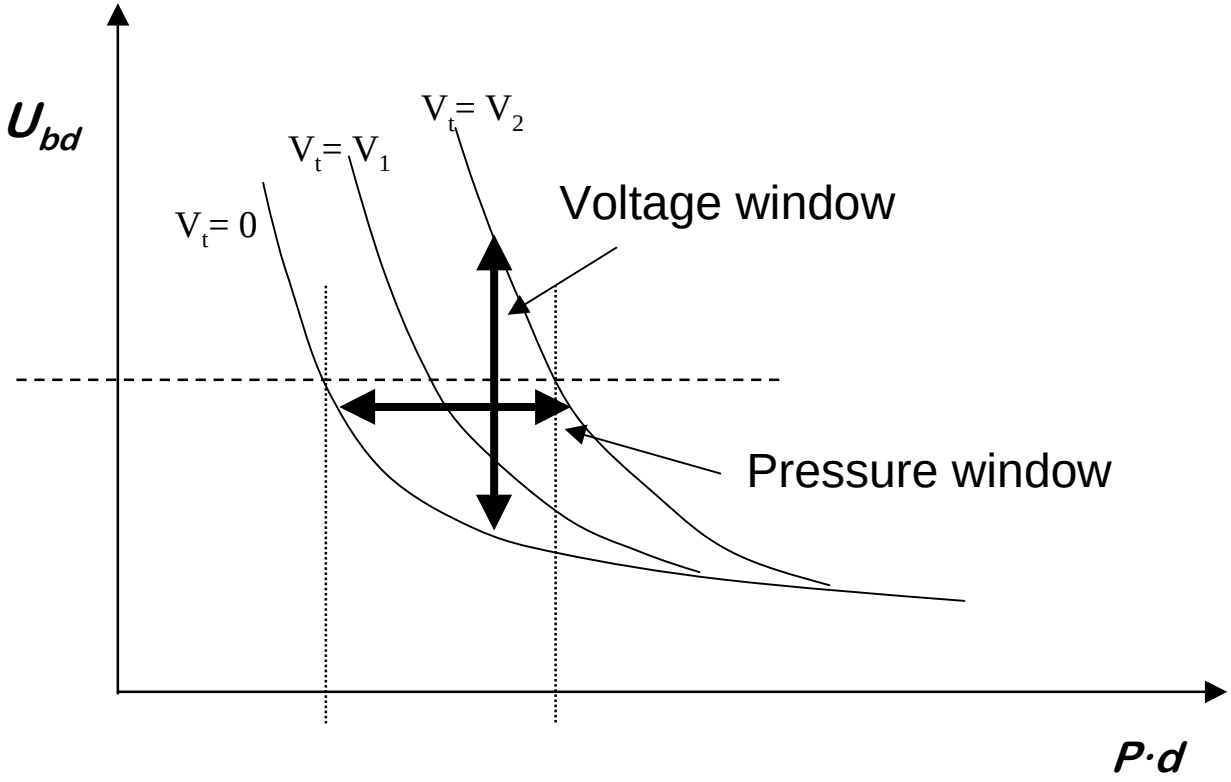


Triggering facility



Takes away the initial electrons

Triggering is key to open operation margins and precise timing



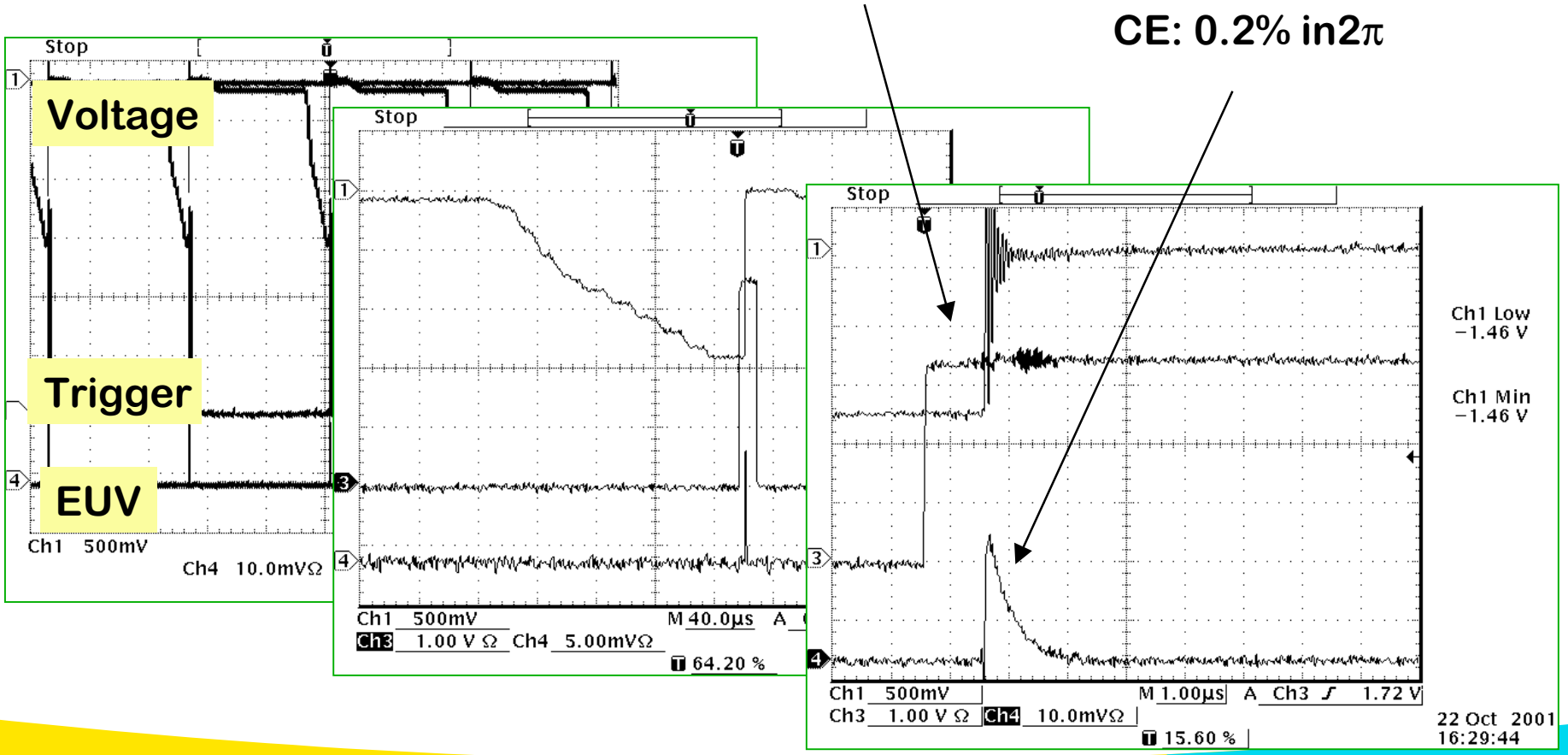
Power scaling

- Scaling of frequency and pulse energy
- Power supply
- Conversion efficiency
- Run-up behaviour
- Cooling
- Timing of pulses

Trigger operation

jitter <200 ns

CE: 0.2% in2π



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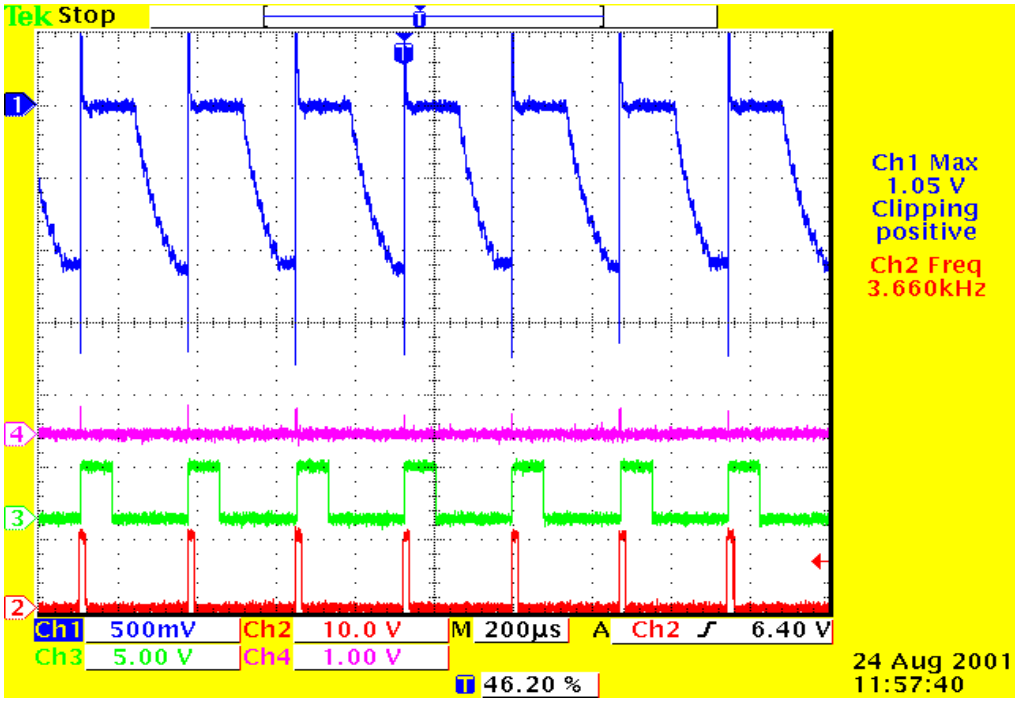
High frequency and power

voltage

EUV diode signal

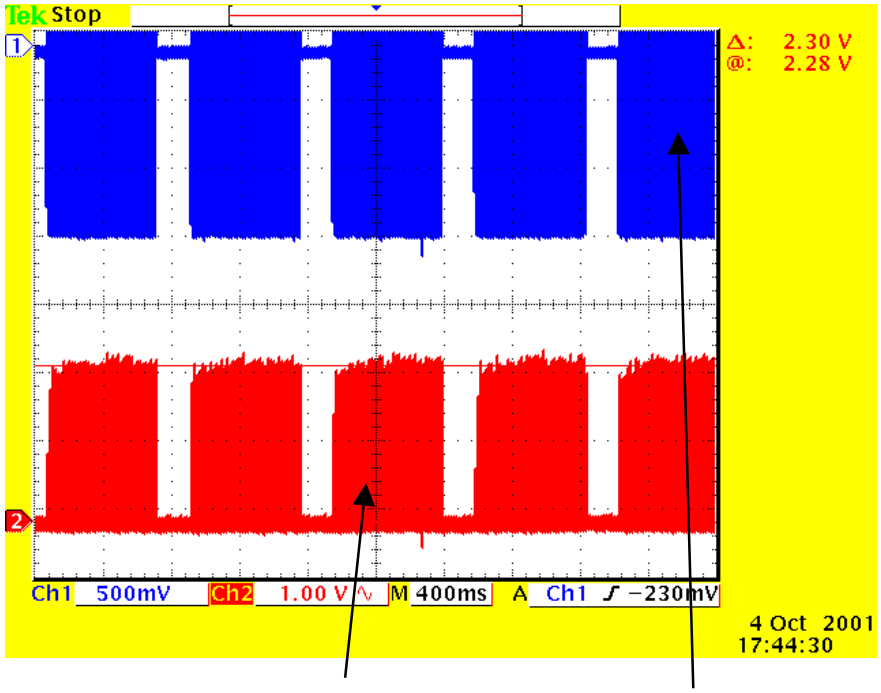
trigger signal

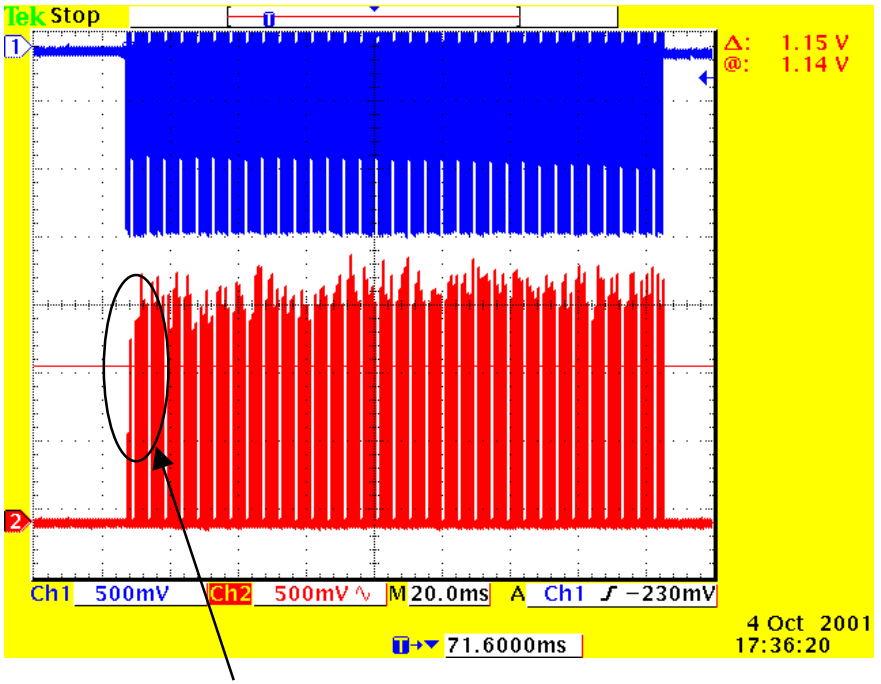


3660 Hz @ 3J pulse energy

(operation for few seconds)

Block wise operation





EUV signal

Voltage

Transient of 2 shots

Energy stability: 10% (1σ)

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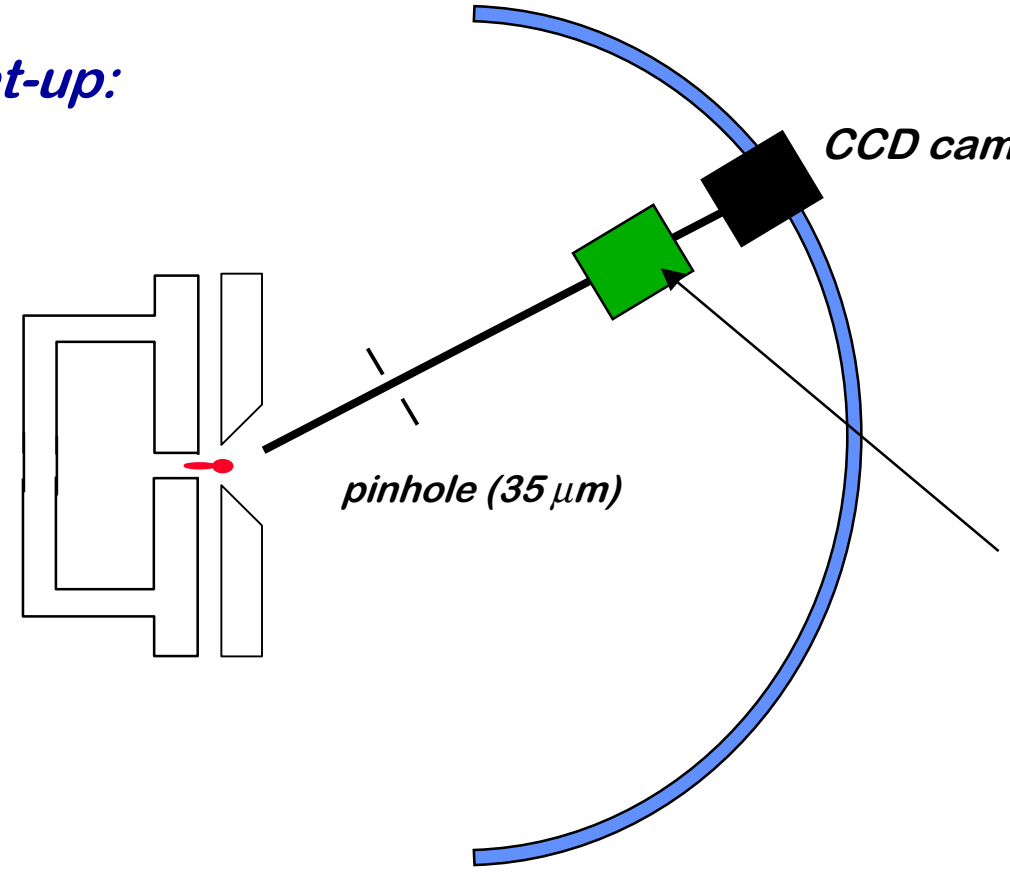
Cooling

- Water cooling in all the metallic electrodes
- Finite element modelling
- Thermal imaging for verification

- 30 kW cw input power feasible
- 90 kW input power with 1:2 duty cycle equally feasible

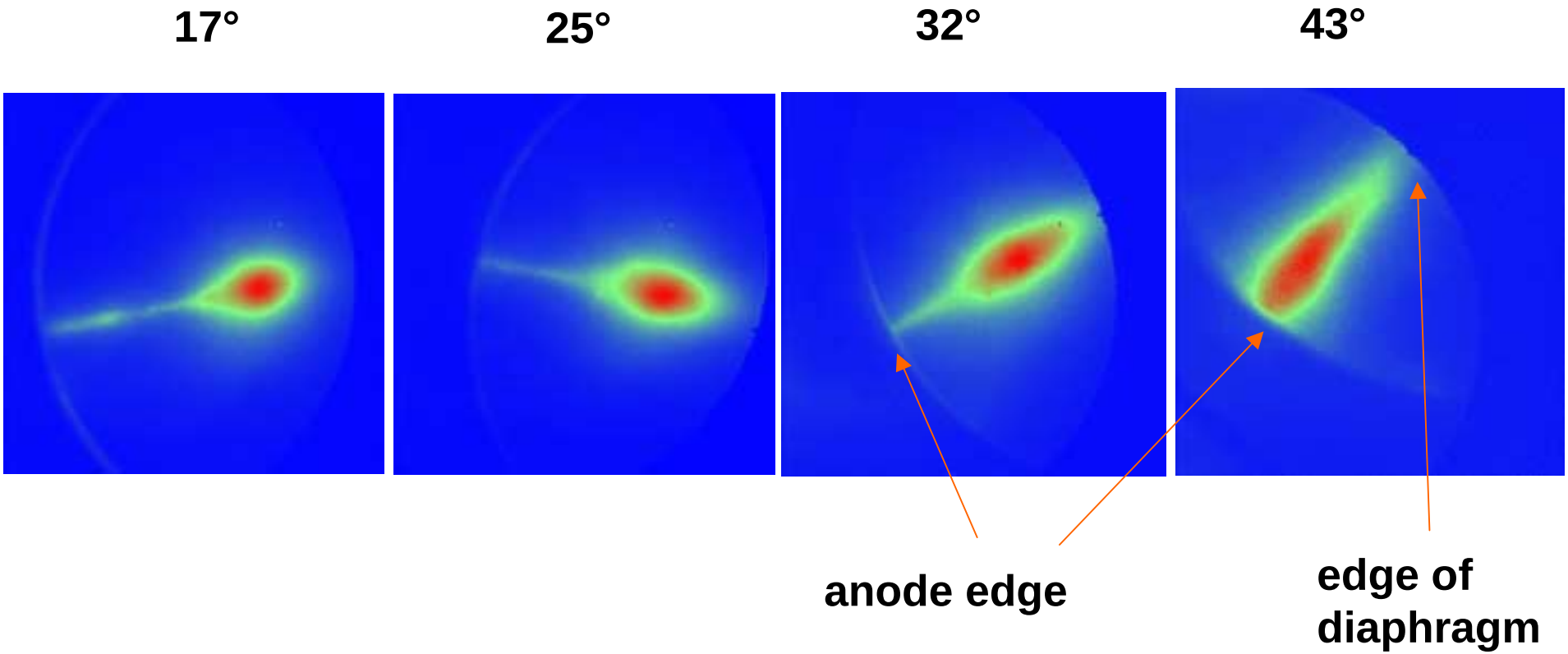
Pinch geometry

Set-up:

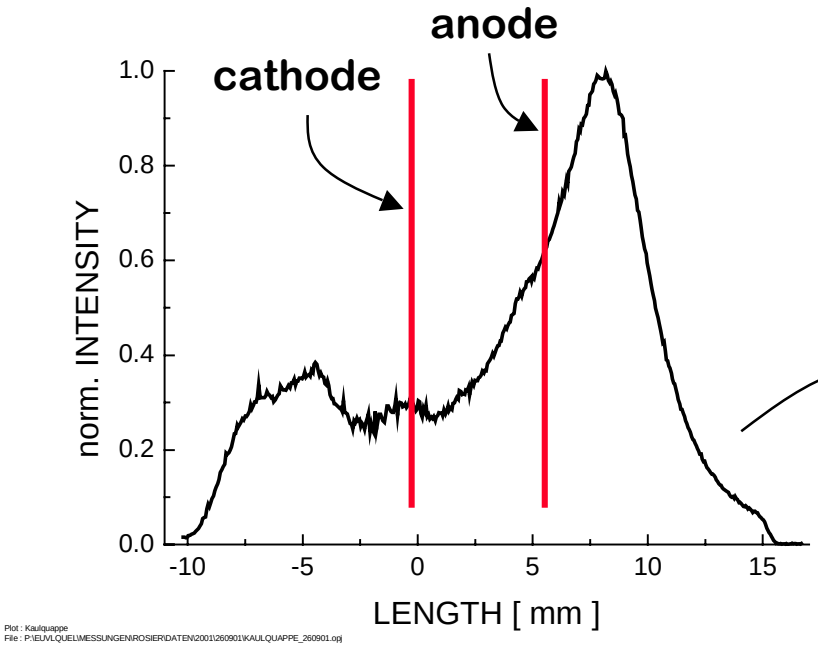


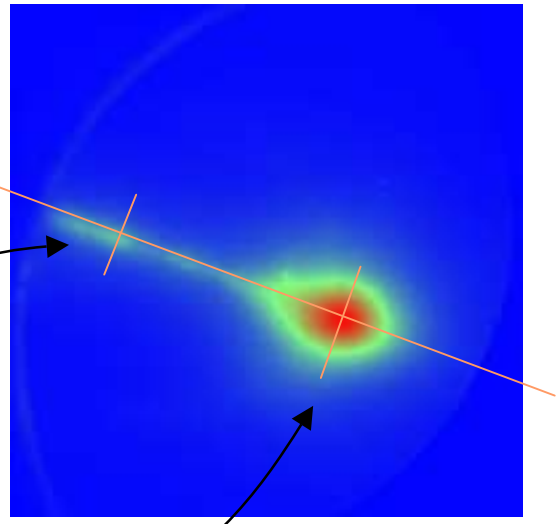
Filter box:
- **Zr filter**
- **multilayer filter**
- **CaF filter**
- **no filter**

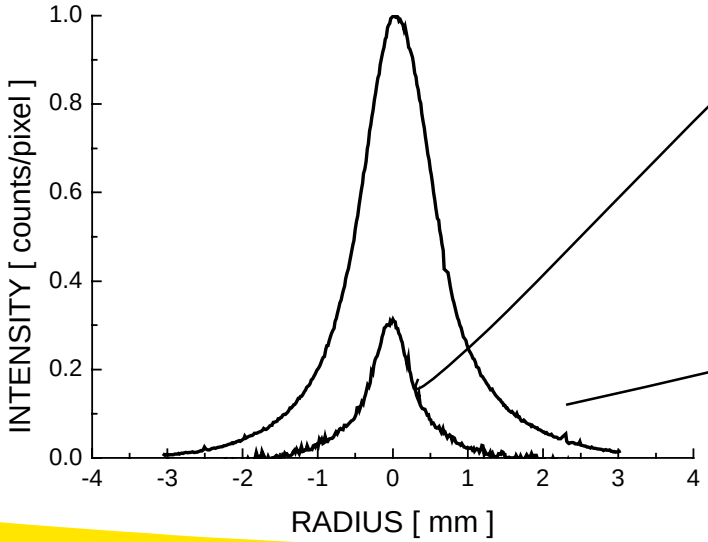
pinch geometry (average 200 shots, 5 J pulse energy)



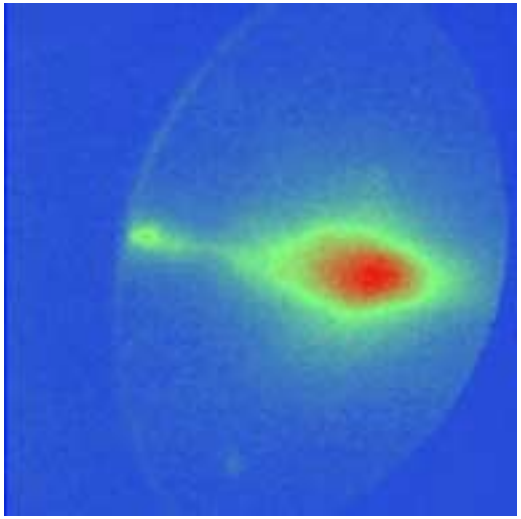
line scans:

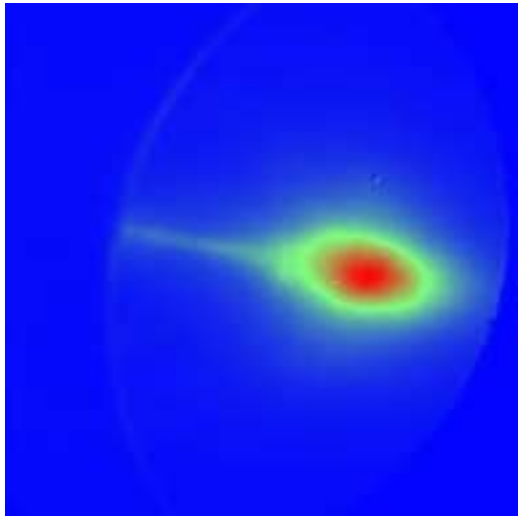

anode
cathode
norm. INTENSITY
LENGTH [mm]
Plot : Kaulquappe
File : P:\EUVLQUEL\MESSUNGEN\ROSIER\DATEN\2001\260901\KAULQUAPPE_260901.opj




INTENSITY [counts/pixel]
RADIUS [mm]
Plot : Radial
File : P:\EUVLQUEL\MESSUNGEN\ROSIER\DATEN\2001\260901\KAULQUAPPE_260901.opj

Single shot versus average

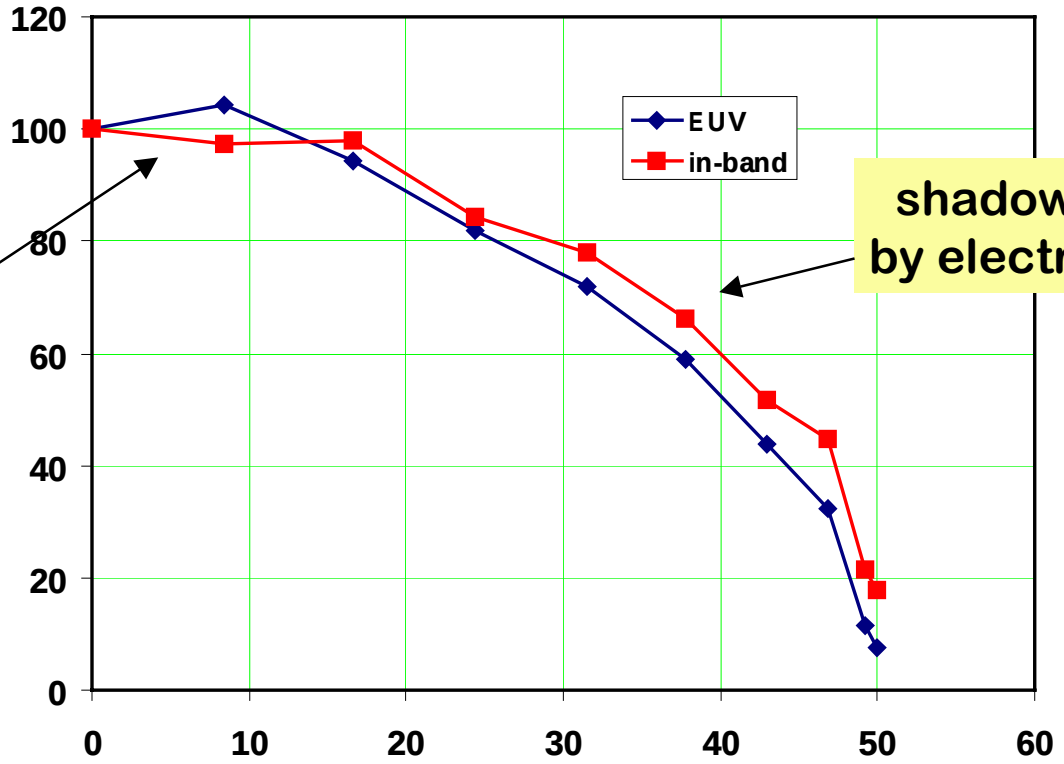




single shot without filter

200 pulses with Zr-filter (12.4-20nm)

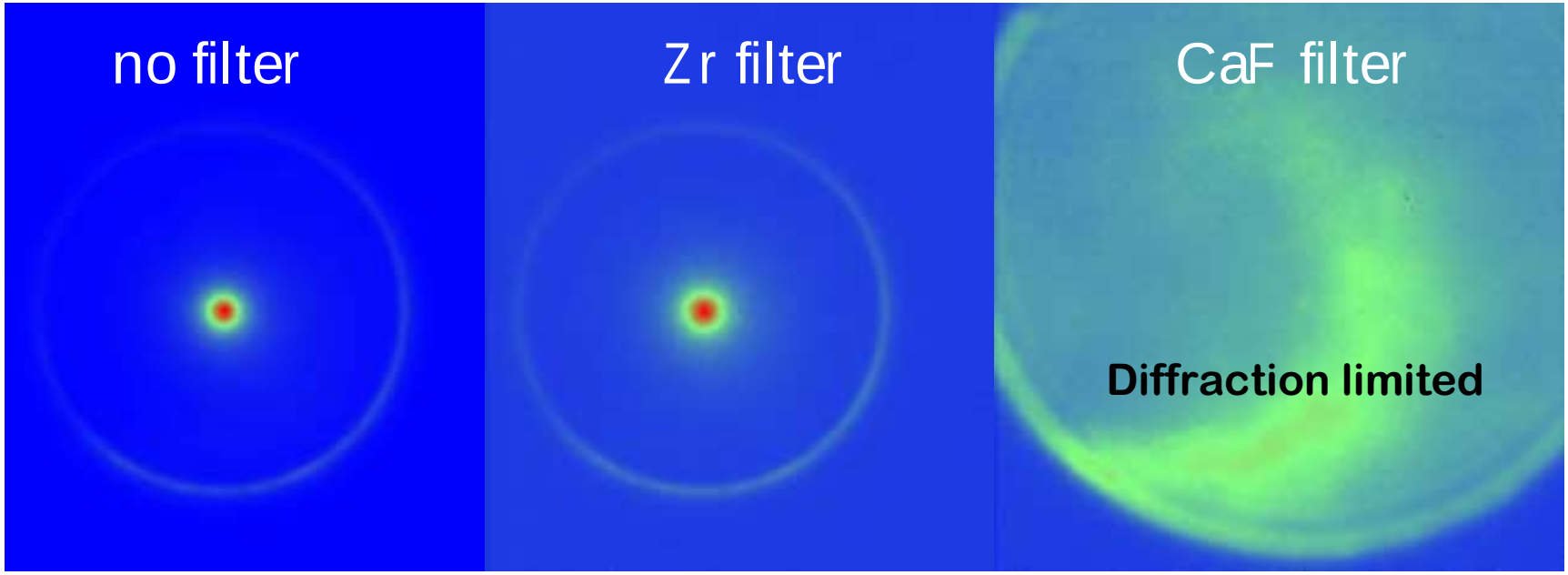
Angular dependence of total signal



radiation optically thin

shadowing by electrodes

CCD End-on measurement (35μm pinhole)



max. 160 cts/pulse max. 7.5 cts/pulse max. 0.1 cts/pulse

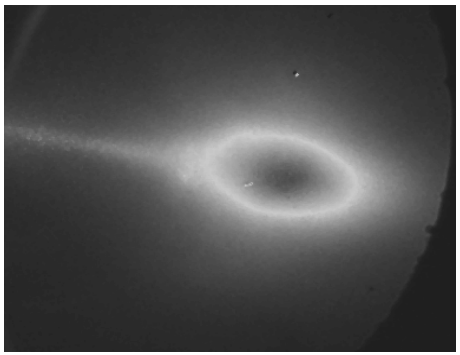
- no significant intensity > 130 nm (UV or visible)
- max. 50% of the radiation outside 11 - 16 nm
- out of band radiation mainly below 130 nm

Collectable power

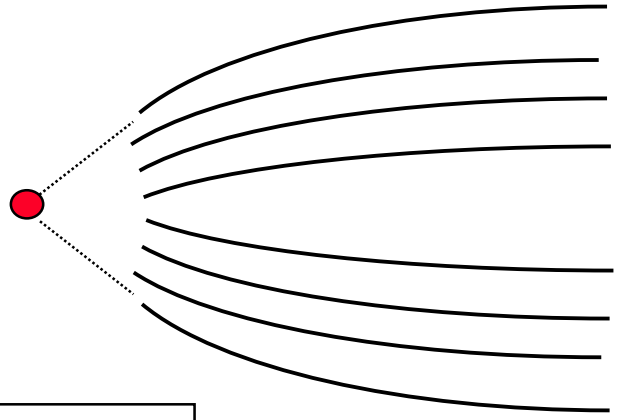
10 kW @ CE 0.2% in 2π means 20 W in-band power in 2π!

however:

Etendue limitation



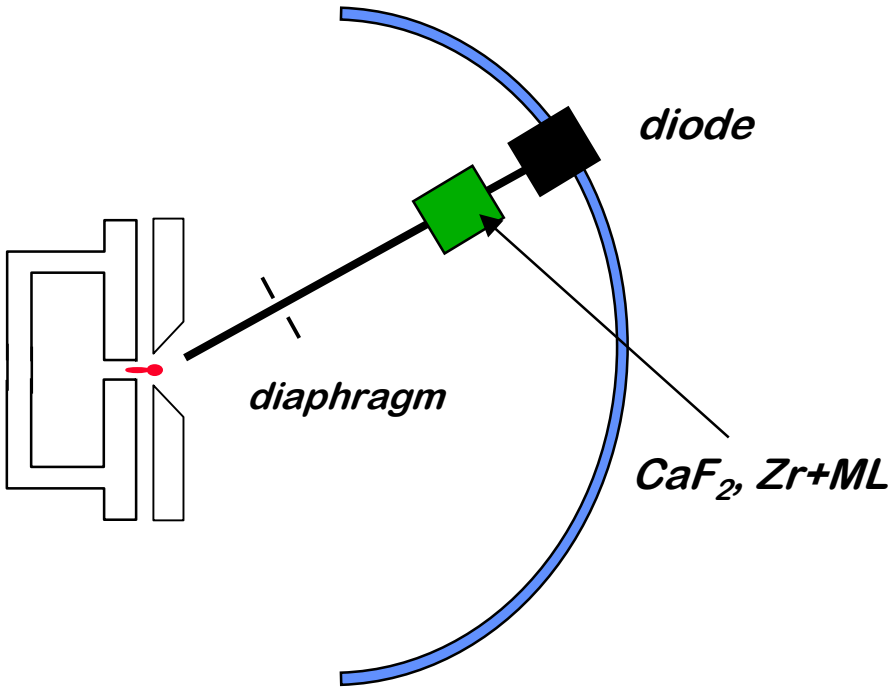
Typical collector opening 2sr



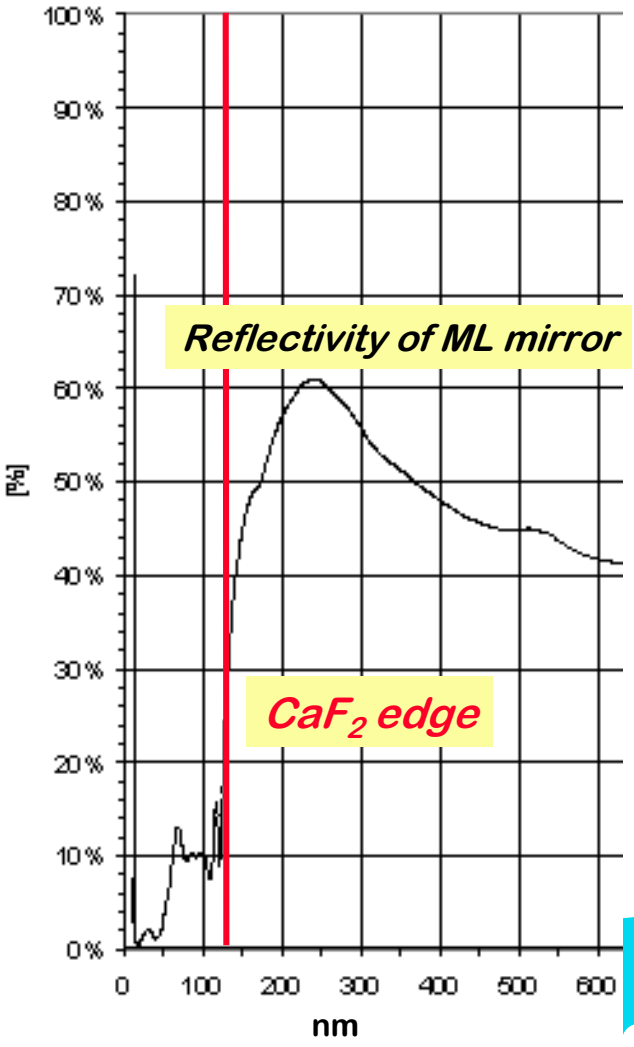
collectable power: ~ 2W

Property of source and optics

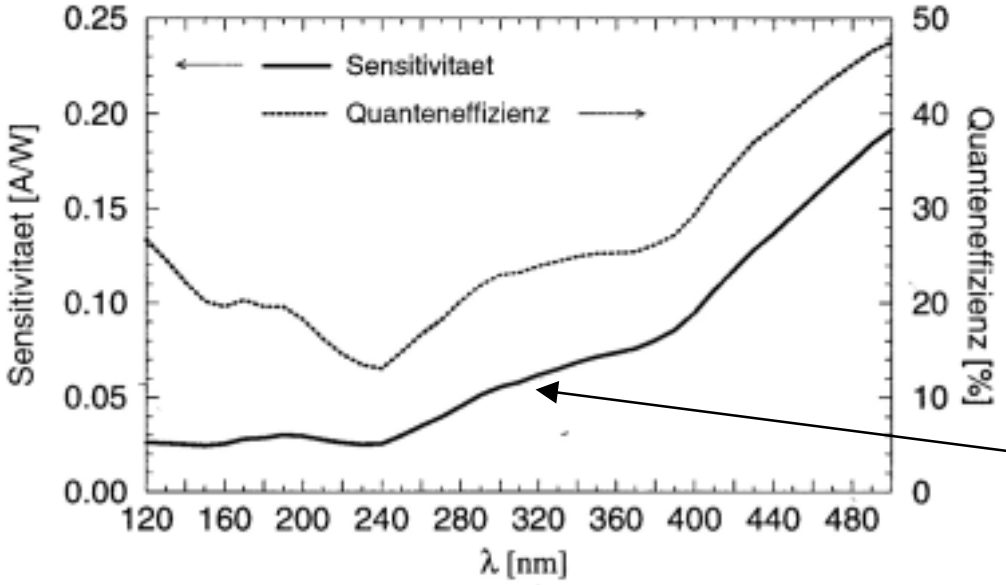
Spectral purity: A filter costs 50% of the energy



diaphragm diameter:
1. Open
2. Cut-out of source volume



DUV + visible spectrum unknown
worst case assumption: All the energy is at 130 nm



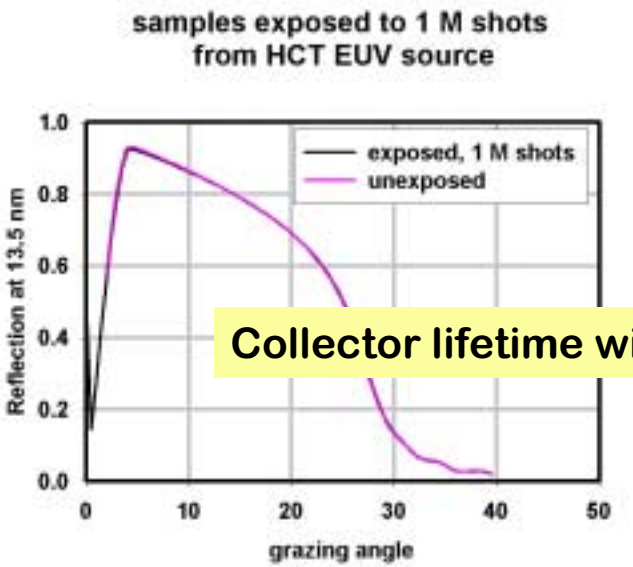
Diode Sensitivity

(DUV+vis)/in-band EUV: ~ 150% over total volume
~ 10 % in source volume

spectral purity filter not necessary

Long term stability

Erosion of electrodes is a problem!



Collector lifetime without mitigation

Electrode life time:

- traces of erosion visible after 10^8 shots
- 10^{11} shots serious challenge

Roadmap power:

2W @ 10 kW input

collection efficiency ×2

conversion efficiency ×2

input power ×3

= 24 W @ 30 kW cw input
=72 W @ 90 kW input 1:2 duty cycle

We may have to resort to another radiator (Li, Sn)!

Acknowledgement:

W. Neff, K. Bergmann, O.Rosier, S. Seiwert, J. Klein, Ch. Smith, R. Prümmer, G. Derra, Th. Krücken, P. Zink, E. Bosch, M. Guguan, B.v.Rens, J. Jonkers, R. Apetz, M. Löken