Power Scaling of DPP Source for EUV Lithography: Xe or Sn?*

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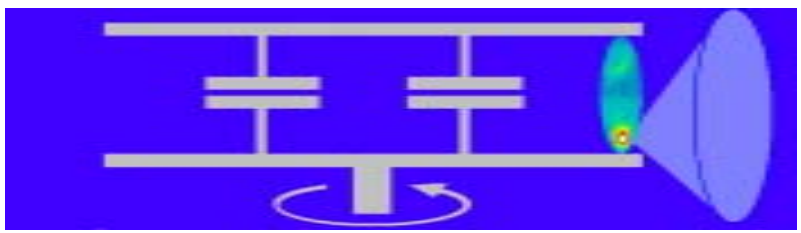

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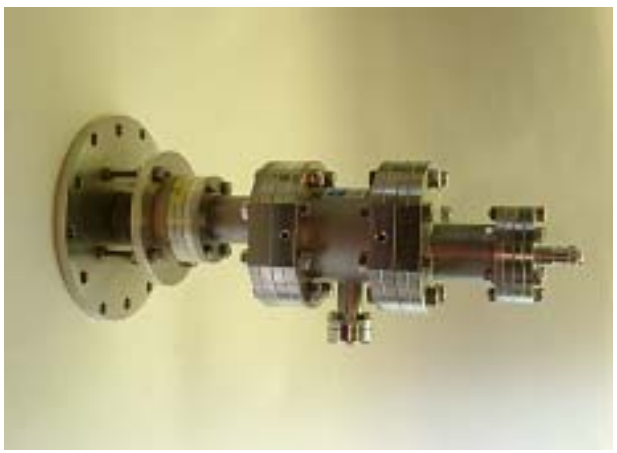
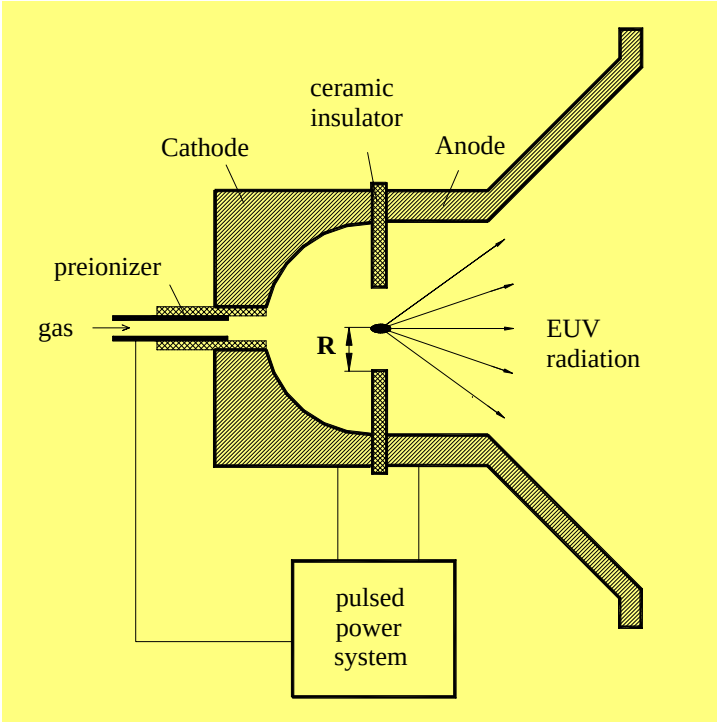
Xe DPP source with single discharge unit and EUV measuring instruments

Pinhole camera developed in cooperation between XTREME technologies GmbH and Laser Laboratorium G?ttingen to measure an EUV image of the pinch

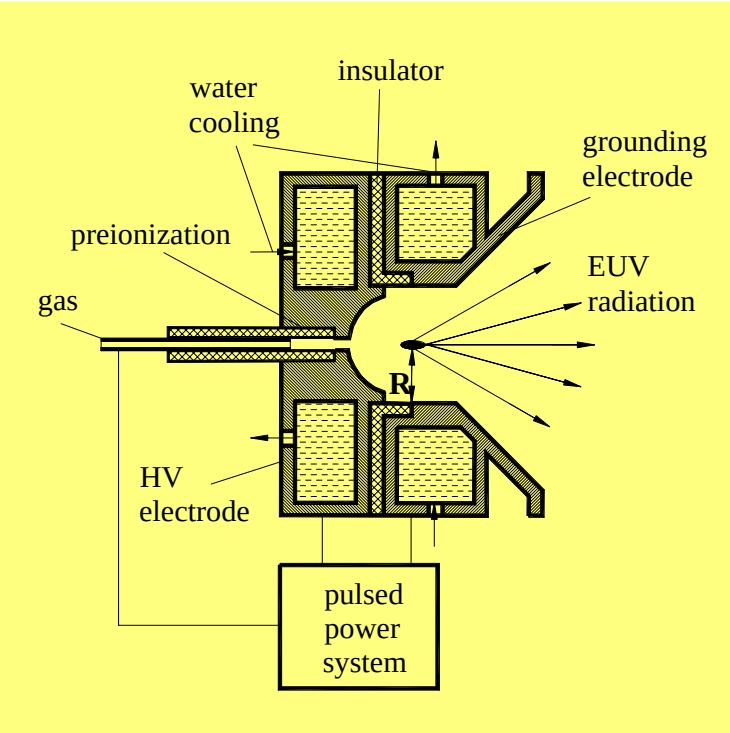


Calibrated EUV energy measuring instrument made in Jenoptik Mikrotechnik, Jena

Single discharge unit at increase of plasma-to-wall distance



Electrode configuration I

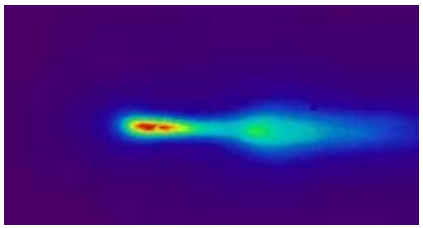


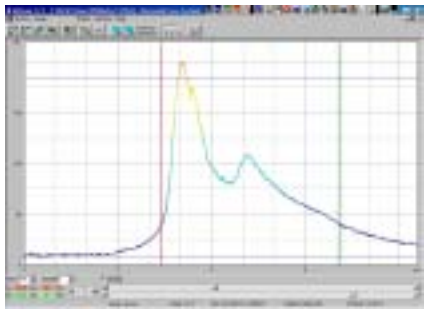
Electrode configuration II

If CE≈0.5% (intrinsic CE≈1.2%), 115W at IF means about 100 kW power into discharge. It will be resulted to very high surface heat load on wall. The way to reduce the surface heat load on wall is an increase of plasma-to-wall distance which is limited by optimal input energy and pinch length.

Metamorphosis of the pinch length in Xe DPP source

Pinch length is very sensitive to small changes of discharge conditions

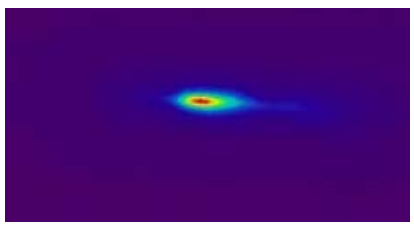


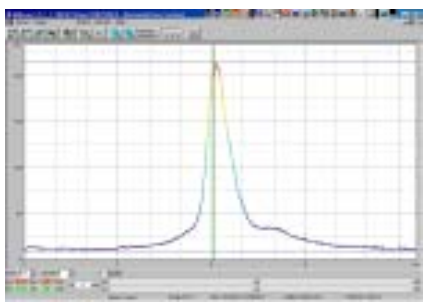


Pinch length averaged on 20 pulses at 1000 Hz

2.2 mm (FWHM)
9.8 mm (1/ e^2)

Minimal pinch length

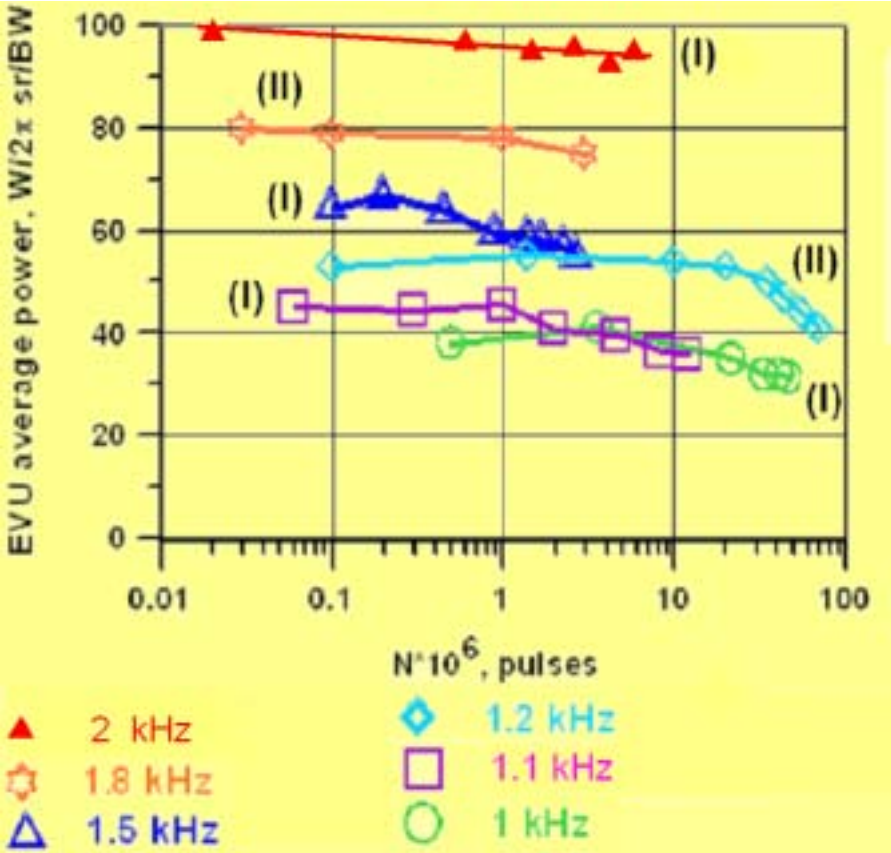




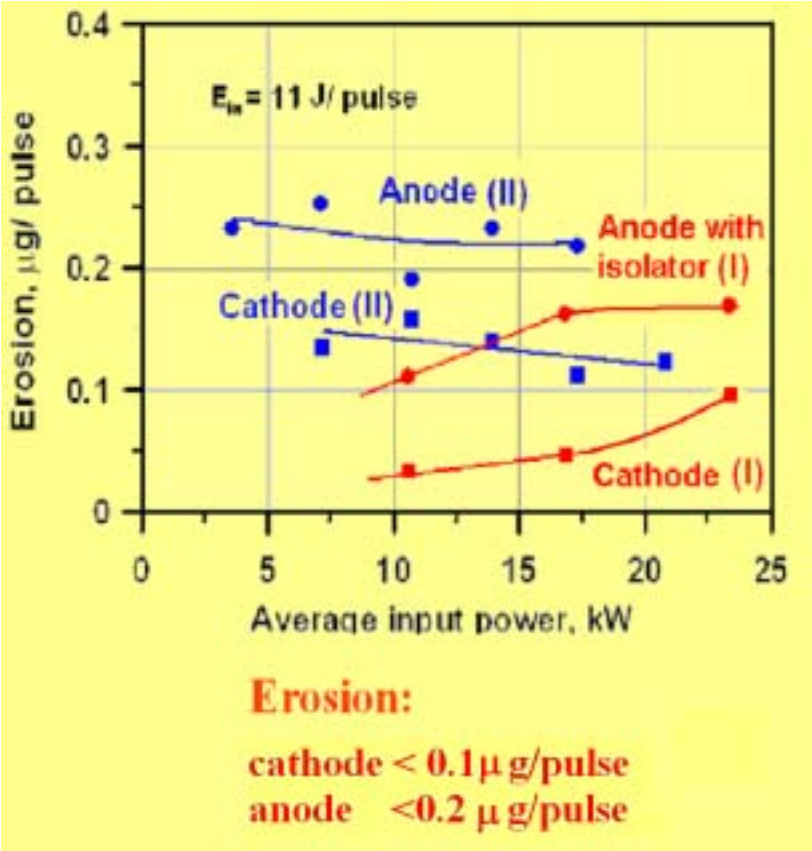
1.4 mm (FWHM)
3.1 mm (1/e^2)

DPP source with Xe: long term tests

EUV average power measured at distance of 1.2 m



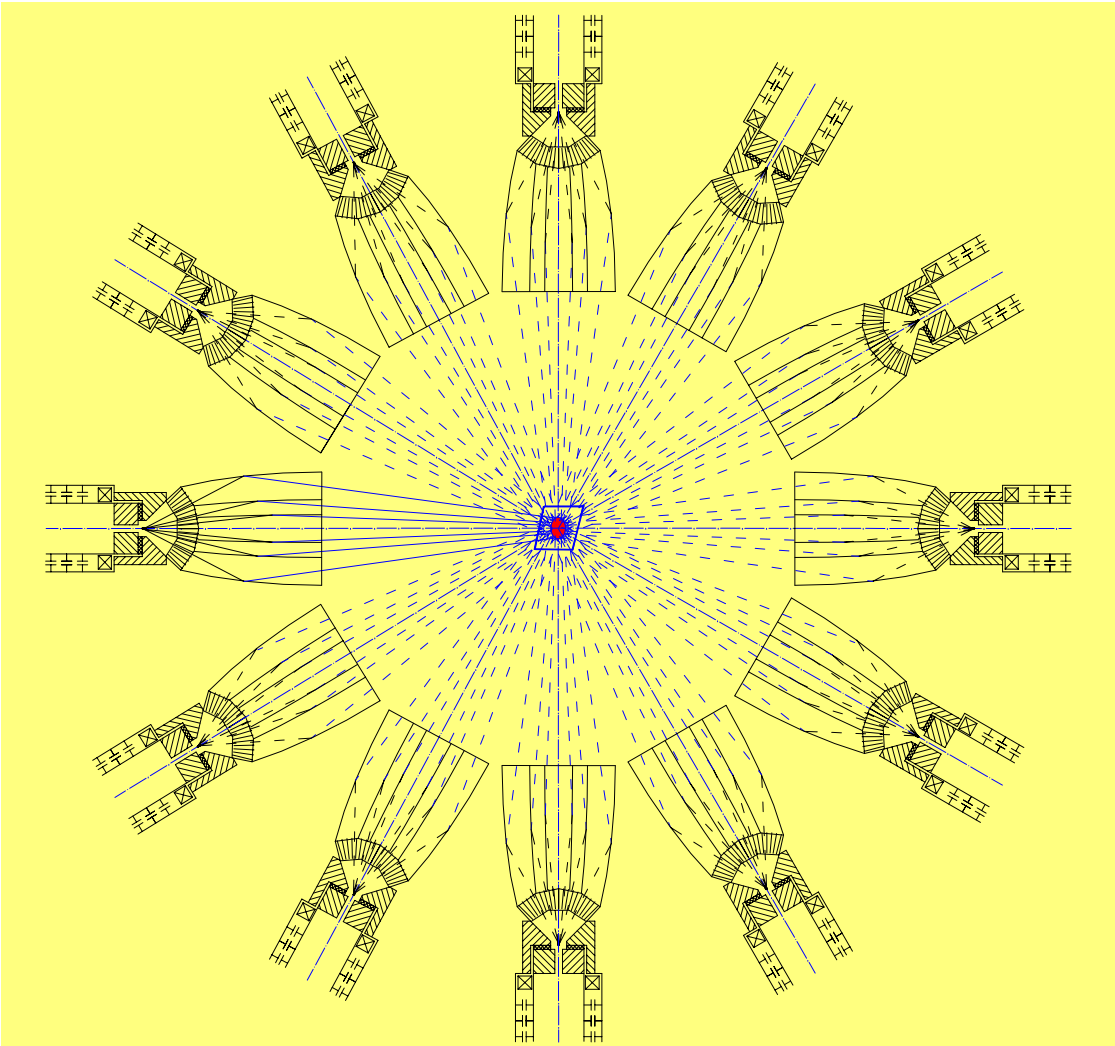
Electrode erosion



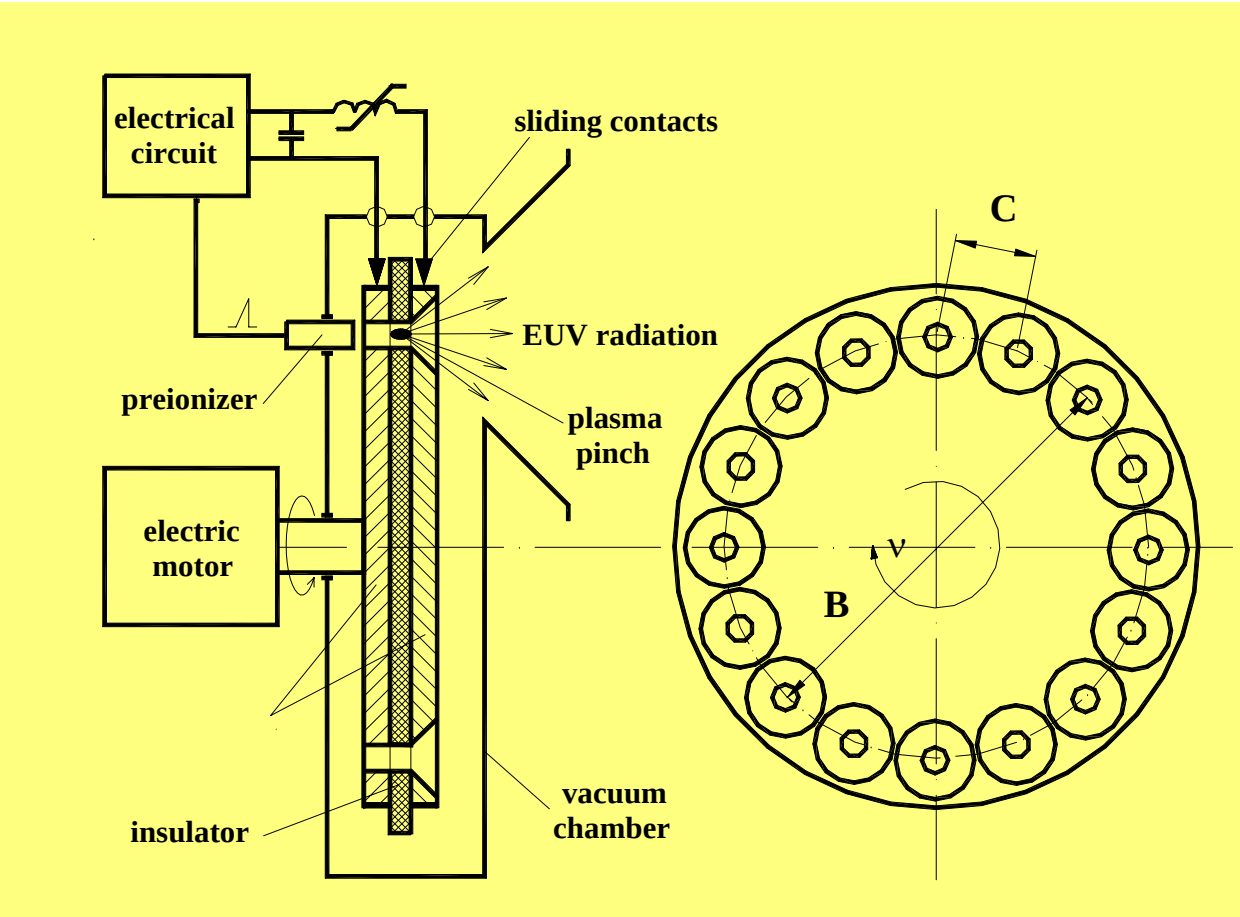
Input power up to 23 kW

EUV power just near the plasma up to 250 W/ 2π sr/ 2%BW

Multi discharge units source with rotating mirror



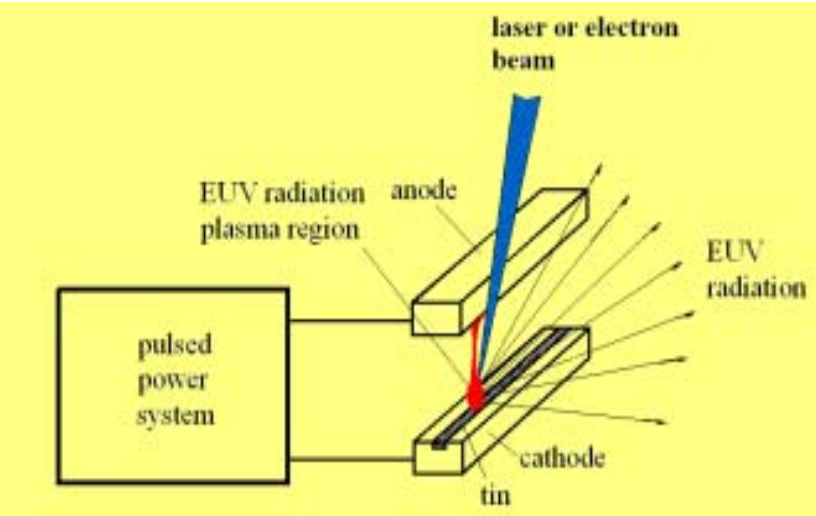
Rotating multi discharge units source

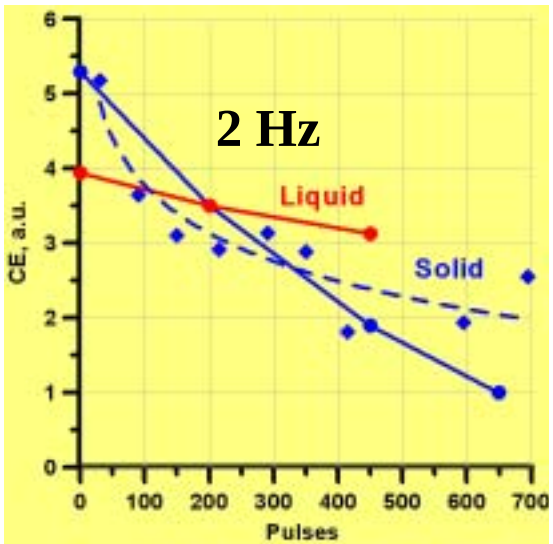


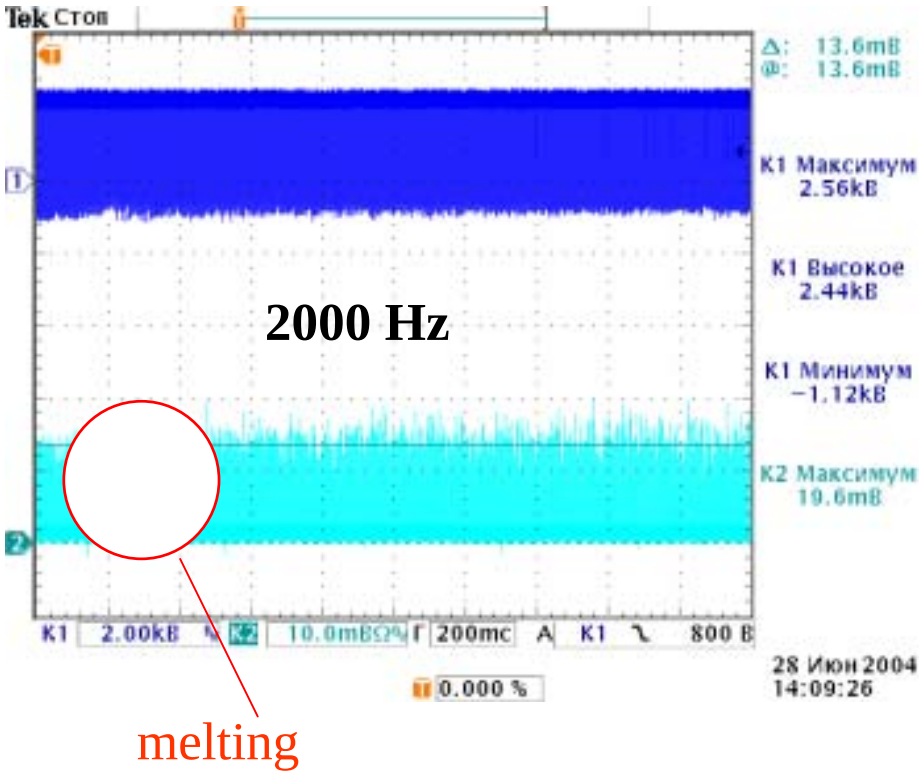
If f=10 kHz,
C=3 cm
B=0.5 m
$\nu = f \cdot C / \pi \cdot B = 200$ rev/sec

Borisov et al., Russian Patent Application Number 2002120301.

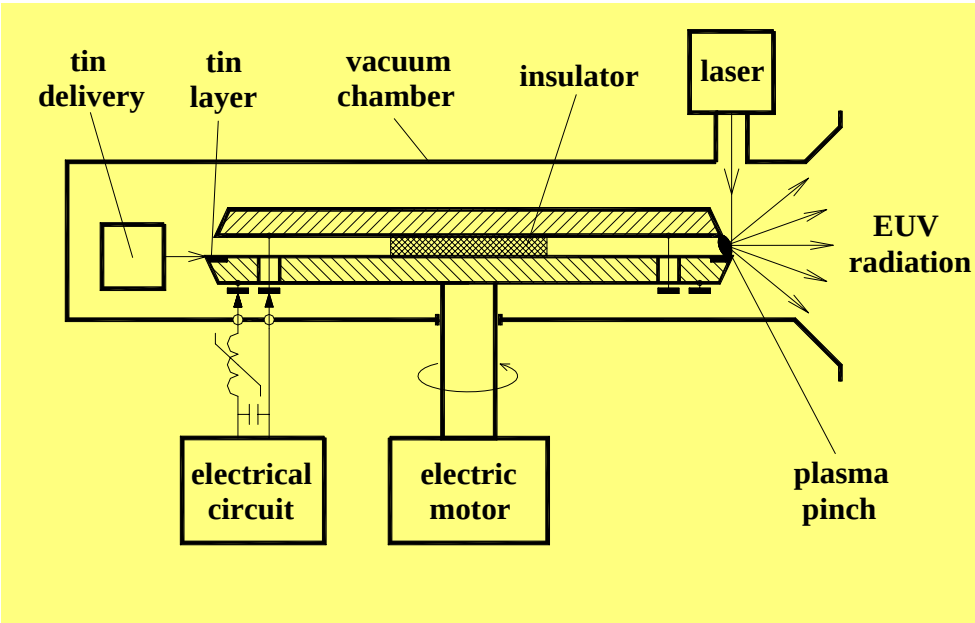
Edge electrode configuration in DPP source with Sn vapour initiation by KrF laser







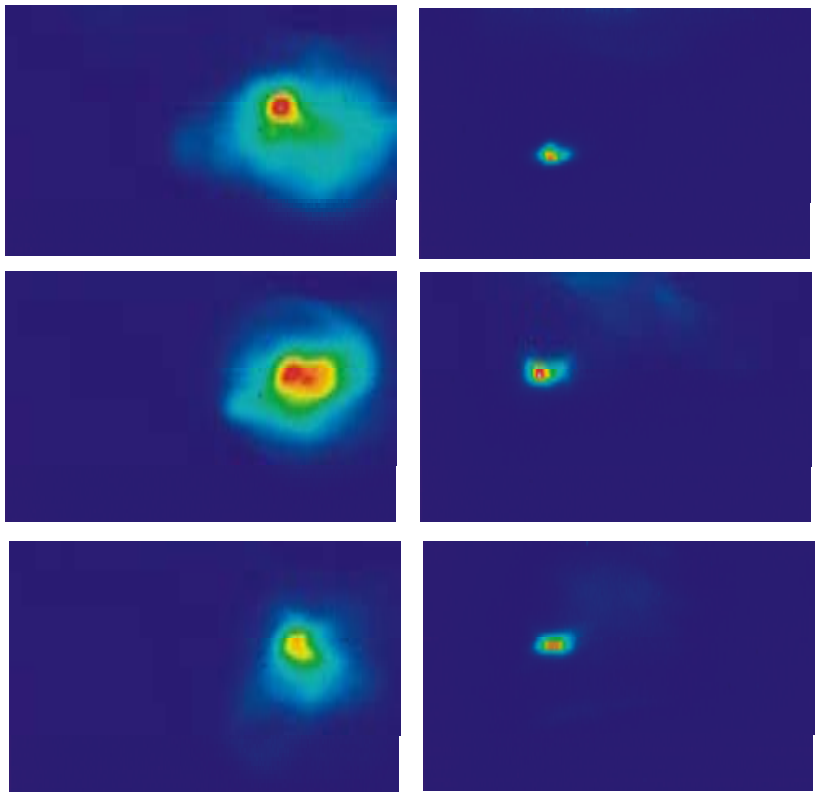
Rotating disc electrodes (RDE) Sn EUV source



Borisov et al., Russian Patent Application Number 2004111488.

Plasma size in DPP source with Sn vapour initiation by KrF excimer laser

HV anode HV cathode

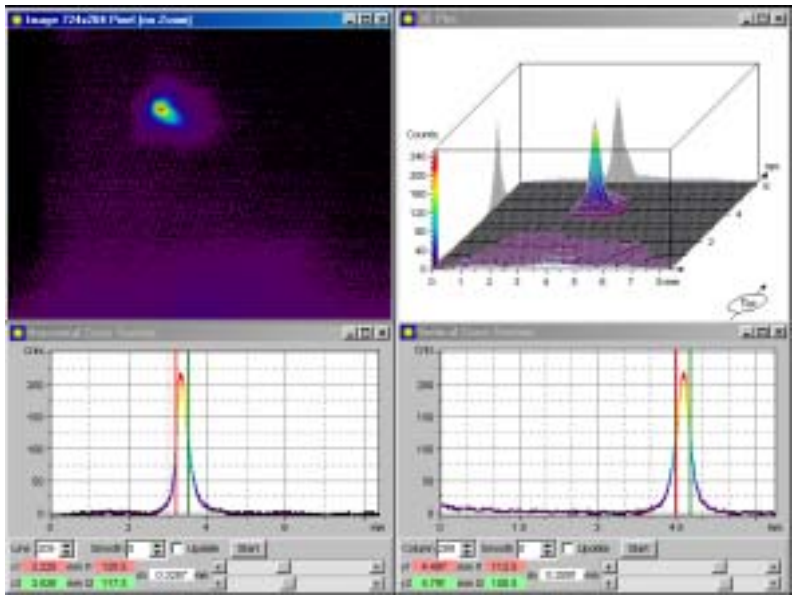


E_{laser}

48 mJ

33 mJ

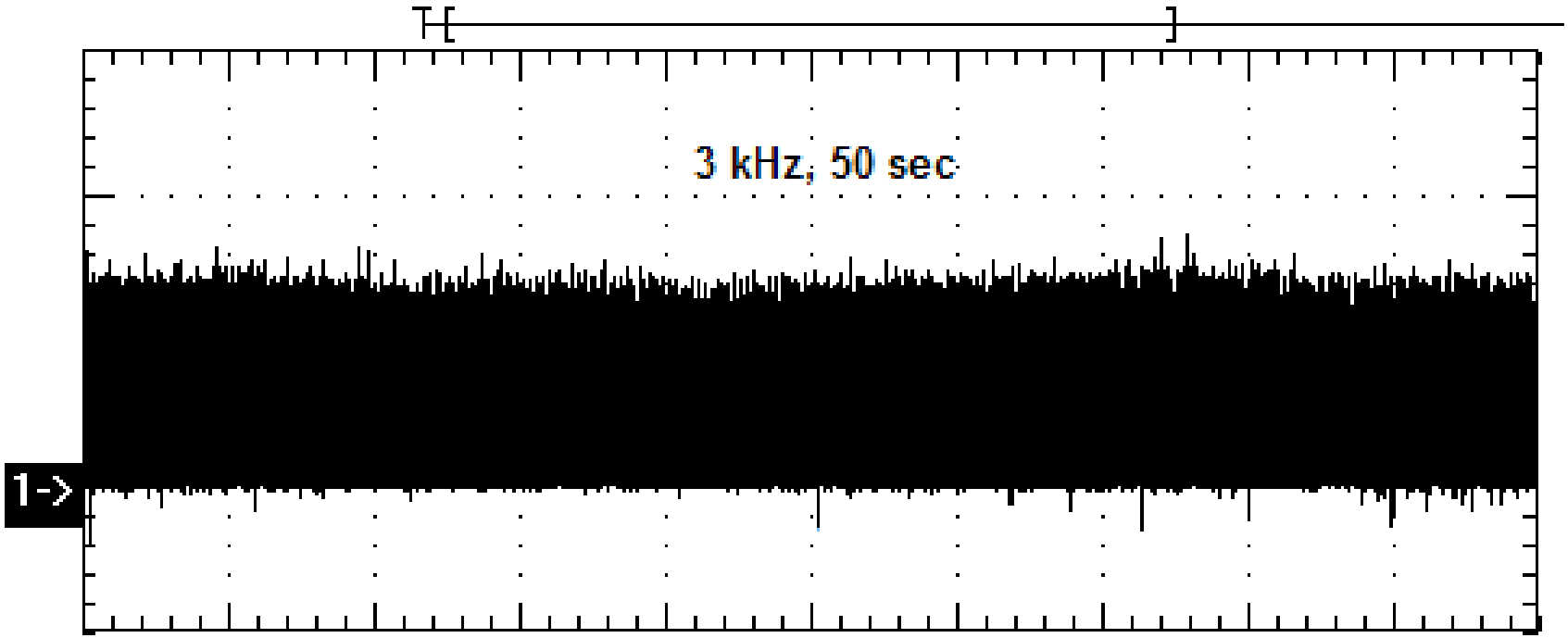
20 mJ



0.29 mm x 0.54 mm (FWHM)
0.62 mm x 1.08 mm (1/?^{2})

Operation of RDE EUV source with melted Sn

180 W/ 2%BW in 2π sr measured at distance 1.2 m from Sn plasma



Summary and conclusion

1. The highest in band output power at continuous repetition rate of 2000 Hz is around of 100 W/2% BW in 2π sr measured at distance 1.2 m from Xe plasma, it corresponds 250 W just near the plasma.

2. In order to decrease a heat load on both electrode and ceramic surfaces the DPP source with plasma-to-wall distance about 10 mm with acceptable short pinch length and input energy ≤ 10 J have been developed.

3. Various methods of Sn vapor production were studied. CE around of 2% was obtained with the use of focused KrF laser beam or electron beam.

4. Main progress has been made on development of the Rotating Disc Electrodes (RDE) Sn source based on non-axial symmetric (edge) electrode configuration.

4.1. 180 W (2% BW in 2π sr) measured on the distance 1.2 m from the plasma pinch at 3 kHz was demonstrated.

4.2. The plasma pinch has extremely small size: 0.29 mm (FWHM), 0.62 mm ($1/e^2$) in diameter and 0.54 mm (FWHM), 1.08 mm ($1/e^2$) in length.

Concept of RDE Sn source opens the principal way to reduce thermal load on electrode and provide required lifetime. Obtained results make the concept of RDE Sn source very attractive for next study to meet high volume manufacturing specification.