

One Watt EUV Production by 80cm Outer Diameter Tabletop Synchrotron MIRRORCLE-20SX



Practical way to 100 W, high efficiency, and small emittance EUV source



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- MIRRORCLE-20SX is a EUV and Soft X-ray source for lithography and LIGA process
- Small electron storage ring of 80 cm OD, 45 cm high magnet body
- EUV beam is generated using a thin foil target placed in the synchrotron orbit.
- Necessary power: 100kVA

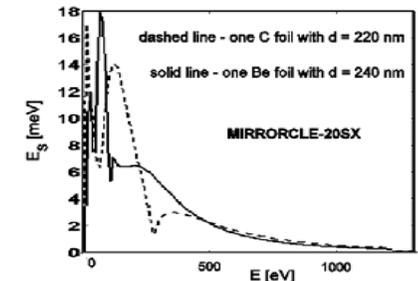
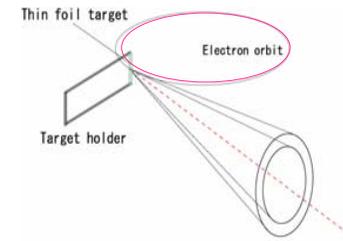
Machine parameter

Synchrotron:	weak focus
Magnet OD:	80 cm
Central orbit radius:	15 cm
Weight:	~2 tons
Frequency:	2.45 GHz
Klystron:	10 kW
Injection repetition rate:	400 Hz
Microtron:	classical
Magnet OD:	1.3 m
Weight:	~2 tons
Electron energy:	20 MeV
Beam peak current:	100 mA

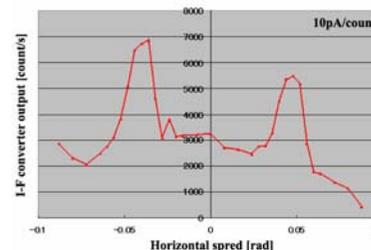
Transition radiation scheme

Transition radiation (TR) occurs when an electron passes through a boundary between two different media. TR has emission angle of $1/\gamma$. The spatial distribution of TR is corn shape.

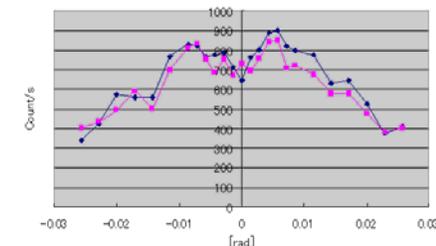
Critical photon energy is $\gamma \hbar \omega_p$



20MeV electron beam and thin foil target of hundreds nm are useful to generate soft x-ray and EUV.



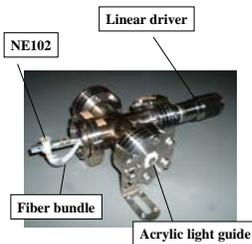
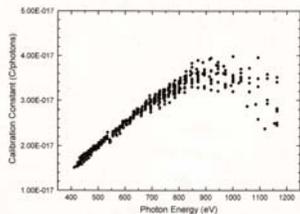
EUV angular distribution with MIRRORCLE6X



Angular distribution with MIRRORCLE20SX



Detector calibration is made by the service offered by AIST synchrotron light source .



NE102 detector is only sensitive to EUV and soft X-rays

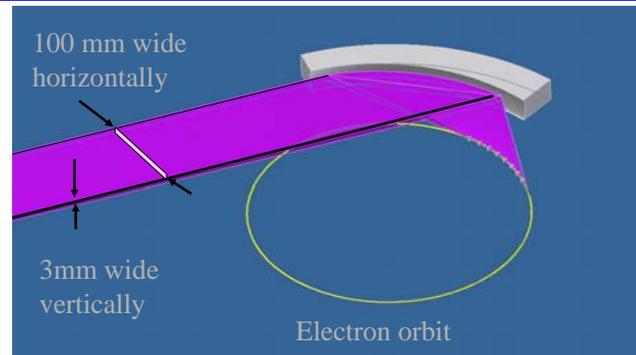
Observed EUV total power
 with MIRRORCLE-6X: 2.9 mW
 with MIRRORCLE20SX: 0.6 W

Summary for experimental results

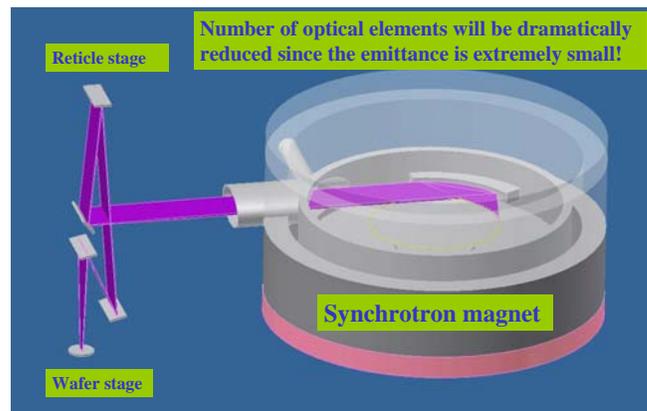
The MIRRORCLE-20SX is a EUV ~ soft X-ray source using a thin foil target which enables to generate transition radiation.
 The observed angular distribution is ± 15 mrad for MIRRORCLE20SX, which indicates $7 \times 10^{-4} \text{ mm}^2 \text{ rad}^2$ emittance for 1mm width foil. This must be a big advantage for EUV lithography
 In total power 2.9 mW is observed with MIRRORCLE-6X.
 0.6W is observed with MIRRORCLE-20SX.

60 W EUV source design

- Use 100 of thin foil target > 60W
- Use a magic mirror (quasi ellipsoidal mirror)
- Thin parallel beam is produced. The emittance is the 100 rays of $7 \times 10^{-4} \text{ mm}^2 \text{ rad}^2$
- Beam is shaped in 3 x 100 mm wide

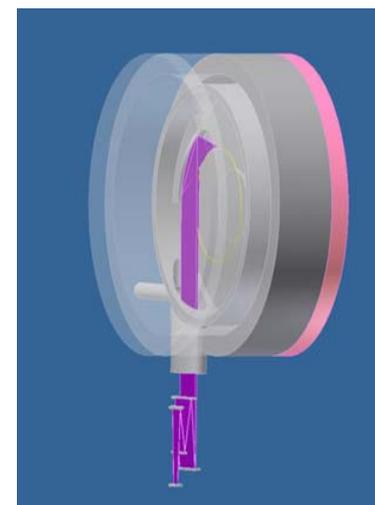


4 optical elements will be enough because our EUV emittance is extremely small



Number of optical elements will be dramatically reduced since the emittance is extremely small!

- Band width 5.4% > 600mW
- Total reflection coefficient: 18% by 4 multi-layer mirror
- >100mW / 25mm² on wafer
- Irradiation field is exact rectangular of 1 x 25 mm² on wafer
- 4 times projection
- Exposure time: 3 sec/wafer

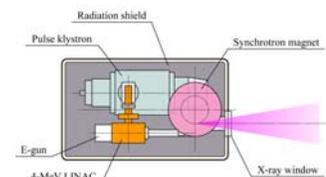


MIRRORCLE type tabletop synchrotron makes near future of lithography

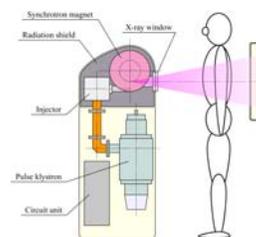
We are the company well experienced with manufacturing many tabletop synchrotrons: www.photon-production.co.jp/e/PPL-HomePage.html



CV4 for non-destructive testing



CV1 for medical diagnosis



20SX for protein crystallography



6X for life science

