High Aspect Ratio LIGA Apertures in an X-ray Pinhole Camera

L. Bobb

L.M. Bobb and G. Rehm, ``Beam Size Measurement Using High Aspect Ratio LIGA Apertures in an X-Ray Pinhole Camera'', Proc. IPAC2017 (MOPAB132)

X-ray Pinhole Overview

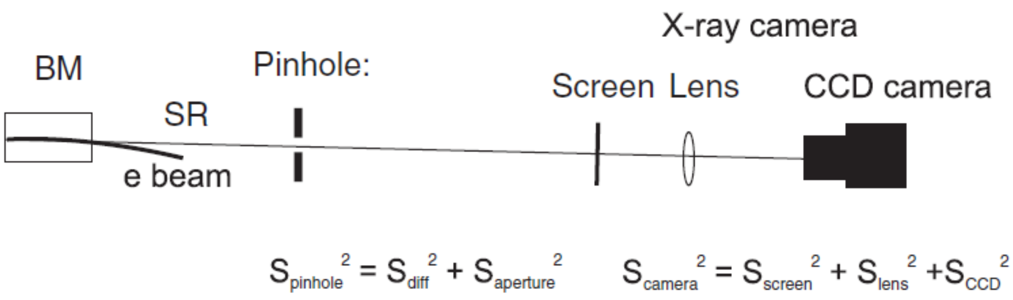
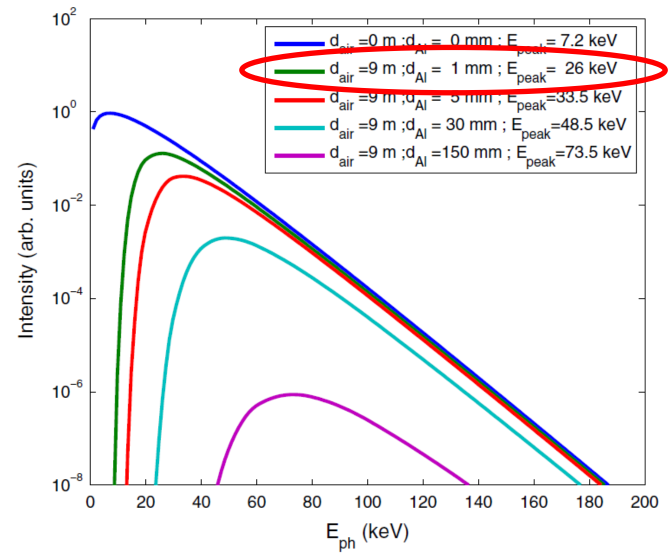
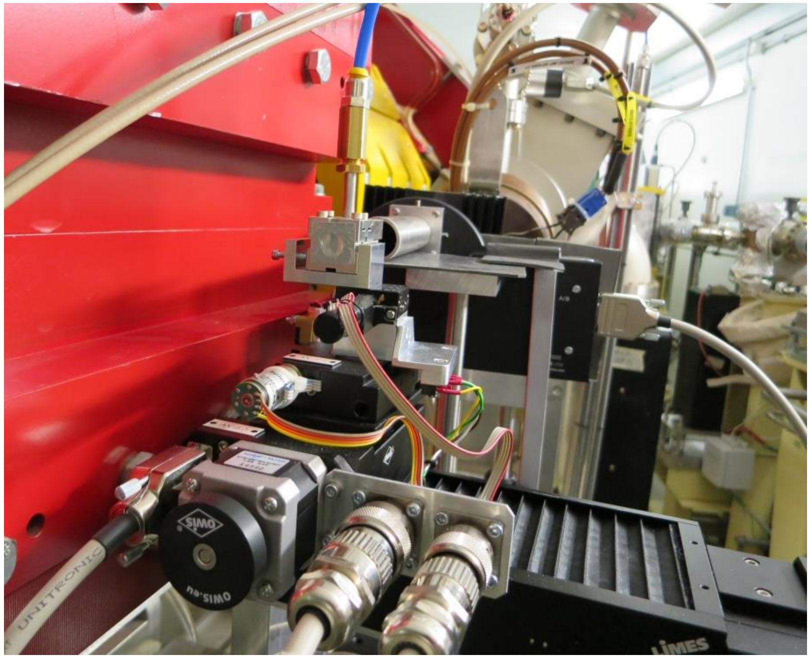


FIG. 1. Schematic of the pinhole camera system and the decomposition of the PSF. The relativistic electron beam (e beam) goes through a bending magnet (BM), emitting synchrotron radiation (SR). The electron beam is imaged by the pinhole onto the x-ray camera. For each element having a PSF Gaussian, the total PSF, $\Sigma_0^2 = S_{\text{pinhole}}^2 + S_{\text{camera}}^2$.





C. Thomas et al., ``X-ray pinhole camera resolution and emittance measurement'', Phys. Rev. ST Accel. Beams 13, 022805, (2010).

PSF = Point Spread Function

Pinhole Requirements

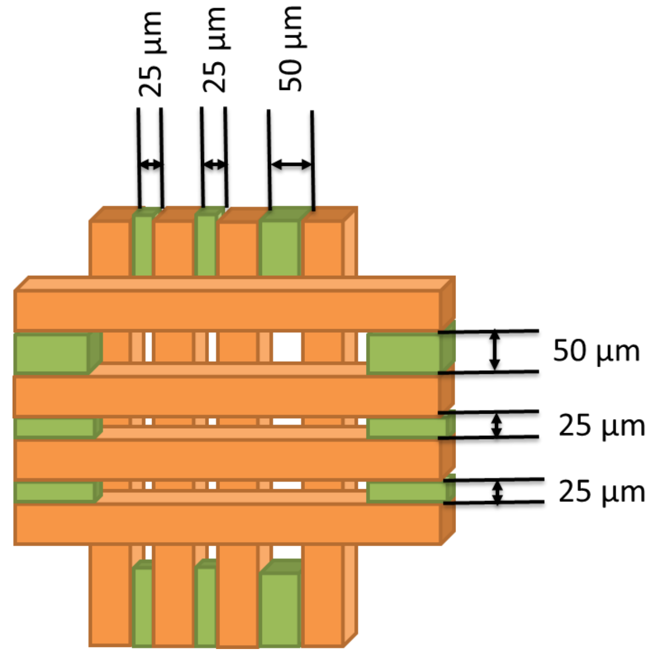
- Rectangular and cylindrical holes in a screen where the edges of the hole through the bulk material are perpendicular to the screen surface.

- Opaque to keV X-rays
  → high atomic number material e.g. tungsten, gold, …
  → 1 mm thickness.

- 10 – 25 µm apertures (typically).

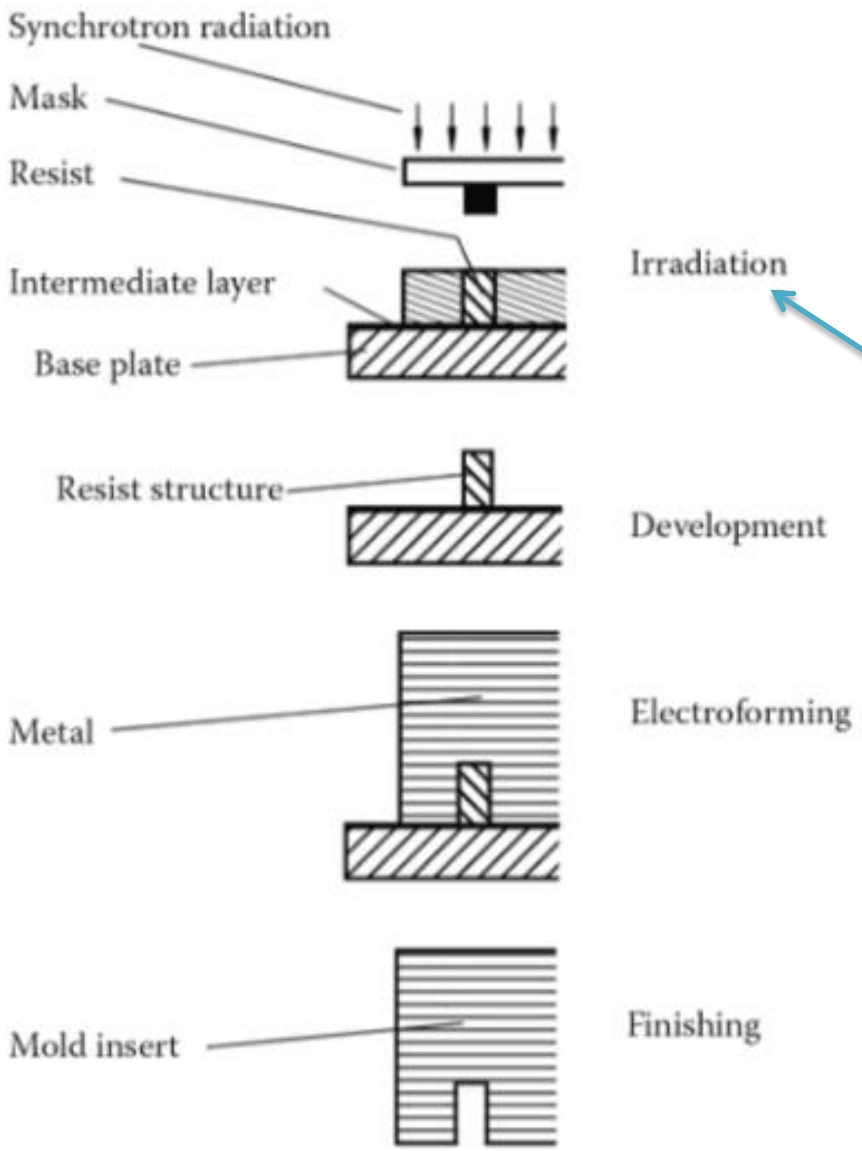
→1:100 aspect ratio

Traditional pinhole assembly



L.M. Bobb et al., ``Performance Evaluation of Molybdenum Blades in an X-ray Pinhole Camera'', Proc. IBIC2016, p. 796-799.

What is LIGA?



German acronym for X-ray lithography (X-ray lithographie), electro-deposition (galvanoformung), and molding (abformtechnik).

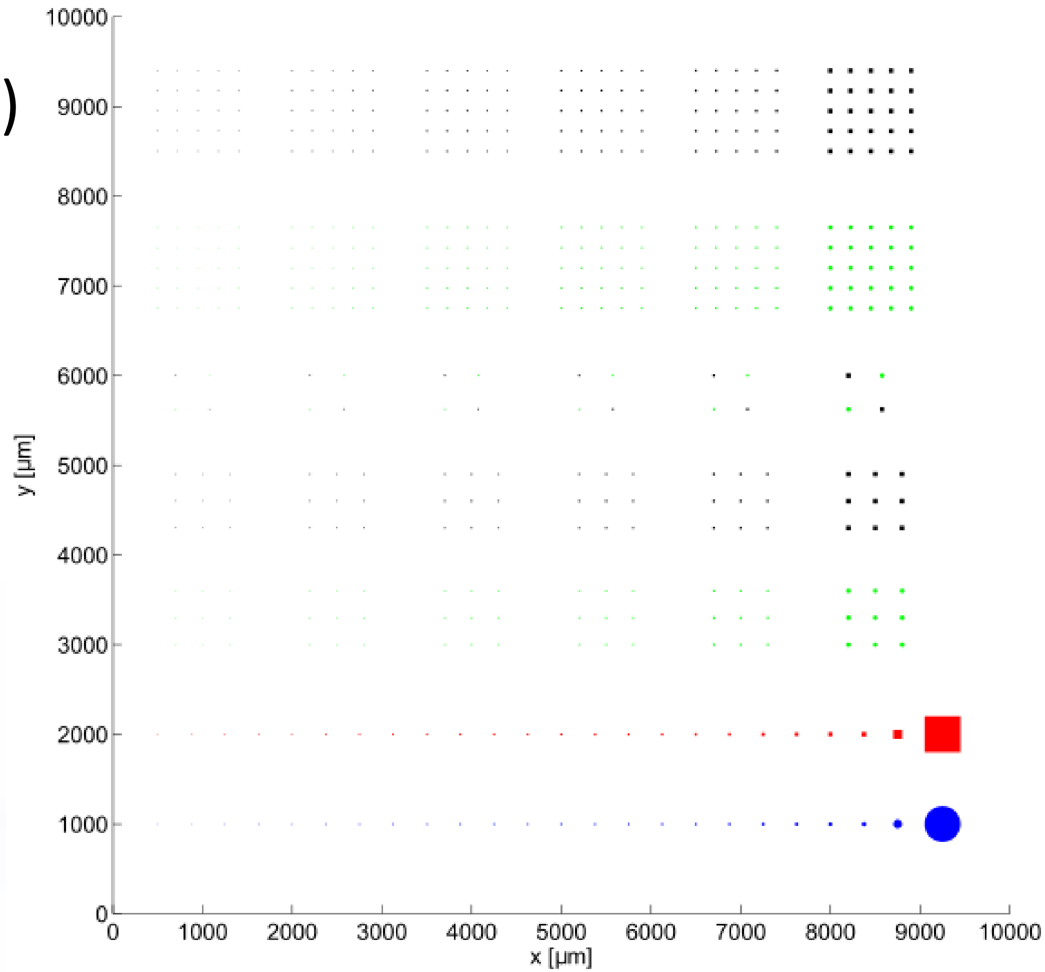
X-ray exposures done on B16 beamline at Diamond.

M. Madou, ``Chapter 10: Micromolding Techniques - LIGA'', Fundamentals of Microfabrication and Nanotechnology, Vol. 2, Third Ed., CRC Press, 2012, p.591-642.

Pinhole Screen Designs (1)

- Rectangular and circular holes for direct imaging of the electron beam.
- 10 – 400 µm width (square) or diameter (circle).
- Arrays of holes for averaging the beam size at a specific location in the storage ring.
- Allows investigation of the PSF from different shape and size apertures.

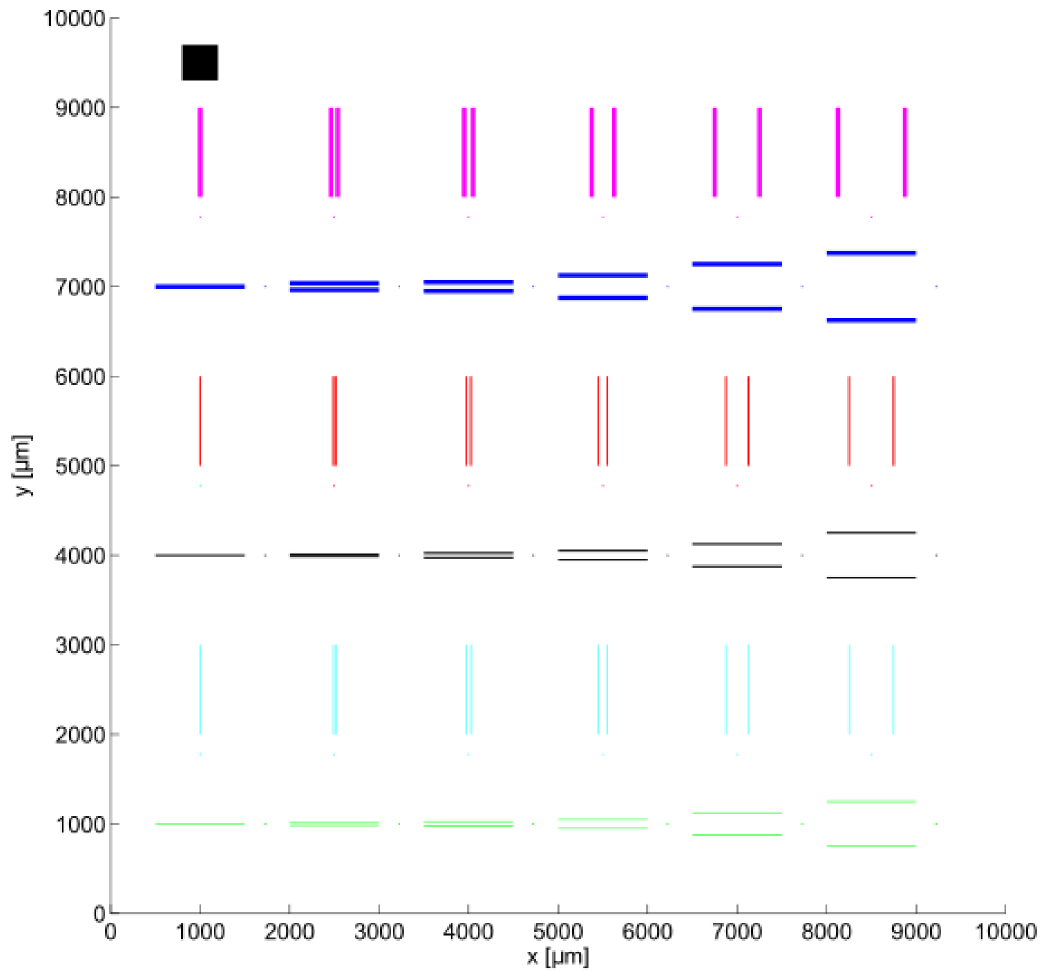
Imaging



Pinhole Screen Designs (2)

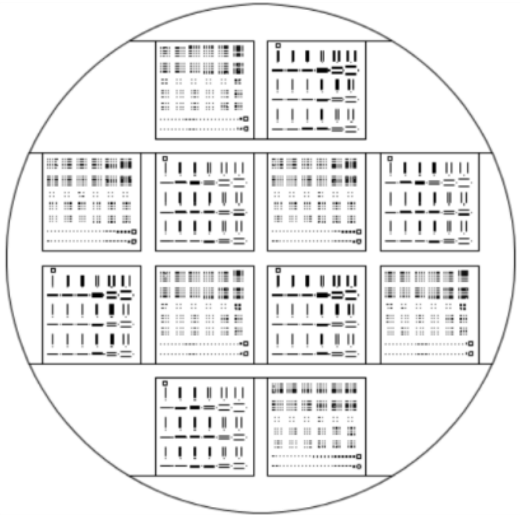
Interferometry

- Single and double slits for X-ray interferometry.
- 10 – 50 µm slit width.
- 1 mm slit length.
- 400 µm x 400 µm alignment aperture.
- Square apertures also included for imaging.

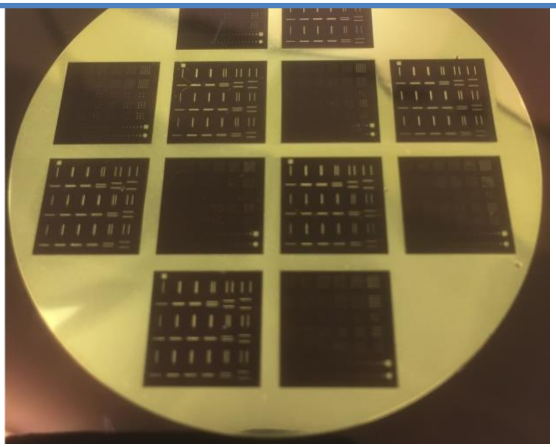


Development Status (1)

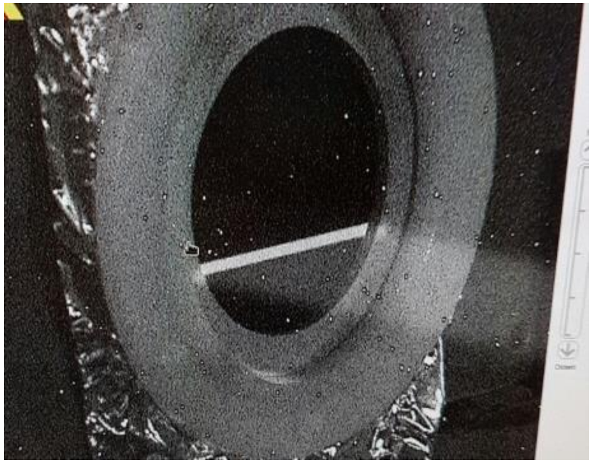
Chrome Mask Design and Fabrication ✔



X-ray Mask Fabrication ✔



X-ray Exposure ✔

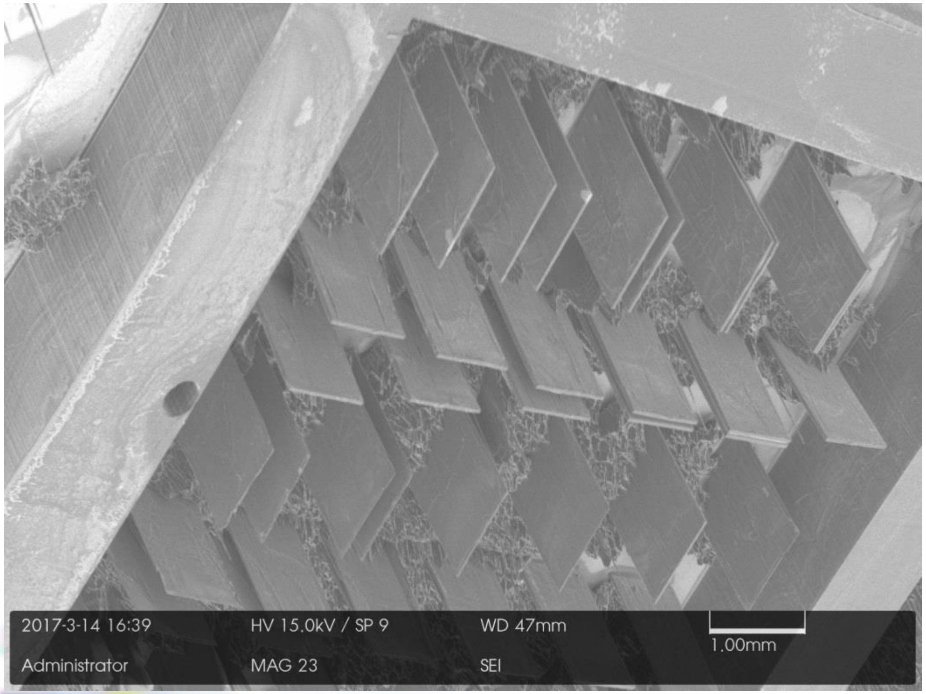


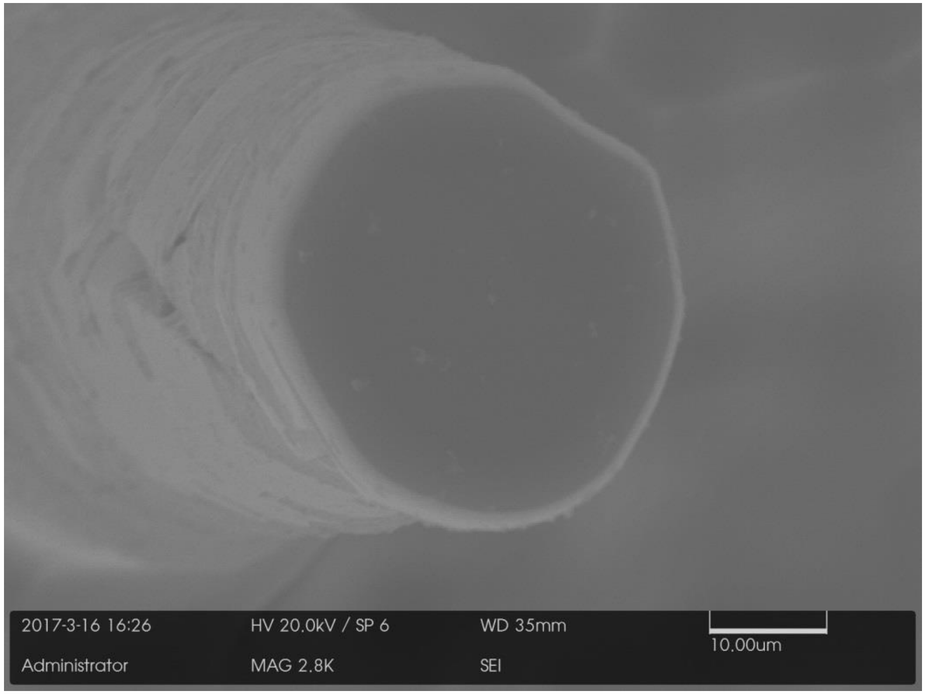
Develop Resist ✔

Development Status (2)

Metrology of Structures in Developed Resist ✔

Since the gold screens are made by electroplating the developed resist, it is assumed that the aperture sizes in the 1 mm thick gold screens must be equal to the structures of the developed resist.





Electroplating and removal of resist

Why?!

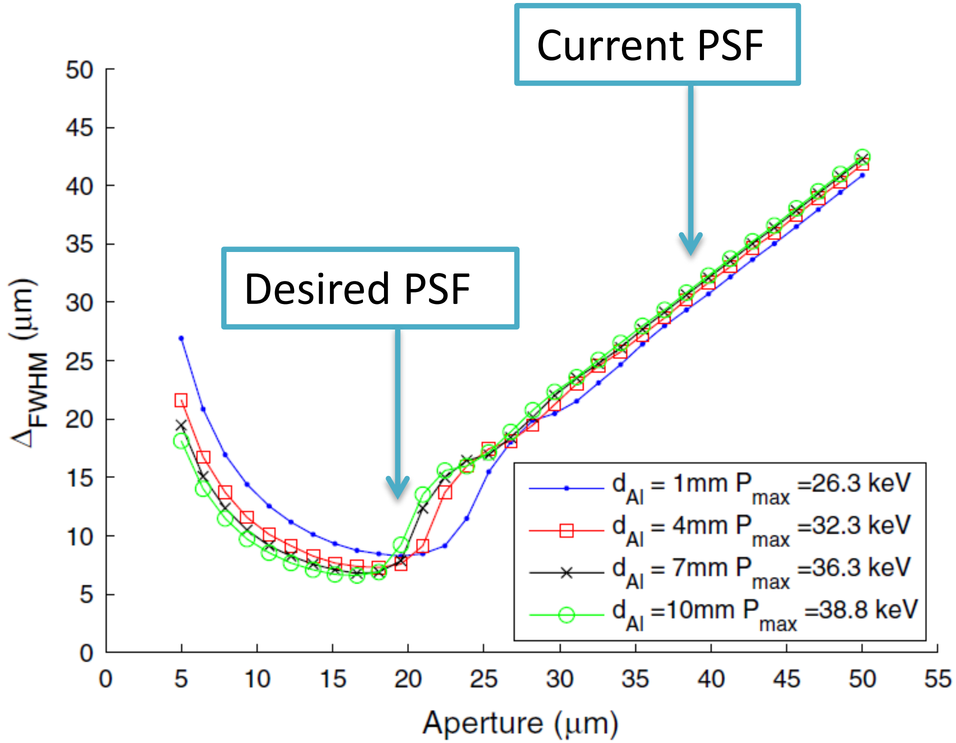


FIG. 12. (Color) FWHM of the PSF of pinhole 2 as a function of the slit apertures and for several thickness of Al filter.

Imaging the electron beam with the different aperture sizes, I plan to generate a similar plot using real data, to that shown (left) from simulations.

In this way, I can choose the optimum pinhole aperture to minimise the PSF for a given photon energy.

C. Thomas et al., ``X-ray pinhole camera resolution and emittance measurement'', Phys. Rev. ST Accel. Beams 13, 022805, (2010).

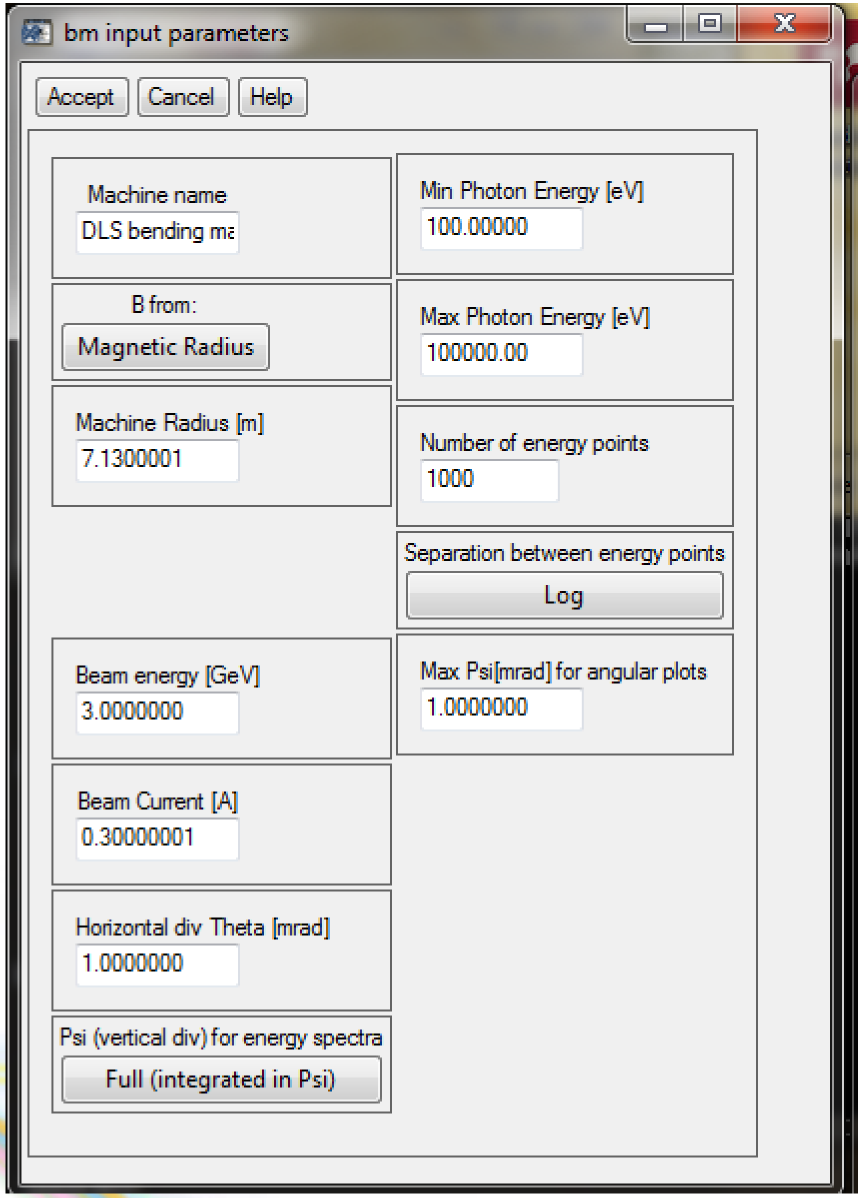
Thank you for your attention!

Acknowledgements

Thanks to K. Sawhney and I. Pape for the use of the B16 beamline and many useful discussions. Thanks are also attributed to G. Arthur from Scitech Precision.

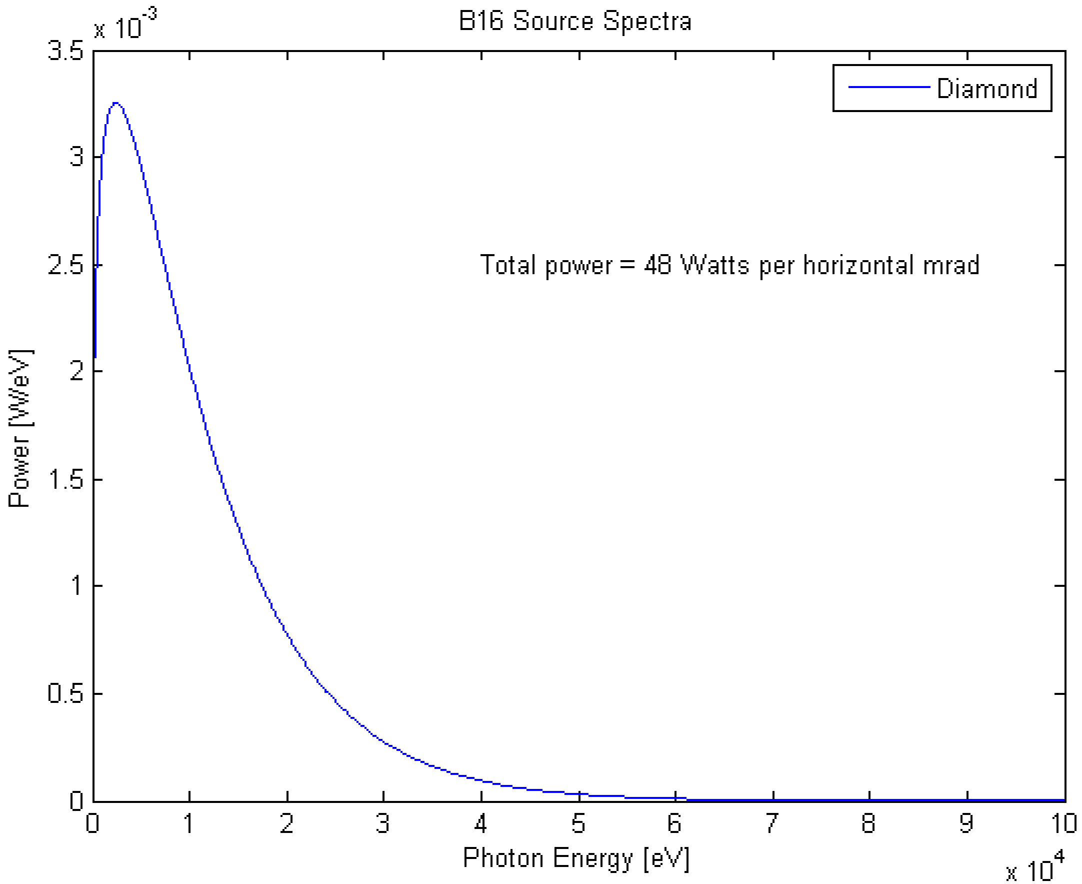
Extra slides

B16 Source Parameters

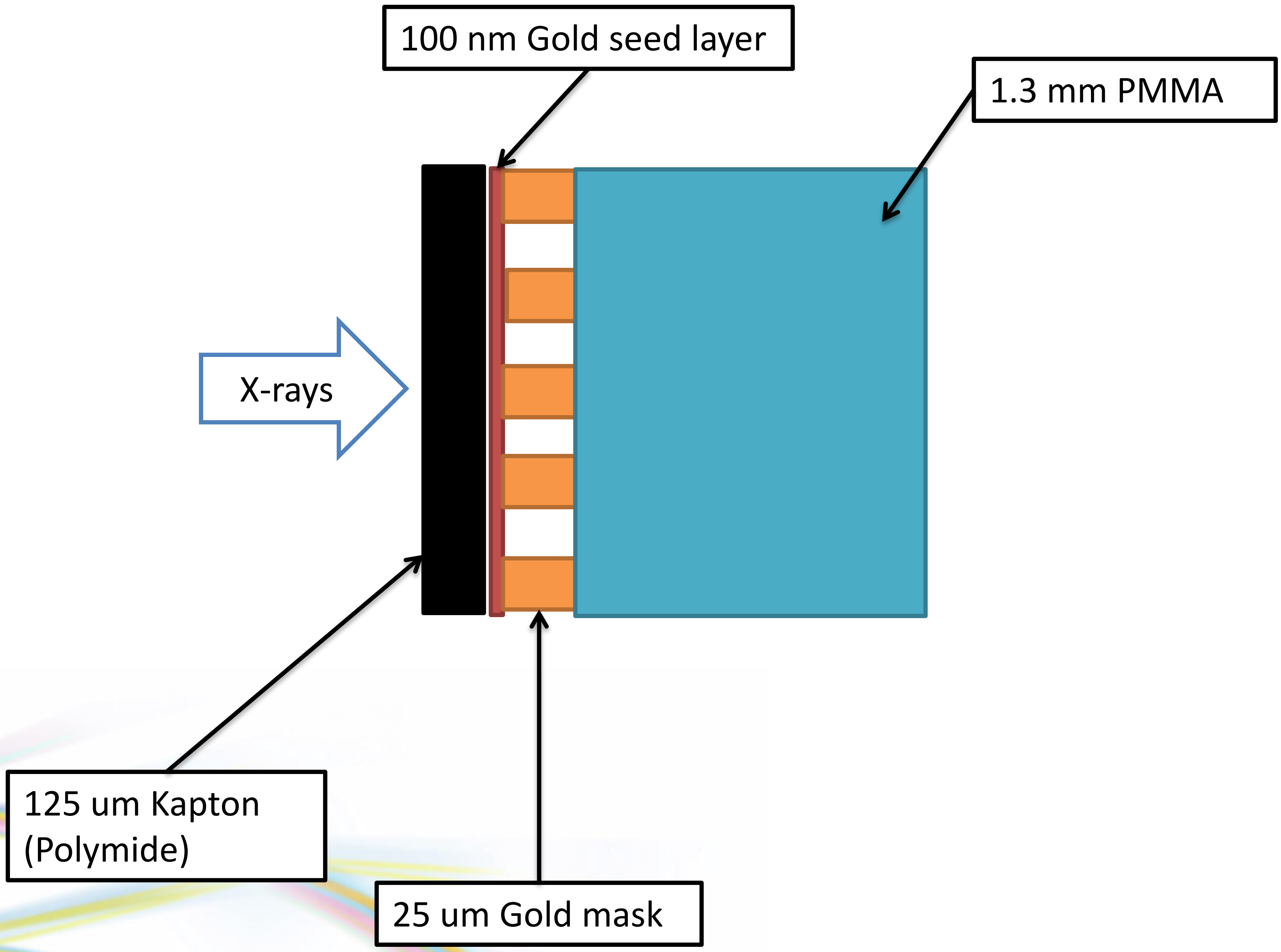


B16 Source

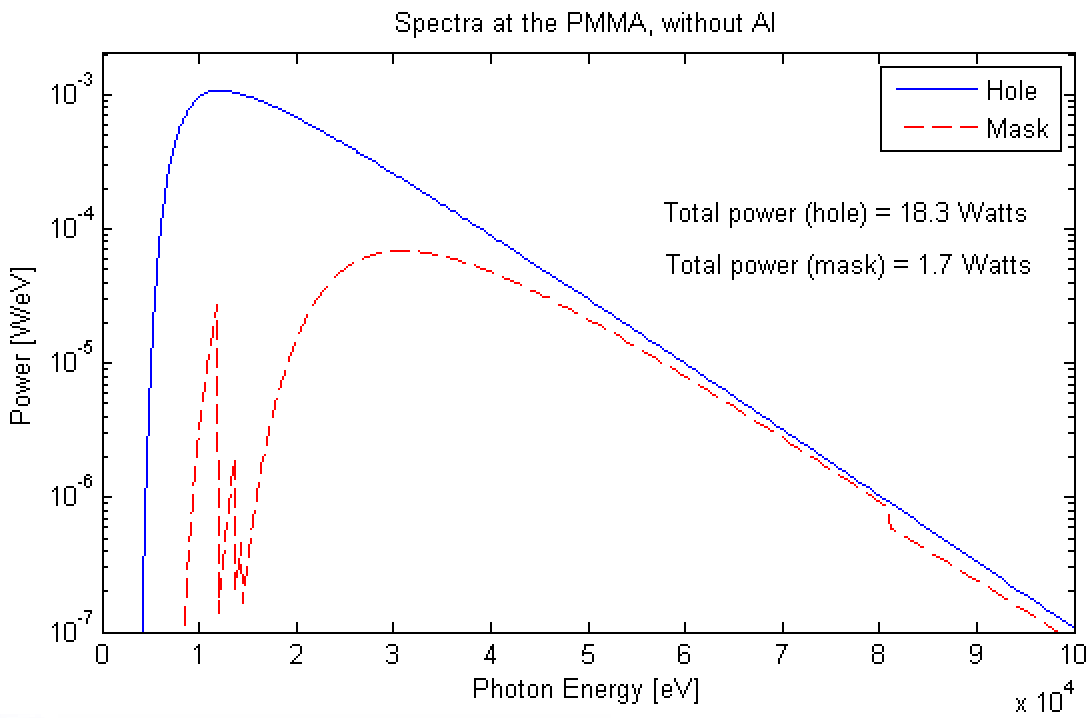
All data form XOP



Sample Layout



Spectra at PMMA through X-ray mask



Power incident on PMMA through mask without Al

HOLE:

Power per horiz mrad = 18W/ mrad

Diamond beamline geometry:
1 mrad at 40 m illuminates 40 mm

Power per horiz mm = 0.45 W/mm

Collimating beam width 50mm:
Power incident on sample = **23W**

Vertical opening angle = 1/gamma (gamma = 5870)
So 6.8 mm x 50mm strip is exposed

MASK:

Power per horiz mrad = 1.7W/ mrad

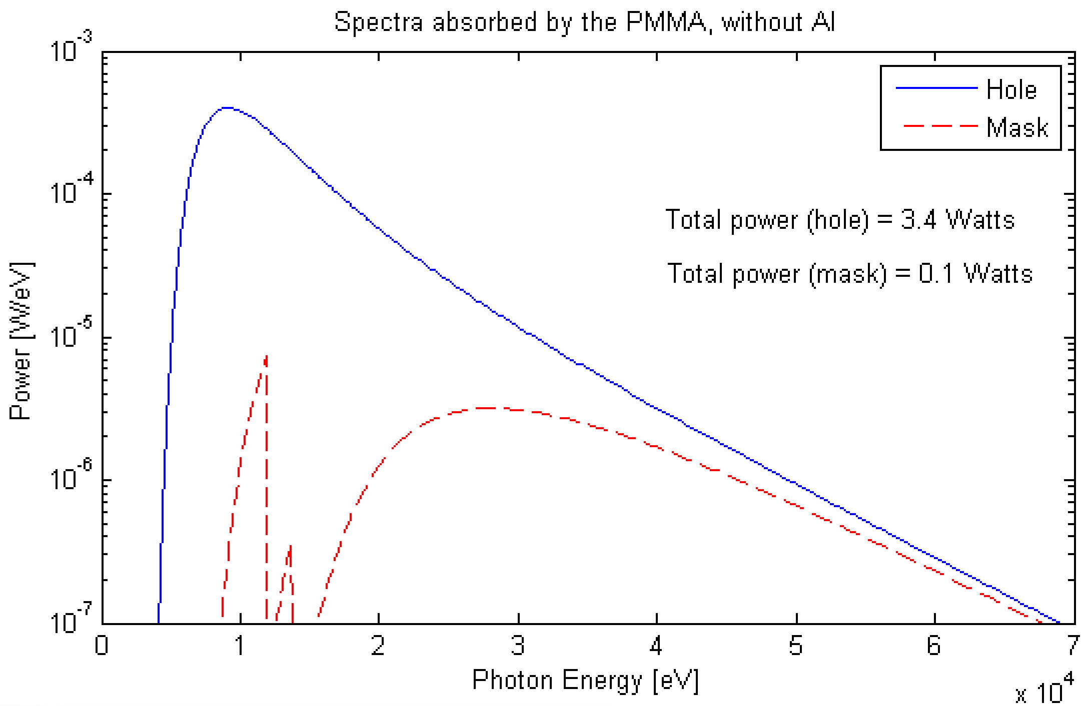
Diamond beamline geometry:
1 mrad at 40 m illuminates 40 mm

Power per horiz mm = 0.04 W/mm

Collimating beam width 50mm:
Power incident on sample = **2.1W**

Vertical opening angle = 1/gamma (gamma = 5870)
So 6.8 mm x 50mm strip is exposed

Spectra absorbed by PMMA without Al



0.5 mm Be
1m Air
~~0.5 mm Al~~
125 um Kapton
100 nm Gold seed
25 um Gold
1.3 mm PMMA

Extinction Ratio = 43

Compare top/bottom PMMA

0.5 mm Be
1m Air
~~0.5 mm Al~~
125 um Kapton
100 nm Gold seed
25 um Gold
1.3 mm PMMA

HOLE:
Power absorbed in top 100um of the PMMA (6.8mm x 50 mm) = 0.54 W
Power absorbed in bottom 100um of the PMMA (6.8mm x 50 mm) = 0.34 W

HOLE:

```
trapz(dls_p(:,1), dls_p(:,2).*Be(:,2).*air(:,2).*kapton(:,2).*goldseed(:,2).*(1-pmma(:,2).^(1/10)))/...
trapz(dls_p(:,1), dls_p(:,2).*Be(:,2).*air(:,2).*kapton(:,2).*goldseed(:,2).*(pmma(:,2).^(9/10)).*(1-pmma(:,2).^(1/10)))

ans =    1.5959
```

Exposure Time for Specified Dose

- Volume of exposed strip (h x v x d)
  = 50 mm x 7 mm x 1.3 mm

- Consider the bottom 100um of the PMMA
  Therefore,
  Volume of exposed strip (h x v x d)
  = 50 mm x 7 mm x 0.01 mm
  = 0.035 cm^3

- Dose = Energy absorbed / Volume
  So,
  Energy absorbed = Dose * Volume

- Given Dose = 4500 J/cm^3:
  Energy absorbed = 4500 * 0.035 cm^3 = 157 J

- Power = Energy/Time
  So,
  Time = Energy/Power

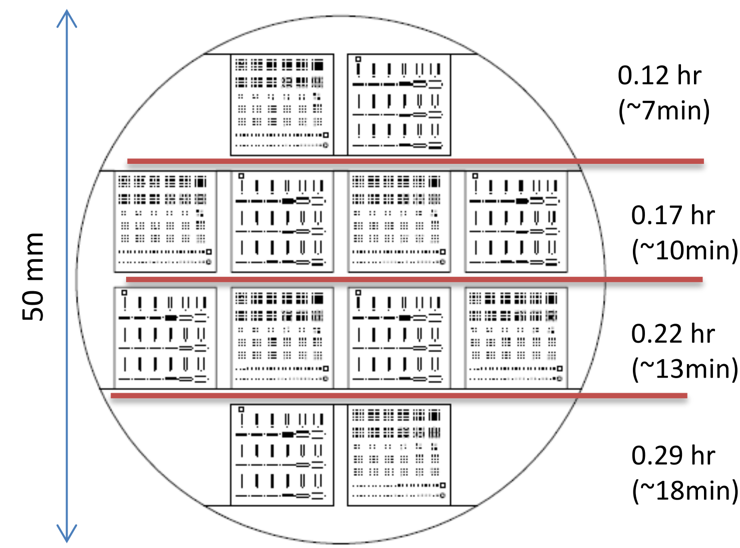
- Exposure time for 7mm x 50mm area = 157/0.34 = 0.13 hours

Exposure Time for Specified Dose

Dose [J/cm^3]	Energy absorbed in bottom 100um of PMMA *[J]	Power absorbed in bottom 100um of PMMA *[W]	Exposure time required *[hour]	Exposure time required per screen row $^+$[hour]
2500	87.5	0.34	0.07	**0.12**
3500	122.5		0.10	**0.17**
4500	157.5		0.13	**0.22**
6000	210.0		0.17	**0.29**

Setup:
0.5 mm Be
1m Air
~~0.5 mm Al~~
125 um Kapton
100 nm Gold seed
25 um Gold
1.3 mm PMMA

Since we cannot attenuate the beam and maintain a good extinction ratio we need cooling
→Air blower
→Water cooled copper block



*Assuming 7 mm x 50 mm exposure area
$^+$Assuming 12 mm x 50 mm exposure area