AN X-RAY PINHOLE CAMERA FOR SESAME STORAGE RING

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Introduction

SESAME is a 2.5 GeV synchrotron radiation facility operated on 2016 as a user facility located in Allan (Jordan), An X-Ray pinhole camera beamline has been installed recently at SESAME Storage Ring as a very beneficial non-destructive tool, used to characterize the electron beam size and behavior. The design of the beamline is kept as simple as possible with a modification on the copper absorber to provide a sufficient flux of X-ray proper for imaging. The beamline is under operation now and used for the measurement of beam size, emittance, coupling in the ring, and detection of beam instabilities.

Pinhole Camera Setup

The X-ray pinhole camera consists of a source, a pinhole, a screen, and a camera. At SESAME, the X-ray pinhole camera is installed in cell 16 of the SR to measure the beam size from the 6.5° port of the bending magnet (BM). The X-ray beam passes through a beam port absorber, which is a copper block designed to absorb the majority of the X-ray beam while allowing a portion of the high-energy X-rays to pass through to the pinhole assembly in air, and subsequently to the YAG screen and imaging system. The system layout is illustrated in Figure 1

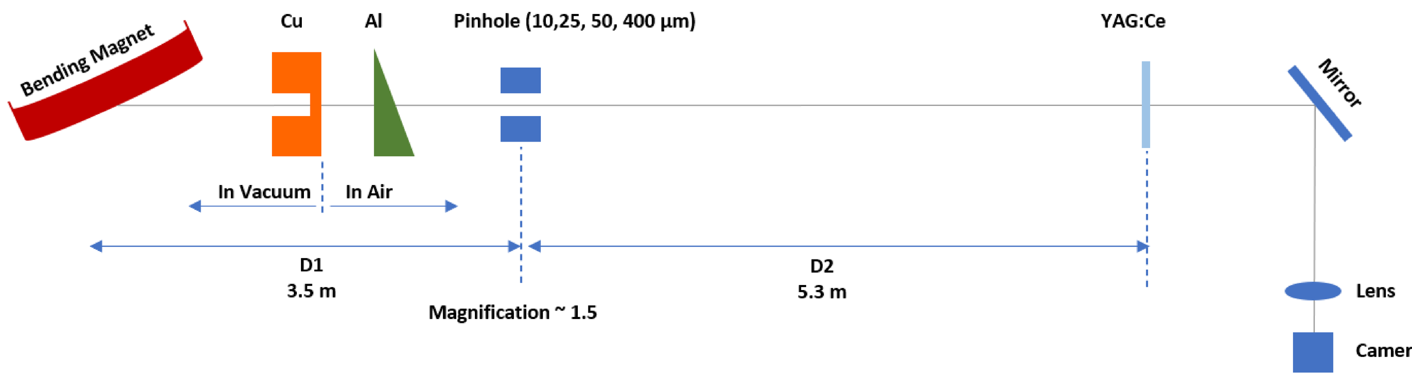

Figure 1: Layout of X-ray pinhole camera beamline.

X-Ray Beam Absorber

The X-ray beam absorber was originally designed to be made of copper, featuring a slot for a port leading to an aluminum window. However, due to financial constraints, an alternative approach was adopted. The solution involved repurposing a defective full copper mirror, previously used in the diagnostics beamline in the SR, designed to handle an X-ray beam of 400 mA at 2.5 GeV.

To repurpose the mirror as an absorber and beam extractor with minimal absorption in its thin layer that will extract part of the beam after polishing its surface, simulations and finite element analysis (FEA) were conducted.

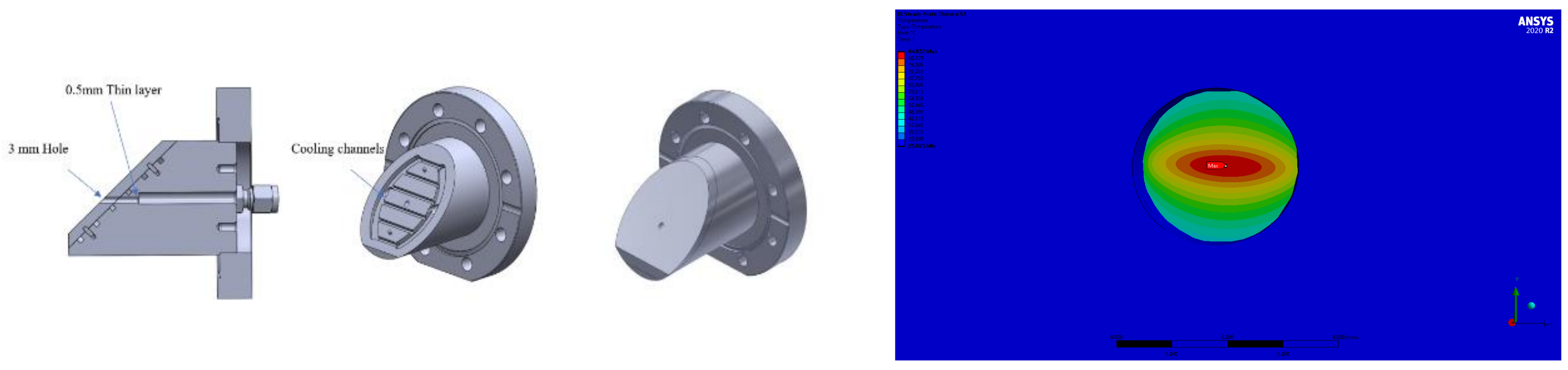

Figure 2: Defected mirror used as absorber, left 2D side view, middle the internal face with cooling channels and right the 3D view , the thermal distribution of the 3mm diameter 0.5 mm thick copper layer on the right , max temperature 84.8°.

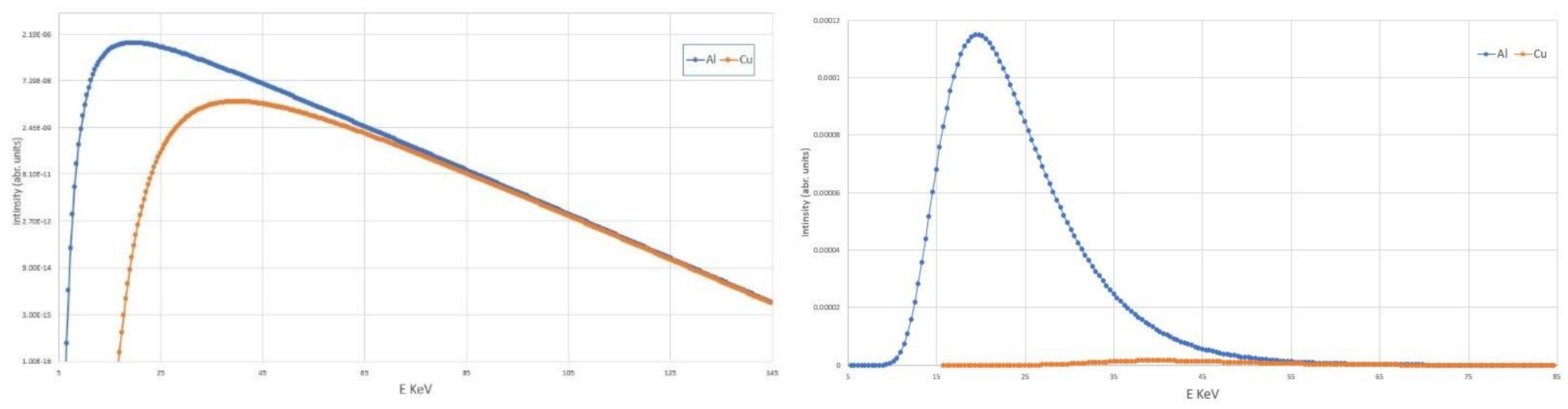

Figure 3: Spectrum of extracted X-ray photon beam showing how copper attenuate the intensity and shift the energy in logarithmic and linear scale .

As a consequence of using copper instead of aluminium the intensity of the final beam is significantly reduced, as illustrated in Fig. 3, and the electron beam at injection energy (800MeV) can't be seen or measured. The beam is started to be seen at ~ 2.4 GeV, and the photon intensity at 2.5 GeV keeps sufficient to see the beam over the decay time in the SR. The aluminium wedge was ultimately not used due to the reduced photon intensity. The copper absorber shifted the X-ray beam energy to be ~38KeV

PSF of Pinhole Camera

The image formed on the camera is the convolution of the source profile, and of the point spread function (PSF) of the diffraction through the pinhole, and of the PSF of the X-ray camera. The total PSF contribution is composed quadratically to the total resolution of the X-ray pinhole camera and approximated to be Gaussian PSF overall PSF may be represented as:

$$\sigma_{PSF}^2 = \sigma_{pinhole}^2 + \sigma_{image}^2$$

$$\sigma_{pinhole}^2 = \sigma_{diffraction}^2 + \sigma_{aperture}^2$$

$$\sigma_{diffraction}^2 = \frac{\sqrt{12}}{4\pi}\frac{\lambda D}{A} \qquad \sigma_{aperture}^2 = \frac{A}{\sqrt{12}}\frac{D+d}{d}$$

d is the distance from source to pinhole and D pinhole to screen, λ is the wavelength, and A the pinhole aperture. we evaluate the PSF by varying the aperture size from 5μm to 50μm, but using only one thickness (without any attenuation) due to intensity limitations caused by the Cu window.

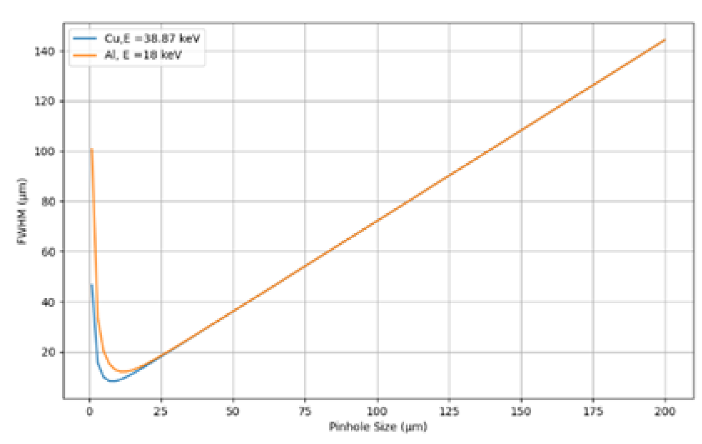

Figure 3: FWHM of the PSF from Pinhole as function of different apertures for 1mm Al (18KeV) and 0.5mm Cu(38KeV) windows.

Measurements Results

Measurements of the emittance can be done indirectly by measuring the transverse beam size using the synchrotron radiation produced by it. The horizontal and the vertical emittances are calculated by using the following formula

$$\sigma_i^2 = \beta_i \varepsilon_i + (\eta_i \, \sigma_\varepsilon)^2$$

σi is the measured beam size in the horizontal or vertical plane, βi and ηi are the betatron and dispersion functions at the source point and in the corresponding plane, ϵi and $\sigma\varepsilon$ are the emittance and the relative energy spread of the electron beam. The parameters βx, ηx and $\sigma\varepsilon$ are known from the model

The results from both planes show strong agreement with the machine's design values for both planes with ϵx = 26nm.rad and ϵy = 0.256nm.rad . The stability of the measurement is in good shape since the machine works in decay mode with single injection a day, where the beam decays from 250mA to ~130mA. Although the intensity is reduced with the decay nevertheless, we stay on same gain and exposure time of the camera

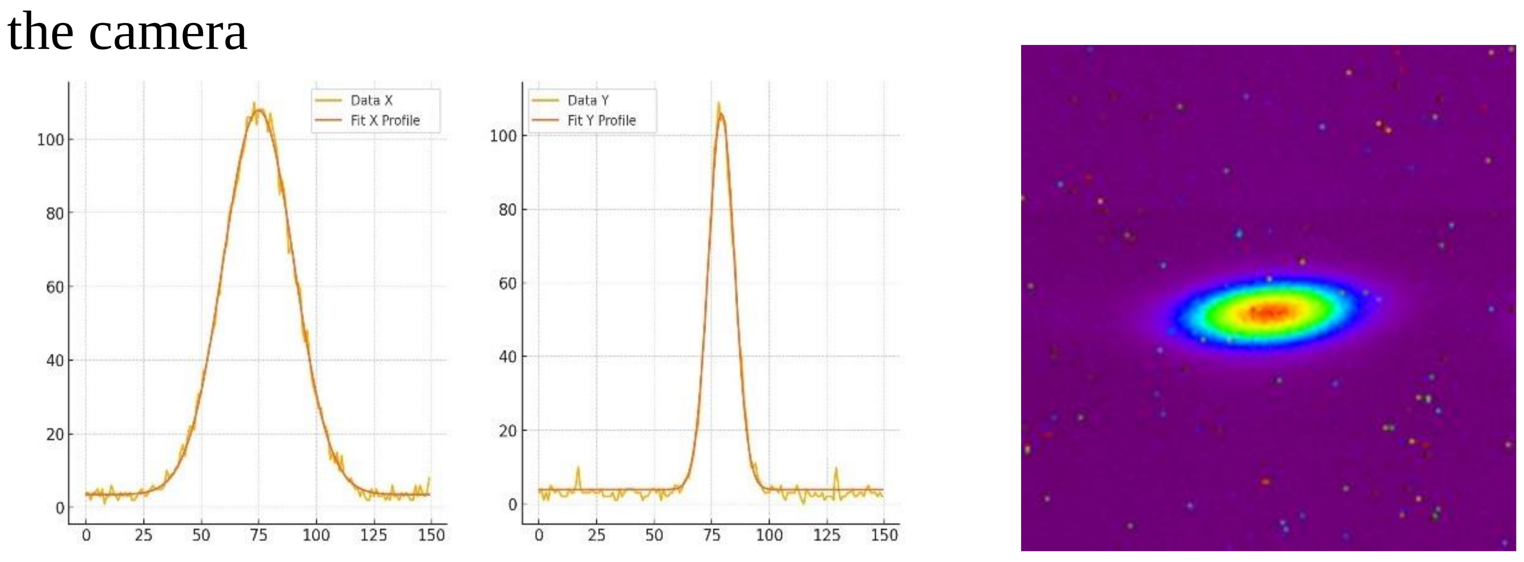

Figure 4: Beam image from the pinhole camera and fitted profiles using 2D Gaussian fit, left is horizontal right the vertical.

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