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CHARACTERISING INJECTED BEAM DYNAMICS IN THE AUSTRALIAN SYNCHROTRON STORAGE RING*

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Abstract

The injected beam trajectory at the Australian Synchrotron needs to be studied to assess the suitability of non-linear kicker installation. To achieve this, multiple diagnostics including cameras and radiochromic films were used to determine the position at several points inside the storage ring tunnels. This was used to infer the momentum data, and then simulated to model the new kicker installation.

INTRODUCTION

At the Australian Synchrotron, the Bright Project has recently begun. This will expand our current 10 beamlines to 18, nearly doubling our capacity. This means that any spare space in our accelerator straights has become more important. One method of freeing up space available to us is the implementation of multipole injection kickers. Our current kickers operate by providing the stored beam a kick out of its regular orbit before the new shot is injected, and then kicking both the injected and stored beam back into the normal orbit. These kicks are only applied on the horizontal plane.

Multipole fields have the advantage that at the center, the field strength is zero. This is how we avoid kicking the stored beam at all, and to instead apply a correction to only the injected beam [1]. See Fig. 1.

Unfortunately, this means that the required injected beam parameters change, so we must know both the position and momentum of the injected beam to a high degree of accuracy. While we have a screen and camera set up at the point of injection, we do not currently have a way to measure the horizontal momentum of the injected beam relative to the stored beam.

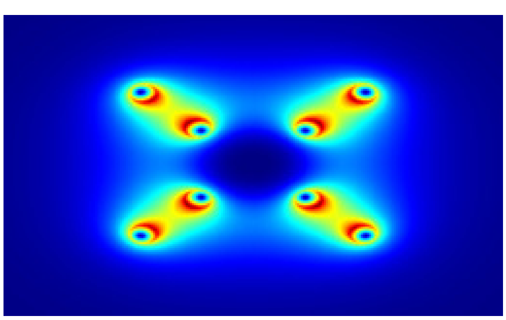

Figure 1: Multipole field (Navy blue is low intensity).

If the steering magnets in the first sector of the storage ring are turned off, the injected beam will follow a path that travels past a YAG screen (See Fig. 2) and ends in the beamstop for what would be a photon beamline at the end of the sector 1 straight. This study uses radiochromic films placed at the end of this beamstop to detect the horizontal position of the beam at this beamstop, to then infer the momentum of the injected beam.

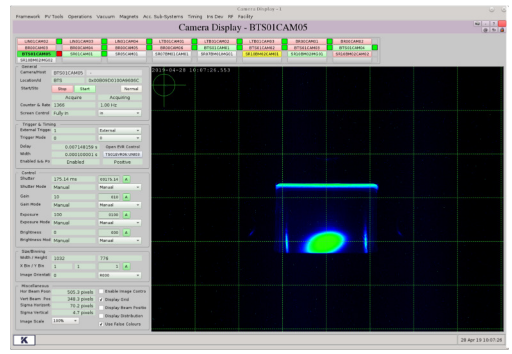

Figure 2: Image of YAG screen illuminated by beam.

FILM CONFIGURATION

Luckily the Imaging and Medical Beam Line (IMBL) have provided us with spare expired radiochromic films used for dosimetry purposes. As we do not require a measurement of dose, these are perfect for our purposes. A way of mounting the films was still required however. A coupling mount was designed in Tinkercad [2] to be 3d printed (See Fig. 3). This was printed on an industrial 3D printer in PLA plastic and fit on the flange in the desired position with the film taped to the front. Arrows designed to indicate positioning were incorporated into the design, to later provide accuracy in identifying the beam position. This mount provided a snug and highly repeatable fit.

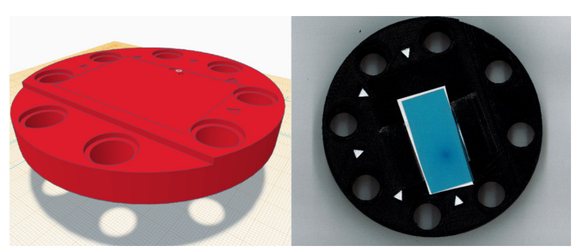

Figure 3: Film holder CAD model designed in Tinkercad for 3D printing(Left) vs the real thing with film (right).

Five shots were taken on each film, both to provide sufficient darkening and to average any variance from shot to shot.

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IMAGE PROCESSING

The holder was then removed and placed on a 600dpi office scanner and the image was imported into MATLAB [3]. Image recognition was used to identify the 5 marking triangles on the image (Fig. 4 left) and then to rotate the image to a consistent orientation. Each film was scanned at least 5 times to ensure the repeatability of this process, which resulted in a repeatability of σ = 0.0079 mm of the final beamspot fit.

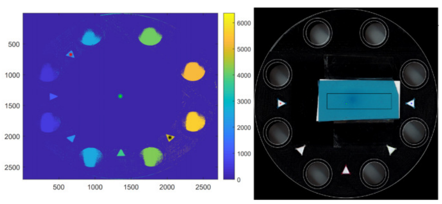

Figure 4: Shot catcher rotated with identifing indicators drawn on.

This orientated image was then cropped down to the important area of the film automatically (Fig. 5). Then the image was inverted, with only the blue channel data being used (Fig. 6). This gave us a higher signal to noise ratio, and the image was then summed over the vertical pixels to produce a plot of Position vs Intensity (Fig. 7)

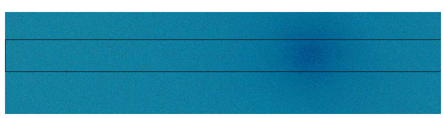

Figure 5: Cropped scan image.

Figure 6: Image cropped further to include high intensity data, and inverted.

Initially a multiple gaussian fit was applied to the data this achieved a repeatability of σ = 0.0220 mm. This located the peaks, but a better repeatability of σ = 0.0079 mm was found using a combination of MATLAB's smoothing and findpeaks functions. The angles of these beamspots were then calculated to be in a range of -0.01 to 0.23 degrees.

A variety of currents were selected to determine the relationship between septa current and beam angle. As expected this appeared linear (Fig. 8), and most values fell between the 95% confidence intervals.

FURTHER WORK

Now that the initial position and angle of the beam is known, further work can be completed to identify just how much the beam varies between shota. It has been observed

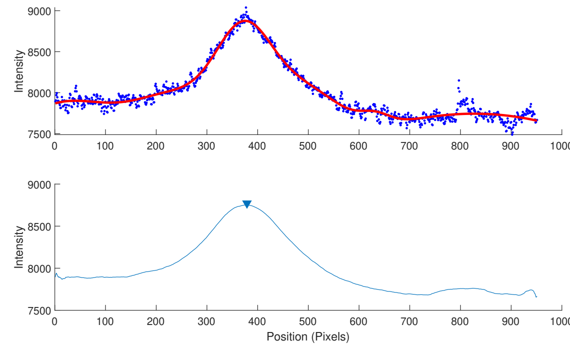

Figure 7: Resulting plot of image intensity vs Position with a Gaussian fit as compared to data smoothing and findpeaks function.

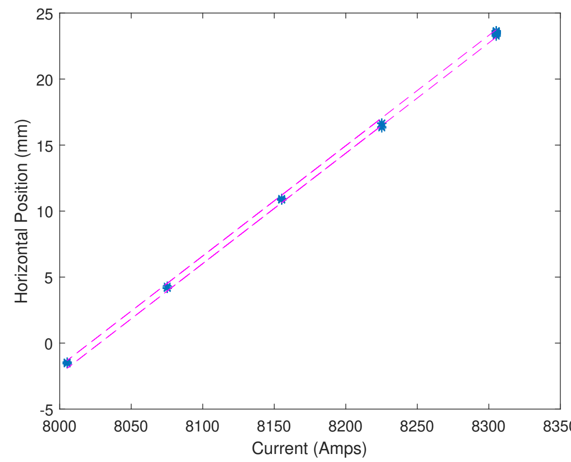

Figure 8: Current of final septa steering magnet vs beamspot position.

with a YAG screen and camera combination, that there is a drift in position as the machine warms up from previous shots. This will require either a more sensive radiochromic film, the use of a detector such as a Pilatus, or the installation of another YAG/Camera combination at the beamstop.

AKNOWLEDGMENTS

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REFERENCES

[1] R. Auchettl and Y. E. Tan, "Proposed Nonlinear Injection Kicker for the Australian Synchrotron", presented at the IPAC'19, Melbourne, Australia, May 2019, paper WEPMP001, this conference.

[2] Autodesk Tinkercad, https://tinkercad.com

[3] MATLAB, https://au.mathworks.com/Matlab