INJECTED BEAM PROFILE MEASUREMENT DURING TOP-UP OPERATION

M.J. Boland, Australian Synchrotron, Clayton, Victoria, Australia
T. Mitsuhashi, KEK, Ibaraki, Japan
K.P. Wootton, The University of Melbourne, Victoria, Australia

Abstract

A coronagraph-like apparatus was constructed on the optical diagnostic beamline on the storage ring to observe the injected beam during top-up operations. An image was created on an intensified CCD (ICCD) that can be gated on a single bunch or on a bunch train for a stronger signal. The bright central stored beam was obscured so the comparatively faint injected beam could be observed. The injected beam comes in at a large enough offset so that it was clearly visible above any diffraction or beam halo signals. The beam profile measured was in good agreement with the observations made of the injected beam only using a telescope apparatus. The measurements were made during user beam in top-up operation mode and can be used to optimise the injection process.

CORONAGRAPH APPARATUS

The beam current injected into the Australian Synchrotron storage ring is ≈1 mA per shot in multi-bunch mode and ≈0.05 mA per shot in single-bunch mode. This is a relatively small current compared with the 200 mA of stored beam. In order to measure the beam profile of the injected beam in the presence of the stored beam and requires an apparatus with a dynamic range of more than four orders of magnitude. However, the stored beam can be masked so that an ICCD camera on the optical diagnostic beamline is sensitive enough to capture a single bunch injection. A coronagraph apparatus used to measure beam halos [1] was adapted to masked the stored beam and used to observe the injected beam during user mode top-up operation. The mask needed to be wide enough to obscure the stored beam size plus the residual oscillations caused by the injection kickers but narrow enough to observe the injected beam. During the first few turns the beam at the optical diagnostic beamline (ODB) source point reaches a horizontal amplitude of between -5 and 2 mm (see Fig. 4 and Ref. [2]) so a vertical mask was used which allows the injected beam to observed on either side of the mask.

EXPERIMENTAL SETUP

The ODB at the Australian Synchrotron [3, 4] was used to image the visible light from the injected electron beam. To accommodate this imaging apparatus, the lens in the optical chicane [3] was removed. Instead, the principal focusing optic was positioned on the optical table, as highlighted in Figure 1 below. A real image of the electron beam photon source was formed close to the ICCD camera [5]. The

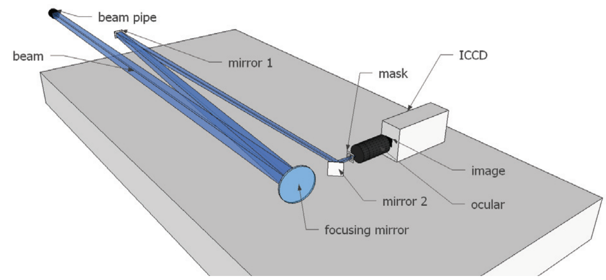

Figure 1: Optical table configuration for the ICCD coronagraph measurement.

mask was then cut to stop the stored beam (shown in Fig. 2) but allow the injected beam to be observed on either side of the mask. Fig. 3 shows the first five turns with only the stored beam and no injected beam. The mask was made large enough to obscure this beam motion due to the kicker imbalance.

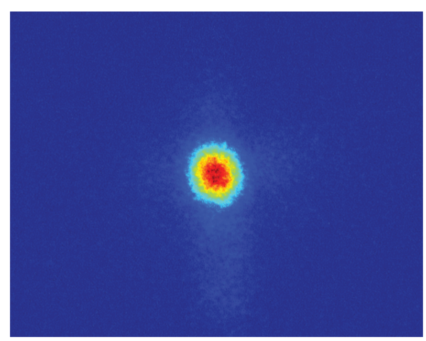

Figure 2: One turn of stored beam with a 5 mA single bunch in the ring.

Figures 2, 3 and 4 show that in principle if the stored beam including the kicker imbalanced induced motion, is masked out, the injected beam can be observed during top-up injection on turns 1 and 3.

RESULTS

The best image captured can be seen in Fig. 5 where turns 1 and 3 of the injected beam can be seen to the left and right of the masked stored beam. Turn 2 is also masked since the horizontal phase advance places the injected beam almost on top of the stored beam, as can be seen in the image with only the injected beam in Fig. 4. Turn 1 is quite washed out in Fig. 5 since the ICCD gain had to be reduced

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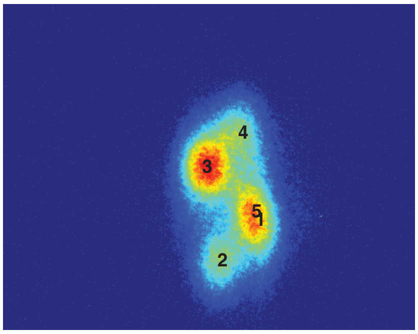

Figure 3: Superposition of 5 turns of stored beam during the injection kick with a 5 mA single bunch and no injected beam.

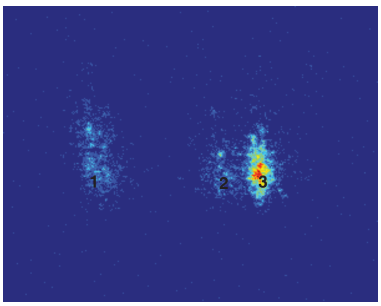

Figure 4: First 3 turns of single bunch injection with no stored beam.

to remove some of the noise from the stored beam. If the ICCD acquisition was synchronistion to the injected beam bunch offset, the gate could have been tighter and the gain increased to improve the dynamic range of the measurement.

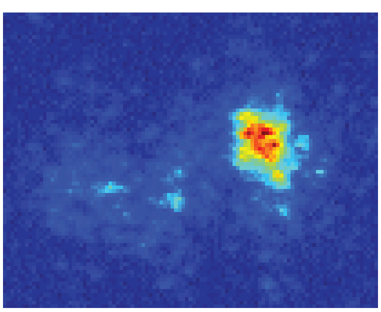

Figure 5: Injected beam turns 1 and 3 observed on either side of the coronagraph mask which blanks the stored beam (compare with Fig. 4 with no stored beam).

Looking at the 1D horizontal projection with background dark field subtraction, the injected beam can also be seen above the stored beam noise. Fig. 6 shows the horizontal projection of ten images before the injection event, the injection event at point 0, followed 10 more imaged after injection. The images are taken at 1 Hz and each image contains a superposition of three turns. In this representation the first and third turns of the injected beam can be seen more clearly above the background generated by the stored beam in the acquisitions before and after the injection.

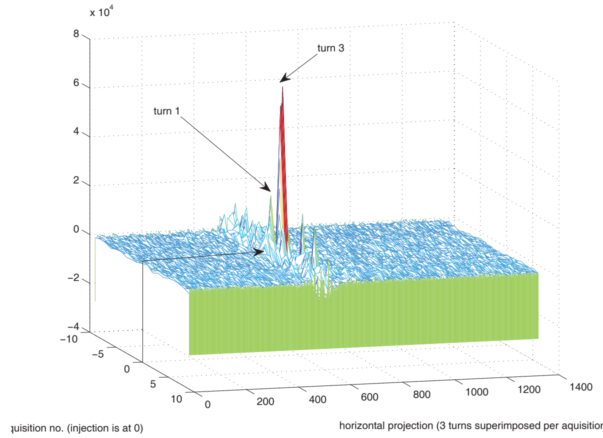

Figure 6: Waterfall plot showing the horizontal projection of each acquisition, with three turns captured per acquisition. The injection event is at acquisition point 0.

ANALYSIS

Firstly these measurements were taken during user beamtime, so the storage ring and injection settings could not be altered; this was as purely parasitic measurement to demonstrate the proof of principle. As a result the ICCD trigger conditions were not optimal to capture the injected beam. The gate had to be opened up for several turns since the absolute timing of the 75 pulse injected bunch train relative to the 300 stored bunches was not known. In principle this can be achieved but the software was not configured to do so. An improved setup would take the injected bunch timing offset and adjust the ICCD gate timing accordingly. This would allow the gate to be narrowed down to the length of the injected bunch train (75 bunches) which will also reduce the background diffraction caused by the stored beam. In this way the background can be reduced by a factor of 4, since only 75 of the 300 stored bunches will be captured in the reduce ICCD gating time.

CONCLUSIONS

A proof of principle measurement was performed with a coronagraph type apparatus to observe the injected beam in the storage ring during user beamtime top-up operations. The injected beam was observed despite being three orders of magnitude weaker than the stored beam. Several shortcomings of the experimental setup were identified and will be improved in future measurements. It is planned to use the data to observe and optimise the injection process for top-up operations.

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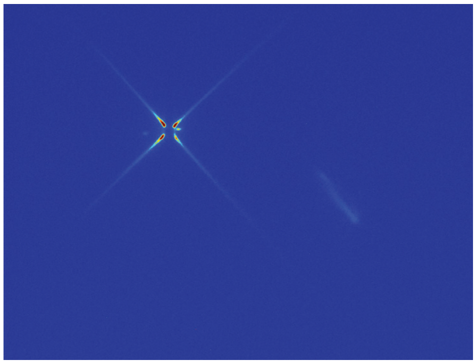

Figure 7: Image taken during the tuning of the coronagraph, great care must be taken to eliminate unwanted diffraction effects.

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