TURN-BY-TURN OBSERVATION OF THE INJECTED BEAM PROFILE AT THE AUSTRALIAN SYNCHROTRON STORAGE RING

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Abstract

A fast gated intensified CCD (ICCD) camera was used to observe the beam profile turn-by-turn in the visible light region. Using the visible light from the optical diagnostic beamline on the storage ring at the Australian Synchrotron an optical telescope was constructed to focus an image on the ICCD. The event driven timing system was then used to synchronise the camera with the injected beam. To overcome the problem of dynamic range between the amount of charge in an injected bunch and the stored beam, the beam was dumped by slowly phase flipping the RF by 180 degrees between each one 1 Hz injection cycle. The injection process was verified to be stable enough so that measurements of the different turns could be captured on successive injections and did not need to be captured in single shot. The beam was seen to come in relatively cleanly in a tight beam but would then rapidly decohere due to the strong non-linear fields needed to run the storage ring at high chromaticity. It would take thousands of turns for the beam to damp down again and recohere into a tight beam spot again. This measurement technique will be used to tune the storage ring injection process.

MOTIVATION

Observation of the beam profile can give extra information that is not available using other position diagnostics which are only sensitive to the centroid of the beam, such as BPMs, DCCT or striplines. Turn-by-turn beam profiles of the beam in the Australian synchrotron storage ring can be captured using the visible light Optical Diagnostic Beamline which is equipped with an ICCD [1].

In May of 2012, the Australian Synchrotron changed its user beam mode from decay mode to top-up injection. Since the x-ray beamline shutter are open when the top-up beam is injected into the storage ring it has become more important to optimise the injection process. Two areas that can be improved in the system are the injection kicker bump and the sextupole settings. By observing the beam profile and motion during injection it is planned to improve the injection efficiency and the beam stability during injection.

Turn-by-turn measurements of the transverse beam position can be made using electron BPMs [2], however these measure only the bunch centroid. Using a synchrotron light monitor, the transverse electron beam distribution can be measured. Employing the ICCD camera, we are able to gate acquisition fast enough to measure single bunches on single turns. Hence, events on a highly reproducible cycle – like injection – can be accurately measured.

Of particular interest is both closing the injection bump [3], as well as minimising the effect of sextupoles within the injection bump [4].

EXPERIMENTAL SETUP

The optical diagnostic beamline (ODB) of the Australian Synchrotron [5, 6] was used to image the visible light from the injected electron beam. To accommodate this imaging apparatus, the lens in the optical chicane [5] was removed. Instead, the principal focusing optic was positioned on the optical table, as described elsewhere in these proceedings [7]. We form a real image of the electron beam photon source at the ICCD camera.

The imaging system of the ICCD camera [1] can be triggered down to a shutter gate of 200 ps, sufficient to capture a single bunch of 23 ps which are spaced by 2 ns in the storage ring. Acquisition using the ICCD was triggered using the programmable accelerator timing system [8] Event Receivers which are synchronised to the accelerator RF system. The event-driven timing system was used to synchronise the camera with the injected beam and change the delay to monitor a different bunch or a different turn on a 1 Hz cycle. The reproducibility of the data was checked from one injection to the next to confirm that data taken on different turns during different injection events can be combined in a single data set.

The storage ring can be injected to a maximum of 200 mA with an injection rate of $\approx$ 1 mA per shot at a 1 Hz injection rate. To overcome the problem of sufficient dynamic range of the ICCD to observe both the an injected bunch and the stored beam, the stored beam was dumped by slowly phase flipping the storage ring RF phase by 180 degrees at the end of each 1 Hz injection cycle. In this way the storage ring was empty of charge during each injection and the ICCD could be set to maximum sensitivity to observe the low current injection shot. In order to record the sequence of images of the beam each turn, the gated ICCD camera was triggered by delay times equal to a multiple of the revolution period. The timing system can be set in unit of clock cycles which simplifies this process. The Event Receivers have a clock frequency of $\approx$125 MHz, so 90 clock cycles equals one revolution cycle of $\approx$1.38 MHz.

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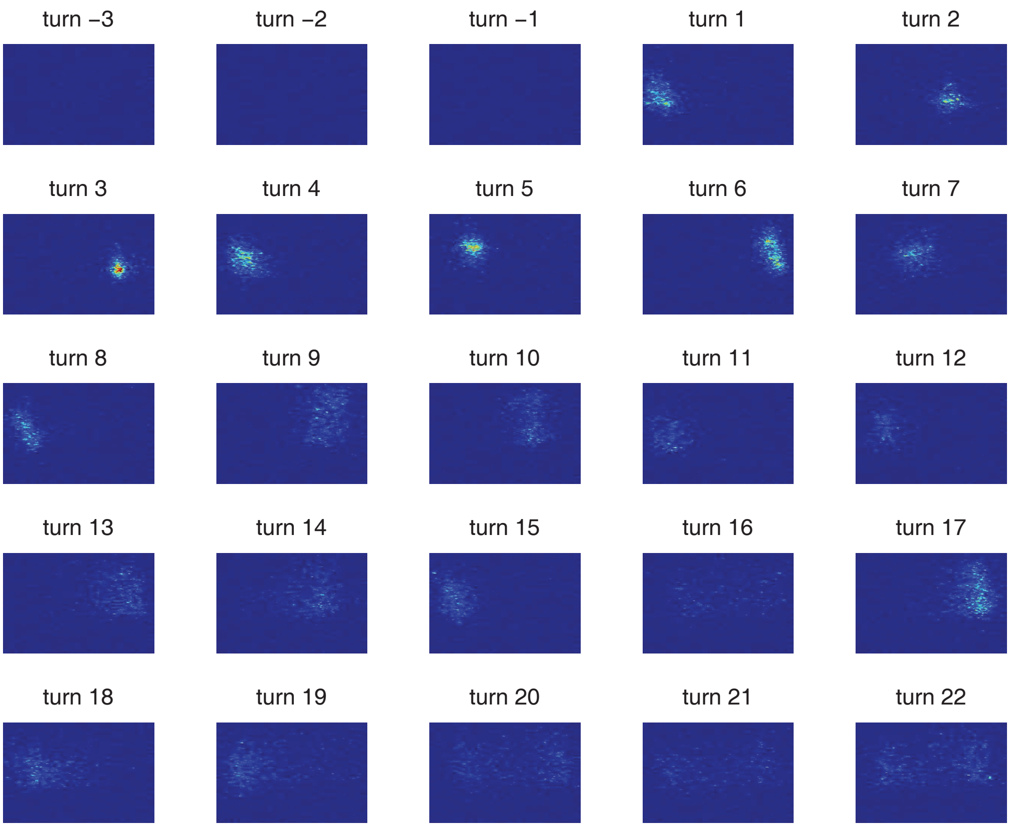
turn −3 turn −2 turn −1 turn 1 turn 2
turn 3 turn 4 turn 5 turn 6 turn 7
turn 8 turn 9 turn 10 turn 11 turn 12
turn 13 turn 14 turn 15 turn 16 turn 17
turn 18 turn 19 turn 20 turn 21 turn 22

Figure 1: Injected beam first 30 turns of the storage ring, imaged using ICCD camera.

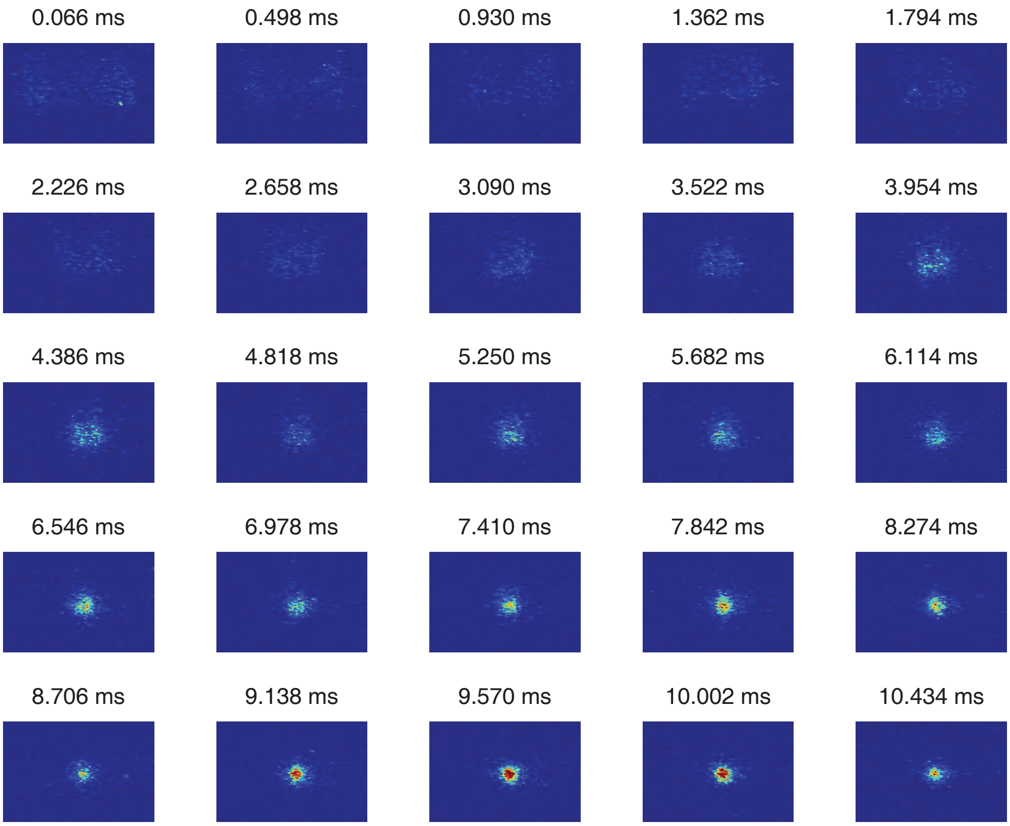
0.066 ms 0.498 ms 0.930 ms 1.362 ms 1.794 ms
2.226 ms 2.658 ms 3.090 ms 3.522 ms 3.954 ms
4.386 ms 4.818 ms 5.250 ms 5.682 ms 6.114 ms
6.546 ms 6.978 ms 7.410 ms 7.842 ms 8.274 ms
8.706 ms 9.138 ms 9.570 ms 10.002 ms 10.434 ms

Figure 2: ICCD images of the injected beam taken at intervals of 600 turns after injection.

RESULTS

The first few hundred turns of the beam were imaged turn-by-turn to establish the timing and performance of the system. The injection process was determined to be stable enough since the position and profile for a given turn was very similar from injection to injection. The first 8 turns shown in Fig. 3 were then examined in more detail and compared with the model shown in Fig. 4. The positions were in very good qualitative agreement and only turn 5 had a significantly different horizontal position compared with the measurement. Next the profile was examined for the first 22 turns as shown in Fig. 1, where the dark field frame for *turn* -1 was subtracted from the subsequent frames to remove the background noise. For the first 8 turns the beam seems to oscillate as expected about the central beam axis. However, from turn 9 onwards the beam appears to decohere and filament into a large diffuse blob covering the whole of the injection coordinate space. As seen in Fig. 2 this diffuse beamprofile persists for several thousands of turns until the beam damps down into a smaller profile after about two damping times ($\tau \approx 4$ ms).

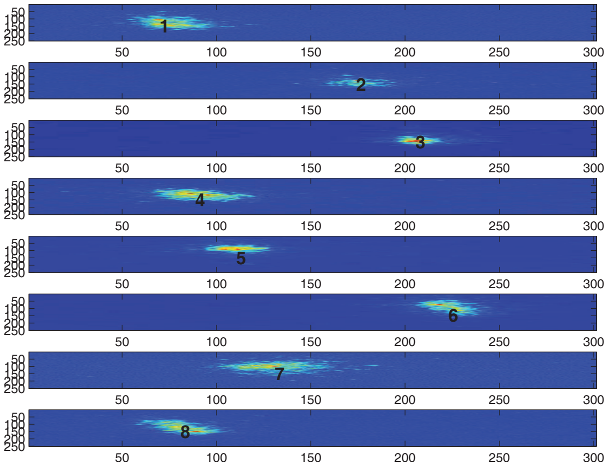

Figure 3: Injected beam over first eight turns . Images measured using optical telescope and ICCD camera.

ANALYSIS

The measured position of the injected beam for the first few turns in the storage ring are in excellent agreement with the model. Interestingly the beam appears to decohere after about 8 turns in the ring which can be due to the strong sextupole fields that are present due to the high chromaticity used to damp current dependent instabilities. It is hoped that by tuning the injection kicker bump the motion in the beam during injection will be reduced. In addition the operation of a bunch-by-bunch transverse feedback system is planned so the chromaticity can reduced and maybe the filamentation of the beam will be reduced, thereby improving the injection efficiency.

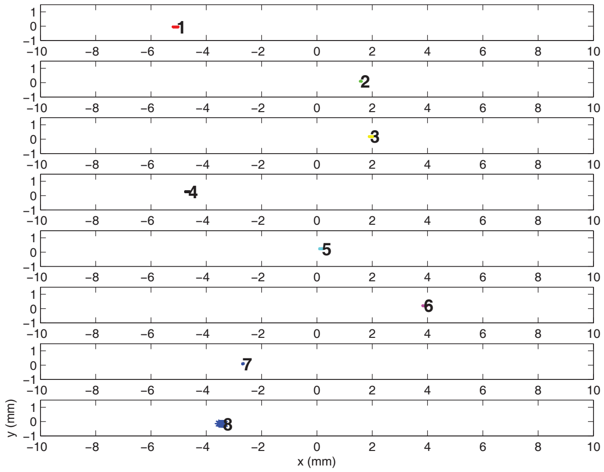

Figure 4: Tracking simulations over the first eight turns. Australian Synchrotron storage ring, modelled in AT [9].

CONCLUSIONS

A fast gated intensified CCD camera was used to observe the beam profile turn-by-turn in the visible light region. This measurement technique will be used to tune the storage ring injection process. The close agreement between measurements and tracking simulations illustrates the importance of this technique in observing real electron beam motion on fast gated timescales. In the future this technique will be used to fine tune the storage ring and the injection process.

ACKNOWLEDGMENTS

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