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OPTICAL TRANSITION RADIATION SYSTEM FOR ATF2*

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Abstract

In this paper we present the first measurements performed during the fall 2010 and early 2011 runs. Software development, simulations and hardware improvements to the Multi-Optical Transition Radiation System installed in the beam diagnostic section of the Extraction line of ATF2 are described. 2D emittance measurements have been performed and the system is being routinely used for coupling correction. Realistic beam simulations have been made and compared with the measurements. A demagnifier lens system to improve the beam finding procedure has been designed and will be implemented in a future run. We also discuss further work planned for the subsequent run periods.

INTRODUCTION

The Accelerator Test Facility (ATF) is a Damping Ring (DR) built at KEK (Japan). ATF2 is a Final Focus System (FFS) prototype for a future linear collider, designed to generate nanometer spot sizes at the main beam focal point, termed the Interaction Point (IP). The goal vertical size is 37nm. A secondary goal is to control the beam position at the nanometer-level at the IP to fully demonstrate the capability of this optics design to reliably deliver high luminosities at future high-energy linear colliders. The mOTR system is located in the transport beam line from the DR to the FFS (the extraction line, EXT [1]). The design vertical beam emittance in the EXT for the ATF2 experiment is 12 pico-mrad. The beam sizes at the locations of the 4 OTRs in this system for the default design optics are (from upstream to downstream): 114μm/8.6μm, 147μm/7.2μm, 90μm/11.5μm, 142μm/7.2μm for horizontal/vertical dimensions respectively. The mOTR system was installed in the diagnostic section of the EXT during the autumn of 2010. The system consists of four OTR monitors, each positioned close to existing wire-scanner systems (WS). The monitors are based on the transition radiation effect, a light cone emitted when charged particles cross a metallic interface. This light is emitted in a specular fashion from the target, which is utilised so the device can extract the light from the vacuum chamber and focus it onto a CCD camera. The WS measurements require many pulses, often with an overestimation of the beam size due to beam position and intensity jitter, and can take many minutes to complete a single set of beam size measurements. The OTRs on the other hand, are able to take single-shot measurements of the beam ellipse at the beam repetition rate (1.5Hz). This enables us to measure the emittance with high statistics and perform correlated measurements, e.g. for studying emittance preservation during extraction from the ATF DR [2]. The minimum beam size that this OTR system is capable of measuring is about 2um (the 2-lobe distribution of the OTR light starts to become a domanant factor at this scale, whereupon a different measurement scheme would be required). The measurement resolution of this system is typically a few-percent

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HARDWARE AND SOFTWARE STATUS

This OTR system design was an evolution of a previous system placed in the EXT line [3] of the previous configuration of ATF prior to 2008. It includes some new modifications related to the optical system, the target actuator, the target material itself, the OTR main body and the total footprint [4]. Four of these OTRs were installed in the present EXT during the first half of 2010. The commissioning and successful testing of the complete system was completed in the autumn of 2010. Also during 2010 some other improvements have been incorporated into the installed OTR system. A set of wires below the target allows us to make measurements of the beam size in a complementary way to using the OTR image by scanning the wires with the OTR motor system and detecting the Compton scattered photons in the background detector of the IP beam size monitor diagnostics system. A new calibration system now includes a small lamp that can be pushed into the beam pipe to illuminate the target when there is no beam. The last change to be introduced will be a double optical system (see Fig. 1) in order to be able to select a shorter focal length that will ease beam finding difficulties, ensure that the full beam ellipse is imaged at the locations with larger horzontal spot sizes as well as ensuring the beam ellispse will fit onto the screen in cases where the beam is larger than the design.

The target material used is aluminum-coated kapton for OTR 2 and 3, and 1 m thickness aluminum foils for OTRs 0 and 1. The user interface is programmed in Matlab and includes basic control commands, for example: the horizontal and vertical motion of the devices plus target, machine protection alarms, single-OTR data analysis functions for beam size measurement. The control software uses simultaneous information given by the four OTRs and the Flight Simulator (software running the online model for ATF2) (FS) [5] to calculate the emittance and perform other analyses. The emittance reconstruction algorithm is based on

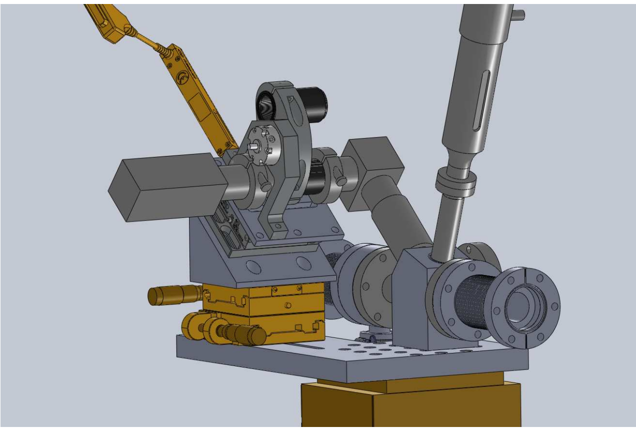

Figure 1: OTR demagnifier lens.

the one used for the WS. Occasionally, this algorithm has been observed to have an issue regarding the generation of imaginary emittance results when measurement errors are of a too high level [6]. This is not a big problem here since the mOTR takes less than a minute to perform the emittance measurement and the size is not over-estimated due to the jitter. A simulation-based analysis was performed to understand the limitations of this algorithm as it pertains to this OTR system, which is presented below. A 4D algorithm that will take into account the additional information given by the direct imaging of the beam ellipse (the tilt of the beam ellipse at the OTR locations) is under study. This will allow determination of the coupling terms and give us the possibility of correcting these with a single set of measurements rather than scanning the emittance with different skew-quadrupole settings as is currently required. Other functions to be implemented include automatic beam finding using information from the surrounding beam position monitor systems, automatic coupling correction, and an auto-focus mechanism.

CALIBRATION AND FIRST MEASUREMENTS

A calibration of the positioning system for all OTR devices was made in December 2010. To calibrate the scale, an OTR is moved in one direction and the centroid position versus the mover position curve is fitted. To determine the roll alignment of the system, the beam is steered in one direction using an upstream corrector magnet whilst recording the centroid position in the other axis.This aligns the OTR system in the same co-ordinate frame as that of the corrector magnets. Other accelerator components are so-aligned, leading to a common co-ordinate frame. From autumn 2010 until March 2011, the OTRs were used during ATF2 beam operations for emittance measurement and coupling correction. The system gives a single bunch size for each OTR and, after the targets are correctly aligned, provides an emittance measurement along with a statistical error in less than a minute. The measured beam

Table 1: Comparison between beam simulations and real measurements (sizes in μm).

	x		**y**	
	Tracked	Measured	Tracked	Measured
OTR0	183	143	20	24
OTR1	231	282	17	18
OTR2	93	96	22	26
OTR3	85	165	8	14

sizes were crosschecked with the wires installed in the target holder and the WS system. Emittances around the nominal ones were obtained in the tests with about 10% measurement-measurement fluctuation (Figure 2). Figure 3 shows the mOTR system being used for coupling correction by changing the strength in four upstream skew-quadrupole magnets and looking for the setting in each one that minimises the measured emittance.

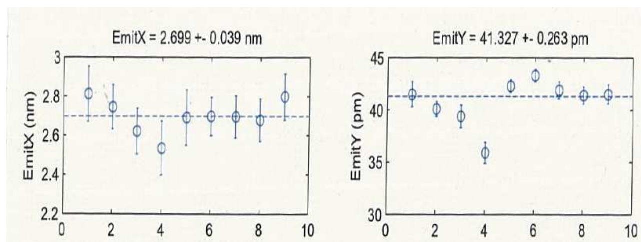

Figure 2: A set of systematic emittance measurements.

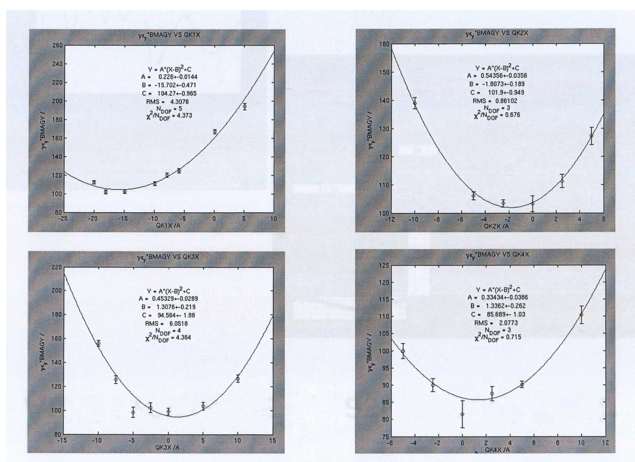

Figure 3: $emit_{norm} * Bmag$ versus skew quad intensity for coupling correction.

Realistic beam simulations were made and compared with the measurements. Table 1 shows the results of the comparison between realistic beam simulations and measurements as in Dec. 17th 2010 while Figure 4 shows a set of horizontal sizes as an example.

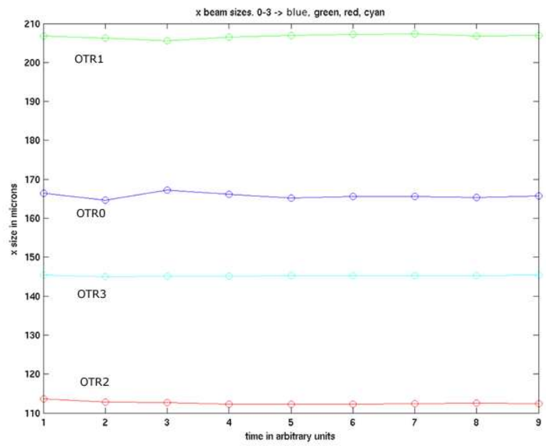

Figure 4: Set of x measurements.

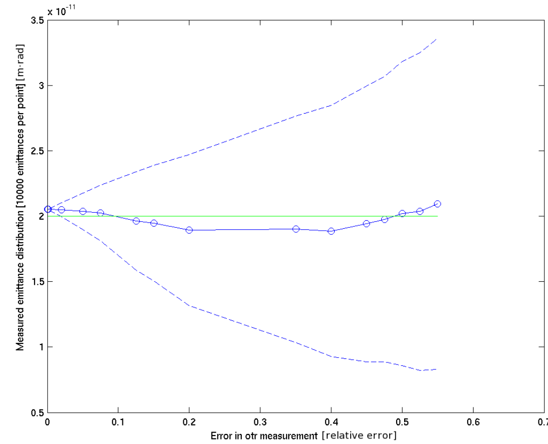

Figure 5: Comparison between input and mean of calculated emittances.

EMITTANCE ALGORITHM STUDIES

Simulation studies were performed to understand the limitations of the emittance reconstruction algorithm that is sometimes observed to give imaginary values for the calculated emittance. The fraction of non-real emittance values was calculated as a function of input accuracy of the beam size measurements at the OTR locations and the degree of coupling put into the simulated beam. Fig 5 shows a comparison between the calculated emittance value and the input emittance. The blue solid line shows the mean value of 10k emittance calculations, the dashed lines show the +/- one sigma values. The green line shows the input beam emittance. With a relative beam size measurement error below 10% there is a systematic over-estimation of the emittance at the level of about 4%. Taking as an example a 5% error in the beam size measurement, fig. 6 shows a histogram displaying the simulated reconstructed values. The blue line is the mean measured emittance and the green one is the input. The systematic relative error on the emittance reconstruction in this case is 1.9%. For the 5% measurement error the emittance statistical jitter is around 10%, which is in agreement with the 10% measurement-measurement fluctuation given above.

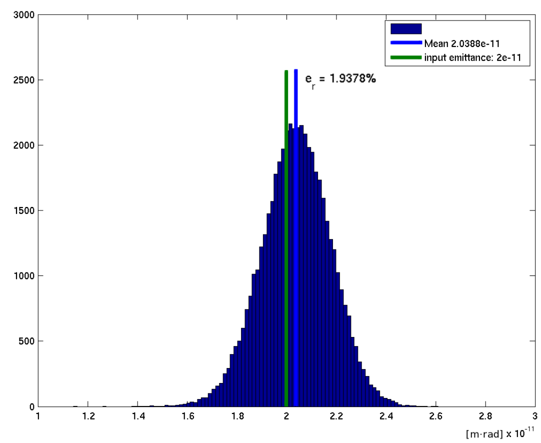

Figure 6: Calculated emittance distribution for a 5% size measurement error. 50k emittance calculations.

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REFERENCES

[1] ATF2 Group, “ATF2 Proposal Vol.1,CERN-AB-2005-035”, (August 11, 2005)

[2] J. Bosser et al., “Optical transition radiation proton beam profile monitor”, Nuclear Instruments and Methods in Physics Research A238, (1985), 45-52

[3] M. Ross et al., “A very high resolution optical transition radiation beam profile monitor”, SLAC-PUB-9280, (2002)

[4] J. Alabau et al., “Multi optical transition radiation system for ATF2”, IPAC’10, Kyoto, MOPE050, (2010)

[5] G. White et al., “A flight simulator for ATF2: A mechanism for international collaboration in the writing and deployment of online beam dynamics algorithms”, EPAC’08, Genoa, TUPP016, (2002)

[6] I. Agapov et al., “Beam emittance measurement with laser wire scanners in the International Linear Collider beam delivery system”, Phys. Rev. ST Accel. Beams 10, 112801 (2007)