THE ATF2 MULTI-OTR SYSTEM: STUDIES AND DESIGN IMPROVEMENTS*

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Abstract

A multi-Optical Transition Radiation (mOTR) system made of four stations has been installed in the extraction line of ATF2 and has been fully operational since September 2011. The system is being used routinely for beam size and emittance measurements as well as for coupling correction and energy spread measurements. In this paper we present the current design and a OTR monitor future upgrade to avoid the wakefields when a simultaneous measurement is made. Finally we report the measurements made in ATF2 during 2011-2012.

INTRODUCTION

ATF2 is an extension of the Damping Ring (DR) of ATF built at KEK (Japan) [1, 2]. ATF2 is a prototype of a Final Focus System (FFS) for a Future Linear Collider such as the International Linear Collider (ILC) or the Compact Linear Collider (CLIC). The first of the ATF2 goals is to generate a vertical beam size of 37 nm at the Interaction Point (IP). The second ATF2 goal it to achieve nanometer-level beam stabilization at the IP in order to be able to demonstrate the capabilitiy of this optics design to reliably deliver high luminosities at future high-energy linear colliders. A mOTR system was installed in the ATF2 extraction line (EXT line) during autumn 2010. This system consists of four OTR monitors [3], and is currently being used for beam size measurement and emittance reconstruction during the ATF2 operation. The mOTR system was installed near an existing wire scanner system (WS) [4] in order to compare the performance of both systems. The WS needs a high number of pulses to make a measurement, resulting in an overestimation of the size due to the beam position and intensity jitter. Moreover, it can take several minutes to complete a single set of beam size measurements. On the other hand, the OTRs are capable of single-shot measurements of the beam ellipse at the beam repetition rate (1.56 Hz). This permits reconstructing the emittance with high statistics and making correlated measurements such as studying the emittance preservation during the extraction from the ATF DR. The minimum beam size that the OTR system can measure is about 2 μm (the 2-lobe distribution of the OTR light starts to become a dominant factor at this scale, whereupon a different measurement scheme would be required). The measurement resolution of this system is typically a few-percent. Figure 1 shows the layout of the mOTR system in the diagnostics section of the EXT line, highlighting the WS location for comparison.

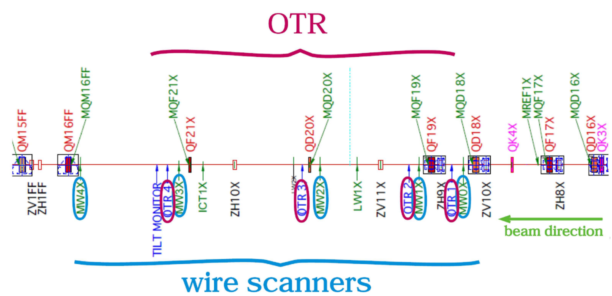

Figure 1: Layout of the ATF2 diagnostics section of the EXT line where the WS and the Multi-OTR system are located, the beam going from right to left.

CURRENT DESIGN AND FUTURE UPGRADES

The 4 OTRs are based on the design of a previous one labeled as OTR1X [5], placed near one of the WSs in order to compare them and to demonstrate the ability to measure the small beam sizes likely to be found after a linear collider DR. Some of the issues presented in the old design were improved in the new one: the footprint was lowered from 55 cm to less than 30 cm, the target actuator was placed on the top, thus reducing the interference problems with the supporting structure, the lens darkening and the camera damage due to radiation was solved by using a 90 degree mirror and a lead protection shield, the targets were changed using two made of 2 μm aluminum and two targets made of 3 to 5 μm kapton with 0.12 μm aluminum coating.

Figure 2 shows a general overview of the new OTR design and Figure 3 shows it as it is installed in ATF2 EXT line. The yellow scotch covers the main body and the side window to protect from light coming in from outside. Below it, the vertical and horizontal stepper motors are shown. From the body, in the upper-left direction is the target actuator and in the upper-right direction the optical elements. The lead shielding for preventing CCD camera damage can be seen on the left of the OTR. At the left and right sides of the body there are a couple of bellows that allows some horizontal and vertical displacement of the whole OTR system.

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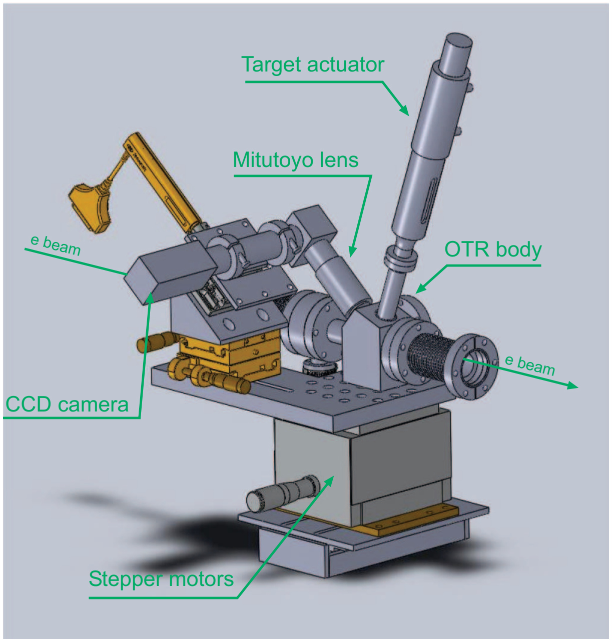

Figure 2: 3D view of the new OTR design.

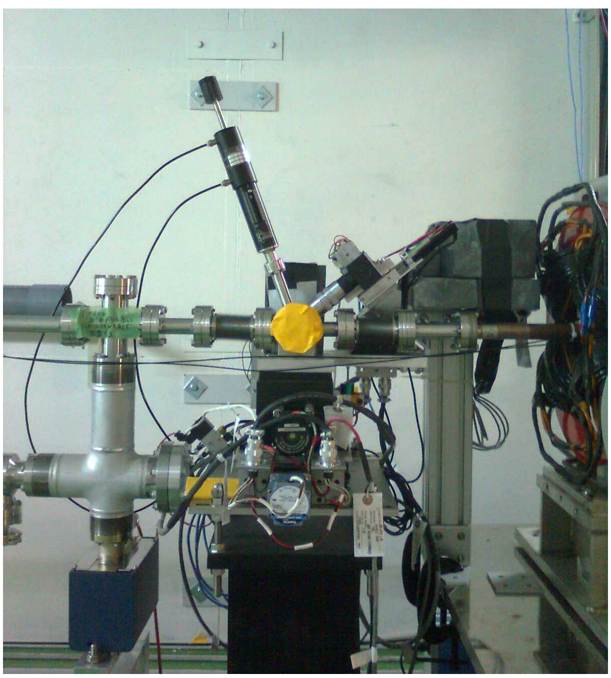

Figure 3: OTR as it is installed in the ATF2 EXT line, the beam going from right to left.

In addition, a calibration lamp was installed, consisting in a bellow that permits the movement in and out the beam pipe of a small lamp which is subjected with a ceramic tube for isolation and feeded by a feedthrough BNC. Another upgrade with respect to the original design is a zoom system that can set a variable Field of View. This was motivated by the difficulty to find the beam in operation and the fact that sometimes the spot was slightly bigger than the screen so that the measured beam size was wrong.

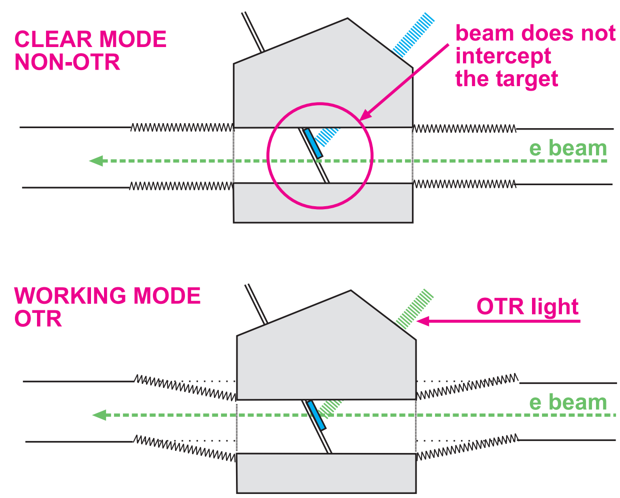

Figure 4: The OTR body is lowered to enable the target to intercept the beam.

In the "non-operation mode" the OTR body is placed in a position such that the incoming and the outgoing beam pipe are straight (Figure 4 up). Due to design constraints the whole OTR body has to be lowered for operation. This brings the chamber closer to the beam (Figure 4 down). This mode of operation generates wakefields that are significant when the 4 OTRs are in measuring position, i.e. simultaneous measurement. This generates an emittance growth that has been measured. Figure 5 shows the wakefield effect on the vertical and horizontal size at the OTR3X when the OTR2X is lowered from the position where the bellows are horizontal and aligned with the beam pipe (here around 5.5 mm) to the measuring position (which is the 0 reference position in the horizontal scale).

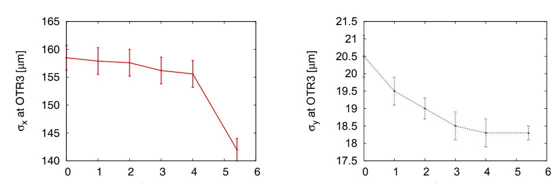

Figure 5: Effect in OTR3X beam size due to wakefields generated in OTR2X when lowering it.

In order to avoid this effect without having to redesign the whole OTR body, a modification of the target holder that brings down the intersection between the optics line and the target has been proposed. The mechanical layout of the new holder is compared with the current one in Figure 6. In this way the whole body has to be lowered only by 1.52 mm instead of 7 mm, thus reducing wakefield effects. The target itself has to be modified as well by having the mirror surface in the opposite side as in the current design and a ramp has to be added in order to avoid interference of the actuator with the OTR body when the target

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is extracted. The microscope lens also has to be changed depending on the last design of the target holder. These improvements are planned to be implemented in autumn 2012.

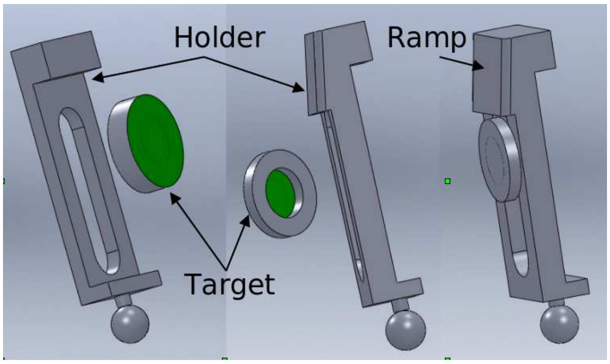

Figure 6: Current target and target holder in the left, new proposal in the right.

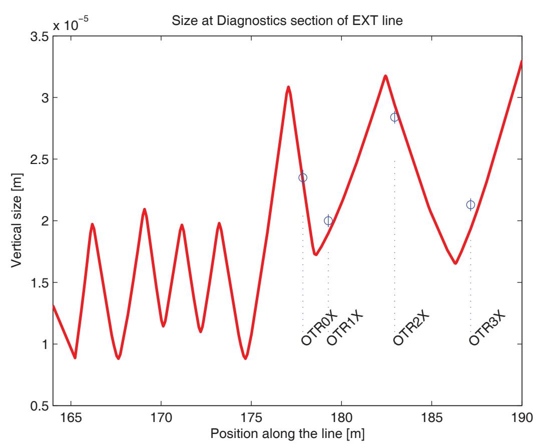

Figure 7: OTR (OTR#X) beam size measurement compared with the model, in solid line. This set of measurements was made in the ATF2 run period of March 2012.

EMITTANCE RECONSTRUCTION AND OTHER STUDIES

Emittance measurements are currently performed with the mOTR system with success. The performance of the system has been compared with that of the WS. Figure 7 shows a set of measurements of the vertical beam size compared with the optical model while Figure 8 shows a measurement comparison with the WS system.

Apart from the emittance reconstruction the mOTR system is being used routinely for cross-plane coupling correction with success. The usual correction method consists in scanning in intensity four skew quadrupoles installed upstream of the OTRs and then reconstructing the emittance with the mOTR system. The optimal set of skew intensities is the one which minimises the vertical emittance and thus

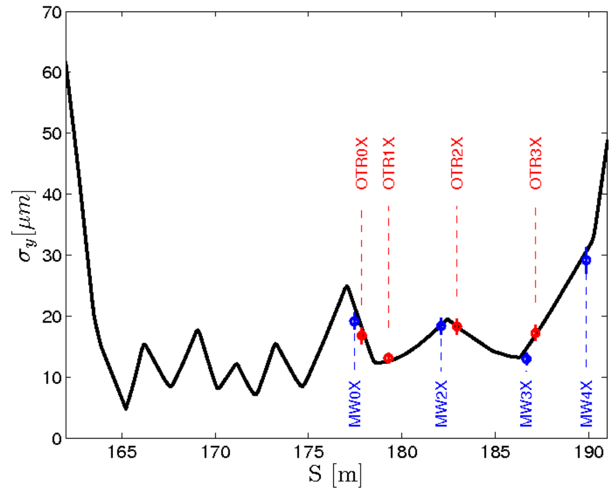

Figure 8: OTR (OTR#X) and WS (MW#X) beam size comparison. Model in solid line. This set of measurements was made in the ATF2 run period of December 2011.

the coupling. An automatic procedure based on a response matrix algorithm has also been implemented in the ATF2 control system and works well when the coupling is low.

Moreover, the mOTR system has been used to measure the beam energy spread giving a value consistent with the nominal one. This measurement was made by changing the dispersion in the OTR location and measuring the consequent growth of the beam size. The mOTR is also helpful to other studies such as investigating the source of the emittance growth after the DR beam extraction.

SUMMARY

The mOTR is working well and is being used routinely in beam emittance reconstruction and in coupling correction. Improvements are planned in both hardware and software including studies in the 4D emittance reconstruction, single-shot coupling correction and automatic beam finding using the data from the nearer BPMs.

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