

# MULTI OPTICAL TRANSITION RADIATION SYSTEM FOR ATF2\*

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## Abstract

In this paper we describe the design, installation and first calibration tests of a Multi Optical Transition Radiation System in the beam diagnostic section of the Extraction (EXT) line of ATF2, close to the multi wire scanner system. This system will be a valuable tool for measuring beam sizes and emittances coming from the ATF Damping Ring. With an optical resolution of about  $2\mu\text{m}$  an original OTR design (OTR1X) located after the septum at the entrance of the EXT line demonstrated the ability to measure a  $5.5\mu\text{m}$  beam size in one beam pulse and to take many fast measurements. This gives the OTR the ability to measure the beam emittance with high statistics, giving a low error and a good understanding of emittance jitter. Furthermore the nearby wire scanners will be a definitive test of the OTR as a beam emittance diagnostic device. The multi-OTR system design proposed here is based on the existing OTR1X.

## INTRODUCTION

The Accelerator Test Facility (ATF) is a Damping Ring (DR) built at KEK (Japan) to reach the world lowest emittance values. ATF2 is a Final Focus System (FFS) prototype for a future linear collider that has been recently built to obtain nanometer spot sizes and to control the beam position at nanometer level at the Interaction Point. The transport beam line from the DR to the FFS is called the extraction line (EXT line) [1].

The beam emittance measurement in the EXT line is required for a single bunch and for a 20 multi-bunched beam with  $2.8ns$  spacing. In order to measure the minimum expected beam size in ATF with a 10% accuracy a  $2\mu\text{m}$  resolution device is necessary.

In the diagnostic section of the EXT line four Optical Transition Radiation monitors (OTRs) close to the current wire scanners (WS) are being installed. These monitors are based on the transition radiation effect, a light cone emitted when the charged particle crosses a metallic interface. This light is emitted in a specular fashion so the device can focus it in a CCD camera. Whereas the WS measurements require many pulses, often with an over-estimation of the beam size due to beam position and intensity jitter, and can take up to half a minute to complete the measurement; the OTRs are able to take many fast measurements and therefore to measure the emittance with high statistics,

moreover, the multi-OTR system will be a valuable tool for measuring beam sizes and emittances from the ATF DR [2].

## MULTI-OTR DESIGN

Nowadays in the EXT line of ATF2 there is one operational OTR, labeled as OTR1X. Its original purpose was to demonstrate that this device could measure the small beam sizes that would be found after a linear collider DR and evaluate target materials for the currents and spot sizes most likely to be encountered [3].

The design of the new device is based on the OTR1X but it implements some new modifications. Schematically an OTR monitor consists in a metallic foil that is inserted in the beam pipe with a certain angle and an optical system that takes an image of the light emitted when the beam passes through the target.

The positioning of the target is made by a pneumatic actuator and repeatability of the target position is assured by a stainless steel ball at the end of the actuator shaft that is pushed into a titanium conical receiver inside the OTR body.

Figure 1 shows the latest version of the OTR design, the beam moves from left to right. In the left side of the pipe there is the optical system: a Mitutoyo lens, a 12bit Prosilica camera and a Newport focus adjuster. A pair of horizontal Newport stages are included to make the set up easier and in case of target damage, allow different areas of the target to be viewed. The top of Fig. 1 shows the target pneumatic actuator and in the bottom, a pair of movers. The whole system is vertically and horizontally movable with these stages making it possible to search for the beam for measurements or to leave a clear space for normal beam operations.

The new design's calibration system includes a scribed target and a small lamp that can be pushed into the beam pipe to illuminate the target when there is no beam. The target scribe marks are well illuminated and the stages supporting the camera are used to move the camera precisely over the scribe marks. This produces the required pixels/micron calibration.

The total footprint was reduced with respect to the old one by nearly half and now the overall length is less than 30cm.

In the old design there were problems of copper target destruction because of the energy deposition [3]. A goal of ATF2 is to get  $2 \times 10^{10}$  electrons in a single bunch and to do multi-bunch experiments with over  $2 \times 10^{11}$  in a train. With these levels of currents too small spot sizes cannot be

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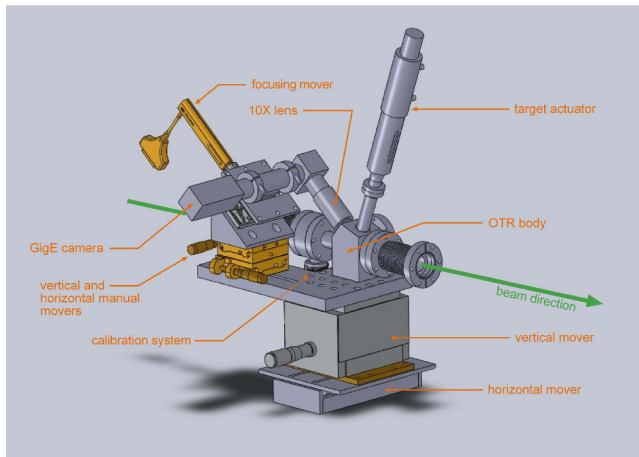


Figure 1: New OTR design.

allowed with OTR operations. During damage tests, round spots of about  $5\mu\text{m}$  were reached and even beryllium copper targets were damaged. With current beam aspect ratios of around 50 times larger than during the tests damage will be much less of a problem but multi-bunch operation will still not be possible without risking target damage. If currents are too low and spots are too large it will be difficult to get enough light output to have a good signal to noise. Taking in account these constraints the ideal spot size would be somewhere around  $20\mu\text{m}$  in  $y$  and  $200\mu\text{m}$  in  $x$ .

For the new design an extremely thin aluminized mylar target will be used and the spot sizes estimated for the four locations will be larger than before so no target damage problems are expected. Figure 2 shows an OTR capture of the beam taken with the new mylar target during November 2009 in the operating old OTR without having any target problems.

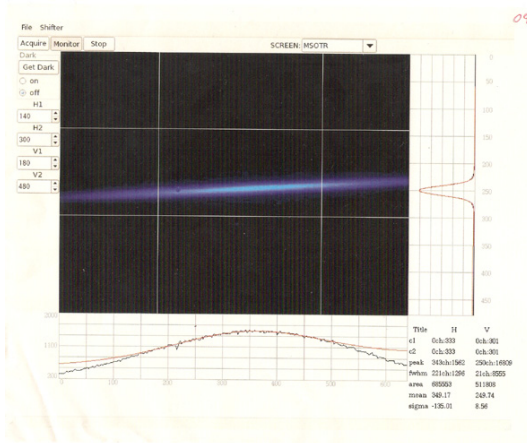


Figure 2: Test of the new target at OTRIX in November 2009.

The optical system is based around a commercial long working distance microscope objective. It uses a 10X lens with Numerical Aperture of 0.28 and  $1\mu\text{m}$  resolving power.

Table 1: Beam Size Comparison in OTR and WS Locations

Label	OTR		WS		units
	$\sigma_x$	$\sigma_y$	$\sigma_x$	$\sigma_y$	
0	118	9	82	11	$\mu\text{m}$
1	148	8	157	7	$\mu\text{m}$
2	92	12	88	13	$\mu\text{m}$
3	144	7	151	6	$\mu\text{m}$

The working distance of the lens is about 34mm which requires a thin compact non distorting vacuum window. ZEMAX calculations indicated that a 1mm thick 7mm diameter fused silica window with a  $\lambda/4$  surface flatness would produce small enough distortions so that the lenses' resolving power was minimally affected. This window is vacuum sealed with an indium wire and a threaded ring.

Since in the old design there are problems of depth of field, in this design the the camera is planned to be tilted so that the CCD is parallel to the OTR target and it is expected than this will reduce the need to always adjust the focus during operation. The optics is to be folded as well, in order to make it easier to shield the camera from radiation damage. Since target thickness is reduced, the radiation from the beam target interaction is going to be lower and less lens darkening is expected.

## OPTIC STUDIES AND BEAM SPOT SIZE TRACKING SIMULATIONS

The four OTRs (labeled as OTR0, OTR1, OTR2 and OTR3) are being installed close to the existing WS (labeled as WS0, WS1, WS2 and WS3) in the EXT line where the dispersion vanishes and emittance measurements are possible. Moreover, the proximity to the WS will be a definitive test of the OTR as a beam diagnostic device.

Optics studies and tracking simulations with MAD program have been made. The beam spots calculated from the optics are big enough not to damage the target and they are comparable to these on the WS. Comparison with the WS beam spot sizes are found in Table 1. The beam spots from tracking simulations are shown in Fig. 3 Input beam for the MAD simulations was 50000 particles with gaussian distribution in  $x$ ,  $y$  and energy, and with  $8.00 \times 10^{-4}$  of dispersion energy.

## SOFTWARE

The high level control software and the user interface are being developed in Matlab. It will include basic control commands like the moving of the devices, taking the target in and out, machine protection alarms as well as single-OTR data analysis functions for beam size measurement. Proper multi-OTR functions will use near simultaneous information of the four OTRs to perform algorithms in order to calculate the emittance value.

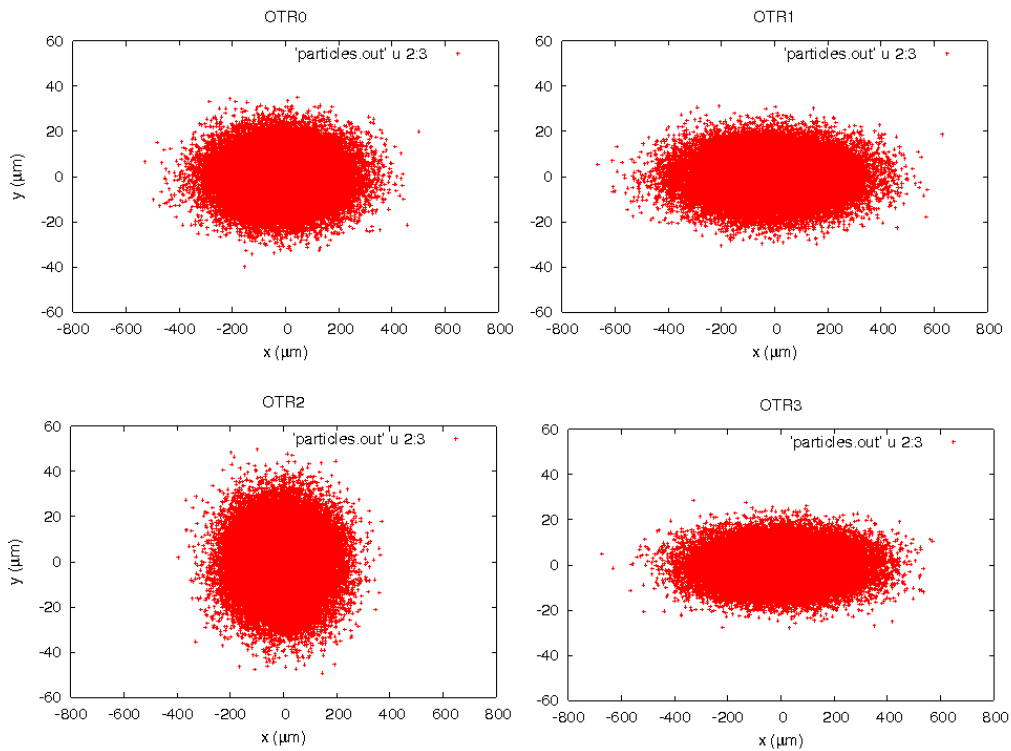


Figure 3: Tracking spotsizes at the OTR locations

The software uses labCA to send EPICS commands to the IOC software and it will be integrated in the on-line Flight Simulator [4]. Because of this, the autotracking of the beam can be implemented in the future by receiving information from nearby Beam Position Monitors so the four targets will be automatically positioned.

### INSTALLATION PLANNING

The first OTR (labeled as OTR1) is already installed, the other 3 OTRs are assembled at the KEK clean room, they are ready for the installation at end of May 2010. Figure 4 shows the first OTR (OTR1) installed in the line on April 2010. Calibration and first tests with beam are expected to be made during June 2010.

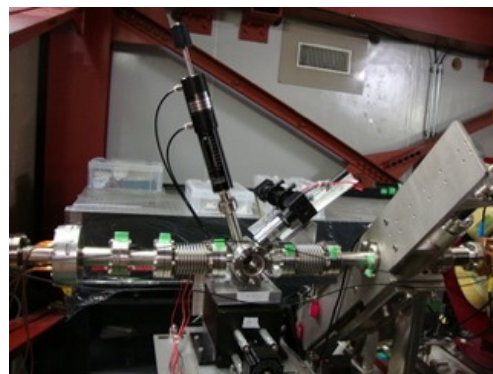


Figure 4: OTR1 installed at ATF2.

### SUMMARY

A Multi-OTR system is being installed in the EXT line of ATF2 and will be soon operative. Measurements with OTR monitors will help to understand emittance jitter in the line and its success will definitely confirm the OTR as a emittance diagnostic device.

### ACKNOWLEDGMENTS

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[06 Beam Instrumentation and Feedback](#)

[T03 Beam Diagnostics and Instrumentation](#)

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