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ADVANCES IN OPTICAL TRANSITION AND DIFFRACTION RADIATION EMITTANCE DIAGNOSTICS*

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Abstract

. Optical transition radiation and optical diffraction radiation interferometry have been used to measure the two orthogonal divergences of the 1.5 pps, 50 MeV electron beam produced at the Accelerator Test Facility at BNL for two different beam tunes. A comparison of the results using OTRI, ODTRI and transport code calculations is presented.

INTRODUCTION

Conventional two foil OTR interferometry has been used with great success to measure the beam divergence of electron beams when the normalized divergence, $\gamma\sigma$ is much larger than the energy spread $\Delta\gamma/\gamma$ and the rms scattering angle in the first foil of the interferometer [1,2]. However, the latter condition is a serious limitation for very low emittance and or low energy electron beams. We have found way to overcome this limitation by using a micromesh front foil.

Electrons passing through the holes and the wires of the mesh produce forward ODR, which is reflected and interferes with backward OTR from a mirror, i.e. ODTRI.

If the mesh is sufficiently thick and the atomic number sufficient high for a given energy, the ODR interferences from scattered electrons in the wires of the mesh are washed out forming a smooth background. The ODR produced by electrons passing through the holes in the mesh produces visible fringes riding on this background. Each of the ODR components are calculated from a simulation code we have developed which is described in [3]. The visibility of the observed fringes is a diagnostic of either the transverse rms x or y divergence, when the beam is respectively focused to either an x or y waist condition. If the beam is simultaneously imaged at the mirror and in the far field (angular distribution pattern), the rms size and divergence can be obtained from these images and used to determine the respective x and y rms emittances.

In this paper we present experimental validation of ODTRI as a beam divergence diagnostic by comparing the measured divergences obtained with ODTRI, OTRI and multiple screen measurements before and after the position of the interferometer along the beam line. The latter data are used to calculate the emittance and divergence of the beam with the help of a transport code.

EXPERIMENTAL SETUP

The experimental setup is similar to the one presented in [4] except that the far field camera is placed on the floor. Relay optics are used to transport the light from the beam line to this camera. The field of view of the optics was approximate 0.1 rad or about $10/\gamma$.

The near field camera, a RS 170, 8 bit CCD, is focused on the mirror to image the beam. An integration of about 10-20 beam pulses is usually needed to obtain a high quality image of the beam. The camera used to obtain the far field interference pattern is an Apogee Instruments Inc. model E47+, a high quantum efficiency (>80% at 500nm) cooled CCD camera with very low electronic noise and a high dynamic range (16 bits). This camera is focused at infinity and an integration time of several minutes, which is obtained by keeping the programmable mechanical shutter of this camera open, is necessary to obtain the far field images (interferograms).

A picture of the type of OTR and ODR interferometers used in our experiments is also presented in [4]. For the ATF beam data the inter-foil spacing is set to ~50 mm to tune the interferometer for the expected rms divergence. The mesh used to generate the ODR was a 5 micron thick copper with 750 lines per inch. The foil in the OTR interferometer was 0.7 micron thick aluminum.

Two different beam tunes were used in our experiments. The beam parameters for the first beam tune are x,y radii = 0.19,0.27 mm; charge per pulse= 500 pC. For the second tune the x,y beam radii = 0.35,0.25; charge per pulse=700 pC .

RESULTS

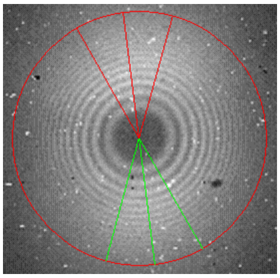

Figure 1 : ODTRI pattern for 1st beam tune showing the sectors over which the horizontal scan is averaged (note that the optics rotates the image by about 85 degrees).

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An ODTR interferogram measured for the first beam tune is shown in Figure 1. This picture is obtained over an integration time of 480 seconds. A 650 nm interference filter with a band pass of 10nm FWHM was used to obtain all interferograms. An improved signal to noise was obtained by averaging the intensity of each interference fringe over the angles bounded by the sectors shown in Figure 1. The width of each sector is chosen so that the fringe visibility of the averaged line scan was not appreciably different from an unaverged single line scan through the center of the sector. The apparent vertical angular orientation of the sectors is due to an 85 degree rotation of the angular pattern produced by the transport optics. The bisecting line shows the true horizontal direction with respect to the beam axis.

Figure 2. shows a horizontal line scan (dotted red line), which is obtained by averaging the intensity of the fringes shown in a horizontal sector of the interferogram and a theoretical line scan (shown in blue) which is obtained using the simulation code described in [3]. The best fit parameters are: E = 50 MeV, beam divergence, σ = 0.28 mrad, inter-foil spacing, d = 44.5 mm.

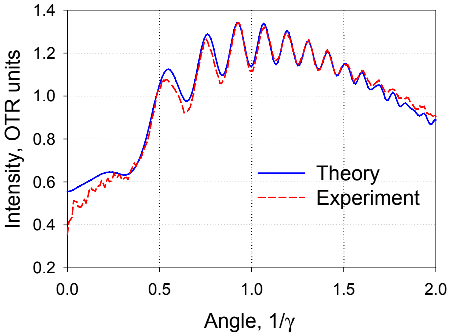

Figure 2: ODTRI horizontal scan (dotted red line) averaged over the sector shown in Figure 1. compared with simulation (solid blue line).

A similar vertical line scan obtained by averaging over a vertical sector of the ODTRI pattern presented in Figure 3. along with the fit from the simulation. The best fit parameters for this scan are: E= 50 MeV, divergence = 0.28 mrad, inter-foil spacing, d = 44.5 mm.

An ODTR interferogram for the second tune is shown in Figure 4. which represents a case when the beam has greater x and y divergences than in the first tune.

Comparisons of the fitted parameters and divergences obtained using OTRI, ODTRI and calculated using multiple screen measurements and a beam transport code are given in Table 1.

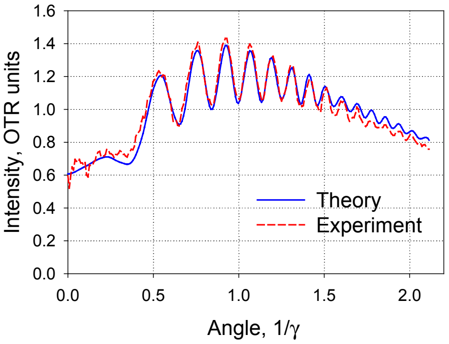

Figure 3: ODTRI vertical sector averaged scan (dotted red line) compared with simulation fit (solid blue line).

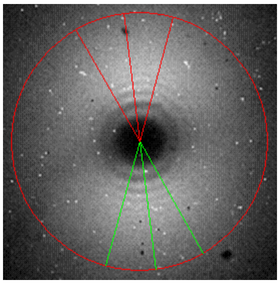

Figure 4: ODTR interferogram obtained for the second beam tune.

Table 1: Measured and Fitted Parameters

tune	interfer-ometer	scan	E (MeV)	d (mm)	σ meas (mrad)	σ calc (mrad)
1	OTRI	H	50.7	47.0	0.35	0.31
1	OTRI	V	50.7	47.0	0.30	0.23
1	ODTRI	H	50.0	44.5	0.28	0.31
1	ODTRI	V	50.0	44.5	0.28	0.23
2	OTRI	H	50.3	47.0	0.50	0.37
2	OTRI	V	50.3	47.0	0.75	0.75
2	ODTRI	H	49.3	44.5	0.60	0.37
2	ODTRI	V	49.3	44.5	0.45	0.75

The results of Table I. show good agreement between the measured values of the divergence (σ meas) obtained from standard OTRI, ODTRI and calculated from the multiple screen measurements and transport code. The agreement is somewhat less satisfactory for the second tune for which the fringe visibility was less and the background was higher than in the first beam tune.

CONCLUSIONS

We have demonstrated experimentally that ODTRI is a viable new method for measurement of beam divergence and can therefore be used to measure rms emittance when the beam is focused to a waist condition in a manner completely similar to conventional OTRI. The use of ODTRI has the distinct advantage that the unperturbed divergence can be measured without the contaminating effect of scattering in the first foil as is the case for OTRI. Thus ODTRI can be used for lower emittance and lower energy beams to measure beam divergences that are less than what is possible with OTRI.

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