OTR MONITORS FOR THE IFUSP MICROTRON*

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Abstract

In this work we describe the design of the Optical Transition Radiation (OTR) monitors that will be used to measure beam parameters of the IFUSP Microtron. The OTR monitor design must allow for efficiency in the entire energy range (from 5 MeV up to 38 MeV in steps of 0.9 MeV), and the devices are planed to monitor charge distribution, beam energy and divergence. An exception is made for the OTR monitor to the 1.8 MeV beam line, which is to be used to monitor only the beam charge distribution at the exit of the linac injector. The image acquisition system is also presented.

INTRODUCTION

The Instituto de Física da Universidade de São Paulo (IFUSP) is building a two-stage 38 MeV continuous wave racetrack microtron. This accelerator consists of a linac injector that delivers a 1.8 MeV electron beam to a five-turn microtron (booster). That small microtron works outside of stability and accelerates the beam to 5 MeV. A transport line guides the beam to the main microtron to be accelerated to energies up to 38 MeV in steps of 0.9 MeV.

The beam diagnostics is made using phosphor screens for beam positioning and faraday cups for total beam current measurements. A diagnostic device capable of doing measurements of transversal current distribution at the exit of the linac injector is necessary to future experimentations [1]. A beam monitor based on OTR emission is a good choice due to the linear relation between radiation emission and incident charge.

For this purpose we designed and constructed an OTR monitor to measure beam current distribution of the 1.8 MeV beam. In this work we present the results obtained. It is also planned to measure beam divergence and energy in the 5 to 38 MeV energy range.

THEORY AND MONITOR DESIGN

Transition Radiation is emitted when a charged particle crosses the boundary between two media with different optical properties. The angular distribution of the radiation, observed in the incidence plane, from an electron incident with any energy on an inclined perfect conductor has the following form [2, 3]:

$$\frac{d^2W}{d\omega d\Omega} = \frac{e^2\beta^2}{4\pi^2 c}\left(\frac{\sin(\theta-2\psi)}{1+\beta\cos(\theta-2\psi)} + \frac{\sin\theta}{1-\beta\cos\theta}\right)^2$$

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where e is the electron charge, c is the speed of light, β is the relativistic factor v/c, θ is the observation angle measured with respect to the particle velocity direction and ψ is the inclination of the conductor surface.

Figure 1 shows the angular distribution of OTR emitted when a 5-MeV electron strikes a perfect conducting surface with an inclination of 45°. Figure 2 shows the same for a 38-MeV electron. Both figures show that the angles of maximum emission are contained in the field of view (FOV) formed by the camera lens.

This situation allows for the measurement of the beam energy, since one can determine the position of the maximum emission, and the beam divergence analysing the angular distribution around the two maximum [4].

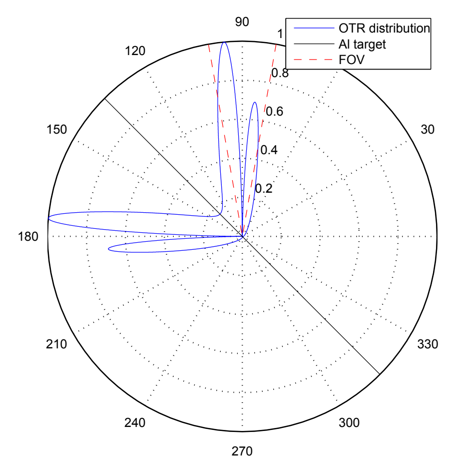

Figure 1: OTR emission of a 5 MeV electron incident on a 45°-inclined perfect conductor. Beam propagation from 0° to 180°.

Figure 3 shows the angular distribution in the incidence plan, of an electron with 1.8 MeV energy incident on a 38.5°-inclined perfect conductor. The inclination angle was set to 38.5° in order to maximize the intensity of the radiation collected by the camera. It is possible to observe in this figure that only one angle of maximum emission is contained in the FOV. Therefore, with this energy, since it is not possible to analyse the angular distribution around the two maximum, it is only possible to make current distribution measurements.

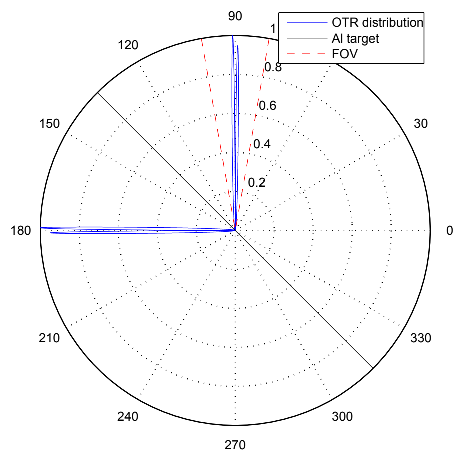

Figure 2: OTR emission of a 38 MeV electron incident on a 45°-inclined perfect conductor. Beam propagation from 0° to 180°.

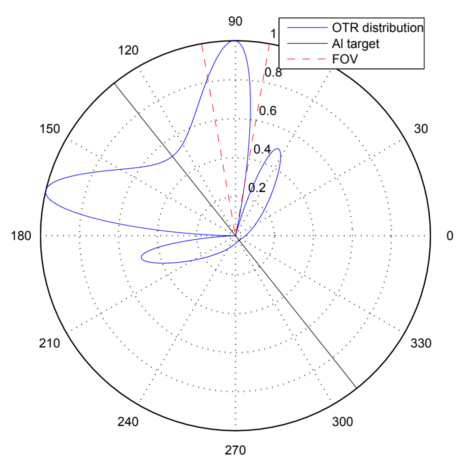

Figure 3: OTR emission of a 1.8 MeV electron incident on a 38.5°-inclined perfect conductor. Beam propagation from 0° to 180°.

THE OTR MONITOR

The Target

A sputtering process was used to coat a Si(100) substrate with a thin Al film. A picture of the target fixed on the 38.5° holder is presented in Fig. 4.

The target was characterized by Rutherford Backscattering (RBS) using a 2.2 MeV He^+ beam. The measurements showed that the coating film is 208 nm thick, divided in three layers. The deepest, with one oxygen atom for every four aluminum atoms, has a thickness of 83 nm. The intermediate, with one oxygen atom for every five aluminum atoms, has 42 nm. And the surface layer, with no oxygen contamination, has 83 nm.

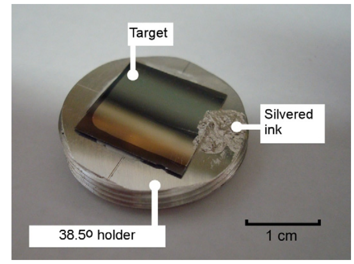

Figure 4: OTR target fixed in the holder.

The Device

The OTR device uses an OTR target holder and a phosphor screen monitor mounted at right angles. The phosphor screen is used to center the beam before the OTR observations. Figure 5 shows the device installation at the linac injector exit and Fig. 6 presents the device in more details in .

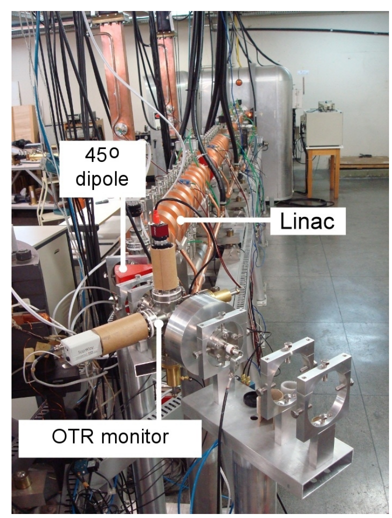

Figure 5: The OTR device installation.

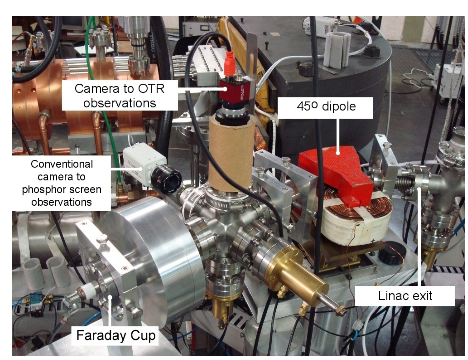

Figure 6: The OTR device in details.

RESULTS

OTR Verification Measurements

To check if the radiation observed from the Al target is OTR we tested two properties: 1) linearity of emitted intensity with beam current; and 2) the polarization of the radiation [5].

The linearity test was made taking OTR images with different repetition rates of the beam pulse (thus changing the average current). The OTR intensity was measured integrating the OTR image. Figure 7 shows the excellent agreement between experimental data and a linear fit. The images were obtained with exposure times of 30 s and gain 160.

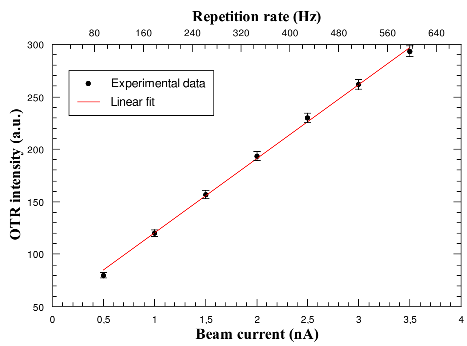

Figure 7: OTR intensity as a function of the beam average current.

The polarization test was performed by taking OTR images through a polarization filter. The image presented in Fig. 8, was obtained with the polarization axis in the horizontal plane, while the one shown in Fig. 9 with the polarization axis in the vertical plane. Both images were obtained with exposure time of 30 s and gain 573.

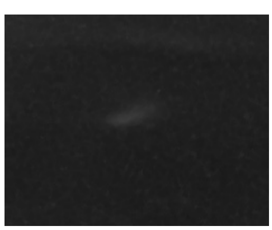

Figure 8: OTR image through a horizontal polarizer.

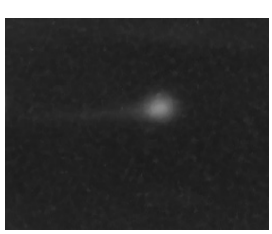

Figure 9: OTR image through a vertical polarizer.

The radiation was observed to be mainly polarized in the horizontal direction as expected by the theoretical prediction, which, along with the observed linear dependence of the intensity on the beam current confirm the observation of OTR radiation.

Current Distribution Measurements

With the OTR monitor it was possible to measure the transversal current distribution in the 1.8 MeV beam. Figure 10 presents this distribution.

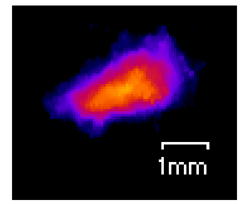

Figure 10: Beam current distribution measured with the OTR monitor.

CONCLUSIONS

This work describes the OTR monitor used to measure the beam current distribution of 1.8 MeV electrons in the linac injector beam at the IFUSP Microtron. It is shown that using a different support to the target it will be possible to make far field observations to measure beam energy and divergence.

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REFERENCES

[1] T. F. Silva; et. al.: *Commissioning of the pre-accelerating section of the IFUSP Microtron*, in this proceeding.

[2] R. B. Fiorito, et. al.: *OTR measurements of the 10 keV electron beam at the University of Maryland Electron Ring (UMER)*, In: Proceedings of PAC07, Albuquerque, New Mexico, USA.

[3] V. L. Ginzburg; V. N. Tsytovich: *Transition radiation and transition scattering*, Adam Hilgert, 1990.

[4] F. Sakamoto; et. al.: *Emittance and energy measurement of low-energy electron beam using optical transition radiation techniques*, **Jpn. J. Appl. Phys.**, 2005, 44, 1485-1491.

[5] M. L. Mikaelian: *High-energy electromagnetic processes in condensed media*, John Wiley and Sons, 1972.