Non-Interceptive Beam Current and Position Monitors for a Cyclotron Based Proton Therapy Facility

Srinivasan, Sudharsan

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by

Sudharsan Srinivasan

born on 25 January 1990
in Kumbakonam, India

Supervisors
Prof. S. Brandenburg
Prof. J.M. Schippers

Co-supervisor
Dr. P.A. Duperrex

Assessment Committee
Prof. A.M. van den Berg
Prof. O. Jäkel
Prof. C. Welsch

Abbreviations

ADC	Analog-to-Digital Converter
ATF	Accelerator Test Facility
AWA	Argonne Wakefield Accelerator
BALUN	Balanced to Unbalanced
BCM	Beam Current Monitor
BCT	Beam Current Transformer
BP	Bandpass
BPM	Beam Position Monitor
CTF3 DBL	CLIC Test Facility 3 Drive Beam Linac
CW	Continuous Wave
DDC	Digital Down Converter
DUT	Device Under Test
ESS	Energy Selection System
FC	Faraday Cup
FPGA	Field Programmable Gate Array
HFSS	High Frequency Structure Simulator
HOM	Higher Order Mode
IC	Ionization Chamber
IPHI	Injecteur de Protons à Haute Intensité
NSLS – II	National Synchrotron Light Source –II
PIF	Proton Irradiation Facility
PEEK	Polyether Ether Ketone
PSI	Paul Scherrer Institut
Q	Quality Factor
S	Scattering parameters
SEM	Secondary Emission Monitor

SNR	Signal-to-Noise Ratio
TE	Transverse Electric
TEM	Transverse Electromagnetic
TM	Transverse Magnetic
TSOM	Through, Short, Open, Match
WCM	Wall Current Monitor

Abstract

In PSI's dedicated proton therapy facility PROSCAN a pulsed 250 MeV proton beam is delivered by a superconducting cyclotron. During the proton-irradiation treatments, there is a need to accurately measure beam current, in the range of 0.1-10 nA, and beam position (required accuracy 0.5 mm). The beam current is directly associated with the dose-rate in the treatment and the beam position with the quality of the dose distribution in the patient. However, the presently used measurements compromise the beam quality. Nevertheless, it is a necessity to perform these measurements online and with minimal beam disturbance. This thesis reports on the development of two types of cavity resonators to perform non-interceptive measurements of these beam parameters, within the required accuracy.

For beam current measurements, a single cavity resonator has been built. For the beam position measurements, a cavity resonator consisting of four separate segments has been built. Both cavity resonators have been tuned to the second harmonic of the beam pulse rate, i.e., 145.7 MHz. In test bench experiments and with proton beams, a good agreement between the expected and measured sensitivity of these resonators has been found. The cavity used to measure beam current can measure currents down to 0.15 nA with a resolution of 0.05 nA. The cavity for measuring beam position delivers position information with the required accuracy and resolution demands of 0.5 mm. The design, tests and performance in the beam as well as special applications, future improvements and limitations are discussed.

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