DESIGN, PRODUCTION AND TESTS OF BUTTON TYPE BPM FOR TAC-TARLA IR FEL FACILITY

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Abstract

Turkish Accelerator and Radiation Laboratory in Ankara (TARLA) facility is an IR FEL and Bremsstrahlung facility as the first facility of Turkish Accelerator Center (TAC) that is under construction in Golbasi Campus of Ankara University. TARLA is proposed to generate oscillator mode FEL in 3-250 microns wavelengths range and Bremsstrahlung radiation. It will consist of normal conducting injector system with 250 keV beam energy and two superconducting RF accelerating modules in order to accelerate the beam 15-40 MeV. The electron beam will be in both continuous wave (CW) and macro pulse (MP) modes. The bunch charge will be limited by 77pC and the average beam current will be 1 mA.

To detect electron beam position, BPM (Beam Position Monitor) has to use through beam line. Wall current monitor based system button type TARLA BPM are briefly mentioned.

In this study, simulation results of design in CST, production and test studies for button type TARLA BPM are presented. Mechanical and electronic design, antenna simulations, and the latest testing procedures are given for a button type BPM.

INTRODUCTION

The Turkish Accelerator Center (TAC) Collaboration is established in 2006 as an inter-university collaboration with 12 Turkish Universities under the coordination of Ankara University by support of Ministry of Development of Turkey. Main aim of the collaboration is to study on technical design and construction of proposed accelerator facilities in Turkey for accelerator based scientific research and technological developments in basic and applied sciences [1].

Turkish Accelerator and Radiation Laboratory in Ankara (TARLA) facility is under construction as a first facility of TAC which is proposed to generate infrared FEL beams in 3-250 micrometers wavelength range based on superconducting electron linac with 15-40 MeV beam energy [2]. TARLA electron source is a thermionic DC gun with 250 keV energy. It is planned that the TARLA facility will provide electron beam in continuous wave (CW) and macro pulse (MP) modes based on SRF modules. Longitudinal electron bunch length will be change between 6ps and 0.4 ps along to accelerator. Repetition rate of electron bunches will be 13 MHz. The bunch charge will be limited by 77pC and the average beam current will be

1 mA. The schematic diagram of TARLA facility is shown in Figure 1 [3].

The facility will contain also IR FEL and Bremsstrahlung radiation production halls and experimental stations. It is planned that the facility will produce two FEL beams by two different undulator magnets U25 and U90 with 2.5 cm and 9 cm period lengths, respectively. The main aim of the facility is to use IR FEL beams for research and application in material science, nonlinear optics, semiconductors, biotechnology, medicine and photochemical processes. In addition, a bremsstrahlung station is planned for nuclear spectroscopy studies up to 35 MeV. The main parameters of TARLA Facility are given in Table 1[3].

Table 1: The Main Parameters of TARLA Facility

Parameters	Value
Energy [MeV]	15-40
Bunch charge [pC]	77
Average beam current [mA]	1.0
Bunch repetition rate [MHz]	13 (16.25)
Bunch length [ps]	0.4-6
Norm. RMS trans. emit. [mm mrad]	< 16
Norm. RMS long. emittance. [keV.ps]	< 100
Macro pulse duration [μs]	50 - CW
Macropulse reputation rate [Hz]	1- CW
Wavelength [μm]	U25:3-20 U90:18-250

BEAM POSITION MONITORS FOR TARLA

Beam diagnostics is an essential part for all types of accelerators; because it should be known different beam characteristics such as beam position, beam current, beam charge etc. Beam characteristics have been kept under control by diagnostic devices. Beam position monitors are one of important online diagnostics devices to measure the position of the beam in the beam line. They are designed in order to provide reliable and accurate beam position readings. Typical BPM is composed of four opposite mounted plates called electrodes or antenna.

The difference of signal from opposite electrodes gives information about the beam position and average beam current in the beam line and report it to the control system [4].
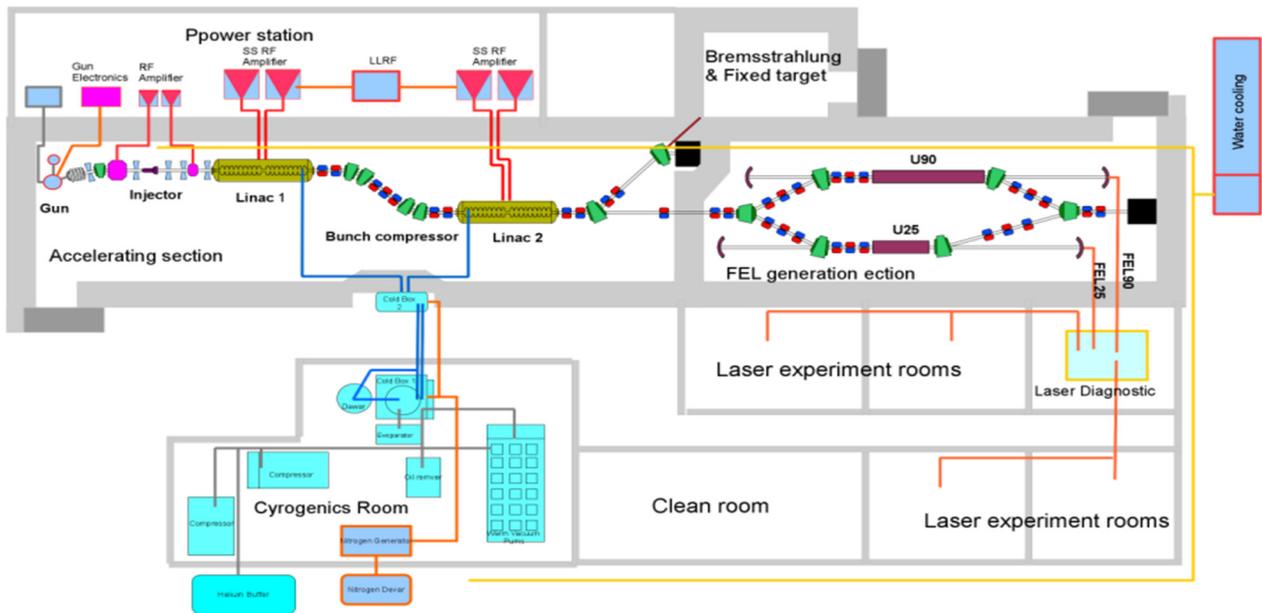
Figure 1: The hardware installation plan of TARLA facility.

There are different types of BPMs to detect signal for different purposes; such as button, stripline and cavity type BPM etc. Design ideas of button type BPMs are detect electro static radiations of bunches. Stripline type monitors are used traveling wave of bunches. Button type monitors have a good resolution more than stripline type BPMs. But signal strength of a button type monitor is lower than stripline type. A Cavity type BPM requires different design. They are more complex than the others [5].

Button and stripline type BPMs will be used in TARLA facility. Because, TARLA beam repetition frequency and average beam current are high enough to give suitable signal on electrodes of monitors. It is planned that, 16 button and 10 stripline type BPMs will be used in TARLA.

DESIGN AND SIMULATION STUDIES FOR BUTTON TYPE BPM

In this study, a licenced CST (Computer Simulation Technology) Particle Studio code was used to design most effective geometry of electrodes [6]. The geometry of BPM antennas are shown in Figure 2. Four antennas were located as mutually. Distance between opposed button electrodes are 28 mm. An electron beam bunch passes through the four antennas.

1 pC Gaussian bunch and 0.99c (c is speed of light) velocity along the z axis are used in simulation studies (Figure 3).

Output signal is expected to be Fourier transform of input signal. The output signals are observed from second and fourth antenna wave ports. BPM calculated output voltages in time domains are shown in Figure 4.

We performed numerical simulations of a button electrode with wake-field solver on a hexahedral mesh. Electrical field energy (E) of electron bunch is given by CST EM Studio (E= 6.21x10^{-13} Joule). The capacitance (C) is calculated using the Equation 1

$$E = \frac{1}{2}CV^2 \qquad (1)$$

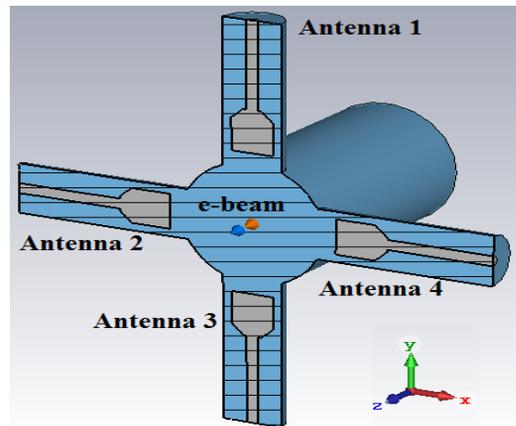where V is the voltage applied to electrodes that is applied as 1V.
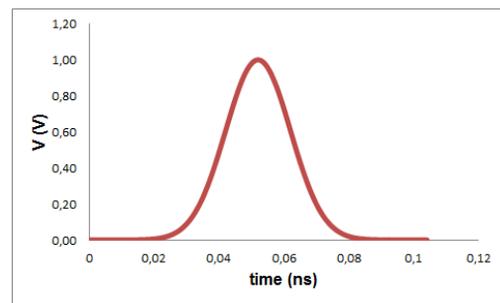

Figure 2: A view of button type BPM by CST.

Figure 3: BPM input voltage in time domain.

For the button BPM with radius 3.5 mm the capacitance C is calculated 1.24 pF. Equivalent circuit of BPM is shown in Figure 5.
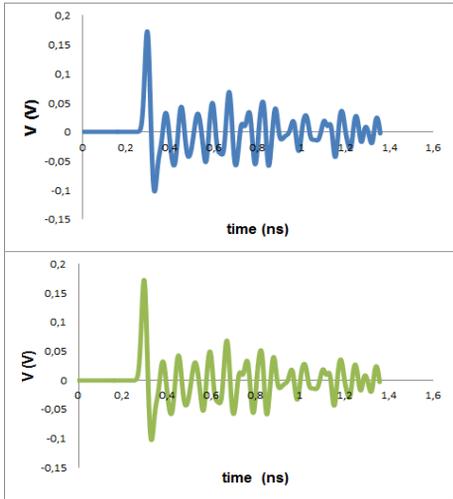
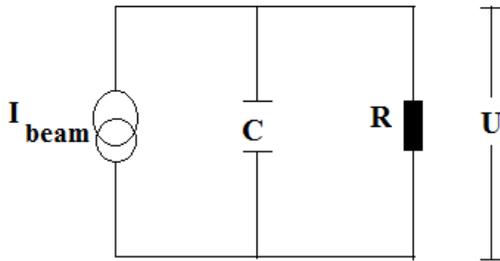Figure 4: BPM output voltages from second (up) and fourth (down) antennas in time domain.

Figure 5: Equivalent circuit of BPM.

For all type electrodes, the general quantity of longitudinal transfer impedance (Z_t) is defined in the frequency domain according to Ohm's low (Equation 2).

$$U = Z_t . I_{beam} \qquad (2)$$

Absolute value of the transfer impedance is shown in Figure 6. The impedance is dependent on frequency (w), on the velocity of the beam particles (β) and on geometrical factors (the area of button plate A and distance of two opposite buttons a).

$$Z_t = \frac{1}{\beta c} \frac{1}{C} \frac{A}{2\pi a} \frac{w/w_{cut}}{\sqrt{1+w^2/w^2_{cut}}} \qquad (3)$$
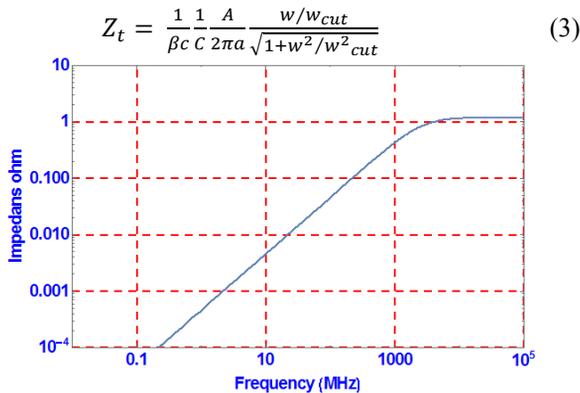

Figure 6: Antenna impedance distribution versus of the frequency.

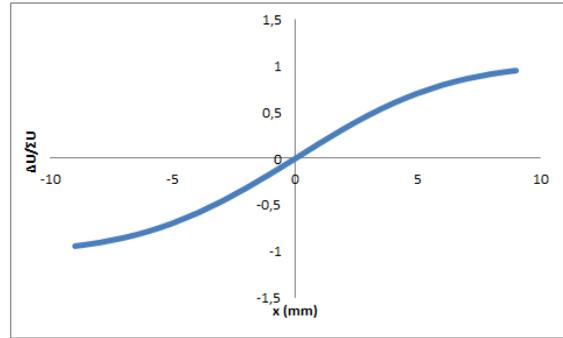The results of resolution were calculated by CST and the value is 150 mV/mm that is shown in Figure 7.

Figure 7: The resolution curve of designed BPM.

PRODUCTION AND TEST STUDIES FOR BUTTON TYPE BPM

After completed simulation, our own design of button type BPM was manufactured by NTG (Neue Technologien GmbH) Company (Germany). They are cupper coated and have a 3.5 mm radius. The picture of manufactured BPM is shown in Figure 8.

Figure 8: The picture of button type BPM produced by NTG Company.

Tests of BPM was made in the test setup in TARLA. The test setup is shown in Figure 9.
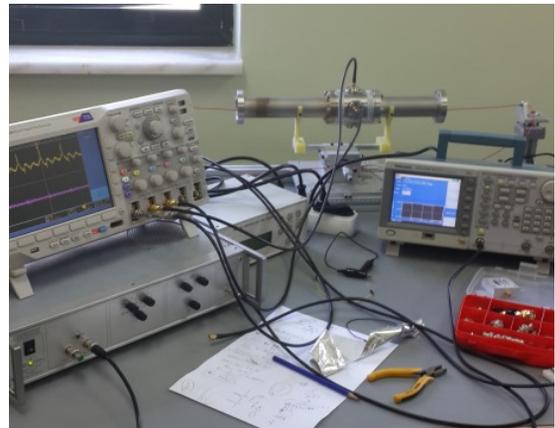

Figure 9: The BPM test setup.

The test setup consists of a signal generator (Tektronics AFG3101), pulse source (Avtech) and a scope (Agilent 500 MHz). 13 MHz of external clock was used as a trigger

signal to lock pulse source. Output signal amplitude of pulser was 70V and pulse repetition was 77ns. 70V pulses were applied to thin wire. Wire was installed inside of monitor and 100 ohm resistor was used to block electronic reflections in monitor. The block diagram of test setup is shown in Figure 10.
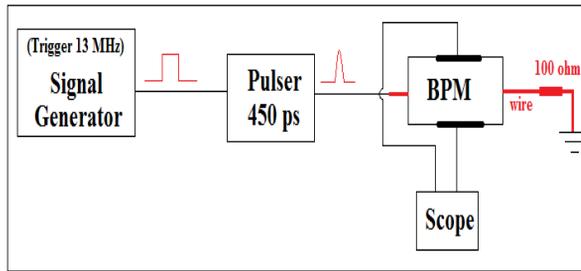

Figure 10: The block diagram of the test setup.

Output voltages of BPM electrodes were measured by scope. The position of wire was changed in the beam line with range of 0.5 mm then voltages were measured step by step for each location of wire. The resolution in x-axis was calculated using Equation 4.

$$\frac{\Delta U}{\sum U} = \frac{U_2 - U_4}{U_2 + U_4} \qquad (4)$$
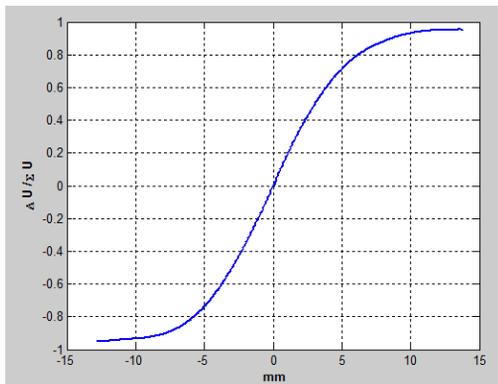

Figure 11: The resolution curve of test setup.

The resolution curve for a 28 mm button radius is shown in Figure 11. The slope of the linear fit function of resolution curve gives position sensitivity factor. Resolution was calculated as 150 mV/mm.

CONCLUSION

A Button type BPM was designed and manufactured for Turkey's TAC-TARLA Facility. Design of TARLA button type BPM antenna performance was numerically simulated with CST Particle Studio. The resolution of designed BPM is obtained 150 mV/mm by simulation. The resolution of produced button BPM is obtained 150 mV/mm by test measurements. Simulation and experiment results are matched each other. TARLA beam line radius is 40mm, therefore to make effective measurements we need to work on different type of BPMs with large beam line radius. It is planned that, 16 pieces button BPM will be used in TARLA Facility. The stripline BPM and cavity type BPM studies will be keep going for TARLA facility.

ACKNOWLEDGEMENT

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