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BEAM DIAGNOSTICS OF E-GUN TEST STAND AT TARLA *

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Abstract

Turkish Accelerator and Radiation Laboratory in Ankara (TARLA) facility, which is essentially proposed to generate oscillator mode FEL in 3-250 microns wavelengths range, will consist of totally normal conducting injector system with 250 keV beam energy, two superconducting RF accelerating modules in order to accelerate the beam 15-40 MeV. Continuous wave (CW) electron beam will provided by TARLA thermionic electron gun (E-GUN). Various aspects of the Thermionic E-GUN test stand to deliver the necessary electron beam in terms of bunch charge, current, energy, emittance and profile for the beam diagnostic will be discussed. Primarily measurements results of electron beam energy loss and transverse orbit will be shown as well as beam image and shape measurements.

INTRODUCTION

TAC is a national project aimed to build an accelerator center in Turkey and it is founded by Turkish Ministry of Development [1].TARLA is planned as a superconducting electron accelerator based on an infrared free electron laser and a Bremsstrahlung facility. TARLA were inaugurated to service on May 9th, 2011 in Golbasi Campus of Ankara University (Figure 1)[2]. In the red circle of 12x10 m2 area reserved as Electron Gun (E-GUN) Test Stand Building. When all measurements are successfully finished, all setup will carry on main accelerator building.

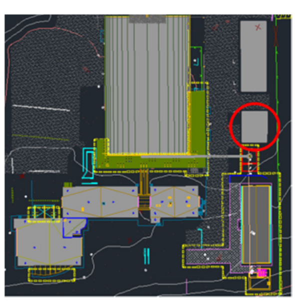

Figure 1: TARLA Layout Plan.

Before generated FEL and Bremsstrahlung radiation at the TARLA, electron gun pulsing system and various diagnostic setups should be tested. Therefore in this study E-GUN test setup is explaining depending on electron beam diagnostic measurements.

E-GUN TEST SETUP

The thermionic electron source is designed for the radiation source ELBE* (Electron Linac for beams with high Brilliance and low Emittance) project- HZDR (Helmholtz-Zentrum Dresden-Rossendorf) at Dresden and still in operation. The mechanical design of gun is obtained with the collaboration of HZDR. A standard cathode is used to generate electrons in this gun (Eimac Y-845)[3]. E-GUN test stand (Figure 2) consists of:

- -350kV DC High Voltage (HV) system,
- two ion pumps (150 l/s) to get ultra-high vacuum region (UHV),
- a solenoid magnet to make well focus of electron beam,
- two steerer magnets-to change direction of electron beam,
- integrated current transformer (ICT) and a fast current transformer (FCT)-to measure beam current and profile,
- various low energy view screens (YAG:Ce and chrome doped aluminum oxide ceramic)-to observe and measure beam image and size,
- pepper-pot mask- to measure beam emittance,
- water cooled beam dump-to measure beam current and stopped,
- dosimeter and lead shielding-to measure and protect from radiation.

BEAM PULSING SYSTEM

Faraday Cup (FC) is using for protect to all electronic pulsing system from HV. FC consists of:

- Pulse Generator- Our pulse generator model produces max. 60 V pulses, 10 ps rise time, repetition frequency 40 kHz-26 MHz and adjustable duration less than < 1 ns (Figure 3),
- Remote Control Unit of Pulse Generator- Digital control of rise, fall times and amplitude,
- Trigger Unit of Pulse Generator- It is possible to control three different pulse structure DC / MP / CW beam options, adjustable 12-14MHz, adjustable Macro Pulse period (50/ 100/ 150/ 200/ 400/ 800/ 1000 ms) and durations (0.1-40 ms),
- 100 V constant DC Power Supply,
- 120 V DC Adjustable power supply (Gate Voltage),
- 30 V DC Adjustable power supply (Heater Voltage),
- Picoscope sampling oscilloscope 12 GHz
- Fiber Transceivers-to control of power supplies.

In front of the cathode there is a grid (distance between grid and cathode 50um). Electron beam pulse structure

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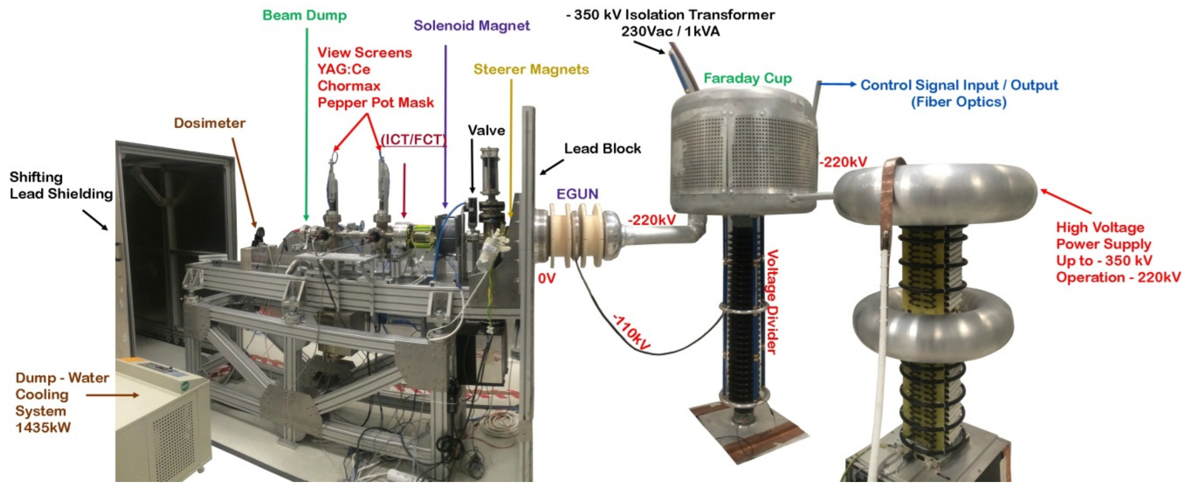

Figure 2: TARLA E-GUN Test Stand.

i.e. CW MP or DC and bunch current depence on grid voltage Formula (1):

$$V_{Grid} = V_{Gate} + V(t)_{Pulse\ Gen.} - 100V \qquad (1)$$

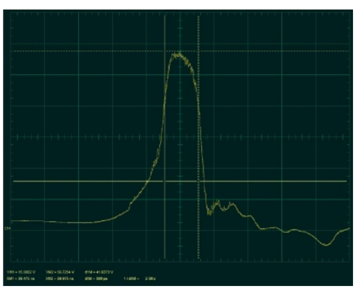

Figure 3: Electron Pulse Signal of Pulse Generator on Picoscope.

BEAM ENERGY

Negative polarity DC HV power supply can reach maximum up to 350 kV. Our gun system has a cathode and two anodes. Maximum applied voltage to the cathode is 220 kV. Limitation is coming from vacuum, because when pressure of the beam line is increasing, breakdown ratio is increasing too. HV training should be kept going to minimize the pressure level of all system (If there is no electron beam, vacuum pressure is ~10^{-10} mbar). In our setup cathode voltage is 220 kV, and first anode voltage is 110kV (HV resistors used to divide main voltage) and second anode is ground voltage i.e. 0 V. Total potential difference between cathode and second anode is 220 kV, that is why during our measurements electron beam energy is 220 keV.

BEAM CURRENT

There are two different beam current measurements components in our test beamline.

First component is ICT / FCT. The other one is constant beam dump (faraday cup) at the end of the beam line.

A fast current transformer (FCT) has enough bandwidth for the high minipulse repetition rate. The current can be measured by ICT (Integrating current transformer) and the longitudinal beam profile can be viewed by FCT [4]. Before install to the beamline, calibration and test measurements of current transformer have been made by us. Peak voltage have been measured from FCT output as a function of different heater voltage (Figure 4), in CW mode, repetition rate of the beam=13MHz and gate voltage=65 V (Maximum bunch charge), Gate voltage range is changing between 25 V and 65 V.

Faraday cup is the easiest way to measure beam current. But it is destructive for the beam and it is placed at the end of the beamline. It is made of a conductive material (Copper thickness is 1.5 cm). The beam current can be measured directly by an ammeter (for D.C. current) or oscilloscope (for pulsed beam). To measure average beam current at the exit of the beam line, beam dump used with really sensitive electrometer (pA range). Average beam current have been measured in same conditions like in FCT measurements (Figure 5).

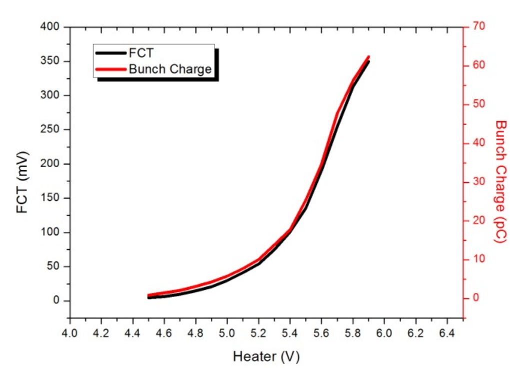

Figure 4: FCT peak Voltage vs. Heater Voltage.

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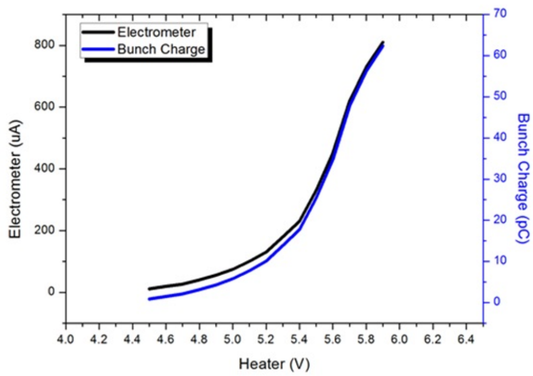

Figure 5: BD average current vs. Heater voltage.

BEAM PROFILE

The beam profile measurements have been made with low energy electron beam scintillator viewers. All view screen dimensions are 30 mm diameter and 0.5 mm thick. On the our stand two Chromoxs and three YAG:Ce screens used. The scintillating screen has two limitations. YAG:Ce is linearity of response curve and Chromox is the time persistency of emission. Figure 6 shows beam size measurement on the y-axis as a function of solenoid voltage. To make this measurement YAG:Ce screen used behind solenoid magnet. Screen 45 degree perpendicular to the beam line and y-axis has not change with camera direction but x-axis has 45 with camera direction.

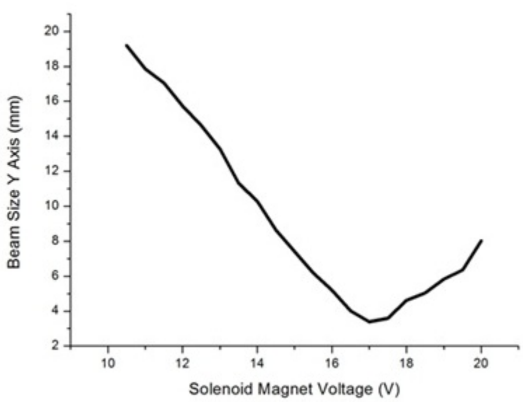

Figure 6: Beam Size (y-axis) vs. Solenoid voltage.

BEAM EMITTANCE

Since the beam emittance is the measure of the beam size and beam divergence, it cannot be measured directly. So, different method is needed to measure emittance. At high energy (40 MeV) quadrupole scan method is appropriate. For low energy beam, space charge is dominated; therefore the emittance must be measured by multi-slit or pepper pot techniques. Behind solenoid magnet pepper-pot mask and third YAG:Ce used to measure emittance. Distance between pepper-pot mask and screen is 30 cm. Mask is a copper plate and its thickness is 0.5 mm. Distances between every hole is 1 mm and diameter of one hole is 100 um. For low beam current, measured rms emittances are in horizontal and vertical direction, respectively 2 mm-mrad and 3 mm-mrad (Figure 7). Also emittance analysis program to calculation have been written in LABview program.

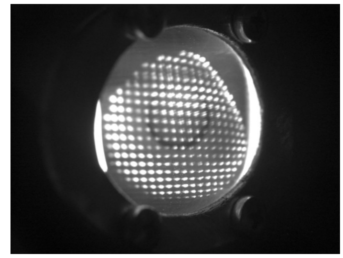

Figure 7: Mask image on the screen.

RADIATION SAFETY

Radiation protection has been made with shifting lead shielding and it covers all beamline (thickness=1 cm). Also all people should carry passive active dosimeter in the E-GUN test stand building. During the measurements to check radiation level of alpha gamma and beta radiation, detectors are using at the end of the beam line inside the lead shielding.

CONCLUSIONS

Our experiments showed us, beam diagnostic studies should be much more precisely and capable. Still there are some absent diagnostic equipments in the setup. Such as, beam position monitor (BPM) and beam loss monitor (BLM). BPM and BLM are under construction and should be checked on the table top test stand. Also our emittance measurement setup shows us, distance between PP mask and second screen should decrease or PP mask holes should be bigger than 100 um.

ACKNOWLEDGEMENTS

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