CURRENT STATUS OF TURKISH ACCELERATOR AND RADIATION LABORATORY *

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Abstract

Turkish Accelerator and Radiation Laboratory (TARLA) which is designed to deliver various accelerator based radiation sources, aims to be outstanding research instrument for users from both Turkey and region. Within the current scope of TARLA its superconducting accelerator will drive two of free electron laser (FEL) beamlines in order to provide Continuous Wave (CW) tunable radiation of high brightness in the mid- and far-infrared range as well as a Bremmstrahlung radiation station. Main components of TARLA, such as injector, superconducting accelerating modules and cryoplant are under commissioning currently. In this paper commissioning results and current status of facility are presented.

Table 1: Electron Beam Parameters of TARLA

Parameter	Unit	Value
Beam energy	MeV	15 - 40
Max. average beam current	mA	1.5
Max. bunch charge	pC	120
Horizontal emittance	mm.mrad	<15
Vertical emittance	mm.mrad	<12
Longitudinal emittance	keV.ps	<85
Bunch length	ps	0.4 - 6
Bunch repetition rate	MHz	0.001-104
Macro pulse duration	µs	50 - CW
Macro pulse repetition rate	Hz	1 - CW

INTRODUCTION

TARLA is basically designed to drive two FEL covering the range of InfraRed region between 5-450 µm wavelengths. Its electron beam will be provided by a thermionic triode electron source operating at 250 kV with CW mode. And the beam will further be accelerated up to 40 MeV by two super conducting RF modules that are designed for ELBE project[6]. The electron beam will be transported to two independent optical resonator systems housing undulators with different period length. Additionally, a bremsstrahlung production target and some fixed target applications will use the available electron beam at facility [1,2]. The schematic view of the facility is given in Fig. 1 and the main electron beam parameters of TARLA are given in Table 1. The facility is located at Institute of Accelerator Technologies of Ankara University in Golbasi Campus of Ankara University which is about 15 km south of Ankara. The commissioning of the facility continues since 2011.

THE STATUS OF ACCELERATOR

The electron bunches will be provided by a thermionic triode electron source operating at 250 kV at Continious Wave (CW) mode. The buhnches that has about 500 ps length jusft after gun further be compressed without acceleration through the injector that is totally based on normal conducting technology. And the beam will further be accelerated up to 40 MeV by main accelerating section.

The main accelerating section of TARLA will consist of two cyromodules (Linac-1, Linac-2) and a magnetic bunch compressor (BC) in between (see Fig. 1). Each cyromodule contains two nine-cell TESLA cavities [3] with a maximum achievable accelerating gradient of 10 MV/m at CW mode, thus, the maximum reachable beam energy is about 40 MeV. The (fixed R_{56}) bunch compressor located between the two modules will allow to optimize the micropulse duration and energy spread of the beam by phasing the cavities. The electron beam accelerated up to 40 MeV will be transported either to the bremsstrahlung beamline of two independent optical resonator systems housing undulators with different period length. The electron beam parameters of TARLA are prsented in table 1. The cryostat and mechanical tuning systems of the cryomodule have been developed and built for the ELBE project [4]. The parameters of TARLA cryomodule is given with table 2.

Table 2: TARLA CM Parameters

Parameter	Unit
Frequency @1.8 K (MHz)	1300 ± 0.05 MHz
Tuning range (kHz)	120 kHz
Ext. Q of input couplers	$(1.2 \pm 0.2) \times 10^7$
Ext Q of HOM couplers	$> 5 \times 10^{11}$
Accelerating voltage/CM (MV)	> 20
Cryogenic losses at max grad. (W)	< 75
Coupler power @CW (kW)	≥15
Tunning Resolution	1 Hz
Tunning speed	1 kHz

The tunning system of the cryomodules has been modified slightly to have better RF performance by adding piezo stack on the lever arms of the mechanical tunning system. The resolution and the speed of tunning has been improved from 10 Hz-5 Hz/ms to 1 Hz - 1 kHz. Each cavity has been tested in accordance with XFEL cavity manufacture procedure and assembled into helium vessel then vertically tested at DESY in 2016. Fig. 2 shows the vertical test results of TARLA

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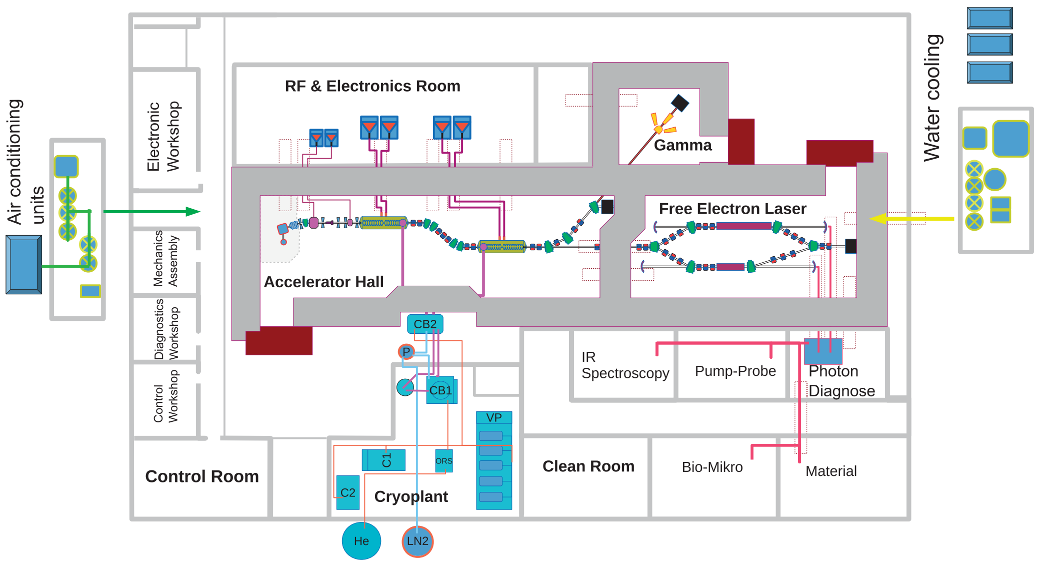

Figure 1: Layout of TARLA facility.

cavities. As it can be seen on the figure, except one all the cavities has gradient arround 40 MV/m.

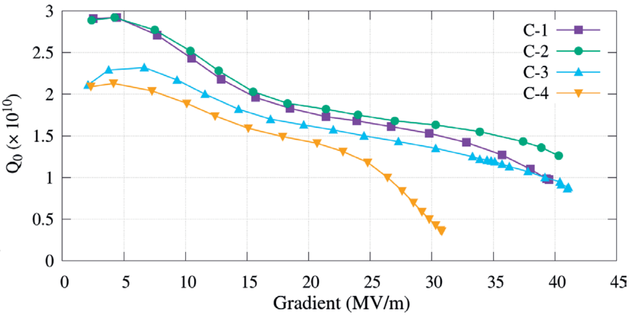

Figure 2: Vertical tests of TARLA cavities.

All the components of two cryomodules have been tested and assembled after successful tests i.e. cavity vertical test, piezo tunning test, coupler tests, leak test etc. The cavities has been manufactured and delivered to TARLA site by Research Instruments GmbH by the end of 2017 and ready for assembly to the helium plant. Fig. 3 shows TARLA cryomodules during the final test with 4 K liquid helium.

HELIUM PLANT

The cryogenic system of TARLA is designed to provide helium cooling at 1.8 K with ±0.2 mbar pressure stability. An extensive cryogenic distribution system connects the cryomodules with the cryoplant. The plant includes the He refrigerator associated to its compressor station, a dewar, a storage tank for helium gas and transfer lines. In addition, an in-house cold compressor associated to ambient temperature helium vacuum pumps was designed to generate 2K Helium flows. The schematic view of the plant is given with Fig. 5

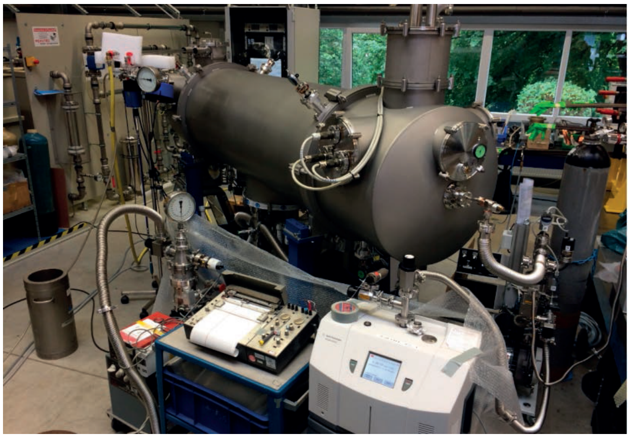

Figure 3: Photo of TARLA cryomodule.

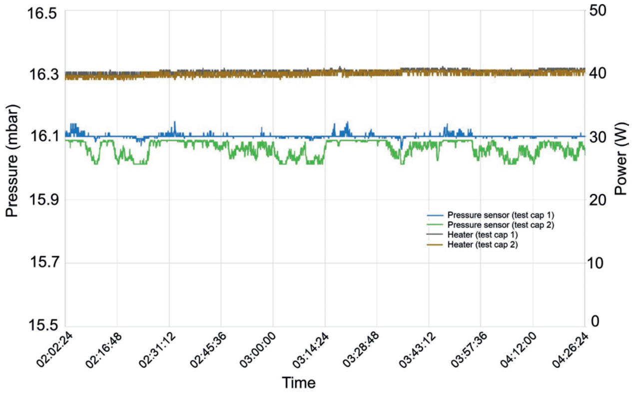

Figure 4: Pressure stability of liquid helium in test caps.

The helium plant of TARLA has been manufactured and delivered by Air Liquide Advanced Technologies in 2016. It has been operated for long period of time with the test caps as simulator of TARLA cryomodules. The main concern of the plant is the pressure stability at sub atmospheric pressure (16 mbar). Fig. 4 shows one of the measurement performed with the test caps which are equipped with heater equal to the full heat loss of the modules.

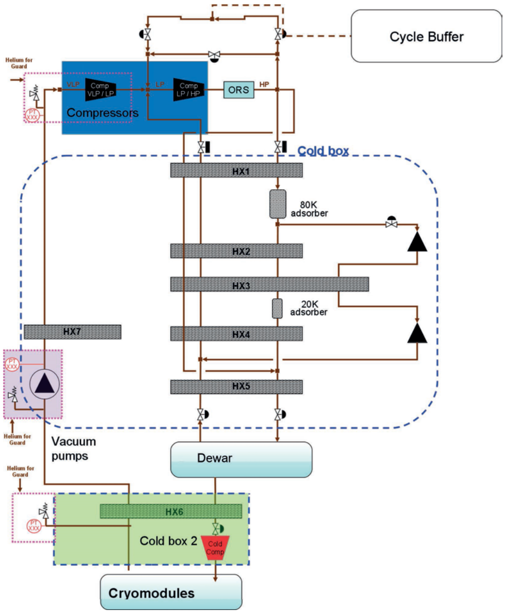

Figure 5: Schematic view of Helium Plant

FREE ELECTRON LASER

In order to cover all desired wavelength between 5-350 µm we plan to use two optical resonators which have two different NbFe hybrid undulators with periods of $\lambda_{U110} = 110$ mm and $\lambda_{U35} = 35$ mm. Figure 6 shows possible observable wavelength range for beam energy vs. undulator strengths.

Table 3: Some Resonator and Expected FEL Parameters

Parameter	**U35**	**U110**
Wavelength (µm)	3.5-34.	24.-390.
Period Length (mm)	35.	110.
No of poles (#)	52	24
Length (m)	1.47	2.6
Undulator Strength (min-max)	0.39-1.	1.3-2.5
Max Peak Power (MW)	10	5
Max. Average Power (W)	0.1 - 100	0.1-90
Max. Pulse Energy (µJ)	10	8
Pulse Length (ps)	1 - 10	1 - 10

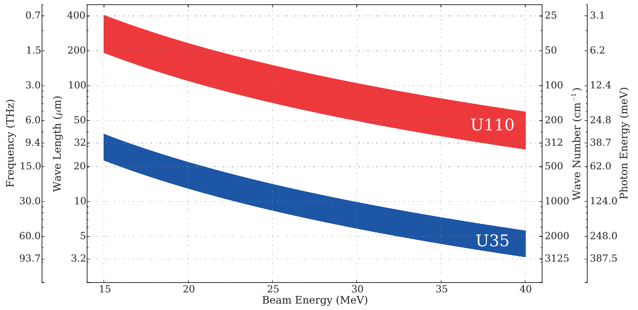

Figure 6: The wavelength range with respect to beam energy and undulator strength for U35 and U110.

To model TARLA FEL we have used GENESIS and Optical Propagation Code (OPC) in order to calculate the light-beam interaction within the undulator and the propagation of the light outside the undulator [6]. Fig. 7 shows the power intensity of the FEL at the surface of outcoupling mirror for various wavelengths. Expected FEL parameters found out by simulations are given in Table 3.

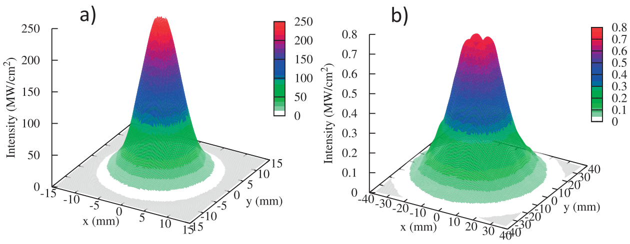

Figure 7: Intra-cavity power intensity of FEL a) for 3.5µm b) for 32 µm

CONCLUSION

The thermionic triode DC electron gun and injector part of accelerator is operating currently [5]. The cryoplant of facility is installed and commissioned. Two superconducting accelerating modules was delivered by the end of 2017. First section of the accelerator is planned to be operational in 1st quarter 2020 and the second part will be put in commission the end of 2020. First lasing is planned to be achieved in 2022 and provided to the users in the same year. A laser experimental station with conventional laser sources have already been in operation since 2018.

TARLA facility which is the first user laboratory in the region of Turkey will give opportunities to the researchers in basic and applied science especially the ones who need high power laser in middle and far infrared region. Experimental stations for laser diagnostic, Pump-Probe, IR spectroscopy, are under construction presently.

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