TARLA: THE FIRST FACILITY OF TURKISH ACCELERATOR CENTER (TAC)*

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Abstract

Turkish Accelerator and Radiation Laboratory in Ankara (TARLA) is proposed as first accelerator based infrastructure in Turkey as a first step Turkish Accelerator Center (TAC). The facility under construction at Institute of Accelerator Technologies of Ankara University since 2012. Based superconducting technology, TARLA accelerator will offer a multi-experiment facility providing various accelerator-based radiation sources for the users coming from different fields like physics, chemistry, biology, material sciences, medicine and nanotechnology. Two of the planed free-electron laser (FEL) beamlines of TARLA will provide Continuous Wave (CW) tunable radiation of high brightness in the mid- and far-infrared regime. In addition a Bremmstrahlung radiation station is proposed within current scope of TARLA. In this paper current status of facility is presented.

INTRODUCTION

TARLA, was also called the Turkish Accelerator Center (TAC) IR FEL Oscillator facility, has been supported by Ministry of Development (MD) of Turkey since 2012 [1, 2]. Turkish Accelerator Center (TAC) project that has been studied since 2006 to establish an accelerator based research center in Turkey [3, 4]. TAC project had following goals;

- Construction of an InfraRed Free Electron Laser facility (TARLA)
- Detailed design of a third generation light source based on 3 GeV synchrotron.
- Conceptual design of a fourth generation light source facility based on 6 GeV electron linac
- Feasibility design of an ion facility based on 2 GeV proton linac
- Feasibility design of linac-ring type charm factory based on 1 GeV electron linac and a 3.56 GeV positron ring .

Following the completion of the design reports TAC project has been finalized in 2016 and the only TARLA is continuing as a first step of TAC.

TARLA is basically designed to drive two FEL covering the range of Infra-Red region between 3-250 μm wavelengths. Additionally, a bremsstrahlung production target and some fixed target applications will use the available electron beam at facility. The schematic view of the facility is given in Fig. 1. TARLA facility is located at Institute of Accelerator Technologies of Ankara University in Gölbaşı Campus which is about 15 km south of Ankara. The installation has been continuing since 2011.

TARLA ACCELERATOR

The electron bunches will be provided by a thermionic triode electron source operating at 250 kV with CW mode. The buhnches 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 two super conducting RF modules. The electron beam will be transported to two independent optical resonator systems housing undulators with different period length. The electron beam parameters of TARLA are presented in Table 1.

Table 1: TARLA Electron Beam Parameters

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

The thermionic triode DC electron gun, pulsing system and some injector part of accelerator is operating currently.

TARLA Accelerating Module

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 with a maximum achievable accelerating gradient of 10 MV/m, 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 cryomodules each contains two SC Nb cavities which are identical to the structures developed for the TESLA project at DESY [5]. The cryostat and mechanical tuning systems of the cryomodule have been developed and built for the ELBE project [6]. The parameters of TARLA cryomodule is given with Table 2. For CW operation at 10 MV/m

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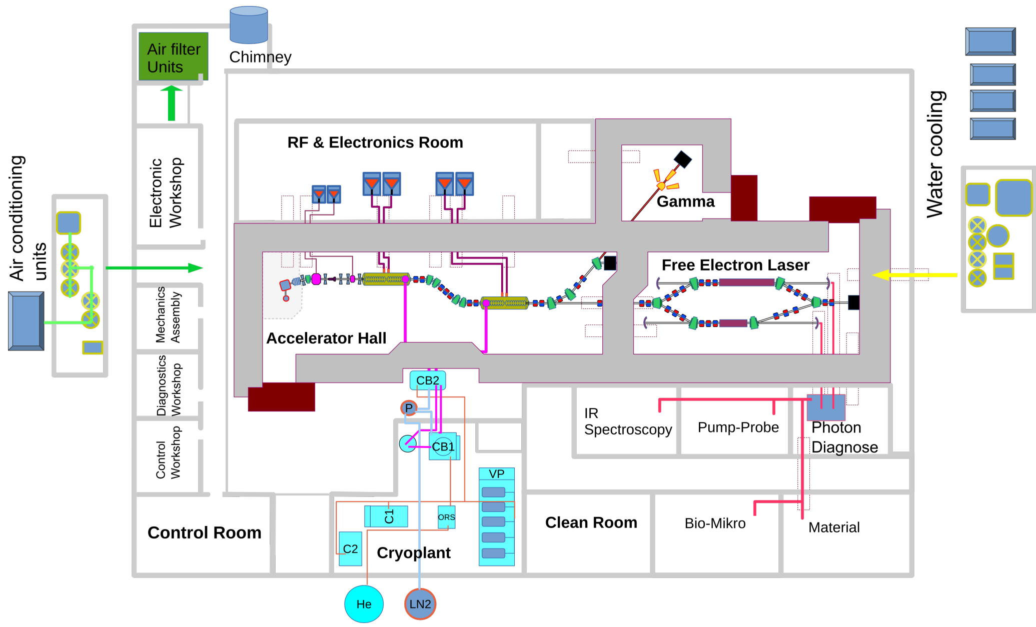

Figure 1: Layout of TARLA facility.

gradient for 1.5 mA beam current have been demonstrated during long-term operation at ELBE.

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

All the components of the cryomodules have been manufactured by the supplier. Each cavity has been tested in accordance with XFEL cavity manufacture procedure and assembled into helium vessel then vertically tested at DESY in 2016. Figure 2 shows the vertical test results of TARLA cavities. As it can be seen on the figure, except one all the cavities has gradient above 40 MV/m.

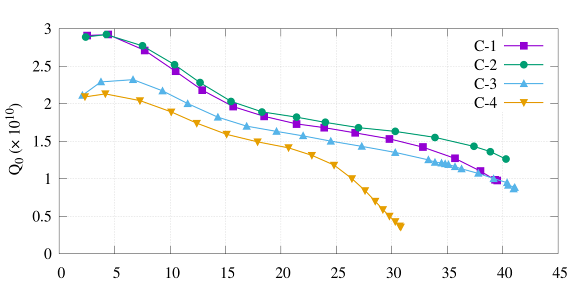

Figure 2: Vertical tests of TARLA cavities.

Original tuning mechanism of ELBE has tuning range of 120 kHz and resolution of 10 Hz with 5 Hz/ms tuning speed. To improve RF performance of the cryomodules and have option of pulsed RF mode option, the original tuning system has been modified slightly by adding piezo stack on the lever arms of the mechanical tuner. Figure 3 and 4 shows the modification of the mechanical tuner and the geometry changes of the cavities after using piezo on that location. This piezo design will allow TARLA cavity to have 1 Hz tuning resolution, 1 kHz tuning speed with bandwidth of 10 Hz.

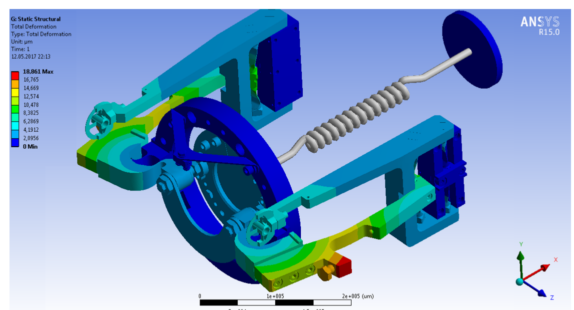

Figure 3: Vertical tests of TARLA cavities.

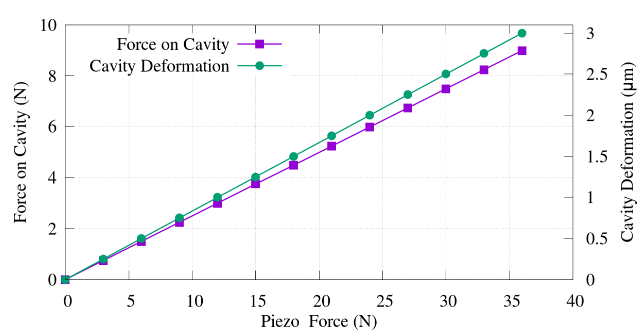

Figure 4: Piezo force and displacement vs the force experienced by cavity and the change of cavity length.

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RF System

Each cavity will individually be driven by independent low-level RF controller and 16 kW RF power sources (Solid States Power Amplifier) that allows easy control of the energy spread and beam energy at any location on the beamline. The power sources have been contracted in 2016 and will be delivered in 2017. DESY-XFEL design Micro TCI4 based LLRF controller will be used for TARLA. Figure 5 shows proposed the schematic of LLRF control for each SC cavity. Since XFEL-LLRF has been designed to operate 8 cavities with one driver, TARLA LLRF system will have more degrees of freedom to diagnose the RF during single cavity operation.

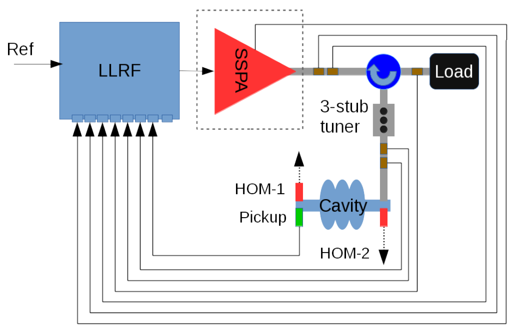

Figure 5: Block Diagram of TARLA LLRF.

FREE ELECTRON LASER

In order to cove all desired wavelength between 3-250 μm we plan to use two optical resonators which have two different NbFe hybrid undulators with periods of $\lambda_{U90} = 90$ mm and $\lambda_{U25} = 25$ mm. Expected FEL parameters are given in Table 3. Figure 6 shows possible observable wavelength range for beam energy vs. undulator strengths.

Table 3: Resonator and Expected FEL Parameters

Parameter	**Unit**	**U25**	**U90**
Period length	mm	25	90
Number of poles	#	60	40
Undulator strength	#	0.25 - 0.72	0.7 - 2.3
Wavelength	μm	3 - 20	18 - 250
Max. peak power	MW	5	2.5
Max. average power	W	0.1 - 40	0.1-30
Max. pulse energy	μJ	10	8
Pulse length	ps	1 - 10	1 - 10

CONCLUSION

The thermionic triode DC electron gun and injector part of accelerator is operating currently [7]. 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 2017 and the second part will be put in commission

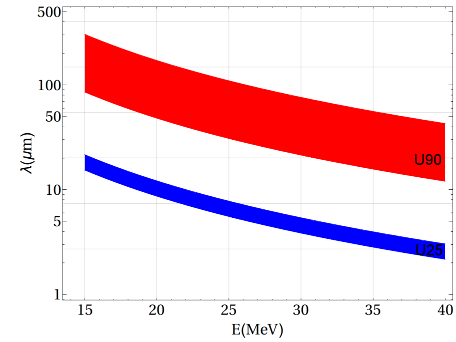

Figure 6: The wavelength range with respect to beam energy and undulator strength for U25 and U90.

the end of 2018. First lasing is planned to be achieved in 2019 and provided to the users in the same year. A laser experimental station with conventional laser sources is planned to be in operation by 2017.

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. Main purpose of TARLA-FELs is to use IR FEL for research in material science, nonlinear optics, semiconductors, biotechnology, medicine and photochemical processes. At the beginning, we plan to start up three of five experimental stations for laser diagnostic, IR spectroscopy and microscopy, material science. After taken some experiences and according to our region needs the rest of four stations will be carried out including medical science and optics and chemistry laboratories as well.

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