THE TURKISH ACCELERATOR AND RADIATION LABORATORY IN ANKARA (TARLA) PROJECT*

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Abstract

The Turkish Accelerator and Radiation Laboratory in Ankara (TARLA) which is proposed as a first facility of Turkish Accelerator Center (TAC) Project will operate two Infra-Red Free Electron Lasers (IR-FEL) covering the range of 3–250 microns. The facility will consist of an injector fed by a thermionic triode gun with two-stage RF bunch compression, two superconducting accelerating modules operating at continuous wave (CW) mode and two independent optical resonator systems with different undulator period lengths. The electron beam will also be used to generate Bremsstrahlung radiation. The facility aims to be first user laboratory in the region of Turkey in which both electromagnetic radiation and particles will be used. In this paper, we discuss design goals of the project,present status and road map of the project.

INTRODUCTION

TARLA, also called the Turkish Accelerator Center (TAC) IR FEL Oscillator facility, has been proposed as a sub-project of TAC in Turkey. TAC is an accelerator based research center project which consists of the conceptual design studies of a third generation synchrotron radiation facility based on 3.56 GeV positron ring, a SASE/X FEL facility based on multi GeV electron linac and a 1–3 GeV proton accelerator,a linac-ring type charm factory, since 2006 [1–3]. The construction phase of TARLA has been supported by Ministry Development (MD) of Turkey since 2010 and the laboratory has been still under construction [4, 5].

The main goal of TARLA is to provide FEL radiation between the ranges of 3–250 µm in the infrared region by using two undulator-resonator system. The facility will also have a bremsstrahlung production target and some fixed target applications using the available electron beam which is in the energy range of 15–40 MeV. The electron beam will be obtained by a thermionic triode electron source operating at 250 kV in continuous wave (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 the different period lengths of 25 mm and 90 mm. The schematic view of the facility is given in Fig. 1 and the main electron beam parameters as well as some FEL parameters of TARLA are given in Tables 1 and 2 respectively.

TARLA laboratory building completed in May 2011 under Ankara University Institute of Accelerator Technologies in Golbasi Campus which is about 15 km south of the center of Turkey, Ankara.

Table 1: Electron Beam Parameters of TARLA

Parameter	**Unit**	**Value**
Beam energy	MeV	15–40
Max. average beam current	mA	1
Max. bunch charge	pC	77
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	13
Macro pulse duration	µs	50 - CW
Macro pulse repetition rate	Hz	1 - CW

TARLA ACCELERATOR

TARLA will consists of three main parts: the injector, the main accelerator and the transport lines to the U25 and U90 undulators (Fig. 1). The high current (1 mA) CW electron beam from injector which provides the energy of 250 keV will be transported to two superconducting modules including two TESLA RF cavities that are separated by a bunch compressor. The maximum available energy of the electron beam with these accelerator modules will be between the range of 15–40 MeV and two independent optical resonator systems will support the generation of FEL radiation.

Injector

TARLA injector will have a thermionic triode DC electron gun, two buncher cavities operating at 260 MHz and 1.3 GHz, five solenoid lenses, one dipole magnet and several steerer magnets. The total length of the injector is about 5.75 m. Although the designs of electron gun and buncher cavities are the same with the ELBE Radiation Source [7], there will be a small difference with the beam line of ELBE by using a bend about 15° just after the gun, in order to avoid the field emission current from the SC cavities to back-bombard the cathode.

Main Accelerator

TARLA main accelerator will include two ELBE cryomodules (Linac-1, Linac-2) and a magnetic bunch compressor (BC) between them (see Fig. 1). Each cyromodule

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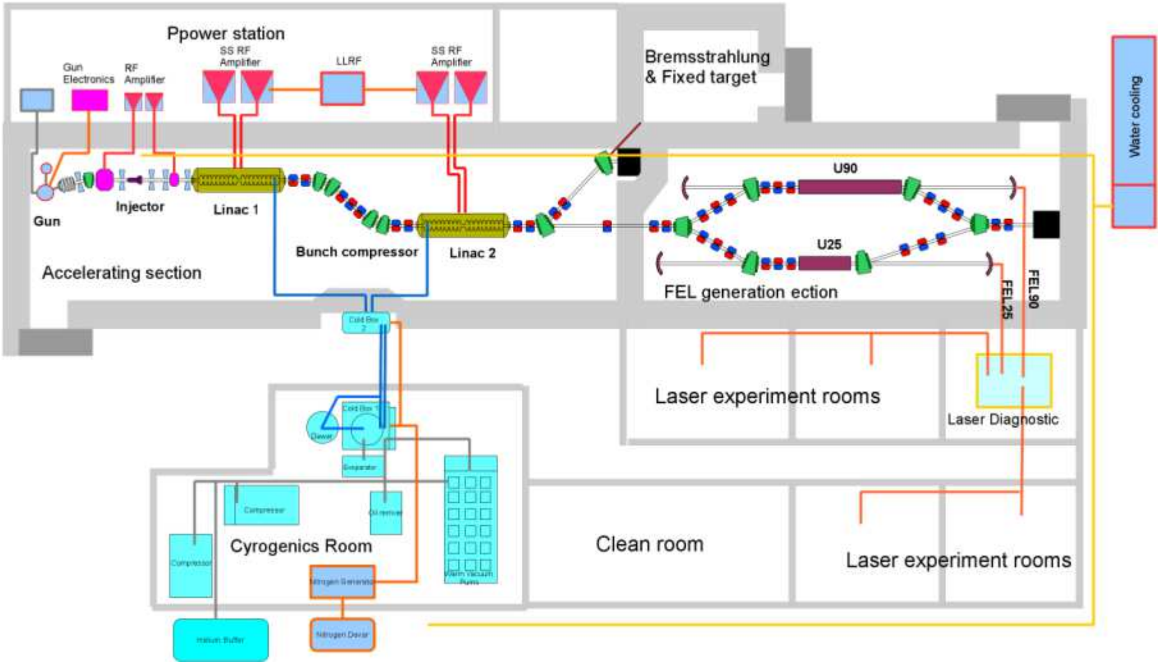
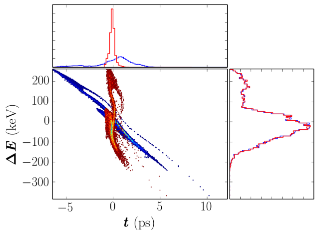


Figure 1: Layout of TARLA facility.

contains two nine-cell TESLA cavities with a maximum achievable accelerating gradient of 10 MV/m, thus, the total maximum reachable beam energy is about 40 MeV. The (fixed R_{56}) bunch compressor between the two modules will allow to optimize the micropulse duration and energy spread of the beam by tuning the phase of the cavities.

ELBE Cryomodule The cryomodules each contains two SC Nb cavities which are identical to the structures developed for the TESLA project at DESY [8]. The cryostat and mechanical tuning systems of the cyromodule have been developed and built for the ELBE project in close collaboration with the Stanford University [9]. For CW operation at 1 mA about 10 MV/m gradient have been demonstrated during long-term operation at ELBE using 10 kW RF sources. Recently it has been shown that the cavities are capable to accelerate 1.5 mA beam current using 16 kW power sources [10].

Bunch Compressor During the capture process from the injector into the first SC cavity the bunch acquires a chirp about 200 keV/ps with the leading electrons having higher energies. If one considers to use a chicane for compressing the bunch, the sign of the chirp would have to be changed operating the second cavity of Linac-1 off-crest. Such an operation would yield a large overall energy reduction. In order to have shortest bunch length at maximum energy we have designed an arc type bunch compressor with R_{56} =11 cm. For increased dispersion we have used a pair of bending magnets each bending by 20°. If one wants to increase the length of the bunch using this type of bunch compressor one has to drive the second cavity of Linac-1 off-crest and change the sign of the chirp. The reduction of the maximum achievable beam energy can here be accepted as the long-bunch mode is only of interest for long FEL wavelengths. Figure 2 shows the longitudinal phase space of beam before and after bunch compressor. As it can be seen the beam is compressed down to 0.4 ps.



Parameter	Before BC	After BC
$\boldsymbol{E}$ (MeV)	18.26	18.26
$\varepsilon_{N,x}$ (mm.mrad)	11.969	12.799
$\varepsilon_{N,y}$ (mm.mrad)	11.921	12.069
ε_z (keV.ps)	24.808	29.060
σ_t (ps)	2.046	0.333
σ_E (keV)	92.98	93.55
$\Delta E/E$ (%)	0.509	0.512

Figure 2: Longitudinal phase space of beam before and after bunch compressor.

TARLA RF System The two main control schemes which are Generator Driven Resonator (GDR) and Self Excited Loop (SEL) will be used for driving the RF structures at TARLA. Each cavity is individually driven with the independent low-level RF controllers and 16 kW saturated RF power sources (Solid states power amplifiers with 18 kW power) that allows easy control of the energy spread and beam energy at any location on beamline. It is planning that the RF system will be implemented for TARLA by the middle of 2015. Figure 3 shows the schematic view of RF system of TARLA.

FREE ELECTRON LASER

In order to cover all desired wavelength between 3–250 µm we plan to use two optical resonators which have two dif-

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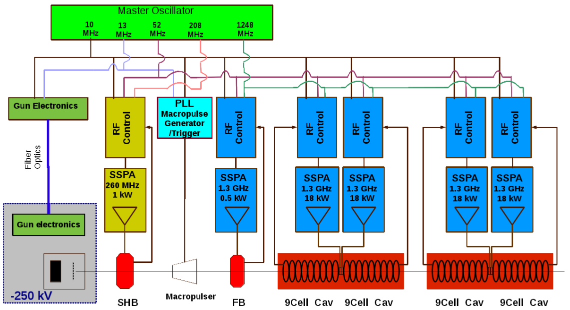
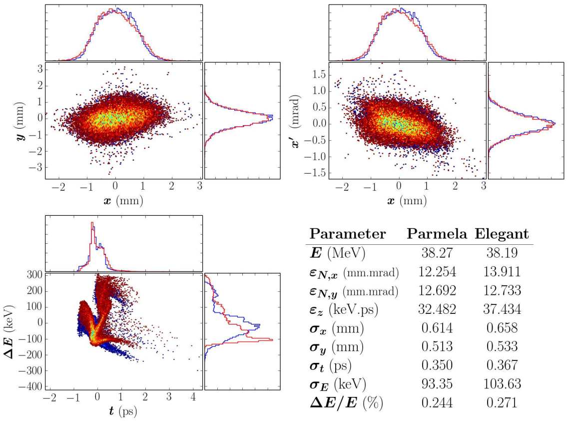


Figure 3: Schematic view of TARLA RF network.

ferent NdFeB hybrid undulators with periods of $\lambda_{U90} = 90$ mm and $\lambda_{U25} = 25$ mm.

FEL Transport Lines

For injecting the beam into the undulators a dogleg design consisting of two 30° bending magnets with a quadrupole triplet in between has been used for both FEL line. The quadrupole triplet and the symmetry of dipoles (including the pole face angles) are applied to obtain achromaticity in which the central qudrupole is free for tuning while side quadrupoles are used to minimize the dispersion. Three more degrees of freedom are provided by the triplet focusing the beam into the undulator. For instance for FEL25 line, Figure 7 shows that there exists matching covering the full energy range as well as the range of undulator's strengths suitable for lasing (given in Table 2). Figure 4 shows the bunch phase spaces at the entrance of U25 undulator for maximum beam energy and minimum undulator strength.



Parameter	Parmela	Elegant
E (MeV)	38.27	38.19
$\varepsilon_{N,x}$ (mm.mrad)	12.254	13.911
$\varepsilon_{N,y}$ (mm.mrad)	12.692	12.733
ε_z (keV.ps)	32.482	37.434
σ_x (mm)	0.614	0.658
σ_y (mm)	0.513	0.533
σ_t (ps)	0.350	0.367
σ_E (keV)	93.35	103.63
$\Delta E/E$ (%)	0.244	0.271

Figure 4: Bunch phase spaces at the entrance of U25 undulator for maximum beam energy and minimum undulator strength.

FEL Generation

The undulators have been chosen NdFeB with 2.5 cm and 9 cm periods in order to scan desired wavelength ranges. Expected FEL parameters are given in Table 2 and Figure 5 shows possible observable wavelengths for beam energy vs. undulator strengths.

Table 2: Some Resonator and Expected FEL Parameters of TARLA

Parameter	Unit	U25	U90
Period length	mm	25	90
Magnetic gap	mm	14	40
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

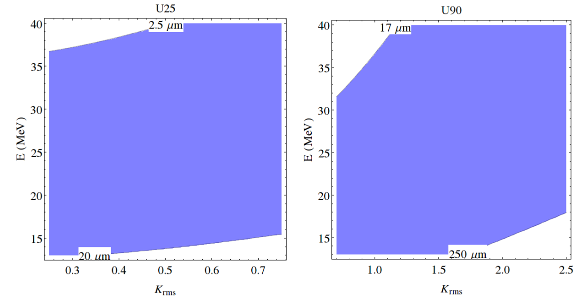


Figure 5: The possible wavelength range with respect to beam energy and undulator strength for U25 and U90.

Figure 6 shows laser pulse energy variation vs number of passes for various wavelengths obtainable from U25 and U90 undulators. As it can be seen the laser saturates around 200 round trip.

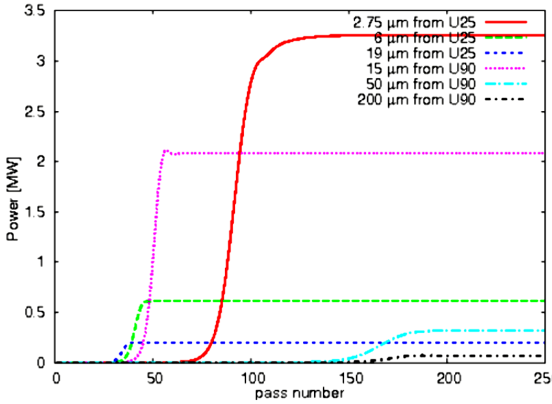


Figure 6: Laser saturation processes versus number of passes for various wavelengths obtainable from U25 and U90 undulators.

ELECTRON GUN TEST SETUP

The electron gun has been commissioning for more than 1 year at Institute of Accelerator Technologies of Ankara University (see Fig. 8). Fast pulsing electronics in order to create electron bunches with 500 ps has been developed by

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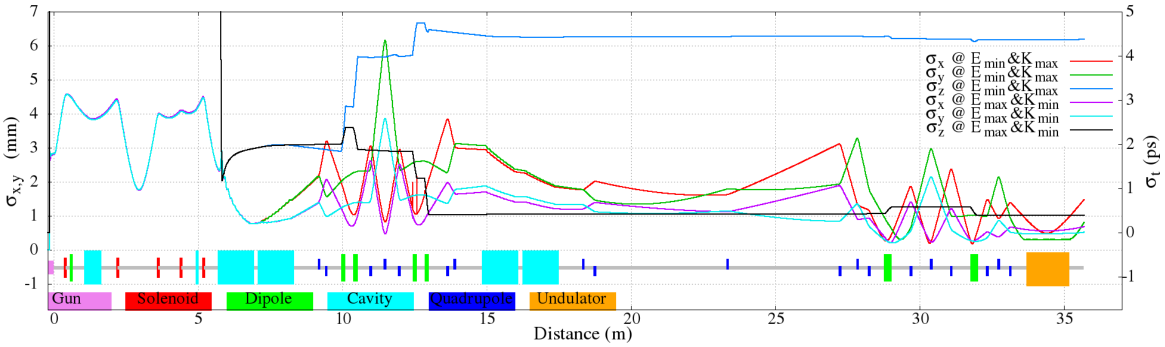

Figure 7: Beam envelope and bunch length variation along to U25 undulator.

TARLA team. It has been demonstrated that the beam can be created at 250 keV with more than 1 mA current in CW mode with required bunch length and emittance.

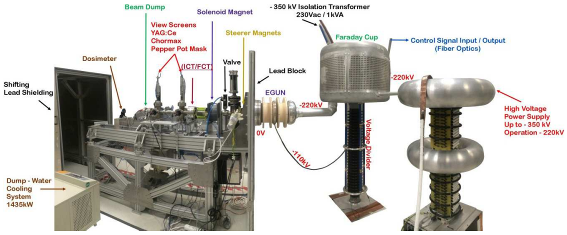

Figure 8: Test setup of TARLA electron gun.

CONCLUSION

First electron beam from TARLA gun has been observed in April 2013 and the injector is being installed and commissioned at present. The cryogenic plant is going to be installed by the end of 2014 and first cyromodule will be delivered by the beginning of 2015. We expect the first electron beam from first linac by the end of 2015 and from second linac not too much later. The first FEL beam is expected by beginning of 2018.

TARLA facility which is the first user laboratory in the region of Turkey will give good 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 diagnosic, IR spectroscopy and microscopy, material science. After taken some experiences and according to our region needs the rest of the stations will be carried out including medical science and optics and chemistry laboratories as well.

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