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DESIGN PARAMETERS AND CURRENT STATUS OF THE TARLA PROJECT*

A. Aksoy†, Ö. Karslı, Ç. Kaya, E. Kazancı, Ö. Yavaş,
Institute of Accelerator Technologies, Ankara, Turkey
S. Ozkorucuklu, Istanbul University, Istanbul, Turkey
P. Arıkan, Gazi University, Ankara, Turkey

Abstract

The Turkish Accelerator and Radiation Laboratory in Ankara (TARLA) will operate two InfraRed 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 ELBE 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. In this paper, we discuss design goals of the project and present status and road map of the project.

INTRODUCTION

TARLA, also called the Turkish Accelerator Center (TAC) IR FEL Oscillator facility, has been supported by Ministry of Development (MD) of Turkey since 2006 [1, 2]. TARLA is one of the sub-project of the Turkish Accelerator Center (TAC) project which is being studied since 2000 to establish an accelerator based research center in Turkey [3]. TAC project includes a linac-ring type charm factory, a third generation synchrotron radiation facility based on 3.56 GeV positron ring, a SASE FEL facility based on 1 GeV electron linac and a 1-3 GeV proton accelerator [4, 5].

TARLA is basically designed to drive two FEL covering the range of InfraRed region between 3-250 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. 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 table 1 and 2, respectively.

TARLA facility building is located at Institute of Accelerator Technologies of Ankara University in Golbasi Campus of Ankara University which is about 15 km south of Ankara. It is being continuing to installation since 2011.

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

The TARLA beamline can be subdivided into three main parts: the injector, the main accelerating section and the transport lines to the U25 and U90 undulators (see Fig. 1). The injector will provide a high current CW electron beam at 250 keV. Two SC accelerating modules separated by a bunch compressor will accelerate the beam to 15-40 MeV energy, and two independent optical resonator systems will support the generation of FEL radiation.

Injector

The TARLA injector which is about 5.75 m long will mainly consist of 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 electron gun and buncher cavities are identical to those designed for the ELBE Radiation Source [7]. The injector is more or less identical to ELBE injector except the axis of the beamline just after gun has a bend about 15° in order to avoid the field emission current from the SC cavities to back-bombard the cathode.

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 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.

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* Work supported by Ministry of Development of Turkey
† avniaksoy@ankara.edu.tr

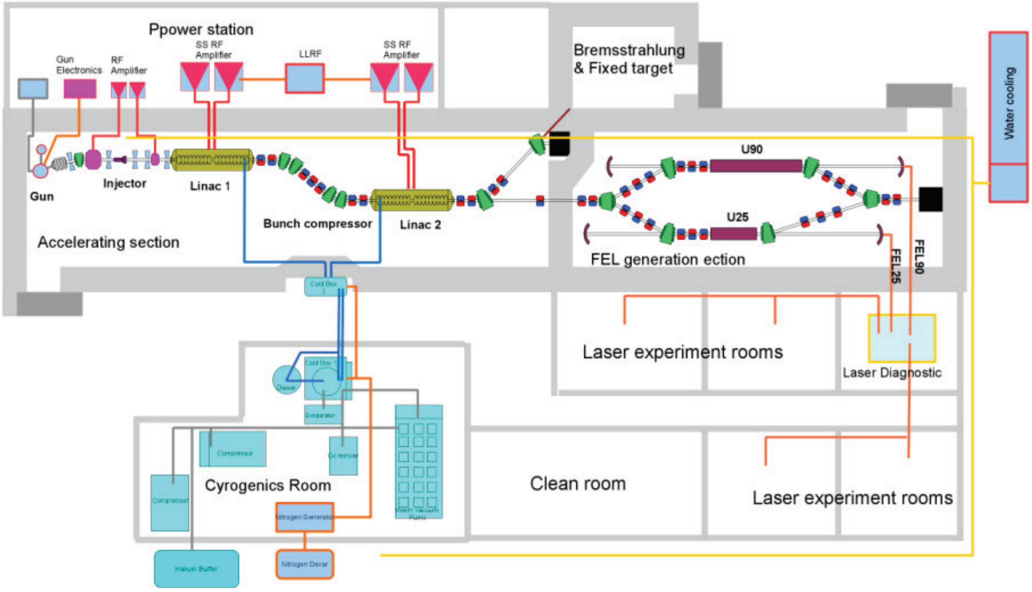

Figure 1: Layout of TARLA facility.

ELBE cyromodule The cyromodules each contains two SC Nb cavities which are identical to the structures developed for the TESLA project at DESY [9]. 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 [8]. For CW operation about 10 MV/m gradient have been demonstrated during long-term operation at ELBE.

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.

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 2 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).

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 independent low-level RF controllers and 16 kW RF power sources (Solid states power amplifiers with 18 kW saturated power) that allows easy control of the energy spread and beam energy at any location on beamline. It is planning 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 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 2. Figure 4 shows possible observable wavelength range for beam energy vs. undulator strengths.

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.

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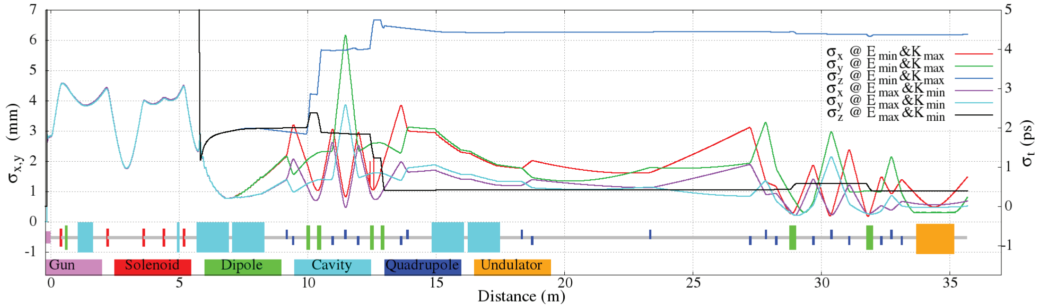

Figure 2: Beam envelope and bunch length variation along to U25 undulator.

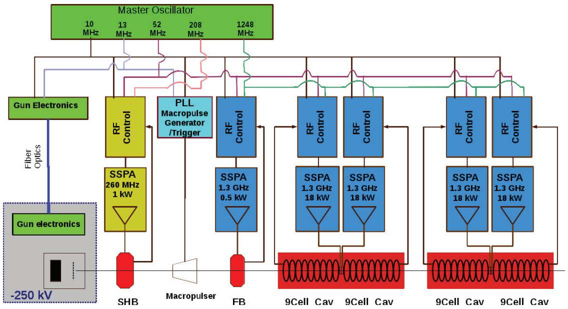

Figure 3: Schematic view of TARLA RF network

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

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 diagnosic, 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.

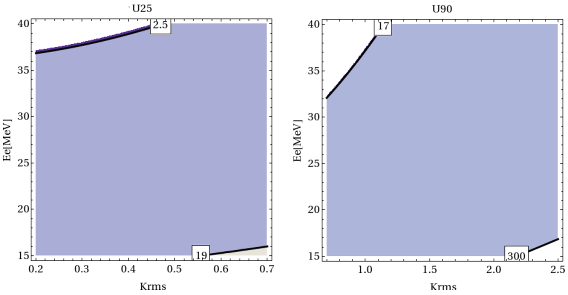

Figure 4: The possible wavelength range with respect to beam energy and undulator strength for U25 and U90.

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