ACCELERATOR BASED LIGHT SOURCE PROJECTS OF TURKEY*

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On Behalf of the TAC Collaboration

Abstract

Three light source project is ongoing in Turkey within the frame of Turkish Accelerator Center (TAC) Project which has been supported by Ministry of Development since 2006. As a first facility of TAC, 3-250 μm IR-FEL facility (TARLA) based on superconducting accelerator with an energy of maximum 40 MeV is under construction at Institute of Accelerator Technologies of Ankara University. In addition to TARLA, Conceptual/Technical Design Report of a third generation synchrotron radiation facility based on 3 GeV, and a fourth generation FEL facility based 1-6 GeV is being prepared for the next steps of TAC. Therewithal a proton accelerator facility with up 2 GeV and an electron-positron collider as a super charm factory are proposed within the frame of TAC project. In this presentation, current status of TARLA project and main goals, road map of Turkish Light Sources will be explained.

INTRODUCTION

The Turkish Accelerator Center (TAC) has been studied with the support of Ministry of Development of Turkey since 1990s [1]. Feasibility and Conceptual Design phases of TAC was completed by 2000 and 2005, respectively. Current phase of project has been started in 2006 as an inter-universities collaboration with around cooperation of 150 scientists from 12 national universities. Besides construction an InfraRed Free Electron Laser Facility - TARLA, TAC project includes desining of a linac-ring type charm factory, synchrotron radiation facility, a soft-hard X-Ray FEL facility and a multi-propose proton accelerator. Current phase of TAC has following main goals; (*i*) Construction of an InfraRed Free Electron Laser facility (TARLA); (*ii*) Completing detailed design report of a third generation light source based on 3 GeV synchrotron ; (*iii*) Completing conceptual design report of a fourth generation light source facility based on 6 GeV electron linac; (*iV*) Completing feasibility design report of an ion facility based on 2 GeV proton linac and a linac-ring type charm factory based on 1 GeV electron linac and a 3.56 GeV positron ring.In this document we present current status and main goals, road map of Turkish Light Sources.

TARLA FACILITY

Turkish Accelerator and Radiation Laboratory in Ankara (TARLA) project, also called the Turkish Accelerator Center (TAC) IR FEL Oscillator facility, has been started as sub-project of TAC project [2, 3]. The building of TARLA is located at Institute of Accelerator Technologies of Ankara University in Gölbaşı Campus of Ankara University which is about 15 km south of Ankara. Installation of TARLA has been continuing to installation since 2011.

TARLA is basically designed to drive two FEL lines covering the range of InfraRed region between 3-250 μm wavelengths. Its electron beam will be provided by a thermionic electron source operating at 250 kV in 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 [4]. The electron beam will be transported to 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. The schematic view of the facility is given in Fig. 1 and the main electron beam parameters are given in Table 1. The beamline of facility can be subdivided into three main parts: the injector, the main accelerating section and the transport lines to the U25 and U90 undulators.

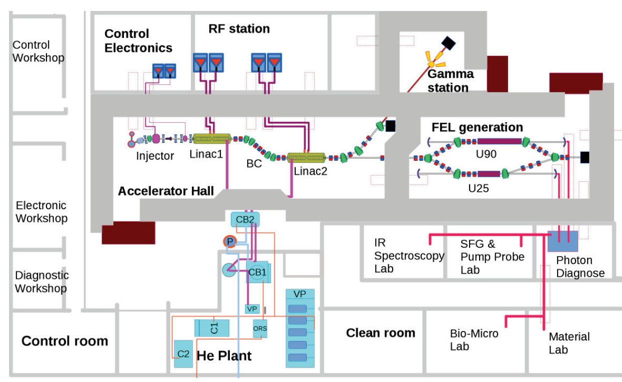

Figure 1: Layout of TARLA facility.

Injector The injector which is about 5.75 m long will mainly consist of a thermionic triode DC electron gun operating at 250 keV, two buncher cavities operating at 260 MHz and 1.3 GHz, solenoid lenses, dipole magnet and several steerer magnets. The electron gun and buncher cavities are identical to those designed for the ELBE facility [5].

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 cyromodules each contains two SC cavities were developed and built for the ELBE project. For CW operation

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Table 1: Electron Beam Parameters of TARLA

Parameter	Unit	Value
Maximum beam energy	MeV	40
Max. average beam current	mA	1 (1.5)
Max. bunch charge	pC	77(120)
Hor. / Ver. emittance	mm.mrad	<15 / <12
Longitudinal emittance	keV.ps	<85
Bunch length	ps	0.4 - 6
Bunch repetition rate	MHz	13 (26)
Macro pulse duration	μs	50 --> CW
Macro pulse repetition rate	Hz	1 --> CW

Table 2: Some Resonator and Expected FEL Parameters

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

about 10 MV/m gradient have been demonstrated during long-term operation at ELBE. The bunch compressor located between the two modules will allow to optimize the micropulse duration and energy spread of the beam by phasing the cavities. In order to have shortest bunch length at maximum energy we have designed an arc type bunch compressor with fixed R_{56} = 11 cm.

Free Electron Laser In order to cover all desired wavelength between 3-250 μm we plan to use two optical resonators which have two different NbFe hybrid undulators with periods of λ_{U90} = 90 mm and λ_{U25} = 25 mm. Expected FEL parameters are given in Table 2. Figure 2 shows possible observable wavelength range for beam energy vs. undulator strengths.

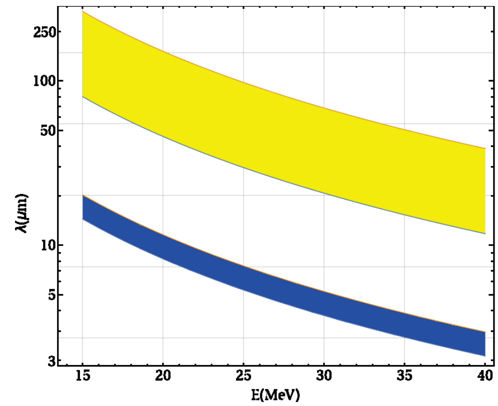

Figure 2: The possible wavelength range with respect to beam energy.

TAC SR PROPOSAL

The second stage of TAC is proposed to be a Synchrotron Radiation (SR) facility named TURKAY, which is the third generation light source that is aimed to achieve high brilliance photon beam from low emittance electron beam at 3 GeV. The project is now entering its detailed design phase: after the completion of the conceptual design report.

Taking into account the construction budget and the user's requirements discussed at the light source user meetings in Turkey, the main goals and parameters of TURKAY were defined. The natural emittance is 0.51 nm rad on a ring based on 4-bend cell lattice with 477 m circumference [6, 7].

Optical Structure of Storage Ring To minimize the emittance of electron beam we have designed a sector consists of 4 bending magnets and 4 different type (16) of quadrupole magnets. The storage ring which has circumference of 477 m is composed of 20 main cells. 7 different families of sextupoles are used to correct chromaticity and to compensate nonlinearities. The length of the straight sections is considered to be 5 m for rf cavity, insertion devices and injection requirements. Two of the straight sections will be used for injection and rf cavity and the rest sections are for undulators. Main consideration on the number of bending magnets and sections comes from the limitation of the circumference and budget. Each bending magnet has length of 1.5 m and magnetic field of 0.52 T.

The lattice can easily be tuned to achromatic type of lattice by adjusting the strength of the quadrupoles and the emittance is 0.93 nm rad in achromatic case. The main parameters of storage ring are listed in Table 3 for finite dispersion mode. Figure 3 shows the first order Twiss functions of main cell.

Table 3: Main Parameters of Storage Ring

Parameter	Unit	Value
Energy	GeV	3.0
Circumference	m	477
Beam current	mA	500
RMS energy spread	%	0.05
Hor./Ver. emittance	nm rad	0.51 /0.0051
Energy loss/part./turn	keV	375.1
No of straight sections	#	20
Length of straight section	m	5
RF frequency	MHz	500
RMS bunch length	mm	2.1

Radiation Properties Some existing or planned insertion devices from other synchrotron radiation facilities [8] with some minor changes are proposed to be used at TURKAY. The amended undulator parameters are given in Ref [6, 7]. As an example a 4 m cyrogenics undulator with

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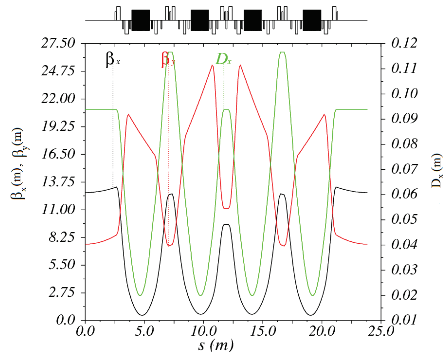

Figure 3: Betatron and dispersion functions in main cell for finite dispersion mode.

period length of $\lambda_U = 18mm$ and strength of $K_{U_{18}} = 2.5$ can provide photon brilliance up to 1.7×10^{21} photon $s^{-1} mrad^{-2}$ per $0.1\% BW$. The brilliance of photon created by bending magnet and insertion devices versus its energy is shown in Fig. 4.

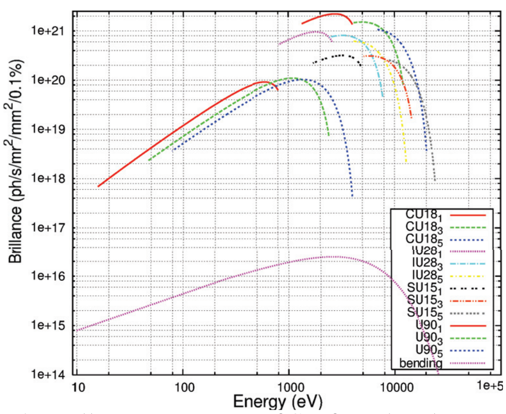

Figure 4: Brilliance spectrum of SR from bending magnets and insertion devices.

TAC HARD X-RAY FEL PROPOSAL

The proposed hard X-Ray facility is a two-stage 6 GeV linac, consisting of an S or X-Band based injector and high-gradient X-band linac which can deliver a high-repetition rate low-emittance beam, one or several undulator sections and photon beam lines with a user facility [9]. The layout of proposal is given with Figure 5. Expected facility length is about 550 m and basic parameters of facility is given with Table 4. The accelerating structure of linac is chosen

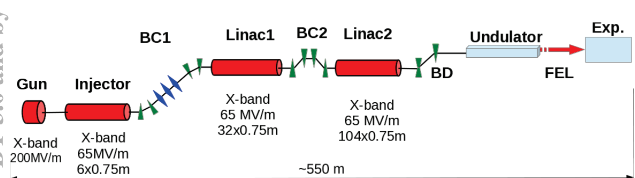

Figure 5: Layout of proposed facility.

modified CLIC structure which have lower gradient and larger aperture than original design [10]. A photo-cathode both S and X-band RF gun was proposed. The bunches are compressed with two stage bunch compression [9, 11]. Simulations show that the electron bunch is successfully compressed to a peak current above 3 kA. FEL simulation indicates that lasing at 0.9 Å wavelength is possible in an undulator with period length of 15 mm and strength of 1. The FEL saturates below 40 meters with an average power about 5 GW. Figure 6 shows the power saturation along beamline using the bunch at the entrance of undulators created by beam dynamics codes [11].

Table 4: Basic Parameters of X-FEL Facility

Parameter	Unit	Value
Energy	GeV	6
Bunch Charge	pC	250
Normalized emittance	μmrad	<0.5
Bunch Length	μm	9
Linac frequency	GHz	12
RF pulse length at structure	ns	150
Pulse repetition rate	Hz	50-500
Number of bunches per pulse	#	1-3
Linac gradient	MV/m	65
Minimum laser wavelength	Å	0.9
Maximum laser power	GW	5

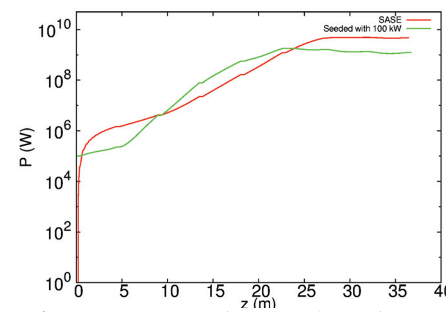

Figure 6: FEL power evaluation along the undulator.

CONCLUSION

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 FEL in middle and far infrared region. The first FEL line of the facility is proposed to be in operation by 2019.

Efforts on TAC has been continuing since 2006 and it is expected that TAC will gain an independent legal entity as a research center soon with a new financial support and technically control mechanism. Following, the construction phase of proposed light source facilities will start. Based on international scientific advisory committee and user potential in Turkey it is planned that, third generation synchrotron radiation facility (TAC SR) will take place as a second big construction step just after the operation of TARLA. The third step, soft-hard X-Ray facility needs more demonstration about X-band technology and international user collaboration.

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