THE STATUS OF TAC INFRARED FREE ELECTRON LASER (IR-FEL) FACILITY*

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Abstract

Turkish Accelerator Complex (TAC) Infrared Free Electron Laser (IR-FEL) project was approved by State Planning Organization (SPO) of Turkey as a first step of the national complex project in 2006. The facility will consist of 15-40 MeV superconducting electron linac and two different optical cavity systems with different undulator period length to obtain FEL in 2-185 microns wavelengths range. In this study, the results of optimization and current status of TAC IR FEL facility project is presented. The facility will give opportunity to search applications in material science, biotechnology, nonlinear optics, semiconductors, medicine and chemistry using IR-FEL in Turkey and our region.

INTRODUCTION

A group of scientists from Ankara and Gazi Universities proposed the Turkic Accelerator Center (TAC) project in 2000 considering to establish an accelerator based research center.During the feasibility and conceptual design studies of TAC, a linac-ring type particle factory and the light sources (synchrotron radiation and free electron laser) was proposed in the frame work of the project [1, 2]. According to the proposal, TAC will include 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 [3, 4].

In order to become familiar with accelerator and light source technologies in our country and our region, an infrared free electron laser (IR FEL) facility in oscillator mode is proposed as a first step [5, 6]. In 2006, SPO of Turkey charged a team, which includes scientists from 10 Turkish Universities, to write the technical design report of TAC proposal and to construct IR FEL facility as a first step until 2011.

The IR FEL facility which will be situated at Ankara University Gölbaşı Campus, is planned to cover middle and far infrared region wavelengths using a superconducting (SC) linac. It is also planned that the facility will include Bremsstrahlung experimental station which based on the same linac with 20 MeV option to study nuclear physics [6].

ELECTRON BEAM AND FEL OPTIMIZATION

TAC Oscillator IR FEL will include a linac to get an electron beam in 15-40 MeV energy range and two optical resonators with two undulators (λ_{U1}=3 cm; λ_{U2}=9 cm) to obtain FEL in 2-185 microns range General layout of TAC IR-FEL is given with figure 1.

Accelerating Structure and Beam Optics

Available two ELBE module which houses TESLA 9-cell SC structure and has limitation about 1 mA average beam current at 10 kW beam power (@ CW operation), has been taken into account for main accelerating section [7, 8]. In order to design simplest beam line, and to have minimum dispersion effects on the electron beam, and to use less diagnostic tools, the beam line from linac towards undulators is chosen as it will be straight (fig. 1).

In calculations, PARMELA code is used for longitudinal beam dynamics issues as well as Mathematica code for first order transverse beam optics calculations [9, 10]. The beamline elements taken into account during calculations has been chosen familiar to ELBE beamline. Some parameters of main beamline elements are given with table 1.

Table 1: Main Parameters of beam line elements used in calculations

Quadrupoles	
Effective length (cm)	10
Radial aperture(cm)	3
Max gradient (G/cm)	1000
Chicane rectangular magnets	
Bending curvature (cm)	30
Max magnetic field at center (G)	3000
Pole gap (cm)	3
Max bending angle (deg)	30
Bending magnets ”Both side (single side)”	
Bending curvature (cm)	30
Max magnetic field at center (G)	6000
Pole gap (cm)	3
Bending angle (deg)	45

During injector simulations, it was assumed that the electron beam delivered from a thermionic gun has 10 mm.mrad transverse emittace with 1.5 mm rms transverse

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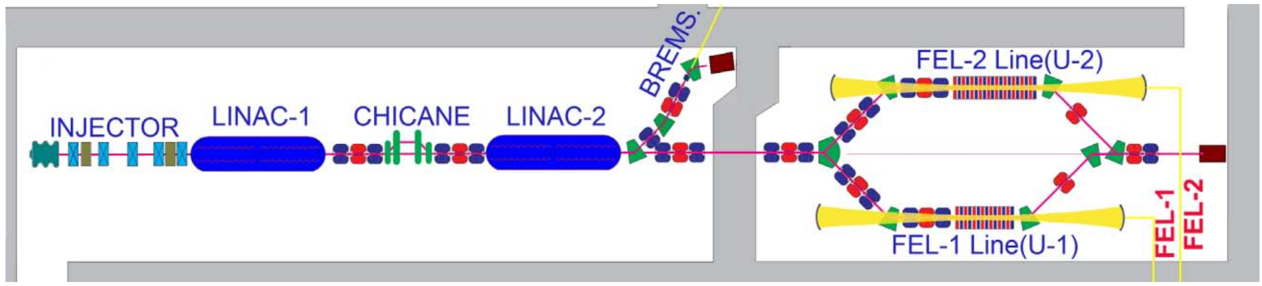

Figure 1: General layout of TAC IR-FEL Facility.

beam size and 500 ps bunch length. The beam is compressed by one sub harmonic buncher which operates at 260 MHz and one fundamental buncher which operates at 1.3 GHz in injector part and the length becomes around 5 ps [11].

The beam is inserted to first accelerating module just after the injector. Second module is located after a chicane which is located between two triplets for obtaining round beam at the entrance of second module. This choice is also allows us to determine beam sizes easily as well as we can manage periodicity of the chicane.

The electron beam delivered by Linac-2 is transferred out of accelerating hall to the FEL hall using one common transfer line.Same as accelerator section transfer line, quadruple triplets are chosen for FEL transport lines. This choice also allows us to match the beam easily to the undulators. The PARMELA results of the beam at the entrance of undulators for common line are given with figure 2.

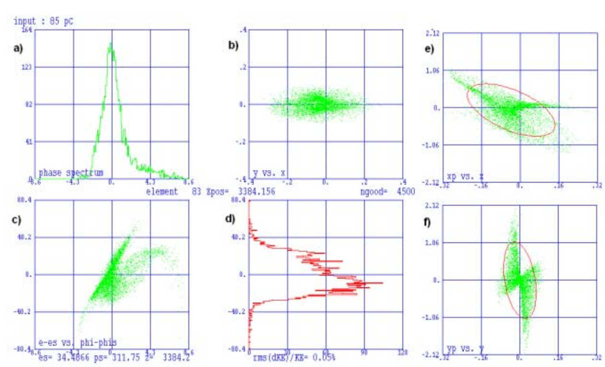

Figure 2: PARMELA results at the entrance of undulators a) Long. phase spectrum, b) Trans. beam profiles, c) Long. phase space, d) Energy spectrum, e) Horizontal phase space, f) Vertical phase space

FEL mechanism requires that the electron beam to beam should be matched both horizontal and vertical plane to the undulator such as the horizontal beam envelope should be matched to the the Rayleigh length of the optical beam while vertical envelope should be matched as it will stay stable through the undulator. This process is done with first order transverse beam dynamics calculation using mathematica for both FEL line. The beam envelope variation after Linac-2 through beam dump for FEL-1 line is given with figure 3.

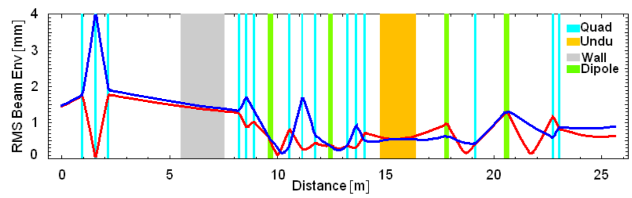

Figure 3: The beam envelope variation after Linac-2 through beam dump for FEL-1 line

Beam dynamic issues was also checked for 16 kW beam power for same module in case it will be possible to feed same ELBE module with available 16 kW RF power source [12, 13]. Calculated main beam parameters is given with table 2.

Table 2: Main e^- beam parameters of TAC IR-FEL

Parameter	**10 kW RF**	**16 kW RF**
Max Beam Eenergy (MeV)	40	40
Bunch Charge (pC)	80	120
Average Current (mA)	1	1.6
Rms Bunch Length (ps)	1-10	1-10
Bunch Separation (ns)	77	77
Nor.rms Tran.Emt.(mm.mrad)	<15	<15
Nor.rms Long.Emt.(keV.deg)	<35	<38
RMS Energy Spread (%)	0.05	0.08

FEL Optimization

For the FEL optimization mainly FELO simulation program which is one-dimensional free electron laser oscillator simulation code (developed by ASTeC CCLRC Daresbury Laboratory,UK [14]) was used as well as mathematica code. The undulators have been chosen Sm_2Co_{17} with 3cm and 9 cm periods according to scan wavelengths range which is desired and availability of undulator material. The resonator parameters including undulators are given with table 3. During calculations both 1 mA and 1.6 mA options were taken into account and the results of FEL optimization calculations are presented in table 3 and the figures below.

Table 3: Main Parameters of optical resonators and FELs

Parameter	**U1**	**U2**
Undulator material	Sm_2Co_{17}	Sm_2Co_{17}
Undulator period [cm]	3	9
Undulator gap [cm]	1.5-3	4-9
Rms undulator strength	0.2-0.8	0.4-2.5
Number of period	56	40
Resonator length [m]	11.53	11.53
Radii of curve of mir.[m]	5.92	6.51
Rayleigh length [m]	0.97	2.08
Parameter	**FEL-1**	**FEL-2**
Wavelength (μm)	2.7-30	10-190
Pulse energy @80 pC[μJ]	2	4
Pulse energy @120 pC[μJ]	4	10
Max peak Pow @80 pC [MW]	8	10
Max peak Pow @120 pC [MW]	12	15
Pulse length (ps)	1-10	1-10

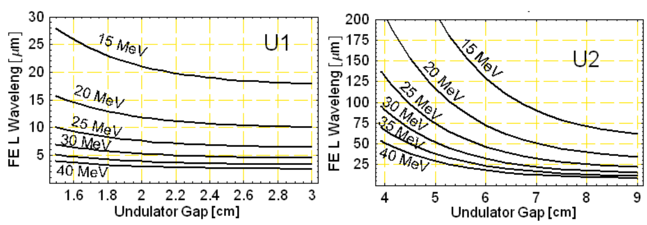

Figure 4: The FEL wavelength tunability vs the undulators' gaps with respect to beam energy. (a)U1 (b)U2

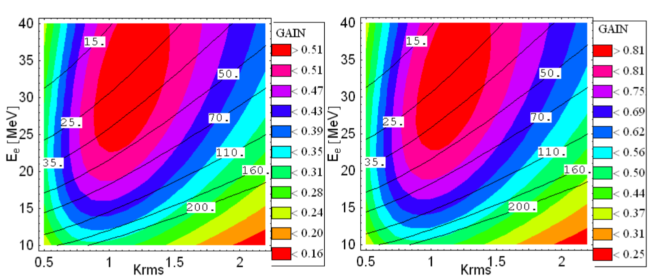

Figure 5: Single pass ideal maximum gain respect to beam energy and undulator strength for U2 (a)1 mA average beam current,(b)1.6 mA average beam current

CONCLUSION

TAC IR FEL facility will give some new research opportunities in basic and applied sciences using FEL in middle and far infrared region. It will have seven experimental stations for laser diagnosic, IR spectroscopy and microscopy, material science, medical science, optics and chemistry. It is planed to finish the IR-FEL facility construction by the end of 2009 and to install modules by the end of 2011. The commissioning is planed for early of 2012.

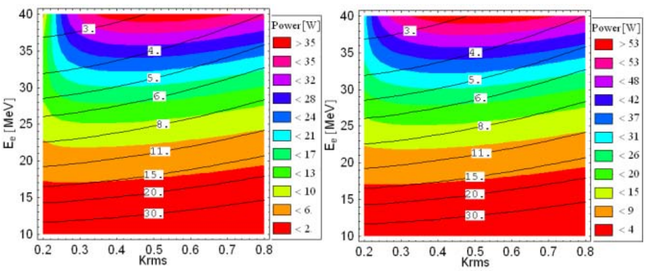

Figure 6: Expected average output power respect to beam energy and undulator strength for U1 (outcoupling hole of the mirror has a diameter of 1 mm) (a)1 mA average beam current,(b)1.6 mA average beam current

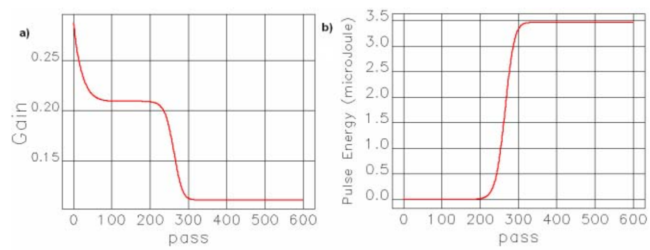

Figure 7: FELO code result for 13 μm laser obtainable from U2 for 1 mA average beam current (a) Gain variation vs passes,(b) pulse energy propagation vs passes

Acknowledgment

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REFERENCES

[1] http://thm.ankara.edu.tr

[2] Ö. Yavaş, A. K. Çiftçi, S. Sultansoy, EPAC 2000, p. 1008.

[3] S. Sultansoy et al., PAC05,(2005) p.449.

[4] A.Aksoy, et. al. "The Status of Turkish Accelerator Complex",This Connf. (ID-3904)

[5] Ö. Mete, Ö. Karslı, Ö. Yavaş, EPAC06 p. 136.

[6] A. Aksoy, et. al. "The Turkish Accelerator Complex IR FEL Project", Infrared Phys. Techn. 51 (2008), p. 373.

[7] F. Gabriel et. al. "ELBE Project Design Report", 1998.

[8] http://www.accel.de

[9] http://laacg1.lanl.gov

[10] http://www.wolfram.com

[11] I.Akkurt, et. al. "Turkish Accelerator Center IR-FEL Project Design Report", 2008

[12] Dr. P. Michel, ELBE, FZD, Germany ,Private comunication

[13] http://www.thalesgroup.com/electrondevices

[14] http://www.astec.ac.uk/id_mag/FELO.htm