BALKAN PHYSICS LETTERS
© Bogazici University Press 19 May 2009
BPL, **17**, pp. 303 - 310, 17039 (2009)

TURKISH ACCELERATOR CENTER (TAC) PROJECT

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Abstract. - Turkish Accelerator Center (TAC) Project will include different particle accelerators in order to study particle and nuclear physics and to obtain synchrotron radiation (SR) and free electron laser (FEL). The Feasibility Report (FR) and Conceptual Design Report (CDR) of the project were completed in 2000 and 2005 respectively. The third phase of project was started in 2006 as an inter-universities project with support of State Planning Organization (SPO). The main aims of third phase are to write Technical Design Report (TDR) of the main TAC complex and to establish an Infrared Free Electron Laser (IR FEL) facility as a first step. The IR FEL facility is planned to be based on 15-40 MeV electron linac and two optical cavities with 3 and 9 cm undulator magnets in order to scan 2-185 microns wavelength range. A Bremsstrahlung station is also planned in case the accelerator system of IR FEL facility is chosen superconducting technology. Main purpose of facility is to use IR FEL for research in material science, nonlinear optics, semiconductors, biotechnology, medicine and photochemical processes. The first facility will be built in Ankara University Golbasi Campus area together with the Institute of Accelerator Technologies. In this study, main parts and parameters of TAC and first facility are explained. Road map of project is given. The first facility and TDR studies are planned to be completed in 2011. Construction phase of TAC will have been covered 2011-2022.

1. INTRODUCTION

In the mid of 1990s, a regional accelerator complex project was proposed [1]. The Turkish Accelerator Center (TAC) project was proposed based on this first idea in 2000 as a result of feasibility project by State Planning Organization (SPO) of Turkey [2, 3, 4]. It is proposed that, TAC will include a linac-ring type particle factory and the light sources (synchrotron radiation and free electron laser) and a GeV scale proton

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accelerator. Conceptual Design Report (CDR) of TAC was completed in 2005 [5]. 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.In this paper, main characteristics and parameters of the accelerator facilities of TAC are defined and research potentials of these facilities are discussed.

2. MAIN FACILITIES OF TAC

According to the proposal, TAC will include a linac-ring type charm factory, a third generation synchrotron radiation facility based on positron ring, a SASE FEL facility based on electron linac (See Fig. 1) [5, 6] and a proton accelerator facility based on a few GeV proton linac . Four main goals of the project;

- Linac-ring type electron-positron collider as a " Charm " factory with a center of mass energy ($\sqrt{s}$) 3.77 GeV.
- A SASE FEL facility based on a 1 GeV electron linac with a wavelength of few nanometers.
- Third generation light source " Synchrotron Radiation" based on 3.56 GeV positron ring.
- GeV scale proton accelerator which consists of 100 MeV linear pre-accelerator and 1-3 GeV energy.

In addition, an oscillator Infrared Free Electron Laser (IR-FEL) facility covering 2-185 μm wavelength range based on an 15-40 MeV electron linac and a bremsstrahlung station will be constructed in the 2008-2011 period as a first facility of TAC for the aim of research, education and training[7, 8].

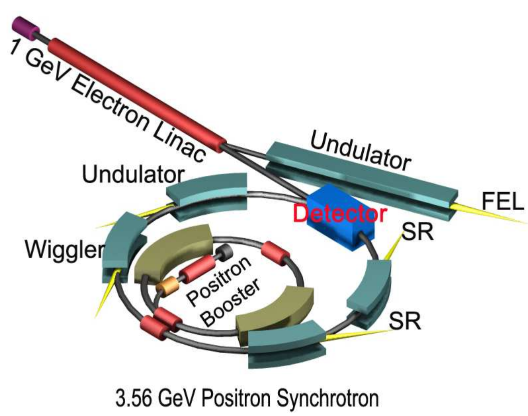

Figure 1: Schematic view of TAC

2.1 Particle (Charm) Factory

It is planned to collide the electrons coming through the linac with an energy of 1 GeV with the positrons coming from the synchrotron with an energy of 3.56 GeV (See fig. 1). It is aimed to produce Charm particle with a center of mass energy $\sqrt{s}$ = 3.77 GeV. Up to now; $\varphi-$, $\tau-$, and $c-$ factory options were analyzed [4, 5]. In principle, $L = 10^{34}$ cm^{-2}s^{-1} can be achieved for all three options. Concerning φ factory option, existing DAΦNE φ factory has nominal $L = 5 \cdot 10^{32}$ cm^{-2}s^{-1} and possible upgrades to higher luminosities are under consideration [9, 10]. Therefore, physics search potential for the φ factory will be essentially exhausted before TAC commissioning. Concerning τ factory option, whereas $e + e^- \rightarrow \tau + \tau^-$ cross-section achieves a maximum value at $\sqrt{s}$=4.2 GeV, this advantage is dissipated with success of B-factories which has luminosity of 10^{34} cm^{-2}s^{-1} already. Moreover super B-factories with $L = 10^{36}$ cm^{-2}s^{-1} are intensively discussed in [9, 10].

2.2 Synchrotron Radiation (SR)

It was planned to obtain a third generation light "Synchrotron Radiation " from the positron ring of the linac-ring collider at energy of 3.56 GeV [2, 3, 4]. Several samples of optical beam lines design and related studies on TAC SR facility can be found in [2] in the CDR of TAC project. Main parameters of TAC SR ring are given in Table 1 and also SR flux versus photon energy graph is given in Figure 2.

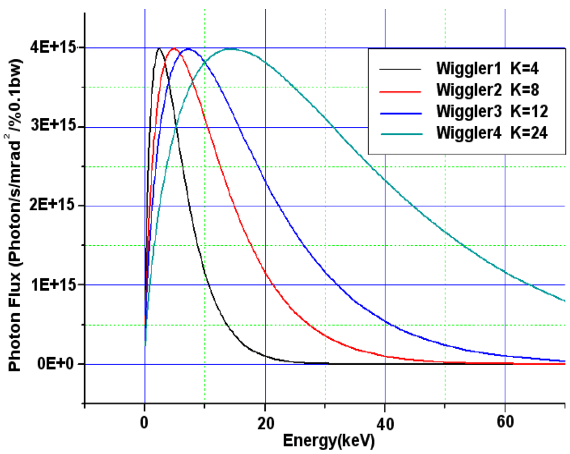

Figure 2: Flux vs photon energy

Table 1: Main parameters of TAC SR ring

Energy (GeV)	3.56
Circumference (m)	264
Beam current (mA)	100
Tune (Q_x,Q_y)	15.8374, 1.2318
Chromaticity η_x, η_y	-22.47305, -12.9
SR tune	0.022997
Harmonic number	432
RF frequency (MHz)	509.9
RF power (kW)	100
Momentum compaction	-0.00143
Long. - trans. emittance (nm rad)	20 - 10

2.3 Self Amplified Spontaneous Emission Free Electron Laser (SASE FEL)

A SASE FEL facility is also planned as 4th generation light source in the frame of TAC (See fig. 3). In the beginning of the proposal the FEL facility may be based on 1 GeV electron linac of the collider . For SASE FEL production, in order to achieve the peak power about ˜GW, the required peak current must be about $\sim kA$. To raise the peak current, modifications for bunch sizes and emittance shows that the linac which will operate for SASE FEL must be performed completely different from the collider's [6, 11].Basic parameters of SASE FEL facility is given with Table 2.

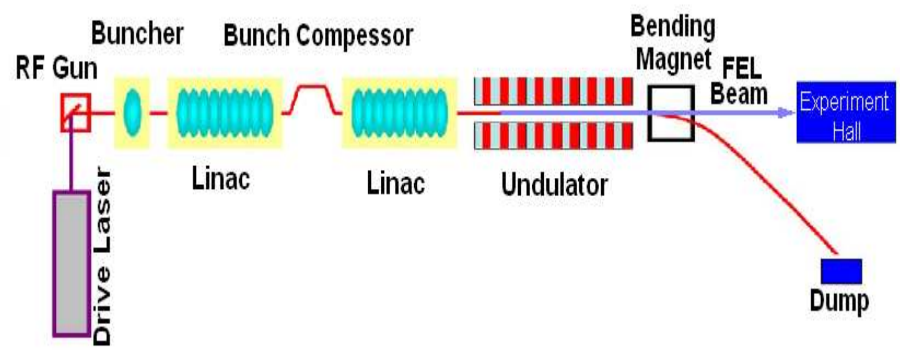

Figure 3: Schematic view of TAC SASE FEL

Table 2: The electron Linac, undulator and SASE FEL parameters

Beam energy (GeV)	1
Peak current (A)	2106
Normalized emittance (μm.rad)	3.1
Period length, λ_u (cm)	3.0
Peak magnetic field, B_u (T)	0.498
K parameter	1.395
SASE FEL wavelength, λ (nm)	7.7
Average power, (kW)	21.8
Peak brightness (photons/s/mrad^2/0.1%bg)	1.7x10^{29}
Peak brilliance (photons/s/mm^2/mrad^2/0.1%bg)	2.9x10^{30}

2.4 Proton Accelerator (PA)

TAC proton accelerator proposal consists of 100÷ 300MeV energy linear pre-accelerator and 1÷ 3GeV main ring or linac. The average beam current values for these machines would be 30 mA and 0.3 mA, respectively. Proton beam will be forwarded to neutron and muon regions, where a wide spectrum of applied research is planned. In muon region, together with fundamental investigations such as test of QED and muonium-antimuonium oscillations, a lot of applied investigations such as High-Tc superconductivity, phase transitions, impurities in semiconductors et cetera will be performed using the powerful Muon Spin Resonance (μSR) method. In neutron region investigations in different fields of applied physics, engineering, molecular biology and fundamental physics are planned. In addition, some Accelerator Driven System (ADS) applications are planned.

3. THE FIRST FACILITY OF TAC: IR FEL and BREMSSTRAHLUNG

TAC IR FEL facility will be an oscillator FEL and will be situated at Ankara University Gölbaşı Campus, was proposed in order to become familiar to accelerator technology as a first step to the main complex [2]. It was planned to obtain FEL in 2-185 microns range using electron beam up to 40 MeV and two undulators ($\lambda_{U1} = 3cm; \lambda_{U2} = 9cm$) at the facility. Super conducting accelerator option have been studied for 40 MeV electron beam. 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 [7, 8].

Available two Sc RF(ACCEL) modules, which houses TESLA 9-cell SC structure, were taken into account for providing beam up to 40 MeV. The module can provide 1 mA average beam current at 10 kW beam power (@ CW operation) [12]. Recently developed 16 kW RF sources were also taken into account in order to obtain 1.6 mA average beam current. Sm_2Co_{17} material undulators which have λ_{U1}=3cm and λ_{U2}=9cm periods have been chosen. General layout of TAC IR FEL is given in figure 4. Optimized electron beam parameters for both 1 mA and 1.6 mA case and obtainable FEL parameters using corresponding electron beam are given with table 3, figure 5, and table 4, respectively.

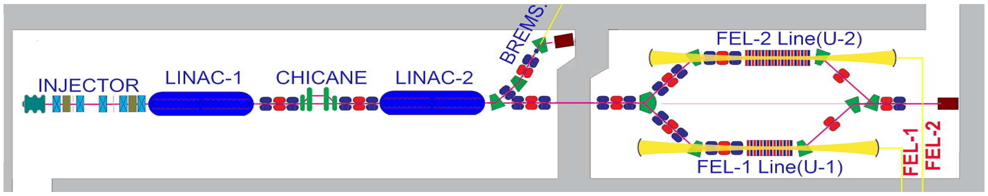

Figure 4: General layout of TAC IR FEL

Table 3: Main e$^-$ beam parameters of TAC IR-FEL

Parameter	**10kW RF**	**16kW 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

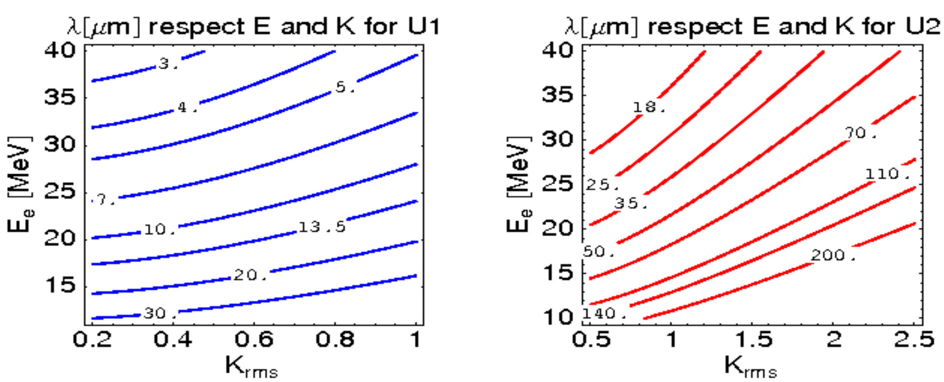

Figure 5: Laser wavelength change respect to beam energy and undulator strengths for undulator-1 and undulator-2.

Table 4: Main Parameters of optical resonators and IR 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 mirrors[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

Besides, FEL production in the facility, a Bremsstrahlung beam line which based on 20 MeV electron beam and an experimental station for nuclear physics studies is planned. Results of design studies of Bremsstahlung station can be found in ref [13].

4. 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 eight experimental stations for laser diagnostics, IR spectroscopy and microscopy, material science, medical science, optics and chemistry. It is planned that TAC IR FEL facility will be completed in 2011. In future, TAC project will also give opportunity to use synchrotron radiation, and SASE FEL in basic and applied sciences. Additionally, it will create some valuable contributions to particle and nuclear physics studies by linac on ring type electron positron collider as a particle factory in Turkey and around.

Acknowledgement

This work is supported by SPO of Turkey (Grant No: DPT2006K-120470).

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