Turkish Accelerator and Radiation Laboratory in Ankara (TARLA)

Avni Aksoy
On behalf of TARLA Team

Ankara University

August 15 2012

Outline

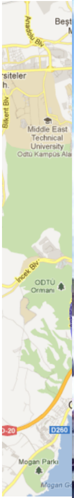
- Introduction
- Main components
  - Injector
  - Main Accelerating section
  - FEL Section
  - Helium Plant
- Proposed FEL applications
- Conclusion
- TAC Project

TARLA facility at Institute of Accelerator Technologies of Ankara University

- TARLA project which is essentially one of the sub-project of national project (TAC) has been coordinated by Ankara University since 2006.
- TARLA facility belongs to Institute of Accelerator Technologies of Ankara University (located in Gölbaşı, 15 km south of Ankara), and it is supported by Ministry of Development of Turkey.
- The institute which is only 2 years old is the first institute established as research in the fields of accelerators and related topics
- We have 18 full-time employee in the institute now (12 technical, 6 administrative)

  about 10 part time collaborator from different universities

TARLA facility at Institute of Accelerator Technologies of Ankara University

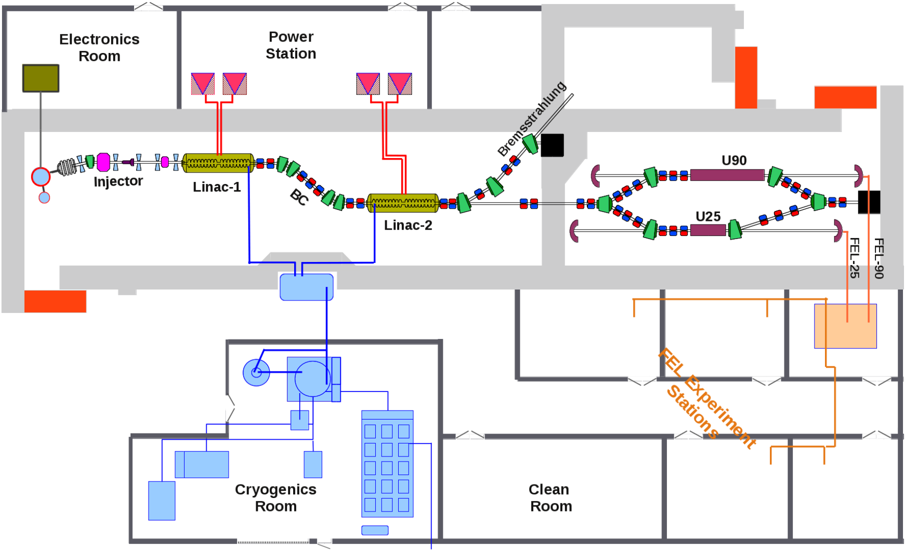


- TARLA project which is essentially one of the
en
rator
n
rkey.
first
of
te now

Main Goals of TARLA

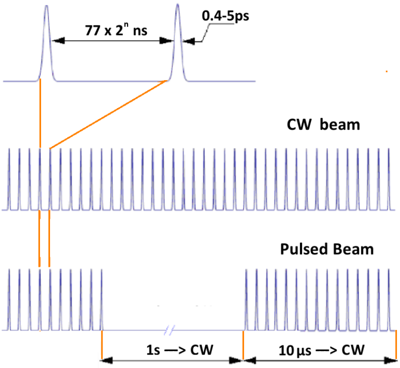
- TARLA basically proposed to generate Free Electron Laser between 3-250 μm using 15-40 MeV electron beam.
- In order to have wide research area, the electron beam is requested to be continuous wave with high current as well as pulsed with low current.
- We plan to use high average current normal conducting injector which operates CW mode and superconducting accelerators which are fed by solid state power amplifiers.
- To obtain FEL 3-250 micron range we plan to use two different optical resonators with 2.5 and 9 cm period length undulators.
- Additionally a bremsstrahlung station is also proposed for nuclear structure and gamma radiation studies.
- We propose to use electron beam itself for material and detector research in the future

TARLA layout



TARLA Beam

Micropulse repetition is controlled at gun with fast grid modulation system



Macropulse time structure is manipulated with macropulsed installed on injector

CW Electron beam

1 mA, 0-40 MeV

Coherent IR (FEL)

$3 - 250\mu m$
* materials research
* biophysics
* biochemistry
* environment

Polarized Bremsstrahlung

0 – 20 MeV
* nuclear physics
* nuclear astrophysics

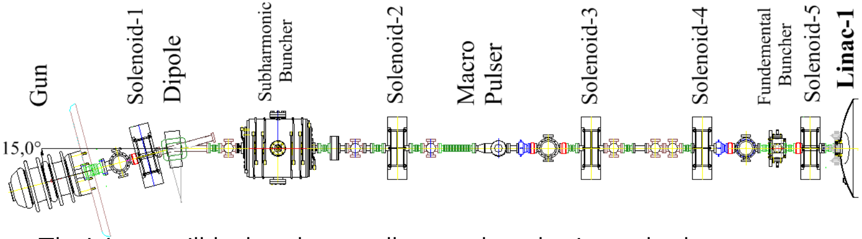
Electrons

0 – 40 MeV
* radio biology
* detector studies
* materials research

Main Electron Beam Parameters

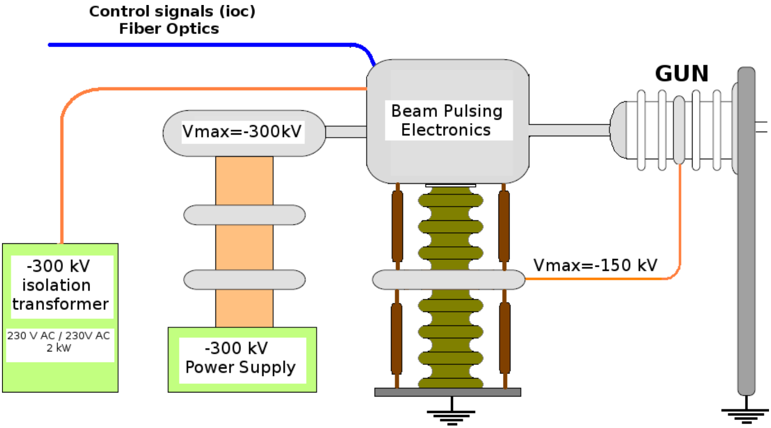
Parameter	Unit	Base Value	Upgrade Value
Beam Energy	MeV	16 - 40	16 - 40
Max Bunch Charge (@13 MHz)	pC	77	115
Max Average Beam Current	mA	1	1.5
Horizontal Emittance	mm mrad	<15	<15
Vertical Emittance	mm mrad	<12	<12
Longitudinal Emittance	keV ps	<85	<85
Bunch Length	ps	0.4 - 6	0.4 - 6
Bunch Repetition	MHz	13	13-26
Macro pulse Duration	μs	10 - CW	10 - CW
Macro pulse Repetition	Hz	1 - CW	1 - CW

Electron source and Injector setup

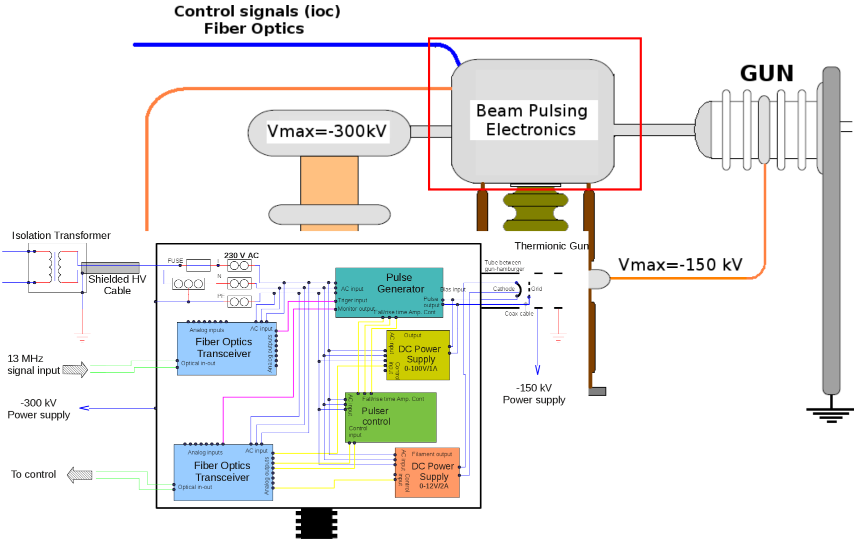


- The injector will be based on totally normal conducting technology
- It will consist of mainly
  - 250 kV DC thermionic gun (ELBE Design)
  - 260 MHz and 1.3 GHz buncher cavities (ELBE Design)
  - 5 solenoid and one dipole
- Bunches will be created at gun with length of 500 ps @250 keV @CW mode
- They will be compressed to 10 ps with Subharmonic (260 MHz) and Fundamental (1.3 GHz) bunchers before they are injected to main accelerating section.
- The time structure of the beam will able to be manipulated with a macro pulser. The time structure can be modified by grid-pulsing system as well.
- In order to avoid the field emission to be stored at cathode the gun is bended 15 degree.

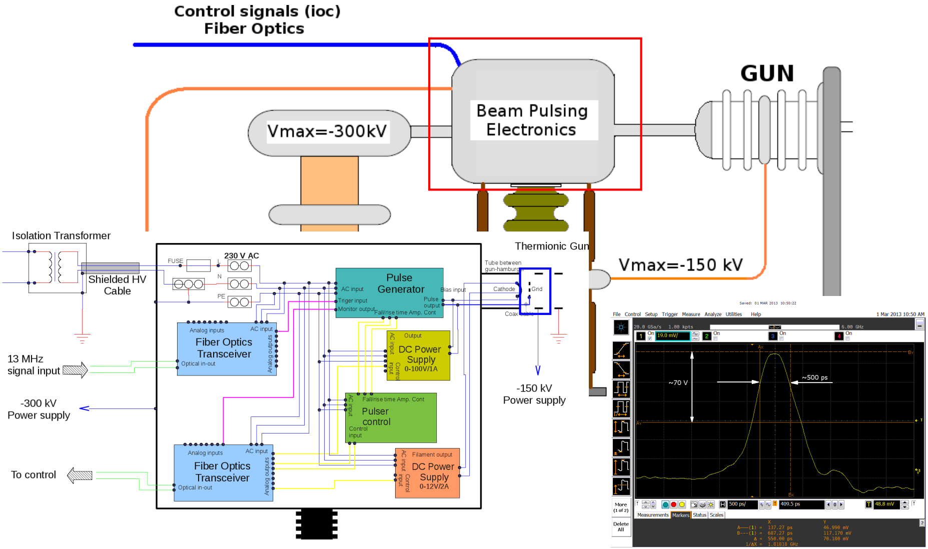
Gun Setup and Pulsing system



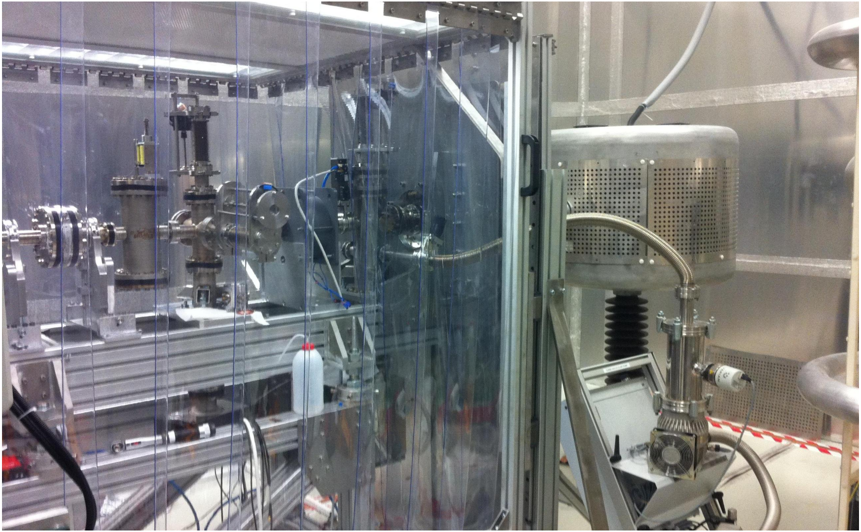
Gun Setup and Pulsing system



Gun Setup and Pulsing system

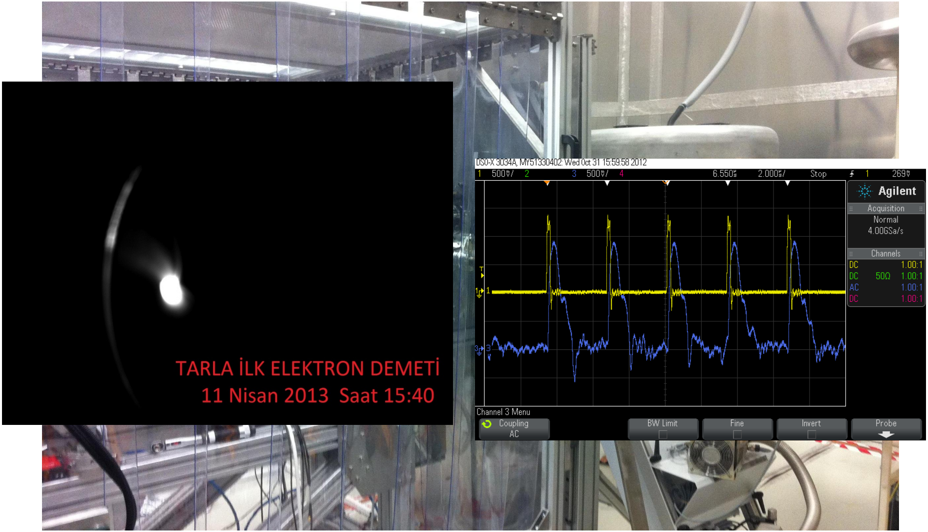


Gun test stand



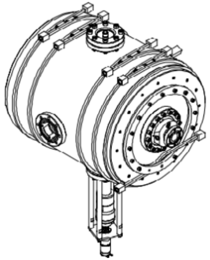
Gun commissioning has been continuing for more than 6 months.

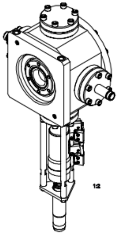
Gun test stand



we could observe first beam in April 2013.

Buncher Cavities





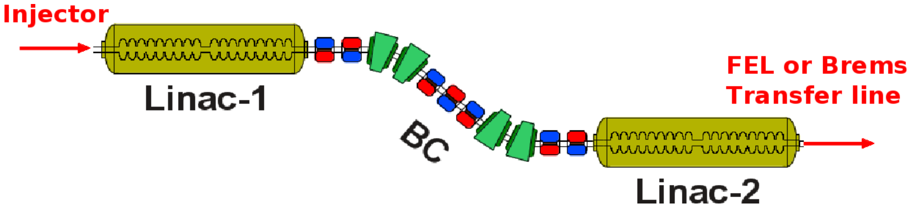
TM_{010} 260 MHz resonator

Q	12200	
R/Q	225	Ω
T_0	0.992	
V_{acc}	0.06	MV/m
ΔE	25	kV

TM_{010} 1300 MHz resonator

Q	13700	
R/Q	100	Ω
T_0	0.92	
V_{acc}	0.1	MV/m
ΔE	20	kV

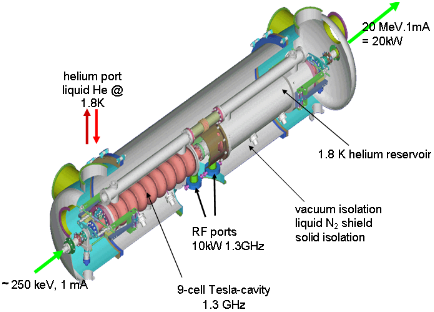
The buncher cavities are ELBE design. They were ordered to Research Instruments and will be delivered by the end of 2013.



- Main accelerating section will consist of
  - 2 superconducting SRF modules
  - Bunch compressor located between two modules
- 1 mA CW beam provided by injector will be accelerated up to 18 MeV in first linac;
- The bunches at maximum 18 MeV will be compressed down to 0.5ps (or decompressed) in bunch compressor section. (Due to capture process a dogleg style bunch compressor has been designed.);
- In the second state of this section beam will able to be accelerated up to 40 MeV.

ELBE Superconducting Module

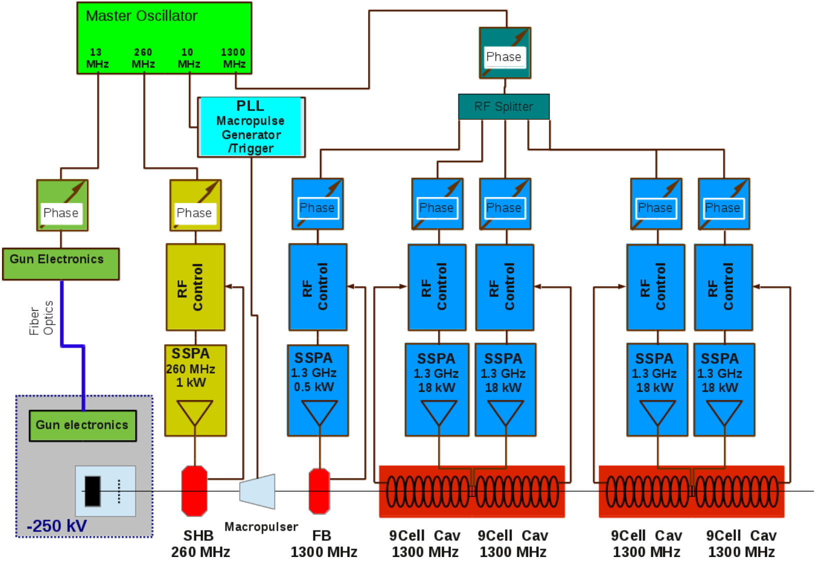
- Super conducting RF accelerating modules will be manufactured by Research instruments (Contract in 2012 Oct)
- This module is compact and houses two TESLA cavities
- It is designed for continuous operation with accelerating gradient up to 15 MV/m.
- The cryostat design has been developed by ELBE team (HZDR) and is used under a license agreement.



Module Parameters

Frequency (@ 2K)	1300 ± 0.05	MHz
Tuning range	120	kHz
External Q of input couplers	$(1.2 \pm 0.2) \times 10^7$	
External Q of HOM couplers	$> 5 \times 10^{11}$	
Accelerating voltage / module	>20	MV
Total cryogenic losses at 20 MV (@ cw)	< 75	W
Power coupler performance (standing wave)	$\geq$8	kW

TARLA RF – System, Block Diagram



RF Amplifiers

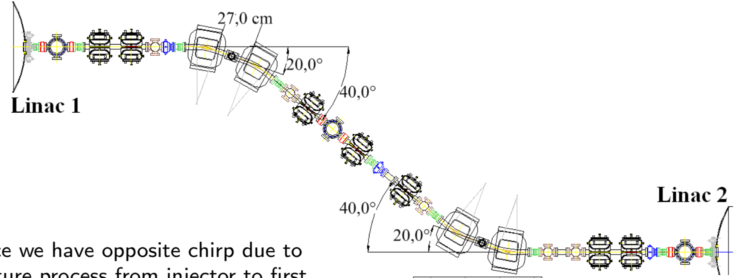
- Each SC cavity will be fed by solid states transmitters with a power of 18 kW.
- Such transmitters were manufactured by Sigmaphi (Bruker) and demonstrated at ELBE
- We plan to sign a contract in two months..

SIGMAPHI ACCELERATOR TECHNOLOGIES

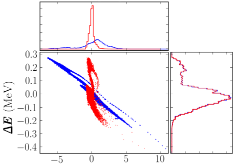
Module Parameters

Output Power (1 dB compression) pulse or CW	18	kW
Saturated Output Power pulse or CW	20	kW
Linear gain	<72	dB
Center frequency (@ 2K)	1300	MHz
Bandwidth (-3 dB)	$\pm$ 5	MHz
Output Signal Form	CW/Pulse	
Power out load	0...∞	
Compression Point @ P_{nom}	1	dB
Gain flatness in active bandwidth	$\pm$ 0.2	dB
Pulse length	10 ... CW	μs
Pulse repetition rate	1 ... CW	Hz
Pulse Rise / Fall time	<60	ns

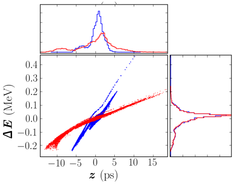
Bunch Compressor



- Since we have opposite chirp due to capture process from injector to first cavity we need positive R_{56} bunch compressor
- For compression second cavity of first module must be on crest
- For decompression we only need to change phase of second cavity
- Max bunch length is about 6ps

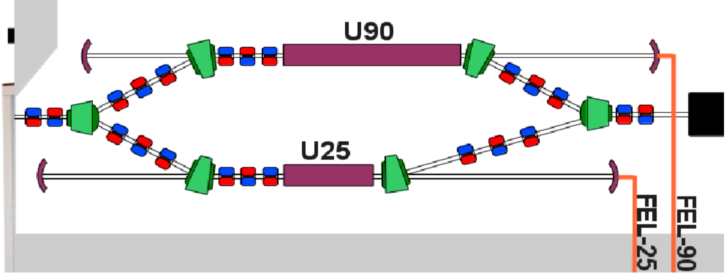


Parameter	BeforeBC	AfterBC
E (MeV)	18.271	18.271
$\varepsilon_{n,x}$ (μmrad)	11.968	12.161
$\varepsilon_{n,y}$ (μmrad)	11.921	12.108
ε_z (keV.ps)	24.807	31.817
σ_z (ps)	2.046	0.399
σ_E (keV)	97.270	97.876



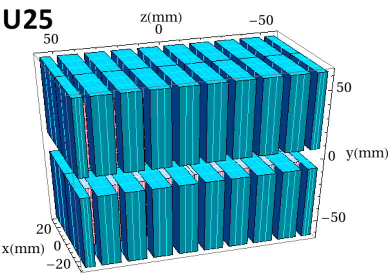
Parameter	BeforeBC	AfterBC
E (MeV)	7.607	7.606
$\varepsilon_{n,x}$ (μmrad)	11.977	14.503
$\varepsilon_{n,y}$ (μmrad)	11.929	13.927
ε_z (keV.ps)	24.255	55.012
σ_z (ps)	1.977	4.681
σ_E (keV)	66.379	63.411

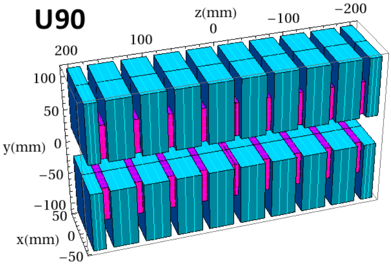
Free Electron Laser Hall

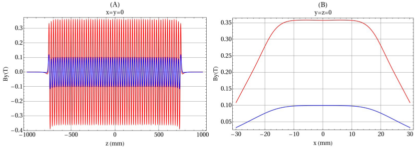


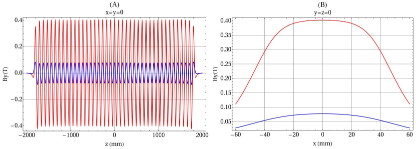
- We propose to use 2 different optical resonator in order to scan all wavelengths between 3-250 μm. (hopefully!!)
- The beam is injected to undulators with achromatic beamlines with 30° bending magnets and quadrupole triplets in between.
- U90 $\Rightarrow$ undulator with 90 mm period length and U25 $\Rightarrow$ undulator with 25 mm period length
- Besides the length of the periods of the undulators, the waveguide structure of U95 is another main difference between resonators.

Undulators





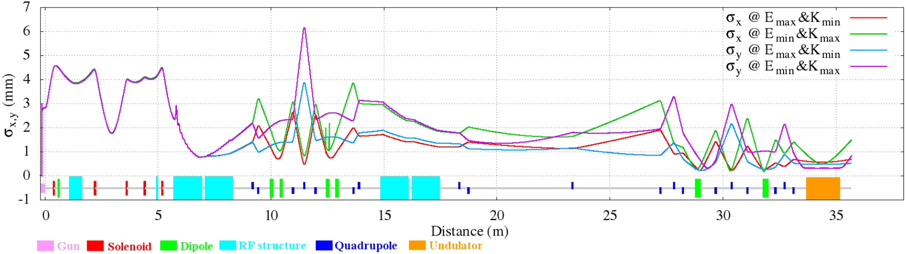


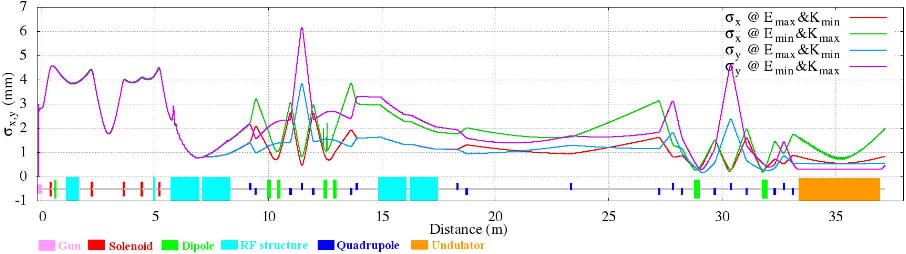


- NbFe pole material, steal blocks
- Roll off filed for max field is 0.04

- NbFe pole material, steal blocks
- Roll off filed for max field is 0.1

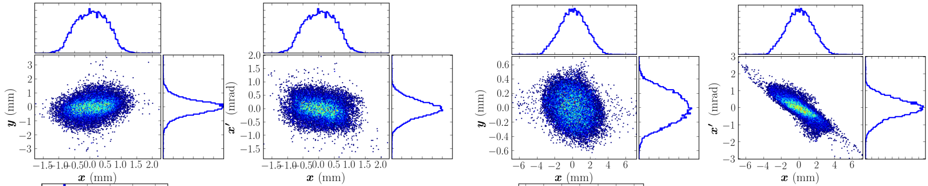
Beam Undulator matching

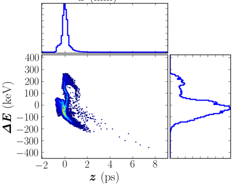




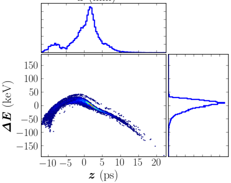
Beam transport through the U25 (top) and U90 (bottom) for 16 and 38.5 MeV beam energy and maximum and minimum field at undulators, respectively

Phase space at Undulator entrance





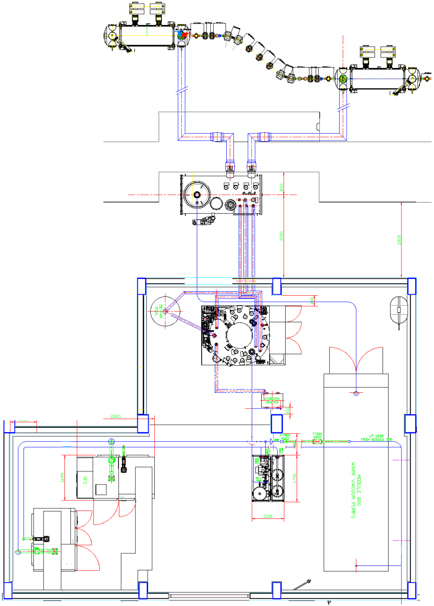
Parameter	Unit	Value
E	MeV	38.209
$\varepsilon_{n,x}$	μmrad	12.263
$\varepsilon_{n,y}$	μmrad	12.697
ε_z	keV.ps	35.174
σ_x	mm	0.489
σ_y	mm	0.561
σ_z	ps	0.378
σ_E	keV	94.902
$\Delta E/E$	%	0.248



Parameter	Unit	Value
E	MeV	16.075
$\varepsilon_{n,x}$	μmrad	14.533
$\varepsilon_{n,y}$	μmrad	13.190
ε_z	keV.ps	82.951
σ_x	mm	1.516
σ_y	mm	0.199
σ_z	ps	4.308
σ_E	keV	20.116
$\Delta E/E$	%	0.125

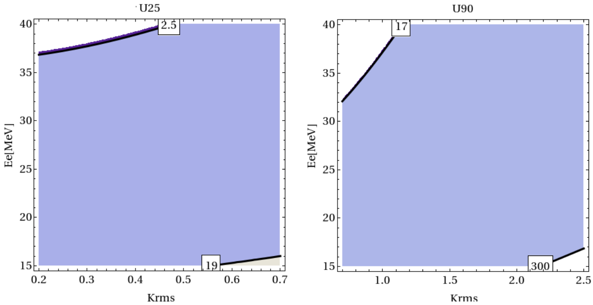
Main feature of TARLA beamline is achieving maximum beam energy with minimum bunch length. It is chromatic and almost isochronous

Helium Plant



- Cryogenics system is being manufactured by Air Liquide.
- The system will consist of
  - Helium refrigerator (4 K box)
  - Distribution Box (2 K box, housing cold compressors)
  - Two compressors
  - Warm vacuum pump station
  - Oil remover, transfer lines, vaporizer etc..
- Capacity
  - 210 W @1.8K
  - 16 mbar ± 0.2mbar
- Contract signed in August 2012, delivery by May 2014 and commissioning August 2014

Expected FEL Parameters

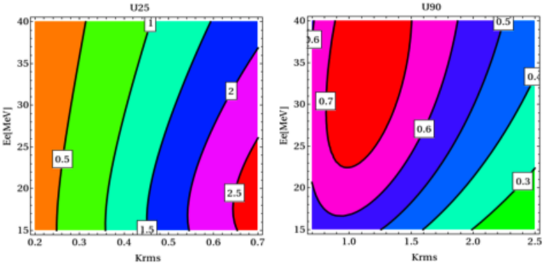


$$\lambda_{FEL} = \frac{\lambda_u}{2\gamma^2}(1 + K_u^2)$$

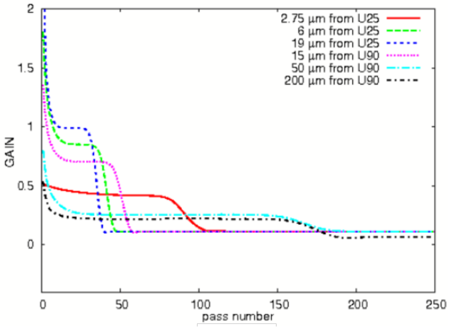
λ_U: Undulator Period

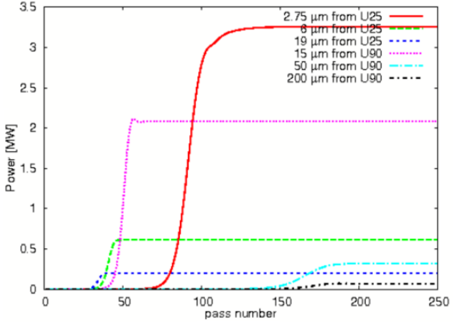
K_U: Undulator Strength

Plots shows possible wavelength range and single pass gain for beam energy vs. undulator strengths. (optimum case; constant bunch length, optimum out coupling factor etc.)
In realistic case obtaining on around limits of the wavelengths would not be possible, due to low strength or long bunch length.



Expected FEL Parameters





- Plots shows gain (left) and intracavity power (right) behavior versus round trips between mirrors..
- It is seen that gain for longer wavelengths (therefore saturated power) is too small..

The calculations was performed for optimum out coupling factor etc. bunch length and detuning has been optimized for different FEL wavelengths lengths

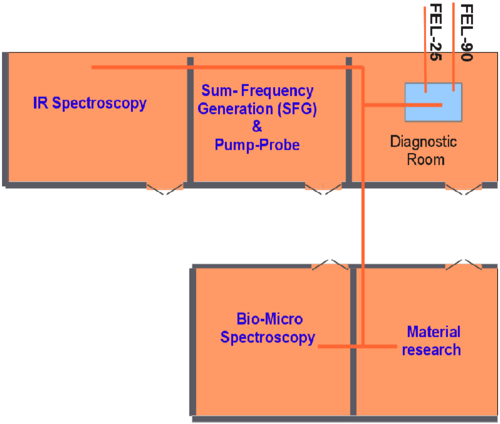
Some resonator and expected FEL parameters of TARLA

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
Resonator Length	m	11.53	11.53
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

* ; depending on wavelength

Proposed FEL applications

- Proposed FEL stations are:
  - IR spectroscopy lab.
  - SFG-PP lab.
  - Bio-Micro Spectroscopy lab.
  - Material research lab.
- Main FEL parameters are available for these labs
  - wavelength range: 3-250 μm
  - Average FEL power: 1-100 W



- Time structure:1-5 ps micro pulse duration CW/macro pulsed laser pulses with 13 MHz micro pulse repetition

Summary and conclusion

- TARLA is the first step of TAC project and will be the first FEL user facility in Turkey and around our region.
- The facility will give opportunity to scientists and industry to make research about material, biotechnology, optics, semiconductors, medicine and chemistry...
- TARLA is essentially divided within two steps about budget..
  - TARLA-1 which is continuing covers infrastructure and accelerating section. (being completed by the end of 2015)
  - TARLA-2 which is going to be submitted next year covers FEL section and user labs. (Planned to be started by 2014 and to complete by the end of 2017)

Summary and conclusion

- TARLA is the first step of TAC project and will be the first FEL user facility in Turkey and around our region.
- The facility will give opportunity to scientists and industry to make research about material, biotechnology, optics, semiconductors, medicine and chemistry...
- TARLA is essentially divided within two steps about budget..
  - TARLA-1 which is continuing covers infrastructure and accelerating section. (being completed by the end of 2015)
  - TARLA-2 which is going to be submitted next year covers FEL section and user labs. (Planned to be started by 2014 and to complete by the end of 2017)

Summary and conclusion

- TARLA is the first step of TAC project and will be the first FEL user facility in Turkey and around our region.
- The facility will give opportunity to scientists and industry to make research about material, biotechnology, optics, semiconductors, medicine and chemistry...
- TARLA is essentially divided within two steps about budget..
  - TARLA-1 which is continuing covers infrastructure and accelerating section. (being completed by the end of 2015)
  - TARLA-2 which is going to be submitted next year covers FEL section and user labs. (Planned to be started by 2014 and to complete by the end of 2017)

Summary and conclusion

- Commissioning of gun is being continuing, we try to fix HV problems...
- Currently we are making some modifications on our building..
  - user labs
  - infrastructure for cyrogenics
  - Infrastructure for radiation safety. . .
- The injector will to be ready by the end of 2014. Commissioning will take about 6 months (including all tests)
- The helium plant will be ready by the mid of 2014
- First cyromodule will be delivered by September 2014. We expect to get first beam from SRF1 by the mid of 2015, and beam from SRF2 is expected by the end of 2015
- Additionally we plan to start TARLA-2 project by next year in order to purchase the undulators and resonators...

Summary and conclusion

- Commissioning of gun is being continuing, we try to fix HV problems...
- Currently we are making some modifications on our building..
  - user labs
  - infrastructure for cyrogenics
  - Infrastructure for radiation safety. . .
- The injector will to be ready by the end of 2014. Commissioning will take about 6 months (including all tests)
- The helium plant will be ready by the mid of 2014
- First cyromodule will be delivered by September 2014. We expect to get first beam from SRF1 by the mid of 2015, and beam from SRF2 is expected by the end of 2015
- Additionally we plan to start TARLA-2 project by next year in order to purchase the undulators and resonators...

Summary and conclusion

- Commissioning of gun is being continuing, we try to fix HV problems...
- Currently we are making some modifications on our building..
  - user labs
  - infrastructure for cyrogenics
  - Infrastructure for radiation safety. . .
- The injector will to be ready by the end of 2014. Commissioning will take about 6 months (including all tests)
- The helium plant will be ready by the mid of 2014
- First cyromodule will be delivered by September 2014. We expect to get first beam from SRF1 by the mid of 2015, and beam from SRF2 is expected by the end of 2015
- Additionally we plan to start TARLA-2 project by next year in order to purchase the undulators and resonators...

Summary and conclusion

- Commissioning of gun is being continuing, we try to fix HV problems...
- Currently we are making some modifications on our building..
  - user labs
  - infrastructure for cyrogenics
  - Infrastructure for radiation safety. . .
- The injector will to be ready by the end of 2014. Commissioning will take about 6 months (including all tests)
- The helium plant will be ready by the mid of 2014
- First cyromodule will be delivered by September 2014. We expect to get first beam from SRF1 by the mid of 2015, and beam from SRF2 is expected by the end of 2015
- Additionally we plan to start TARLA-2 project by next year in order to purchase the undulators and resonators...

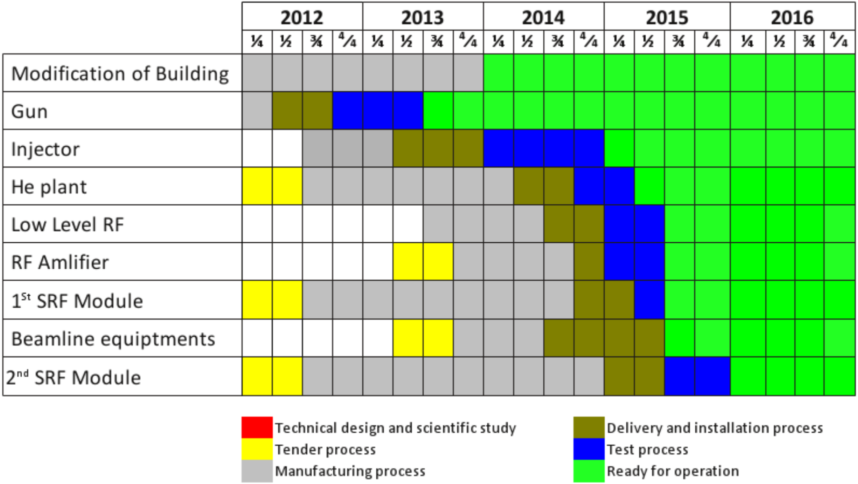
Summary and conclusion

- Commissioning of gun is being continuing, we try to fix HV problems...
- Currently we are making some modifications on our building..
  - user labs
  - infrastructure for cyrogenics
  - Infrastructure for radiation safety. . .
- The injector will to be ready by the end of 2014. Commissioning will take about 6 months (including all tests)
- The helium plant will be ready by the mid of 2014
- First cyromodule will be delivered by September 2014. We expect to get first beam from SRF1 by the mid of 2015, and beam from SRF2 is expected by the end of 2015
- Additionally we plan to start TARLA-2 project by next year in order to purchase the undulators and resonators...

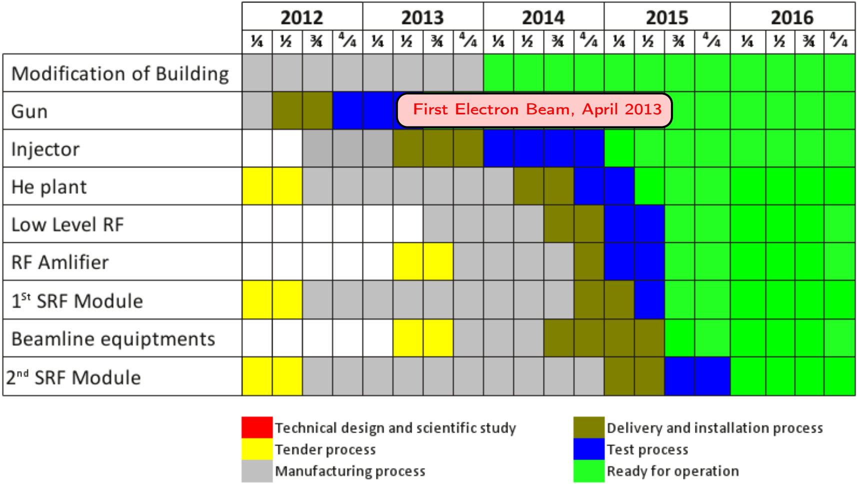
Summary and conclusion

- Commissioning of gun is being continuing, we try to fix HV problems...
- Currently we are making some modifications on our building..
  - user labs
  - infrastructure for cyrogenics
  - Infrastructure for radiation safety. . .
- The injector will to be ready by the end of 2014. Commissioning will take about 6 months (including all tests)
- The helium plant will be ready by the mid of 2014
- First cyromodule will be delivered by September 2014. We expect to get first beam from SRF1 by the mid of 2015, and beam from SRF2 is expected by the end of 2015
- Additionally we plan to start TARLA-2 project by next year in order to purchase the undulators and resonators...

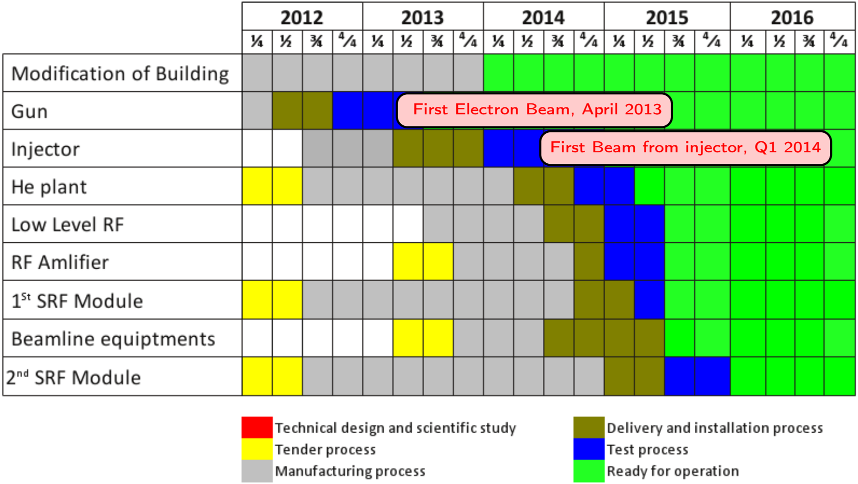
Milestones of TARLA



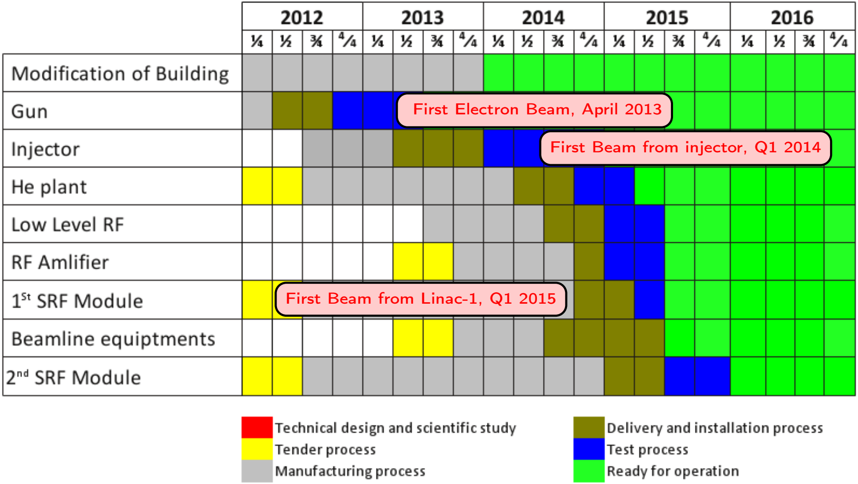
Milestones of TARLA



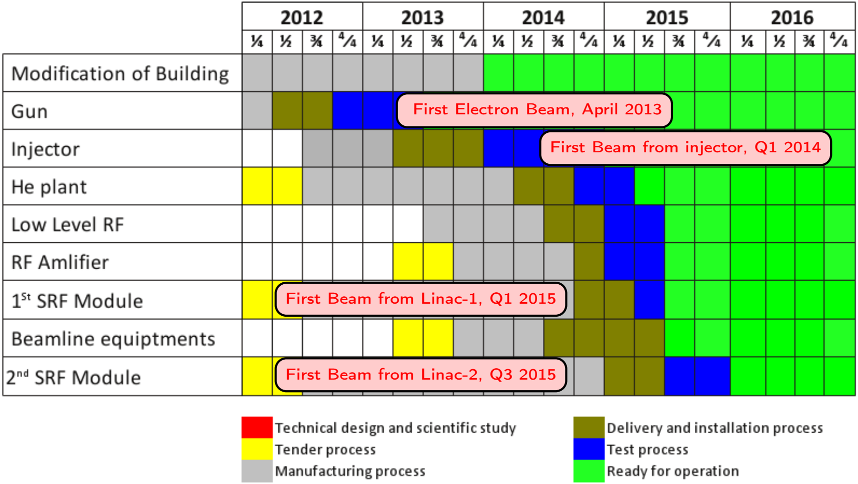
Milestones of TARLA



Milestones of TARLA



Milestones of TARLA



Turkish Accelerator Center (TAC) Project

The TAC project was was first proposed in 2000's as linac-ring type $e^+ - e^-$ collider with 1 GeV center of mass energy as ϕ factory.

After two state of feasibility phases it extended into 5 sub-projects..

Turkish Accelerator Center Project

- **TARLA** — 40 MeV Oscillator FEL
  - Universities: Ankara U., Gazi U., Suleyman D. U.
- **SR** — 3 GeV Synchrotron Rad
  - Universities: Ankara U., Nigde U., Dogus U.
- **PA** — 2 GeV Proton Acc.
  - Universities: Istanbul U., Dumlupınar U., Gebze I.T.
- **SASE** — 5 GeV SASE FEL
  - Universities: Ankara U., Dumlupınar U.
- **PF** — 1-3.5 GeV $e^+ - e^-$ collider
  - Universities: Ankara U., Dogus U., Bogazici Uni

- Red: Installation and commissioning continuing
- Blue: Detailed Design Report phase
- Green: Conceptual Design Report phase
- Yellow: Feasibility Design Report phase

TAC Collaboration

TAC: An Inter University Collaboration

Project Team: 69 member with PhD + 86 graduate students and engineers

Ankara University (Coordinator)

Gazi University

İstanbul University

Uludağ University

Dumlupınar University

Boğaziçi University

Doğuş University

Erciyes University

Süleyman Demirel University

Niğde University

Gebze Institude of Technology

Thank you for your attention!!