Turkish Accelerator and Radiation Laboratory in Ankara (TARLA)

Avni Aksoy

On behalf of TARLA Team

AnkaraUniversity

FCC Physics, Detector and Accelerator Workshop @ Istanbul
March 11-12, 2016

Outline

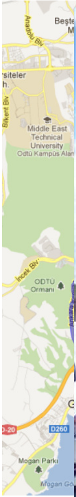
- **Introduction**
- **Main components**
  - Injector
    - Gun
    - Buncher Cavities
  - Main Accelerating section
    - SRF modules
    - RF system
  - FEL Section
    - FEL performance
  - Helium Plant
- **Proposed FEL applications**
- **Conclusion**

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 4 years old is the first institute established as research in the fields of accelerators and related topics
- We have 16 full-time employee in the institute now (10 technical, 6 administrative)

  about 10 part time collaborator from different universities

TARLA facility at Institute of Accelerator Technologies of Ankara University



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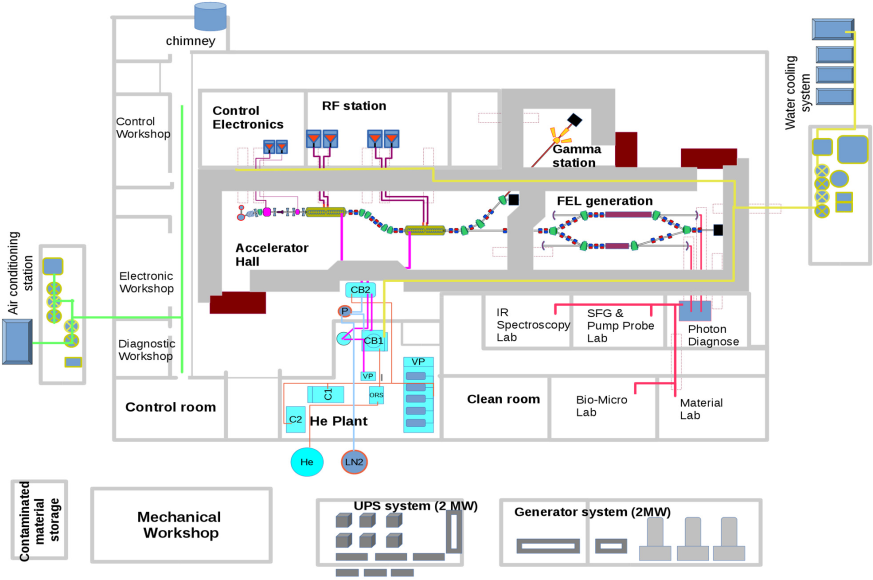
- In order to do all and have wide research area, the electron beam is requested to be continuous wave with high current as well as pulsed with low current.

- We are going to use high average current normal conducting injector which operates CW mode and superconducting accelerators which are fed by solid state power amplifiers.

TARLA layout



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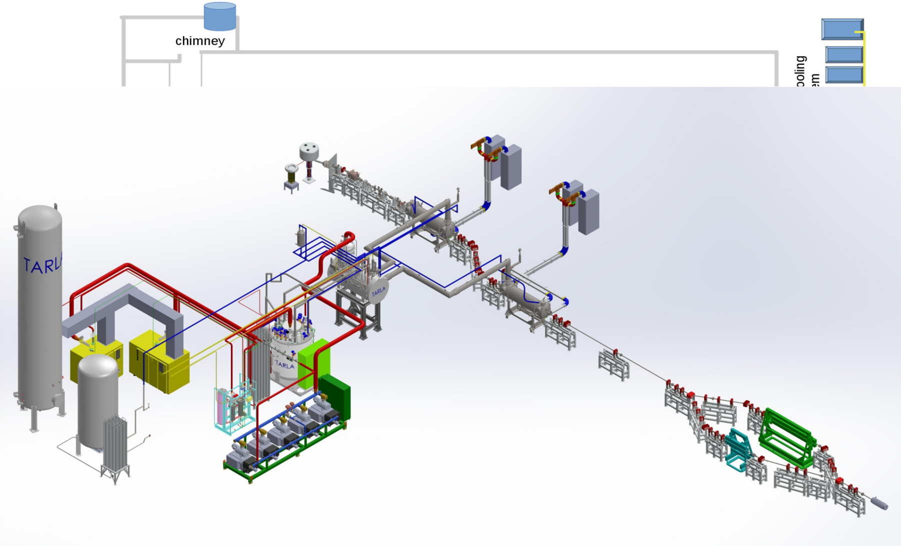

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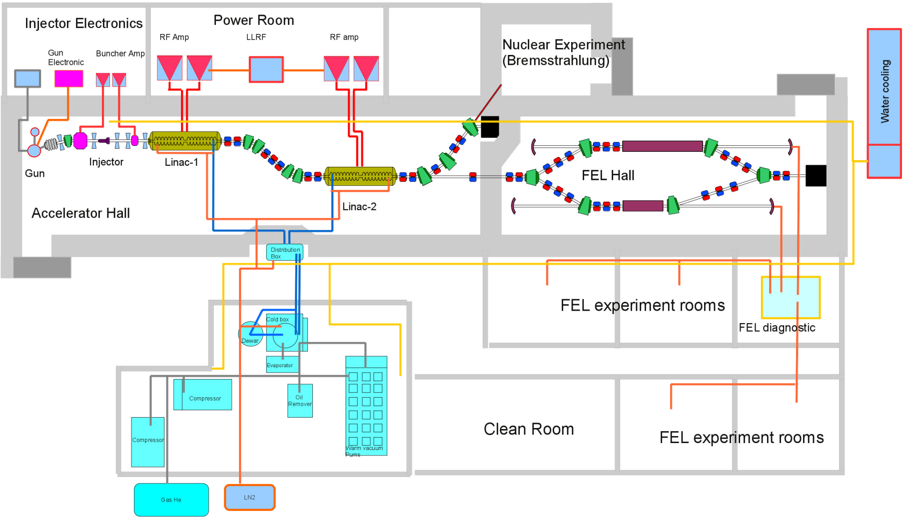

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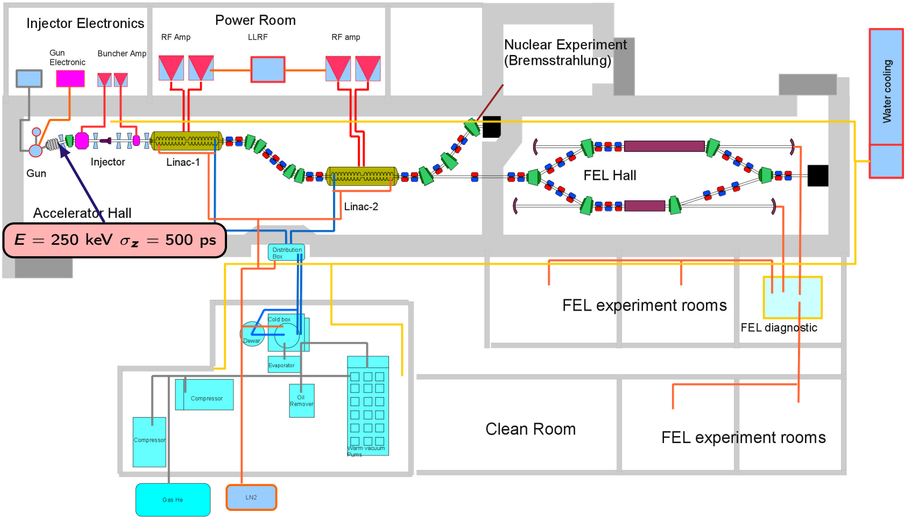

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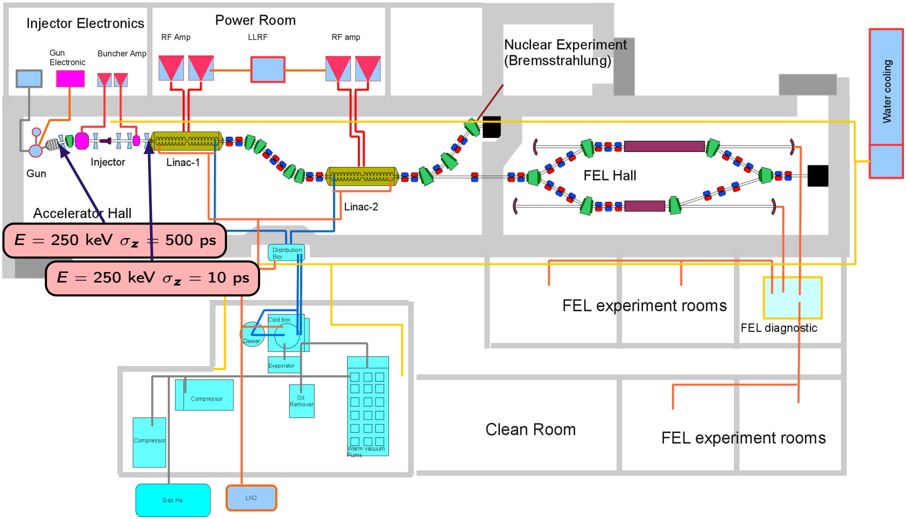

TARLA

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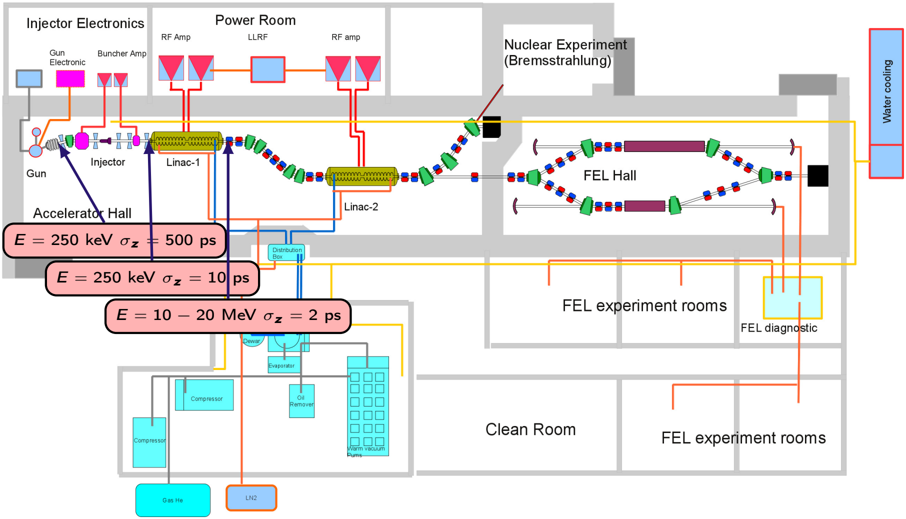

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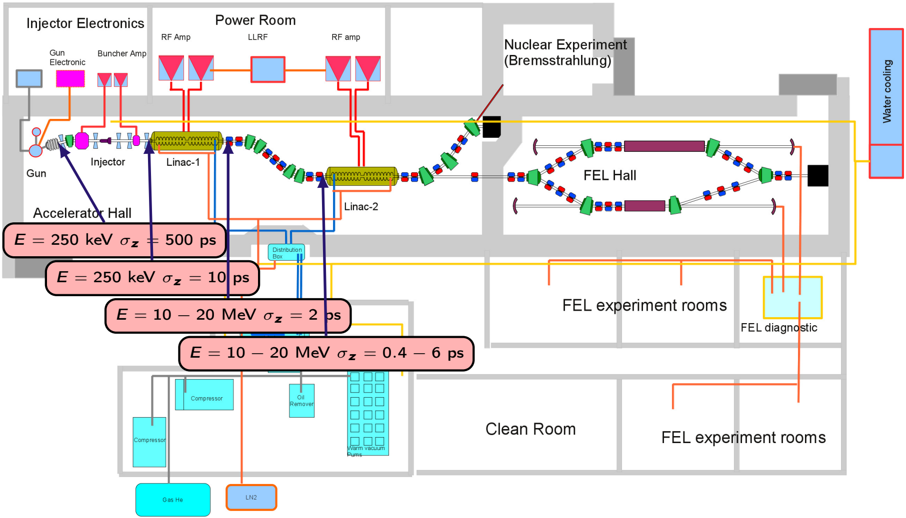

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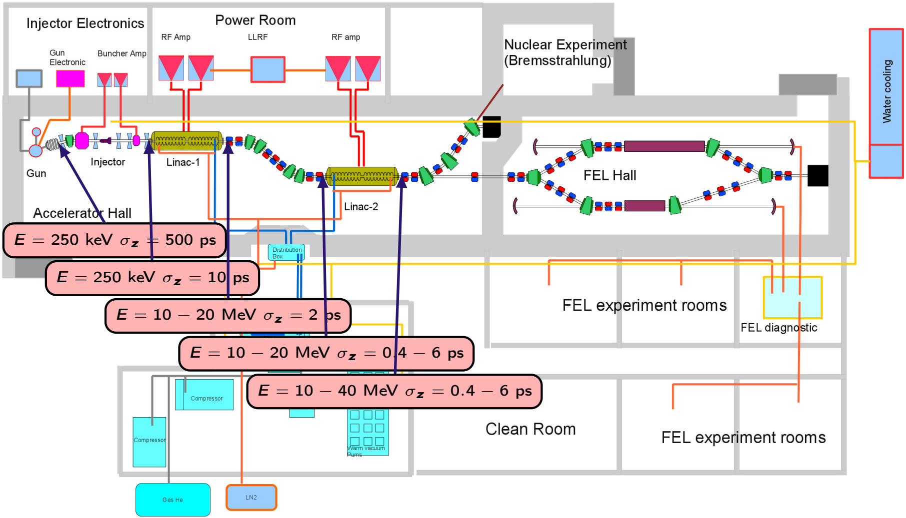

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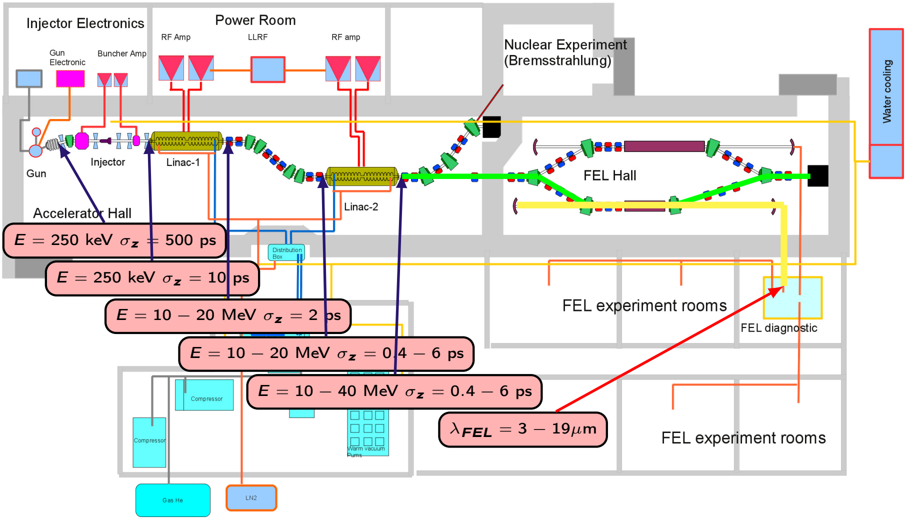

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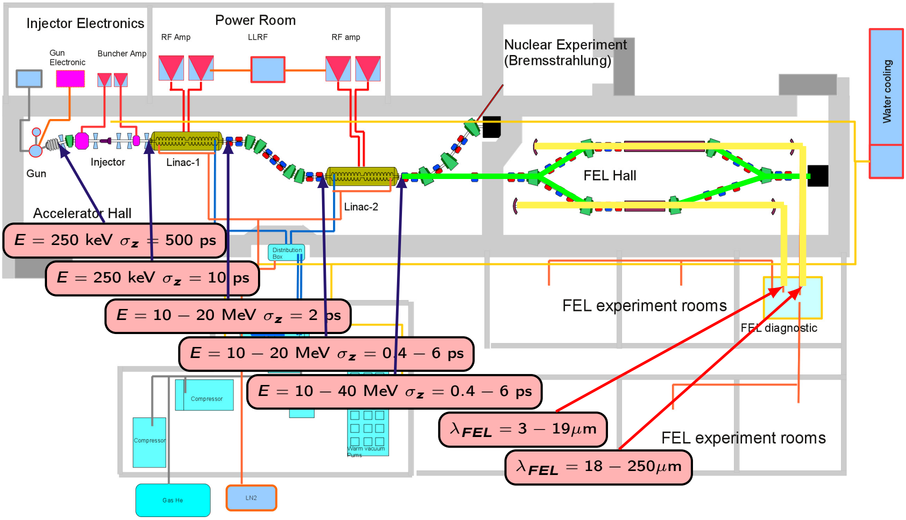

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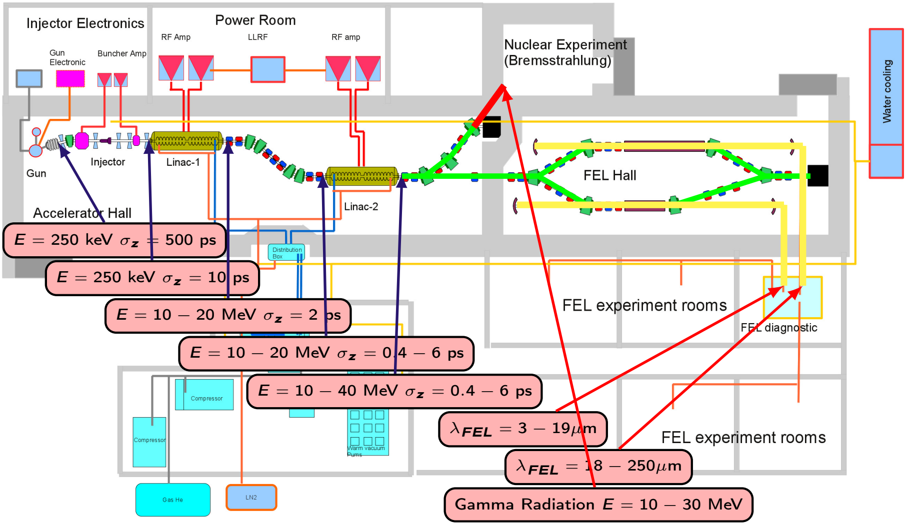
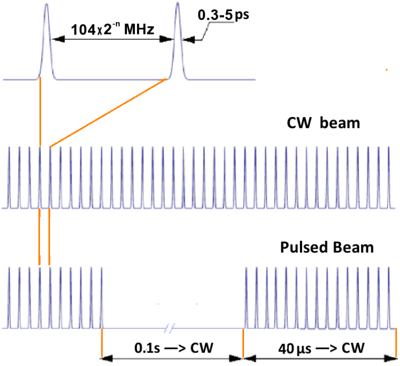


TARLA Beam

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

Research Potential of TARLA

CW electron beam
0 - 40 MeV
0-1 (1.5) mA
40 (60) kW
CW/pulsed

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Material, (bio)physics, (bio)chemistry, medical..

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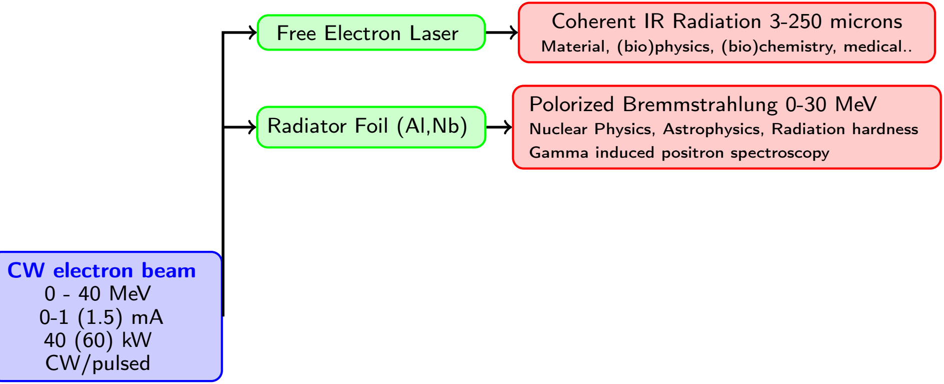

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0 - 40 MeV
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- Free Electron Laser → **Coherent IR Radiation 3-250 microns**
  Material, (bio)physics, (bio)chemistry, medical..
- Radiator Foil (Al,Nb) → **Polorized Bremmstrahlung 0-30 MeV**
  Nuclear Physics, Astrophysics, Radiation hardness
  Gamma induced positron spectroscopy
- Direct Use → **Electron Beam 0 -40 MeV**
  Radyobiolgy, Detector study, Thomson scattering
  Electron difraction, plasma studies

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  Semiconductors, material, ...

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  Radiation physics, Radiobiology..

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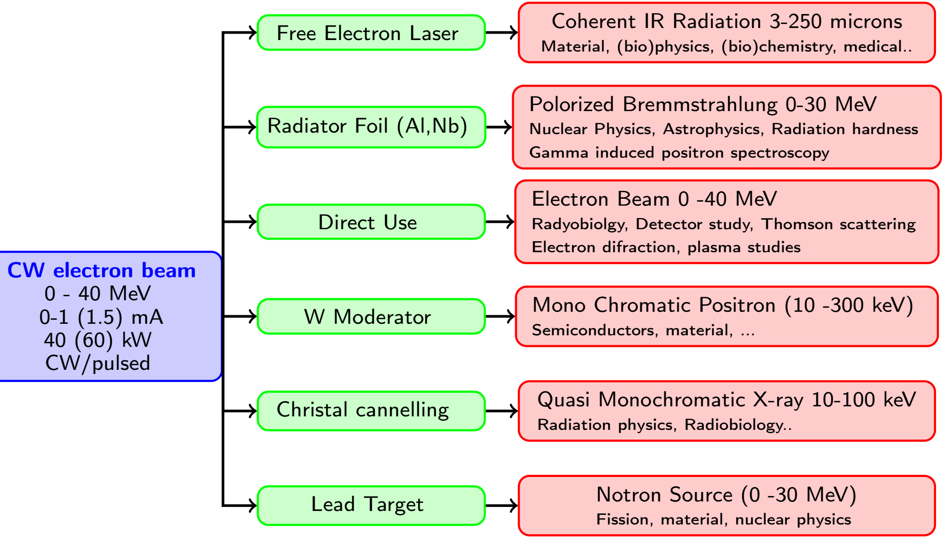

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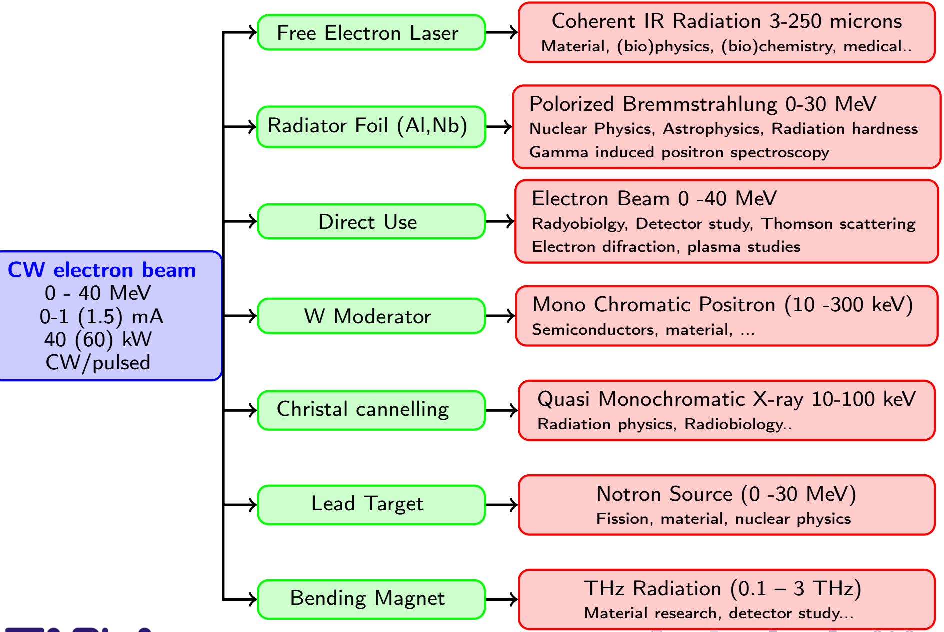

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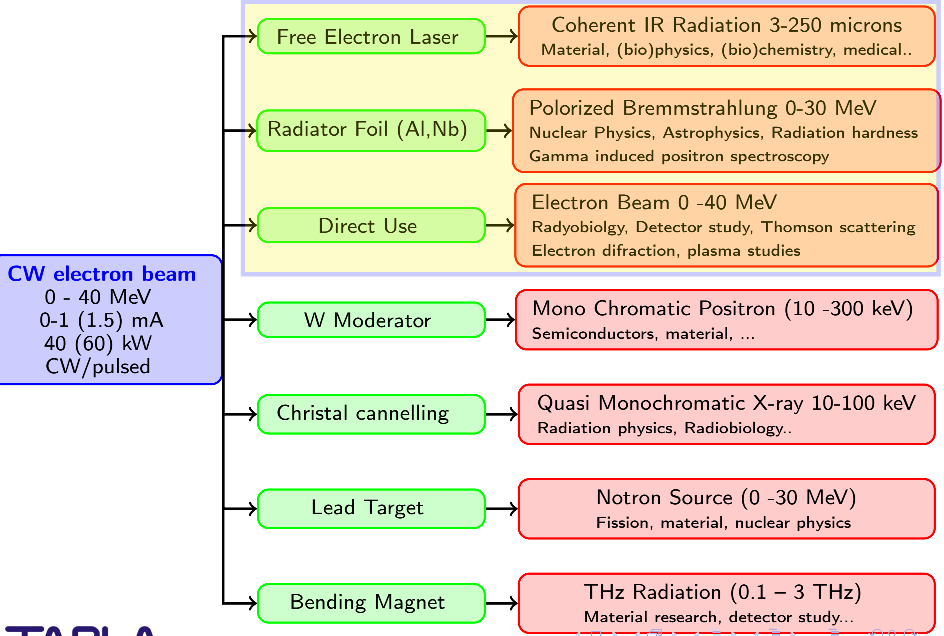
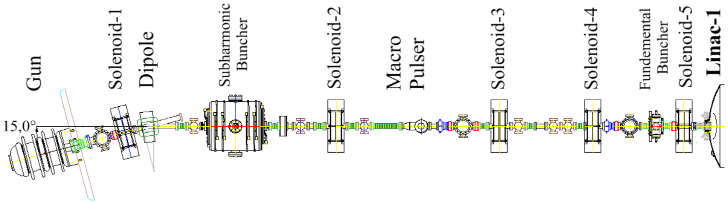


Main Electron Beam Parameters

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
  - 260 MHz and 1.3 GHz buncher cavities
  - 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.

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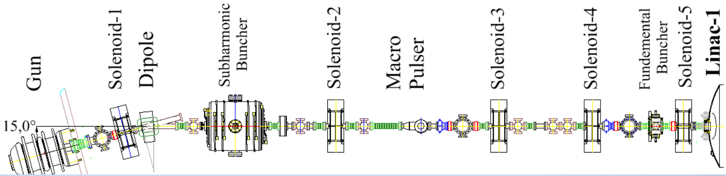

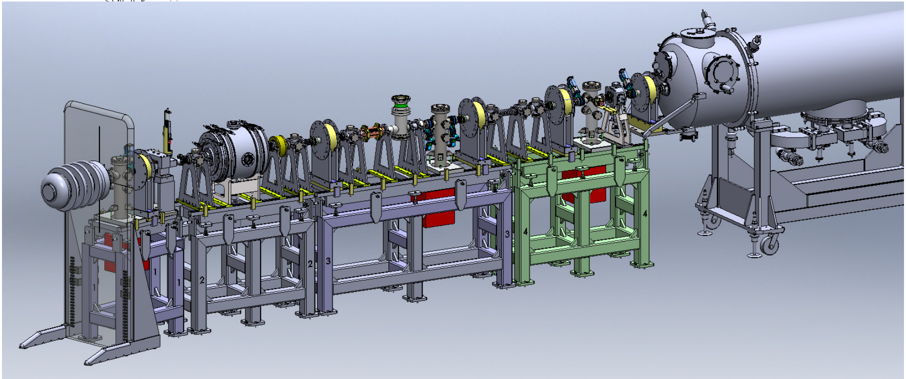

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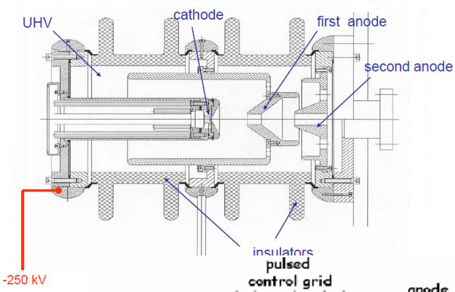
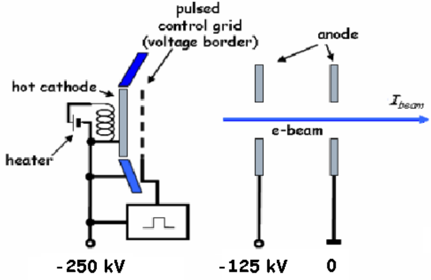
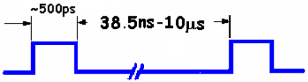
Gun



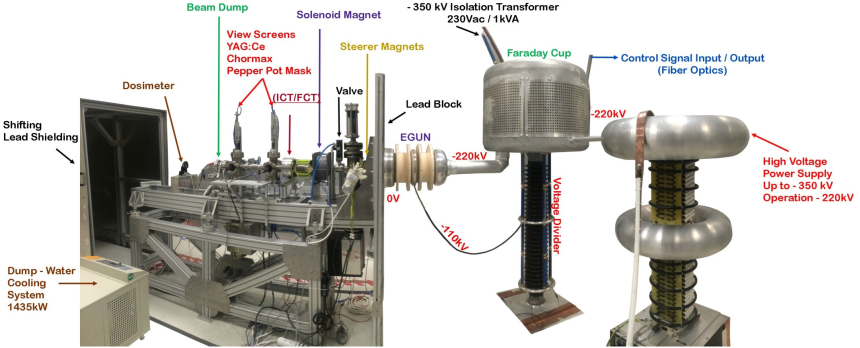
- Pulse length — 500ps → 11cm
- Energy gain — 250 keV DC
- Accelerating field — 2 MV/m
- Max bunch charge — 120 pC
- Transverse emittance — 10 mm mrad
- Max peak current — 0.25 A
- Max average current — 1.5 mA
- Energy spread — 5×10^{-4}





pulse structure of the electron beam

Gun Commissioning Setup



- High Voltage $\mapsto$ 300 kV
- High vacuum $\mapsto$ 3 $\times 10^{-10}$ mbar
- Relativelly high frequency @ high voltage $\mapsto$ $<$ 20 ps jitter , σ=500 ps @13 MHz
- High radiation $\mapsto$ $>$2000 μs/h
- Remote control $\mapsto$ EPICS, LabView, PLC
- ...

Gun Commissioning Setup

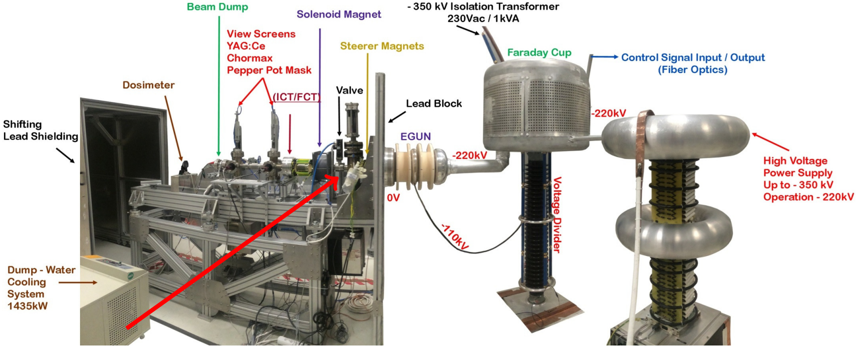
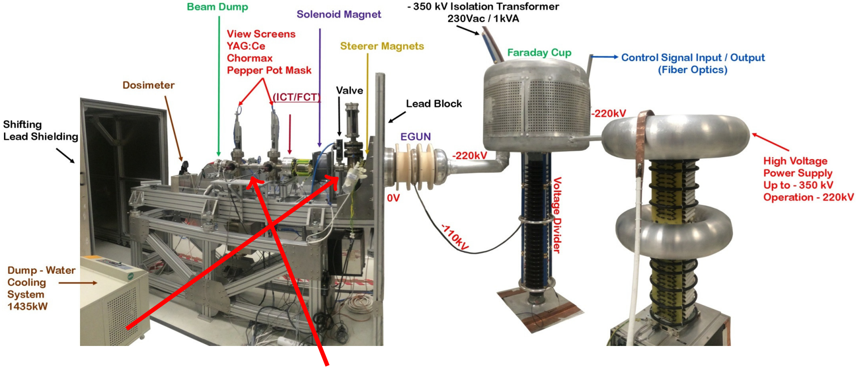


image from screen

Gun Commissioning Setup



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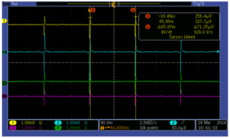
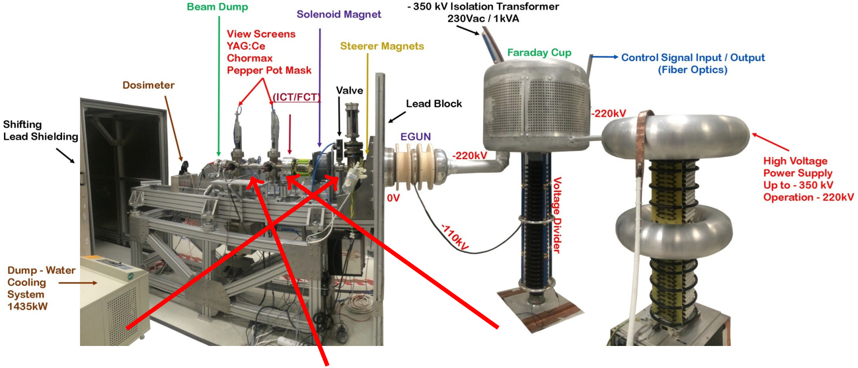


signals from BPM pickup

Gun Commissioning Setup



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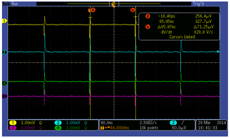

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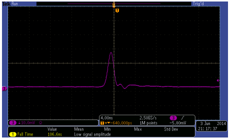
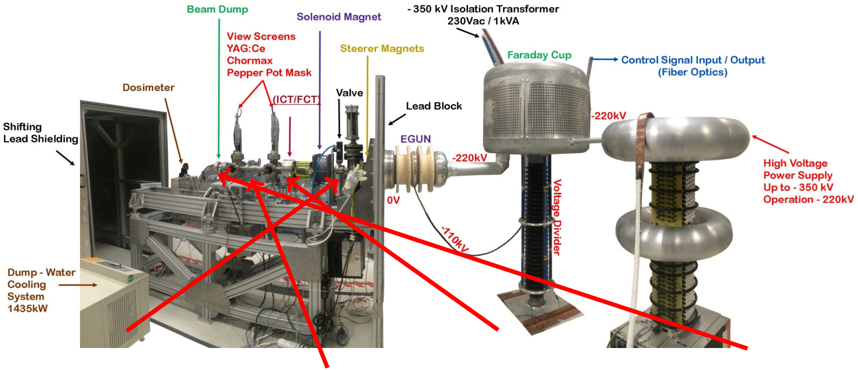


signals from ICT/FCT

Gun Commissioning Setup



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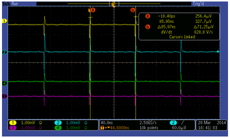

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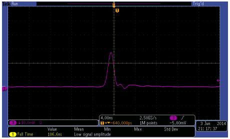

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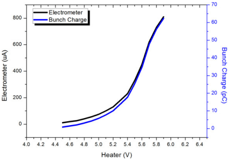
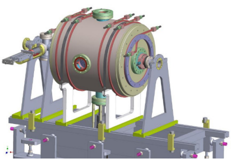
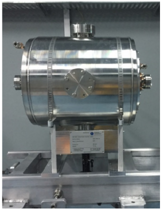


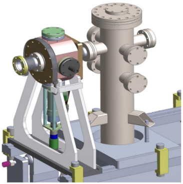
measurement on beam dump

Buncher Cavities

Buncher cavities were delivered in 2015. The acceptance parameters of the cavities are shown in Tables. Factory Acceptance Tests of buncher cavities were performed in December, 2014.







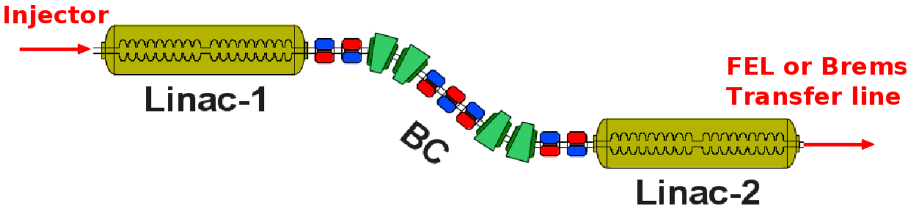
TM_{010} 260 MHz resonator

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

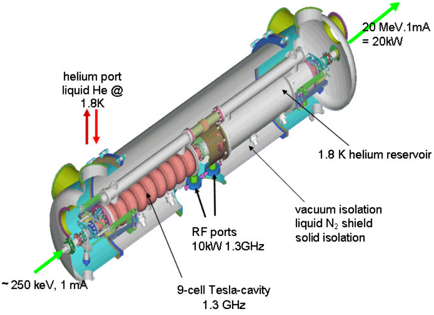
The buncher cavities are ELBE design. We have modified them for higher gradient.



- 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)	≥8	kW

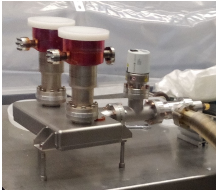
SRF cavity status

TARLA-Cavities (4 cavities) were treated according to the XFEL-recipe (major steps mentioned only)

- Main EP (110 μm removal)
- 800 $^{\circ}$C hydrogen degassing
- Tuning of pi-mode and field flatness to >98%
- Fine EP (40 μm removal)
- Control of pi-mode and field flatness (>98%)
- Welding of ring & bellow
- Control of pi-mode and field flatness (>98%)
- Welding of helium vessel
- Leak check of helium vessel
- Control of pi-mode and field flatness (>98%)
- Final surface preparation; High pressure rinsing & 120 $^{\circ}$C bake

Afterwards the couplers and components for the horizontal tests at HoBiCaT will be assembled to the cavities.

Status of TARLA couplers



TThe RF input couplers were manufactured at RI according to the ELBE-design.

- The couplers were equipped with the proper antenna tip and two couplers were assembled to a test waveguide.
- The warm windows were also preassembled and sent to HZDR for high power testing.

- Each pair of RF input couplers (cold part, coaxial transition, door knob) and RF windows were integrated to the resonant ring test facility at HZDR.
- The power was raised in pulsed mode to a peak power of about 50 kW and in CW mode to about 16 kW.
- To improve the cooling, the outer walls and the cooling channel (fro LN2) were cooled with forced air.

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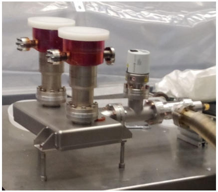

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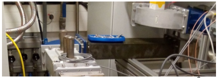
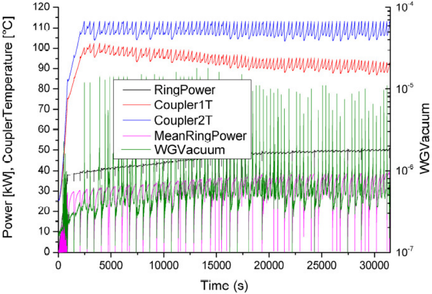
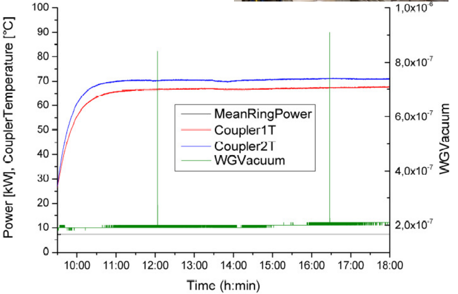




Pulsed mode test @ 50 kW, duty cycle 80%



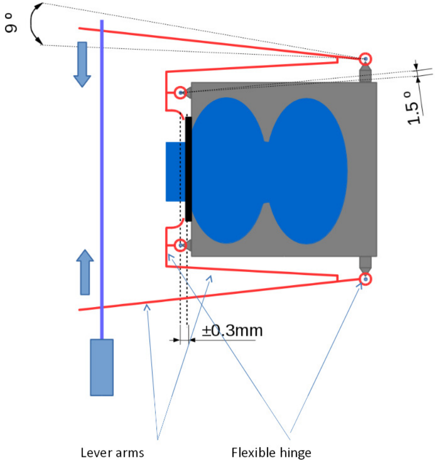
Test @ CW mode, 8 kW

Status of TARLA tuners

- Based on ELBE design mechanical tuning system
- Driven by a stepper motor followed by a gear box (Phytron ZSS25.200.0,6-HD05/80)
- Tuning range → $\pm$ 120 kHz
- Resolution → 10 Hz
- Tuning speed → 5 Hz/ms

Although we will mostly operate @ CW mode we need fast tuning and better resolution to avoid the detuning effect coming from cryo-pumps.

- Tuning speed needed → 1 kHz
- Resolution needed → 1 Hz



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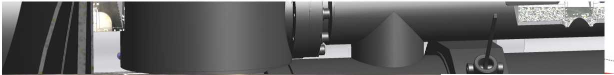
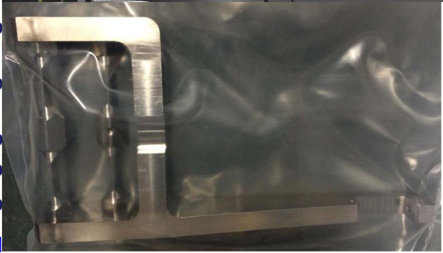


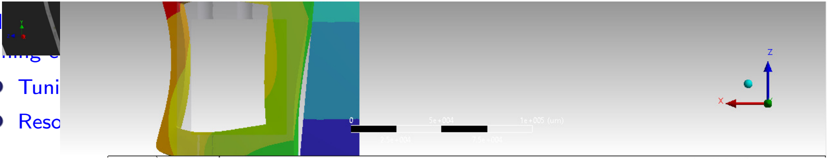


Al

need

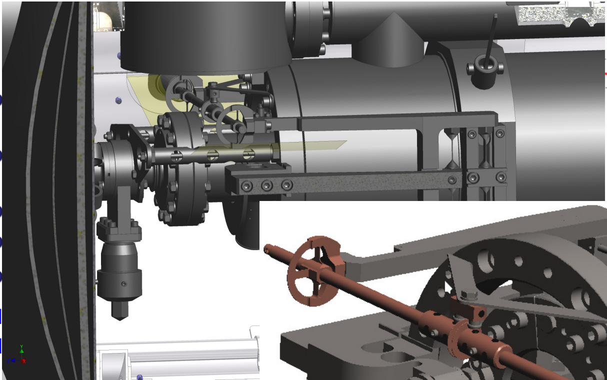
detu

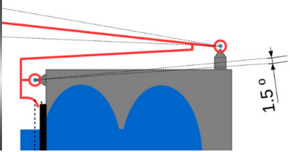
- Tuni
- Reso

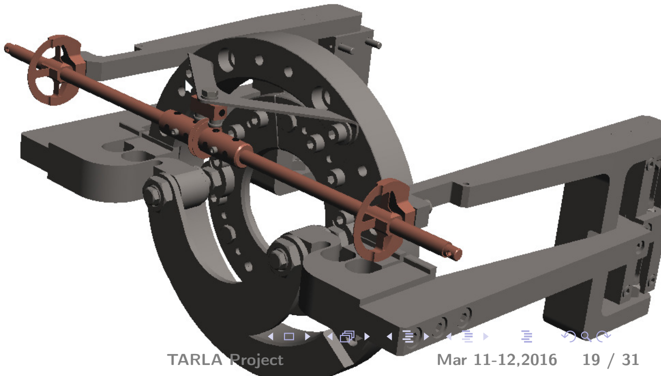


Lever arms Flexible hinge

Status of TARLA tuners







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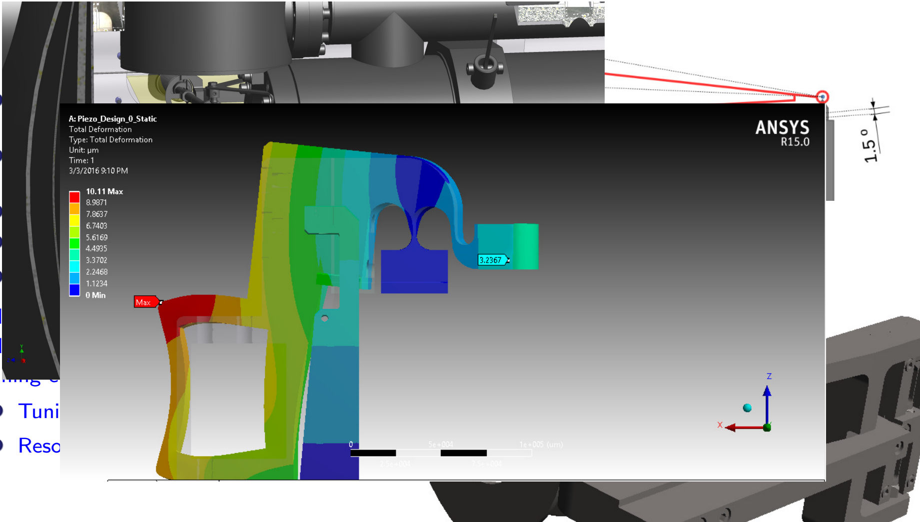
need

detu

- Tuning speed needed →
- Resolution needed → 1 H

Status of TARLA tuners



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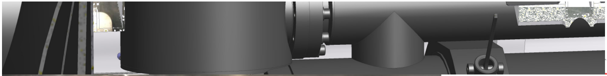

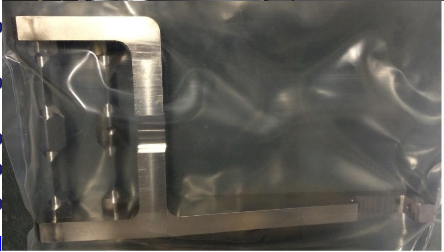

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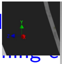
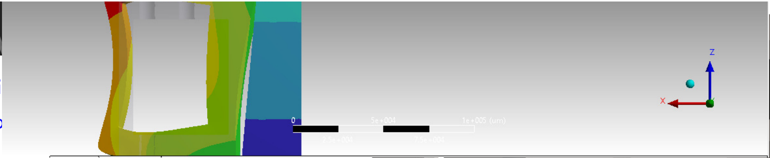
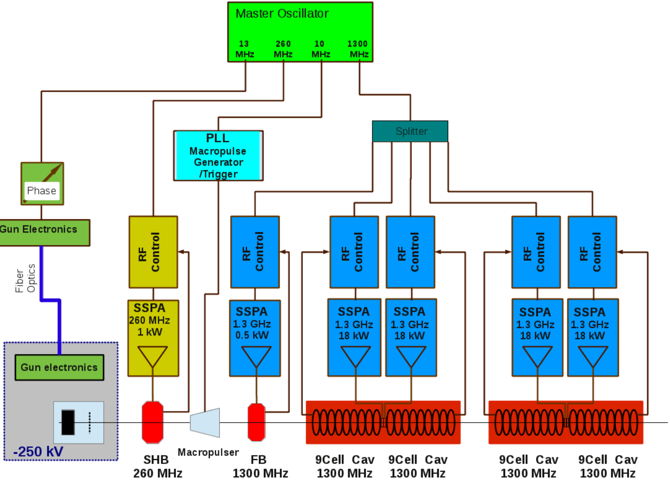




- Tuni
- Reso

TARLA RF – System, Block Diagram



- Each structure will be fed by individual power amplifiers
- Each amplifier will have its own driver / LLRF controller

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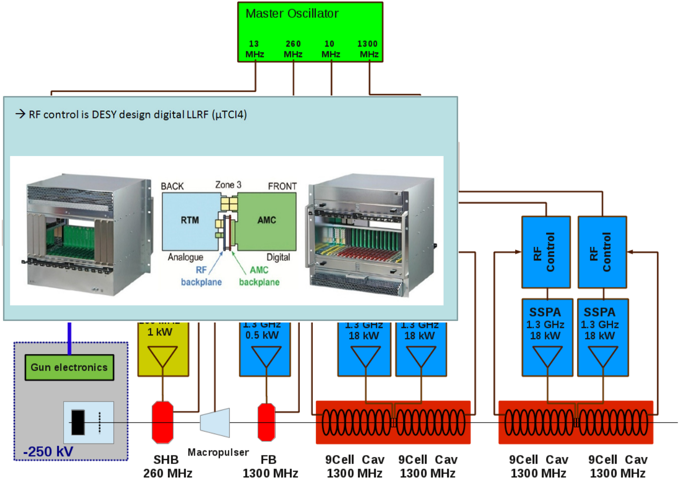

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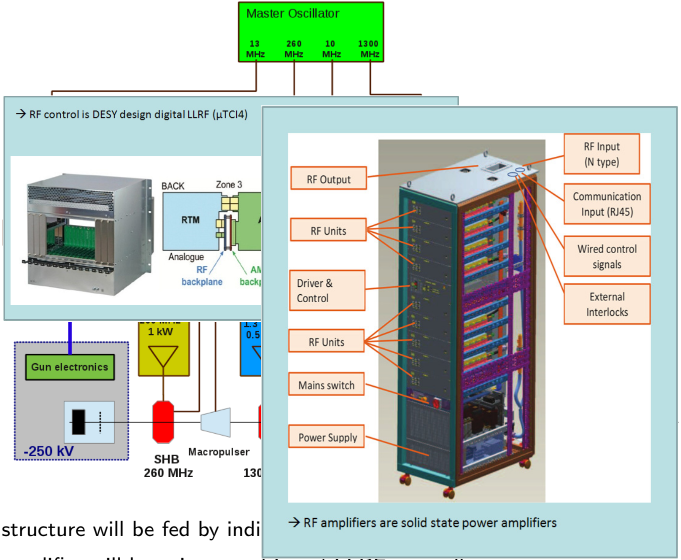

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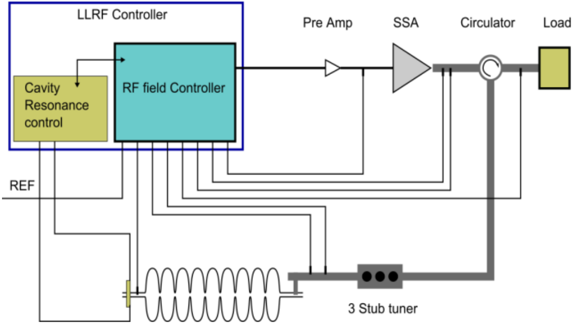
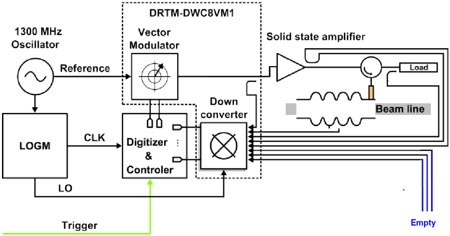
TARLA LLRF System, DESY Design digital LLRF system (μTCI4)



Channel	Description
1.	Cavity pickup
2.	Cavity forward
3.	Cavity reflected
4.	Power to load
5.	Klystron forward
6.	Klystron reflected
7.	Klystron drive
8.	Reference tracking

- We are going to sign with DESY contract beginning of next year for the deliverables of;
  - Field controller
  - heater controller
  - stepper motor driver
  - piezo controller
- We will start purchasing in next months.



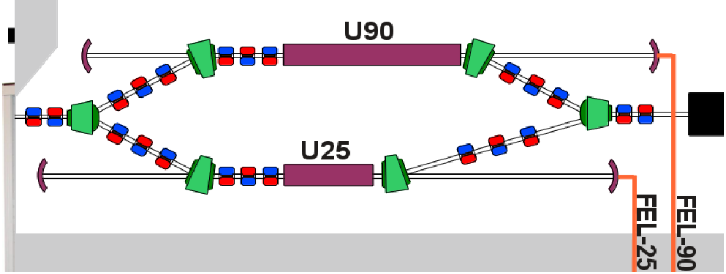
RF Amplifiers

- Each SC cavity will be fed by solid states transmitters with a power of 18 kW.
- We plan to sign a contract in two months..

Amplifier Parameters

Output Power (1 dB compression) pulse or CW	16	kW
Saturated Output Power pulse or CW	18	kW
Linear gain	<72	dB
Center frequency	1300	MHz
Bandwidth (-3 dB)	$\pm$ 5	MHz
Output Signal Form	CW/Pulse	
Power out load	$0 \ldots \infty$	
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

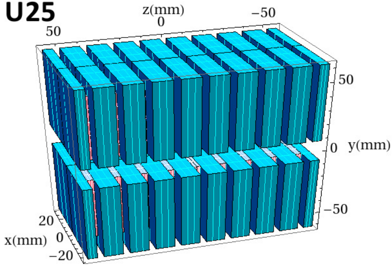
Free Electron Laser Hall



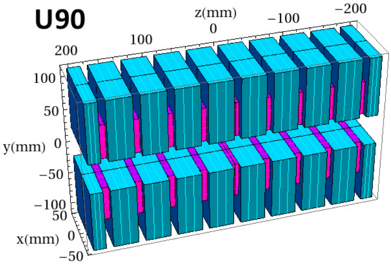
- We propose to use 2 different optical resonator in order to scan all wavelengths between 3-250 μm. (hopefully!!)
- The beam is injected to undulators with achromatic beamlines with 30° bending magnets and quadrupole triplets in between.
- U90 ⇒ undulator with 90 mm period length and U25 ⇒ undulator 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.

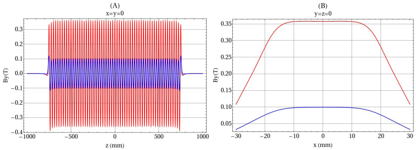
Undulators

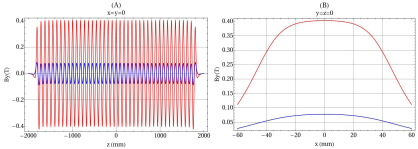
U25



U90

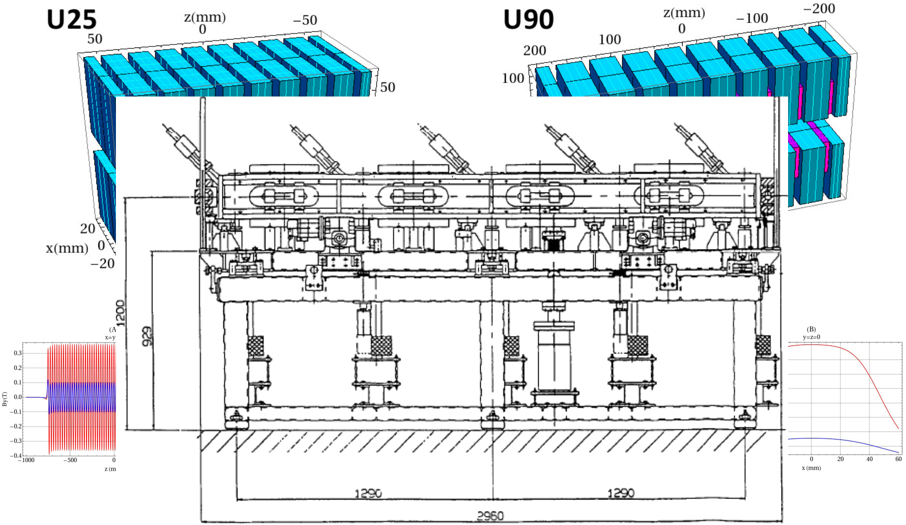






- NbFe pole material, steal blocks
- Roll off filed for max field is 0.04

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



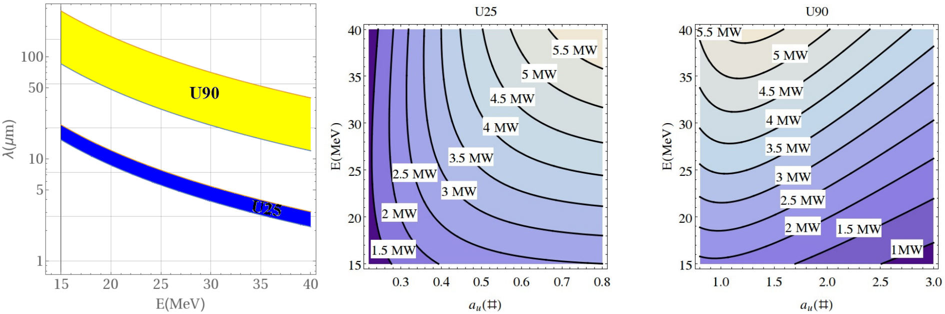
- NbFe p

Fig. 3. Assembly plan of the visible and UV undulator.

locks

- Roll off filed for max field is 0.04
- Roll off filed for max field is 0.1

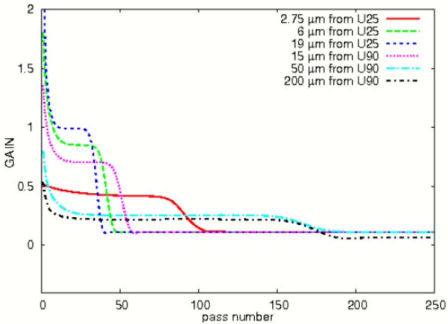
Expected FEL Parameters

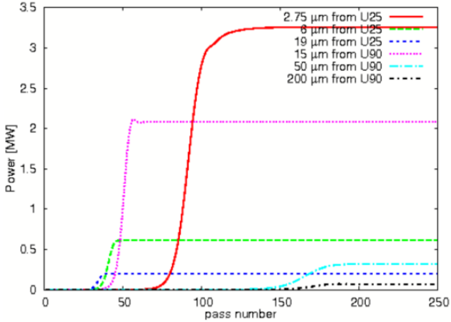


Possible wavelength range and maximum FEL power for beam energy vs. undulator strengths. (optimum case; constant bunch length, optimum out coupling factor etc.)

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





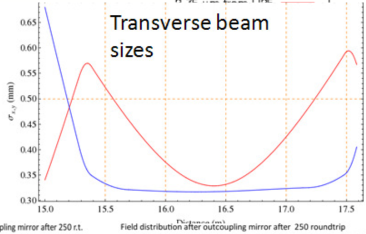
- Gain (left) and intracavity power (right) behavior versus round trips between mirrors..
- It is seen that gain for longer wavelengths (therefore saturated power) is too small..

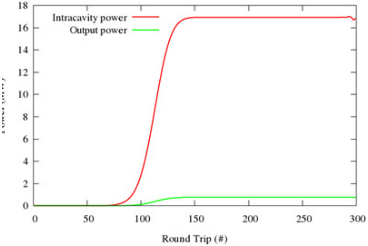
Expected FEL Parameters

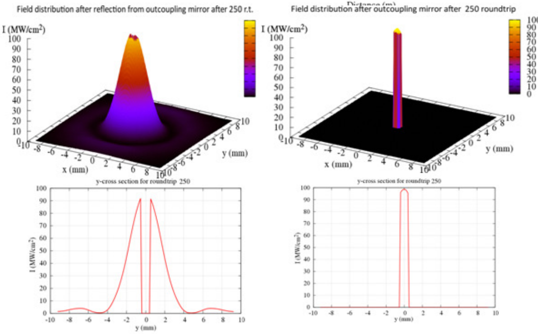
- Time depended simuiation for FEL with 3 μm wavelength

➢E=38:2 MeV
➢K_u = 0.35
➢Z_r=0.75
➢σ_b= 0.5 ps

➢No detunning
➢R_1=R_2=5.86
➢Mirror Reflection ratio=%98





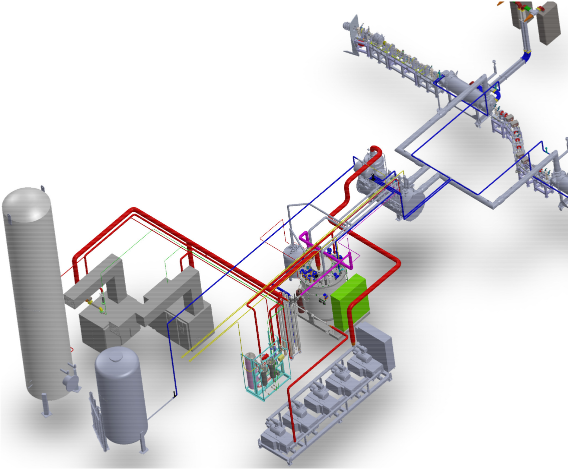


Some resonator and expected FEL parameters of TARLA

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	5.5	5
Max. Average Power*	W	0.1 - 100	0.1-90
Max. Pulse Energy *	μJ	10	8
Pulse Length*	ps	1 - 10	1 - 10

* ; depending on wavelength

Helium Plant



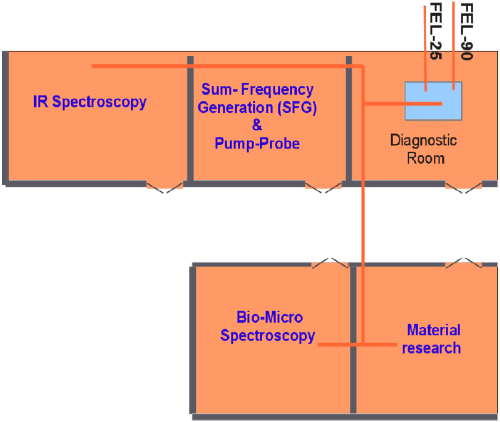
- Cryogenics system has been manufactured by Air Liquide.
- The system will consist of
  - Helium refrigerator (4 K box)
  - Distribution Box (2 K box, housing cold compressors)
  - Two compressors
  - Warm vacuum pump station
  - Oil remover, transfer lines, vaporizer etc..
- Capacity
  - 210 W @1.8K
  - 16 mbar $\pm$ 0.2mbar

Helium Plant

Installation has been completed commissioning is continuing

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
  - $\sigma_{FEL} = 1 - 10$ CW & pulsed
- Each room will be occuppied with table-tab laser sources with 700 – 1000 nm wavelength
  - Ti-sapphire laser
  - Nd:Yag laser
- FEL and external lasers will be sencronised
  - $\Delta\sigma < 100$ fs
- The rooms will have class 1000 standart



Summary and conclusion

- TARLA is the first step of TAC project and will be the first accelerator based research 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...
- It will be an infrastructure for preparetion the future relevant projects of Turkey
- Commissioning of gun has almost been completed...
- Currently we are completing the infrastructure...
  - Infrastructure for power distribution and power synchronization
  - Commissioning of helium plant
  - Installation of chimney, shielded dors, radiation safety
- The helium plant will be ready soon
- The injector will to be ready by the end of 2016. Commissioning will take about 6 months (including all tests)
- First cyromodule will be delivered by June of 2016. We expect to get first beam from SRF1 by 1st quarter of 2017, and beam from SRF2 is expected by the beginning of 2018.
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