Iranian Light Source Facility

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Designing a photocathode RF electron gun for ILSF

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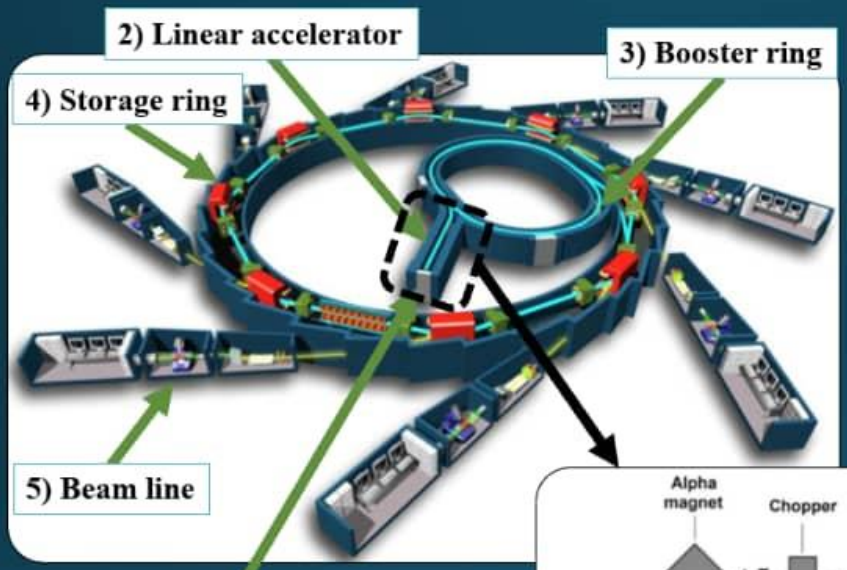
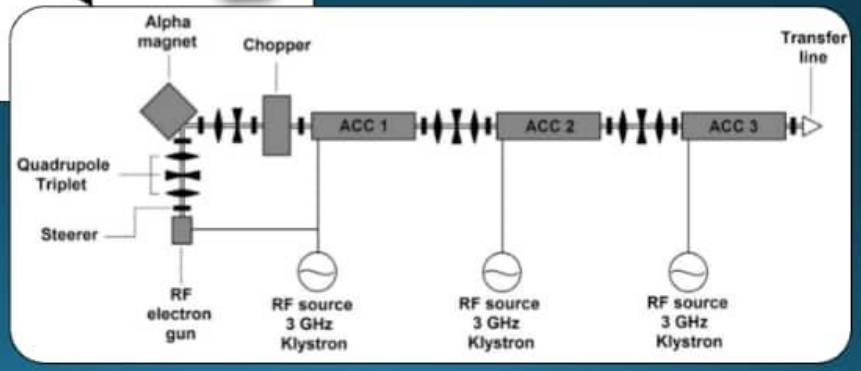
I have a PhD in Gravitation and Cosmology!
I changed to accelerator physics from 2022 (RF part), under the supervision of Dr. Mohsen Dayani.

Outlines:

- ✓ Layout of a synchrotron.
- ✓ History and Characteristic of the ILSF..
- ✓ Designing a photocathode RF electron gun.

Layout of a lightsource





1-Linac: Electron source (cathode) and RF sections (acceleration up to 100 Mev)

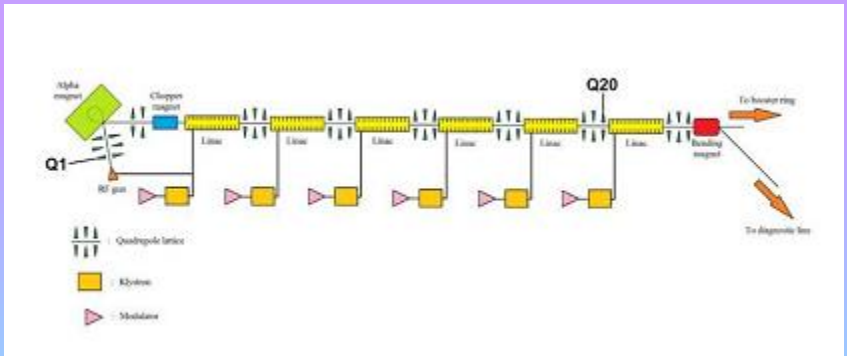
2- Booster: RF cavities to accelerate the beam to its final energy (Gev).

3- Storage ring: Accumulation of electrons + production of SR in bending magnets and undulators.

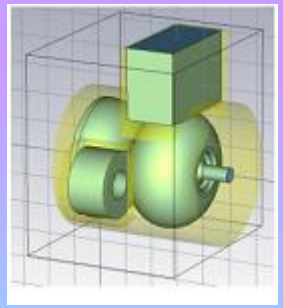
4-Experimental stations: Use of SR

Iranian Light Source Facility

- A new **3 GeV** 4th generation synchrotron radiation (ILSF) will be built in Iran in the next ten years.
- The storage ring has five-Bend achromat lattice design and delivers a horizontal electron beam emittance of **0.27 nm-rad**.
- A **3 GeV booster** synchrotron is fed by a **150 MeV** pre-injection system.
- The ILSF pre-injection provides less than **10 mm-mrad** beam emittance.
- It consists of a π/2 mode RF electron gun with a **thermionic** cathode, an alpha magnet for longitudinal compression, 6 accelerating linac tubes, quadrupoles and steering magnets for transverse beam control.



General layout of the ILSF pre-injection system
https://doi.org/10.1016/j.nima.2015.10.062



The cross-section of the ILSF RF electron gun
Ref: https://doi.org/10.1016/j.nima.2015.10.062

Main parameters of ILSF pre-injector, booster storage ring.

Table 1. Main parameters of the ILSF storage ring.

Parameter	Unit	Value
Beam energy	GeV	3
Beam current	mA	400
Emittance	nm-rad	0.28
Circumference	m	528
RF frequency	MHz	100
Maximum RF voltage	MV	1.5
Number of dipole magnets	-	100
Number of quadrupole magnets	-	240
Number of sextuple magnets	-	320
Bunch length (with higher harmonic cavities)	mm	31.5

. The main beam specifications at the end of the ILSF pre-injector, calculated by ELEGANT

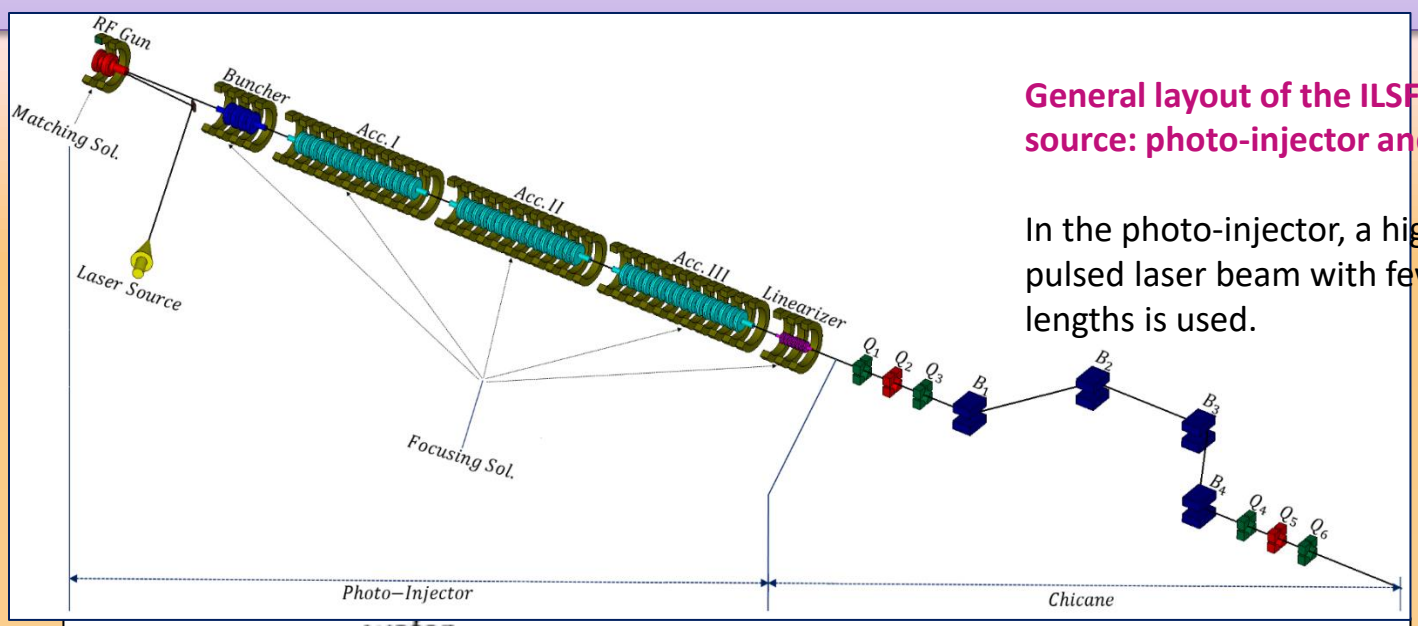
Parameter	Unit	Value
Bunch charge	pC	100
Average beam energy	MeV	154.8
RMS bunch energy spread	–	6×10^{-4}
RMS beam envelope in x direction	mm	0.54
RMS beam envelope in y direction	mm	0.57
Normalized emittance in x direction	mm mrad	6.54
Normalized emittance in y direction	mm mrad	6.51
Absolute bunch length	ps	1.55
Beta function in x direction	m	14.6
Beta function in y direction	m	16

Table 2: Main Parameters of the ILSF Booster

Parameter	Unit	Value
Energy at injection	GeV	0.150
Energy at extraction	GeV	3
Circumference	m	504
Hor. Emittance	nm.rad	3.503
Rep. rate	Hz	
RF frequency	MHz	500

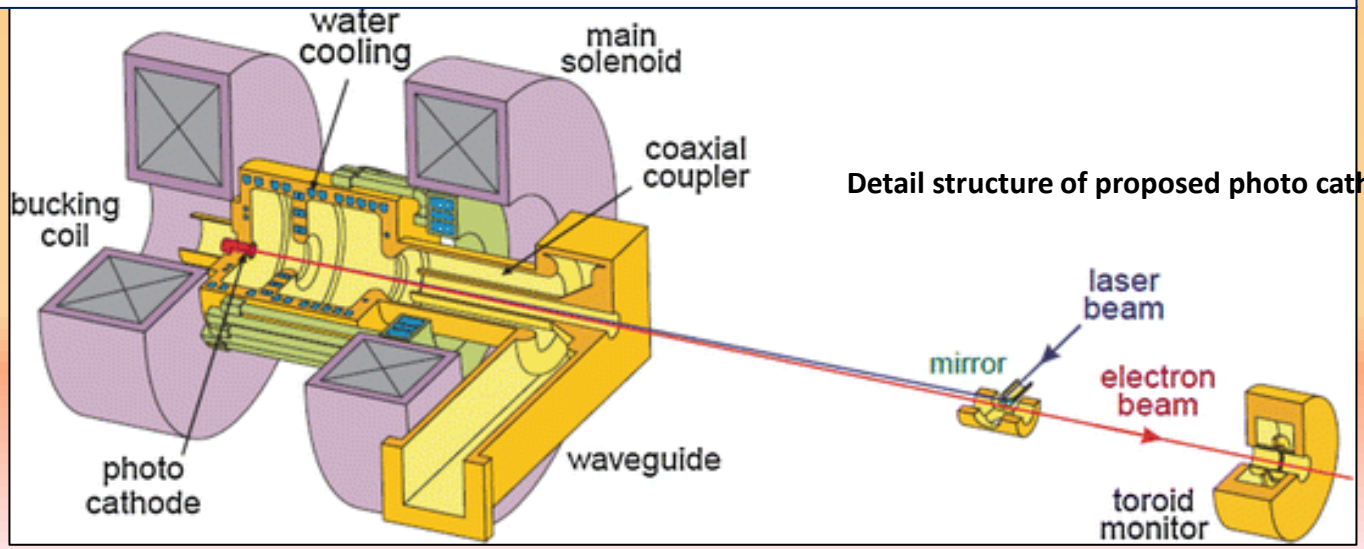
Ref: https://accelconf.web.cern.ch/ipac2014/papers/mopro072.pdf

Detail structure of electron source layout for ILSF project



General layout of the ILSF new electron source: photo-injector and chicane.

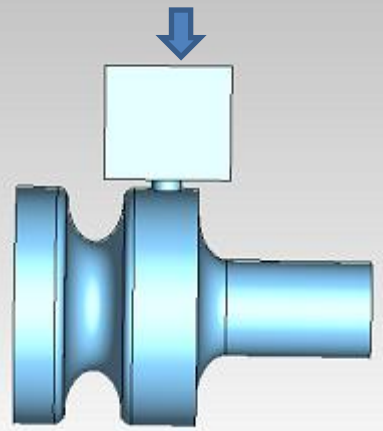
In the photo-injector, a high quality pulsed laser beam with few ps pulse lengths is used.



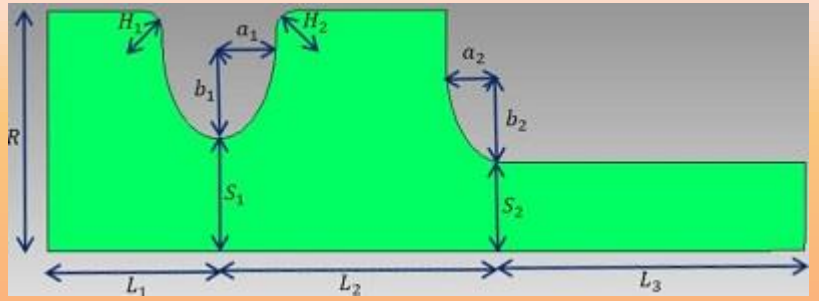
Detail structure of proposed photo cathode RF gun for ILSF project

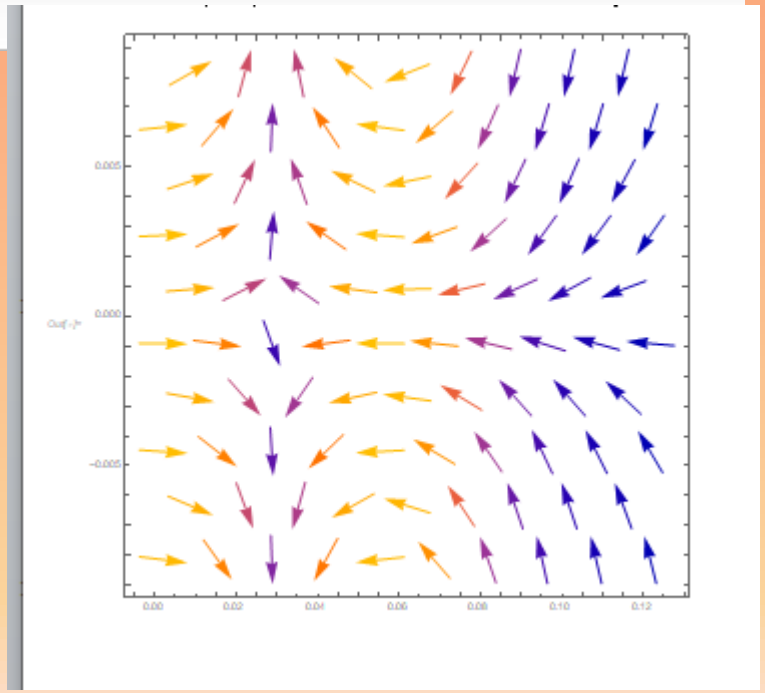
First design

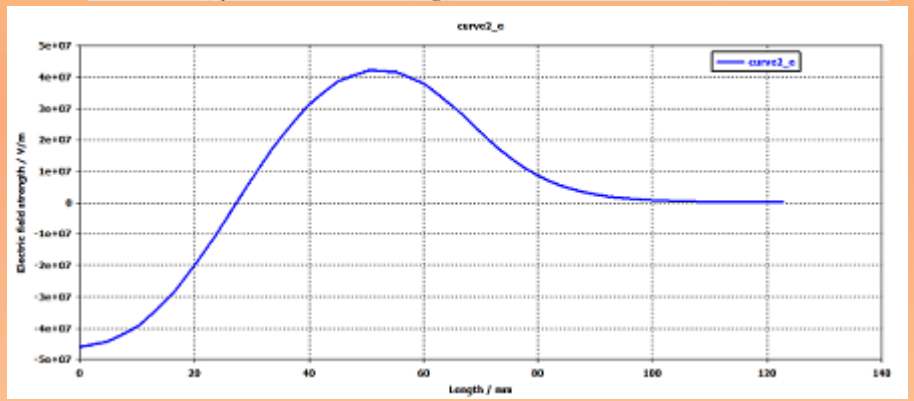
S-band waveguide



R= 42.10 mm
S2= 17 mm
L1= 0.6 L2
L2= L3=50 mm
a1 = a2 = 10 mm
b2 = 17.50 mm
Frequency = 3 GHz
Phase = π
β = 1







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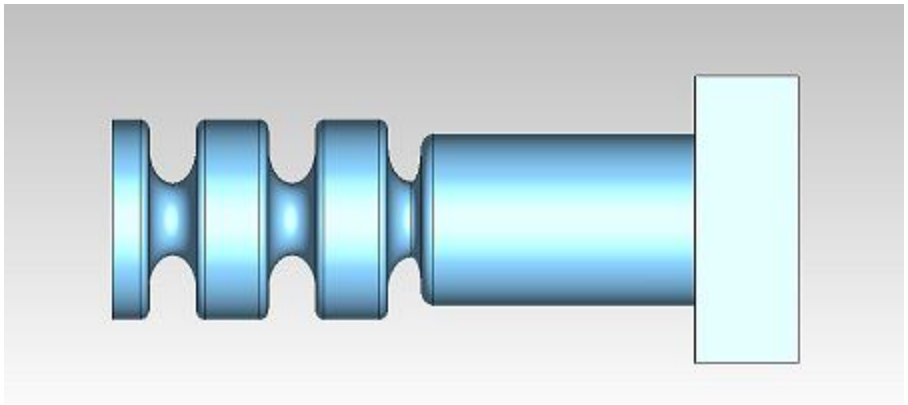
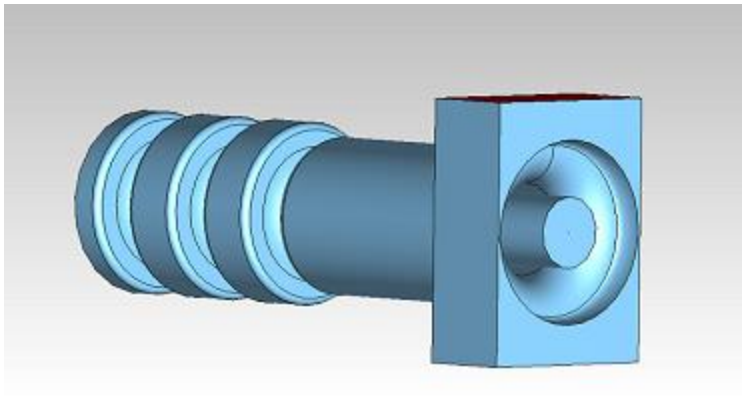
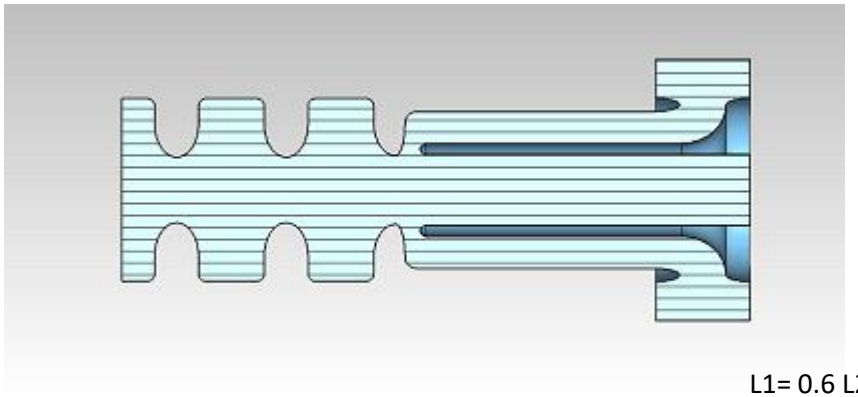
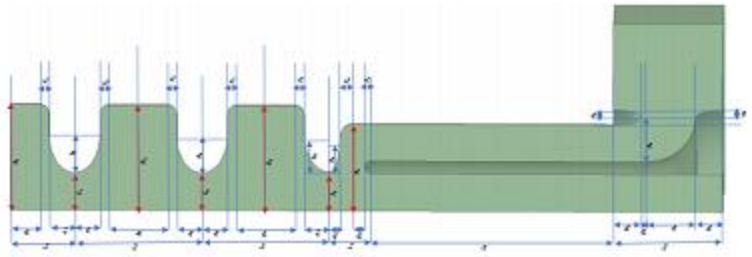
Second design



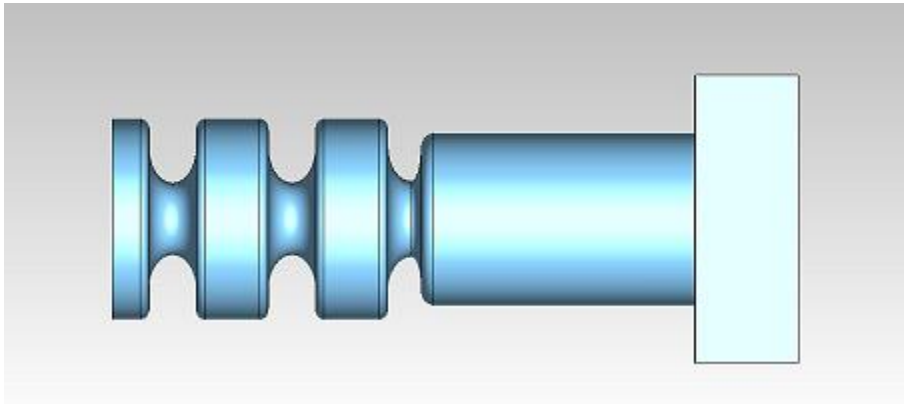


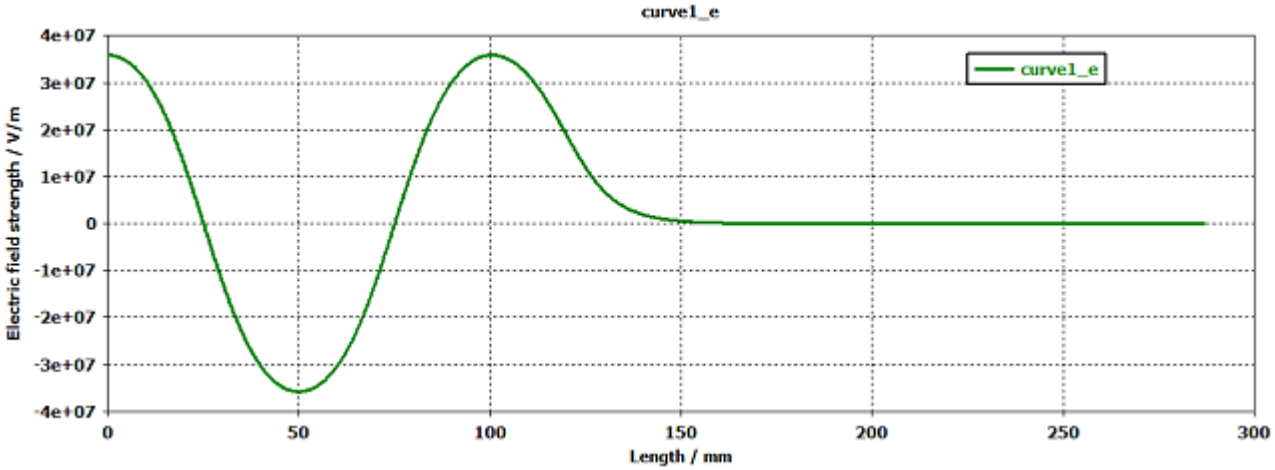




L1= 0.6 L2
L2= L3=50 mm
Frequency = 3 GHz
Phase = π
β = 1

The z component of the electric field





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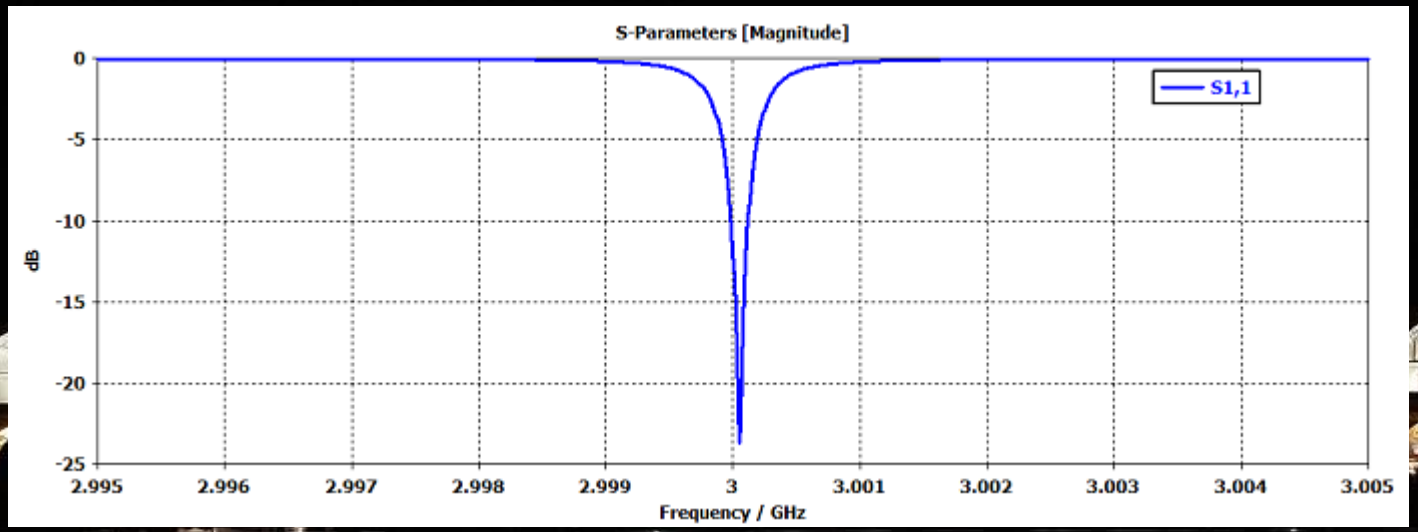
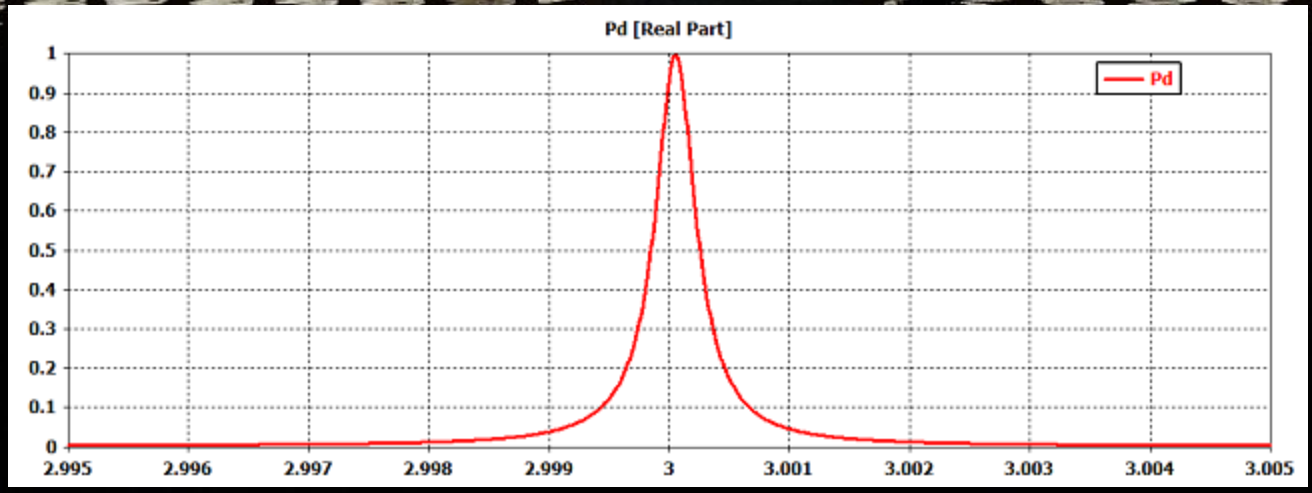


S11 parameter



Delivered power

The next for the future…

Beam dynamics:

ASTRA: A Space Charge Tracking Algorithm" is a tracking code developed at DESY (Hamburg, Germany), can simulate injectors and track in field maps. Simulated photocathodes. Uses its own description language. [injectors, tracking, space charge]

GPT: General Particle Tracer code

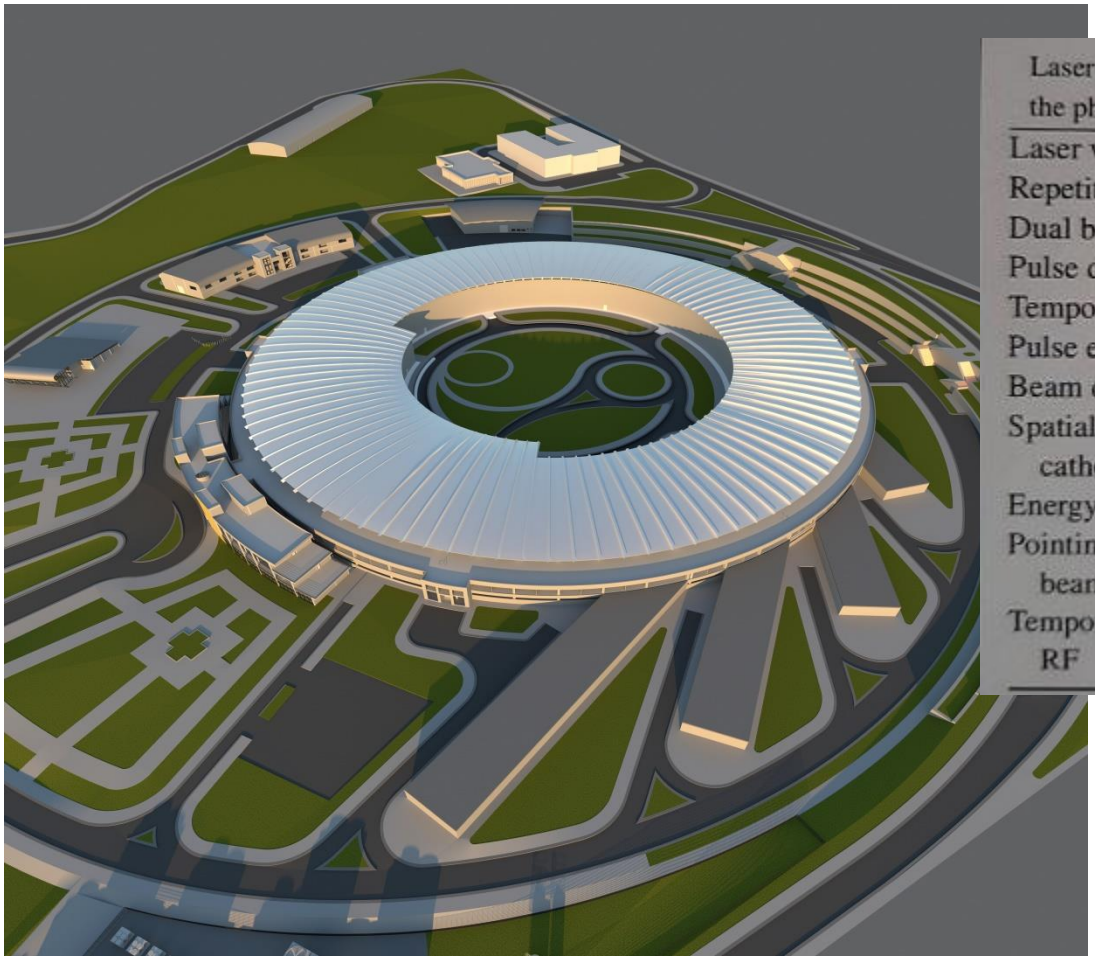
Python

$$\frac{d\vec{p}}{dt} = \frac{q}{m\,c}\left(\vec{E} + \frac{\vec{p}c}{\sqrt{1+\vec{p}}} \times \vec{B}\right)$$

$$\frac{d\vec{r}}{dt} = \frac{\vec{p}c}{\sqrt{1+p^2}}$$


Thank you
Shiraz-Iran
Nasirolmolk Mosque

Render of ILSF



Laser parameter at the photocathode	Typical value
Laser wavelength	260 nm
Repetition rate	100 Hz
Dual bunch separation	28 ns
Pulse duration	3.3–10 ps FWHM
Temporal intensity profile	Gaussian/flat-top
Pulse energy	5–130 nJ
Beam diameter	0.2–0.7 mm
Spatial intensity profile on the cathode	Flat-top
Energy stability on the cathode	<0.8% r.m.s.
Pointing stability relative to the beam diameter	<1% r.m.s.
Temporal jitter with respect to RF	<37 fs r.m.s.