Progress of VHF gun and electron source development at SINAP

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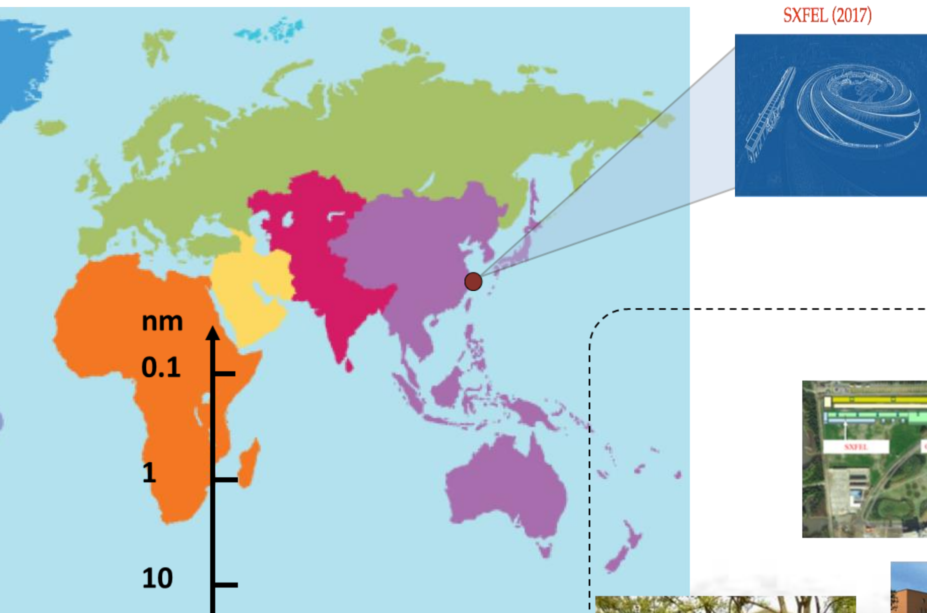
Outline

- Overview & Motivation
- VHF gun R&D at SINAP
- Photocathode R&D at SINAP
- Progress of HXFEL-CW



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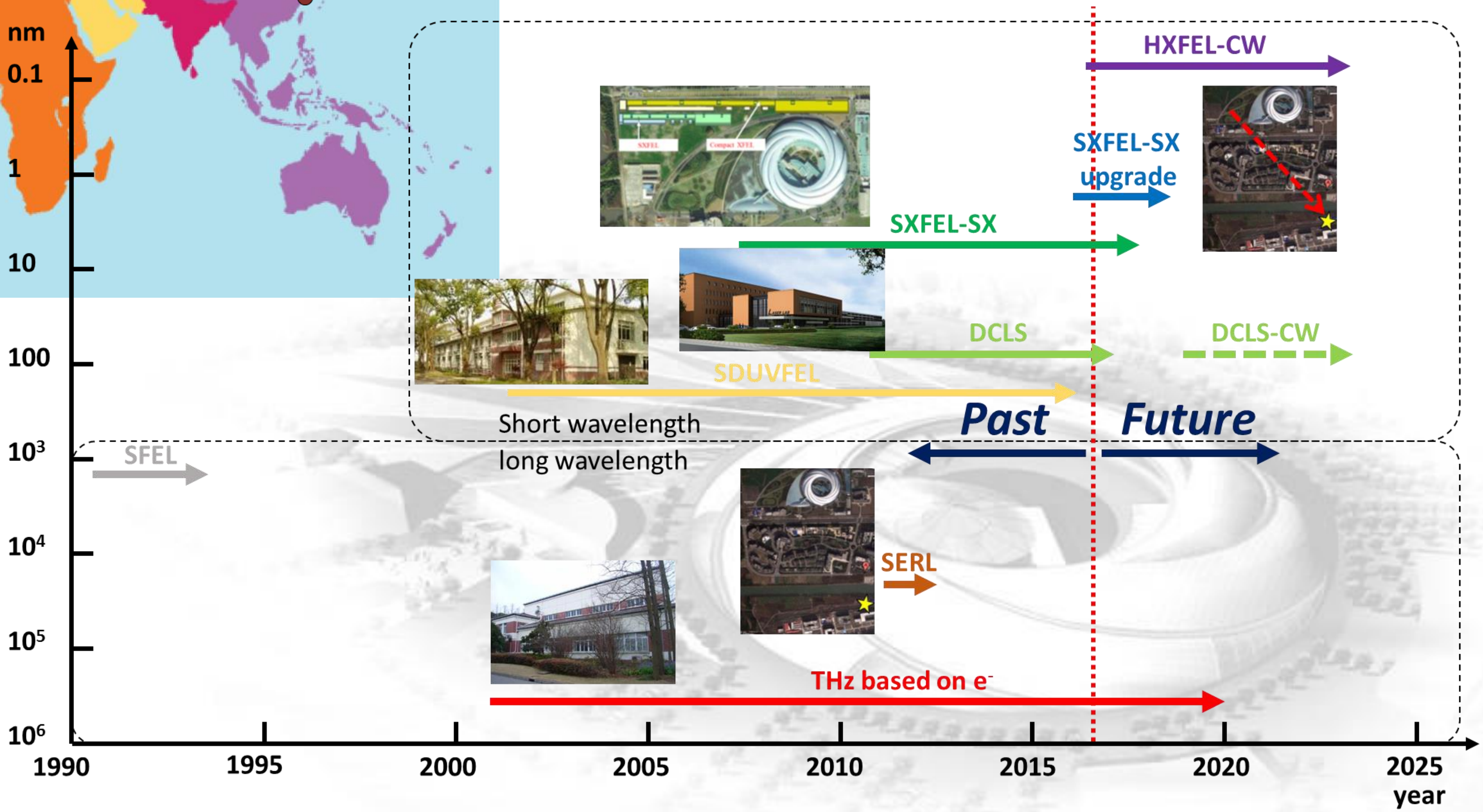
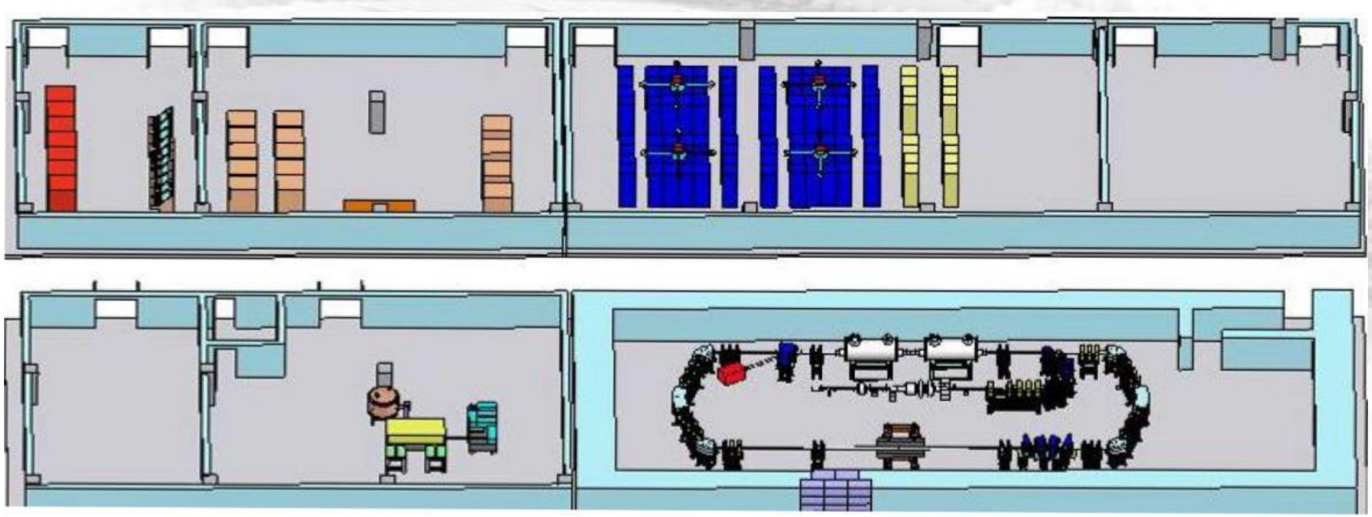
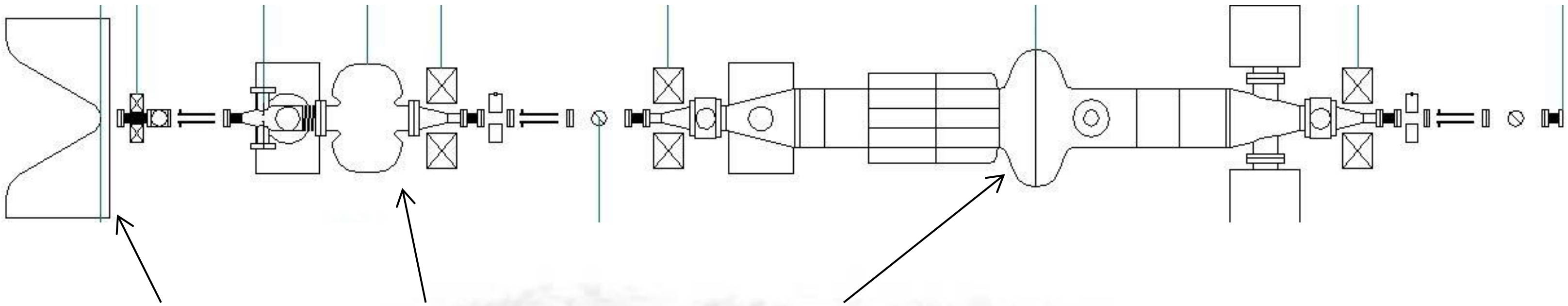


SERL

Beam energy	10MeV	20MeV
Bunch charge	240pC@83.3MHz	240pC@83.3MHz
FWHM bunch length	16ps	8ps
Trans. Emittance	10mm-mrad	10mm-mrad
Laser wavelength	0.5~2 THz	2~10 THz
Avr. power	1kW	1kW



The injector design for SERL



VHF gun
250MHz
0.5MV

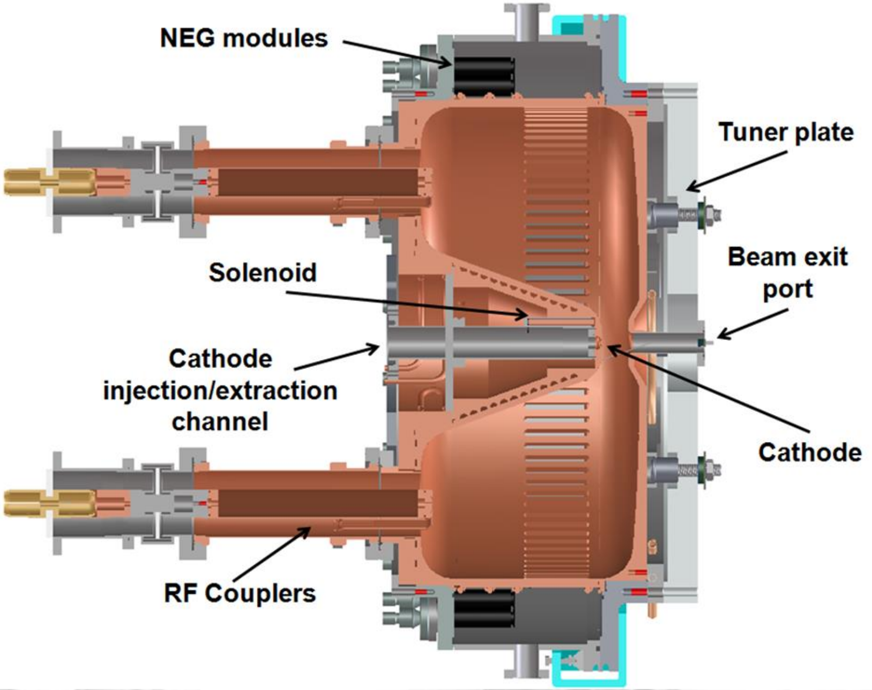
buncher
500MHz
0.36MV

booster
500MHz
2MV

charge	Repetition rate	Bunch length	Peak current	Energy	Energy spread	Nor. Emit.
240pC	83.3MHz	<6ps	15~30A	>2MeV	<0.2%	<10umrad

Technical line of electron gun for SERL

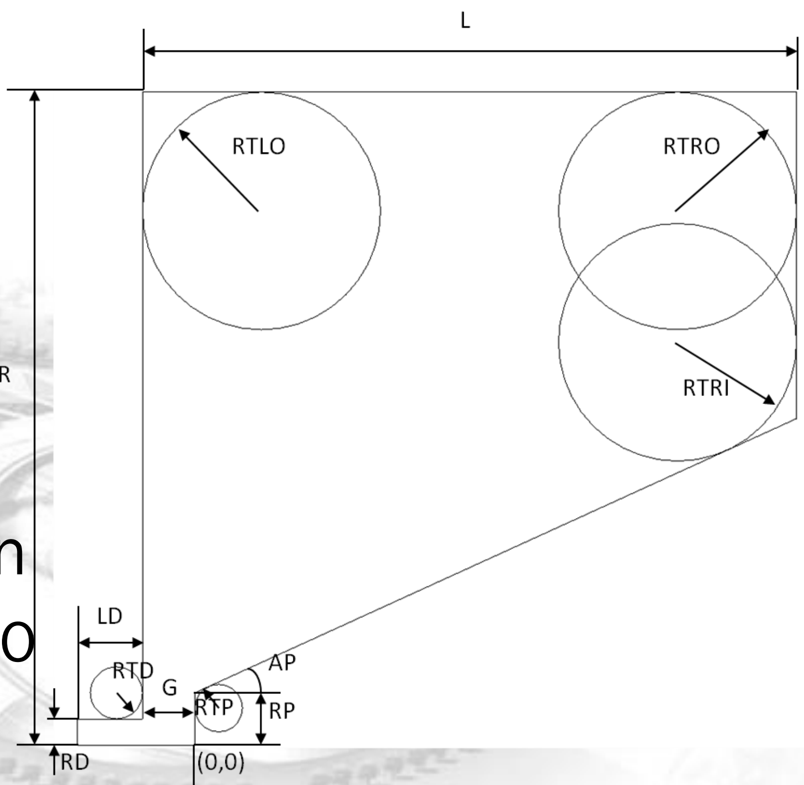
	DC gun	RF gun	
		NC	SC
Frequency	0	100~ 700MHz	700MHz ~1.3GHz
Peak field	<20MV/m	>40MV/m	>40MV/m
Beam energy	350keV~ 750keV	750keV~ 6MeV	2MeV~ 6MeV
Beam current	100mA	100mA	500mA
Emittance	1~10	1~6	1
Efficiency	high	moderate	low



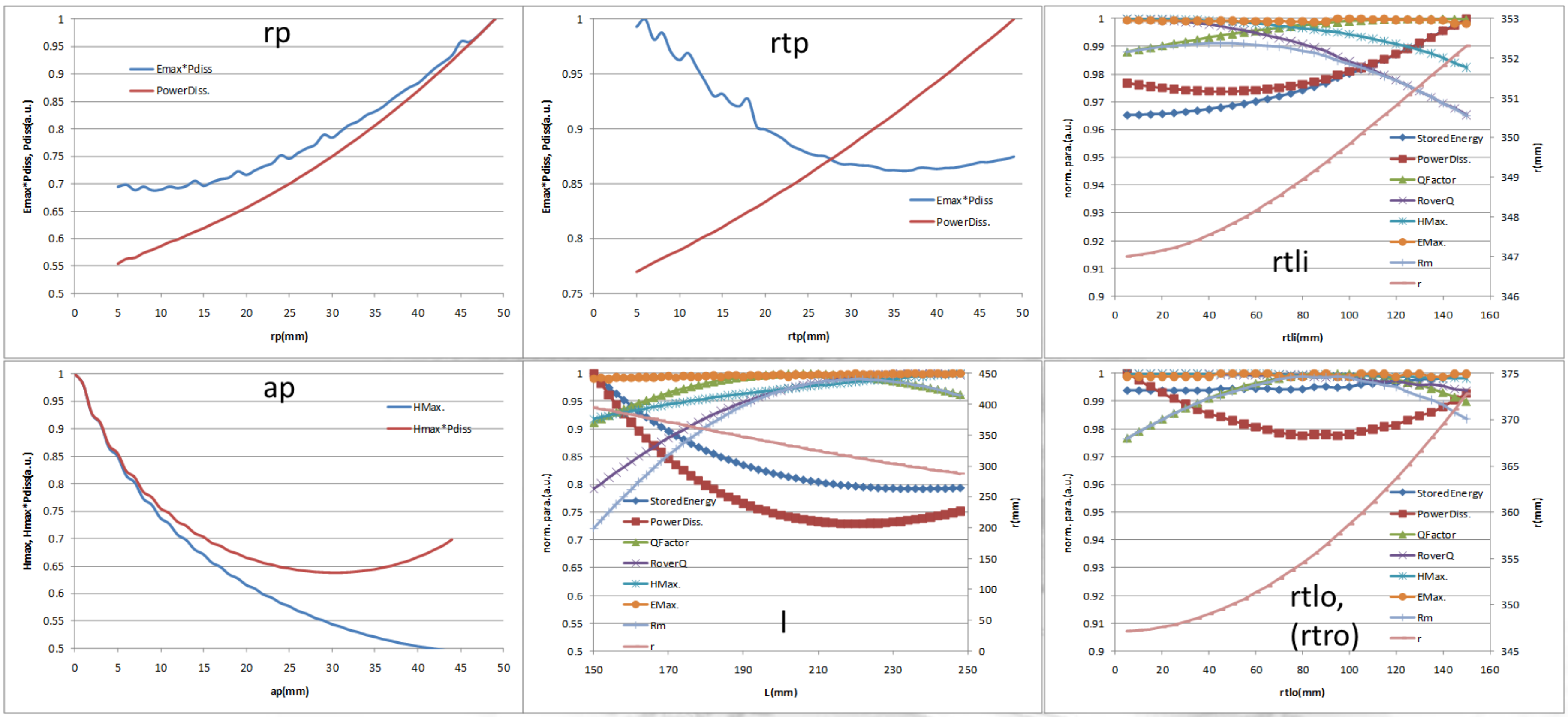
Parameters for RF optimization

Total 12 geometric parameters are used.

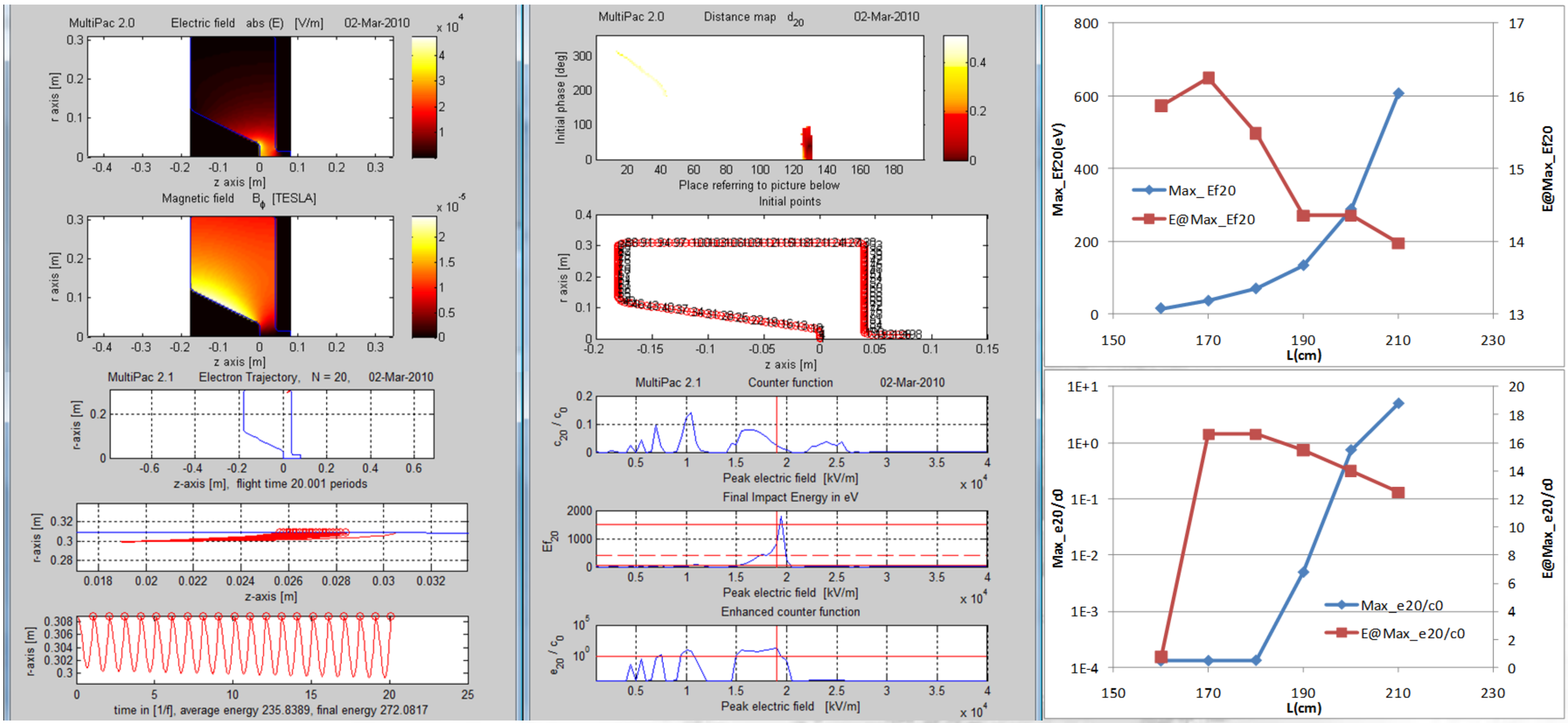
- 4 are fixed for further diode gun optimization
  - G is set to 40mm
  - RD is set to 12.5mm
  - RTD is set to 10mm
  - LD is set to 40mm
- 7 are used for RF optimization
  - L, RP, RTP, AP, RTLI, RTLO, RTRO
- R is used to fit the cavity frequency



Scanning - RF parameters



Multipacting suppression of the cavity



Final parameters

name	value	unit
rp	15	mm
rtp	25	mm
ap	30	deg
rtli	25	mm
rtlo	10	mm
l	190	mm
rtro	10	mm
r	347.222	mm

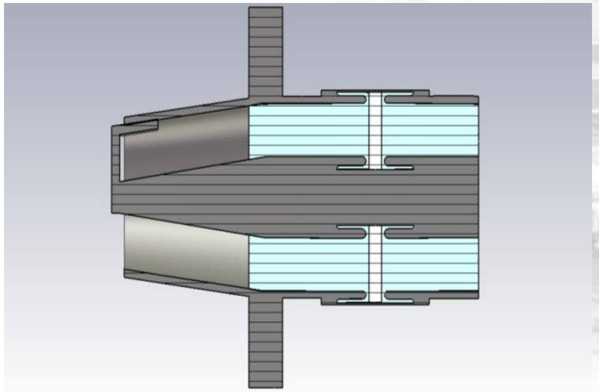
name	value	unit
Frequency	249.8264	MHz
Stored Energy	2.01	J
Power Diss.	109.46	kW
Q factor	28827	
R/Q	176.79	ohm
Pmax.	30.63	W/cm^2
Emax.	28.99	MV/m
Emax./E0	1.32	
Gap voltage	766.5	kV
Beam energy	750	kV

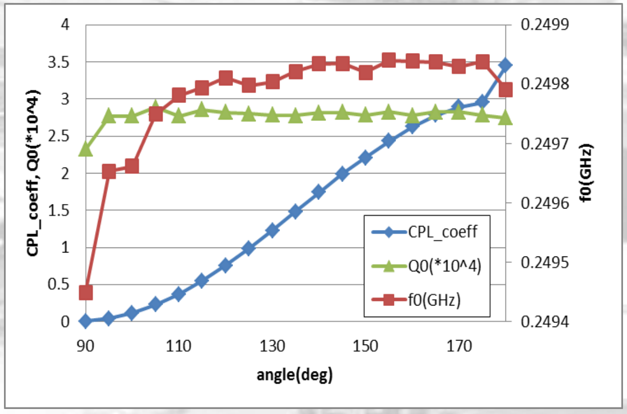
Coupler

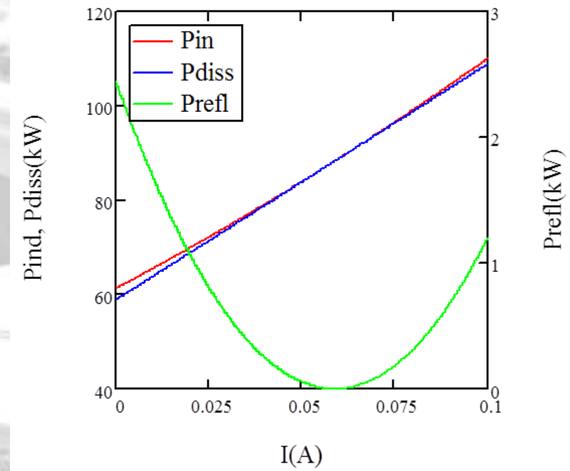
- The coupler is close to cavity to avoid mismatching in coaxial line
- Based on the petra cavity coupler design, but using single ceramic window.

- The maximum coupling coefficient is set to 3 while the loop is perpendicular to the out cylinder.

- The maximum reflecting power is less than 3kW with a current changing from 0 to 100mA

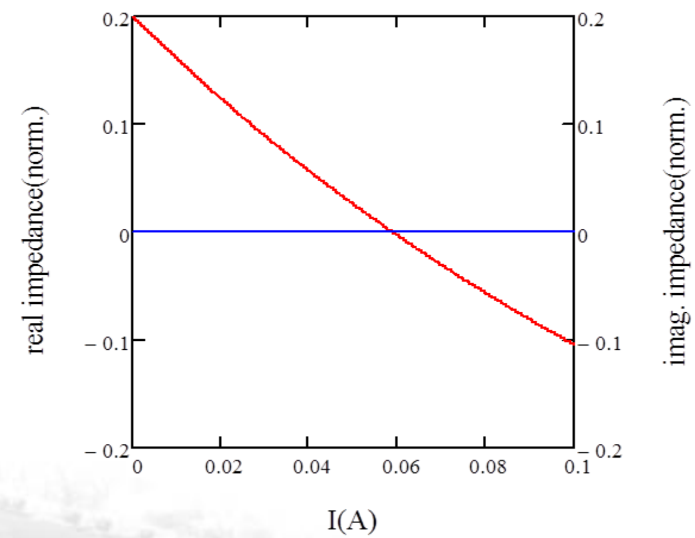


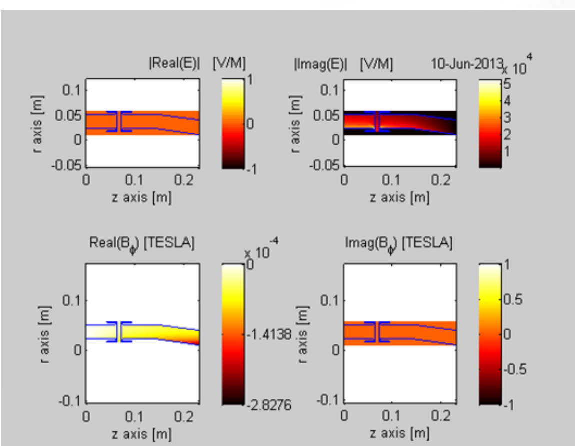


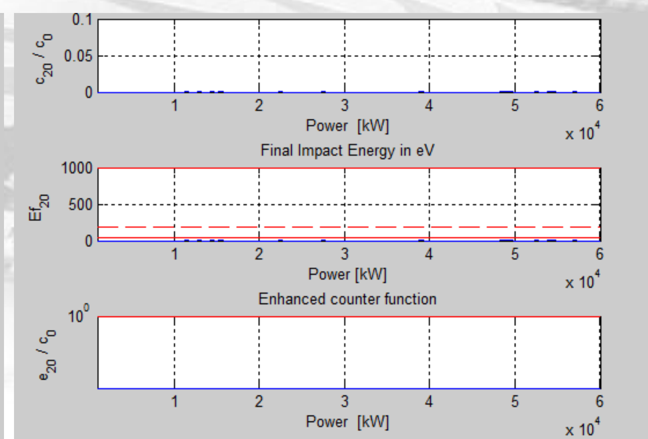


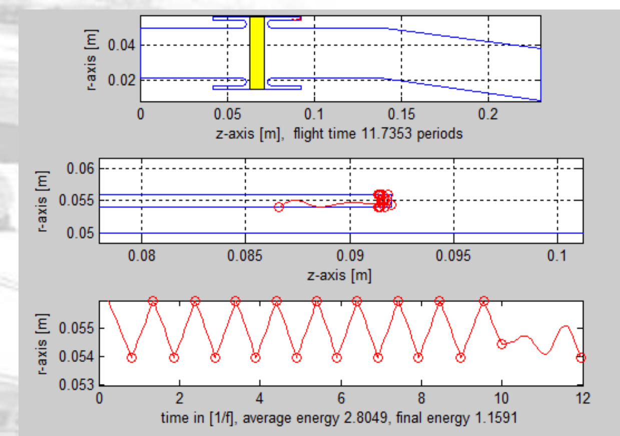
Coupler

- In multipacting simulation, the cavity is on tune. This means the imaginary part of the standing wave is 0.
- Different reflecting status has been studied. No multipacting happen in the coupler.

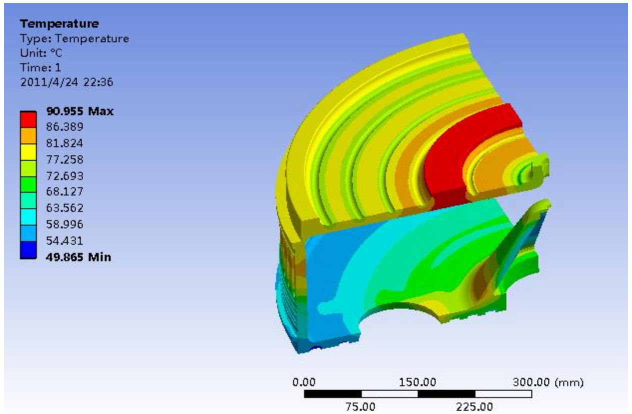


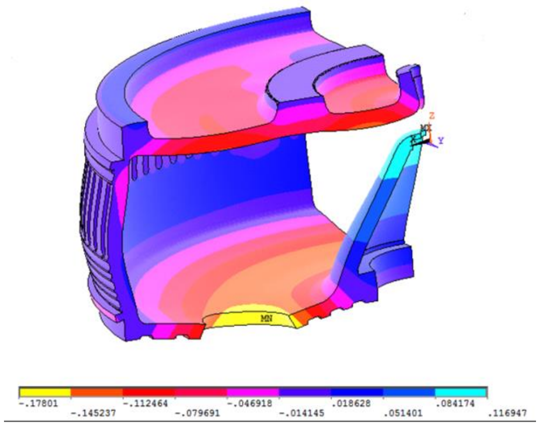


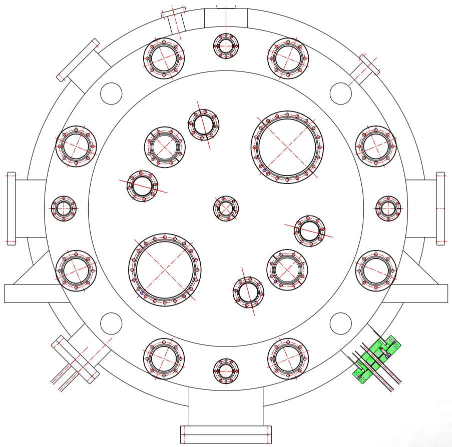


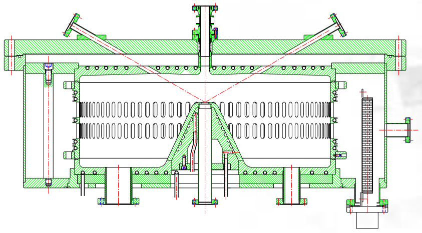


Thermal analysis





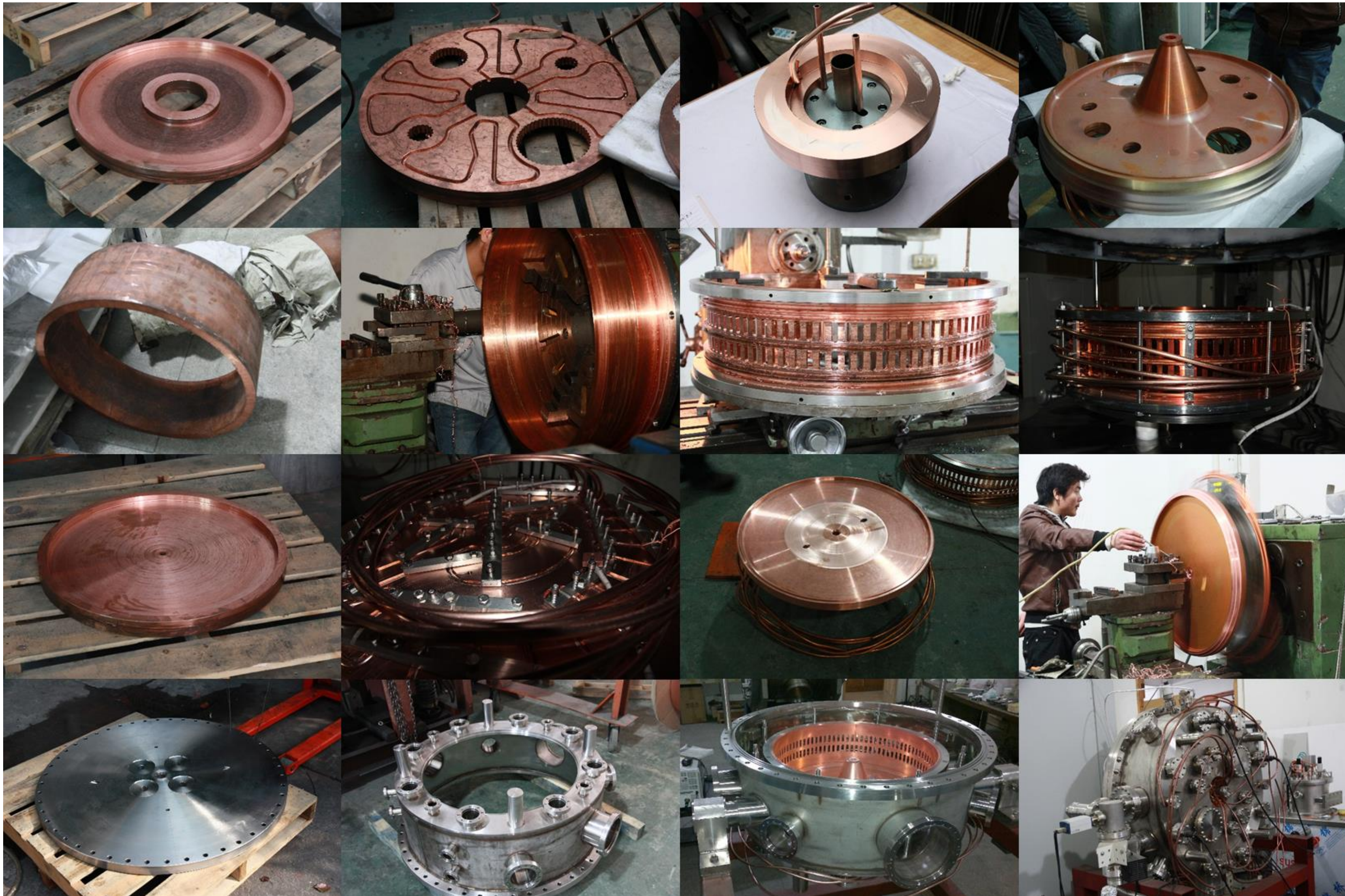




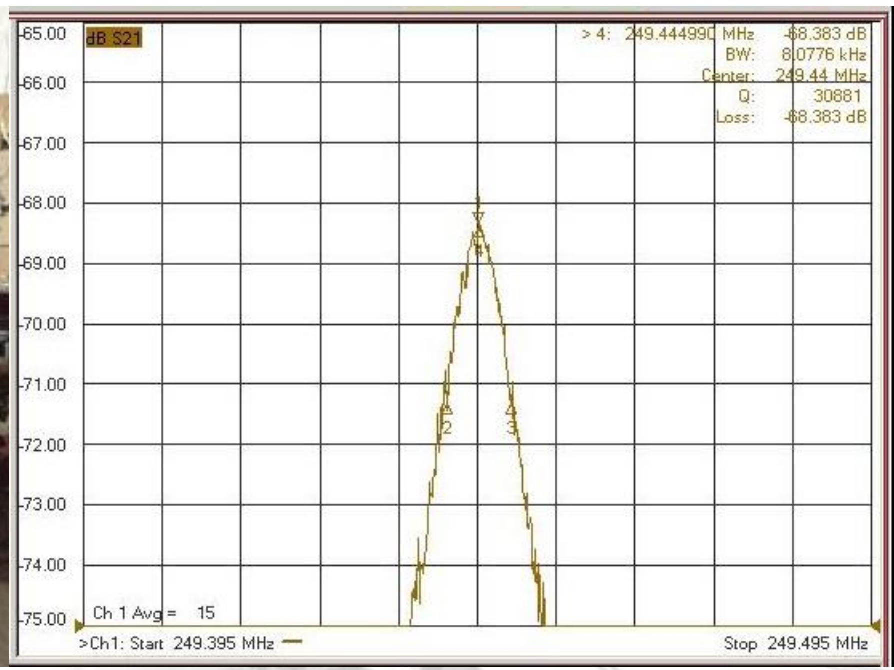
The maximum deformation is about 0.12mm, located at the nose cone. This deformation will induce 100kHz detuning of the cavity, which should be compensated by the tuning system.

	Up plate	Middle ring	bottom plate
RF Power (kW)	31.18	21.909	39.9
Max. power density (W/mm^2)	0.092	0.06123	0.271
Heating of cooling water/hottest at the surface (℃)	38/91	24/85	16/77

Up plate: Ø10mm, 2inlet/2outlet
Bottom plate: Ø10mm, 7inlet/7outlet
Middle ring: Ø8mm, 3inlet/3outlet
Nose cone: Ø8mm,1inlet/1outlet

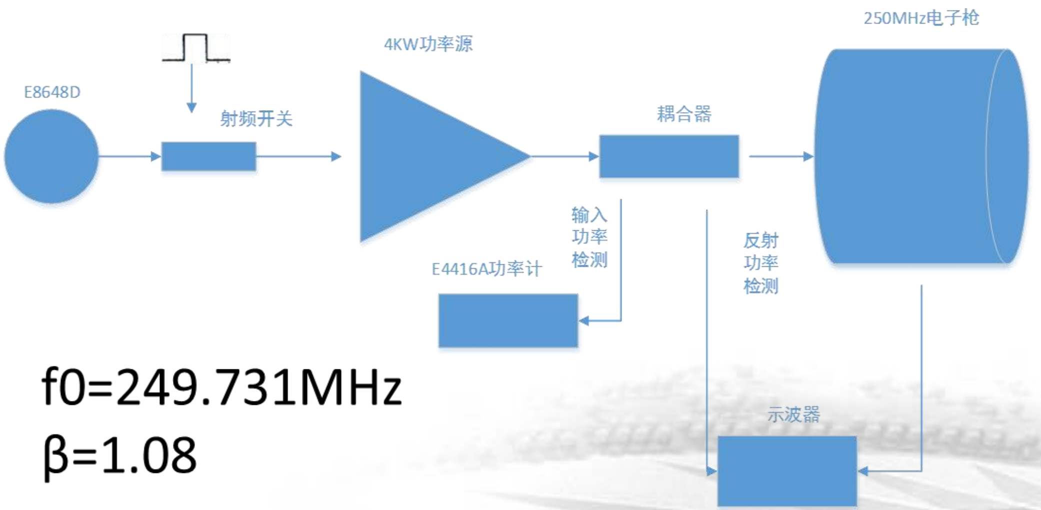


Cold test



Parameters	Measured
Frequency	249.445 MHz
Q_0	30881
Vacuum (Without baking)	$<2.0\times10^{-7}$ Pa
Vacuum leakage	$<1\times10^{-11}$ $Pa*m^3/s$

High power test



f0=249.731MHz

β=1.08

$S21_{pickup}$=40.13dB

Cable=0.47dB

Attenuator=10.4dB

$P_{forward}$=

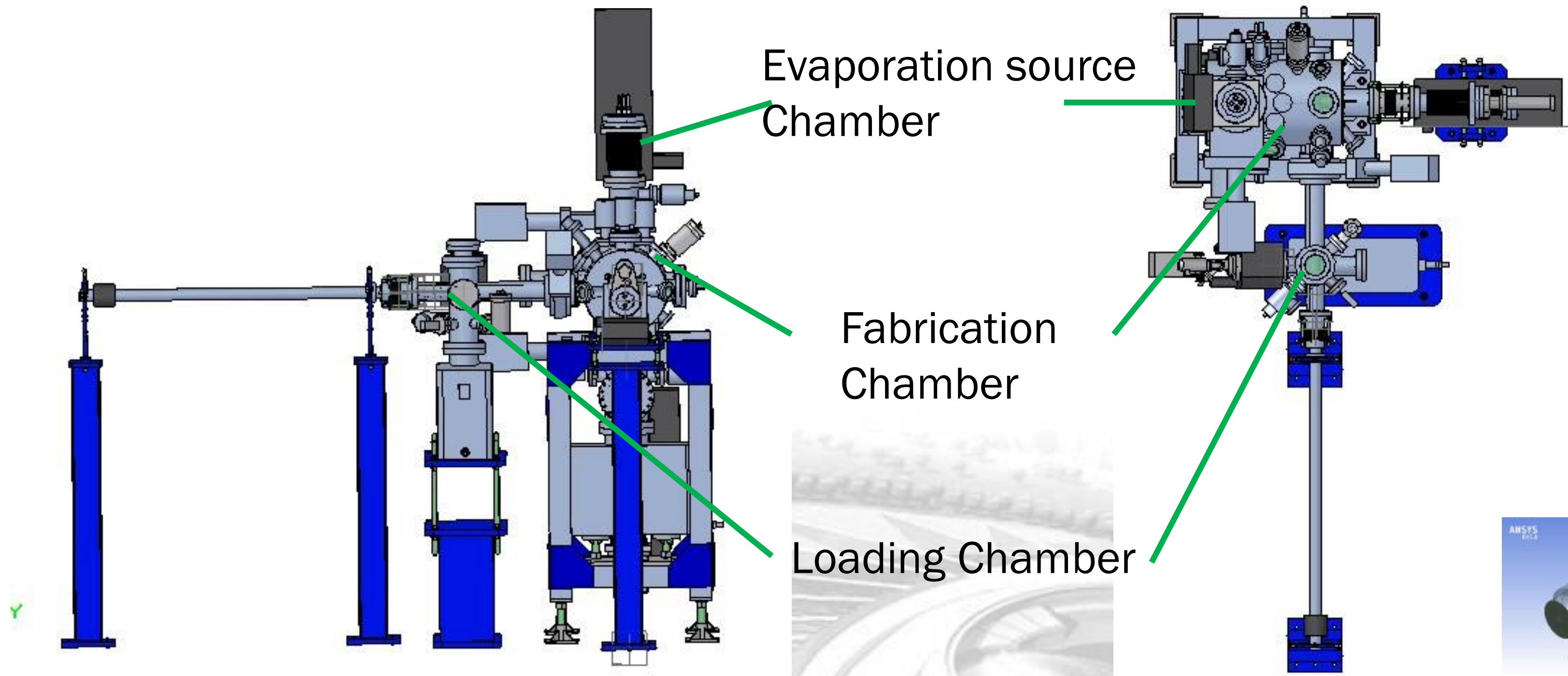
51dB+15.5dBm=

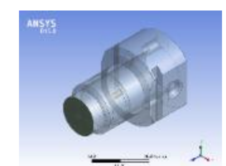
66.5dBm=4.3kW

Technical line for photocathode

	Cs_2Te	K_2CsSb	GaAs:Cs
QE (%)	2%/5%	2%/5%	2%/5%
λ_{laser} (nm)	266	532 (400)	532
P_{laser} (W)	24/47	12/24	12/24
Power density (W/cm^2)	742/1480	371/740	371/740
Response (ps)	~1	~1	20~50
Vacuum (Pa)	$<10^{-7}$	$<10^{-8}$	$<10^{-9}$
E(MV/m)	120	26	3~5
Life time (1/e)	long	moderate	Short

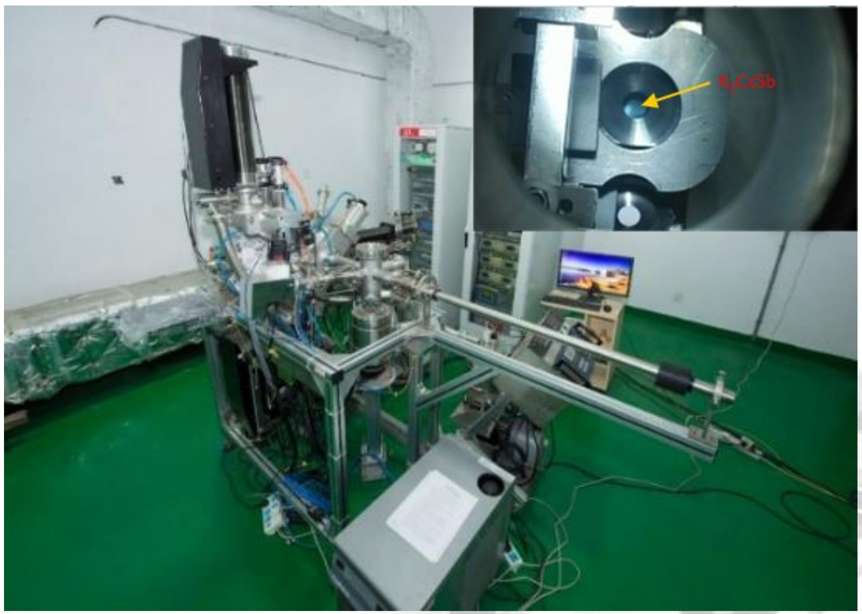
Photocathode Preparation Facility at SINAP

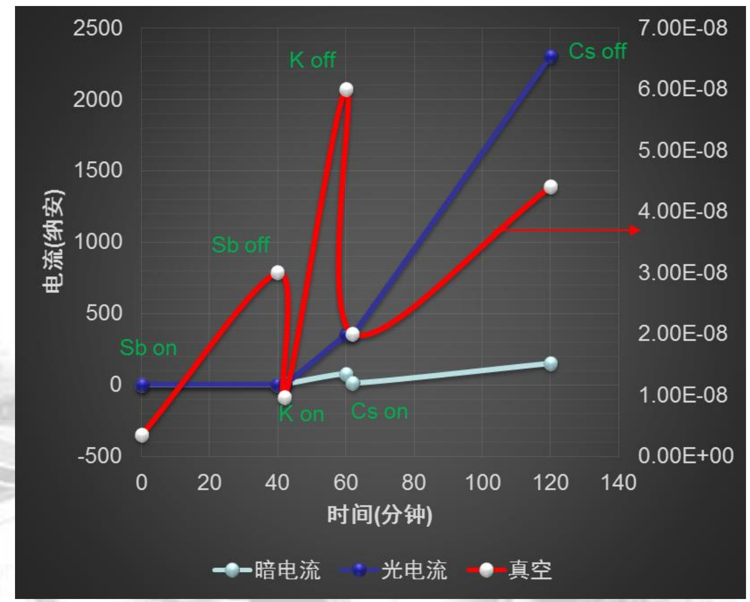




	Static vacuum	Functions for the chamber	Main components
Fabrication Chamber	3×10^{-10} Torr	Preparation and measurement	Evaporator source, temperature control unit, thickness meter, photocurrent measurement unit
Loading Chamber	2×10^{-7} Torr	Replacement, cleaning, transport	Transportation unit、argon-ion gun、vacuum system

Photocathode Preparation Facility at SINAP





QE ~1%

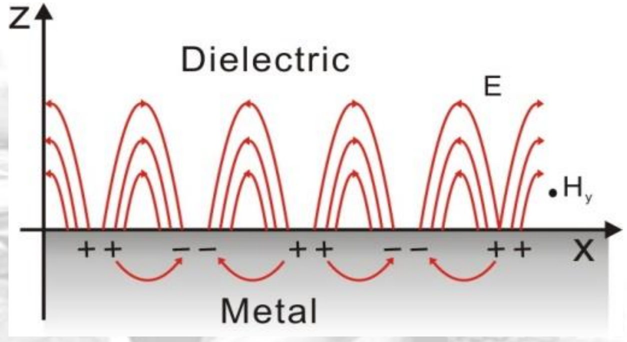
Now the vacuum system maybe is the biggest problem limited the QE for our facility. In the future, we will upgrade the vacuum system, add ion pumps for the evaporation source chambers.

Plasmon-enhanced photocathode

The development of photonics, electronics, nanotechnology provides some new promising ways for high brightness photocathode.

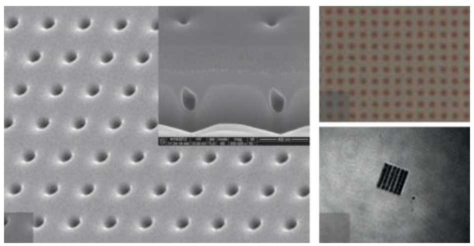
Limitations for Plasmon-enhanced photocathode:

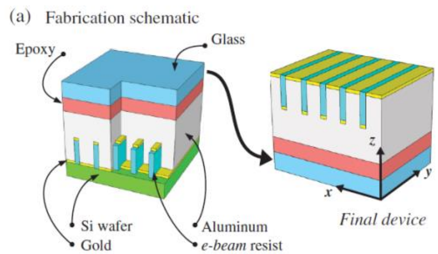
- Simple low-cost Preparation technics
- The emittance?
- How to achieve a higher photoelectronic emission with visible light?



Surface plasmon polarizations (SPPs)

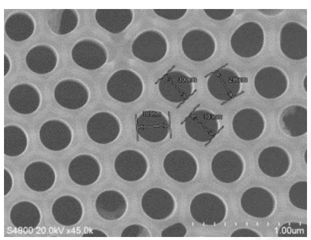
A simplified and feasible preparation method



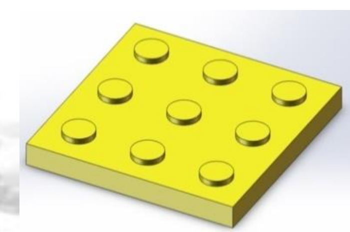


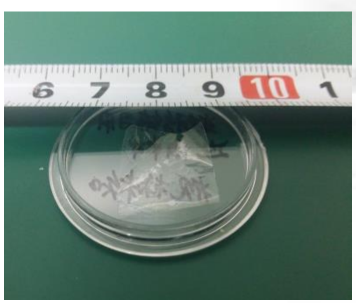
Electron beam/Ion beam lithography:

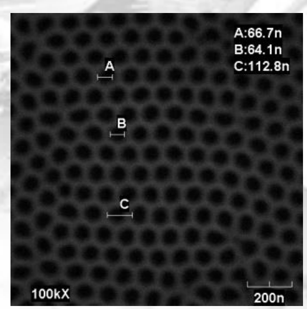
- ➢ Depend on expensive hardware;
- ➢ Image mosaic needed for large area patterning;

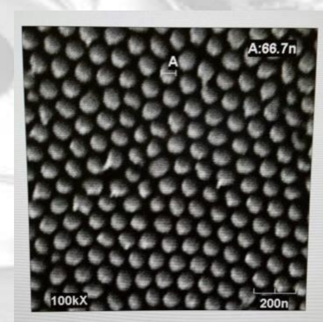


- ✓ approximately periodic
- ✓ Low-cost
- ✓ Ease of large-area processing





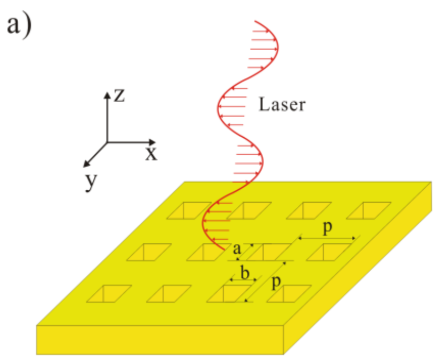


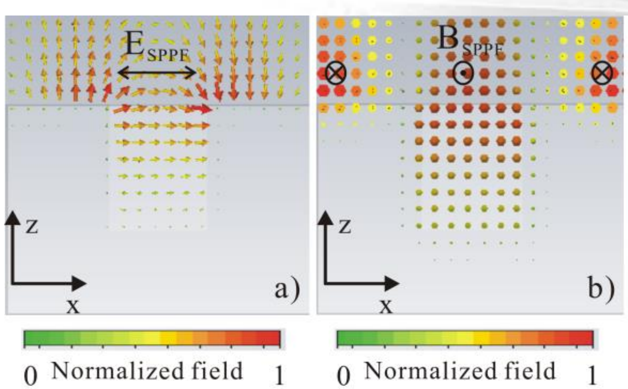


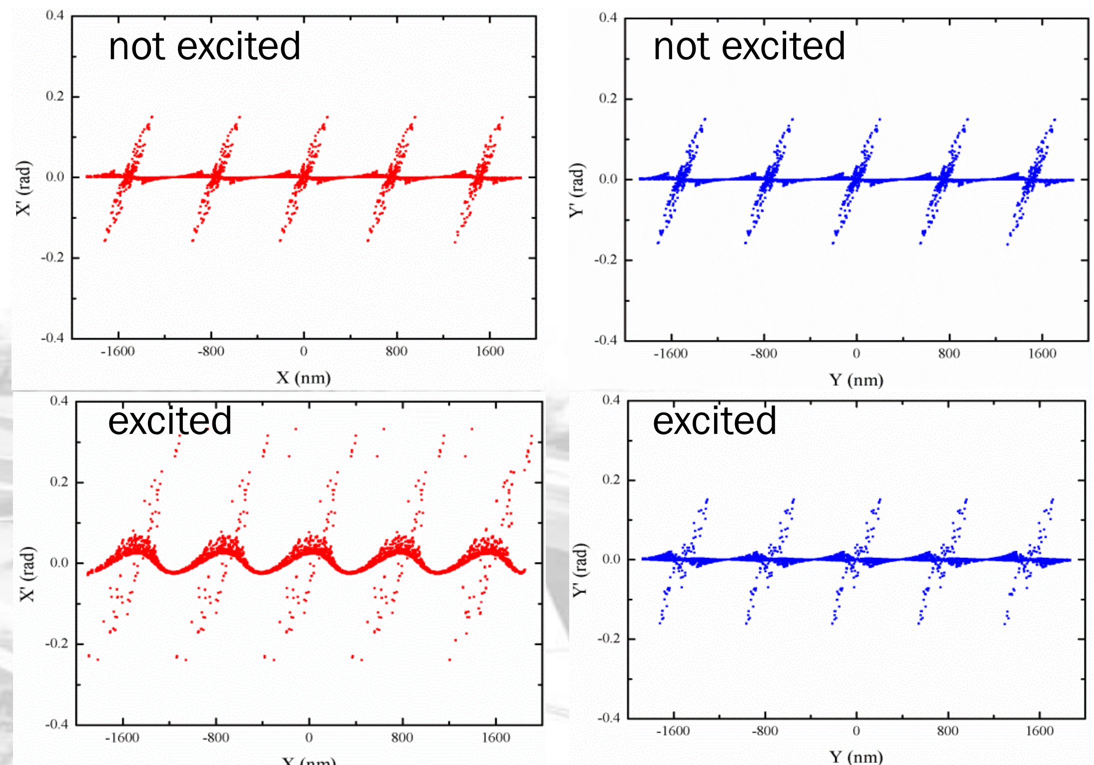
porous anodic alumina template（AAO）

Research on the emittance of the photocathode

What’s the influence of surface plasmon polarizations for the emittance of cathode?

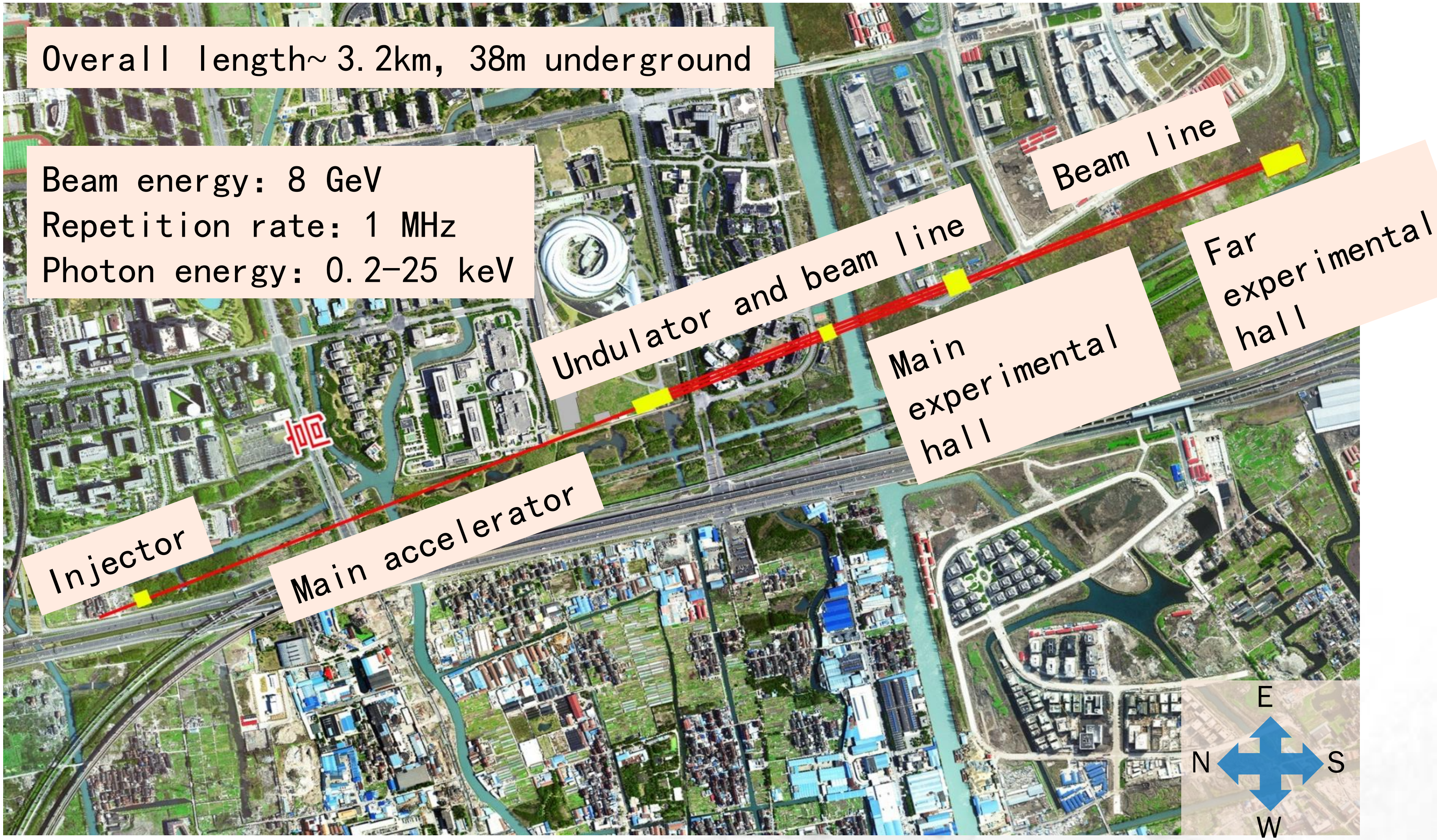






The transverse phase spaces of the bunch in different situations without/with the excitation of surface plasmon polarizations.

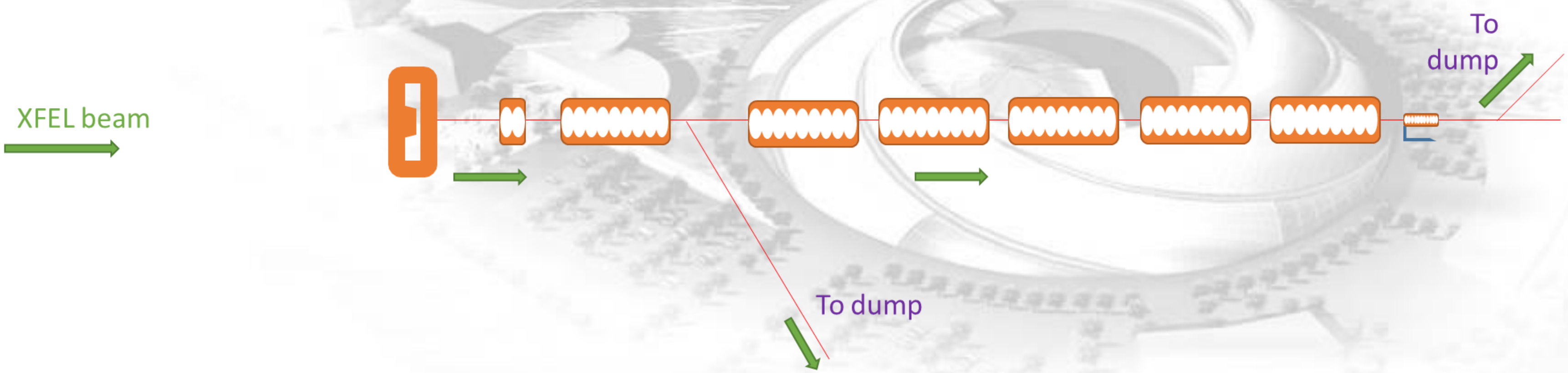
Hard X Ray Free Electron Laser Facility



CW-HXFEL

The MHz high brightness injector is still a major challenge !

- For the electron gun, we are carrying out the technical demonstration of VHF gun, SRF gun, and DC+SRF gun (by Peking university).
- Cs_2Te is current baseline for the project. And other cathodes with high QE, low intrinsic emittance, such as, K_2SbCs, Na_2KSb, etc. will also be considered and researched.



Thanks！