SDUV-FEL Facility Progress

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on behalf of SDUV-FEL team

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SDUV-FEL Facility Progress

- Introduction
- Simulation and Parameters
- Status of main components

Introduction

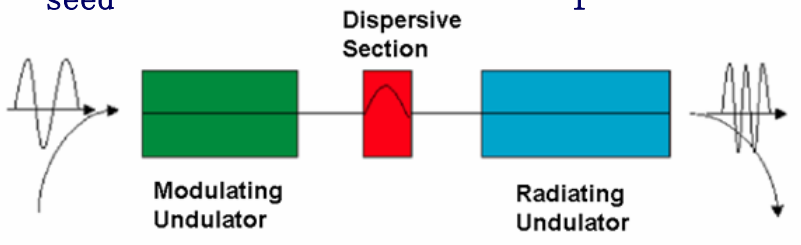
- Shanghai Deep-Ultraviolet FEL (SDUV-FEL), an 80nm High Gain Harmonic Generation FEL test facility, since 2000.
- Being carried out by Shanghai Institute of Applied Physics in cooperation with
  - Institute of High Energy Physics /IHEP
  - NSRL, Univ. of Science and Technology of China
  - Accelerator Lab. of Tsinghua University
- Fund partially supported by
  - Chinese Academy of Sciences/CAS
  - Ministry of Science and Technology of China/MOST
  - National Natural Science Foundation of China/NSF
- Will be executed in phase Ⅰ and phase Ⅱ
- Expect to provide an experiment benchmark for X-ray FEL in future

HGHG FEL in third harmonic case

Phase I

(UV FEL based on 160MeV linac with bunch compressor 1)

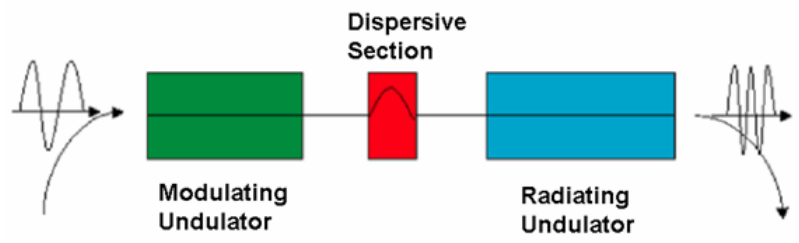
λ_{seed}=786nm λ_1=262nm

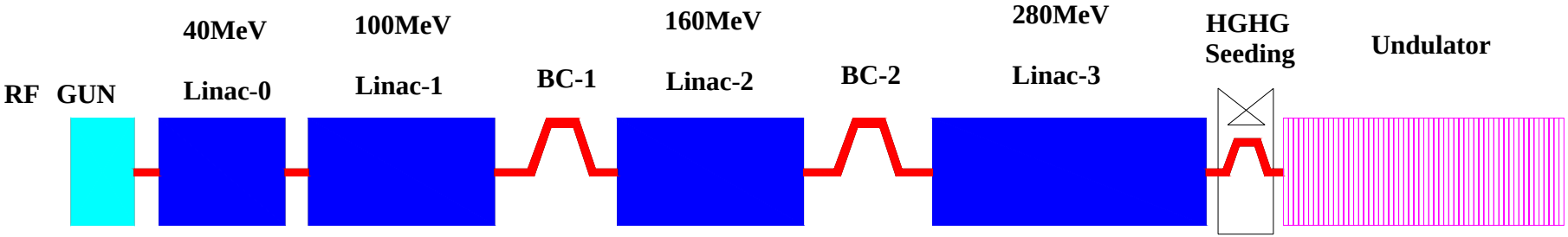


Phase 2

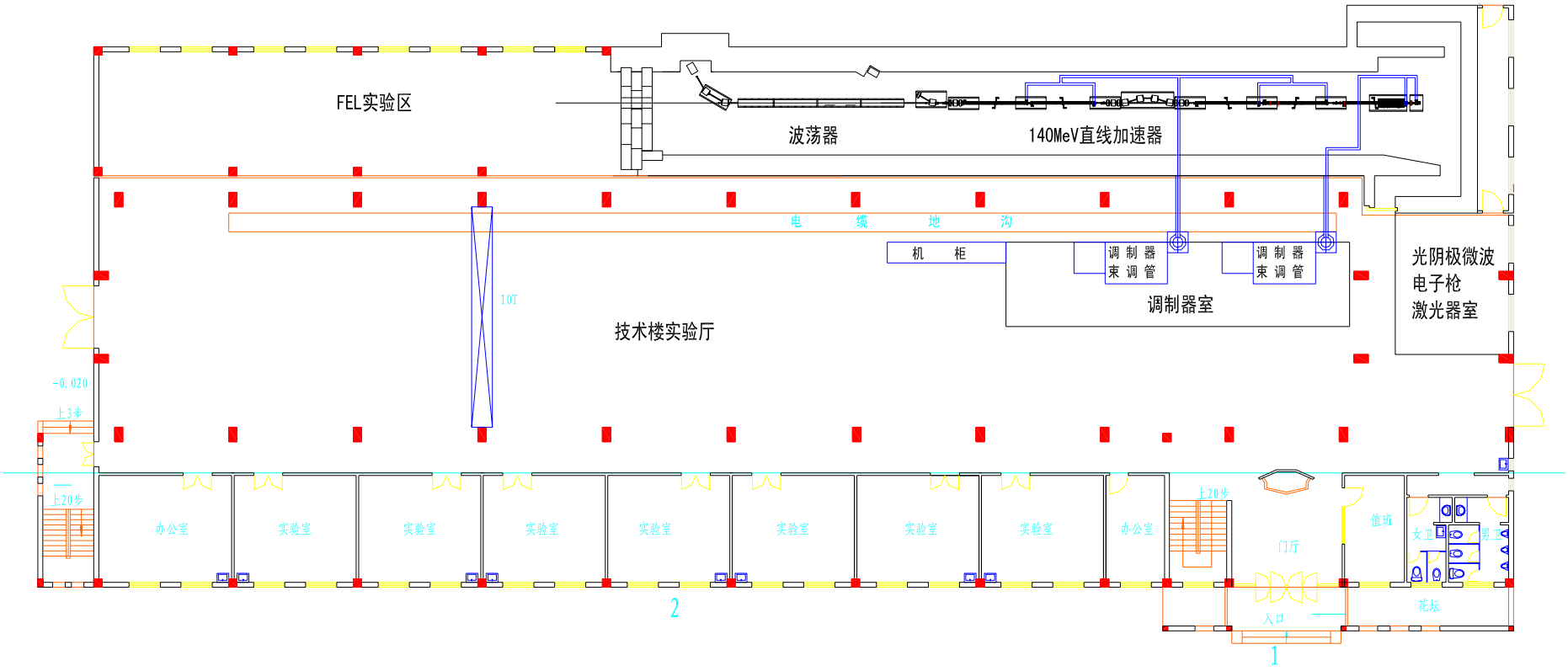
(DUV FEL based on 280MeV linac with bunch compressor 1 and 2)

λ_{seed}=262nm λ_1=87.3nm

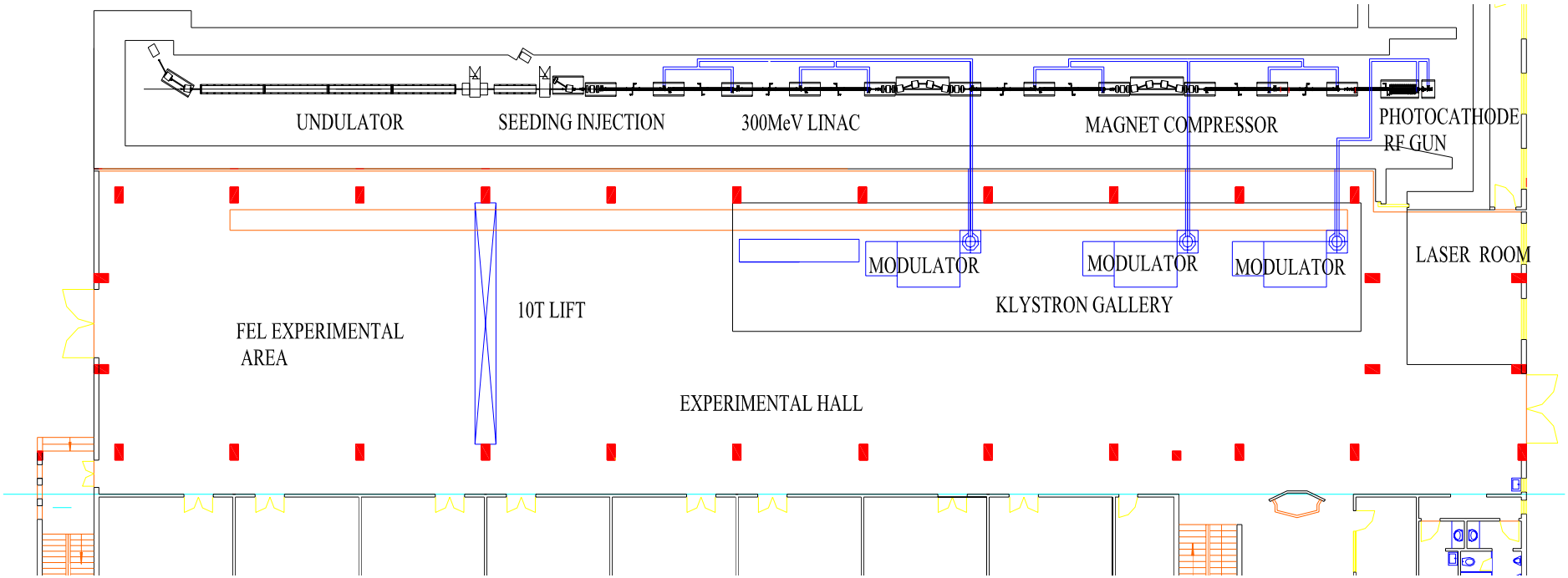




SDUV-FEL Layout (Phase-I)



SDUV-FEL Layout (phase Ⅱ)



Current Schedule of SDUV-FEL

2002.1~2005.12	Construction and commissioning of a 100MeV Linac with grid gun as prototype of pre-injector of SSRF
2006.1~2006.9	Installation of 40MeV injector with photocathode RF gun
2006.9~2007.6	Commissioning of photocathode RF gun and 40MeV injector
2007.1~2007.12 (phase 1)	Installation of undulator system, seeding laser, and electron beam / laser diagnostic instruments; Begin on experiments of UV-FEL (262nm)
2008.1~2009.12 (in phase 2)	Upgrade Linac energy to 280MeV, and begin on experiments of DUV-FEL (88nm)

Simulation and Parameters

- HGHG FEL process was simulated by modified TDA3D and GENESIS
- SASE FEL process was simulated by GENESIS
- Start-to-end (from photocathod rf gun to end of undulator) simulations have been under way since 2002, by PARMELA,ELEGENT,GENESIS and modified TDA3D
- Study sensitivity of FEL parameters on beam emittance, peek current, energy spread and field errors of undulator
- Based on these simulations, parameters of SDUV FEL have been determined, as listed in the following

Main Parameters of SDUV-FEL

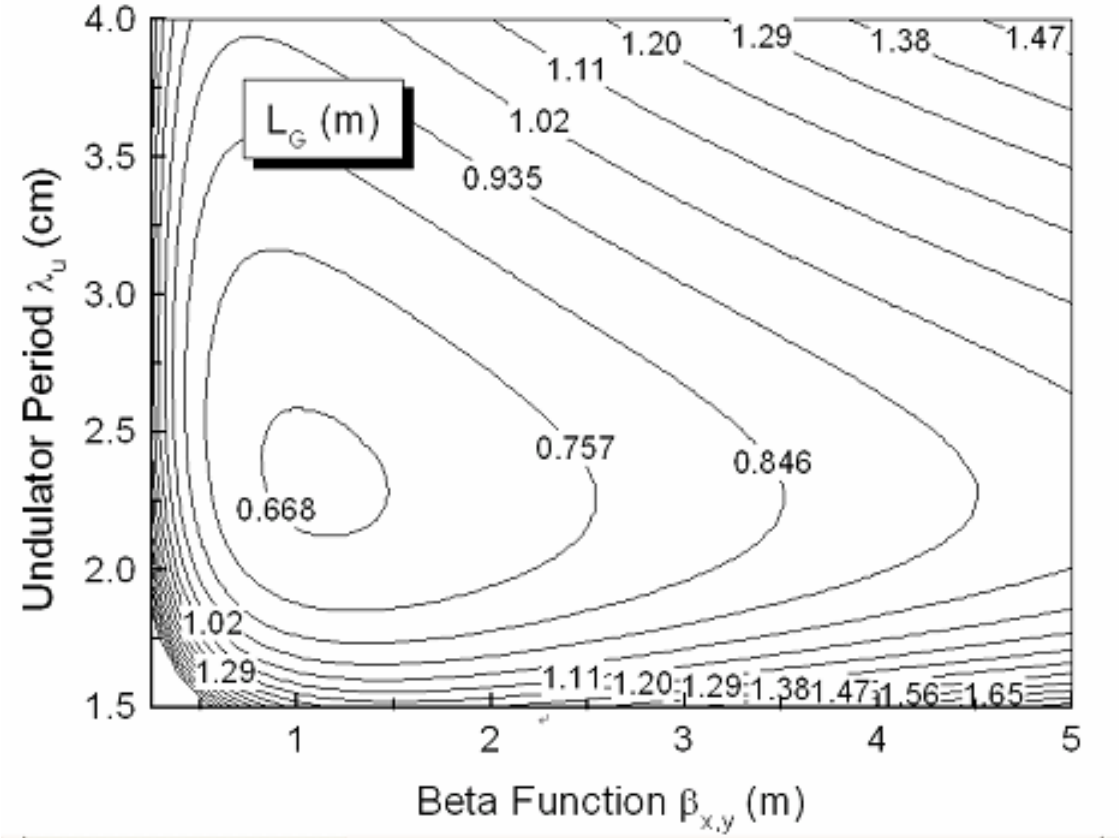
	Phase I	Phase II
FEL Parameters		
Wavelength (nm)	262	87
Output Power (MW)	~80	~140
Gain Length (m)	~0.7	~0.8
Electron Beam Parameters		
Energy (MeV)	~159	~276
Peak Current (A)	300	400
Emittance (mm-mrad)	6	4
Energy Spread (rms)	<0.1%	
Undulator Parameters		
Period (cm)	2.5	
Gap (cm)	1.0	
Length (m)	~9	

Simulation of SDUV-FEL

- 87nm SASE FEL
- 87nm HGHG FEL
- 262nm SASE FEL
- 262nm HGHG FEL

Optimization of SDUV-FEL

- Power gain length as a function of Undulator period and beta function



At λ=87nm

Gu=10mm

Ip=400A

∈n=4mm.mrad

δγ/γ=1‰

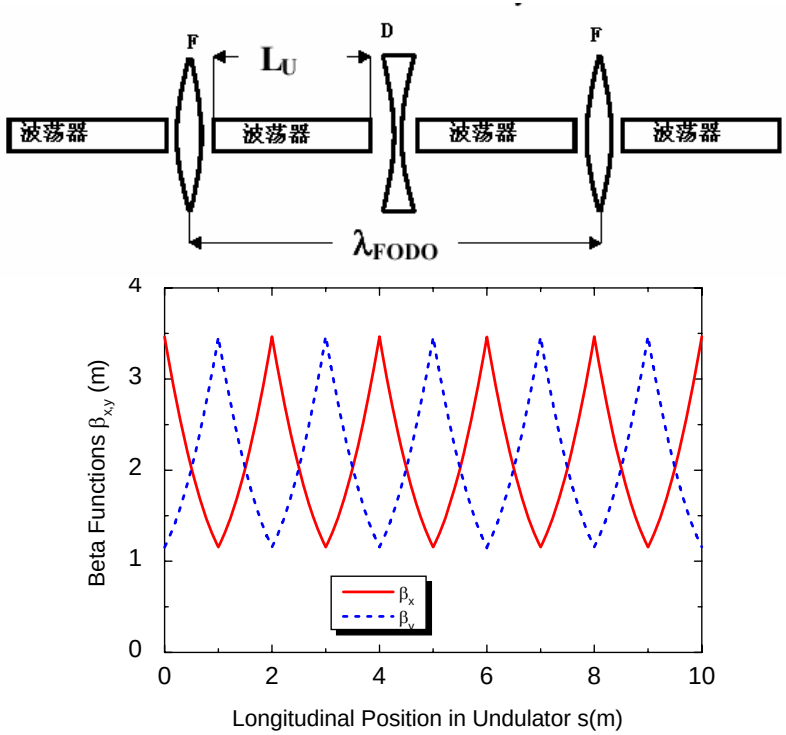
↓

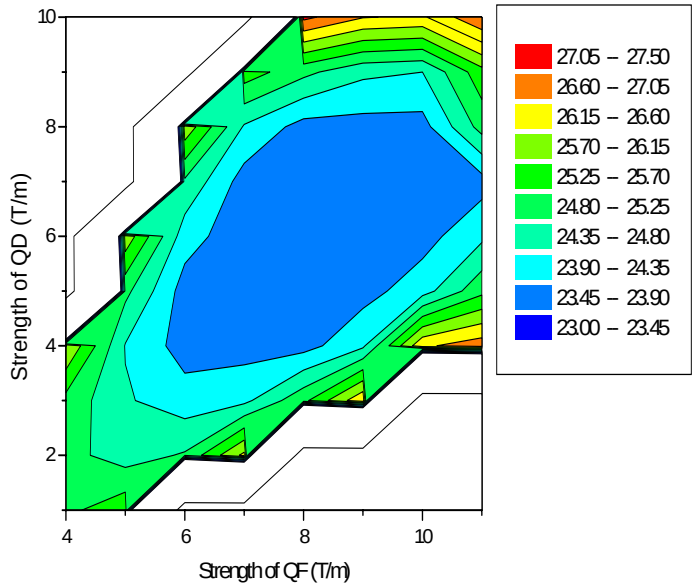
λu=2.5cm

(Lg=0.8m)

Optimization of SDUV-FEL

- Separated FODO lattice (undulator segments +quad.)

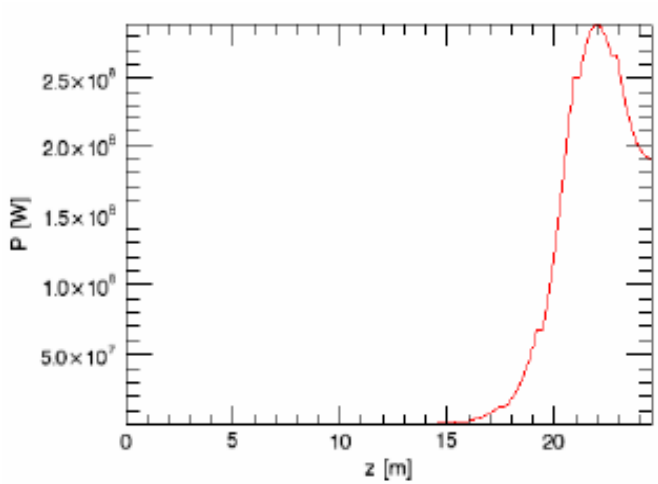


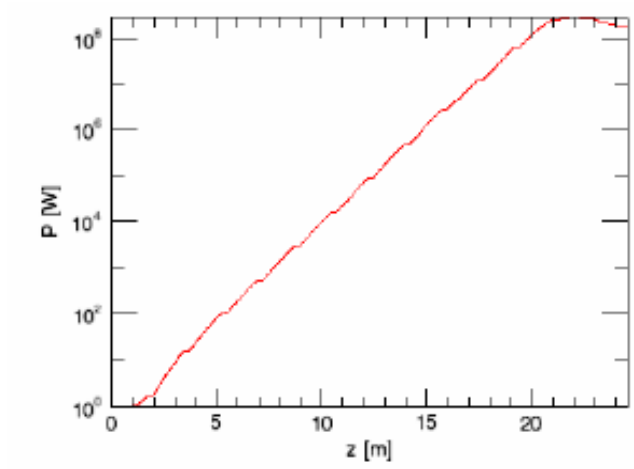


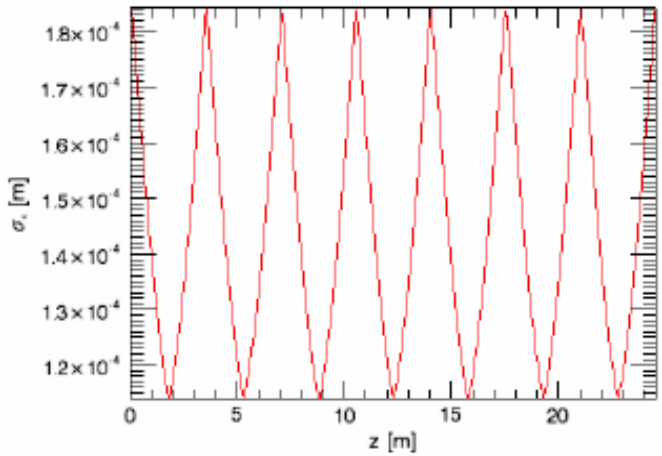
FEL SASE Saturation length(m) as a function of quadrupole strength Qf and Qd

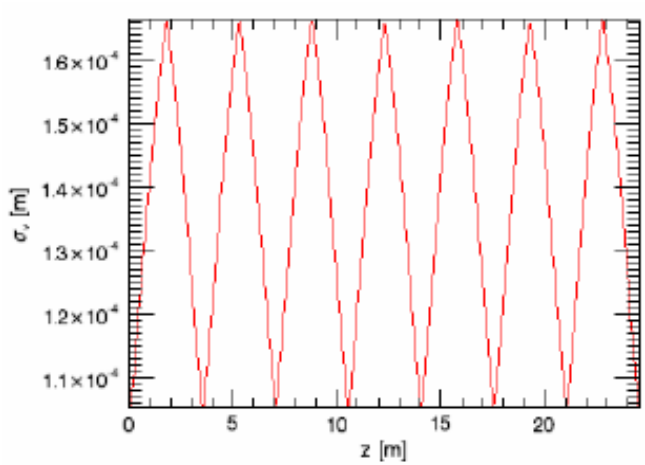
Choose Qd=4T/m and Qf=6T/m to obtain higher saturation power/shorter saturation length for 87nm SASE FEL

87nm SASE FEL

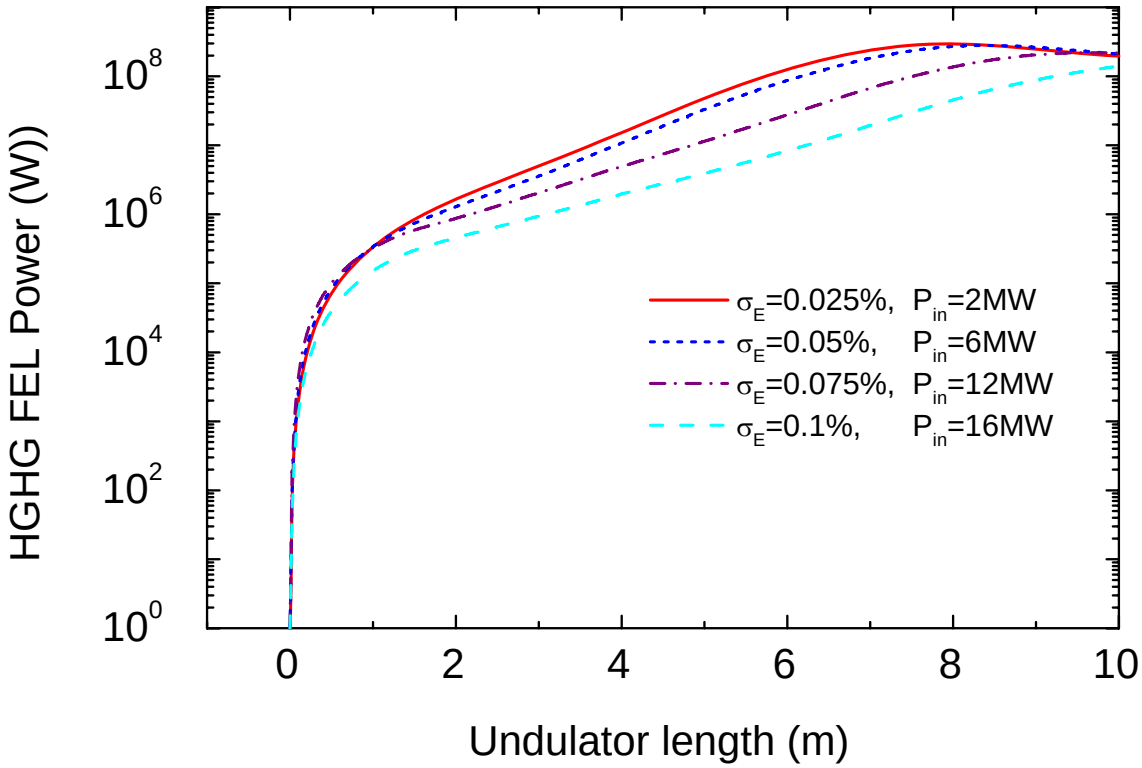






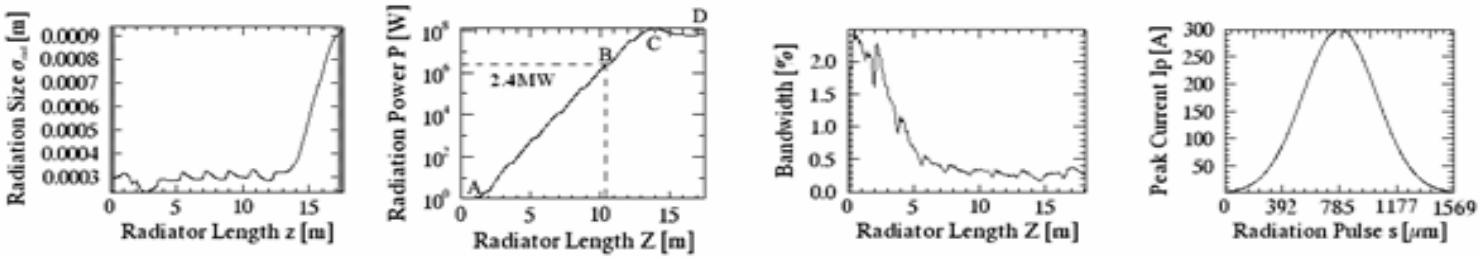


87nm HGHG FEL

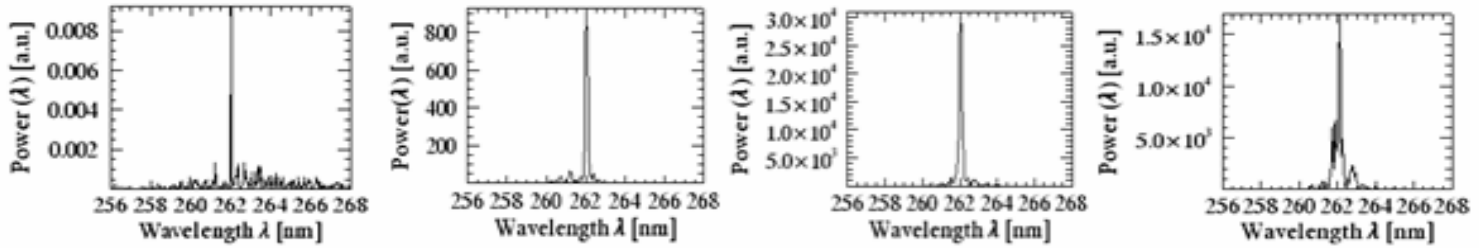


SDUV-FEL(87nm) output power vs undulator length

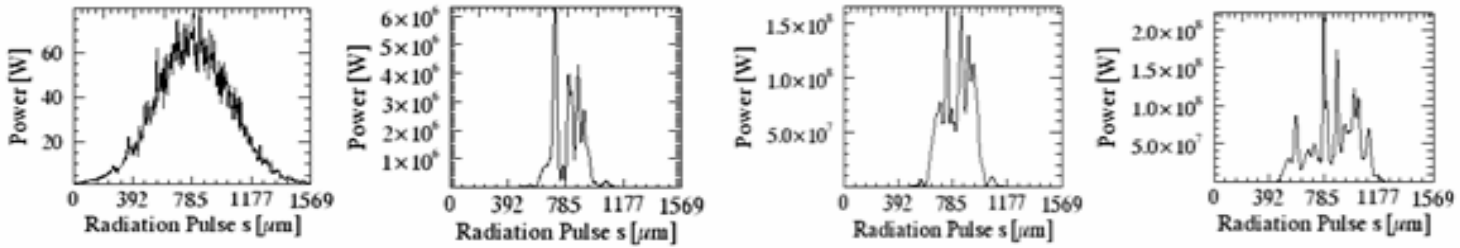
262nm SASE FEL



the optimal SASE FEL performance at 262nm wavelength

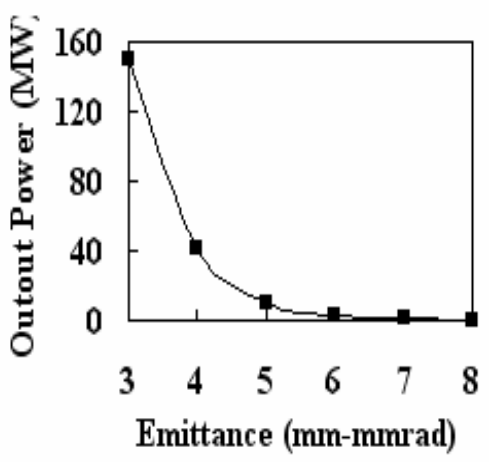


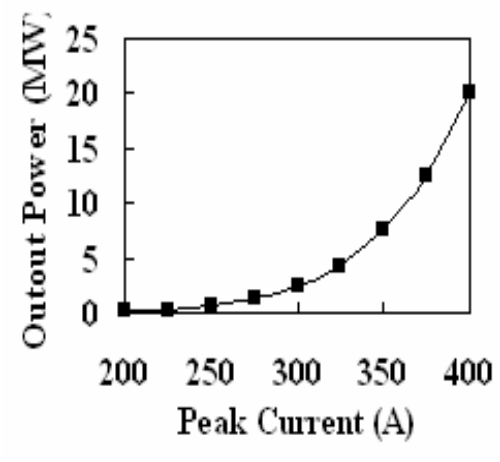
262nm SASE FEL radiation spectrum at four typical radiator positions

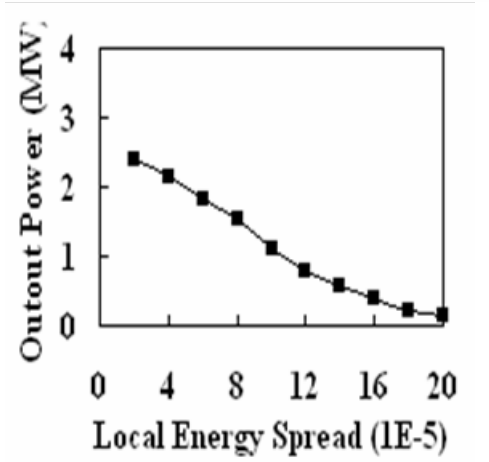


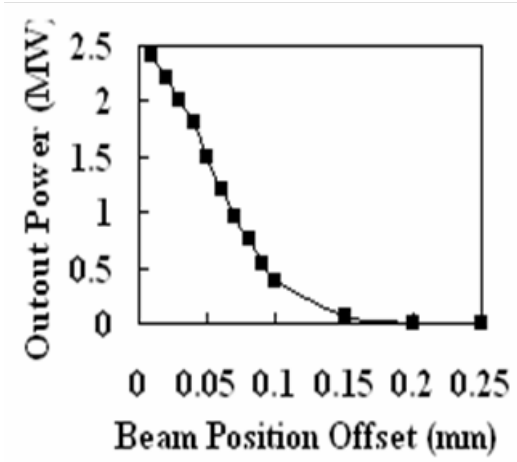
262nm SASE FEL radiation pulse at four typical radiator positions

262nm SASE FEL





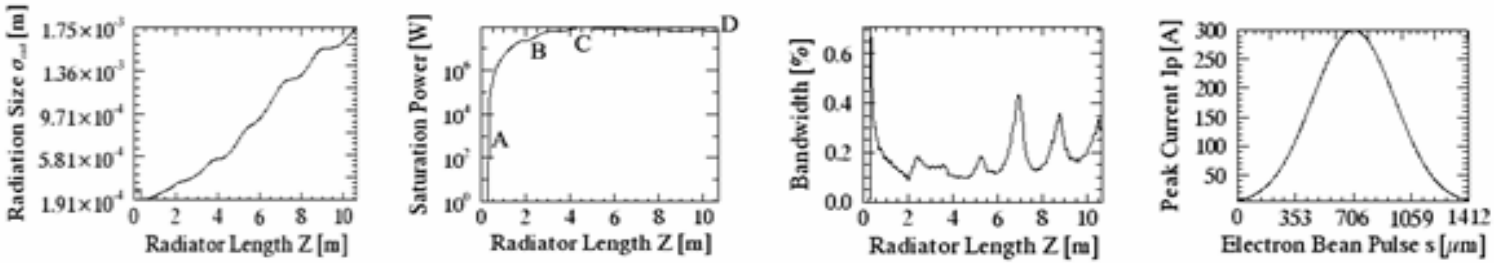




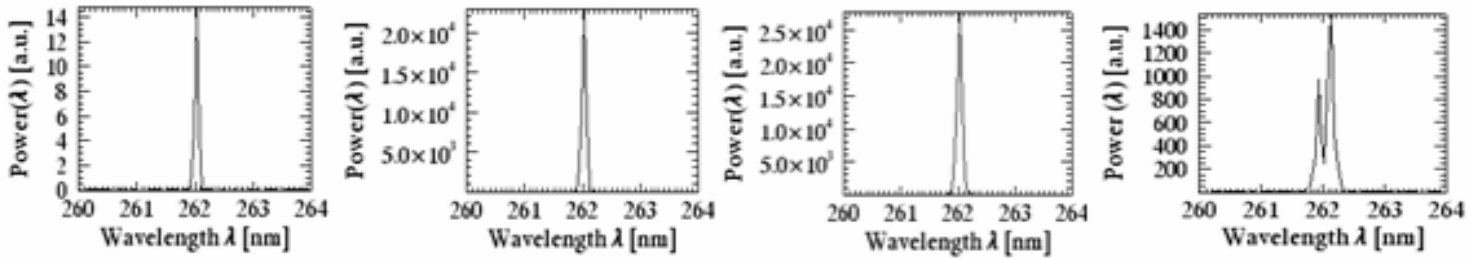
Sensitivity on electron beam parameters

Currently, the undulator system is only about 10m long, therefore, we study the sensitivity of output power at the exit of the undulator system on electron beam parameters.

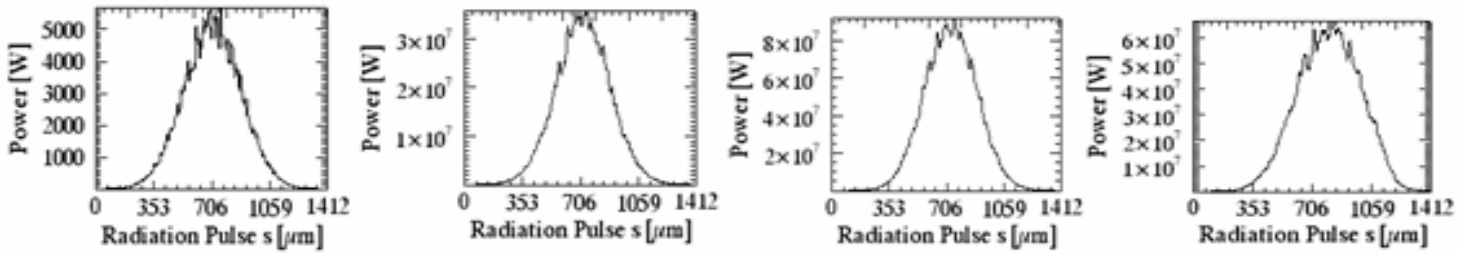
262nm HGHG FEL



the optimal HGHG FEL performance at 262nm wavelength



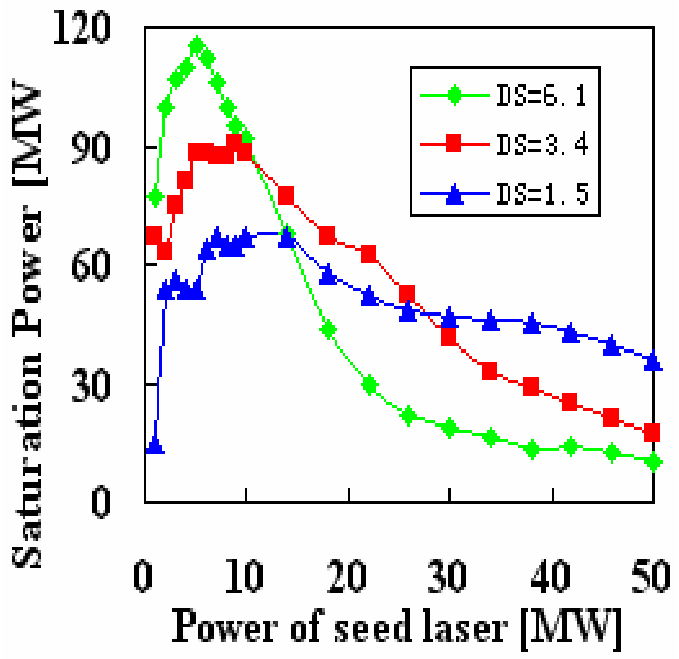
262nm HGHG FEL radiation spectrum at four typical radiator positions

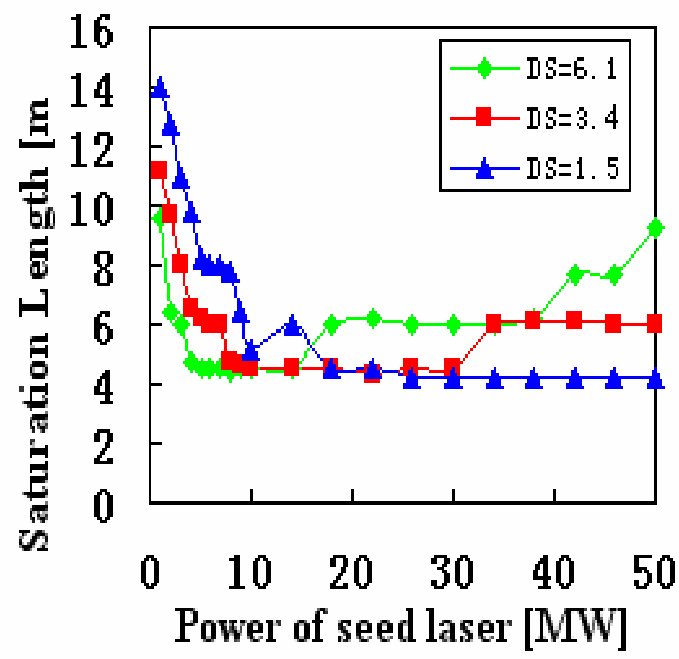


262nm HGHG FEL radiation pulse at four typical radiator positions

262nm HGHG FEL

Stability depending on DS and seed laser





Status of main components

- **Linac system: existing 100MeV linac**

  (commissioned last year)

- **Photocathode Gun (first one, fabricated and tested,**

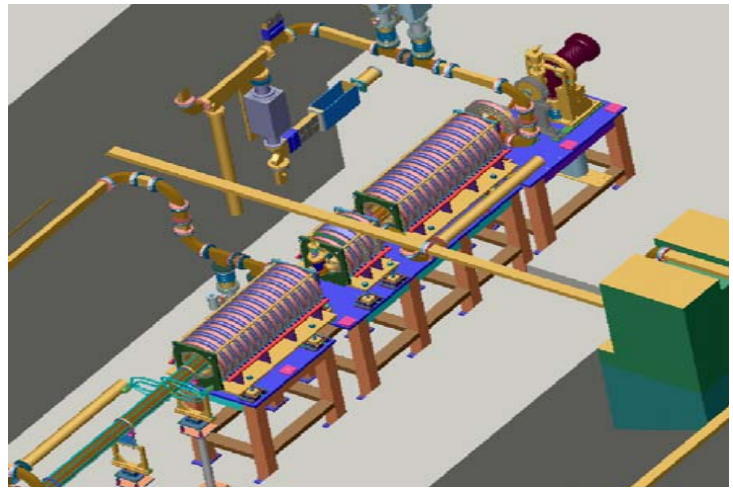
  second one being fabricated)

- **Gun laser (installed and being commissioning)**
- **Undulator (first segment, fabricated and measured)**
- **BC1 (fabricated and measured)**
- **Beam Diagnostic (CTR being tested, YAG-pop-in being fabricated)**

Existing 100MeV linac

100 MeV Linac has been successfully commissioned in 2005

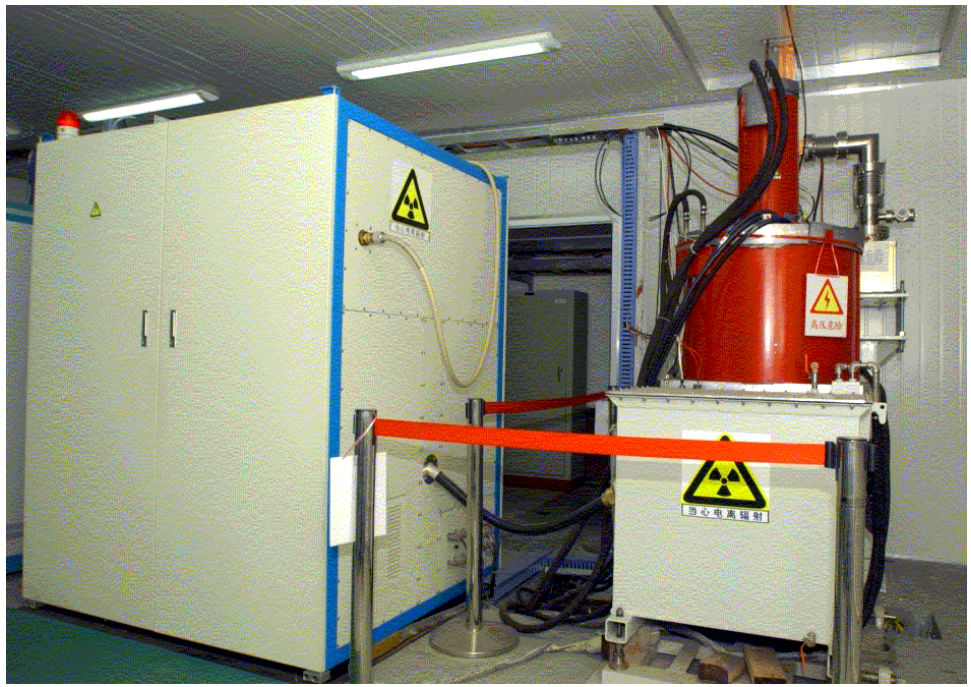
100kV-ns grid gun and 15MeV buncher



Existing 100MeV Linac

Existing 100MeV Linac

Klystron modulator with high voltage pulse amplitude stability of 0.1% and top unflatness of 0.25% has been developed for SDUV FEL

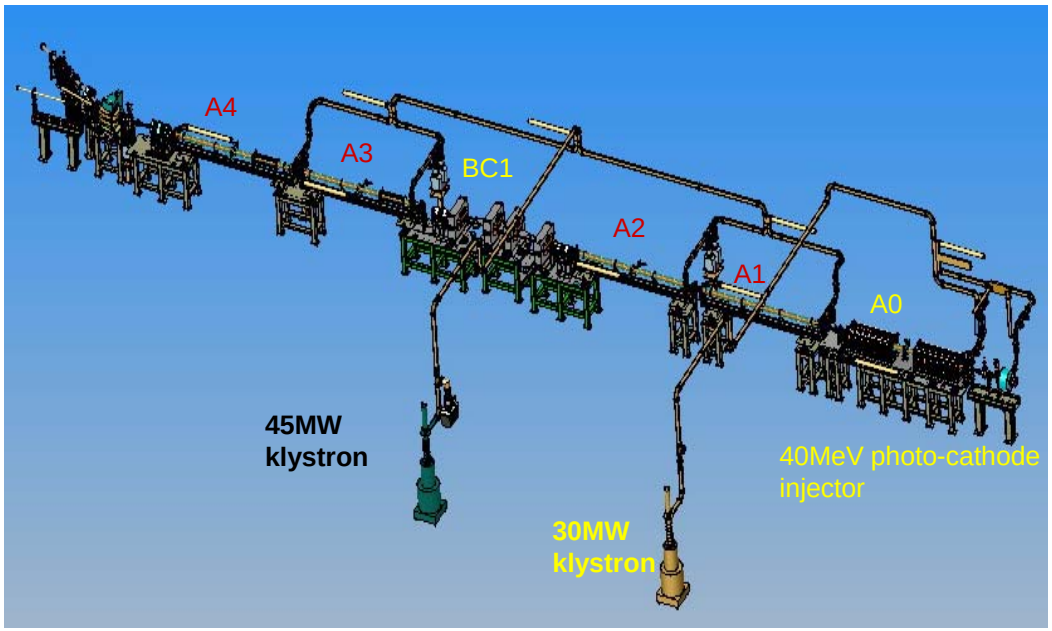


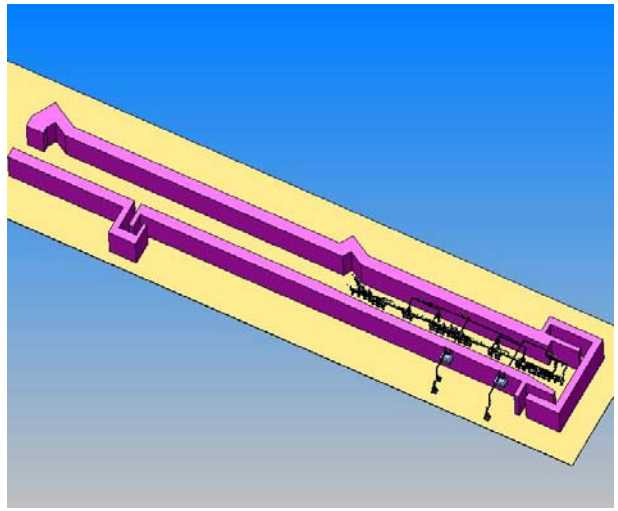
Existing 100MeV Linac

Control room(Software based on EPICS)

Power supplies for focusing solenoids and magnets

Upgrade Linac to 160MeV for phase 1





100kV-ns grid gun and 15 MeV buncher of the existing 100MeV Linac will be replaced by a 40MeV injector consisting of photo-cathode rf gun and an accelerating section in 2006

30MW RF source for 40MeV injector

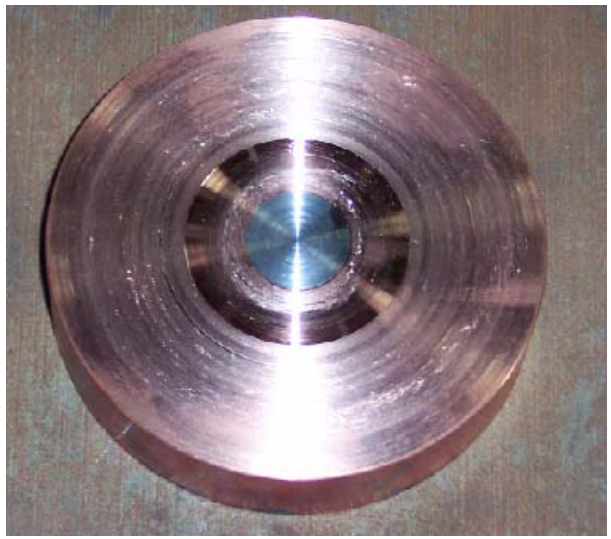
30MW RF source for 40MeV photo-cathode injector is being tested by collaboration with IHEP.

Photocathode RF Gun

- Main parameters: beam energy 4~5MeV
  bunch charge 1.0nc
  normalized emittance 3~6mm.mrad
  bunch length ~8ps
  repetitive rate 10~25Hz
- Design is based on the 1.6 cell s-band rf gun developed at BNL DUV FEL , including emittance compensating solenoid
- Use Magnesium (Mg) or Copper (Cu) photo-cathode
- Developed by Institute of High Energy Physics (IHEP) in collaboration with Tsinghua University
- Commissioning is expected to start in Sept. 2006

Photocathode RF Gun

1.6 cell s-band RF gun (IHEP)



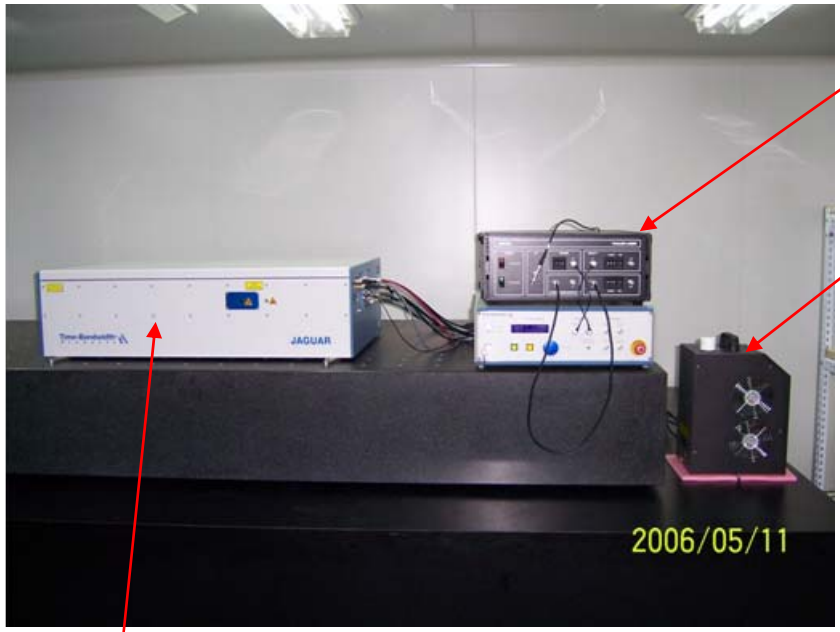
Mg Photo-cathode with 12mm diameter(Tsinghua Univ.)

Laser system for RF gun

- Jaguar-QCW-1000 Laser (+FHG) and Synchronizer CLX-1100 (Switzerland Time-Bandwidth Products，Inc) has been delivery
- Commissioning since February 2006
- Main parameters

Laser medium	Nd:YLF
Wavelength	1047nm/262nm
Pulse length	12ps/8ps
Repetition frequency	0~100Hz
Energy/pulse	1mJ/0.25mJ
Energy stability (p-p)	1%rms
Time stability	0.5ps rms

Laser for RF Gun



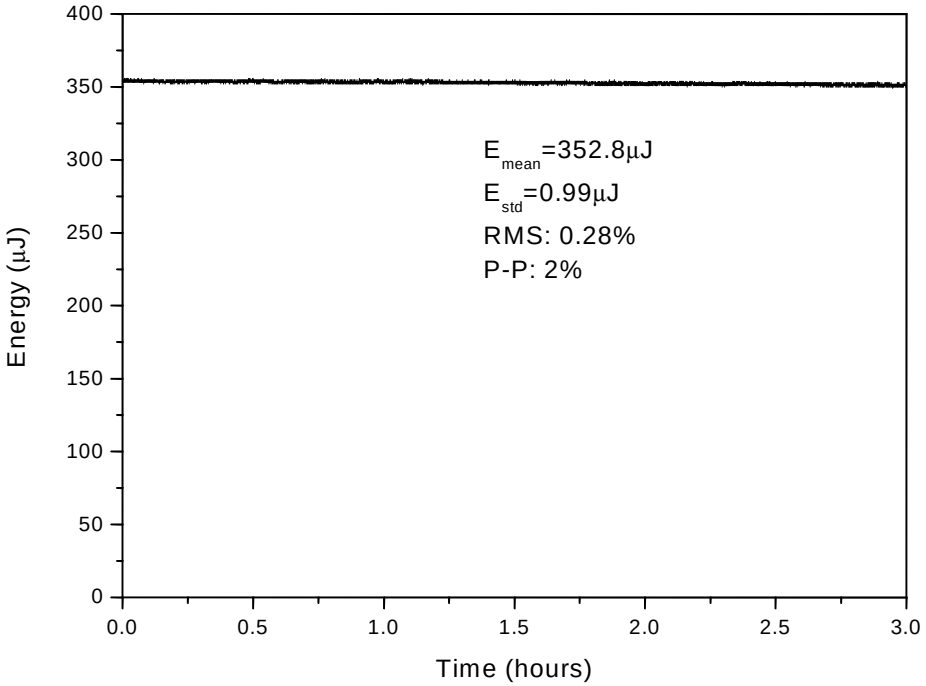
PS Controller and Synchronization

Cooling

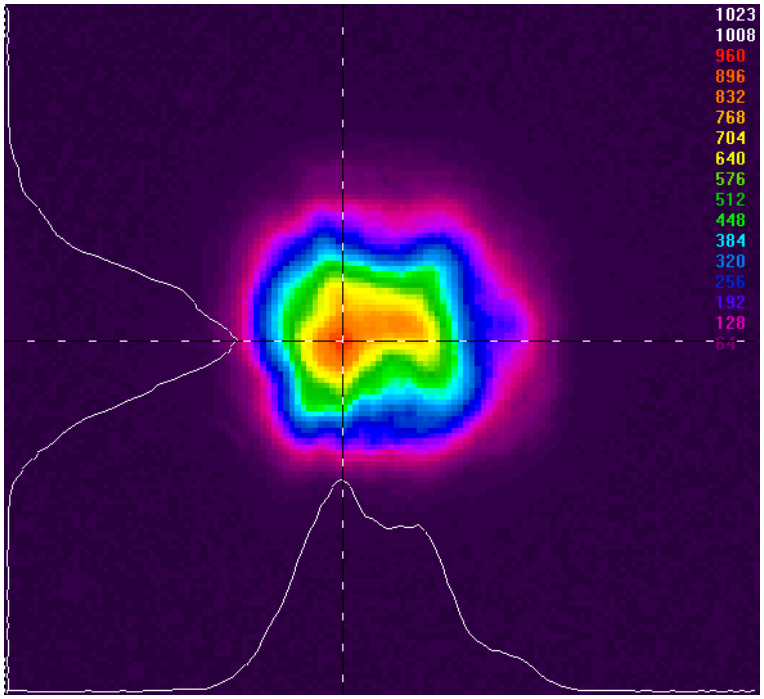
Jaguar-QCW-1000 Laser

Laser inside

Laser for RF Gun



Energy stability of 262nm laser output

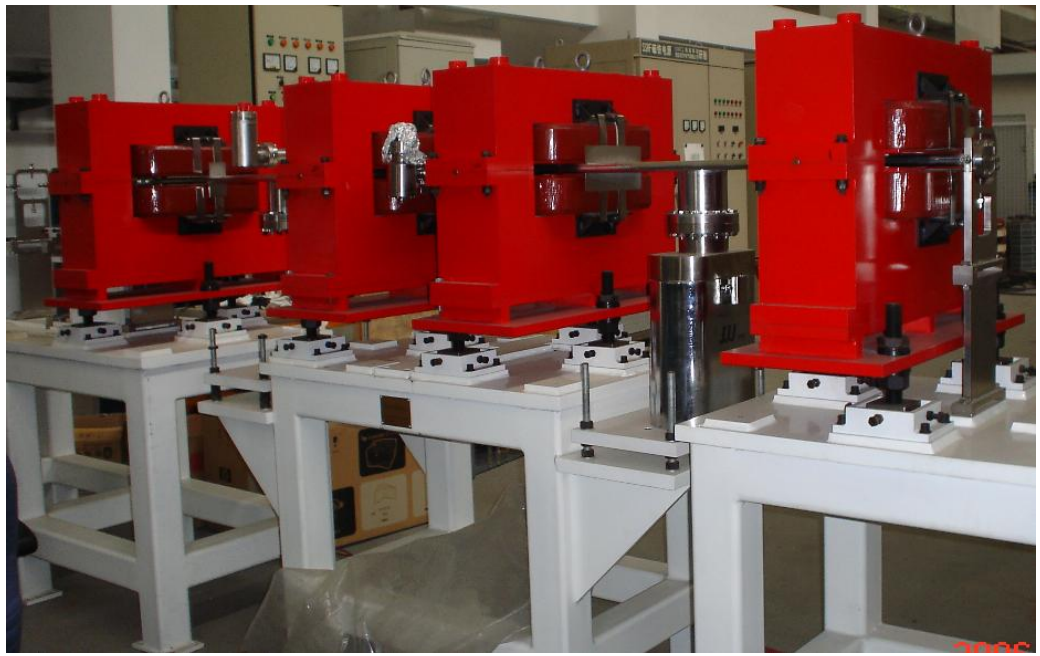


Beam profile of 262nm laser output

Beam pointing: 25urad

Bunch compressor Ⅰ

- **BC1(four-dipoles magnetic chicane)**

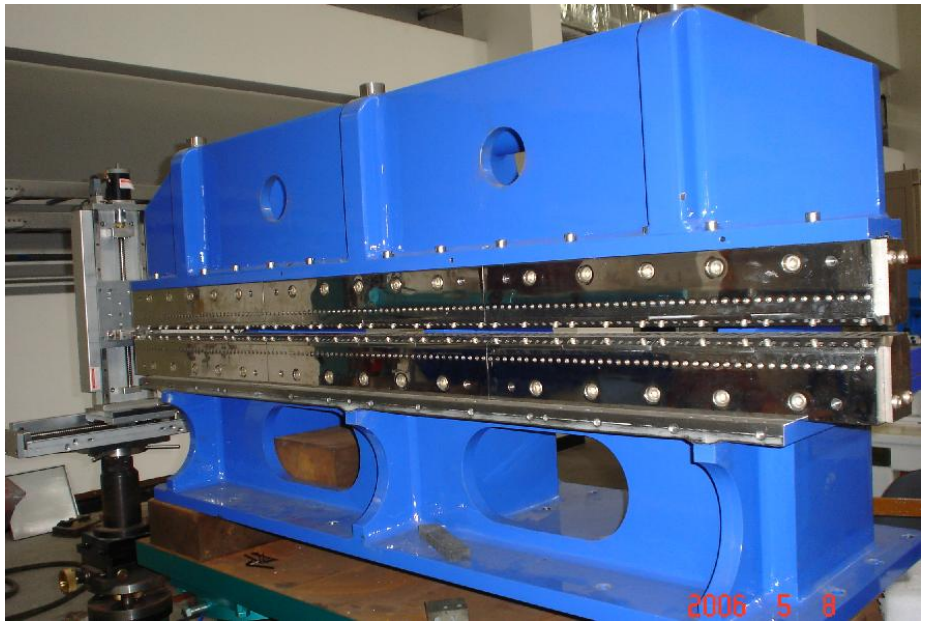


Main parameters

- **Beam energy 100 MeV**
- **Energy spread 1%**
- **Bunch length 8~9/3~4ps**
- **Compression ratio 2~3**
- **Bend angle (deg) 7~14**
- **Maximum field 4000 Gs**
- **R_{56}(Max.) -100 mm**

Undulator System

- **Undulator (developed by NSRL) is under construction**



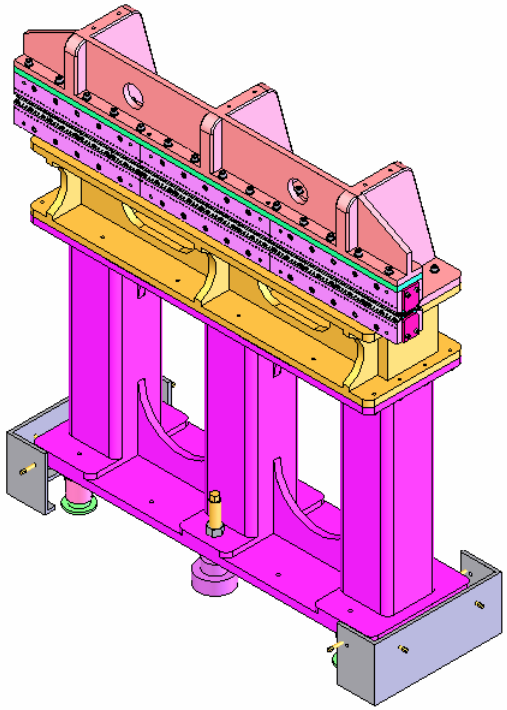
The First segment has been fabricated and measured)

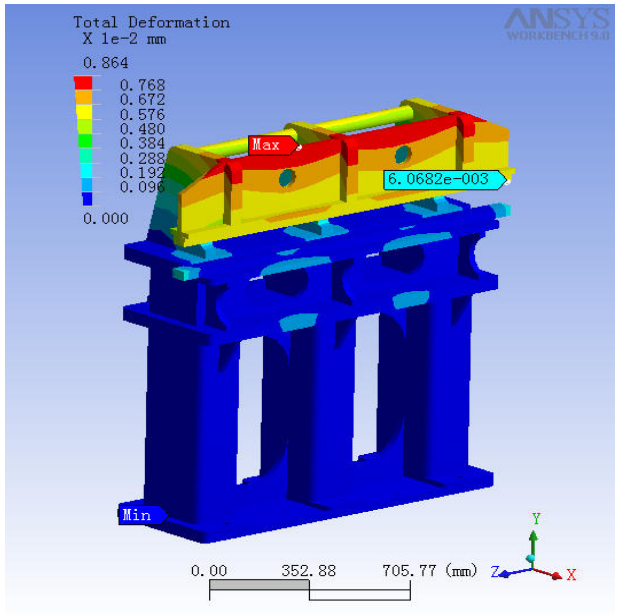
Main parameters

Period length	25mm
Gap	10mm
Peak Field	0.6T
K	1.4
Type	hybrid/Nd-Fe-B
Segment length	1512.5mm
Space between segments	250mm
Segment number	6
First field integral	0.1T-mm
Second field integral	10T-mm*mm

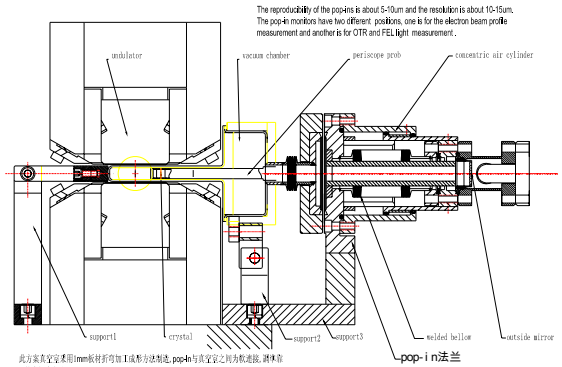
Undulator System

Undulator 3D Layout and deformation analysis by ANSYS code

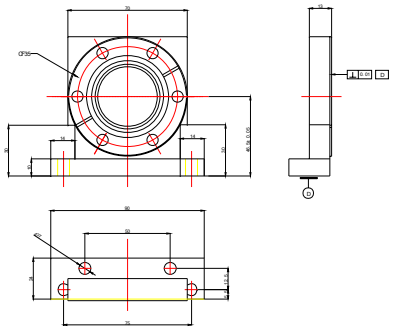




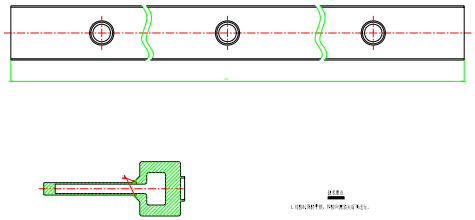
Undulator Vacuum Chamber

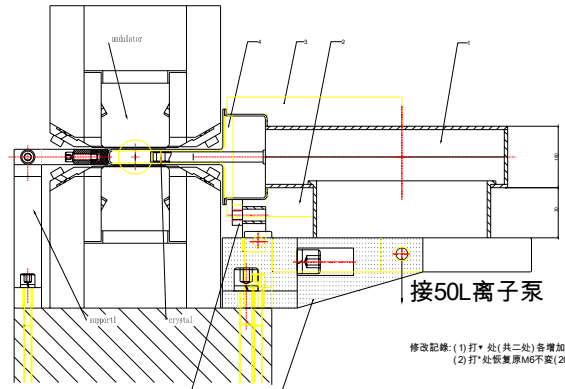


pop-in接口组装(UVD-03-00)
安装示例(甲)

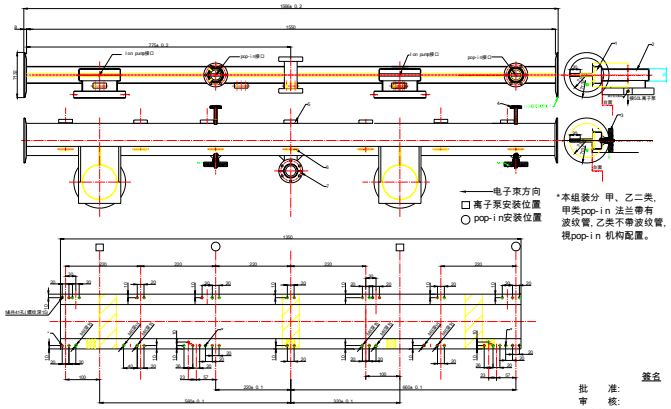


pop-in法兰(UVD-03-06)





离子泵接口组装(UVD-02-00)



修改記錄: (1) 打▼ 处(共二处) 各增加一个M6螺孔(2006. 1. 10)
(2) 打*处恢复原M6不变(2006. 1. 16)

7	UVD-07	预抽气及视窗管道	1	Ti ± 304	
6	UVD-06	抽气管道块	1	Ti ±	
5	UVD-05	束流管道块	1	Ti ±	
4	UVD-04-00	视窗座	2	Ti ± 304	
3	UVD-03-00	pop-in接口组装	2	Ti ± 304	
2	UVD-02-00	离子泵接口组装	2	Ti ± 304	
1	UVD-01-00(A,B)	波通器真空盒 (A,B)	1	Ti ± 304	

批 准:
审 核:
真空核定:
机械核定:
束测核定:

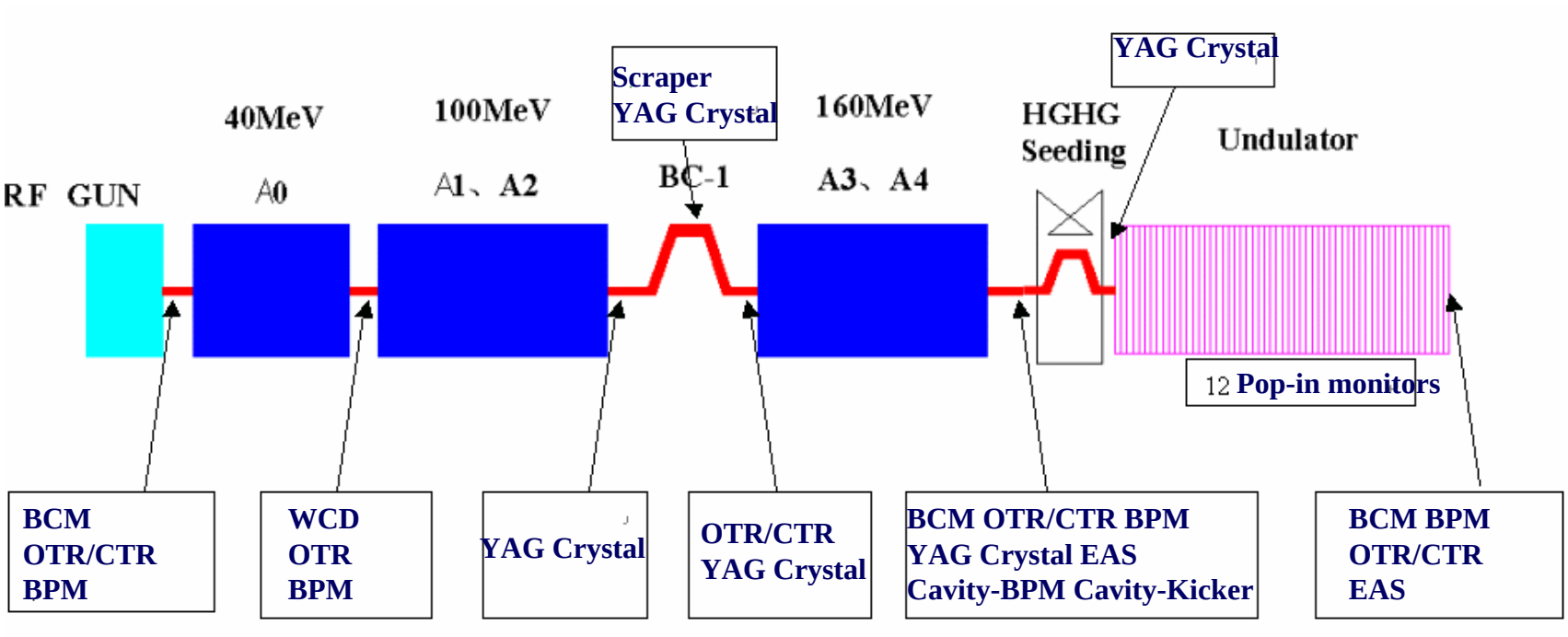
签名 日期

波通器真空盒总装
(合)

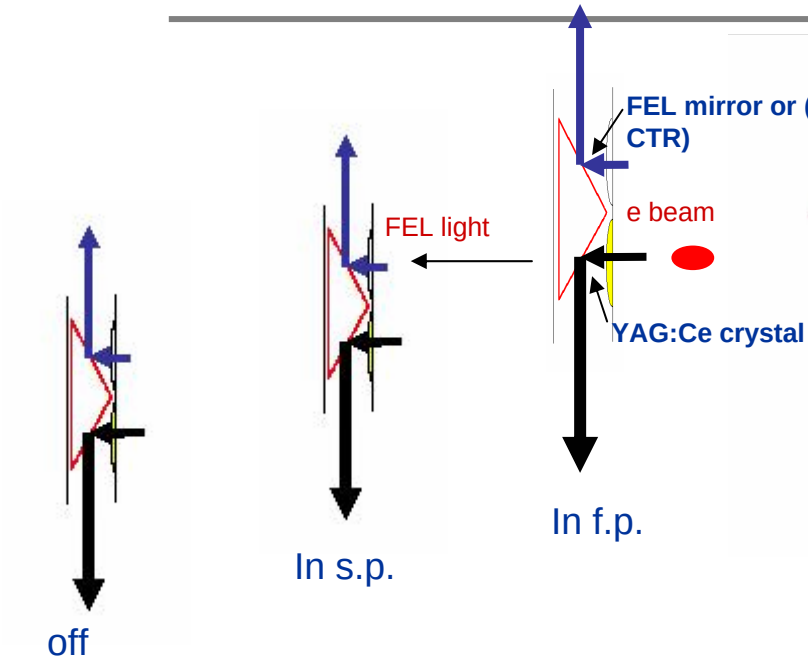
UVD(合)-00

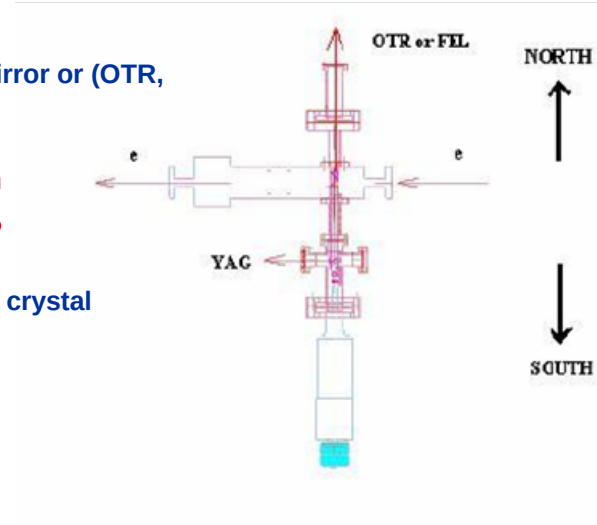
Beam diagnostics for Phase 1

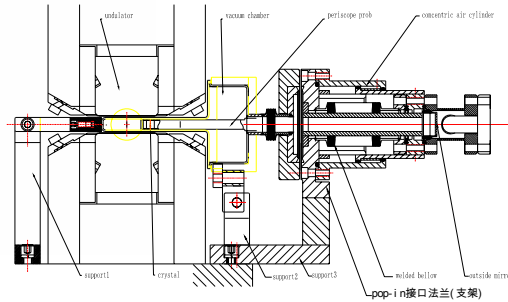
Distribution of diagnostic instruments for SDUV-FEL (Phase-I)



Pop-in Monitor in Undulator





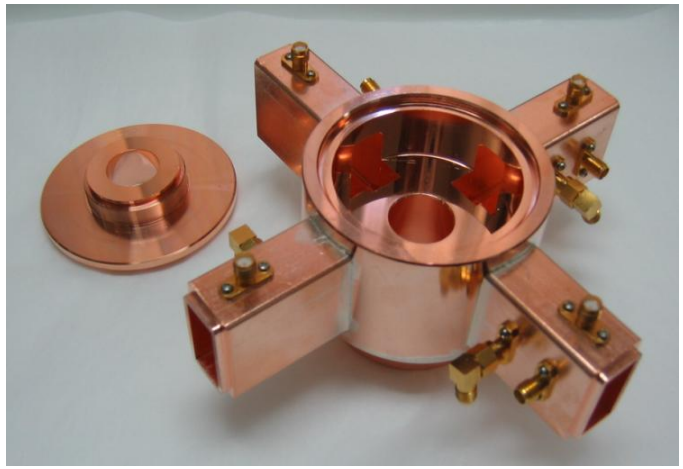


Pop-in monitor

- BNL-DUV-FEL type Pop-in monitors in undulator will be used for FEL lasing experiments
- Each pop-in monitor has two different inserting positions, which are used for two different purposes : in first position(in f.p.) electron beam is blocked by YAG crystal(Cerium doped),and to image electron beam; in second position(in s.p.) pop-in monitor will be inserted less so that a 45 degree mirror reflects FEL light to north side of undulator

Beam Position Measurement

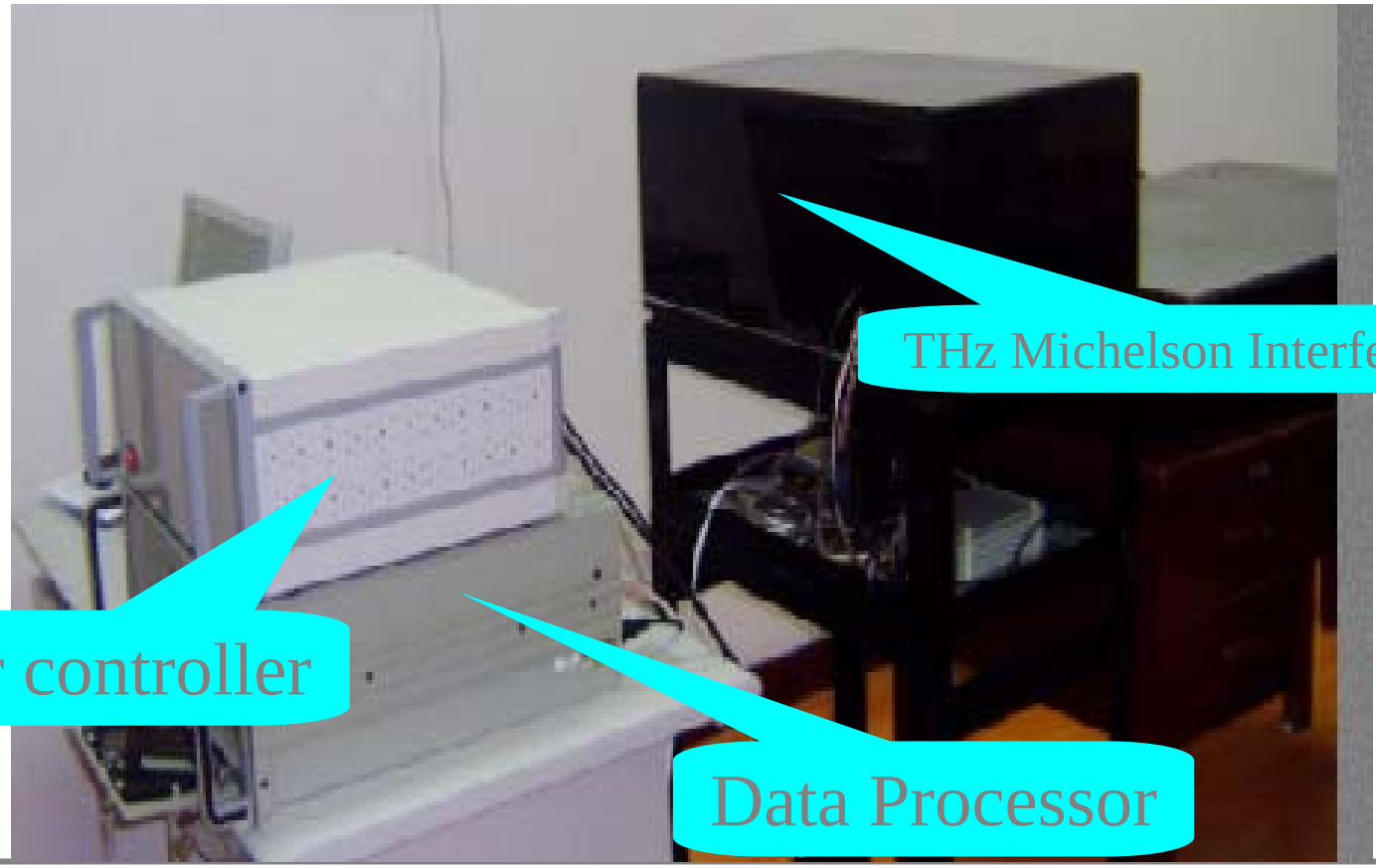
✓**CBPM**



5.712GHz

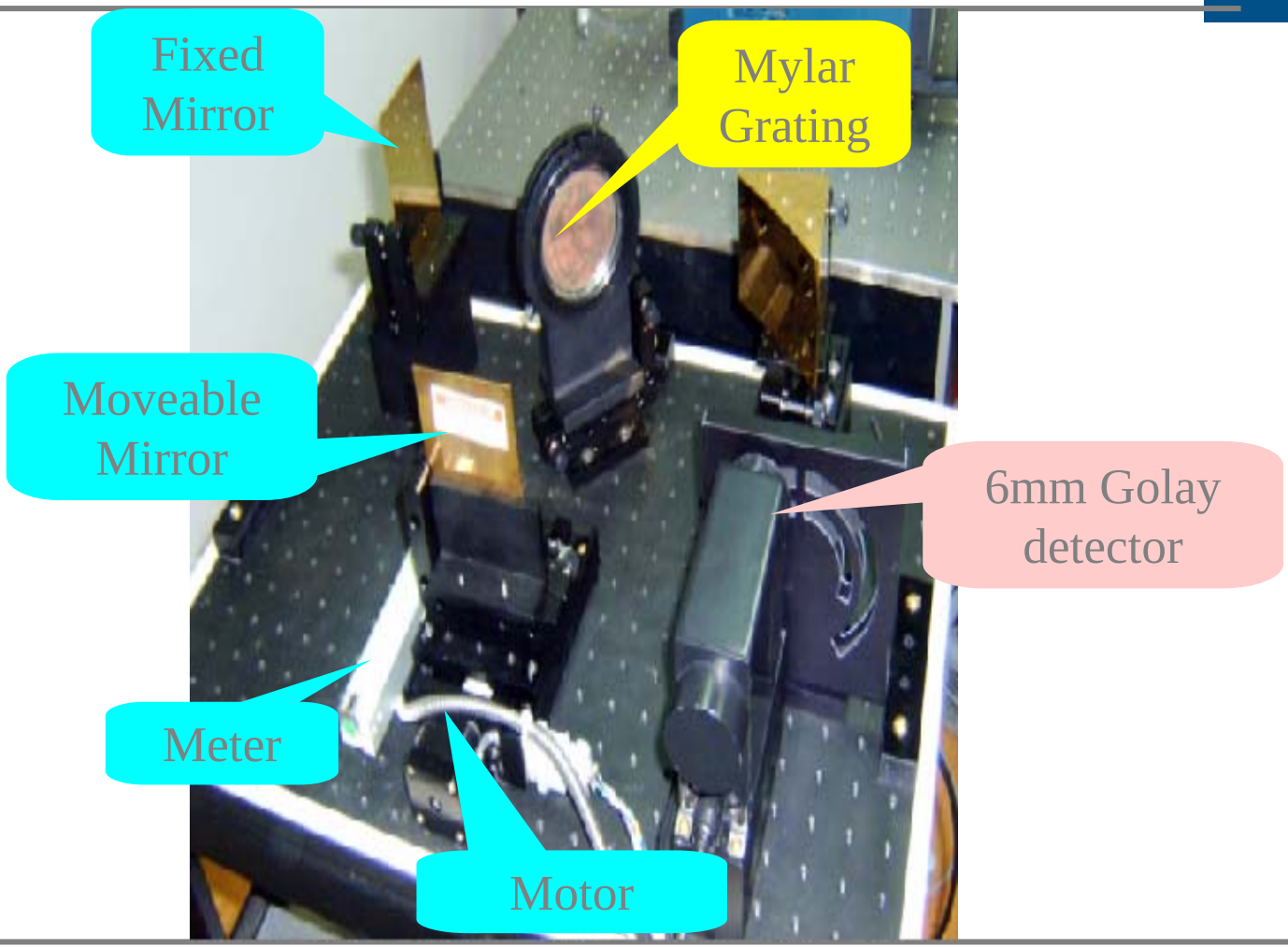
Beam bunch length measurement

(CTR developed by SINAP)



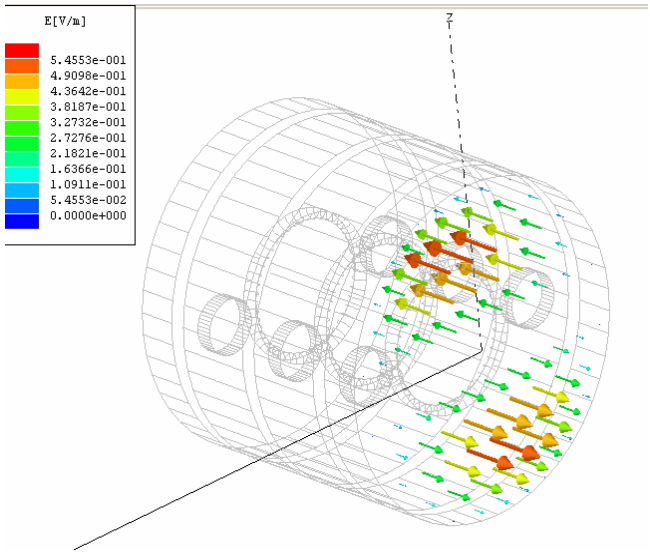
Beam bunch length measurement

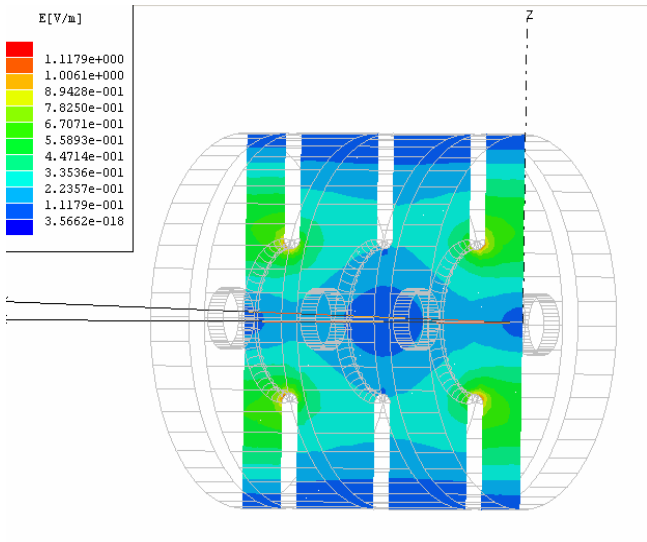
(CTR)



Beam bunch length measurement

✓**SLAC - LOLA studying by IHEP**





Vertical RF deflecting structure（one period) HFSS simulation


Thank you for your attention
谢谢！