SuperKEKB Review /
Electron gun and transport

Mitsuhiro Yoshida

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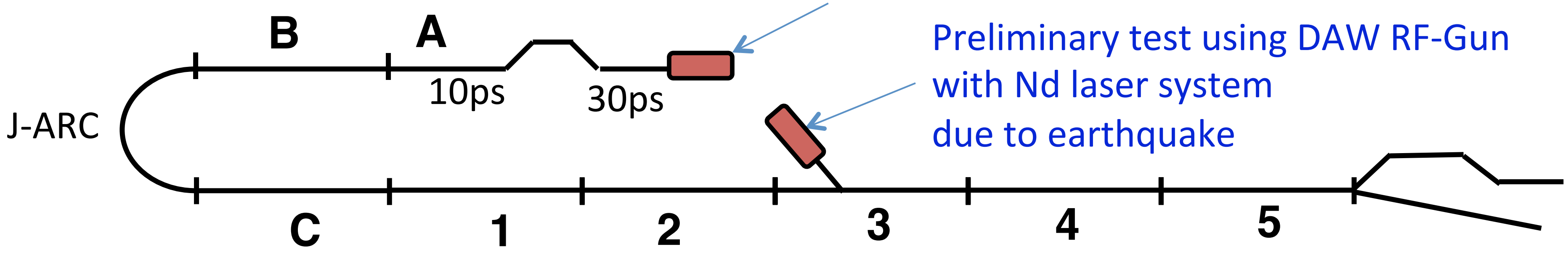
SuperKEKB upgrade for low emittance electron beam

High charge low emittance is required for SuperKEKB.

	KEKB obtained (e+ / e-)	SuperKEKB required (e+ / e-)
Beam energy	**3.5 GeV / 8.0 GeV**	**4.0 GeV / 7.0 GeV**
Bunch charge	e- → e+ / e- 10 → **1.0 nC / 1.0 nC**	e- → e+ / e- 10 → **4.0 nC / 5.0 nC**
Beam emittance (γε)[1σ]	**2100 μm / 300 μm**	**6 μm / 20 μm**

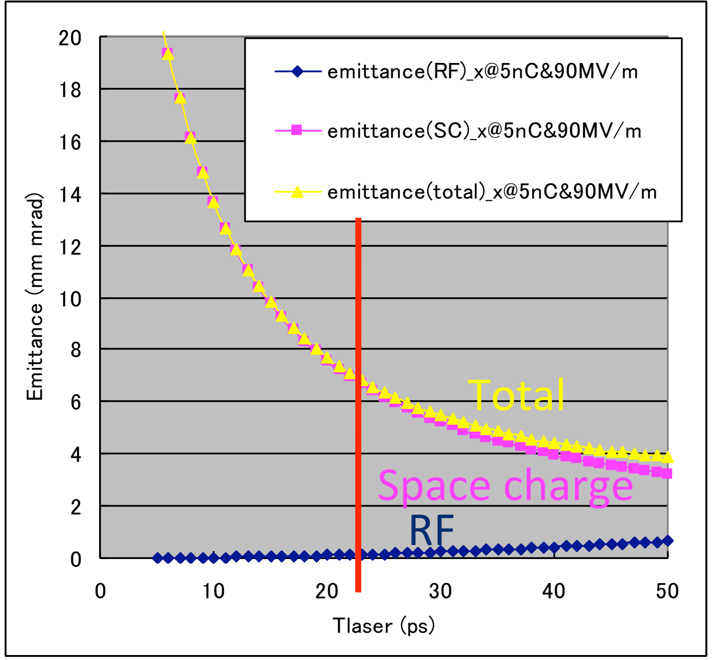
5 nC 10 mm-mrad electron beam generated by RF gun.
+ 10mm-mrad emittance preservation is required.



Quasi –travelling side couple RF-Gun
with Yb laser system

Preliminary test using DAW RF-Gun
with Nd laser system
due to earthquake

RF-Gun for 5 nC



- Space charge is dominant.
  - Longer pulse length : 20 - 30 ps
- Stable operation is required.
  - Lower electric field : < 100MV/m
- Focusing field must be required.
  - Solenoid focus causes the emittance growth.
  - **Electric field focus preserve the emittance.**

~~Epaxial coupled cavity~~ : BNL

Annular coupled cavity : Disk and washer / Side couple

S-band RF-Gun development strategy for SuperKEKB

- Cavity : Strong electric field focusing structure
  - **Disk And Washer (DAW)** => 3-2
  - **Quasi Traveling Wave Side Couple** => A-1

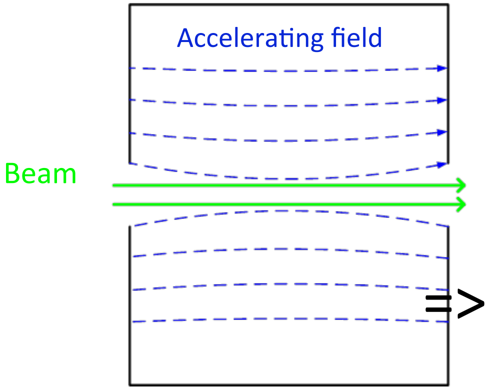
  => Reduce beam divergence and projected emittance dilution
- Cathode : Long term stable cathode
  - Middle QE (QE=$10^{-4} \sim 10^{-3}$ @266nm) and long lifetime
  - Solid material (no thin film) => Metal composite cathode

    => Started from LaB_6 (short life time)

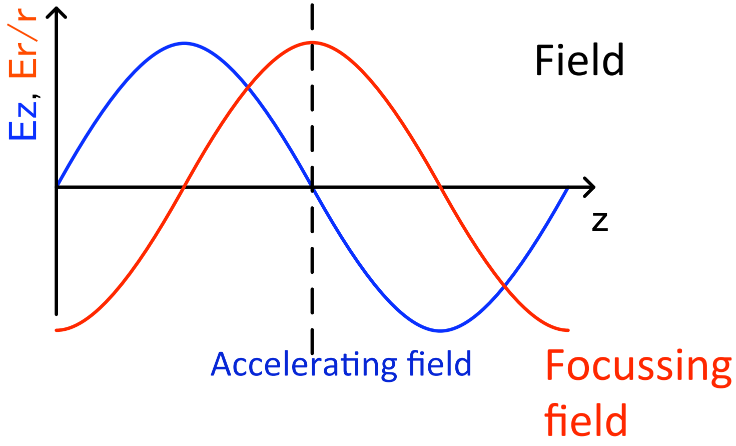
    => **Ir_5Ce has very long life time and QE>10^{-4}** @266nm
- Laser : Stable laser with temporal manipulation
  - LD pumped laser medium
    - Nd doped solid laser => 3-2
    - **Yb doped fiber and solid hybrid laser** => A-1
  - Temporal manipulation => Yb doped

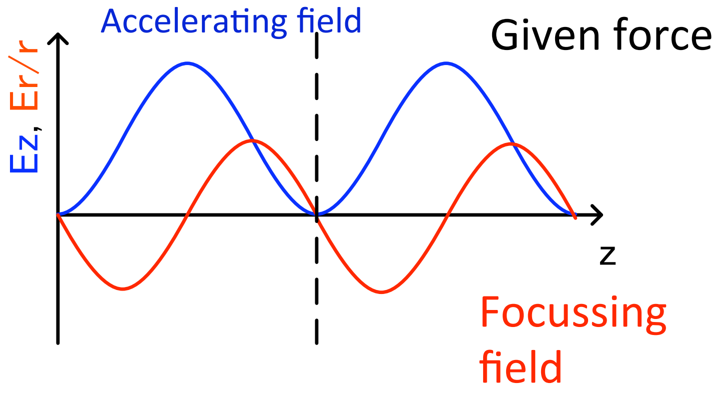
    => Minimum energy spread

Pill-box cavity

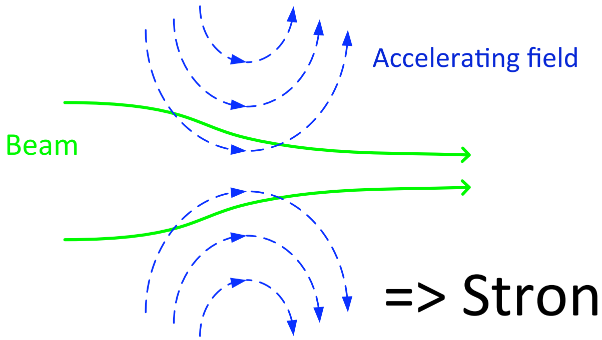


=> Weak focus

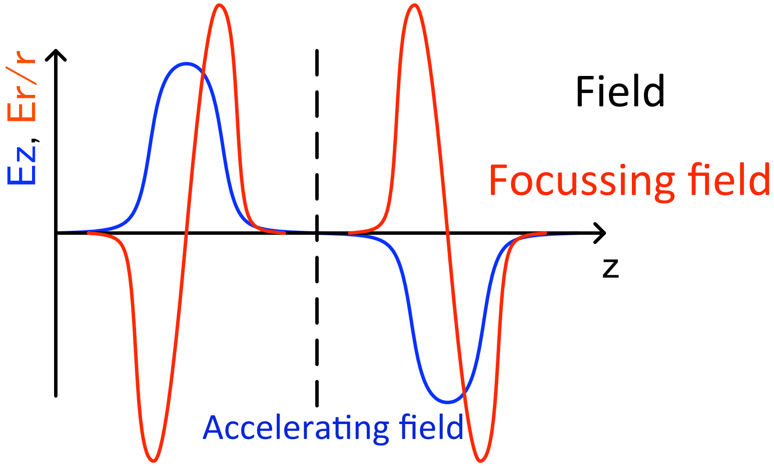


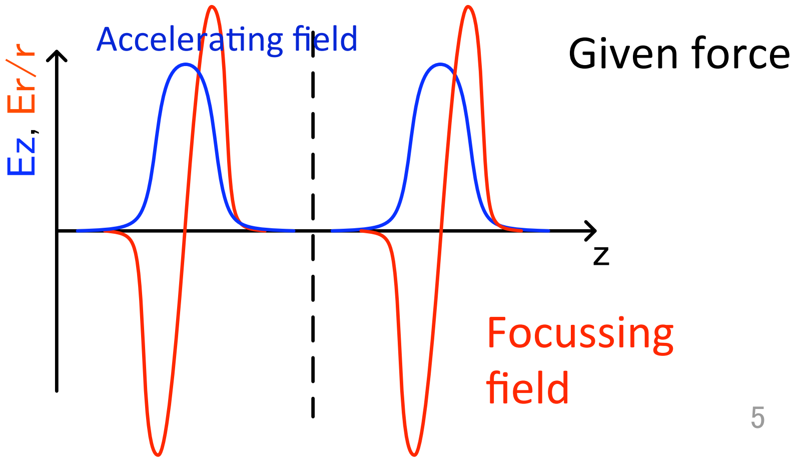


Annular coupled cavity with nose

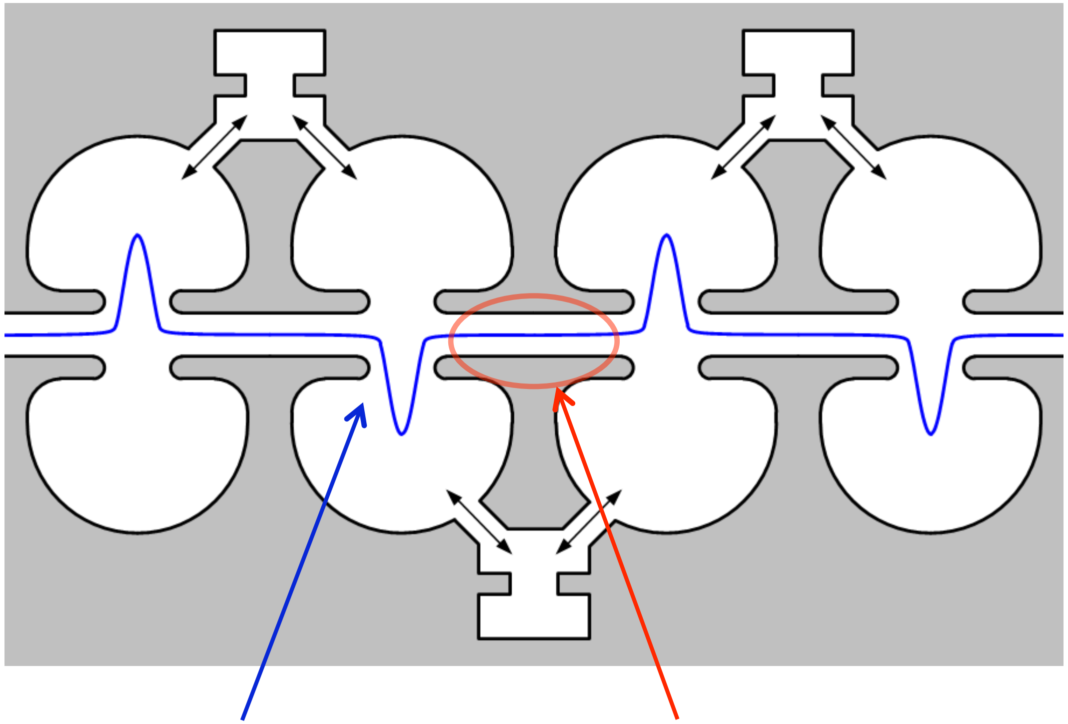


=> Strong focus



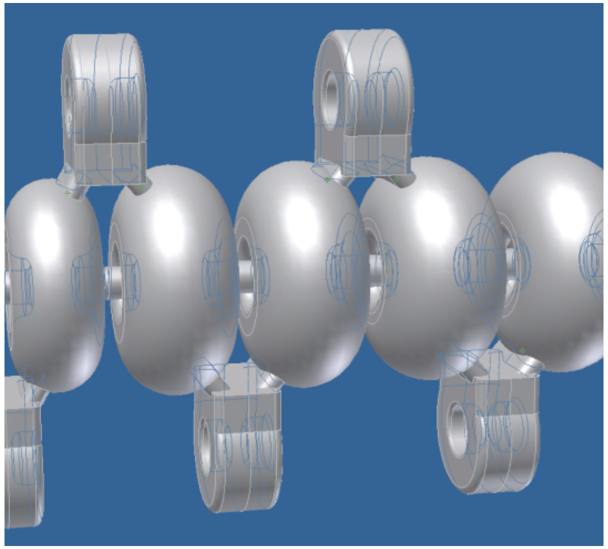


Closed gap makes focus field
Side coupled cavity is one candidate (or DAW / ACS / CDS …)



Concentrated field has focusing effect

This structure has long drift space

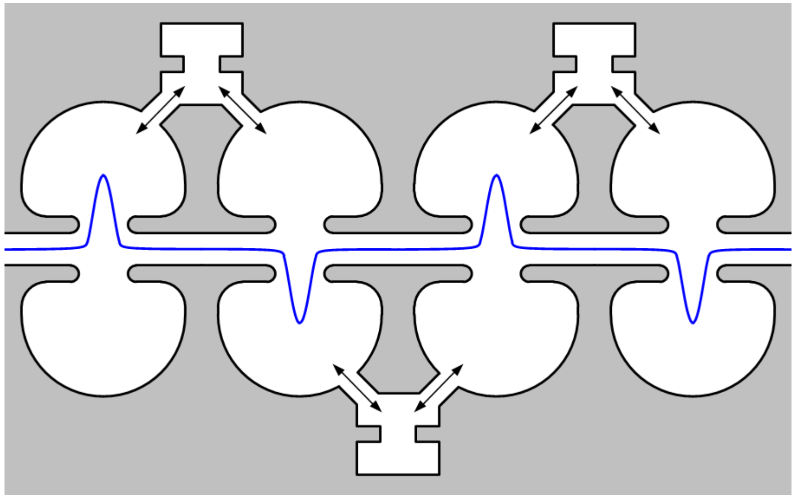


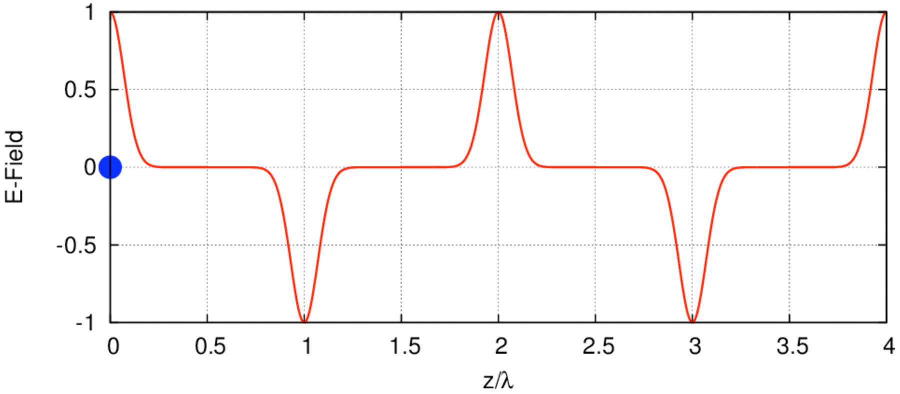
This structure has focusing field.

Long drift space is problem.

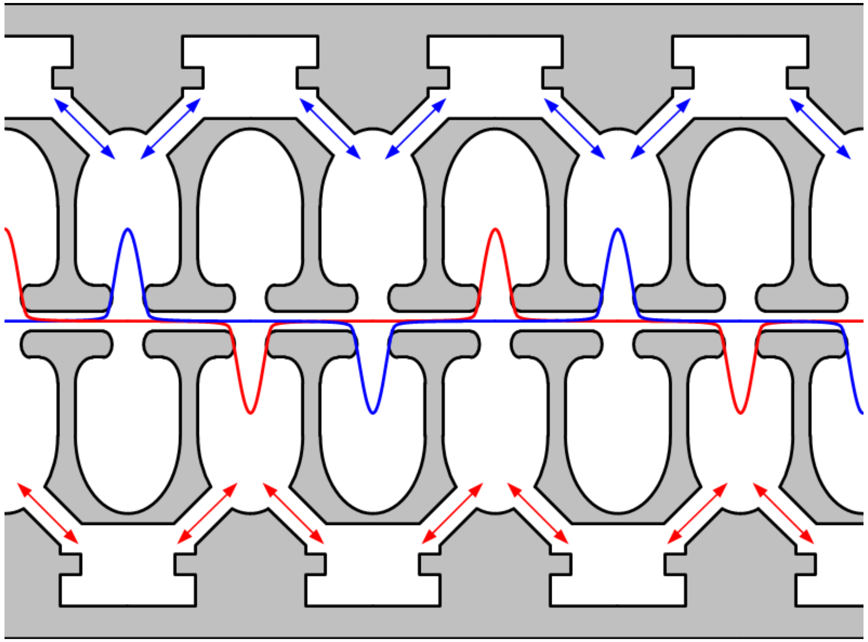
Design of a quasi traveling wave side couple RF gun

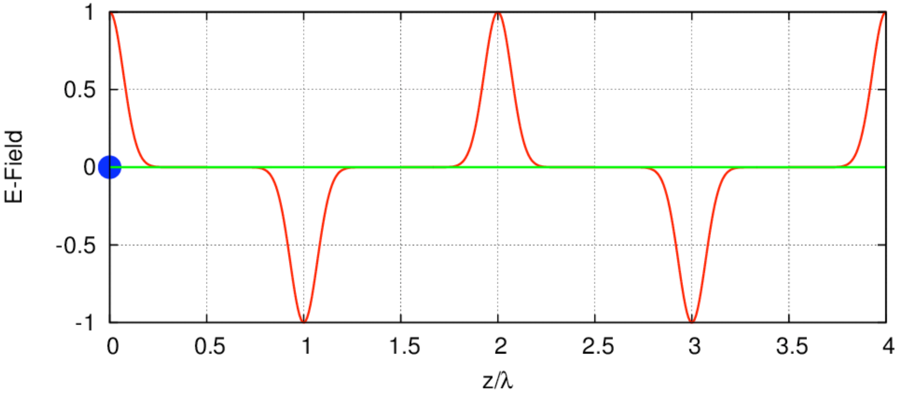
Normal side couple structure





Quasi traveling wave sidecouple structure

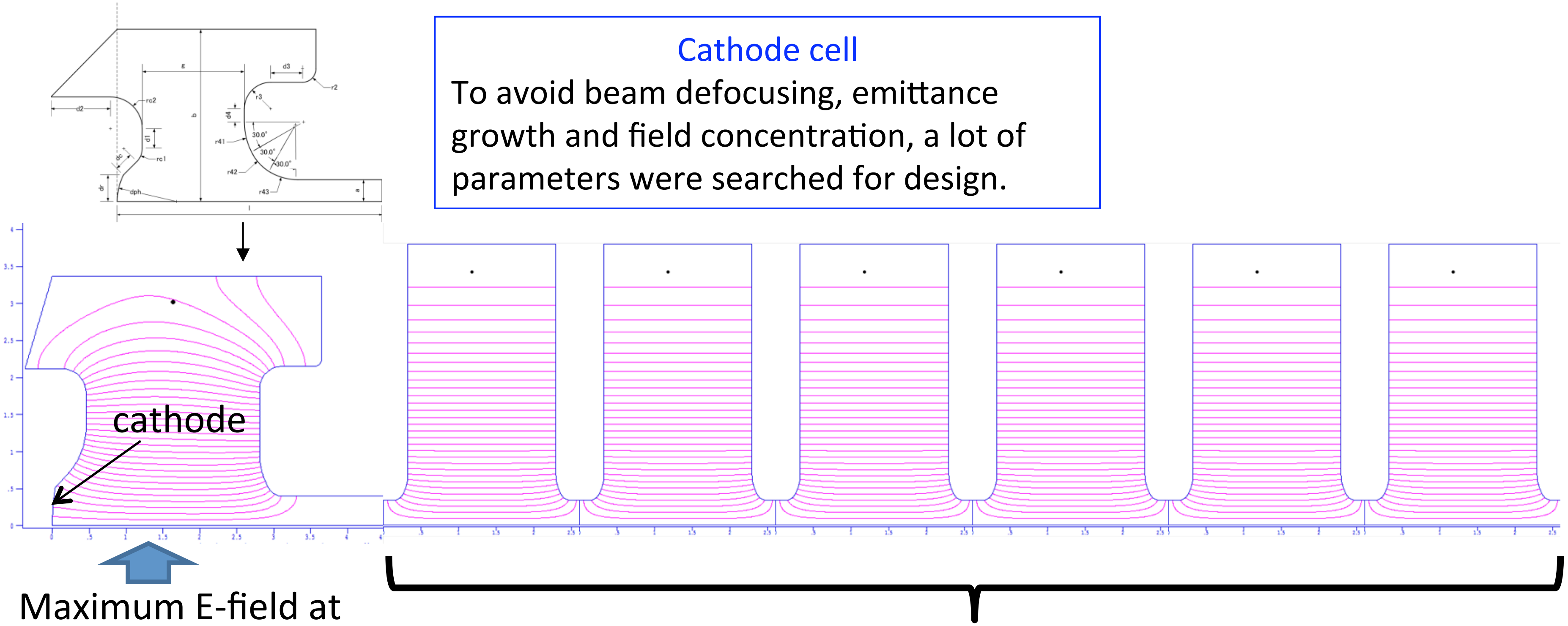




Quasi traveling wave side couple has stronger focusing and accelerated gradient than DAW.

Quasi traveling wave side couple RF gun

This RF gun has total of seven acceleration cavities. These are divided into two standing wave structure of 3 and 4 side coupled cavities respectively.



Cathode cell

To avoid beam defocusing, emittance growth and field concentration, a lot of parameters were searched for design.

cathode

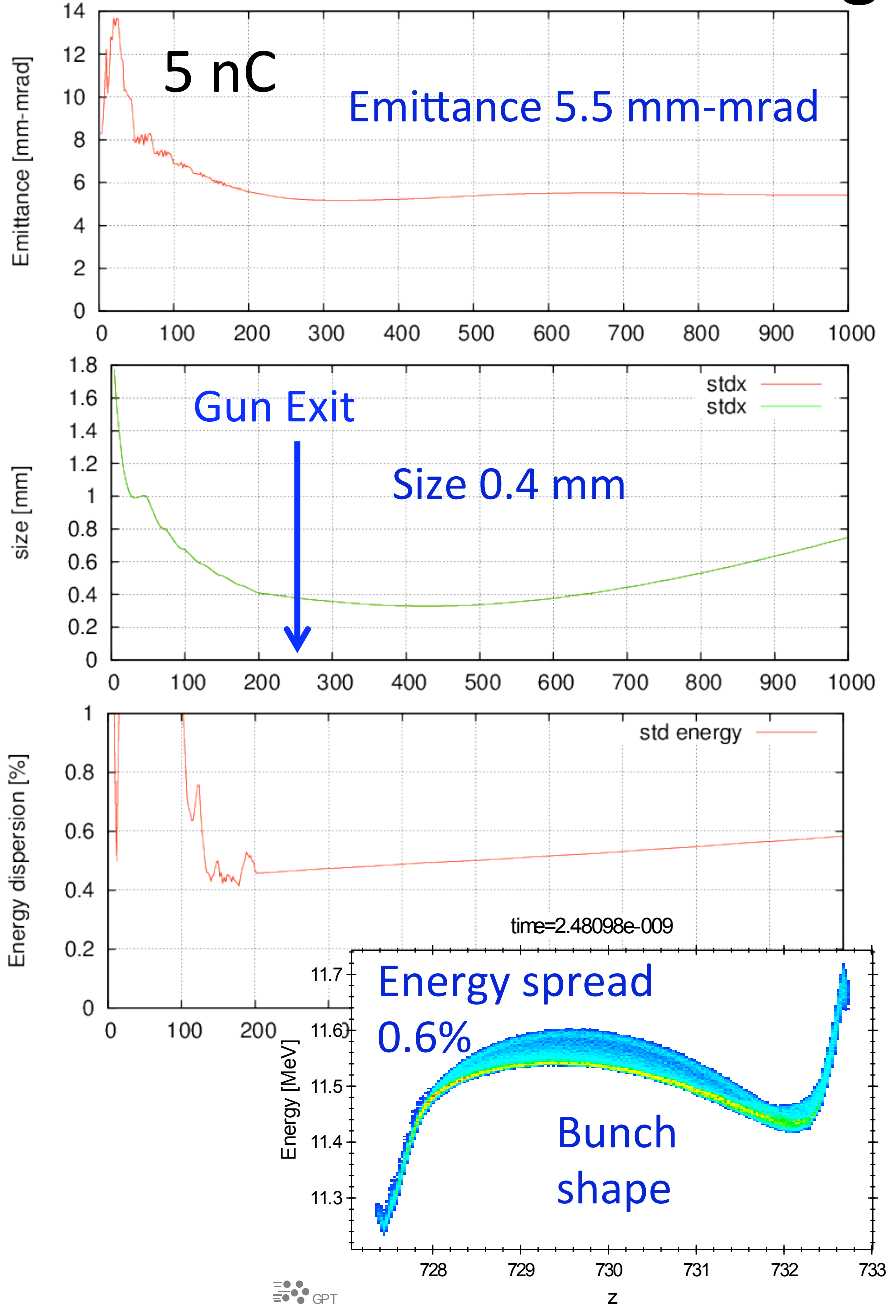
Maximum E-field at surface: 120 MV/m

Maximum E-field at surface: 100 MV/m

Emittance: 5.5 mm-mrad @ 5 nC

This RF gun can generate 10 nC beam

Beam tracking simulation result



5 nC

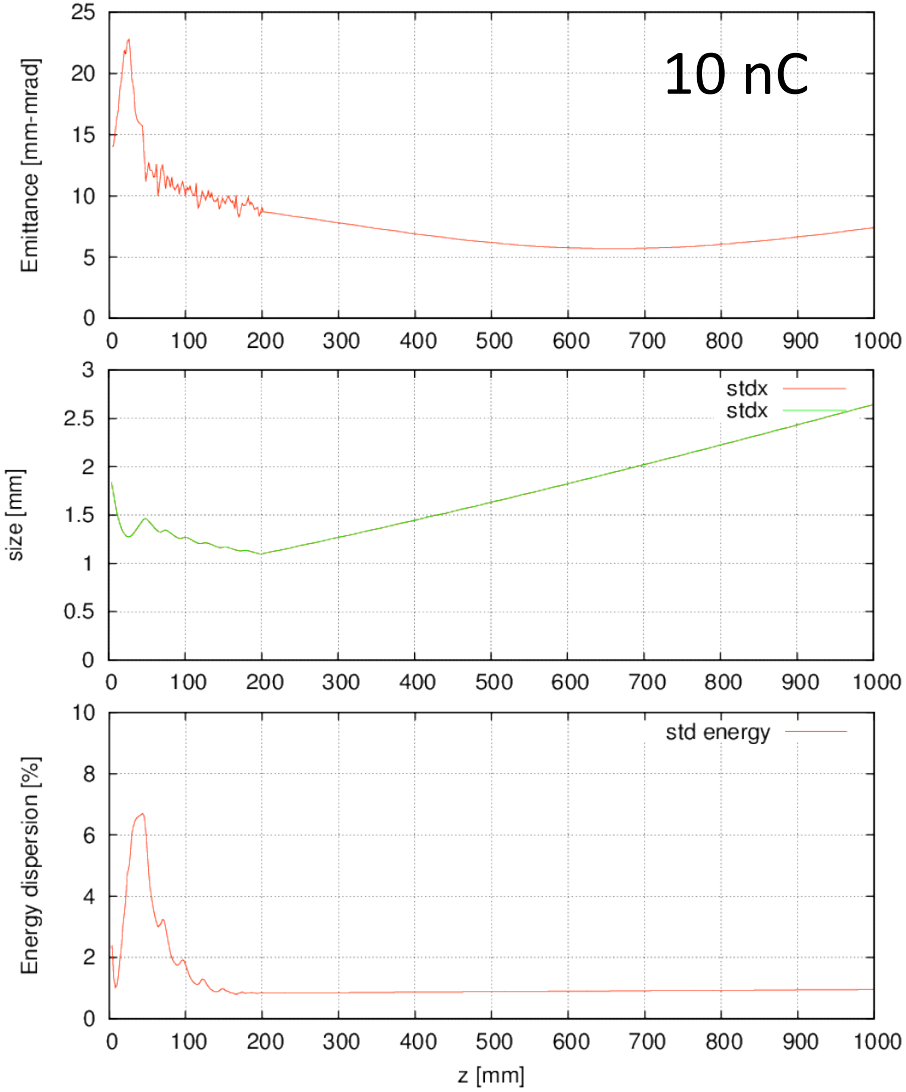
Emittance 5.5 mm-mrad

Gun Exit

Size 0.4 mm

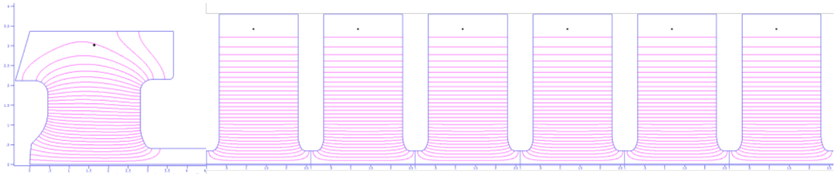
Energy spread 0.6%

Bunch shape

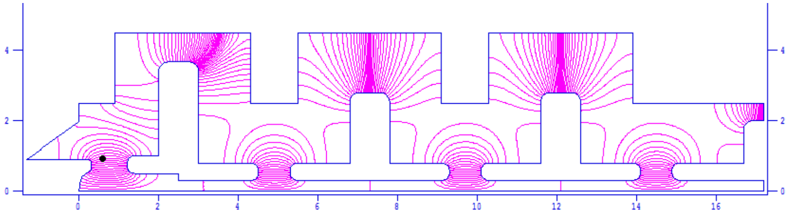


10 nC

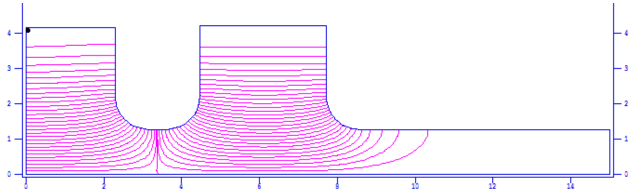
RF-Gun comparison



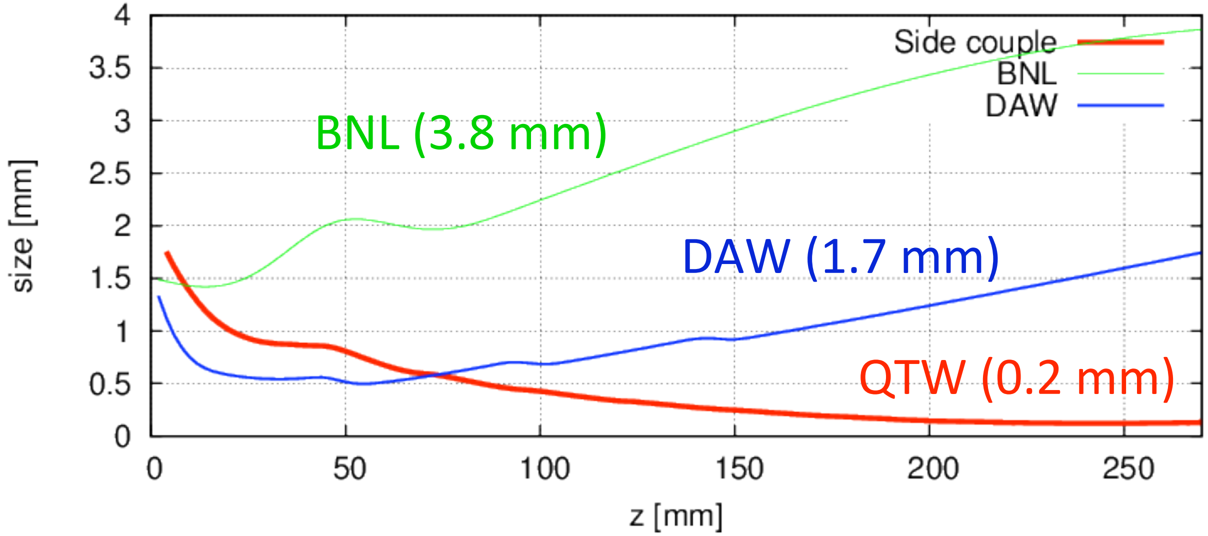
Quasi traveling wave side couple RF gun
(100 MV/m, 6mm-mrad, 13.5 MeV)



DAW-type RF gun
(90 MV/m, 5 mm-mrad, 3.2 MeV)

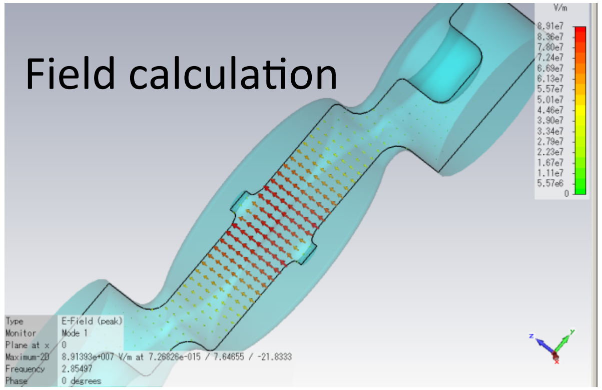


BNL-type RF gun
(120 MV/m, 11.0 mm-mrad, 5.5 MeV)

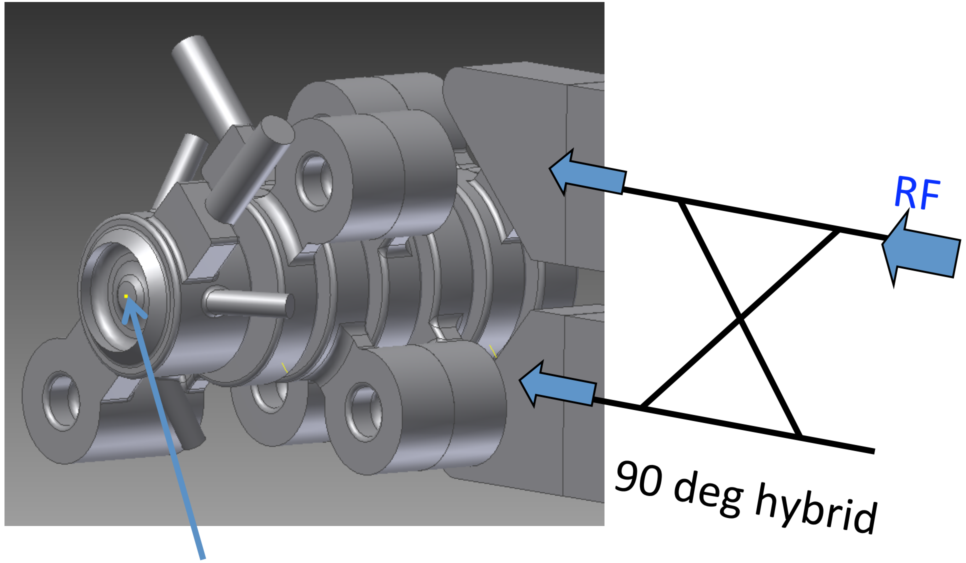


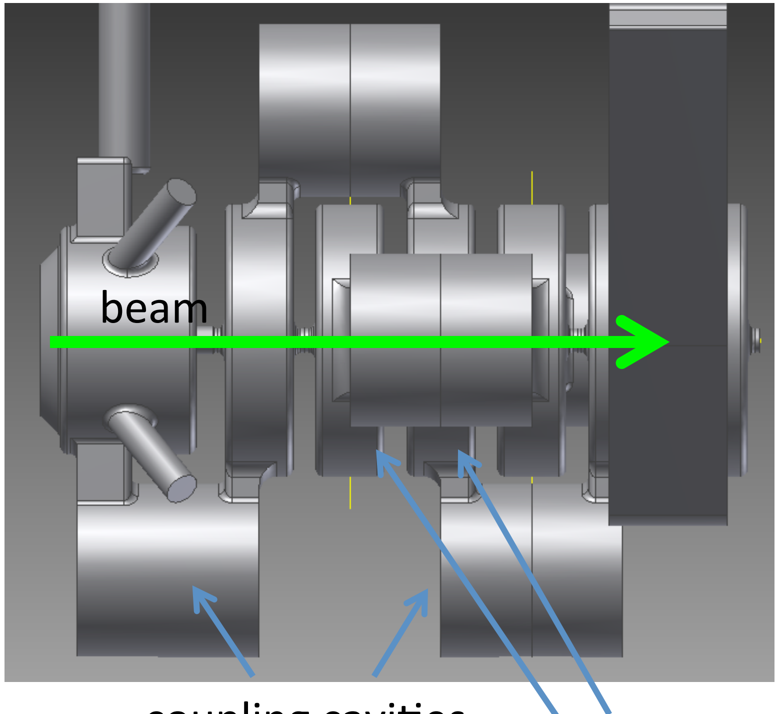
Beam Size

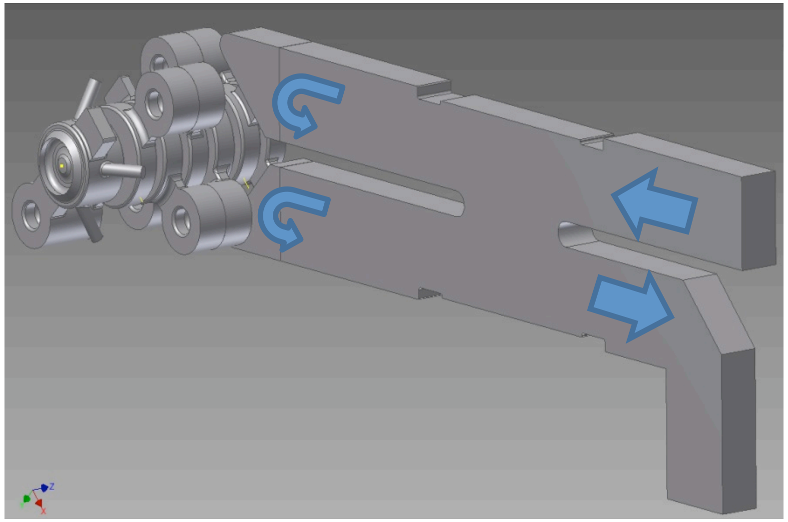
Cavity design



Type E-Field (peak)
Monitor Mode 1
Plane at x 0
Maximum-2D 8.91393e+007 V/m at 7.26826e-015 / 7.64655 / -21.8333
Frequency 2.85497
Phase 0 degrees

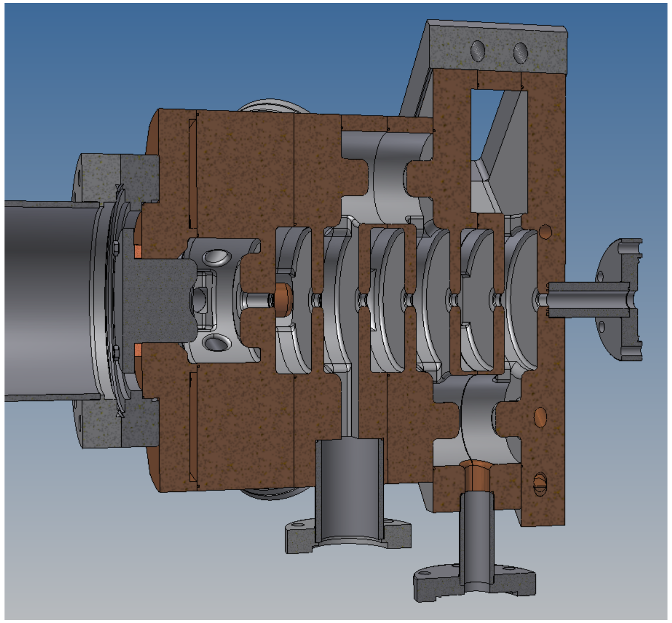


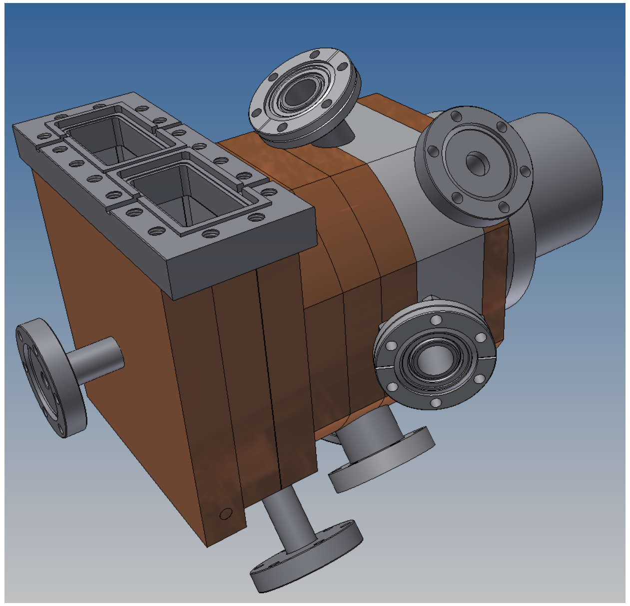


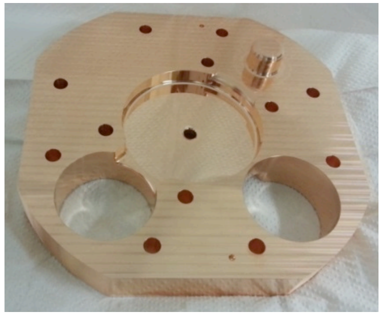


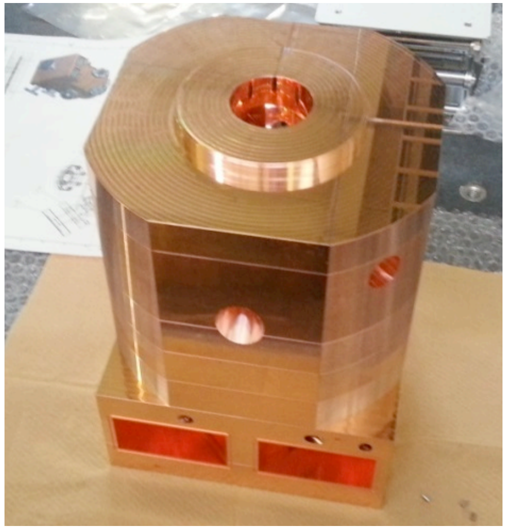
No reflection to klystron

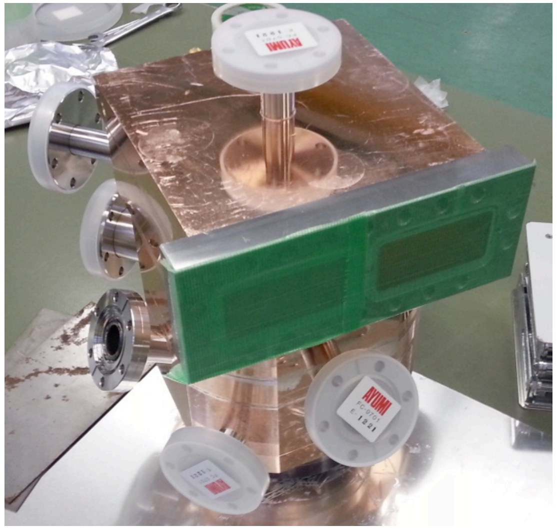
Mechanical design and manufacturing

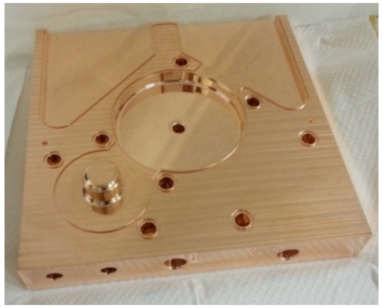






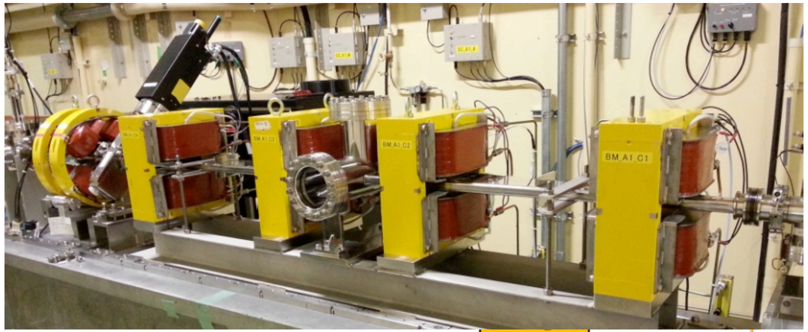






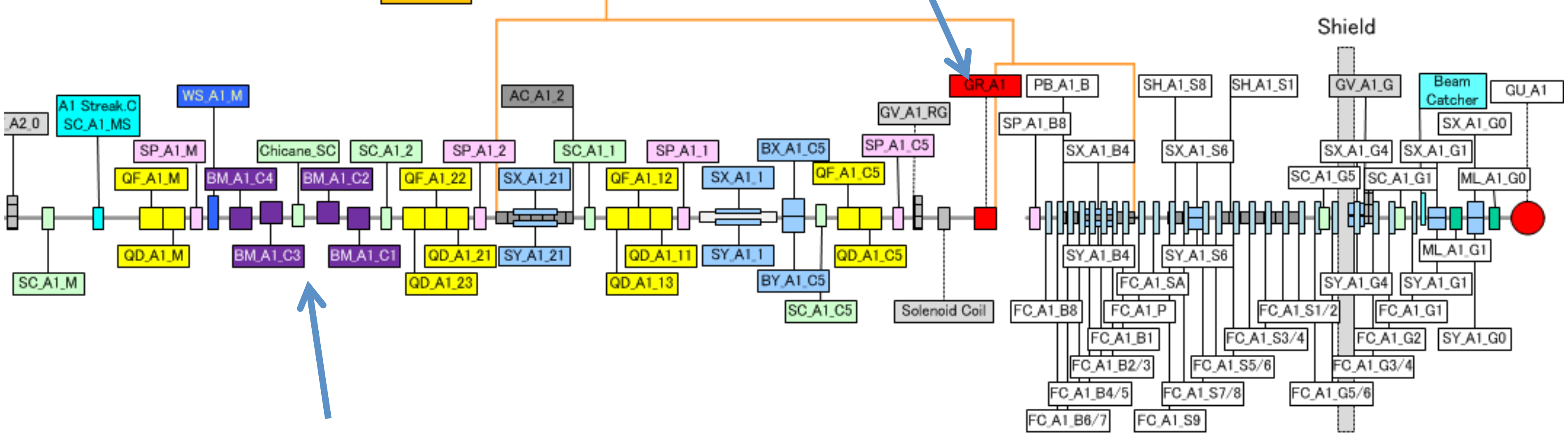
A-1 RF gun

- Quasi-travelling wave side couple RF-Gun
- Yb based laser system



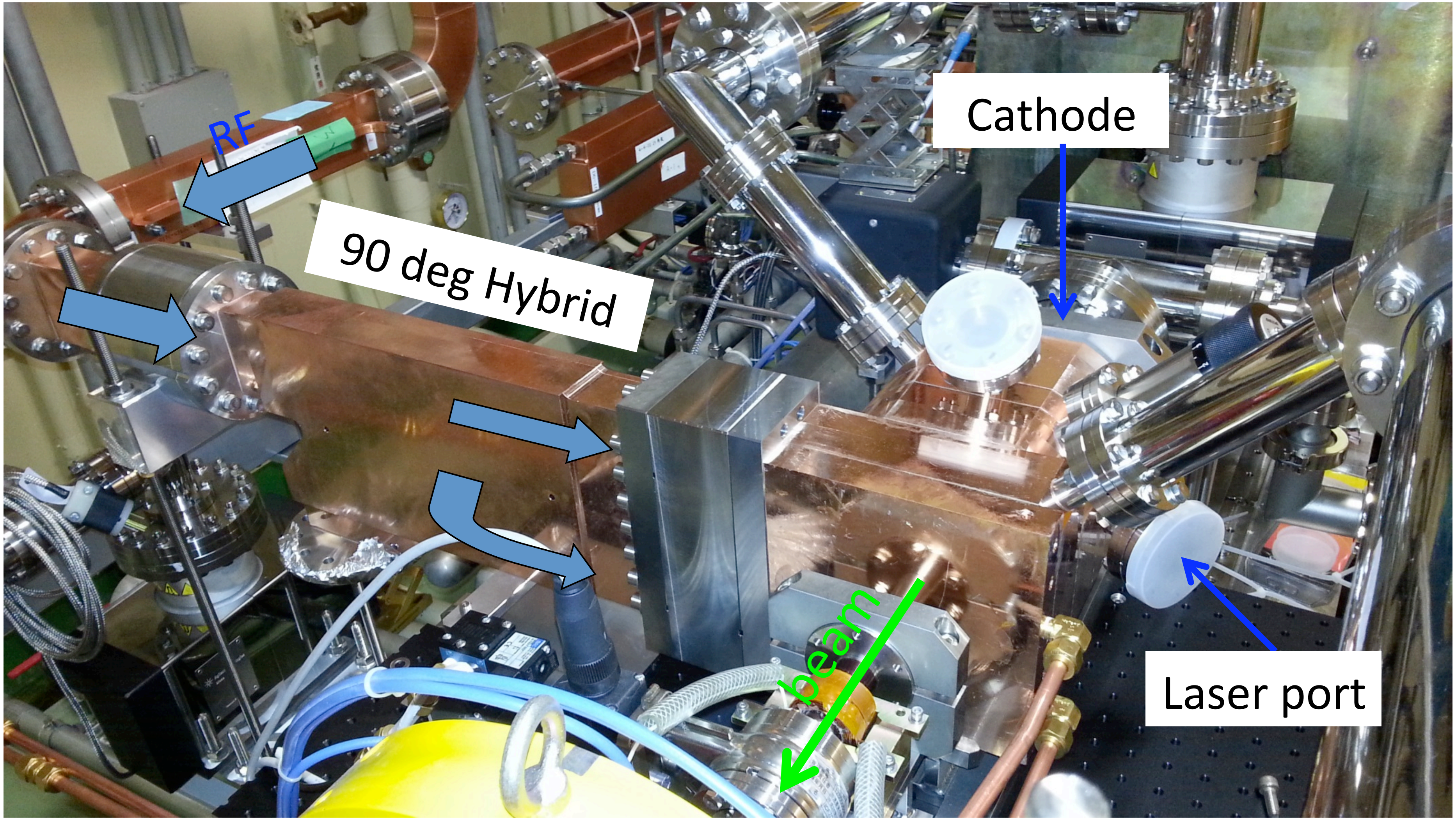
Existing DC-Gun & pre-buncher

Installed RF-Gun



Chicane for bunch compression
30ps => 10ps

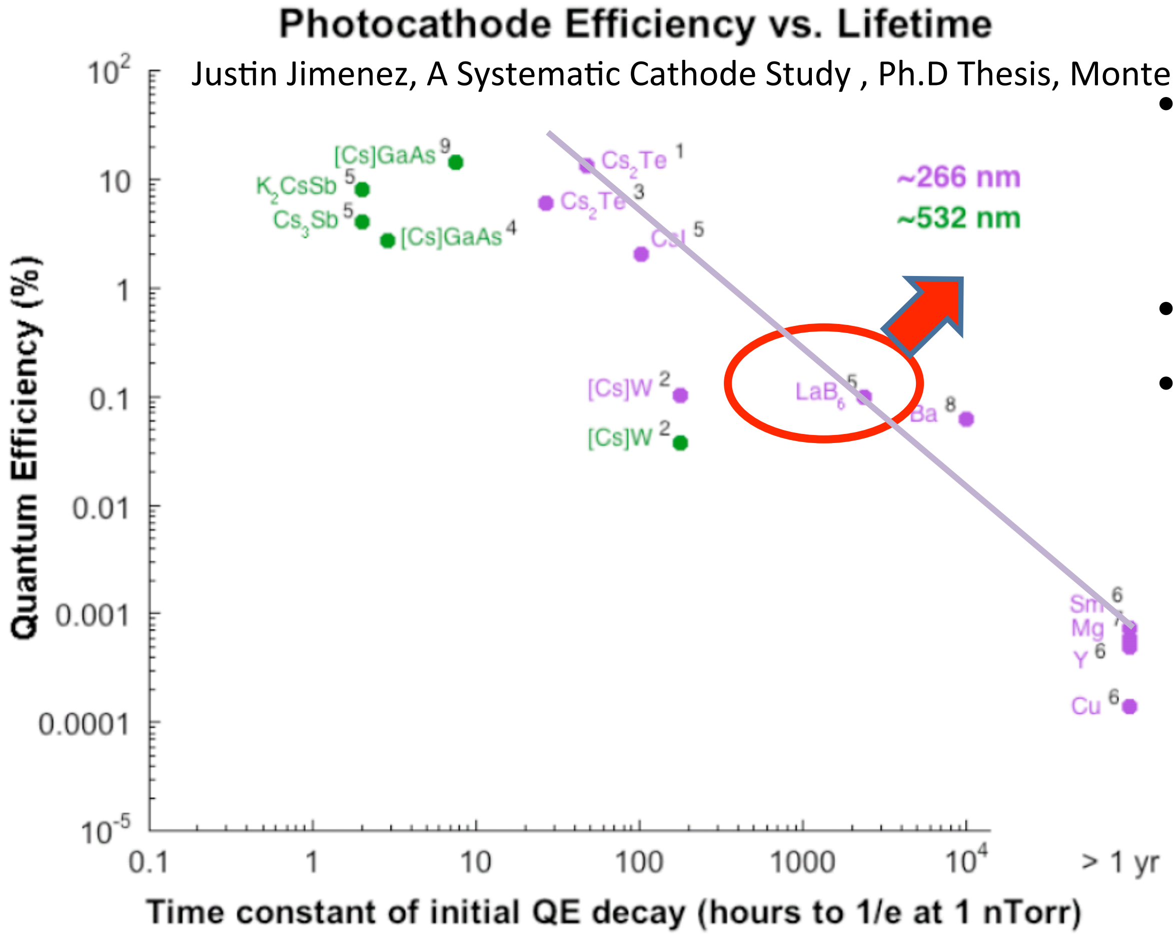
Installed RF gun



- 10 MeV @ 20 MW is designed value
- **6 MeV @ 12 MW is maximum power => Phase slip , Large energy spread**

IrCe cathode

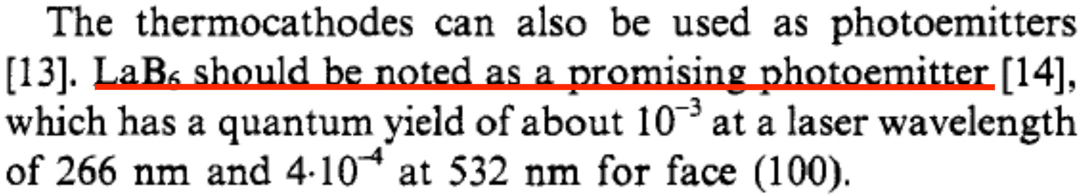
Cathode : Advantage of metal composite cathode (LaB_6 or Ir_5Ce)



Justin Jimenez, A Systematic Cathode Study , Ph.D Thesis, Monterery, California

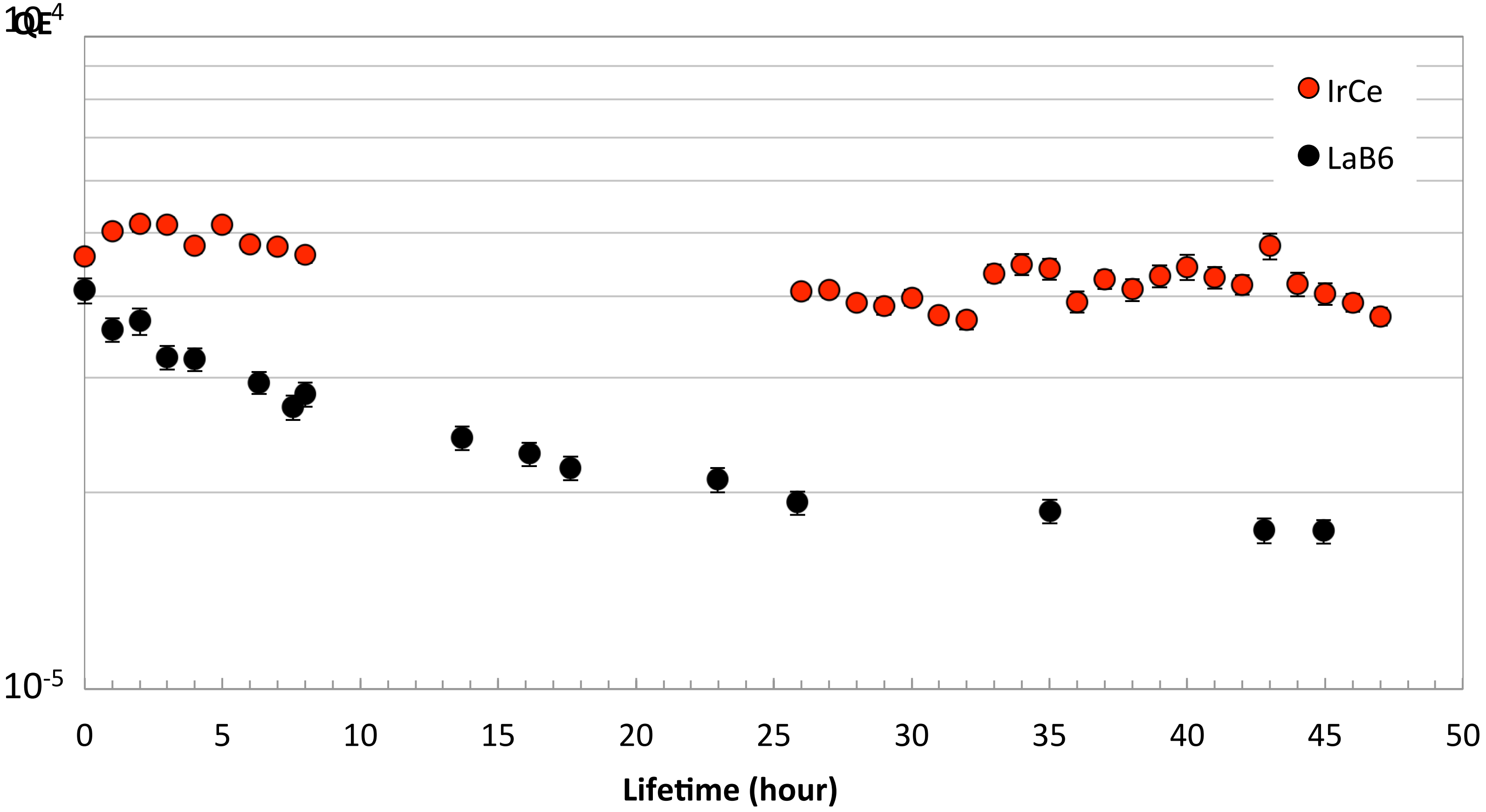
- Low Workfunction (2.8 eV) and enough QE (10^{-4}) at room temperature.
- Inactive in air
- Recover by heating or laser cleaning

Best choice for SuperKEKB 5 nC long time operation


The thermocathodes can also be used as photoemitters [13]. LaB_6 should be noted as a promising photoemitter [14], which has a quantum yield of about 10^{-3} at a laser wavelength of 266 nm and $4 \cdot 10^{-4}$ at 532 nm for face (100).

Physica Scripta. Vol. T71, 39-45, 1997.
Cathodes for Electron Guns
G. I. Kuznetsov

Lifetime measurement（LaB_6 / Ir_5Ce）

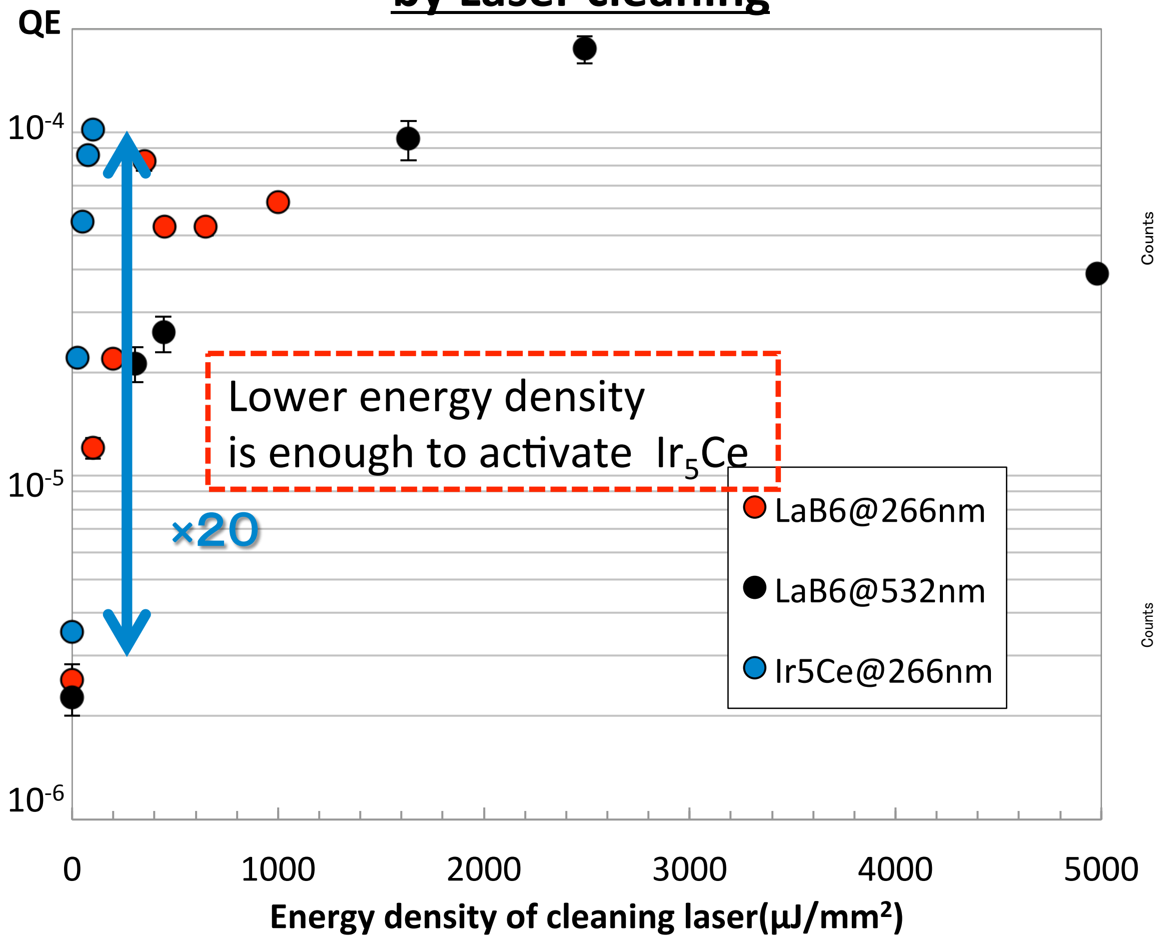


Condition

Continuous pulse laser 200μJ@266nm)
Irradation => 2.5 nC emission

Ir_5Ce Cathode

Quantum efficiency improvement by Laser cleaning



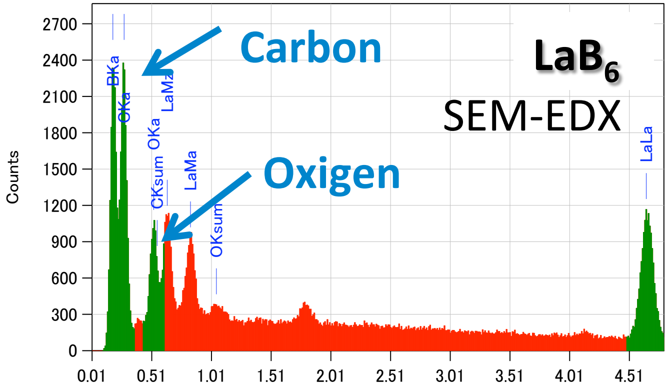
Lower energy density is enough to activate Ir_5Ce

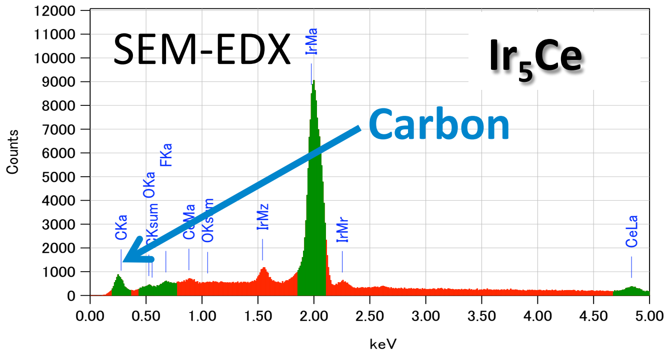
Condition

HV = 16kV

Vacuum ; $5.8×10^{-6}$ Pa

Cleaning time ; 10 min





No oxidization is observed

Non activation

QE = $5.00×10^{-6}$

×20

Laser cleaning

Max **QE = $1.00×10^{-4}$**

[SUPER-KEKB e Linac]

Laser Power ; 233μJ/pulse

(λ=266nm)

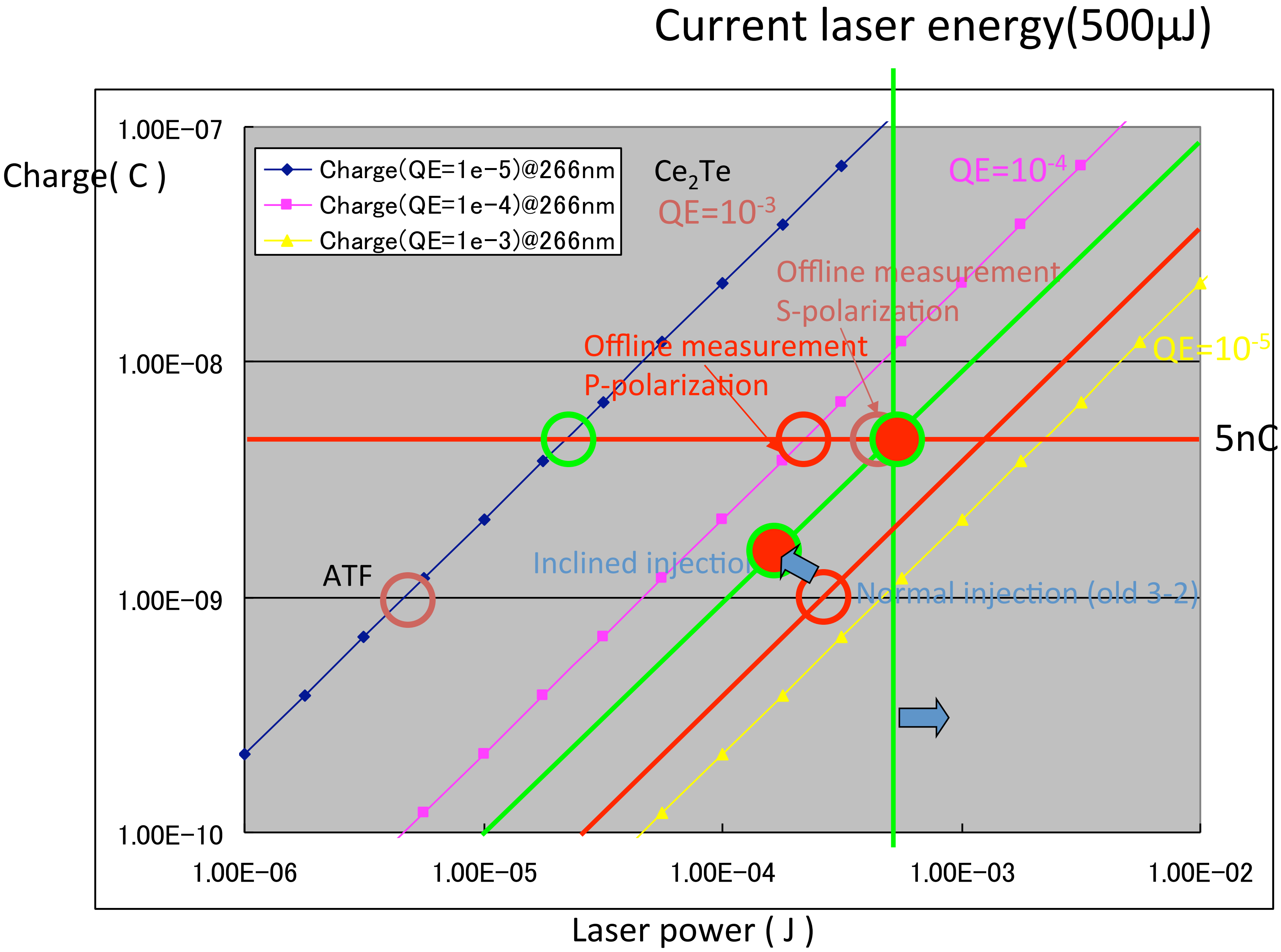
Target value ; 5nC

Laser system for A-1 RF-Gun

Requirement of laser system for RF-Gun

- Laser energy
  - 500 μJ UV for Ir_5Ce cathode
  - 50 μJ UV for Ce_2Te cathode
- 50 Hz, **2-bunch** (96ns spacing)
  => Difficult to adopt commertial products
  using regenerative amplifier.
  => **Multi-pass amplifier**
  or Special regenerative amplifier
- **Temporal pulse shaping**
  - Reduction of energy spread due to longitudinal wakefield
  - Rhombus shape for laser injection with angle (higher QE)
    => Broadband laser crystal (Yb or Ti:Sapphire)
- Continuous operation (limited cost / human resource)
  - Support cost for commertial product is very high.
    (10-20万円=1,000-2,000$/day/person + α **(margin)**)
  - No laser system company in Japan.
  - Recovering time.

Required laser pulse energy

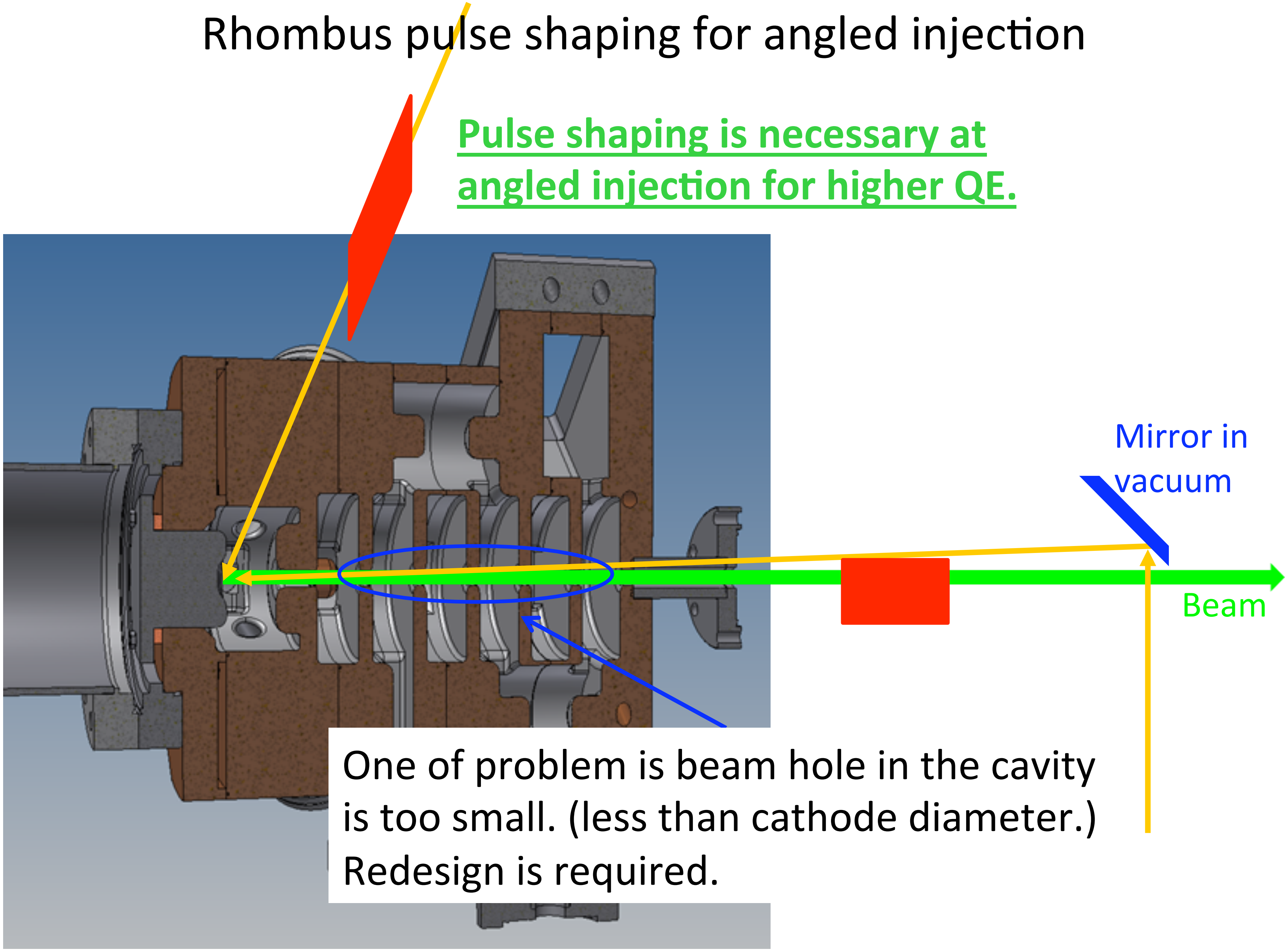


How to generate 2-bunch

- Amplification time of standard regenerative amplifier (usually adopted in commertial product) is around 1 μs.

- Two regenerative amplifier (not good)
- Large regenerative amplifier (built & failed)
  - Unstable output energy due to low gain.
  - Difficult to compensate thermal lens.
- High gain fast regenerative amplifier (built & failed)
  - Difficult to reduce the ghost pulse from first bunch due to limted extinction ratio of pockels cell.
- **Multi-pass amplifier (current configuration)**
  - **More gain is required for the balanced 2-bunch**.
- OPCPA (future candidate)

Rhombus pulse shaping for angled injection

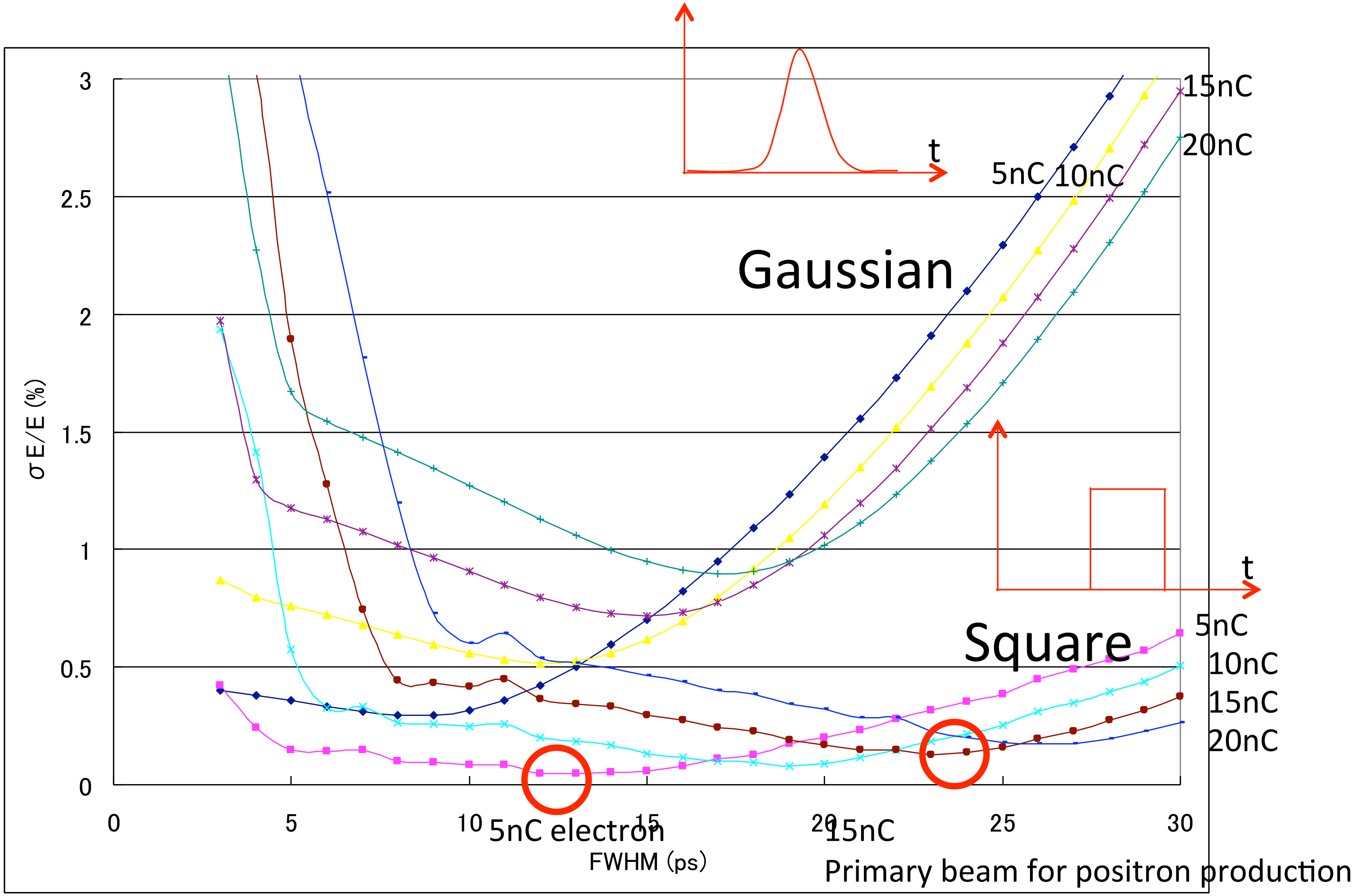


Pulse shaping is necessary at angled injection for higher QE.

One of problem is beam hole in the cavity is too small. (less than cathode diameter.) Redesign is required.

Energy spread reduction by pulse shaping

Energy spread of 0.1% is required for SuperKEKB synchrotron injection.



Properties of laser medium

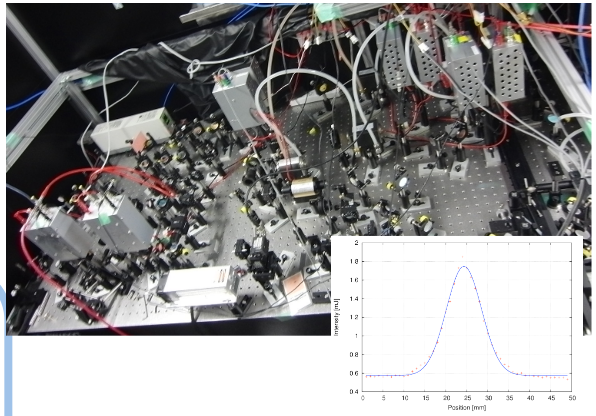
Nd-doped

- ○ 4-state laser is easy to operate.
- ○ High power pump LD is available.
- ○ Large crystal is available
- × Pulse width is determined by SESAM. (Gaussian)

τ～200μs, 40%

LD Pump (808nm) → 808nm → Nd:YVO4 / Nd:YAG → 1064nm → SHG(532nm) 40% / FHG(266nm) 20% / 5HG(213nm) 3%

Nd laser system for 3-2 RF-Gun



Yb-doped

- ○ Wide bandwidth => pulse shaping
- ○ Long fluorescent time => High power
- ○ Fiber laser => Stable
- ○ Small state difference
- × ASE
- × Absorption

τ～900μs, 40%

LD Pump (941/976nm) → 941/976nm → Yb-glass / Yb:YAG / Yb:BOYS → 1040nm → SHG(520nm) 40% / FHG(260nm) 20% / 5HG(208nm) 3%

→ Best for RF-Gun

Ti-doped

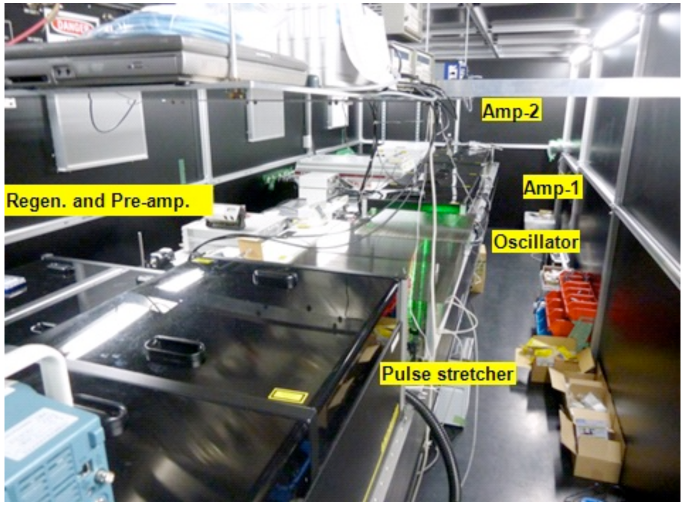
Pump τ=200μs, 40%

Pump (808nm) → 808nm → Nd:YAG → 1064nm → SHG 40% → 532nm → Ti:Sapphire τ～3μs, 40% → 800nm → SHG(400nm) 40% / THG(266nm) 20% / FHG(200nm) 10%

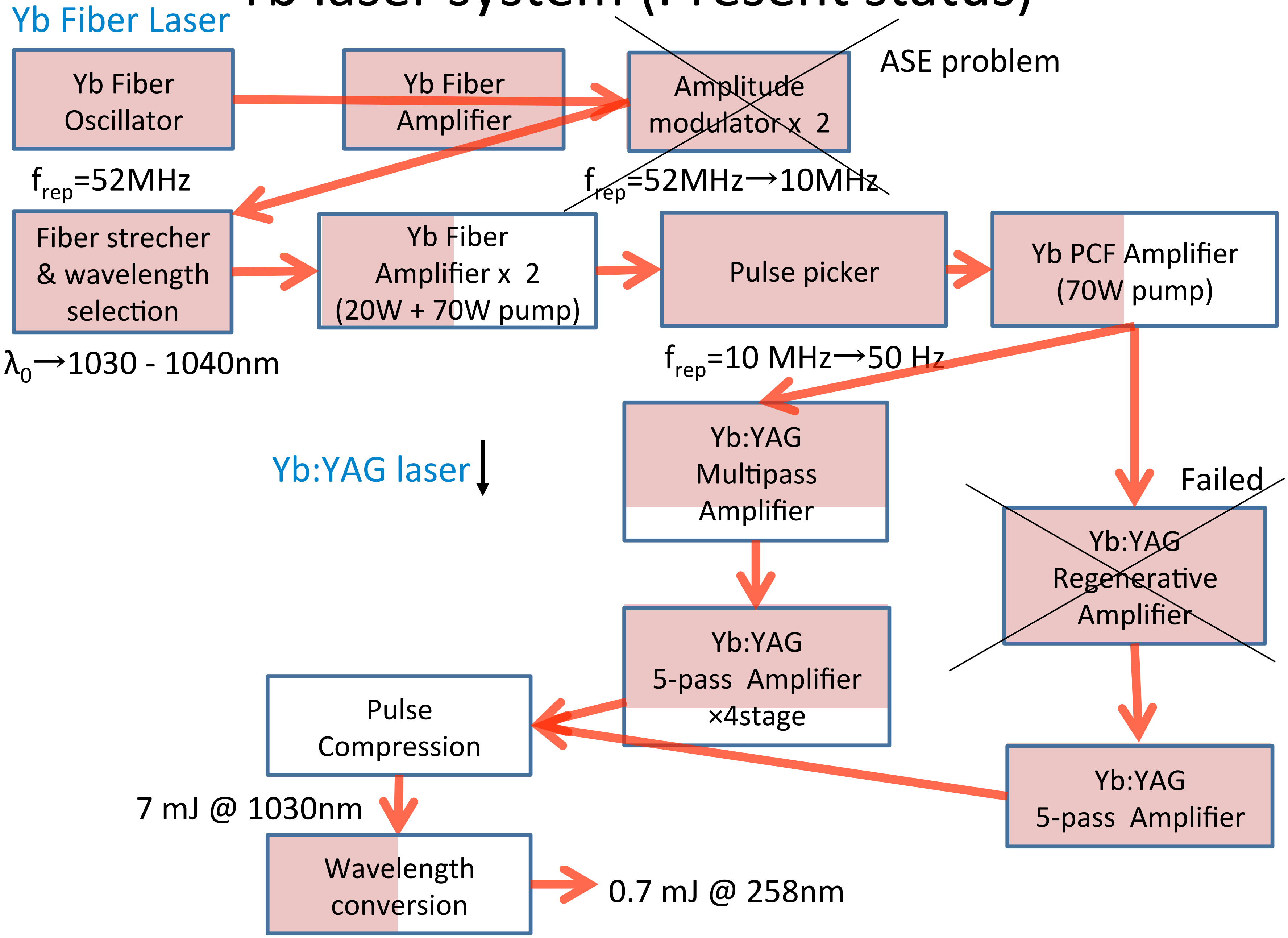
- ○ Very wide bandwidth
- ○ High breakdown threshold } TW laser is based on Ti-Sapphire
- × Low cross section } TW laser is based on Ti-Sapphire
- × Short fluorescent time => Q-switched laser is required for pumping

	Material	Nd:YAG	**Yb:YAG**	Ti:Sapphire
Fluorescence	Wavelength	1064nm	1030nm	660–1100nm
	Fluorescent time	230ms	**960ms**	3.2ms
	Spectral width	0.67nm	**9.5nm**	440nm
	Fourier minimum Pulse width	2.48ps	165fs	2.59fs
Absorption	Wavelength	807.5nm	**941nm**	488nm
	Spectral width	1.5nm	**21nm**	200nm
	Quantum efficiency	76%	**91%**	55%

Ti:Sapphire laser system for beam monitor.



Yb laser system (Present status)



Yb Fiber Laser

Yb Fiber Oscillator

Yb Fiber Amplifier

~~Amplitude modulator x 2~~

ASE problem

f_{rep}=52MHz

f_{rep}=52MHz→10MHz

Fiber strecher & wavelength selection

Yb Fiber Amplifier x 2 (20W + 70W pump)

Pulse picker

Yb PCF Amplifier (70W pump)

λ$_0$→1030 - 1040nm

f_{rep}=10 MHz→50 Hz

Yb:YAG laser

Yb:YAG Multipass Amplifier

Failed

~~Yb:YAG Regenerative Amplifier~~

Yb:YAG 5-pass Amplifier ×4stage

Yb:YAG 5-pass Amplifier

Pulse Compression

7 mJ @ 1030nm

Wavelength conversion

0.7 mJ @ 258nm

Yb Fiber Oscillator

Yb fiber oscillator:

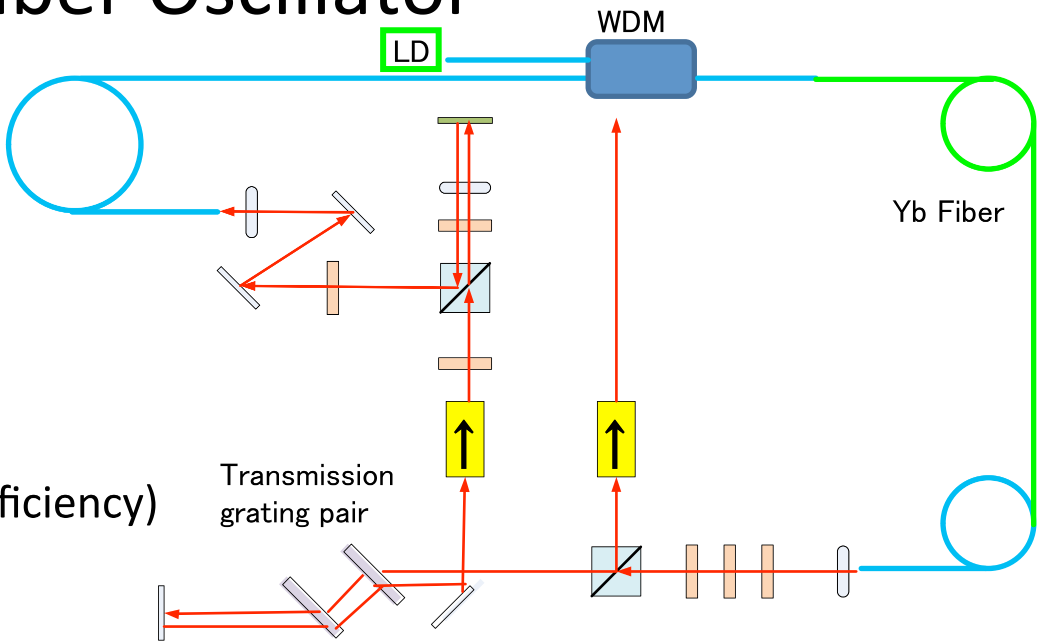
- 30 fs is possible using non-linear polarization rotation.
- 52 MHz is not suitable
  => 114 MHz will be installed

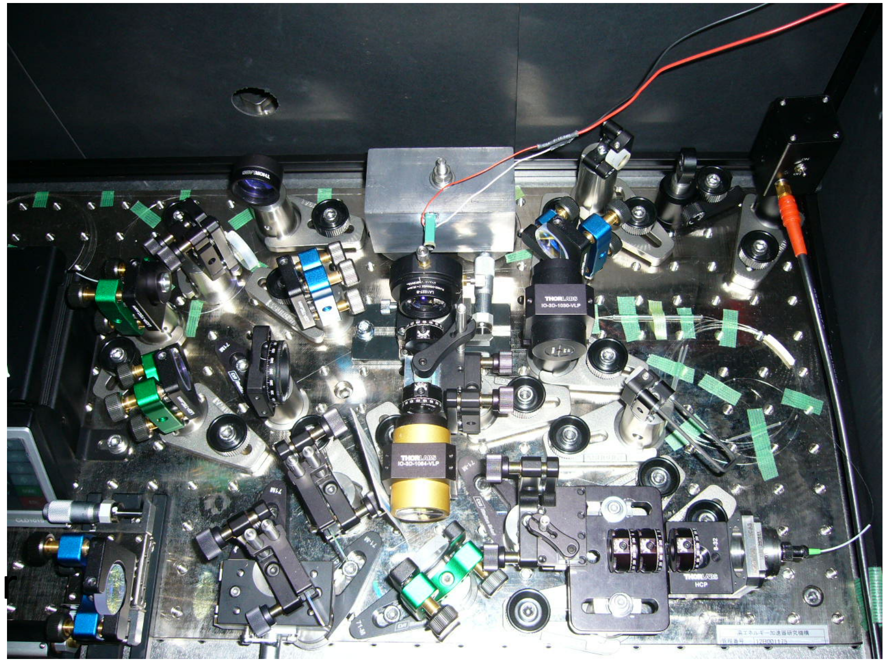
Improved items in FY2013:

- Transmission grating
  => Stable modelock (higher efficiency)
- Super-invar breadboard
  => Improve thermal stability.
- Piezo mirror on large lead block
  => Reduce vibration.
- Broadband oscillator (No.2) is stable.

Remaining problem:

- LD was sometimes broken.
- Bunch structure at higher output power.
  => SESAM is not effective.
  => Replace some components.
- 1030nm oscillator is not stable
- 1030nm component of broadband oscillator is small => large ASE

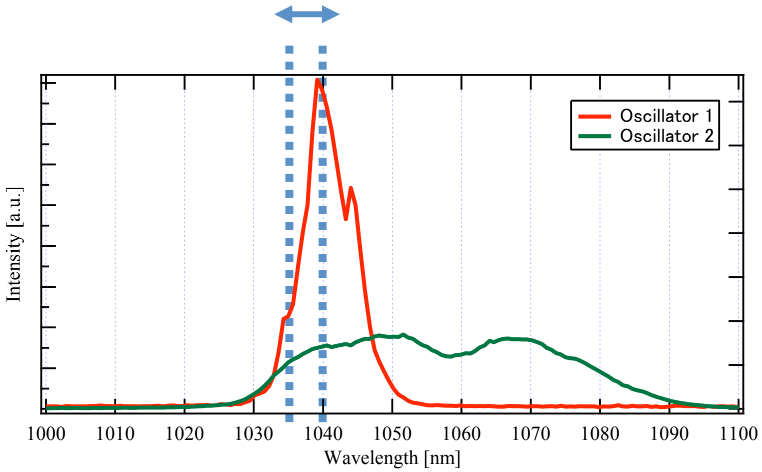




Yb:YAG fiber oscillator

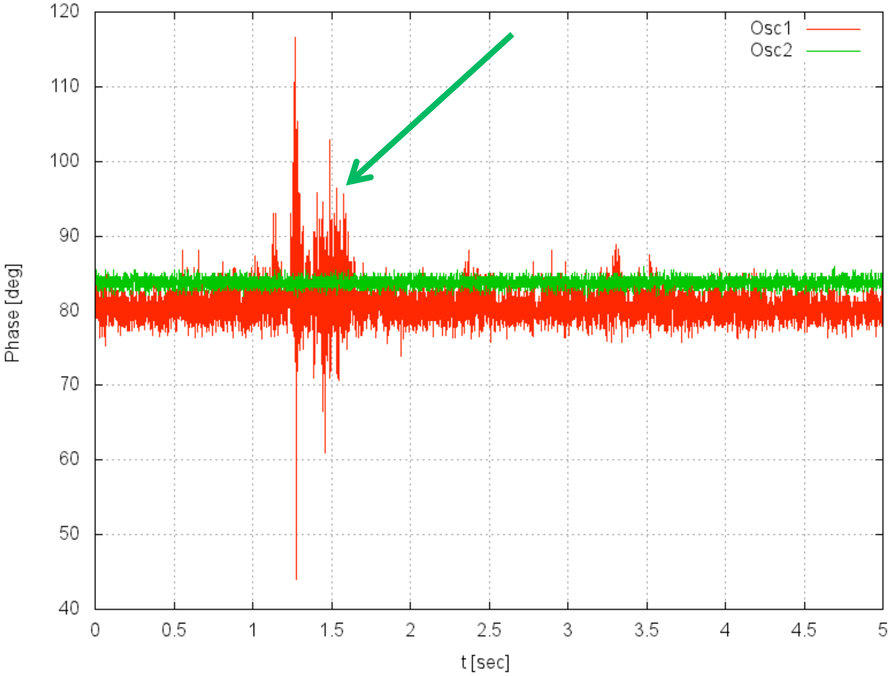
Two 52 MHz oscillators are installed for the underground laser room.

Yb:YAG bandwidth



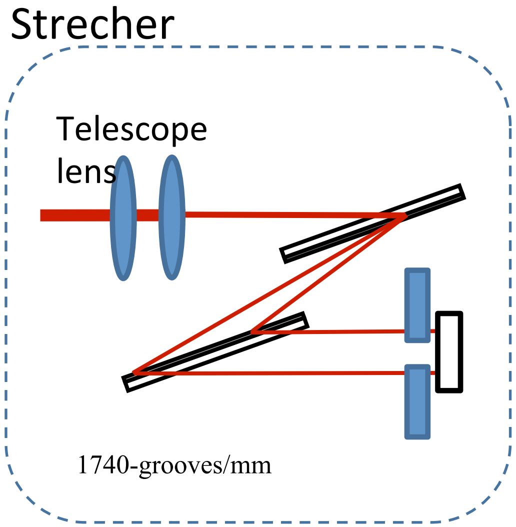
Oscillator1: Narrow (Less ASE)
Oscillator2: Broadband (Stable)

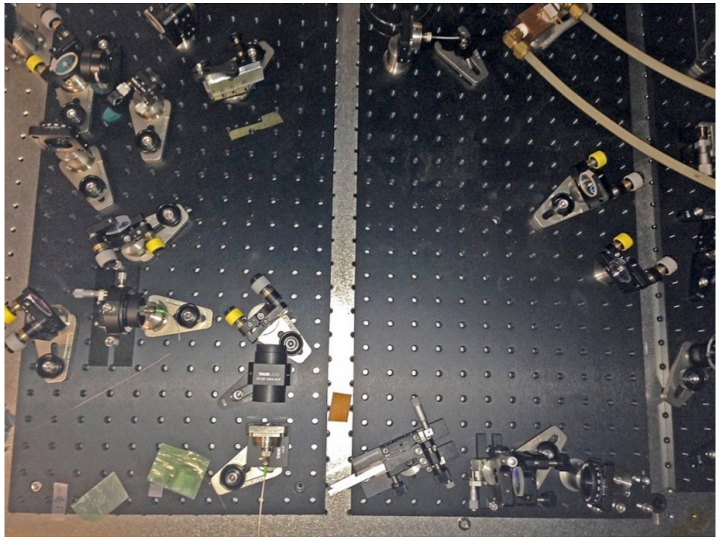
Second oscillator is very stable

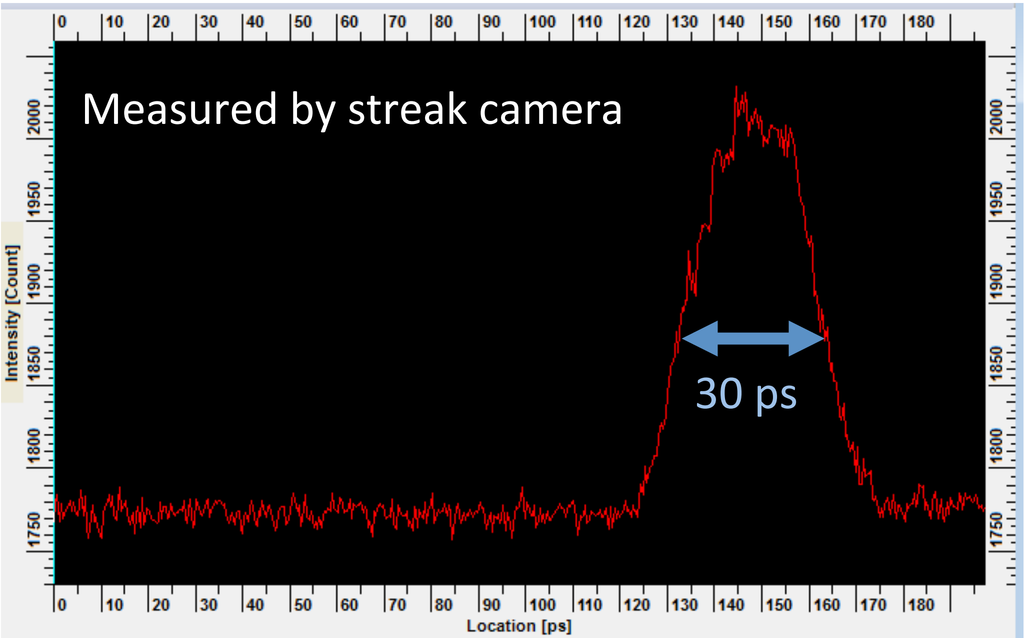


Phase stability (sigma)
Oscillator1 : 2.38 deg
Oscillator2 : 0.58 deg = 560 fs

Pulse shaping using strecher



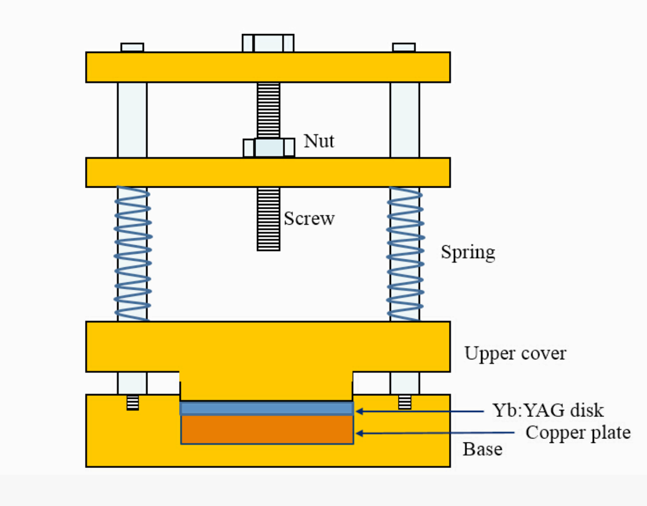


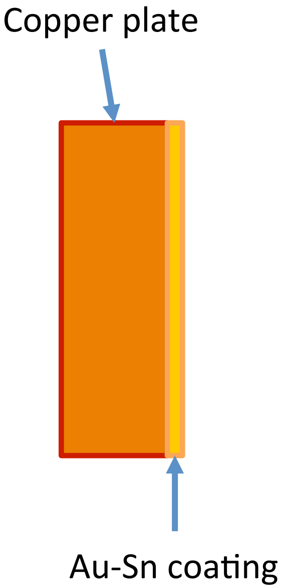


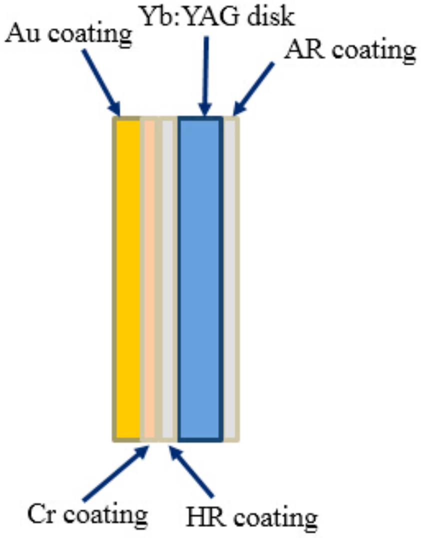
Rectangular-like 30 ps pulse width was obtained.

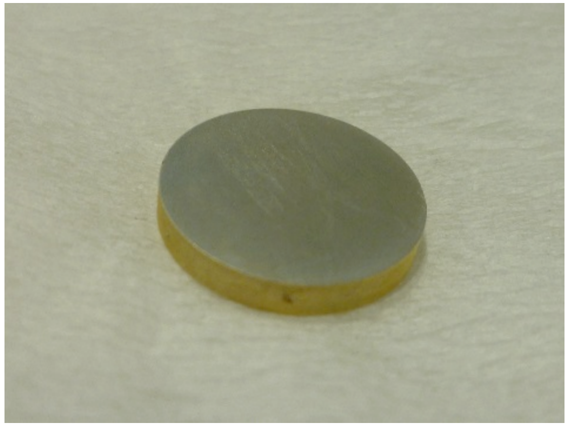
Yb:YAG solid state amplifier

- Improvement of heat conductivity by Au-Sn vacuum soldering.







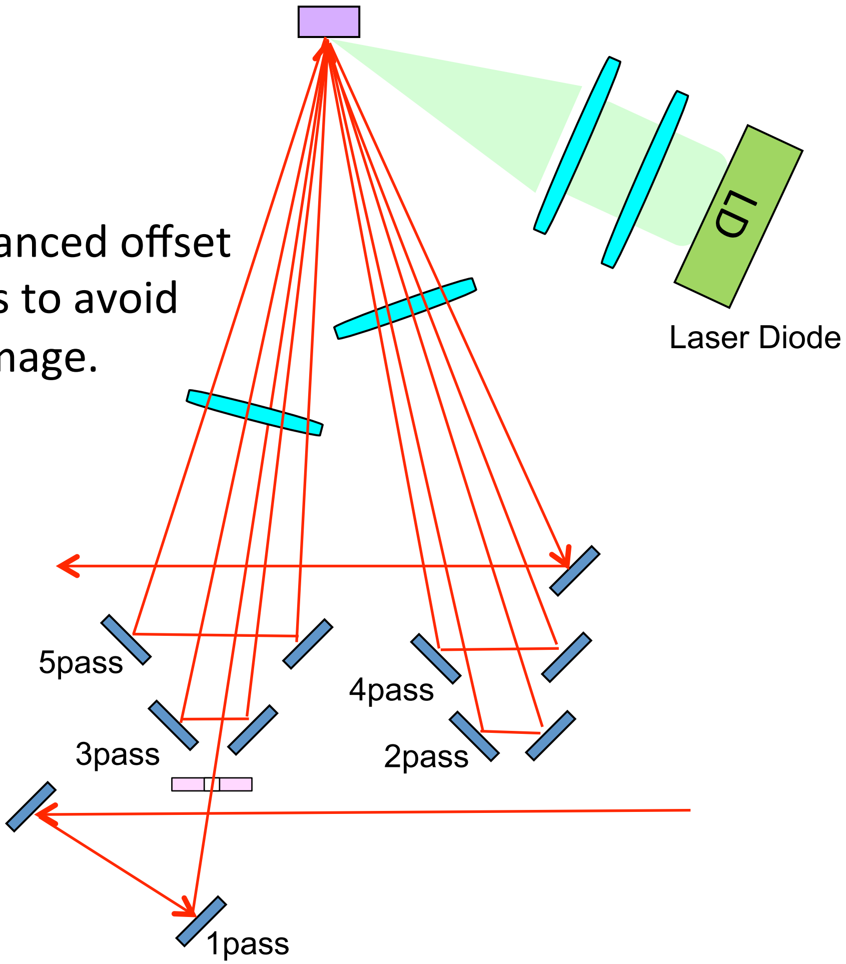


5 Hz =>

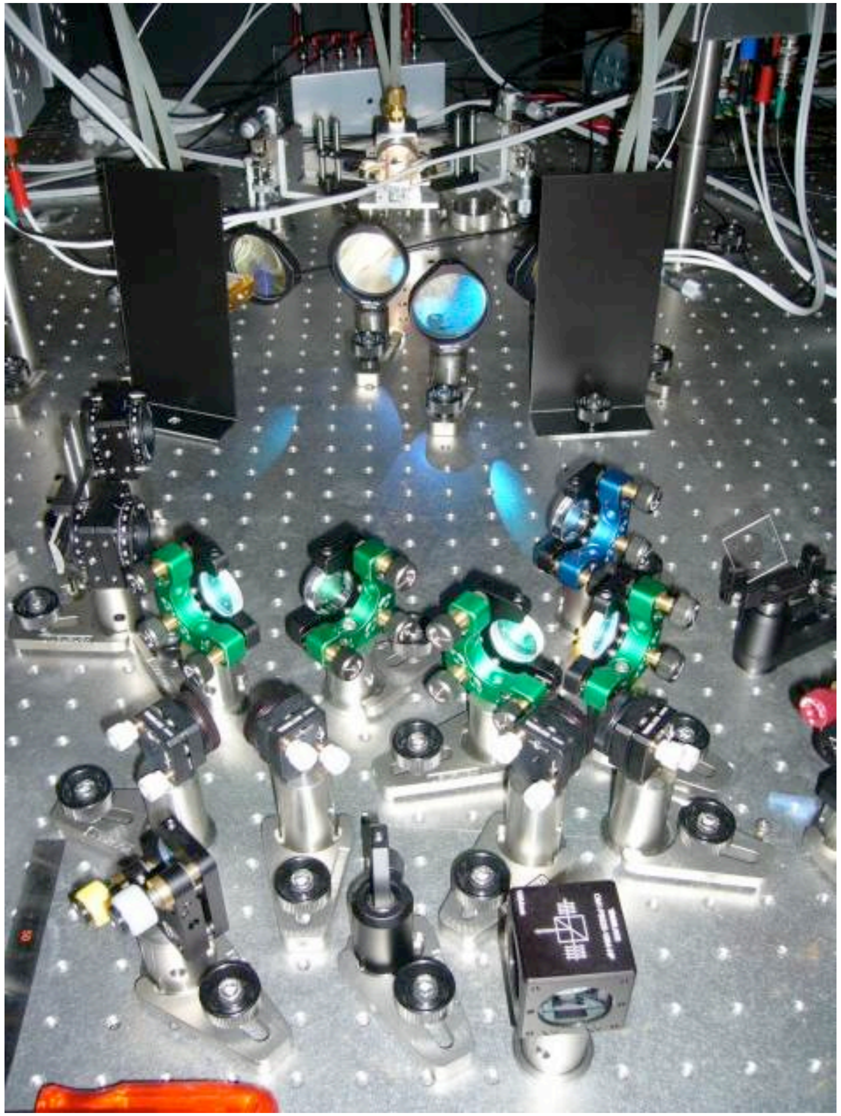
25 Hz operation was achieved.

Original multi-pass amplifier (5-pass)

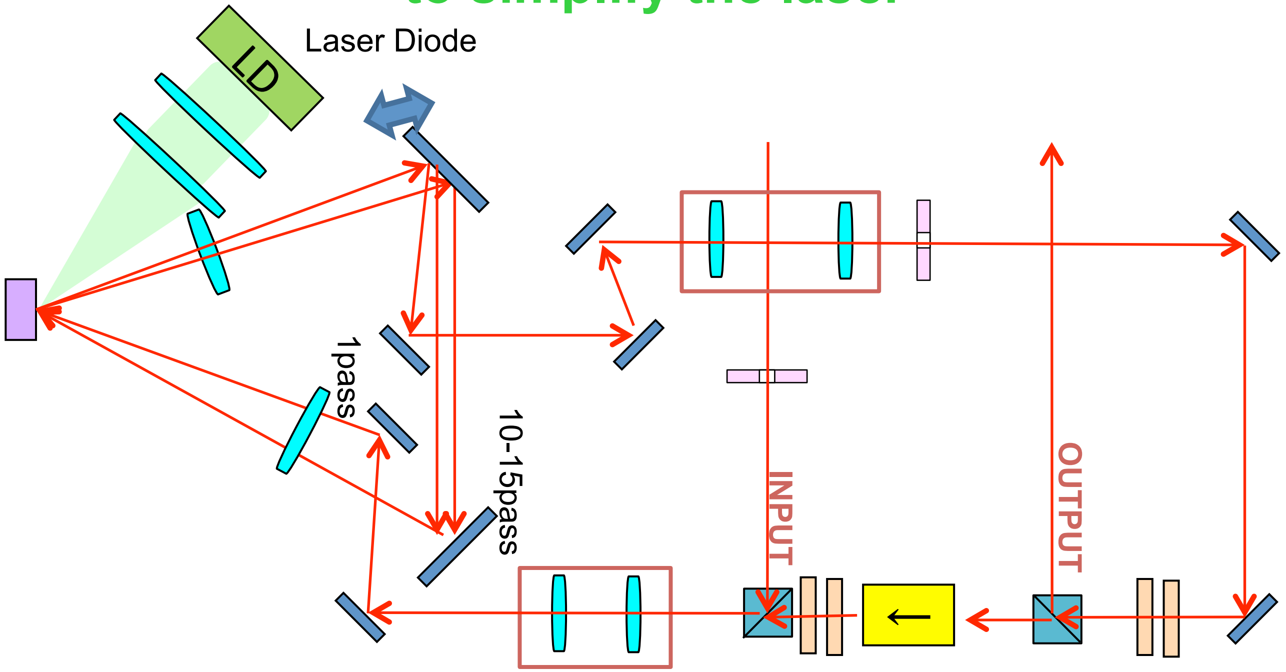
To obtain higher gain,
=> Higher pumping density
⇒ Thermal lens
⇒ Focused type amplifier to
avoid thermal lens.

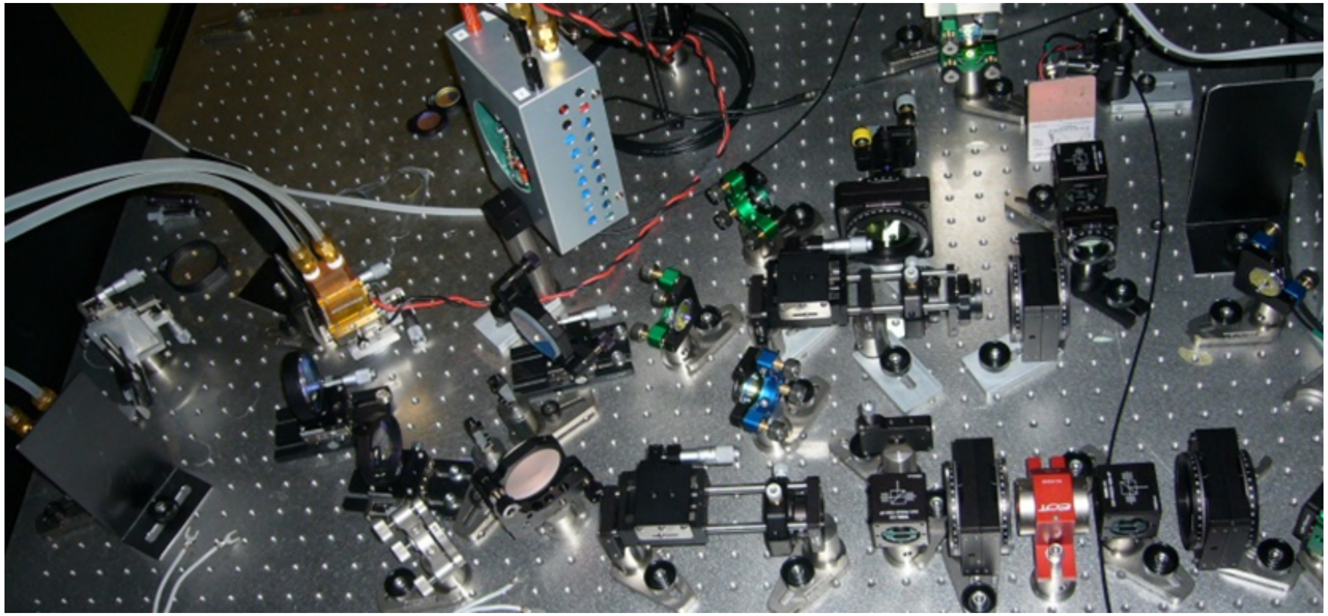


Balanced offset lens to avoid damage.



New high gain multi-pass amplifier(10-15 pass x 2 loop) to simplify the laser





Issues on Yb based laser system

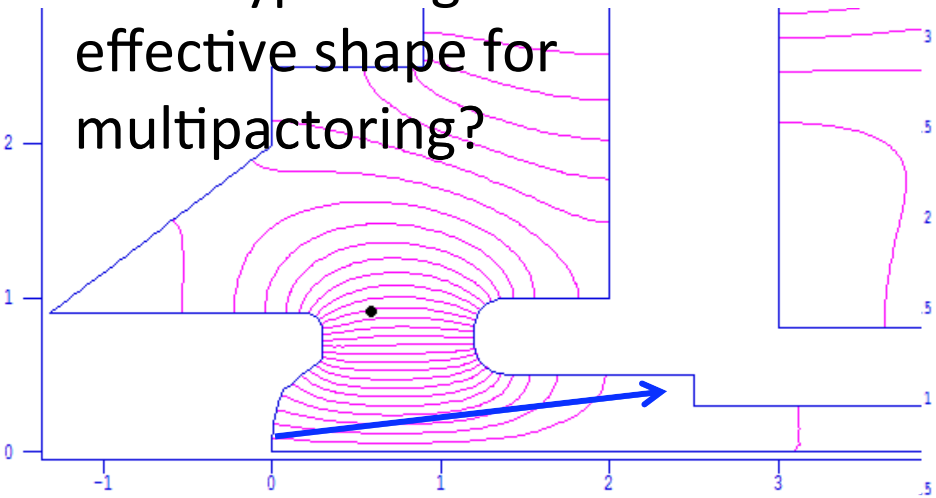
- Yb-fiber oscillator
  - **1030nm oscillator is not stable**.
  - **Broadband oscillator is very stable** => **Further ASE reduction is required**.
- Yb-fiber amplifier
  - **Lack of pulse energy =>**
  - **Lifetime and stability of PCF fiber** => Improve the injection
- Yb-disk amplifier: (Regenerative amplifiers were failed)
  => Multi-pass amplifier for 2-bunch operation.
  => **More gain is required for balanced 2-bunch energy**.
  - 5 Hz => **Soldered cryatal => 25 Hz operation**
    => **x 2 system => 50Hz before May 2015**
  - **Reduce thermal lens effect and simplify laser system**
    => Focused type high gain multipass amplifier x2
    + Non-focused multipass amplifier
- Stability improvement
  - Casing of each block.
  - Gas filled or vacuum laser transportation to improve pointing stability.
  - Assemble on one large optical table (new laser room).
  - Feedback (pointing / amplitude).
  - Increase monitor points (pointing / power / beam pattern).

Comissioning
of A-1 RF-Gun

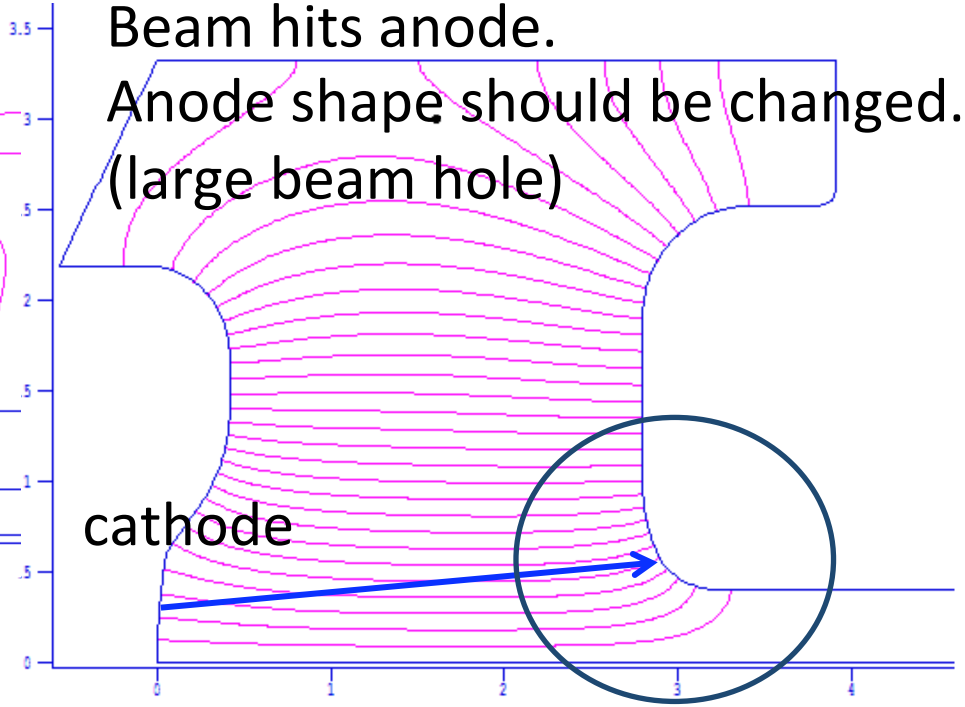
RF voltage

	RF power [MW]	Maximum surface E-field [MV/m]
DAW @ 3-2	3.5	150
QTW @ A-1 target	20	120
QTW achieved @ A-1	14	85

One week RF ageing reach this target.



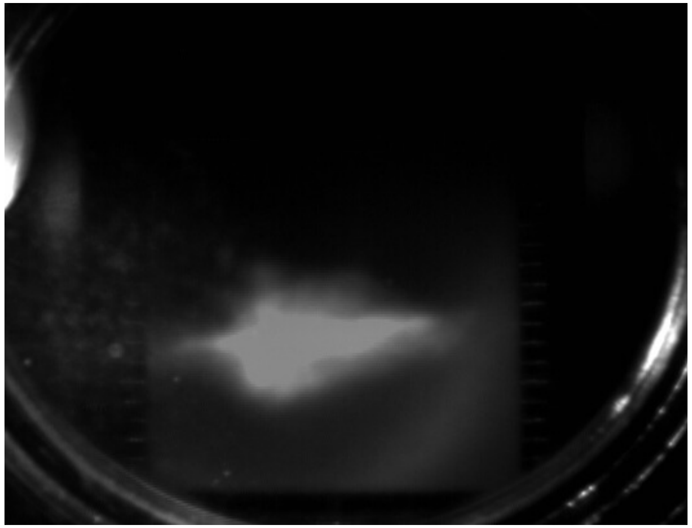
DAW type RF gun is effective shape for multipactoring?



Beam hits anode.
Anode shape should be changed.
(large beam hole)

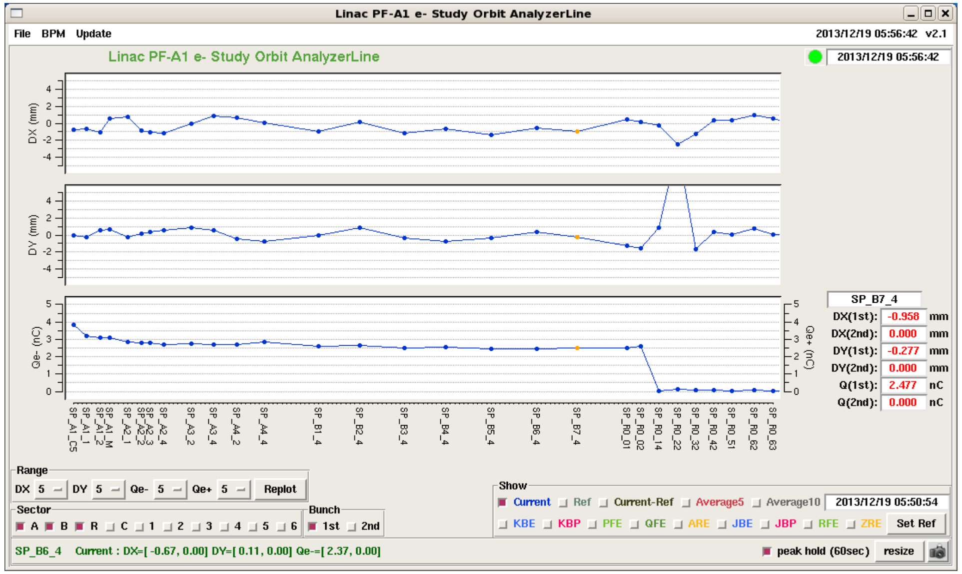
cathode

A-1 RF gun results



5.6 nC was achieved.

However beam profile is not good.



SP_B7_4

DX(1st): -0.958 mm

DX(2nd): 0.000 mm

DY(1st): -0.277 mm

DY(2nd): 0.000 mm

Q(1st): 2.477 nC

Q(2nd): 0.000 nC

Range: DX 5 DY 5 Qe- 5 Qe+ 5

Sector: ☒ A ☒ B ☒ R ☐ C ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

Bunch: ☒ 1st ☐ 2nd

Show: ☒ Current ☐ Ref ☐ Current-Ref ☐ Average5 ☐ Average10 2013/12/19 05:50:54

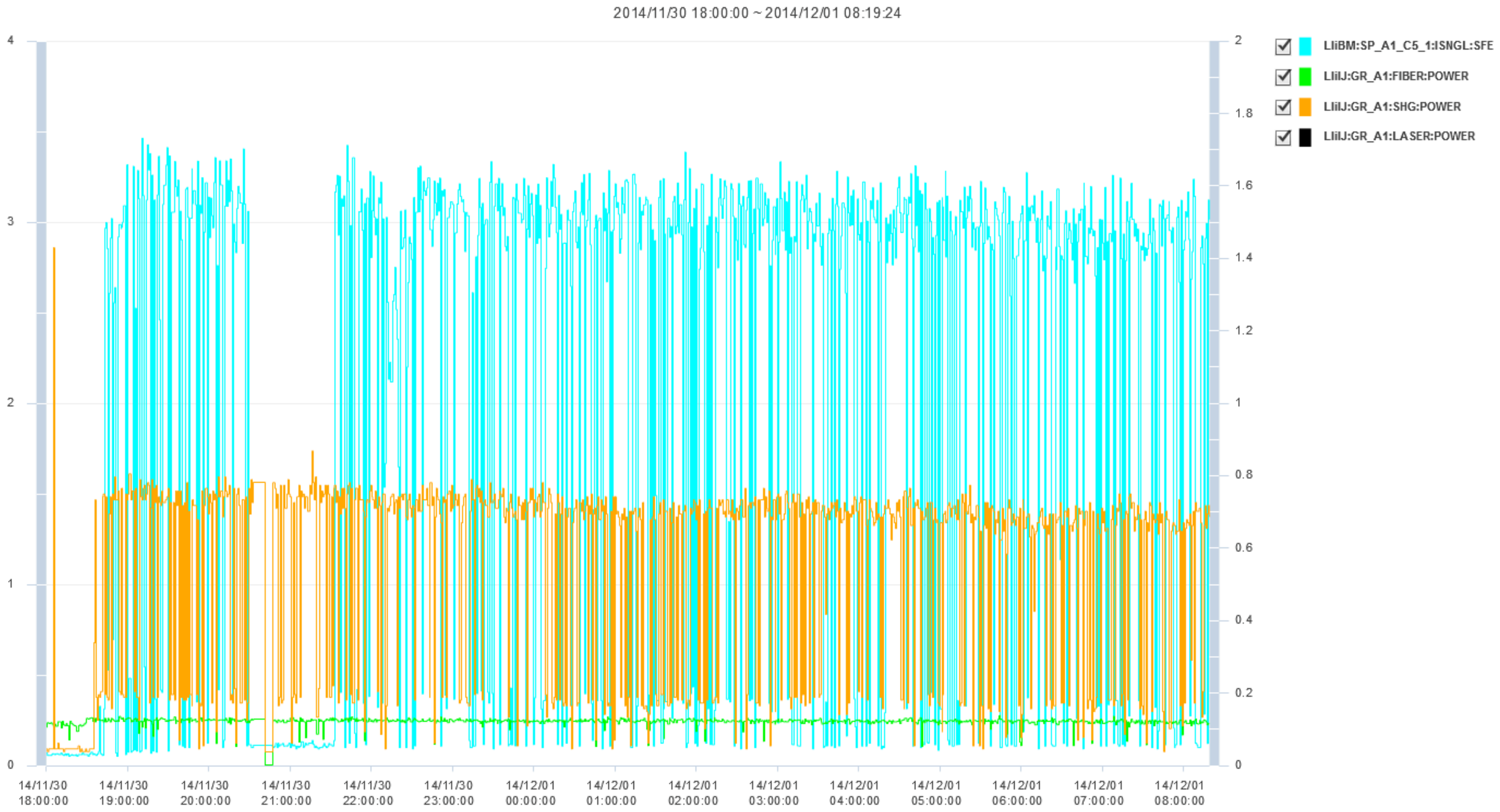
☐ KBE ☐ KBP ☐ PFE ☐ QFE ☐ ARE ☐ JBE ☐ JBP ☐ RFE ☐ ZRE

SP_B6_4 Current : DX=[-0.67, 0.00] DY=[0.11, 0.00] Qe-=[2.37, 0.00]

☒ peak hold (60sec)

3 nC beam delivery was achieved.

Charge history of A-1 RF-Gun (3nC)

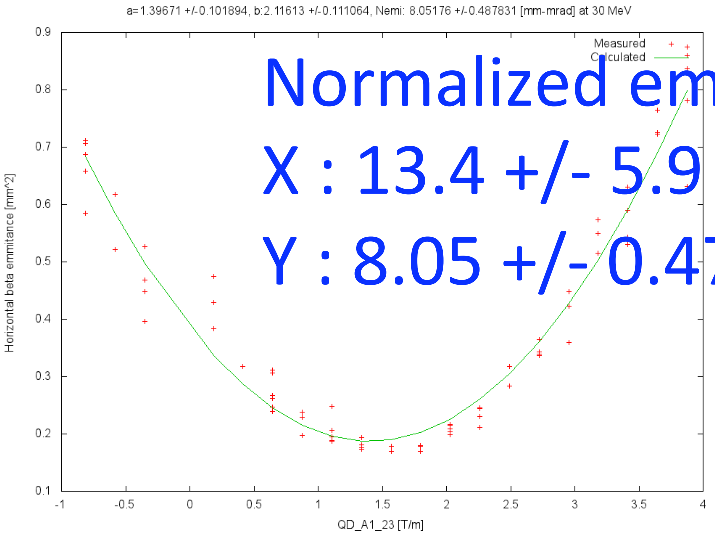


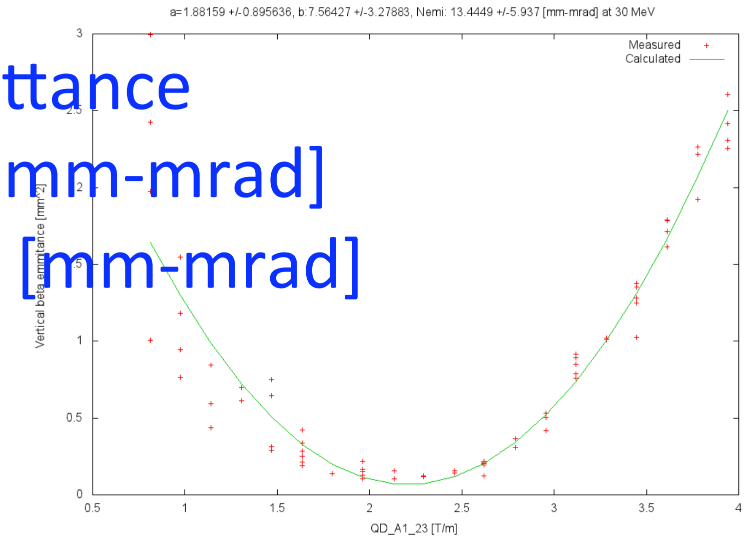
QE : 3nC = 14nJ / 300μJ = 4.5×10^{-5} (QE)

Emittance measurement

beam charge : 0.6nC
beam energy : 30 MeV

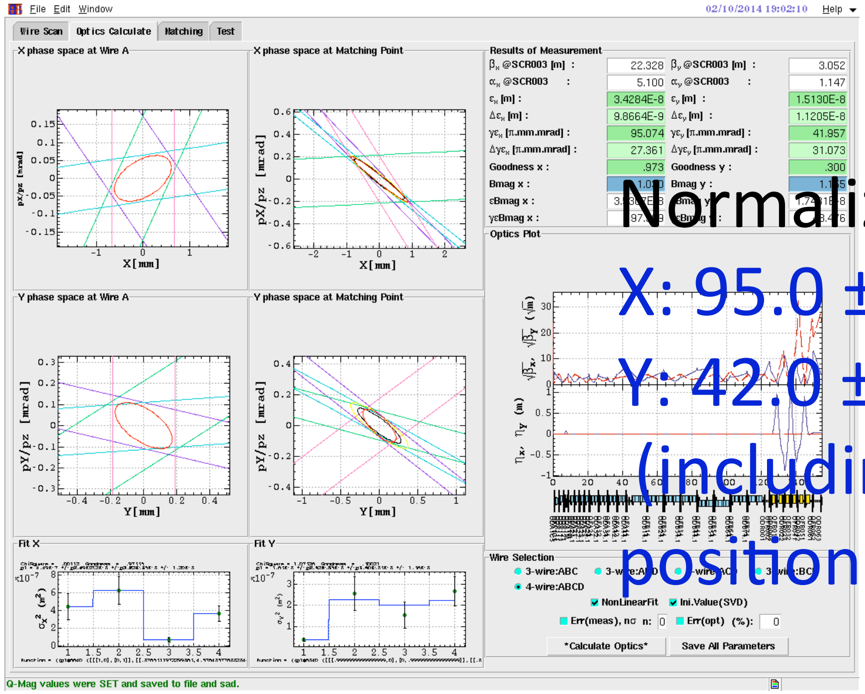
Q scan method
using screen
monitor


a=1.39671 +/-0.101894, b:2.11613 +/-0.111064, Nemi: 8.05176 +/-0.487831 [mm-mrad] at 30 MeV


a=1.88159 +/-0.895636, b:7.56427 +/-3.27883, Nemi: 13.4449 +/-5.937 [mm-mrad] at 30 MeV

Normalized emittance
X : 13.4 +/- 5.9 [mm-mrad]
Y : 8.05 +/- 0.47 [mm-mrad]

Wire scanner
at B sector



Results of Measurement

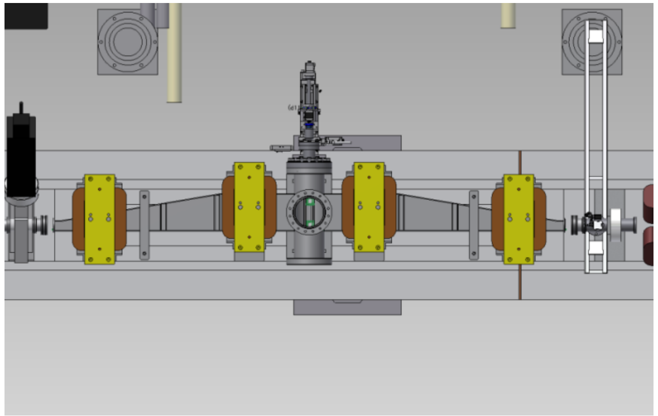
β_x @SCR003 [m] :	22.328	β_y @SCR003 [m] :	3.052
α_x @SCR003 :	5.100	α_y @SCR003 :	1.147
ε_x [m] :	3.4284E-8	ε_y [m] :	1.5130E-8
$\Delta\varepsilon_x$ [m] :	9.8664E-9	$\Delta\varepsilon_y$ [m] :	1.1205E-8
$\gamma\varepsilon_x$ [π.mm.mrad] :	95.074	$\gamma\varepsilon_y$ [π.mm.mrad] :	41.957
$\Delta\gamma\varepsilon_x$ [π.mm.mrad] :	27.361	$\Delta\gamma\varepsilon_y$ [π.mm.mrad] :	31.073
Goodness x :	.973	Goodness y :	.300
Bmag x :	[illegible]	Bmag y :	[illegible]
εBmag x :	[illegible]	[illegible]	[illegible]
γεBmag x :	[illegible]	[illegible]	[illegible]

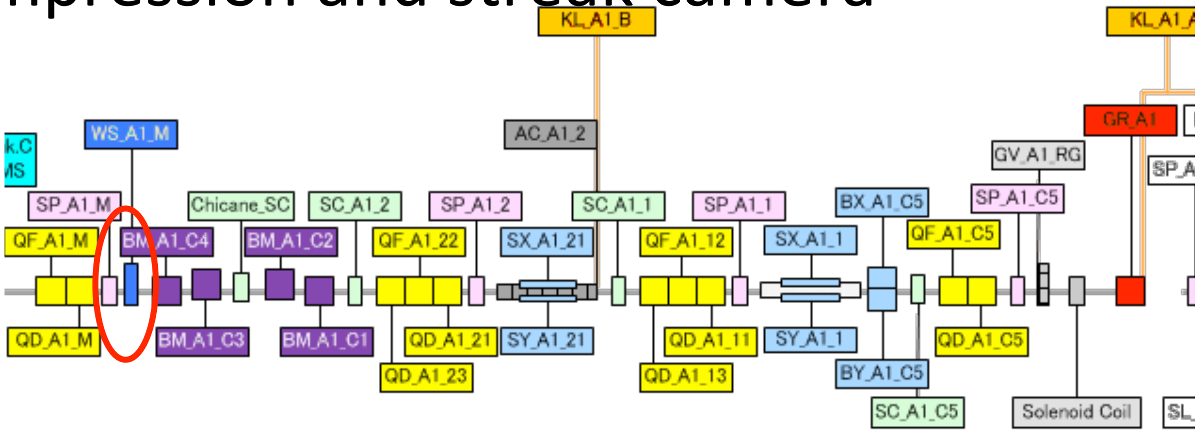
Wire Selection
○ 3-wire:ABC ○ 3-wire:ABD ○ 3-wire:ACD ○ 3-wire:BCD
● 4-wire:ABCD
☑ NonLinearFit ☑ Ini.Value(SVD)
☐ Err(meas), nσ n: 0 ☐ Err(opt) (%): 0
Calculate Optics Save All Parameters

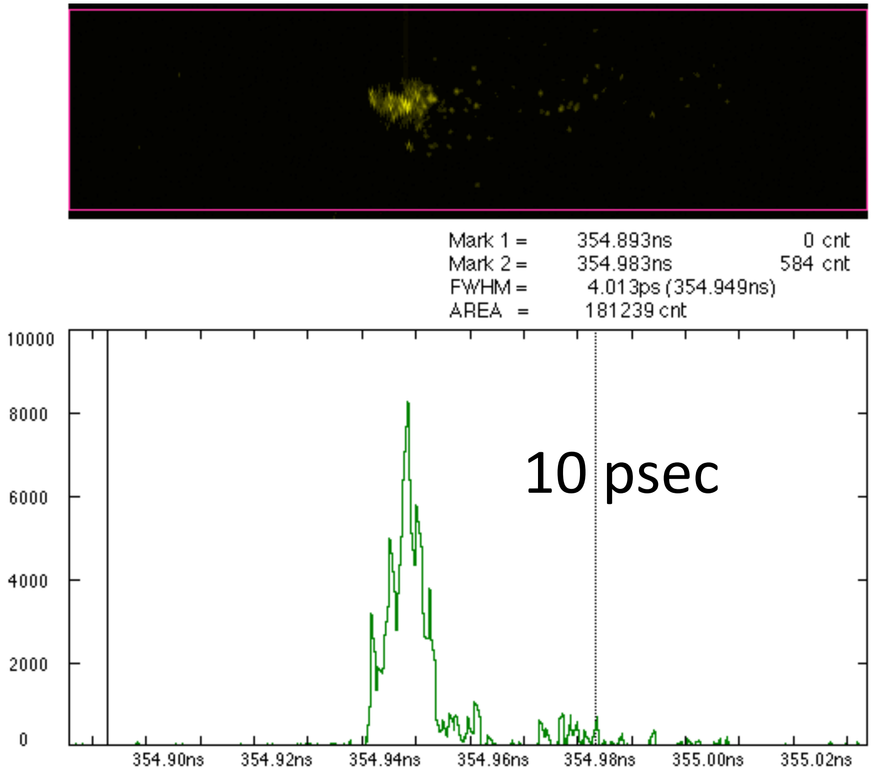
Q-Mag values were SET and saved to file and sad.

Normalized emittance
X: 95.0 ±27.4 mm-mrad
Y: 42.0 ±31.1 mm-mrad
(including the beam position jitter.)

Bunch compression and streak camera



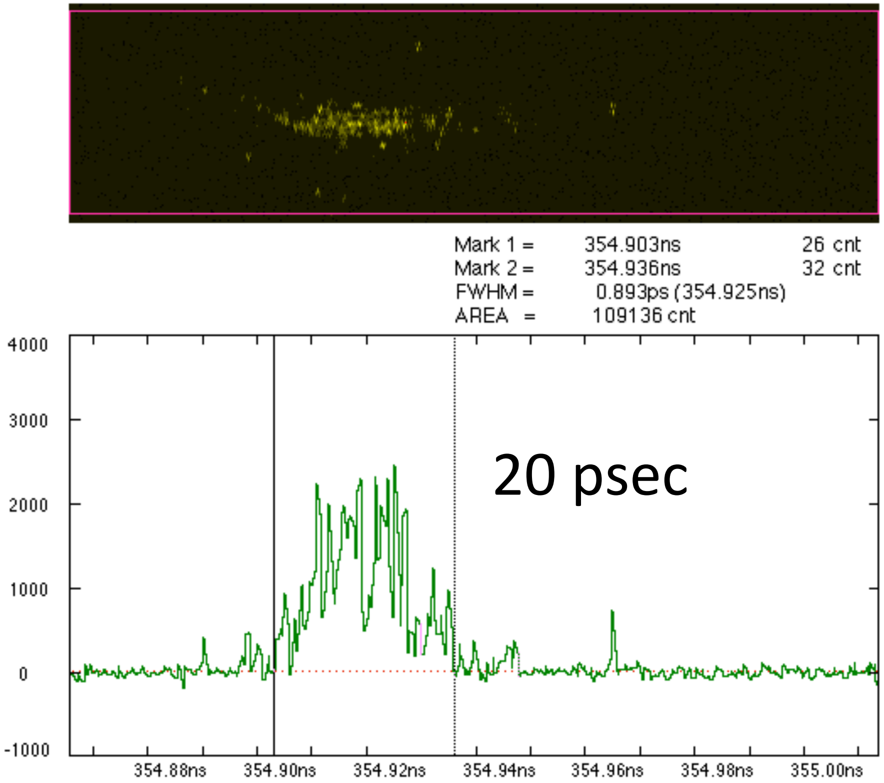




```
Mark 1 =     354.893ns           0 cnt
Mark 2 =     354.983ns         584 cnt
FWHM =        4.013ps (354.949ns)
AREA   =      181239 cnt
```

10 psec

Compression at chicane



```
Mark 1 =     354.903ns          26 cnt
Mark 2 =     354.936ns          32 cnt
FWHM =        0.893ps (354.925ns)
AREA   =      109136 cnt
```

20 psec

No compression

Summary of issues

- RF-Gun cavity
  - Disk and washer (DAW) : very fast RF ageing, 2 MeV is not enough.
  - **Quasi travelling wave side couple structure** :
    - **Lower electric field than designed value**.
      => Thermal electron gun will recover for positron generation in May 2015.
- Cathode
  - Room temperature **Ir_5Ce** cathode seems best cathode !
  - Laser injection angle for surface plasmon is effective.
  - **R&D for the QE improvement and cleaning**.
  - Preparation to use alkaline cathode
- Laser & control
  - Nd based laser system : 3-2 RF-Gun
    - Oscillator: RF synchronization precision is not enough.
    - Repetition rate 10 Hz operation => **how to upgrade to 50 Hz ?**
  - **Yb based laser system : A-1 RF-Gun => next page**
- Beam transportation and diagnostics
  - Beam loss in first accelerating structure (will be solved in May 2015.)
  - Old streak camera for beam diagnostics. (renewed for laser diagnostics)
  - Single cavity RF-Deflector installation.

Plans & Schedule
following
LINAC group strategy
and
RF-Gun review (last week)

- These few months: **Schedule**
  - Reconfigure thermal gun for positron generation
  - **Step by step RF-Gun RF ageing**.
  - New laser system in ground laser room.
    - Increase pulse energy from fiber laser
    - Simplify the laser system (new multi-pass amplifier)

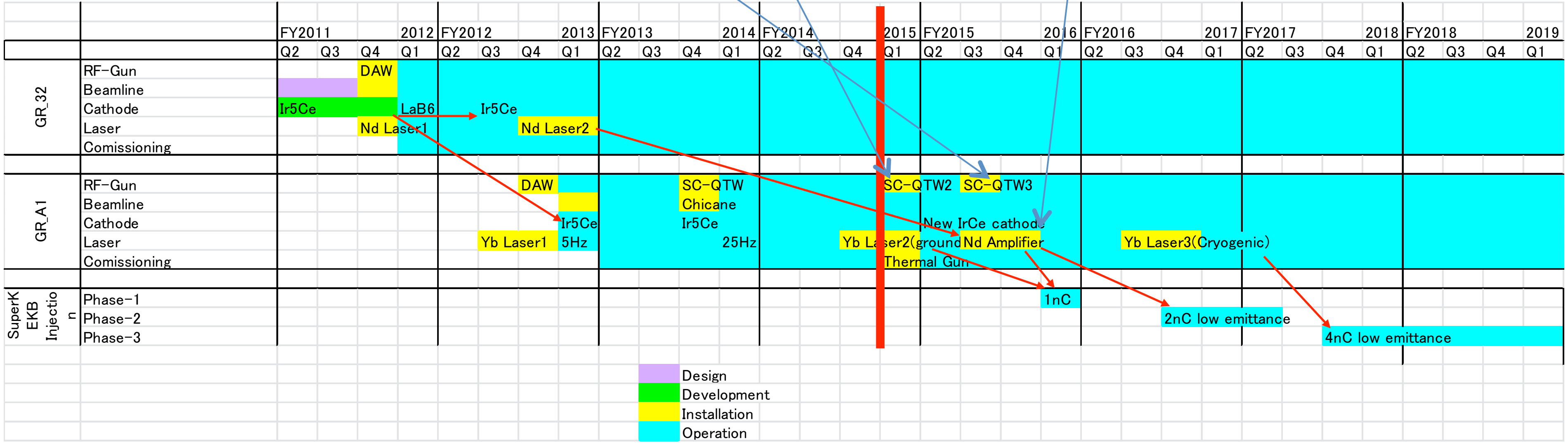
Following the RF-Gun reviewer's comments

- Next summer:

(Postponed the pulse shaping until Phase-III)

  - **Second RF-Gun (nomal laser injection / cavity modification / cathode change)**
  - **Simple Nd amplifier for Phase-I & II stable injection**

10 ps gaussian is enough for Phase-I (1nC) & II (2nC), postponed the pulse shaping until Phase-III

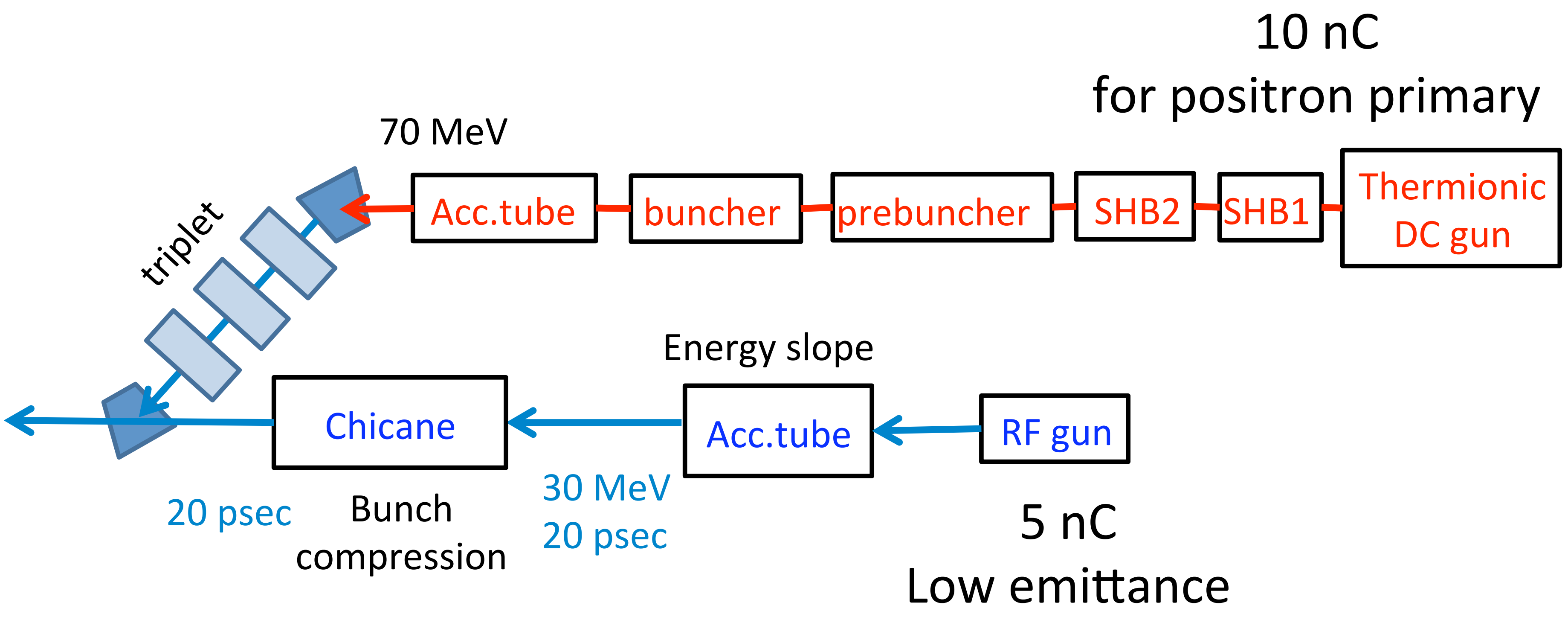


Strategy for emittance preservation and energy spread

- Emittance preservation
  - Alignment : Initial alignment / Continuous monitor / Active mover / Beam based alignment
    0.3 mm mis-alignment tolerance for 2 nC (until Phase-II)
    0.1 mm mis-alignment tolerance for 5 nC (Phase-III)
    => shorter bunch (5 ps) is required for 0.3mm mis-alignment
  - Offset injection compensate the transverse wakefield (RF Deflector will be installed for beam diagnostics for offset injection)
- Energy spread
  - 0.1 % is required for SuperKEB injection
  - 10 ps gaussian pulse is enough for 2 nC (until Phase-II)
  - Laser pulse shaping is only required for Phase-III
  - Bunch compression to 5 ps is required for Phase-III depending on the mis-alignment.

Beam line will be upgrade on up and down.

Thermionic DC gun will be installed to upper beam line.



10 nC

for positron primary

70 MeV

Acc.tube

buncher

prebuncher

SHB2

SHB1

Thermionic DC gun

triplet

Energy slope

Chicane

Acc.tube

RF gun

20 psec

Bunch compression

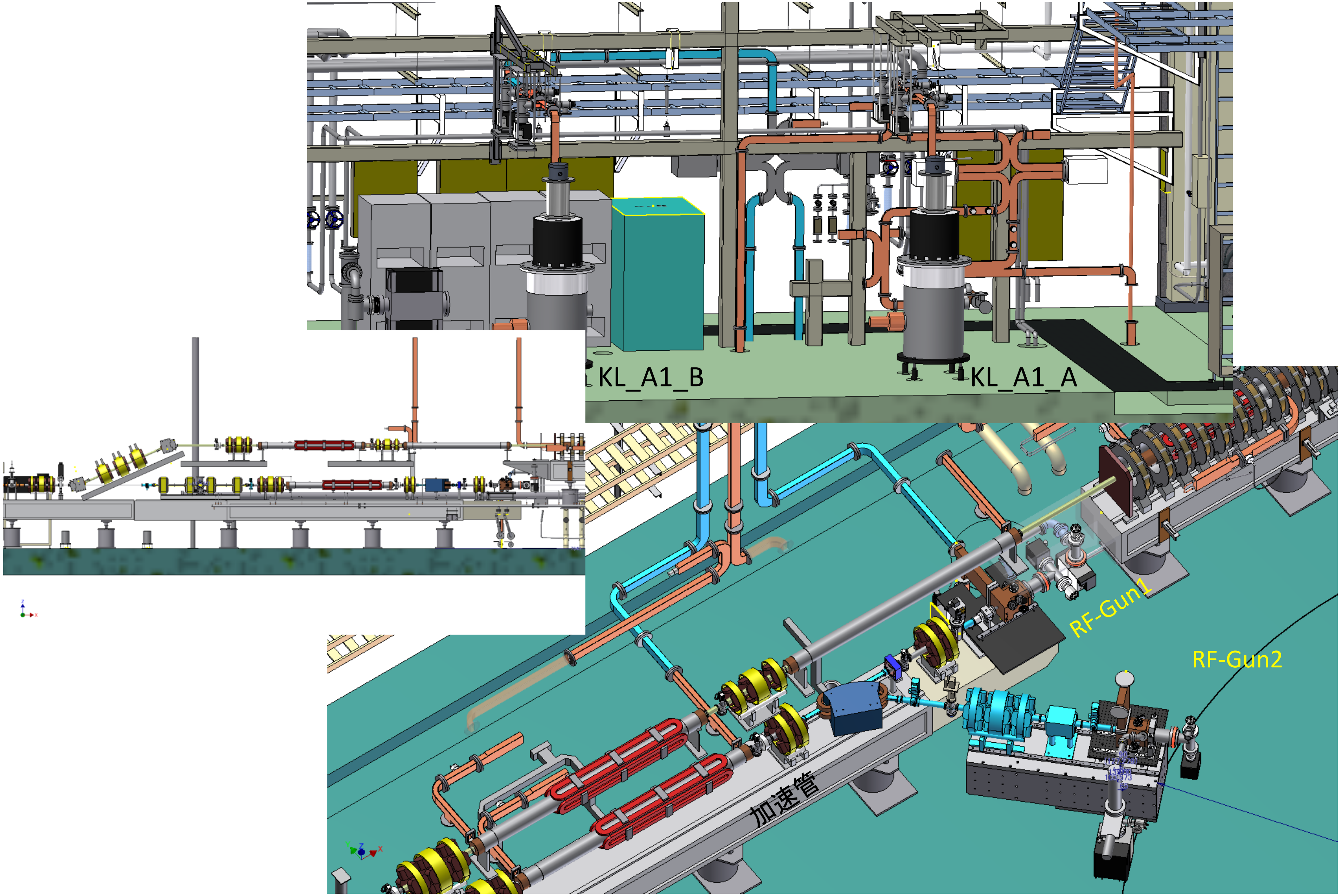
30 MeV

20 psec

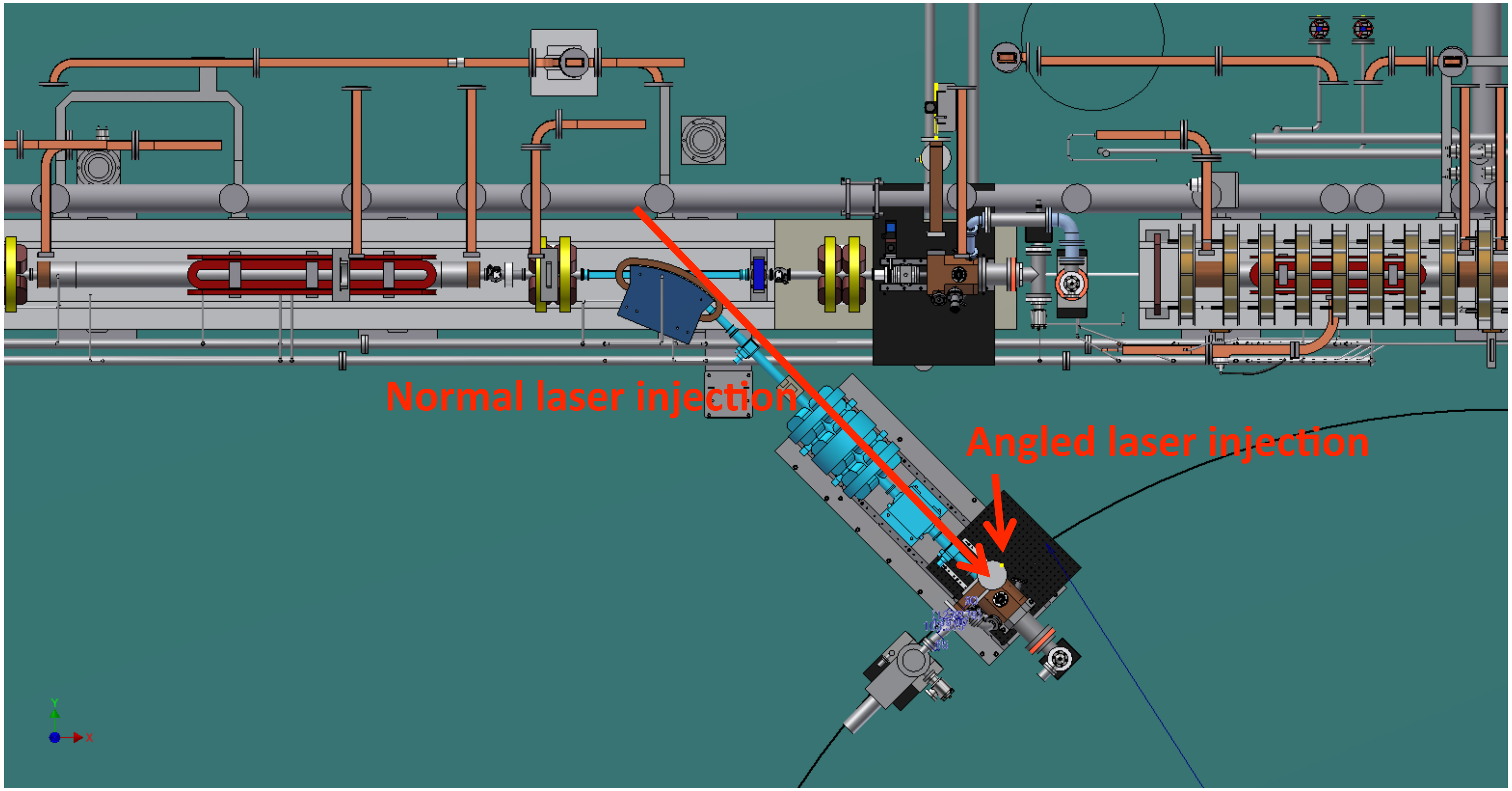
5 nC

Low emittance

Reconfiguration of A-1 injector area



Second RF gun on the 45 degree line

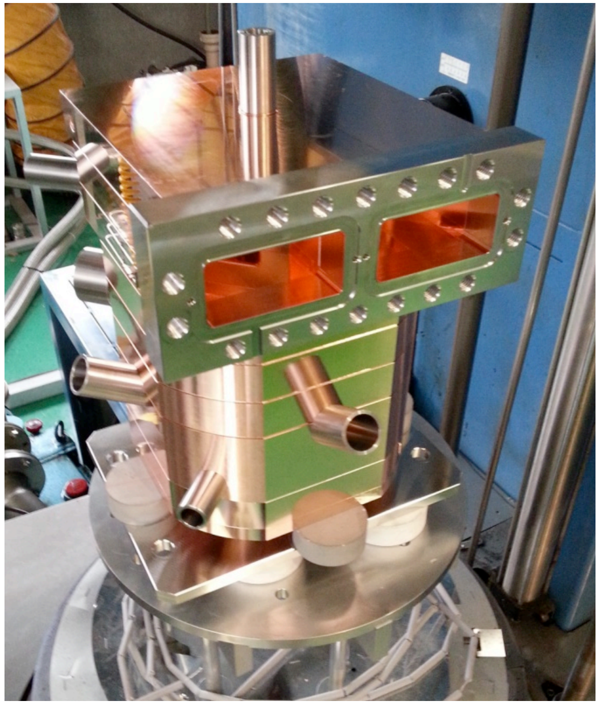


Studies on

- Improved RF-Gun cavity
- Normal laser injection
- Cathode change including alkaline cathode

Second Side coupled Quasi-travelling wave RF-Gun

Second RF-Gun under brazing



Conditioning progress was too slow.

Frequently brake down is big problem.

Cathode rod contact?

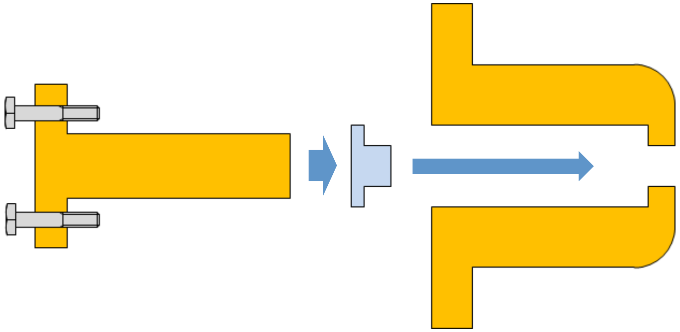
Cathode material fixation?

Cathode material sputtering due to laser?

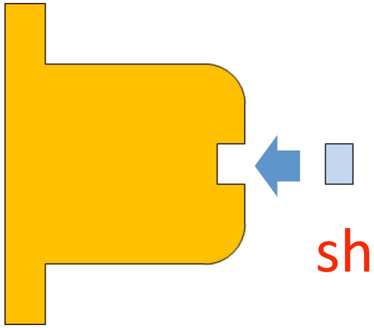
We have to separate causes of brake down.

1. Cavity conditioning, used dummy cathode rod with out cathode material (all Cu).
2. Replace new cathode rod with material (new fixation is shrinkage fit).
3. For reduce multipactoring effect, another cathode cell design is required.

Current cathode

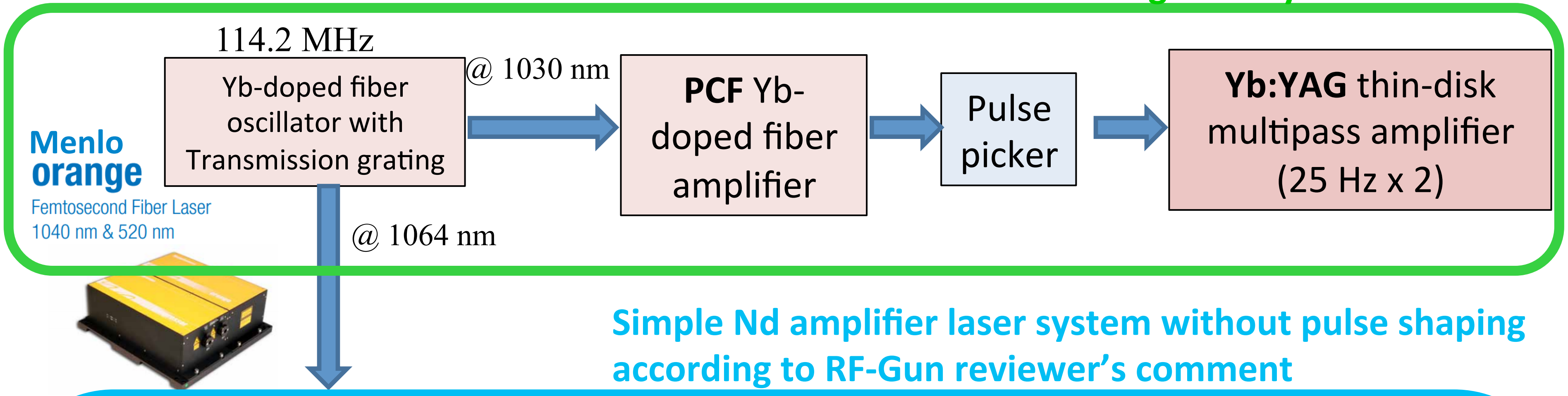


New cathode



shrinkage fit

Simplify and stabilize our laser system without pulse shaping



Existing laser system

114.2 MHz

Yb-doped fiber oscillator with Transmission grating

@ 1030 nm

PCF Yb-doped fiber amplifier

Pulse picker

Yb:YAG thin-disk multipass amplifier (25 Hz x 2)

Menlo orange

Femtosecond Fiber Laser
1040 nm & 520 nm

@ 1064 nm

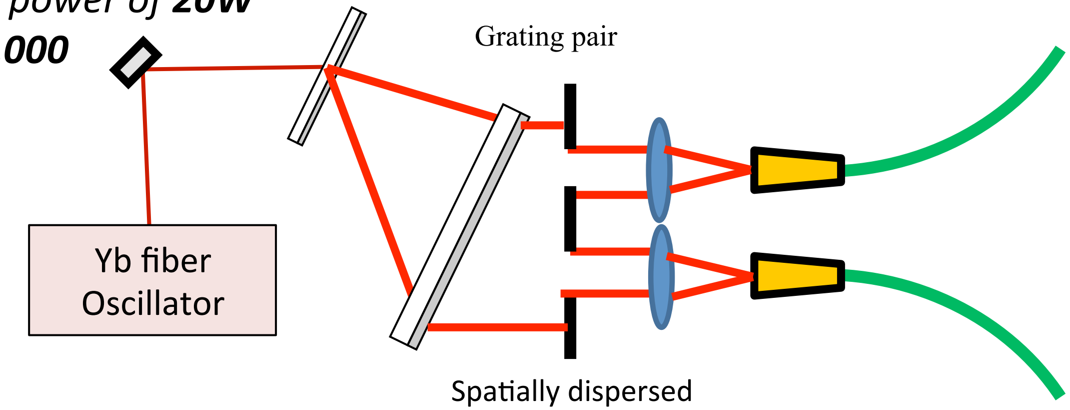
Simple Nd amplifier laser system without pulse shaping according to RF-Gun reviewer's comment

LIEKKI Yb-doped fiber amplifier

Pulse picker

Commertial Nd:YAG rod multipass amplifier (10 Hz **=> 50 Hz**)

Optilab YDFA-r-40-S,
Output power of ***20W***
\3,500,000



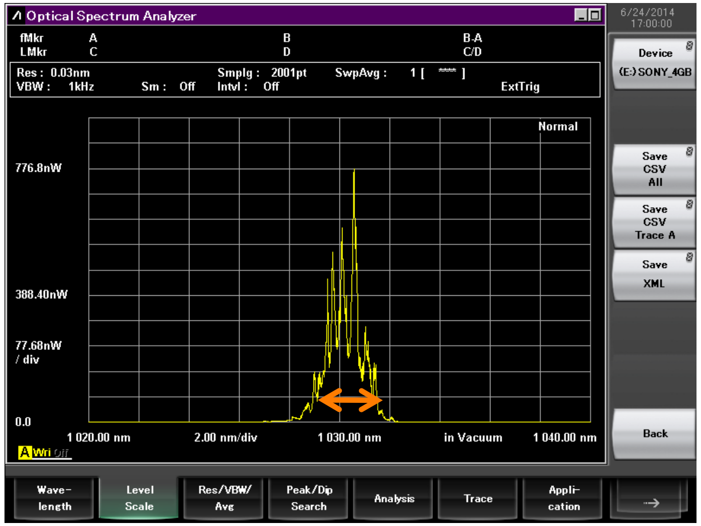
Fiber Amplifier
@1030 nm

Fiber Amplifier
@1064 nm

Strecher for Yb:YAG & Nd:YAG

	Yb:YAG	Nd:YAG
Center wavelength	1030 nm	1064 nm
Gain spectrum width	~2 ns	~0.5ns
Distance of the Stretcher to 30 ps	1.5 m	6 m (×4)

Gain spectrum of Yb:YAG

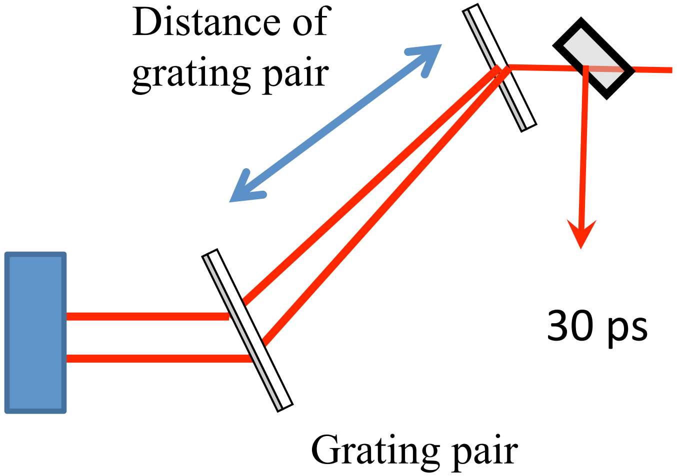


Optical Spectrum Analyzer

6/24/2014 17:00:00

Res : 0.03nm
VBW : 1kHz
Sm : Off
Smplg : 2001pt
Intvl : Off
SwpAvg : 1 [***]
ExtTrig

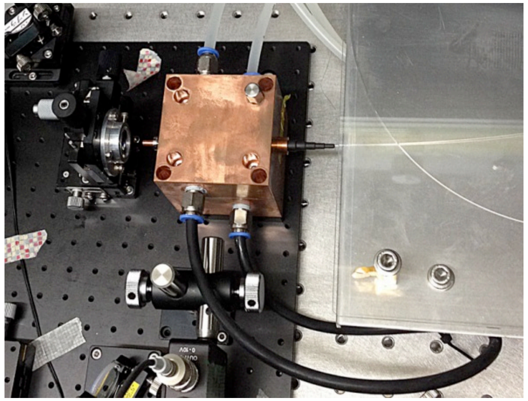
2.0nm



Improvement of fiber collimation

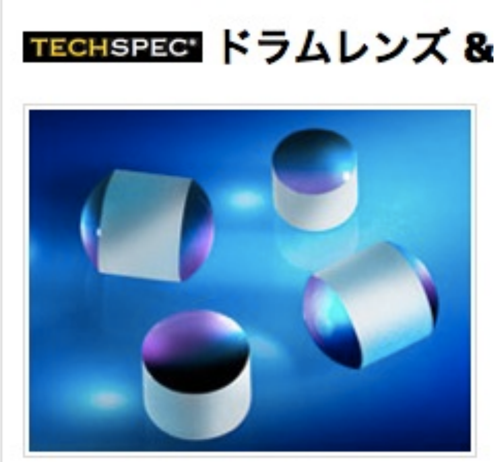
PCF fiber damage is one issue => Improve the fiber collimation

- Fiber coupler
- Cooling system



Fiber coupler in ERL

- Drum Lens



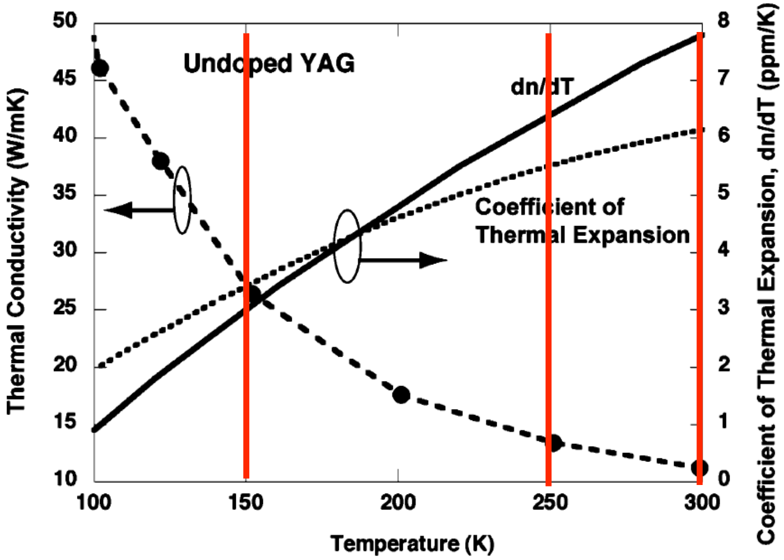
Higher output pulse energy from fiber amplifier

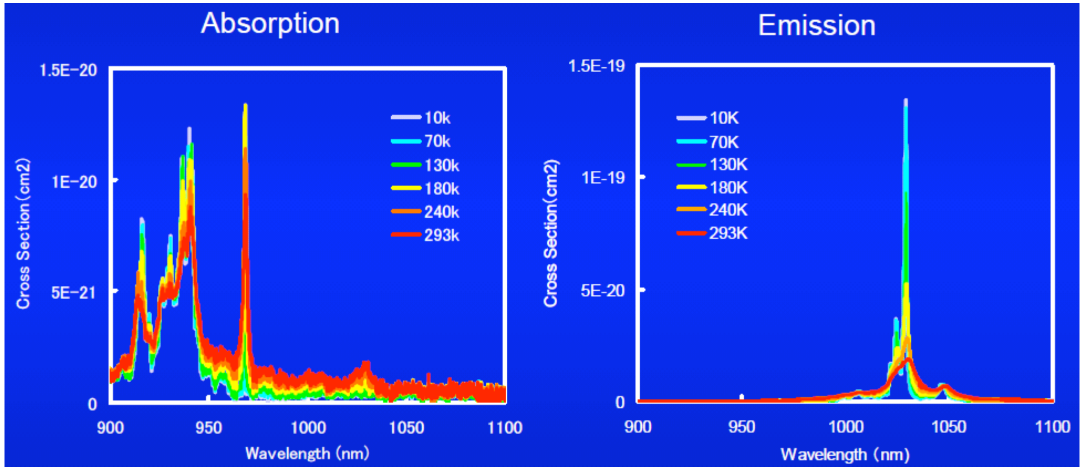
=> Reduce number of stages of Yb:YAG multi-pass amplifier

Temperature dependence of Yb:YAG

- Improvement of thermal and emission property

(Thermal lens effect) (Excitation density)





10 W/m/K , dn/dT = 8ppm/K @ 300K

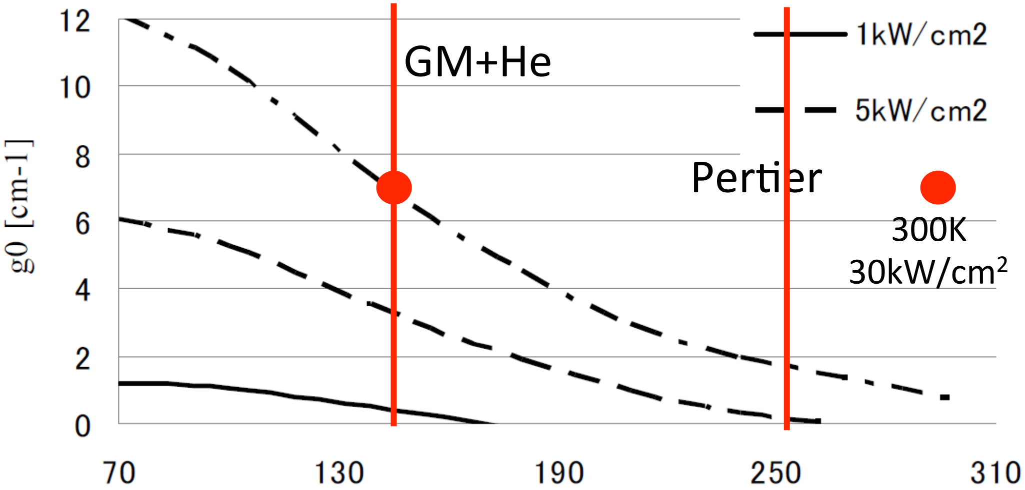
25 W/m/K , dn/dT = 3ppm/K @ 150K

↑ 150K 1/6 Thermal lens

Same gain @ 1/3 excitation density →

↓

150K => 1/20 thermal lens



300K $P/P_0 = \exp(g_0 z) \sim 2$

150K $\rightarrow g = 7\ [cm^{-1}]$

Schedule

- These few months:
  - Reconfigure thermal gun for positron generation
  - Step by step RF-Gun RF ageing.
  - New laser system in ground laser room.
    - Increase pulse energy from fiber laser
    - Simplify the laser system (new multi-pass amplifier)

Following the RF-Gun reviewer's comments

- Next summer:
  - Second RF-Gun (nomal laser injection / cavity modification / cathode change)
  - Simple Nd amplifier for Phase-I & II stable injection

(Postponed the pulse shaping until Phase-III)

10 ps gaussian is enough for Phase-I (1nC) & II (2nC), postponed the pulse shaping until Phase-III