

Report of RF-Gun Review

KEKB Accelerator Review
2016.6.14
Y.Honda

- RF-Gun Review Committee
 - member: T.Shintake(OIST), M.Poelker(JLab), S.Gilevich(SLAC), K.Oide(KEK), Y.Honda(KEK)
- Past reviews
 - (1)Feb.2015, (2)Nov.2015, (3)Jun.2016
 - (3) held Last week
 - ▶ member: Y.Honda, K.Oide, M.Poelker(video)

Past review (1st, Feb.2015)

- Situation at the time: 3-2 RFGun started up quickly (2012), but the new A-1 Gun seems to have problems...
- We reviewed the technical choice and plan of each items.
- RF-Gun Cavity
 - DAW(Disk-And-Washer) RF-Gun (3-2 Gun)
 - ▶ Fine for 5nC/b, emittance 10 mmmrad, smaller aperture
 - QTW(Quasi-Traveling-Wave) RF-Gun (A-1 Gun)
 - ▶ Original design, possibility for 10nC/b, emittance 6mmmrad
 - ▶ Took time for RF Conditioning still not achieving designed E-field
- Cathode
 - LaB6
 - ▶ Well known material, higher QE but shorter lifetime
 - Ir5Ce
 - ▶ New one, seems to have possibility in future, stable and longer lifetime
- Laser
 - Nd-based multi-pass amplifier (3-2 Gun)
 - ▶ Simple system but does not satisfy the final goal
 - * not possible to do temporal shaping, difficult to go 50Hz rep-rate
 - Yb-disk cascaded amplifier (A-1 Gun)
 - ▶ Has upgradability, for example CPA and temporal shaping.
 - ▶ Issues in the hand-made oscillator (stability and synchronization)
 - ▶ A cascaded system of many stages can be chaos
 - Moving to a new laser room for much space and better environment

Support QTW development

Support IrCe development

Seems Diverging

Committee feedback

- Impressed hard works and creativity of the group.
- Seems R&D is diverging, need to select items for limited resources.
- Phase-I starts soon, R&D stage to operation stage
 - Leave R&D items for Phase-II&III
 - ▶ Without temporal shaping, Nd-based is a promising scheme
- Simplify the system
 - Commercial components when possible
 - ▶ oscillator, amplifier unit, etc.
 - 2-bunches generation by a delay-line scheme is simpler
 - Reconsider Nd-based system
- Still many items for operation stage
 - Transport system
 - ▶ Vacuum transport, pointing stability
 - Diagnostic system
 - ▶ Virtual cathode monitoring, prepare many monitoring points in the system

The Review Committee “Philosophy”

- Any component integrated into the accelerator system must be **Reliable, Maintainable, Reproducible**
- Start with a simple, robust system. Improve it and add features step by step afterwards
- Cost is not irrelevant

Past review (2nd, Nov.2015)

- Situation at the time: New laser system under development, commissioning with thermionic gun.
- Status for responding the 1st review
- Beam commissioning
 - Started with a thermionic gun
- RF-Gun Cavity
 - QTW RF-Gun
 - ▶ Cathode plug design improvement, then RF conditioning went well
 - CDS(Cut-Disk-Structure) RF-Gun
 - ▶ New design shown, wider aperture, lower RF power
 - ▶ 0-degree laser injection is possible
- Laser
 - 2-bunch(96ns separation) will be done by a splitter & delay-line scheme.
 - ▶ Regenerative amplifier is promising
 - Designed a system for Nd-based and Yb-based regenerative amplifier
 - ▶ Under construction in the new laser room
 - Existing Yb-based system
 - ▶ Oscillator improvement
 - ▶ High gain multi-pass amplifier, reduced number of stages

Committee feedback

- Impressed progress in limited time
- Need improvement in beam tuning
 - Beam loss and optics mismatch
 - Identify sources of beam fluctuation
- RF-Gun cavity
 - Successful conditioning of improved QTW is great.
 - Supported the idea of CDS
- Cathode
 - Support investigating potential of IrCe (not to shift to CsTe)
- Laser
 - Appears to be more focused work than before, this is good.
 - Stability greatly improved, but still not enough
 - ▶ Identify the fluctuation source, environmental improvement
 - More diagnostics should be installed.

Last review (3rd, Jun.2016)

- Beam commissioning
 - Stable RF-Gun operation and successful HER injection
 - Beam jitter and emittance investigation
- RF-Gun Cavity
 - QTW RF-Gun
 - ▶ Stable beam operation
 - RF conditioning station
 - ▶ Proved choke structure, this is for future cathode plug designing
 - CDS(Cut-Disk-Structure) RF-Gun
 - ▶ Under fabrication. 0-degree laser injection, better for laser pointing jitter.
 - ▶ To be installed in the new beam line
- Cathode
 - Possibility of Ir₇Ce₂ or single crystal IrCe for higher QE
- Laser
 - Existing Yb-based system
 - ▶ Stable operation for a month (no system change)
 - New laser for Phase-II
 - ▶ Nd regenerative amplifier
 - ▶ 10MHz oscillator for further simplification
 - Development for Phase-III
 - ▶ Yb-disk regenerative amplifier
 - ▶ Stretcher and compressor for CPA , Yb-Rod
 - ▶ Cryo Yb R&D

Committee feedback

- Congratulate stable RF-Gun operation and HER injection in Phase-I
- Beam commissioning
 - There are puzzles in emittance/jitter between right after the gun and at the end of the linac
 - If beam jitter dominated the projected emittance, improvement of laser pointing jitter is essential
 - ▶ In this case, 0-degree injection at CDS gun has an advantage.
 - Try 2-bunch injection
- RF-Gun cavity
 - After RF conditioning, QTW gun working well.
 - Need clear explanation on benefits of CDS gun
 - ▶ You can play in the 2nd beam line, but still need clarification.
- Cathode
 - Clear goal of QE should be shown. Critical number that changes/relaxes the laser system design.
 - Seems separated man-power, so doing R&D for Phase-III should be fine.
- Laser
 - Existing Yb multi-pass system worked stably.
 - ▶ Contradiction to our past recommendation of Nd system. Great achievement.
 - ▶ Feedback system for stabilizing should be tested.
 - Regenerative amplifier to be developed will benefit simplifying and beam profile improvement.
 - ▶ Most critical study item at present for Phase-II
 - Detail of 2-bunch generation by splitter&delay system should be shown.
 - Engineering design of transport system should be shown.
 - Diagnostic system is still poor.
 - ▶ Virtual cathode monitoring, prepare many monitoring points in the system

Committee feedback

- Beam operation
 - Now the issues are not only in the Gun but entire Linac
 - ▶ Linac and Ring operation team should join the study of emittance/jitter.
 - Gun team should prepare more monitors to investigate the origin.
 - ▶ Shot-by-shot laser position, intensity, Laser profile, etc.
 - ▶ These should be synchronized with other beam monitors, BPM etc.
 - Present procedure of beam tuning, not just the result.
 - ▶ For example, Phase optimization for short bunch and low emittance
- Lots of works for laser experts, seems some items are put off.
 - Laser transport line and diagnostics
 - Beam optics and diagnostics
 - For these items, support from other team may help.
- Need discussion based on real data
 - Many schematic figures were presented but quantitative discussion was limited.
 - Show data. This may come from issues in poor diagnostic, again.

Summary

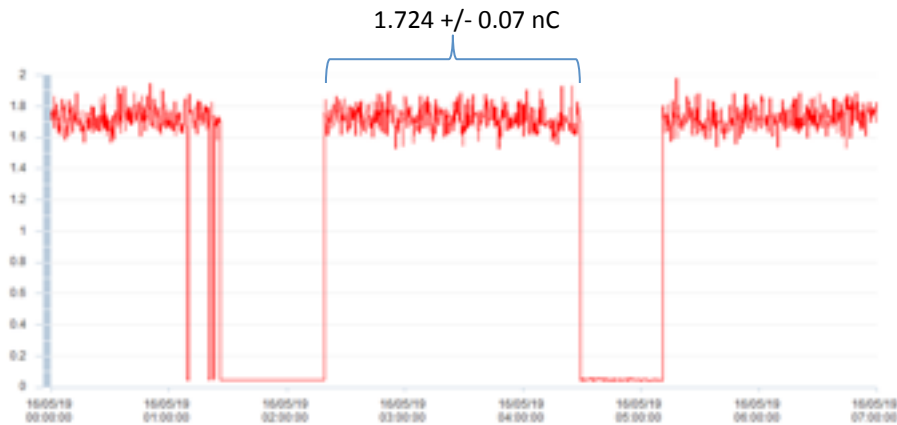
- We appreciate great works of RF-Gun and Laser team.
- We congratulate successful commissioning of HER injection by RF-Gun.
- Now it seems the development work seems organized than before.
- Keep the motivation and improvement works for Phase-II and III.
- Now the issues are in the beam operation of total accelerator system.

Supplement slides

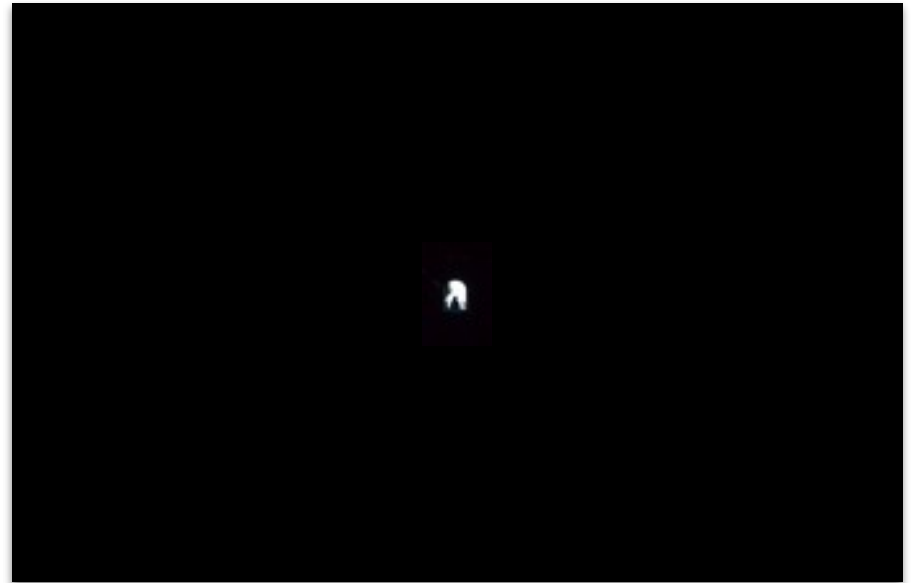
- Report supplied from committee members

Congratulations!

- Successful injection to the HER.
 - ~100% injection efficiency
 - Good stability during operation for days.
- Now you can see the exit of the long tunnel!



T. Natsui

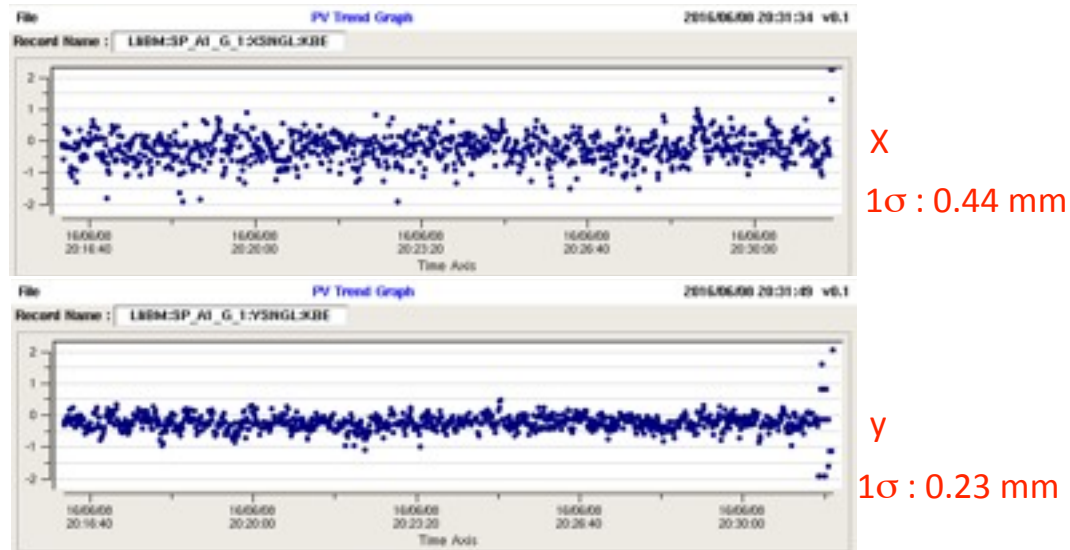


Some issues to be overcome by Phase-II

- 2 bunch injection
- While the emittance measurement right after the gun seems OK ($\sim 20 \mu\text{m}$), significant growth of emittance and jitter have been observed through the linac and beam transport line.

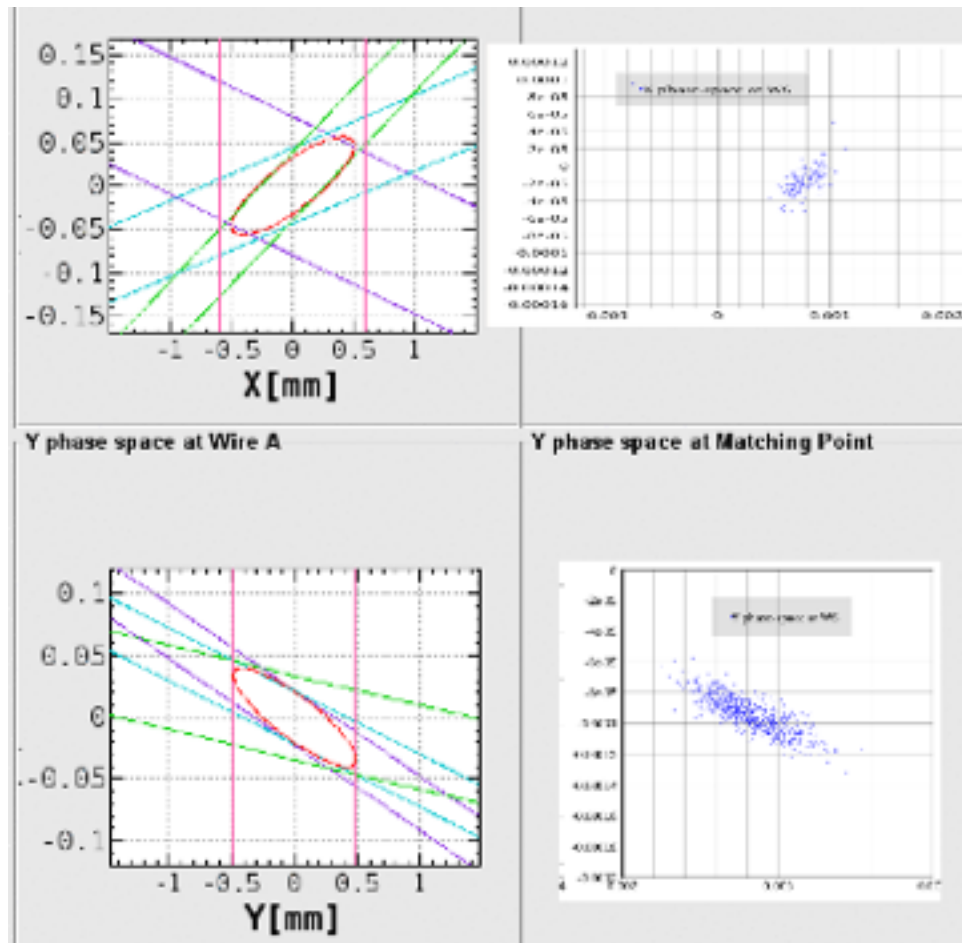
	X	Y
Sector C 4 wire	176±32.3	34.2±7.6
Sector C 3 wire(no B)	100±138	34.2±16.5
Sector 5 4 wire	51.6±31.0	114±34.4
Sector 5 3 wire(no C)	106±24.9	
Sector 5 3 wire(no D)		76.5±38.9
BT 4 wire	211±110.6	133±22.2
BT 3 wire(no D)	334±52.1	
BT 3 wire(no C)		138±45.6

- There are some puzzles in the emittance/jitter:
 - While the horizontal position jitter right after the gun seems much higher than the vertical, the Q-scan at the screen does not show the difference (if it is true, the jitter may not be the issue).



	Horizontal (projection)	Vertical (projection)
A1 chicane	28.3 (31.8)	26.4 (29.4)
A1 M	20.3 (20.8)	17.7 (18.3)
B sector dump	48.5 (52.7)	21.7 (22.2)

- There are some puzzles in the emittance/jitter:
 - The observed phase space of the jitter in the BT line has very similar shape to the measurement of wire, why?
 - Similar observation should be done for the thermal gun.



- More efforts, not only by the Gun team, but by **entire Linac people** are necessary to solve the issue of emittance/jitter growth:
 - identify the source(s)
 - understand the mechanism (via wake? nonlinearity in the J-arc?···)
- As the ring operation halts until Phase-II, the **ring operation team** should join the linac study.

Laser Issues (time structure is very challenging from laser perspective, many options to consider)

- Gain media: Nd vs Yb vs Ti:sap
- Multi-pass amplifier vs Regenerative Amplifier
- Choice of master oscillator laser: commercial vs different in-house manufactured
- 50 Hz operation
- 2-bunch time structure

Factors that influence decisions:

- Reliability, stability...the focus of Phase I
- Enhanced capability(complexity)...the focus for next phases
- The rf gun and the photocathode influence laser choices

The balance between preparing for production running and performing R&D for future phases

- Underground laser system, with Yb gain medium and multipass amplifier shown to be successful for phase 1 (in mild contradiction to past recommendation that urged Nd gain medium)
 - with enhanced capabilities
- Laser operating > 1 month without maintenance!! Great achievement
- Group has benefited from talented troubleshooting and implementation of effective improvements: stable master oscillators, tailored preamplifiers, semiconductor optical amplifier for pulse picking and ASE reduction

The balance between preparing for production running and performing R&D for future phases

Still to do for Phase 1: capabilities (cont.)

- 2 bunch formation
- The optical transport line needs work (is there design and engineering support for this work? Can this be taken off the gun/laser group “plate”?)
- More diagnostics are needed to determine the origin of laser instability (timing vs pointing)
- Virtual cathode
- Feedback applied to multipass amp?

The balance between preparing for production running and performing R&D for future phases

- Underground laser, a “bare bones” system with enhanced capabilities (cont.) for Phase 1. Design is fixed, not changing
- Above ground laser represents the ultimate laser for Super KEKB
- Can the gun/laser group sufficiently maintain and improve the bare bones Phase 1 laser system while conducting R&D, particularly the effort devoted to constructing reliable regenerative amplifier?
- The regenerative amplifier appears to be the most critical R&D topic now...

- You will benefit during a review, if you say “up front” why you are installing the CDS RF Gun. People on review committee who are not intimately aware of specific issues may think you are “playing”. The gun work can be a distraction from laser work?

Specifically, state the benefits of the CDS gun over the QTW gun: e.g. more charge, normal incidence illumination of photocathode which provides more QE?, for

Other questions/Issues

- Is one master oscillator better than the others? e.g., for positron production, with required timing shift, Why are there still three+ choices for MO?
- If the regenerative amplifier is the preferred final choice, please provide a schematic diagram of the beamsplitter/delay line for 2-bunch formation
- Photocathode QE presently 10^{-4} . Help the committee appreciate your effort to increase QE to 10^{-3} . e.g., give us a sense for how important this effort is. The top priority or the 20th priority

Other questions/Issues

- State specifically how the gun/laser group will prepare for Phase2. Priority list the jobs that must be done...