SIMULATIONS OF MODE SEPARATED RF PHOTO CATHODE GUN

Abhay Deshpande[a*], Sakae Araki[b], Masafumi Fukuda[b], Kazuyuki Sakaue[c], Nobuhiro Terunuma[b], Junji Urakawa[b], Noboru Sasao[d], Masakazu Washio[c]

[a] Graduate University for Advanced Studies, Shonan International Village, Hayama, Kanagawa 240-0193, Japan, [b]High Energy Accelerator Research Organization, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan, [c]Waseda University, Tokyo 169-8555, Japan; [d]Kyoto University, Kyoto 606-8502, Japan

Introduction

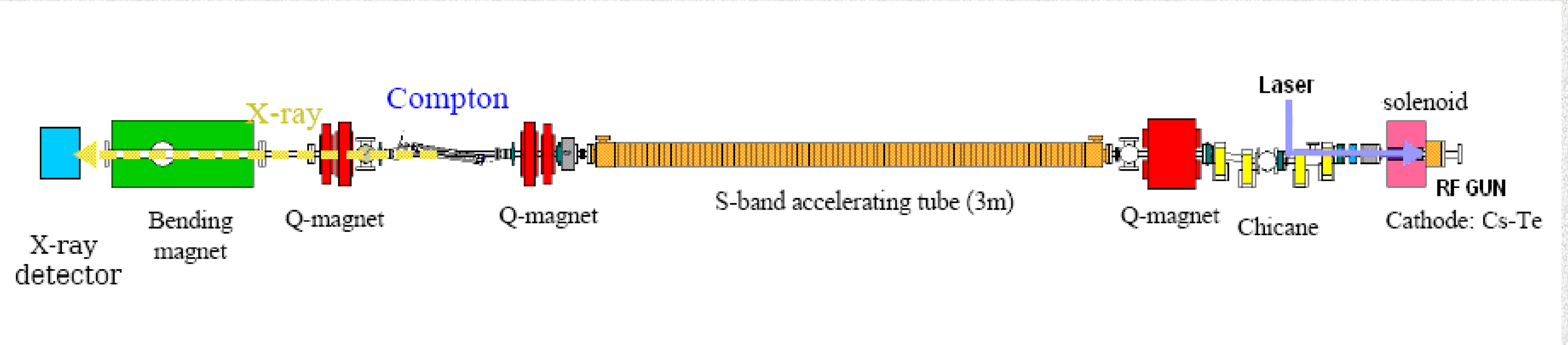
At Accelerator Test Facility (ATF) at KEK we have designed and developed S-Band Compact 'Laser Undulator Compton X-ray Source' called as LUCX. This test bench is as shown in Fig 1. Parameters are listed in Table 1. 60 μm beam at the interaction point interacts with pulsed laser to produce intense X-rays by Inverse Compton scattering principle. Recently we demonstrated 30 KeV X-rays with a flux of 0.93×10^4 photons per train. To meet further challenge of increasing the flux, we started working on various systems to optimize various parameters to achieve a flux of the order of 1.0×10^7 photons per train.

We designed a new RF photo cathode gun cavity to increase the mode separation and the quality factor [1]. The higher mode separation will result in better stability and lower emittance, thus helping to make a good beam at interaction point [2,3]. In the linac section, the power delivery scheme is being modified to achieve 45 MeV energy with 200 nC in 100 bunches. Higher stability will also make it possible to go for higher repetition rates in future, thus further increasing the current. In addition to above changes, a new scheme is being worked out to achieve 5 MeV beam with 2μC in 1000 bunches in the same setup at the interaction point.

Table 1 : Parameters

Energy	45 MeV
Energy Spread	0.13 %
Frequency	2.856 GHz
Bunch Charge	0.5 nC per bunch
Bunch Number	100 bunches
Bunch Spacing	2.8 ns
Beam size at interaction point	60 μm in y plane
Emittance	7 pi-mm-mrad

Fig. 1 : Experimental Layout



Mode separated RF Gun design

- ✓ We designed to increase the mode separation from 3.5 MHz in old gun to 8.6 MHz in the new gun cavity.
- ✓ Curved interior wall geometry was selected for the cells.
- ✓ The operating frequency is 2856 MHz at π mode with a field balance of 1.0
- ✓ The equivalent circuit analysis shows that full cell frequency should be raised by at least 1 MHz to achieve π and π/3 like fields. [4-7]
- ✓ It also shows that with two cell structure like RF gun, π and zero modes may not exist instead the pair like '0 and 2π/3' or 'π and π/3' can exist. Addition of drift tube at the exit in simulation, makes the pair '3π/4 and π/4' or some such pair. The pair of modes excited depends upon the length of drift tube. Full cell frequency increase can bring the modes very close to π like modes
- ✓ The definition of lower mode proves important when studying the effects of lower mode on cathode field which might dilute the emittance.

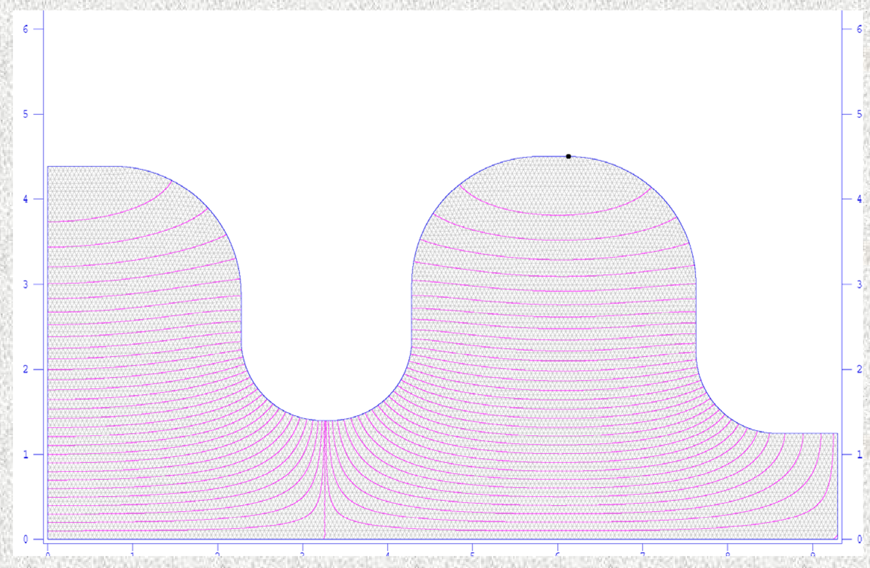


Fig. 2: New Gun Profile

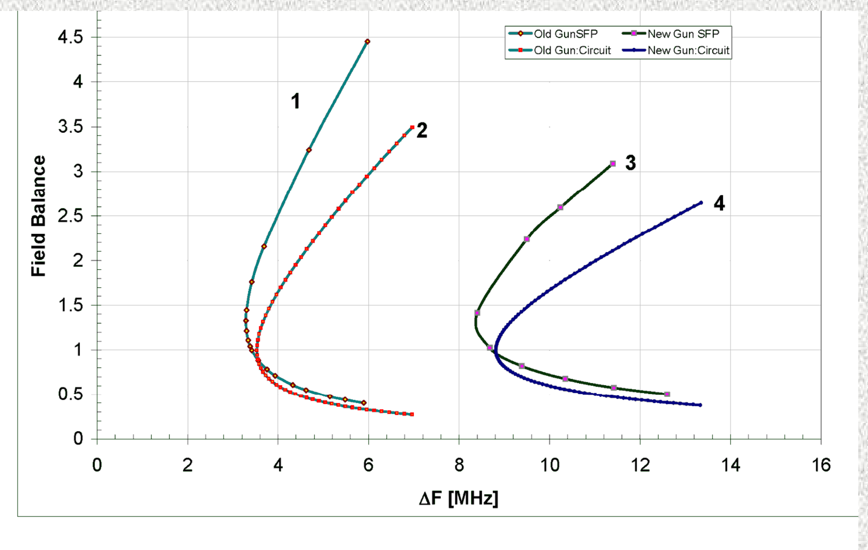


Fig. 3: Field balance as function of Mode separation

Beam Dynamic Simulations using ASTRA

- ✓ Optimized Parameters using ASTRA code [8]
- ✓ Optimization done for
  - Spot Size Variations
  - Axial Field strength and Solenoid Strength

σ_x , σ_y = 0.319 mm σ_z = 5.51 ps

Ez = 140 MV/m Bz = 0.24 T

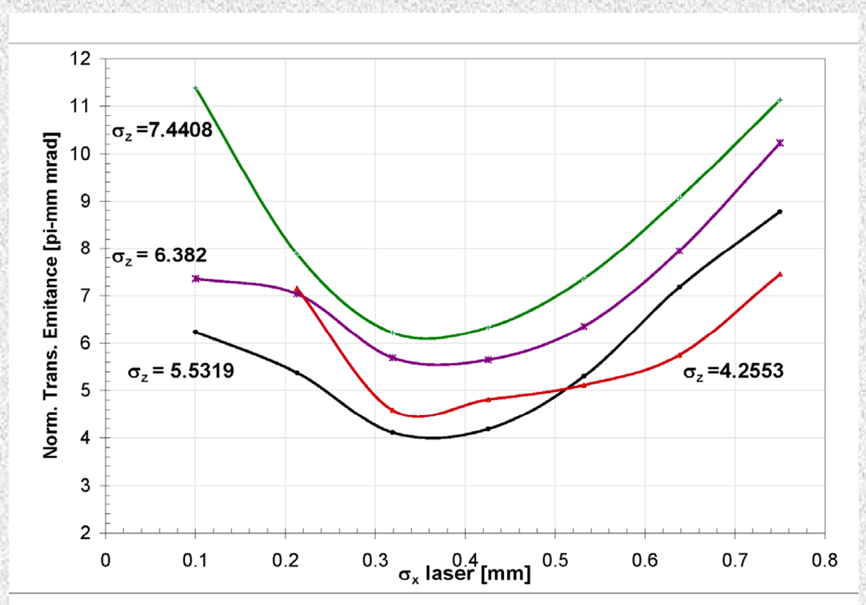


Fig. 4: Emittance variation with spot size

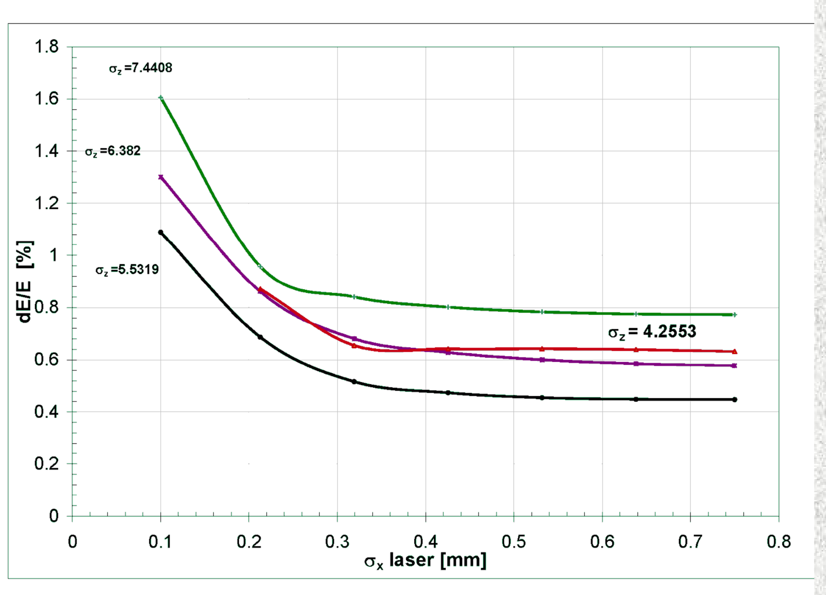


Fig. 5: Energy spread with spot length

1000 bunch, 2 μC Beam

- ✓ Replacing the Linac with a drift tube, we will be able to use same diagnostic setup for high and low energy beams.
- ✓ In the new setup, we plan to achieve 5 MeV, 2 μC in 1000 bunches.
- ✓ This high charge will then be used for experimentation.
- ✓ The new setup will be Dual Energy, with 45 MeV and 5 MeV as two options.

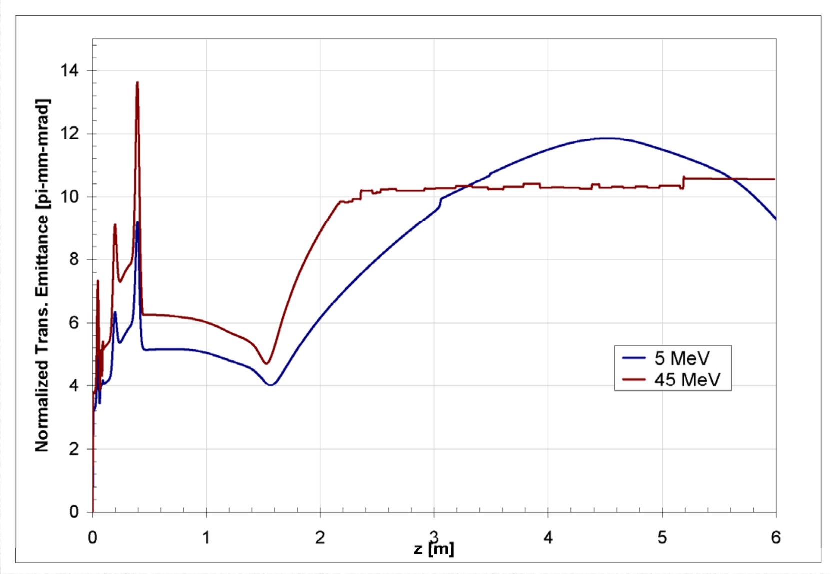


Fig. 8: Emittance evolution for high and low energy beam

Up-gradation for High Charge

- ✓ To increase the charge to 200 nC in 100 bunches, we are up-grading the power delivery mechanism.
- ✓ In the new setup we will use separate Klystrons for Gun and Linac to increase the power at each port.
- ✓ The Linac Klystron uses power multiplier to increase the peak power.

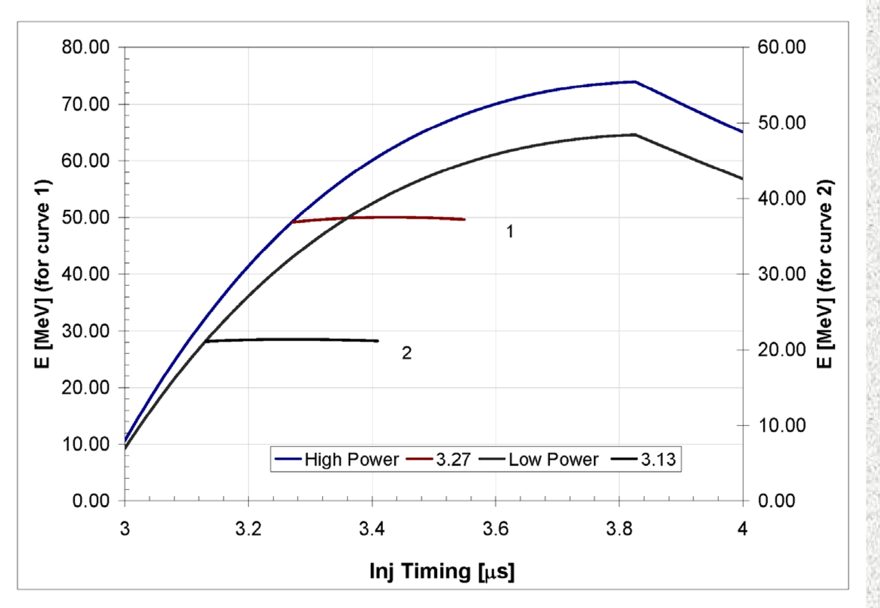


Fig. 6: Energy vs Injection time for two power levels

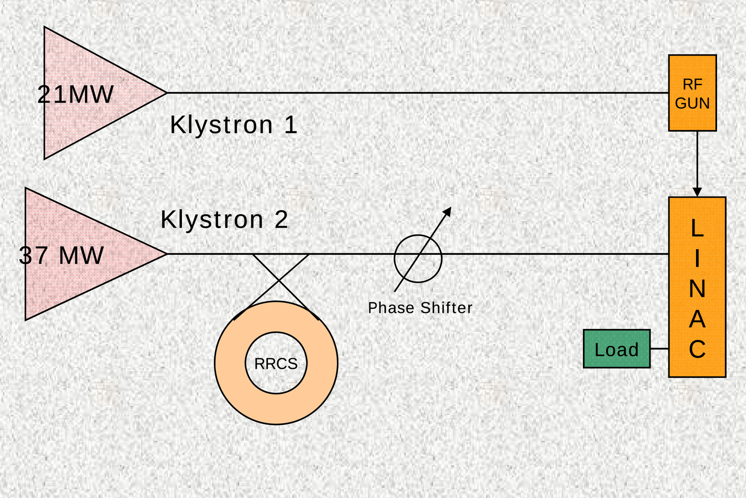


Fig. 7: New Power Delivery Scheme

Acknowledgements

The present work was carried out with the partial support from the "Grant-in-Aid for Creative Scientific Research of JSPS (KAKENHI 17GS0210)" project of the Ministry of Education, Science, Sports, Culture and Technology of Japan (MEXT). This research is also supported by Quantum Beam Technology Program of JST.

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Summary

The new RF gun cavity is under fabrication and expected to be ready for installation by July 2009. The high mode separation will be helpful in making gun stable against drifts due to thermal problems and make gun more stable. Emittance is expected to go down while the exit energy will be higher. With a new power delivery scheme, we expect to achieve 200 nC in 100 bunch with energy of 45 MeV with 7 pi-mm-mrad emittance in the vertical plane. By installing a linac replacement mechanism we will be able to operate the system in dual mode with 5 MeV energy and 2mC charge as low energy option.

*abhay@post.kek.jp ; abhaypd@gmail.com