CONCEPTUAL DESIGN OF MUSES 300MeV ELECTRON LINAC

M.Wakasugi, RIKEN RI Beam Factory Project Office,Japan
T.Katayama, University of Tokyo, Center For Nuclear Study, Graduate School of Science
Y.Kamino, Mitsubishi Heavy Industries, Ltd. Nagoya Aerospace Systems, Japan

Abstract

The Multi Use Experimental Storage rings (MUSES) is planned as one of the main research assets in addition to the super conducting ring cyclotrons(IRC and SRC-6) and RI beam generator(BigRIPS) for RIKEN RI beam factory (RIBF). MUSES is composed of Double Storage Ring (DSR),Accumulator Cooler Ring(ACR) and Booster Synchrotron(BSR) for various collision experiments of RI particle, ions, electron and SOR photon. The MUSES 300MeV electron LINAC provides electron beam to BSR and DSR. This electron LINAC features a compact high energy LINAC with a high quality beam of low energy spread and small emittance. In this paper the conceptual design of the LINAC is presented and the innovative approach to suppress the energy spread is discussed.

1. INTRODUCTION

A double storage ring system (MUSES) is planned as a main experimental asset in addition to super conductive ring cyclotrons (IRC, SRC-6) and RI beam generator (Big RIPS) for RI beam generation. MUSES is composed of a double storage ring (DSR), an accumulator cooler ring, booster synchrotron(BSR) and an electron LINAC for collision experiments of RI particles, Ion, electron and SOR photon. The electron LINAC provides BSR and DSR with 300MeV electron beam as an injector and is required to be a very compact accelerator with the performance specified below. The electron LINAC beam line is also required to be electromagnetically quiet, because sensitive detector devices will be collocated on the same floor.

RF Frequency :2856MHz
Beam energy : 300MeV
Pulse repetition : 50Hz (max.)
Long pulse mode : Beam pulse width 5 μsec
Beam current 100mA
Short pulse mode : Beam pulse width 1nsec
Beam current 1A
Energy spread : ±0.25%(design target)
Normalized emittance : 100• mm mrad (max)

2. SYSTEM DESIGN

A high gradient acceleration is necessary to attain a a short beam line. The 5 μsec beam pulse is required for the Long pulse mode and the SLED is not applicable. A high peak power klystron Toshiba E-3712 (80MW 4μsec) is selected. The 6μsec RF pulse width is required for 5μsec beam pulse including a filling time of the accelerator guides. The klystron high voltage beam pulse of 8.2μsec(-3dB) is necessary. The discussion with the klystron manufacturer concludes 50MW peak power operation will be reasonable with some safety margin. The number of the accelerator guides per klystron is studied with modulator number(economical) and beam line length(compactness) as evaluation factors and the conclusion is 2 accelerator guides for one klystron. The system block diagram of the LINAC is given in Fig.1. The regular section is composed of three klystorns and six accelerator guides. The same klystron is selected for the injector section for the commonality of the spare klystron. The Energy Gain Diagram is given in Fig.2.

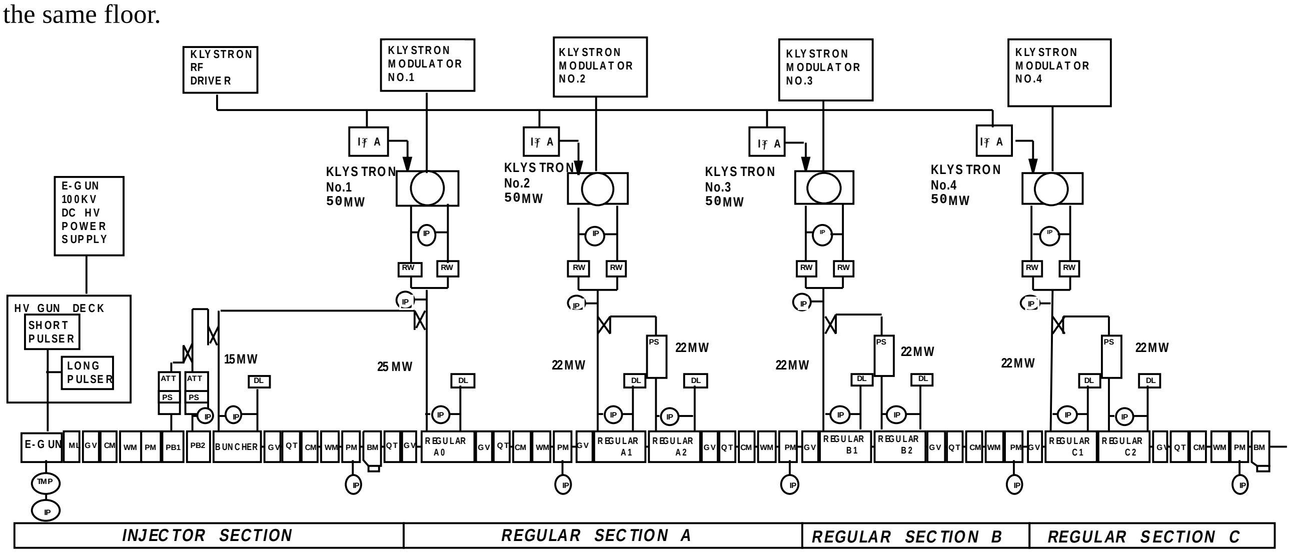

Figure1 System Block Diagram

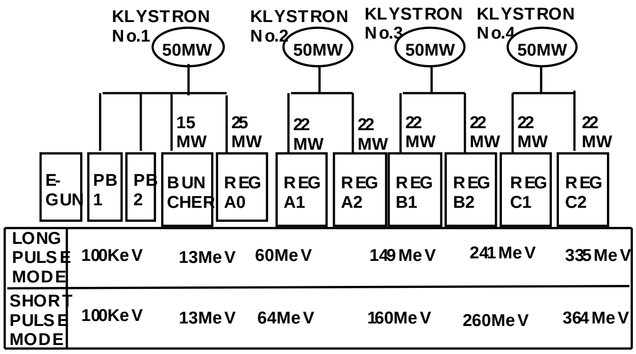

Figure 2 Energy Gain Diagram

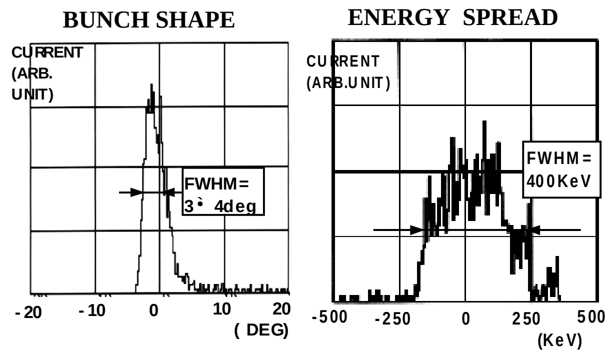

Figure 4 Short Pulse Mode

3. INJECTOR SECTION

The injector section is the SLAC type composed of a standing wave type pre-buncher No.1(PB1), a traveling wave type pre-buncher No.2(PB2) and a traveling wave type accelerator guide of •=1. A rather low gun voltage (100kV) can be used, because PB2 has a acceleration effect. The electron gun is driven by 100kV DC power source for the suppression of electromagnetic noise. The design gun current is 1.3A for the short pulse mode and the gun electrode geometry is optimized for this current. An iris is used to limit the gun current to 130mA for the long pulse mode, which will improve the gun emittance.
The cathode will be EIMAC Y-845 (cathode area 0.5cm^2) to improve the gun emittance with a small cathode area.
Other injector parameter is determined with PARMELA. Fig.3 and Fig.4 shows the PARMELA simulation result.

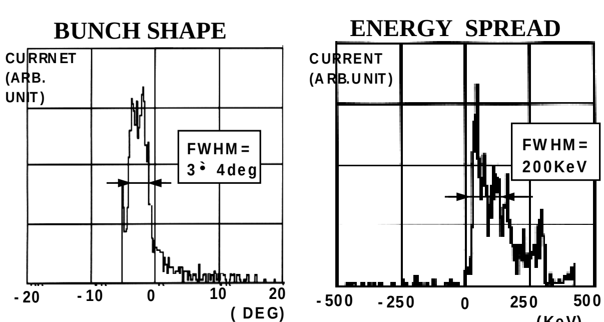

Figure3 Long Pulse Mode

4. REGULAR SECTION

The regular section is composed of three groups of CG type traveling wave type accelerator guides. The attenuation factor of three groups A,B,C is 0.5Neper, 0.6Neper and 0.7Neper respectively to downstream of the beam line. The group A has three accelerator guides and group B and C has two accelerator guides respectively as mentioned in section 2. This arrangement is for HEM_{11} mode dumping to suppress the cumulative type of beam break up (C-BBU) in the long pulse mode. The HEM_{11} mode induced in the upper stream of the accelerator guide by the off axis beam is dumped in the downstream accelerator guide, because the HEM_{11} frequency of the upper stream is cut off frequency in the downstream. This scheme will be too much for 100mA beam current. The minute and quantitative examination of C-BBU should be performed and the unification of the guide parameter will be preferable for economy, if possible.

5. BEAM TRANSPORT

In the injector section the beam is focused by solenoid coil. After the buncher guide, Quadrapole Triplet lenses are used for beam focusing. The beam transport simulation with TRANSPORT is shown in Fig.5 for the long pulse mode.

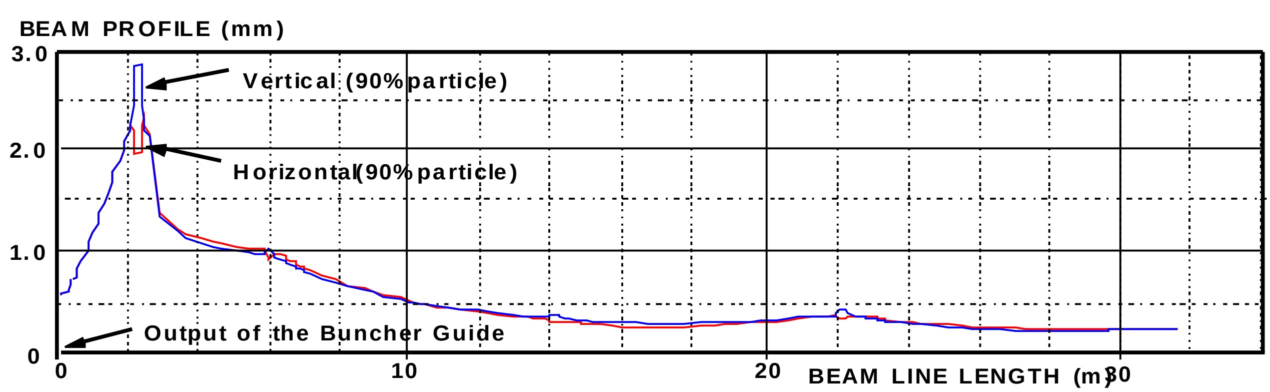

Figure 5 Beam Transport Simulation Result (Long Pulse Mode)

6. ENERGY SPEAD CONSIDERATION

The cause of the energy spread is as follows.

(1) Acceleration field fluctuation caused by the Klystron RF power fluctuation within a beam pulse
(2) Acceleration phase fluctuation caused by the Klystron phase fluctuation within a beam pulse
(3) Phase distribution of the electron bunch
(4) Bunch positioning error caused by the Phasing error of acceleration RF
(5) Bunch positioning error caused by the Reactive Phase Distortion
(6) Beam Loading Effect

The pulse flatness ±0.3%(p-p) of the Klystron voltage will not be difficult with a careful PFN and impedance matching design of the Klystron modulator as for item (1) and (2) above. The PARMELA simulation result shows that the bunch width is less than 4deg FWHM as for item (3) above. The phasing error is less than ±3deg with the existing systems as for item (4). The reactive phase distortion is less than 1deg because of the light beam loading in the long pulse mode. The r.m.s. value of the energy spread caused by item (1) to (5) contribute randomly is less than ±0.2% for both long and short pulse modes. But for the long pulse mode, item (6) causes about 10% energy transient at the rise of the beam pulse, if the electron beam is injected into the accelerator guides fully filled with RF. The width of the transient is about 1μsec and 20% of the 5μsec pulse will be lost at the energy aperture of the following beam devices. One method to compensate this energy transient will be the use of ECS(Energy Compression System) composed of 4 bending magnets and an energy compression accelerator guide. But ECS requires more than 10m of space in the beam line and a compact beam line will not be feasible with ECS.
The second method will be the Klystron trigger timing adjustment to the electron beam trigger. But this method will not have enough compensation. At SLAC, the amplitude modulation of RF fed to the accelerator guide is recognized to have a good energy transient suppression effect with NLCTA.[1][2] With NLCTA, delay line type SLED2 is driven by one Klystron phase modulated to give the required amplitude modulation. Dr• Shintake of KEK has presented another idea to give the required amplitude modulation by feeding conventional cavity type SLED with phase modulated two Klystrons for their C-Band Linear Collider plan.[3]
In our case, there is no SLED. The Klystron is driven by the amplitude modulated RF source as shown in Fig.6. The amplitude modulation will be realized by vector summing of two phase modulated RF signal. The klystron has some phase fluctuation when the input RF drive power is amplitude modulated. The phase fluctuation can be compensated by counter phase modulation. The amplitude modulation pattern and simulated beam energy is shown in Fig.7.

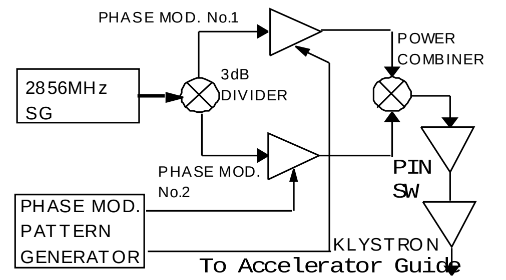

Figure 6 Energy transient Suppression by RF amplitude modulation

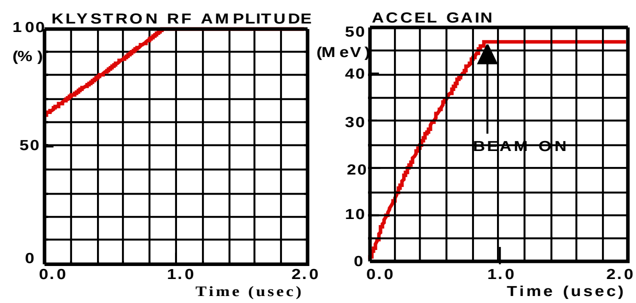

Figure 7 Energy transient Suppression by RF amplitude modulation

7. KLYSTRON MODULATOR

The Klystron modulator will be the conventional line type pulsar with a high voltage charging DC power supply and PFN. But the recent development of the power semiconductor provides a very small and high efficient IGBT driven charging inverter DC power supply commercially available [4].

8. CONCLUSION

The outline of the system design of a compact electron LINAC with a narrow energy spread is presented for RIKEN RIBF MUSES. A further engineering work will be necessary for the BBU analysis and energy transient suppression before the detail design.

9. ACKNOWLEDGMENT

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