# BASELINE DESIGN OF HLS LINAC UPGRADE*

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*Abstract*

The existing 200MeV linac of Hefei Light Source (HLS) mainly consists of electron gun, prebuncher, buncher, one 3m S-band linac section, and four 6m S-band linac sections. Energy gain of electron beam at the end of the linac is 200MeV and energy spread is ±0.8%. In order to improve the electron beam quality, An upgrade project is required. Four 80MW klystrons will be used to instead the old ones, which can improve the beam energy stability. This upgrade can also make it possible to increase the linac energy from 200 MeV to 400 MeV without changing the accelerating structure. In the meantime, New operation modes of HLS linac has been found by extensive computer modelling and optimization. Electron beam dynamics simulation from electron gun to the end of linac has been given, which considering space charge effects and wakefields.

## INTRODUCTION

Hefei Light Source (HLS) is a second generation synchrotron radiation research facility. It's composed of a 200 MeV Linac and a 800 MeV storage ring. The linac is a typical constant impedance travelling wave accelerator operating in S band, which had been accepted to regular service in 1987[1]. Some subsystems' performance has been improved after Phase II Upgrade Project of HLS was accomplished at end of 2004[2]. The linac's RF power supply mainly consists of five 20MW klystrons and modulators. Because there is no spare one about this type of klystron for some reasons of manufactory, four new 80MW klystrons will be used to instead the old one. This upgrade can also make it possible to increase the linac energy from 200 MeV to 400 MeV without changing accelerating structure. In this paper, HLS linac's beam dynamics was presented. New operation modes was also introduced, which can decrease energy spread and improve the energy stability.

## STRUCTRURE & DYNAMICS

HLS linac is composed of electron gun, prebuncher, buncher, one 3m RF linac section($L_0$), four 6m RF linac sections($L_1$,$L_2$,$L_3$,$L_4$), RF power supplies, wave guides, transverse focusing elements, vacuum system, control system, and beam measurement system, etc. Prebuncher, buncher and the 3m section are usually called preinjector which is drove by one klystron. The other four klystrons drive the four 6m linac sections. Table1 shows main parameters of the existing linac[1].

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### *Accelerating Structure*

HLS electron gun is a grid control DC gun, at the end of which 80keV electron beam can be obtained. Beam pulse current is 500mA and macro pulse wide is 1.0μs. Figure1 shows the beam emitting process simulated by OPERA-3D.

Table 1: Main Parameters of HLS Linac.

| Parameters | Value |
|---|---|
| Total length | 35.05m |
| Number of klystrons | 5 |
| Rated power of klystrons | 20MW |
| RF frequency | 2856MHz |
| Pulse repeat frequency | 50Hz |
| Beam pulse width | 1.0μs |
| Beam energy | ~200MeV |
| Pulse current | 50mA |
| Normalized emittance | 150π mm mrad |
| Energy spread | ±0.8% |
| Energy stability | 0.7% |

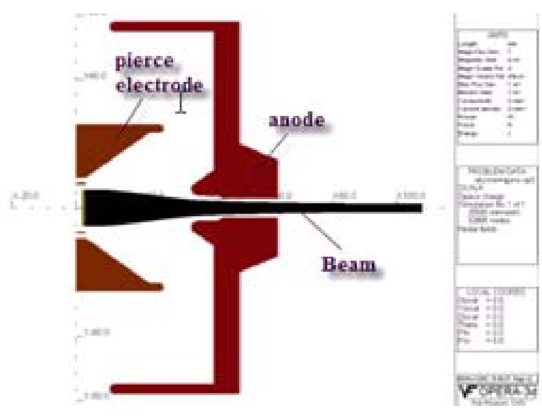


Figure 1: Beam emitting process in DC gun.

Prebuncher is a standing wave cavity made of stainless iron, which can focus the electron beam from continuous one to micro pulses within $90^0$ phase spread. Input power of the cavity is 10kW. Figure2 shows the model of prebuncher simulated by SUPERFISH, and the electric field distribution in the cavity is showed in Figure3. Some parameters have been got: Shunt impedance per unit length is 34.783MΩ/m and quality factor 7085.29.

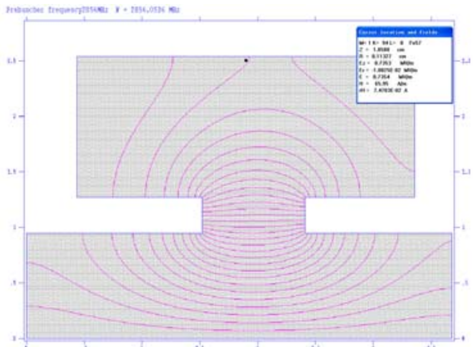

Figure 2: Prebuncher model (superfish).

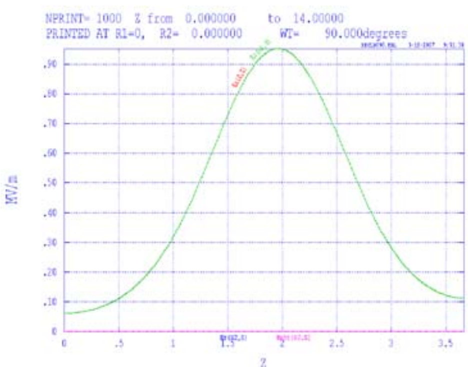


Figure 3: Electric field distribution in the prebuncher.

Buncher is a traveling wave accelerating structure, including two cells of iris-loaded periodic structure and input, output waveguides. Wave phase velocity in the structure is 0.78. Shunt impedance per unit length is 39.318M Ω /m and attenuation factor is $0.2302m^{-1}$. Figure4 shows the electric field distribution when input power is 1MW.

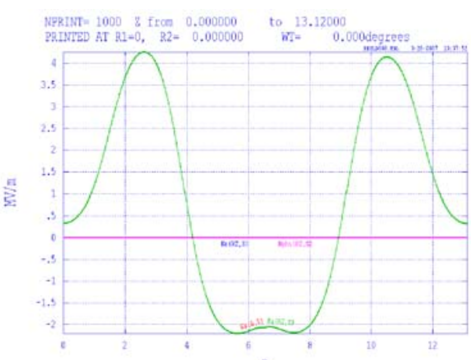


Figure 4: E-field distribution in buncher.

$L_0$, $L_1$, $L_2$, $L_3$ and $L_4$ are the same type of constant impedance accelerating structure with $\beta_p$=1.0. There are nine 3m S-band linac sections considering the above elements. Every 3m section includes 86 iris-loaded periodic cells. Accurate length of the 3m section is 3.115m . Figure5 is the mode of 1.5 Cells, and the electric field distribution in 3m section is showed in Figure6. Shunt impedance per unit length is 60.108M Ω /m and attenuation factor is $0.1845m^{-1}$.

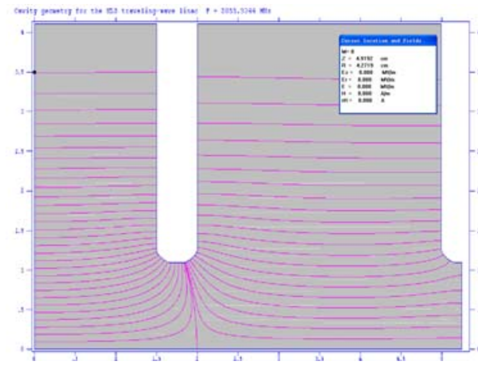

Figure 5: 1.5Cells of periodic structure.

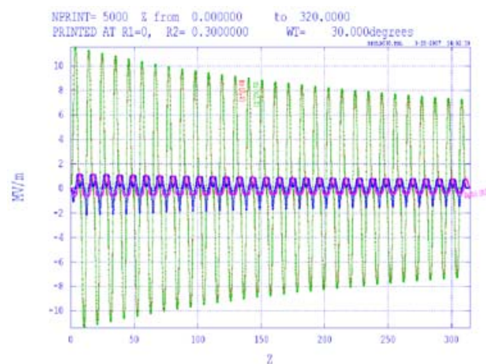


Figure 6: Field distribution in the 3m section.

### *Transverse Focusing Structure*

Transverse focusing elements in preinjecter includes seven solenoids, usually which can be used when beam energy is low. Longitudinal magnetic fields produced by the solenoids are used for electron beam focusing. Table2 shows parameters of the solenoids, and magnetic fields distribution is shown in Figure7.

There are six quadrupoles from the end of preinjector to the end of linac, which is the most common method compensating for the transverse defocusing effects in linacs[5]. $Q_1$ and $Q_2$ are located between $L_0$ and $L_1$ as a quadrupole doublet. $Q_3$ and $Q_4$ are located between $L_1$ and $L_2$, and $Q_5$,$Q_6$ between $L_2$ and $L_3$ , which make a FODO lattice structure. Main parameters of quadrupoles are shown in table3.

### *Beam Dynamics*

Beam dynamics of preinjector section was simulated by PARMELA[4] which considering space charge effects. Another part of the linac was calculated by ELEGANT[3]. The four new klystrons will be used to drive $L_1$,$L_2$,$L_3$ and $L_4$. Because maximum output power of the new klystron is 80MW, Two operation mode has been studied. Preinjector section will keeping the existing condition in both modes.

Table2: Solenoids Parameters

| ID | Length (m) | Total current (Aturns) |
|---|---|---|
| 1 | 0.04 | 1000 |
| 2 | 0.04 | 600 |

| | | |
|---|---|---|
| 3 | 0.04 | 2400 |
| 4 | 0.3 | 14400 |
| 5 | 0.3 | 6000 |
| 6 | 0.3 | 6000 |
| 7 | 0.3 | 14400 |

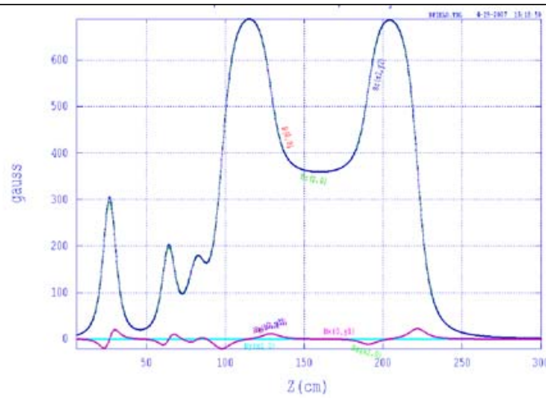


Figure7: Magnetic fields produced by solenoids.

Table3: Main Parameters of Quadrupoles

| ID | K ($m^{-2}$) | Length (m) |
|---|---|---|
| Q1 | 14.0 | 0.08 |
| Q2 | -14.0 | 0.08 |
| Q3 | 7.1 | 0.08 |
| Q4 | -7.1 | 0.08 |
| Q5 | 5.5 | 0.08 |
| Q6 | -5.5 | 0.08 |

(1) Four klystrons work with outputting the same RF power. After optimizing, energy gain at every RF linac section is shown in Table4. Accelerating phase are adjusted to decrease the energy spread[6,7]. Solution proves that energy spread at the end of the linac is 0.2%. 0.18% energy stability has been obtained considering factors of RF power and phase error.

(2) Only three klystrons work.. The other one is kept standing-by. Table5 gives relative parameters like table4. At the end of the linac 0.15% energy spread can be obtained, and beam energy stability can reach 0.175%.

Table4: Synchronous Phase and Energy Gain

| ID | Synchronous phase | Beam energy |
|---|---|---|
| $L_0$ | $5^0$ | 25.6MeV |
| L1 | $10^0$ | 69.00MeV |
| L2 | $10^0$ | 112.34MeV |
| L3 | $2.5^0$ | 156.31MeV |
| L4 | $2.5^0$ | 200.28MeV |

Table5: Synchronous Phase and Energy Gain

| ID | Synchronous phase | Beam energy |
|---|---|---|
| $L_0$ | $5^0$ | 25.6MeV |
| L1 | $15^0$ | 82.73MeV |
| L2 | $2.5^0$ | 141.74MeV |
| L3 | $2.5^0$ | 200.74MeV |

In the same way, 400MeV electron beam( $\delta$ =0.2%) can be got at the end of the linac with the four 80MW klystrons working.

Calculation also shows that it is enough for the klystrons' output power to above all the operation modes.

Figure8 shows Beta function calculated by ELEGANT with Table3's parameters. In order to keep K of quadrupoles fixing in the above three conditions, the magnetic field gradient must change relatively. Simulation proves that all the quadrupoles can work safely in the all conditions.

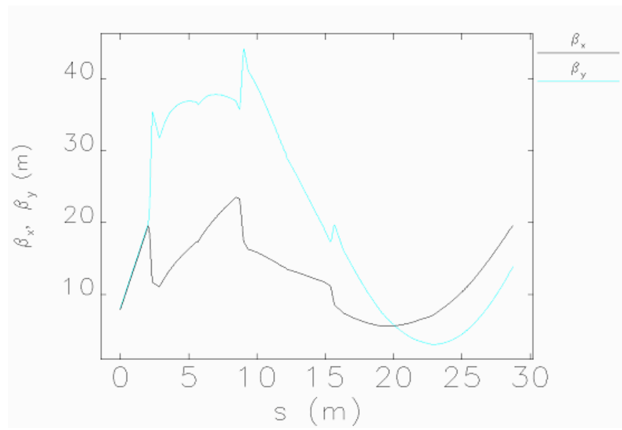


Figure8: Beta function of the linac.

## CONCLUSION

Accelerating and transverse focusing structure of HLS linac are introduced in this paper. New operation modes are studied with the 80MW klystrons working. Longitudinal and transverse beam dynamics simulation shows that it is possible for the linac to work in any of the new modes.

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