THE LINEAR ACCELERATING STRUCTURE DEVELOPMENT FOR HLS UPGRADE *

K. Jin, S. C. Zhang, Y. L. Hong, G. R. Huang, D. C. Jia
National Synchrotron Radiation Laboratory, NSRL USTC,
P.O. Box 6022, Hefei Anhui 230029, China

Abstract

Hefei Light Source (HLS) is mainly composed of an 800 MeV electron storage ring and a 200 MeV constant-impedance Linac functioning as its injector. A new Linac is developed in view of the Full Energy Injection and the Top-up Injection scheme will be adopted in the HLS upgrade. In this paper, an 800MeV linear accelerating system construction, the constant-gradient structure design and the symmetry couplers consideration will be described in detail. The manufacture technology, the RF measurement, the high power test results and the accelerating system operation are presented.

INTRODUCTION

In order to ensure the low-emittance focusing parameters steady operation in the HLS Storage Ring, it's necessary to increase the injector energy to 800MeV. After realize Full Energy Injection, each system of Storage Ring can keep single operation state, the light source stability will be improved eminently. A new Linac is developed in view of the Full Energy Injection and the Top-up Injection scheme will be adopted in the HLS upgrade. An 800MeV Linac layout is shown in Fig.1.

The project is proceeding as planned at present. In this paper, an 800MeV linear accelerating system construction, the constant-gradient structure design and the symmetry couplers consideration will be described in detail. One section of accelerator structure has been fabricated successfully. The manufacture technology, the RF measurement, the high power test results and the project schedule are presented.

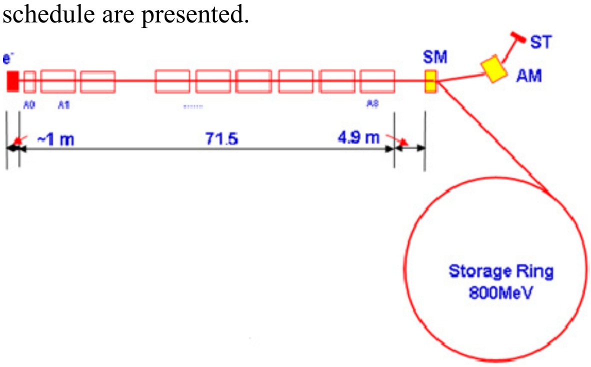

Figure 1: HLS 800MeV Linac layout

800MEV LINEAR ACCELERATING SYSTEM DESIGN

HLS accelerating system consists of a pre-buncher, a buncher and eight units of constant-gradient accelerating structures (6m accelerator unit). Total length is about 73meter. The electron beam energy can be achieved to 800MeV~1GeV. In general, seven such as units is in operation condition and another one is in standby state so that to assure storage-ring stability running (Fig.2).

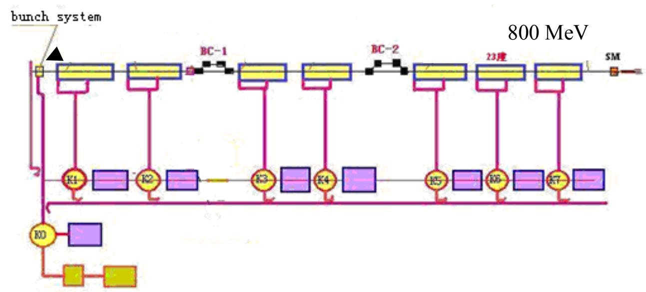

Figure 2: 800MeV electron Linac energy, phase and microwave System

Pre-buncher

Pre-buncher or velocity modulation cavity is a cylindrical reentrant resonator. Its resonance frequency is 2856 MHz, working at TM_{010} mode. Cavity dimensions and physical parameters are calculated with SUPERFISH. To reduce the errors of resonance frequency caused by temperature, beam loading etc., stainless steel is selected to make this cavity to reduce Q (~ 500), the cavity shunt impedance is Rs/Q = 220. So when 2kW power is feeding in, it will produce about 15kV microwave voltage in the cavity. According to beam dynamics calculation, bunching parameter is selected r = 1.92. The beam waist of electron beam from gun is focused at the center of pre-buncher. Through the preliminary bunching cavity and drift 35 cm, its phase width will be focused from 260°to 90°. The work was finished in a HLS phase I project. It is in good condition still. So it will continue to use after upgrading.

The fundamental mode buncher

The bunching system work frequency is 2856 MHZ, including pre-buncher and fundamental mode buncher. The beam from the gun is focused initially in the pre-buncher, then electron beam get into buncher to further complete beam phase bunching process, and further increase the beam energy. The fundamental mode buncher is constant gradient disk load accelerating structure. Solenoids are used to focus in the transverse direction. The length of fundamental mode buncher is 1.63 m, the accelerating gradient is about 8.2 MV/m, and beam energy is about 13.1 MeV after bunching section.

In order to optimize bunching effect, pre-buncher voltage is optimized to 15kV and the distance between buncher and pre-buncher is optimized to 35 cm. The

Table.1: parameters of buncher

No	a (1e-3m)	b (1e-3m)	D (1e-3m)	β	F (GHz)	betag	Q	Rs (Mohm/m)	alpha
1.	11.1550	41.6430	24.4929	0.70	2.855996	0.009970	10955	37.543	0.27400
2.	11.1550	41.6430	24.4929	0.70	2.855996	0.009970	10955	37.543	0.27400
3.	11.1550	41.3210	30.7910	0.88	2.856011	0.010174	12482	49.503	0.23568
4.	11.1550	41.2287	33.2403	0.95	2.856010	0.010202	12911	52.987	0.22722
5.	11.1550	41.1933	34.2900	0.98	2.856000	0.010216	13222	55.533	0.22156
6.	11.1550	41.1820	34.6399	0.99	2.856005	0.010226	13523	58.023	0.21642
7.	11.1550	41.1710	34.9894	1.0	2.855997	0.010230	13719	59.649	0.21325

buncher adopts traveling wave electron accelerating structure. It totally has 45 cavities; the first five cavity is vary phase velocity period structure. The phase velocities are 0.70, 0.88, 0.95, 0.98, 0.99, the others are relativistic accelerating section. The results are in the Table.1.

Accelerating Section

The constant-gradient structure can produce higher energies than an optimized constant-impedance structure when both are operating at the breakdown limit of electric field strength. Considering such structure reduces ration of maximum to average field strengths and increases some advantages [1], the constant-gradient structure was thus adopted for the HLS Linac upgrade.

The cavity type of constant-gradient disk-loaded structure was selected in HLS accelerating section. Operating frequency of 2856MHz, phase shit per cavity of 2π/3, i.e. cavity length of 34.989mm and disk thickness of 5.8mm is set. The optimum cell geometer and its EM performance, calculated with MAFIA-Code [2], are listed in Table 2. The curves of field strength and energy vs. axial distance z are shown in fig.3. Here the power range is 32.0 Mw to 10.1Mw in such accelerator section, the field strength E_z of 20.7Mv/m is acquired and the energy gain is about 62MeV.

In order to realize Full Energy Injection, one klystron of 80Mw provides power to a pre-buncher and a buncher as well as to a 6m accelerator unit which is constructed by two 3m standard sections. Another one of 80Mw and six klystrons of 50Mw with SLED technology will provide

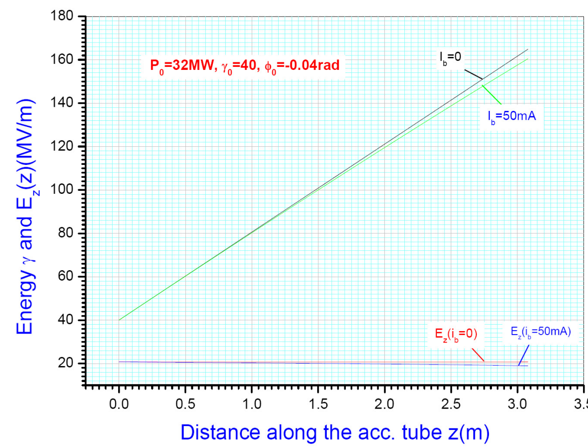

Figure 3: The field strength and energy gain in the 3m accelerating section.

power to each 6m accelerator unit individually.

The average accelerating gradient of 20Mv/m can be obtained in such away. The electron beam energy can be achieved to 800MeV~1GeV. In general seven 6m accelerator units are in operation condition and the other one is in standby state so that to assure storage-ring stability running. The electron beam energy gain in all accelerating structures is shown in Table 3.

Table 2:Final design and performance of the HLS accelerator structure

Parameters	**HLS Linac**
Operating frequency (f)	2856 MHz
Phase shit per cavity	2π/3
Iris diameter range of disk-loaded (2a)	25.386-19.260mm
Cavity diameter range of disk-loaded (2b)	83.118-81.718mm
Range of shunt impedance (R_s)	55-63 MΩ/m
Normalized group velocity range (Vg/c)	0.0177-0.0063
Attenuation parameters (τ)	0.585 Np
Filling time (t_F)	0.8995μsec
Operating state	42℃, vacuum
No. of standard 3m section	16
No. of cavities in each 3m section	86+2 coupler
Distance between inputs of two consecutive sections	31λ
No. of 6m accelerator unit	8

Table 3: The beam energy gain in HLS Linac Ⅱ

Equipments	Beam energy	Δφ
e-Gun	100keV	1ns
Pre-Buncher	140keV	500ps
Buncher	15.5MeV	10ps
1# 6m acc. unit	120.6MeV	10ps
2# 6m acc. unit	225.4MeV	10ps
3# 6m acc. unit	340.3MeV	10ps
4# 6m acc. unit	455.3MeV	10ps
5# 6m acc. unit	570.2MeV	10ps
6# 6m acc. unit	685.1MeV	10ps
7# 6m acc. unit	800.0MeV	10ps

HLS STANDARD 3M SECTION DEVELOMENT

According to the above-mentioned design, an 800MeV traveling wave linear accelerator is being developed. A standard 3m section of accelerator structure has been fabricated successfully. It consists of 86 disk-loaded accelerating cavities. The phase velocity of β_p=1, the operation mode of 2π/3 and the constant-gradient structure are considered.

The RF coupler is an important component for an accelerator structure. It consists of a tapered rectangular waveguide and a coupling cavity with a coupling aperture. It must be well matched to the feeding waveguide and has synchronous frequency for the proper phase advance in the structure so that ensure the input power is fed effectively and an excellent travelling wave is transmitted in the accelerating cavities train. Therefore the sizes of the coupling cavity and the coupling iris aperture should be designed exactly at operation frequency so that the optimum transmission parameter S21 and scattering parameter S11 are obtained. In order to compensate the amplitude asymmetry and the phase shift, offsetting the coupler cavity was adopted. The value of the offset was found by means of microwave perturbation measurement, for the input cavity, it is 1.8mm, and for the output cavity, 1.0mm. The amplitude asymmetry of the order of 1.58%, and the phase shift of the order of 1.0°was obtained over the beam aperture.

In our project, the numerical simulation design of RF coupler assembly was considered. In the wake of the computer program development, special the MAFIA-code [2], it made the three dimensions (3D) S-parameters calculation in time domain becoming possible and the change in dimensions can be easily implemented on the computer. Revising the sizes step by step in such a way, in conjunction with microwave measurement by Kyhl method [3], the optimal matching and tuning results is acquired finally.

The cavities were machined high-precisely in a constant temperature room. It was assembled with the input coupler and the output coupler. Also the external water pipes are used so that the structure can be cooled and keep constant operating temperature. Finally the module was brazed in a hydrogen furnace.

Then each cell of the accelerating structure was tuned to the phase shift φ=120°/cell. The RF parameters are measured with the Network Analyzer Agilent E5071C. The voltage standing wave ratio, VSWR=1.019, was achieved at the operation frequency and VSWR is less than 1.2 in a frequency-bandwidth of 4 MHz, which is shown in Fig.6 for the typical structure.

The high-power test of the 3m accelerator section was processed in May. 2012. The pulse length of 1uS, maximum input power to the section is approximately 50Mw peak; Steady operation of pulse length of 5uS, input power of 40MW peak for such section was obtained. The test results satisfied the design which input power to the section is 32Mw peak. It means that accelerating gradient of 20Mv/m can be achieved in HLS Linac. It is a basic guarantee of the 800MeV Linac upgrade project success.

CONCLUSION

At present a Buncher and all 16 standard 3m sections has been manufactured successfully in NSRL. Microwave measurement and cavities tuning will be finished end of Sep. The HLS Linac Ⅱ will be installed in Oct. and will be operated end of 2012.

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