LINAC DESIGN FOR DALIAN COHERENT LIGHT SOURCE*

M. Zhang #, H.X. Deng, D. Gu, Q. Gu, SINAP, Shanghai 201800, China

Abstract

Dalian Coherent Light Source (DCLS) will use a 300MeV LINAC to produce fully coherent photon pulses in the wavelength range between 150-50nm by high gain harmonic generation free electron laser (FEL) scheme [1]. Beam quality requirements for the linear accelerator (linac) are critical, including not only the beam brightness, but also the stability and the reliability. In this paper, optimization study is performed for the linac. Based on beam stability simulation in the longitudinal direction, the tolerant budget is formed for the short period jitter. For the transverse orbit error, beam orbit correction technique is implemented by beam dynamics simulations and the transverse jitter is also presented accordingly. Measurement method for the beam quality is also described in the paper.

INTRODUCTION

Dalian Coherent Light Source (DCLS) is a FEL user facility based on the principle of single-pass, high-gain harmonic generation scheme, which is located in northeast of China. According to the FEL physical design and corresponding tolerance requirement [2], as shown in table 1, this paper gives the linac design considerations and numerical investigations on the stability for DCLS. Beam measurement method and further upgrade considerations are also presented briefly in the end of the paper.

Table 1: Beam Specification for DCLS Linac

Parameter	Average (Unit)
Charge	0.5 (nC)
Energy	300 (MeV)
Energy Spread	0.1 (%)
Beam length	1 (ps)
Emittance	2~4 (µ mrad)

LINAC DESIGN AND TOLERANCE

Photo-cathode injector is adopted for DCLS linac and one bunch compressor system is employed to generate the required peak current. Before the chicane, two S-band accelerating structures generate the required energy chirp for bunch compression and the following four S-band accelerating structures are adopted to get the required beam energy, while cancelling the energy spread. The overall layout for DCLS linac is shown in figure 1.

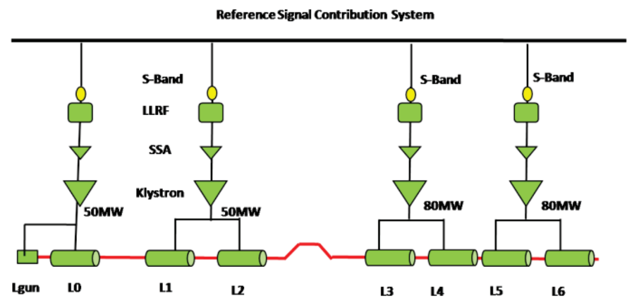

Figure 1: Layout of DCLS linac.

Linac Layout and Parameter Optimization

Initial bunch length is optimized after the bunch charge is fixed to 0.5nC. For this kind of relatively high intensity current, space charge effect is dominated. The emittance dilution effect and bunch lengthening process are obvious shown in figure 2. The initial bunch length, 7 ps, is chosen as a balance between the conflicting requirements of the peak current and the needs to minimize the emittance.

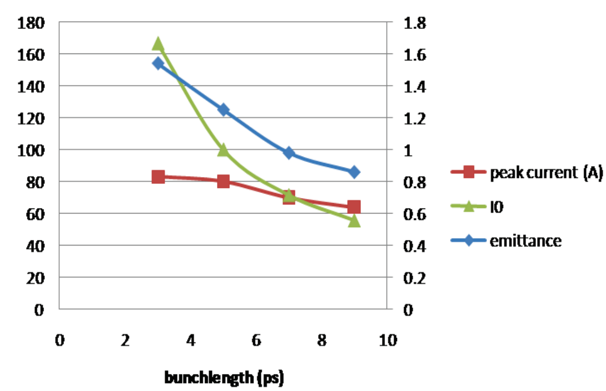

Figure 2: The emittance dilution effect and bunch lengthening process depending on the different initial bunch length.

Next, the position and the strength of the magnetic chicane are optimized to the jitter effect by careful choice of the linac acceleration and compression parameters [3]. After this process, the beam energy for the bunch compressor is at 128MeV and the R_{56} is set to -50mm. Accordingly, the design parameters for DCLS linac are fixed as summarized in table 2.

*Work supported by the Knowledge Innovation Program of Chinese Academy of Sciences.
#zhangmeng@sinap.ac.cn

Table 2: Beam Parameters along the Linac Beamline

Beamline	E_{out} (MeV)	$\sigma_{z\text{-}out}$(mm)	$\sigma_{\delta\text{-}out}$(%)	$\Phi_{rf}\backslash\theta_{bend}$(°)
L0	55	0.638	0.097	0
L1-L2	128	0.638	0.867	-23.9
BC	128	0.207	0.867	5.9
L3-L6	300	0.207	0.066	22

Tolerance Budget in Longitudinal Direction

The tolerance budget is based on summing random uncorrelated effects. For DCLS linac, as shown in table 3, the most average beam energy jitter coming from the L1 and L2 when off-crest acceleration of the beam for the requirement of the chirp and the beam current jitter coming from the injector. The arriving time jitter is almost evenly distributed over the whole devices.

Table 3: Tolerance Budget for the Linac Beamline

Parameter	dE (%)	dI(%)	dt (fs)
Injector time jitter (0.25ps)	0.0247	3.11	59.88
Injector charge jitter (5%)	0.0183	4.17	13.63
L1-L2 rf phase (0.1°)	0.0453	1.073	66.66
L1-L2 rf voltage (0.1%)	0.0645	0.122	95.51
BC R_{56} (0.02%)	0.0176	0.010	-41.79
L3-L6 rf phase (0.1°)	0.0204		
L3-L6 rf voltage (0.1%)	0.0287		
total	0.0945	5.33	137

Random gaussian sampling of all the linac parameters according to the tolerance of table 3 has been performed using particle tracking code elegant [4] and the results give good agreement, as shown in figure 3.

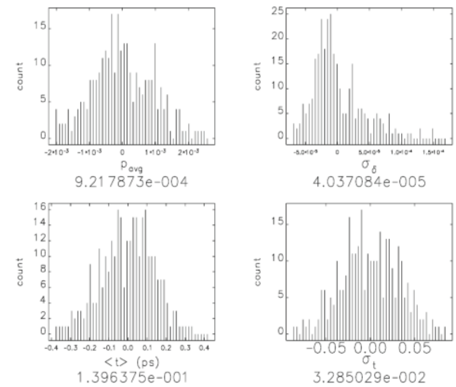

Figure 3: Average beam energy (on the top left), energy spread (on the top right), arrive time (on the down left) and bunch length (on the down right) jittered values obtained by randomly sampling input linac parameters.

Beam Offset and Transverse Jitter

Transverse jitter can be treated in two steps. Firstly, one reference orbit is obtained after beam correction has been applied properly, as shown in figure 4. Without beam correction, the maximum beam offset is about 1.5mm and under this condition the beam can smoothly get through the beam line. After correction, the beam offset is more than one order lower and beam brightness can be maintained.

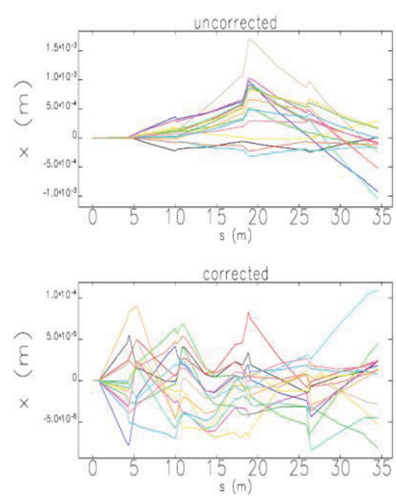

Figure 4: Beam orbit along beamline before (up) and after (down) beam correction techniques are adopted.

For the second step, one random orbit with maximum offset is chosen for transverse jitter calculation because of the implicit strongest influence on the transverse orbit. After all transverse jitter forces are also applied, the transverse orbit jitter is no more than 10 μm which meets the FEL physics requirement, as shown in figure 5.

ISBN 978-3-95450-122-9

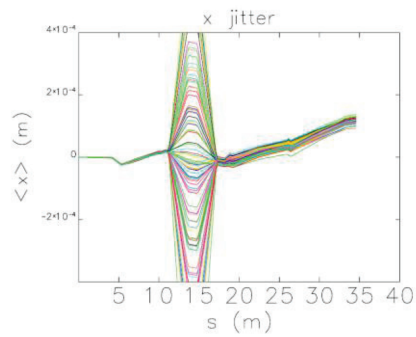

Figure 5: Average beam

CONSIDERATION FOR BEAM MEASUREMENT AND FUTURE UPGRAD

For fully understanding the beam energy gain in any accelerating structure, three beam energy spectrometers are adopted as well as proper combination with the profile monitor in the magnetic chicane. Bunch length can be decided by zero-phasing method[4] or by seeding laser scan method [5] in the modulator stage of the HGHG. Optics can be decided using the eight beam profile monitor stations along the beam line and the transverse projected emittance can also be obtained using the Q-scan method.

DCLS is user facility and aimed to the lasing saturation at the desired wavelength on the first stage. At the design stage of this facility, besides necessary instruments and elements, possibilities for future upgrade are kept and proper space is reserved for this purpose, as shown in figure 6.

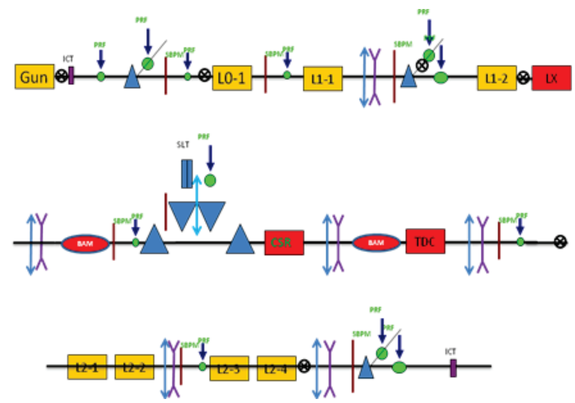

Figure 6: Elements and instruments along the beam line and red coloured blocks are reserved space for future upgrade

CONCLUTIONS

Optimization study is performed for the DCLS linac. Based on beam stability simulation in the longitudinal direction, the tolerant budget is formed for the short period jitter. For the transverse orbit error, beam correction technique is implemented by beam dynamics simulations and the transverse jitter is also presented accordingly.

REFERENCES

[1] Tong Zhang et al., "FEL Polarization Control Studies on Dalian Coherent Light Source", arXiv: 1301.3597.
[2] Haixiao Deng et al., "Simulation studies on laser pulse stability for Dalian Coherent Light Source", arXiv: 1303.6734.
[3] Qiang Gu et al., "Optimization of bunch compressor for two stages FEL linac", LA-TN-02
[4] Wang D X et al. Phys Rev E, 1998, 57: 2283−2286.
[5] B. Liu et al. PRST-AB, 16, 020704 (2013).