# COMMISSIONING EXPERIENCE AND BEAM OPTIMIZATION FOR DCLS LINAC

Zhang Meng†, Gu Duan, Wang Zhen, Huang Dazhang, Gu Qiang,
Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai, China

*Abstract*

Dalian Coherent Light Source (DCLS), which will focus on the Physical Chemistry with time-resolved pump-probe experiments and EUV absorption spectroscopy techniques, is the first high gain FEL user facility in China. The 300MeV linac consists of a laser-driven rf-gun followed by 7 Sband accelerating tubes. A magnetic chicane is adopted to get the desired 300A peak current. After 5 months for component installation, first photoelectrons are generated on 17th August 2016. In this paper, we give a summary of the first stage beam commissioning experience and the beam parameters measurements results.

## 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 north-east of China. According to the FEL physical design and corresponding beam specification requirement [1], as shown in Table 1, this paper gives the primary beam commissioning results of the first month linac test.

Table 1: Beam Specification for DCLS Linac

| Parameter | Average (Unit) |
|---|---|
| Charge | 0.5 (nC) |
| Energy | 300 (MeV) |
| Energy Spread | 0.2 (%) |
| Beam length | 2 (ps) |
| Emittance | 2 (mm-mrad) |

On 1st August 2016, RF conditioning started immediately after completing of the component installation for the 4 RF power plants, as shown in Figure 1 for the overall layout of the linac. Beam commissioning, which started on 17th August, was limited to evening due to the ongoing installation of the undulation hardware during working days.

In this paper, after giving some technical solutions for the critical hardware components, we give the beam commissioning results. Using this beam, FEL saturation is accomplished for SASE and HGHG schemes. Even though, beam optimizations are still in progress further and the beam performance upgrade results could be found in this proceedings [2].

## HARDWARE INSTALLATION

The facility was housed in Changxing island of Dalian, which was constructed in the campus of DICP, as a dedicated building for DCLS project. The installation work was started on the 28th of the March, 2016. It took 4 months until 1st August, completing all installation tasks of the linac beamline elements and immediately started the RF conditioning for the accelerating tubes.

### *Accelerating Structures*

Seven accelerating tubes, designed and fabricated by IHEP, Beijing, were transported to Dalian by truck. Careful packs are issued, but deformations are un-avoided for the 3 meter slim structure. As shown in Figure 2, by probing positions for different disks along the tube, the maximum alignment error for the tube is ±0.3mm. For avoiding the underlying risks of the potential wakefield effect for beam emittance dilution, the structures are re-aligned on the spot. Structure is measured after every minor step for mechanical correction. After 2 or 3 iterations, ±0.15mm are normally achieved for all the 7 acceleration tubes.

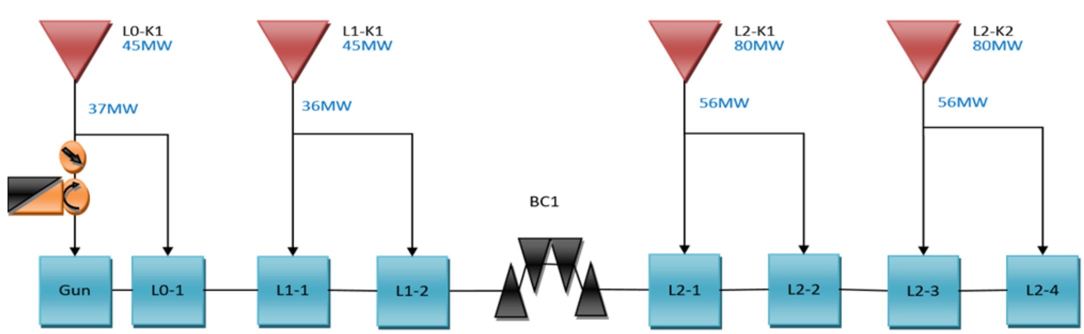


Figure 1: Layout for DCLS linac.

† zhangmeng@sinap.ac.cn




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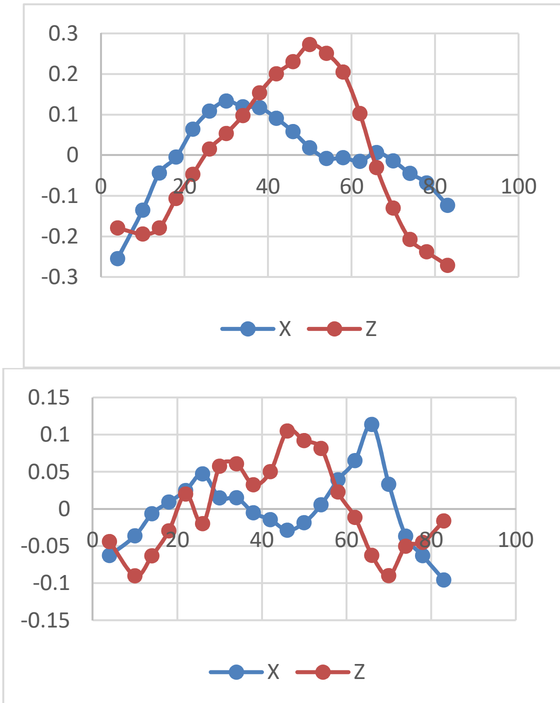


Figure 2: Alignment error along the 3-m accelerating tube. Take A3 as example（before (up) / after (down) correction: 0.6mm/0.21mm.

### *RF Photo-Cathode Gun*

A high brightness injector is a critical system for an FEL facility. Tsinghua University has been developing photocathode RF guns for more than 10 years and DCLS will use this 1.6-cell gun, which is a variation of BNL/SLAC/UCLA photocathode gun. During installing period for the cavity, a dedicated clean room is prepared in advance and all the sealing procedures are done in it. RF photo-cathode gun is protected immediately after installation, keeping it under vacuum, as shown in Figure 3.

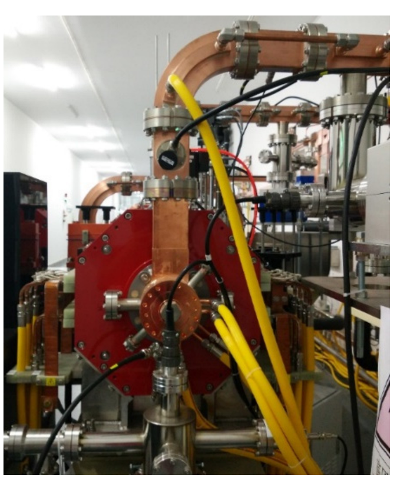

Figure 3: Photo-cathode RF gun after installation.

### *Power Source Test on Site*

As shown in Figure 1, there are 4 power sources for DCLS linac in total. First two 50MW klystrons provide the initial beam energy acceleration for injectors and beam energy boosting and phase space chirping for the bunch compressor. After the chicane, the compressed beam will be accelerated to the designed beam energy by the last two 80MW klystrons. In order to test the specifications, one of the 80MW Toshiba klystron is equipped with the necessary hardware on site, as shown in Figure 4, before the corresponding waveguide and the accelerating tube in tunnel are ready for RF power.

Figure 4: 80MW klystron test site.

## FIRST BEAM AND CALIBRATION

### *Gun Calibrations*

The initial QE values are measured at the nominal peak cathode field of 100MV/m and launch phase of 30degS from zero crossing. The QE is determined by measuring the bunch charge as a function of the drive laser energy. The measured QE and QE map scan results are shown in Figure 5.

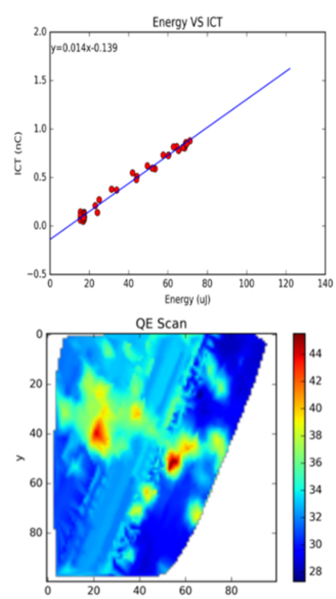


Figure 5: QE measurement by scanning the driving laser power (up) and QE map scan on cathode with 0.2mm spot on 3*3mm area (down).

### *Full Beam Energy*

To verify the design gradient-to-power ratios for accelerating tubes, we measured the energy gains as a function of the rf input power for every rf plants. After a period of RF conditioning, it did not take long to achieve the desired beam energy at the linac exit, as shown in Figure 6.

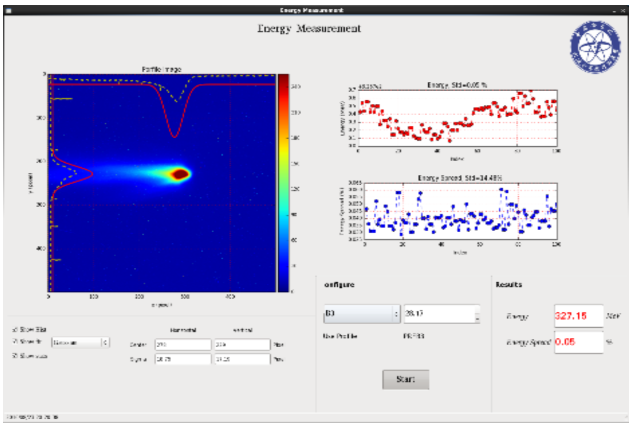


Figure 6: Beam energy spectrometer at linac exit.

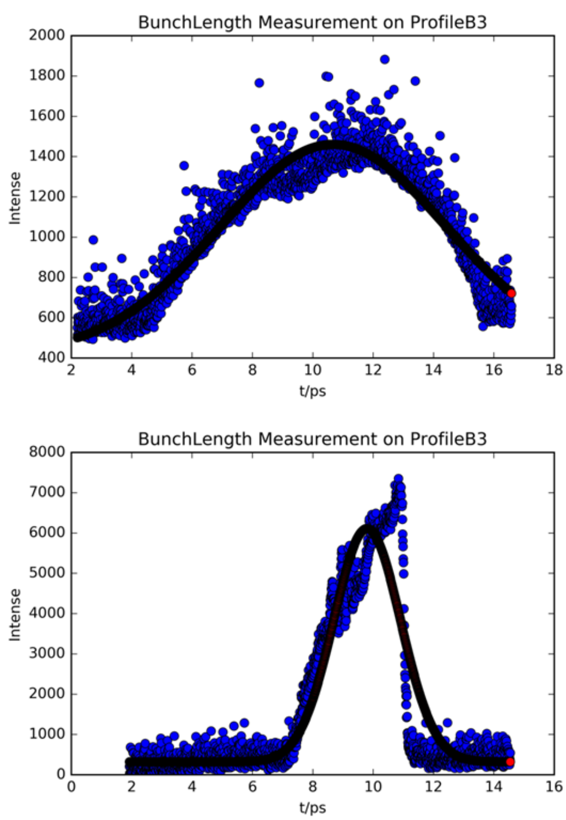


Figure 7: Beam length calibrations by zero-phasing method for un-compressed (up) /compressed (down) beam.

## BUNCH COMPRESSION AND EMITTANCE OPTIMIZATION

As shown in Figure 1, the 2nd rf plant is used to 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. Due to lack of the Xband linearizer, bunch compression ratio is limited to 3~4 times. Bunch length measurements after compression are performed using zero-phasing method by the last rf power station, as shown in Figure 7.

### *Emittance Optimization*

Using OTR screens with a quadrupole scanning method, the transverse emittance is optimized at different locations along the linac. For the nominal 500pC bunch charge, as shown in Figure 8, the projected emittance is better than 1.3/2 mm-mrad at the injector/linac exit. After FEL saturation was accomplished 3 months later, beam emittance is optimized by performing better lasing shaping and higher accelerating field for RF gun.

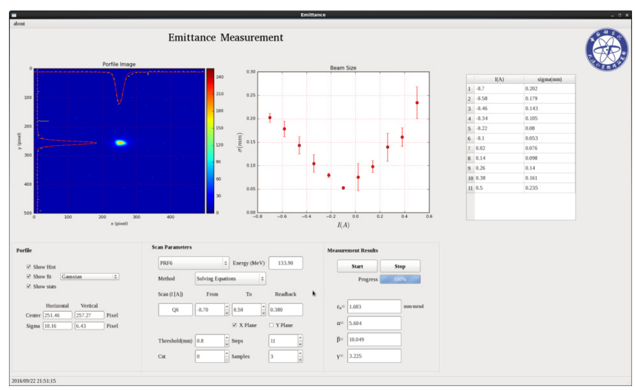


Figure 8: Transverse emittance.

## BEAM STABILITY MODELLING

As a first user guided large scientific instrumentation based on the FEL technology in China, stability and reliability are crucial for users. However, an inevitable topic is the beam stability, i.e., shot-to-shot fluctuation, which will be strongly sensitive to numerous error sources of the beamline elements.

Take beam energy as example, mean beam energy fluctuation are affected by the corresponding jitter from RF power sources, as shown in Figure 9. Beam stability modelling based on real machine status can guide this analysis.


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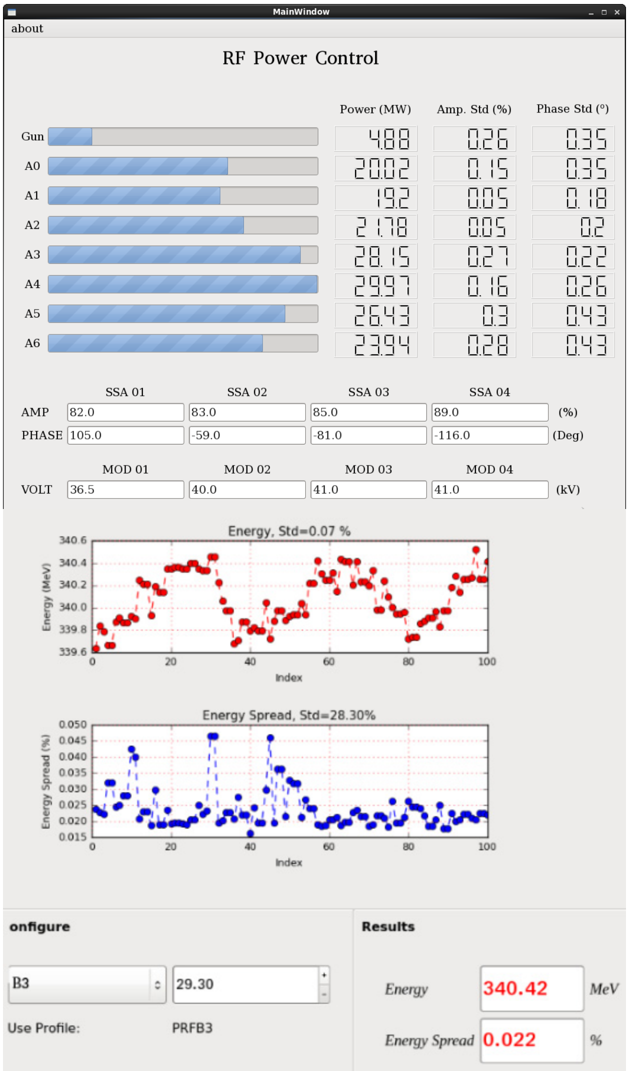


Figure 9: Beam stability modelling by real machine performances.

## SUMMARY

One month beam commissioning is completed on 22th September and on-site beam test results are shown in Table 2. After that, much effort are put on the FEL lasing optimization and the linac beam performance is re-optimized after four months later.

Table 2: Beam Test Results

| | designed | Measured |
|---|---|---|
| Beam energy（MeV） | 300 | 320.1 |
| Energy spread（rms） | 0.2% | 0.117% |
| Bunch length（ps, FWHM） | 2 | ~2 |
| Charge（nC） | 0.5 | 0.506 |
| Normalized emittance（mm·mrad） | 2 | 1.68/1.71 |
| Repetition | 50 | 10 |

## REFERENCES

[1] Z. T. Zhao *et al.*, “Primary design report for DCLS”, unpublished.

[2] G. Wang, “Commissioning Status of the Dalian Coherent Light Source”, presented at IPAC’17, Copenhagen, Denmark, May 2017, paper WEPAB058, this conference.