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Abstract

Since the beginning of commissioning in February 2003, lots of tests on the DC-SC photoinjector test facility have been performed. At present, Q_0 of the 1+1/2-cell superconducting cavity has reached 2×10^8 (at 4.2 K) and the average gradient was about 3.5 MV/m in operation. The DC gun can provide stable electron beams. When the power of output laser went up to 100mW (266 nm), the average beam current reached 500 μ A. Beam tests at 4.2 K have been carried out, and superconducting acceleration was about 100 μ A after acceleration.

Beam loading tests at 2 K will be carried out soon. At the same time, further investigations are in progress to improve diagnostics system and to measure the emittance, energy spread and pulse length of electron beams.

INTRODUCTION

A FEL facility (PKU-FEL [1]) is under construction at Peking University. Based on PKU-SCAF [2], a superconducting accelerator facility, PKU-FEL has the characteristics of high stability and high average power. PKU-FEL will run in IR (5~10 μ m) and THz (100~3000 μ m) region. The facility can also provide high-quality electron beams for experimental studies in some relative fields such as nuclear physics experiments and so on. Figure 1 gives a schematic layout of PKU-FEL facility. One of the most important features is that a superconducting photoinjector - DC-SC photoinjector [3] is selected to supply electron beams with high average current and outstanding beam quality.



Figure 1: Schematic Layout of PKU-FEL facility.

As has been reported before, in January 2003, the DC-SC photoinjector test facility was constructed. After a year of commissioning and testing, we have accomplished the first successful step. The DC gun can provide stable electron beams and when the power of output laser went up to 100 mW (266 nm), the average beam current reached 500 µA. However we found that the 1+1/2-cell cavity had a relatively low Q_0 value and multipacting was encountered frequently which could not be easily eliminated. For some time low Q_0 and multipacting troubled us so much that we almost could not go on. To improve the quality of the 1+1/2-cell sputtering technology employed. cavity, was Experiments show that Q_0 of the 1+1/2-cell cavity has reached 2×10^8 (at 4.2 K). Moreover, multipacting could be easily eliminated, and when eliminated at low input

power (~ mW), multipacting would not appear at higher input power any more.

QUALITY IMPROVEMENT OF SUPERCONDUCTING CAVITY

Earlier experiments indicated that the Q_0 of the 1+1/2cell cavity was about 10⁷. Furthermore multipacting was encountered from time to time during experiments. It seemed that the inner surface of the cavity was not good enough and earlier mechnical polishing and BCP did not work well. To improve the quality of the cavity, a dryprocessing method - DC sputtering - was employed. (Figure 2). DC sputtering has several effects. Fisrt, local annealing. Through controlling the working pressure, sputtering could take place in different areas. The second effect is surface polishing. (Figure 3) Sputting could eliminate small emitters and contaminants. The improvement of inner surface leads to the improvement

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of superconducting performance and also increases the multipacting threshold.



Figure 2: DC sputtering device for post-treatment of 1+1/2-cell cavity.



Figure 3: 1+1/2-cell cavity after DC sputtering.

The post-treatment of the 1+1/2 cavity was carried out step by step, including mechanical polishing, cleaning, DC sputtering, BCP, HP rinsing with ultrapure water and cleanroom assembly. Main parameters of DC sputtering were as following: background pressure was 10^{-6} Pa; sputtering current was about 2 A. High-purity Ar served as sputtering gas and working pressure was 17~20 Pa. Time for DC sputtering was 2 hours.

Experiments after post-treatment validated that DC sputtering worked remarkably. Q_0 of the 1+1/2-cell cavity reached 2×10⁸. Moreover, multipacting could be easily eliminated, and when eliminated at low input power (~ mW), it would not appear at higher input power any more.

BEAM TESTS

Beam loading tests have been carried out at 4.2 K, and we have succeeded in superconducting acceleration. In experiments E_{acc} of the cavity was about 3.5 MV/m (at 4.2 K), and energy of electron beams after acceleration was about 300 keV (after the B-Magnet). Evident superconducting acceleration was observed through RF phase shift. A curve of electron beam current vs. phase difference between RF and laser is shown in figure 4. Acceleration effect could also be observed obviously from the difference between beam spots at fluorescence before and after acceleration. (Figure 5 and Figure 6)



Figure 4: Electron beam current vs. phase difference between RF and laser.



Figure 5: Beam spot at fluorescence target, about 2 m apart from photocathode (before acceleration by superconducting cavity).



Figure 6: Beam spot at fluorescence target, about 2 m apart from photocathode (after acceleration by superconducting cavity).

Energy gain of the electron beams through the superconducting cavity is about 270 keV, which is quite lower than expected. The reason lies in the relative lower

 E_{acc} of superconducting cavity. In the operation E_{acc} of this cavity was 3~4 MV/m, and it was hard to enhance E_{acc} at 4.2 K. Therefore 2 K beam loading tests is underway to improve Eacc and thus to reduce phase slippage in multi-cell cavities.

UPGRADE OF DC-SC PHOTOINJECTOR

DC-SC photoinjector was designed for PKU-FEL, which aims at high average power FEL. Through experiments on the DC-SC photoinjector test facility, we have validated that the DC-SC photoinjector is a good choice to provide moderate average current electron beams with low bunch charge and very high repetition rate.

Table 1: Parameters of the new photoinjector

2+1/2-cell cavity	
E _{acc}	15 MV/m
Drive laser	
Pulse length	10 ps
Spot radius	2 mm
Repetition rate	81.25 MHz
Electron bunch	
Charge/bunch	<60 pC
Energy	3.72 MeV
Energy spread (rms)	1.68%
Emittance (rms)	2.0 mm-mrad

Experiments on the test facility also indicate that to fulfil the requirements of PKU-FEL to the injector, it is necessary to upgrade the core elements of photoinjector- DC gun and superconducting cavity. Voltage of the DC gun will rise to 150 keV, and accordingly, the structure of high voltage terminal will be improved which will lead to some changes in the structure of cryostat. A 2+1/2-cell cavity will be employed for the new injector. Design and optimization have been accomplished. Stamping technology and electron beam welding technology will be used to fabricate the new cavity. High-purity Nb plates from Ningxia of China will be chosen for the 2+1/2-cell cavity. Parameters of the new photoinjector are list in Table 1.

SUMMARY

We have found a new and simple method to process superconducting cavities. Through this method, DC sputtering, the quality of cavity improves remarkably in a dry way.

Beam tests (at 4.2 K) on DC-SC photoinjector test facility have been carried out. The results of beam tests agree with those of simulations. At present 2 K beam tests are in progress.

REFERENCES

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