ADS 650MHz BETA=0.82 SUPERCONDUCTING CAVITY RESEARCH STATUS*

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Abstract

IHEP is developing a 650MHz beta=0.82 superconducting cavity for the China ADS project. The cavity is for the energy range of from 367MeV to 1500Mev. We have chosen a five cell cavity and optimized the cavity with E_{pk}/E_{acc} and B_{pk}/E_{acc} to reach high gradient. The cavity parts for two cavities were fabricated and the EB welding is in process. This paper will show the fabrication status and measurement results.

INTRODUCTION

China is developing the Accelerator Driven Sub-critical System (ADS) which is composed of a nuclear reactor operating in subcritical mode and a main linac providing the required complement neutrons. The aim of the ADS project is to dispose the nuclear waste. And the ADS is also a good choice of solving future energy shortage by safe utilization of nuclear power. Figure 1 shows the schematic of the ADS proton linac project. The option to accelerate proton bunch in the medium energy range is to utilize the 650MHz beta=0.63 and beta=0.82 superconducting cavity. IHEP has started developing SRF technology since about nine years ago. The large grain single cell niobium cavities reached 40MV/m by BCP and 48MV/m by EP separately in 2008. In 2010, one 9-cell low-loss large grain niobium cavity was fabricated and tested. The cavity reached 20MV/m in the first vertical test at KEK [1]. In 2012, two spoke cavities were fabricated and tested and the results show that the cavity is good enough for the ADS project. A 650MHz beta=0.82 superconducting cavity was studied and designed for the energy range from 367MeV to 1500MeV.

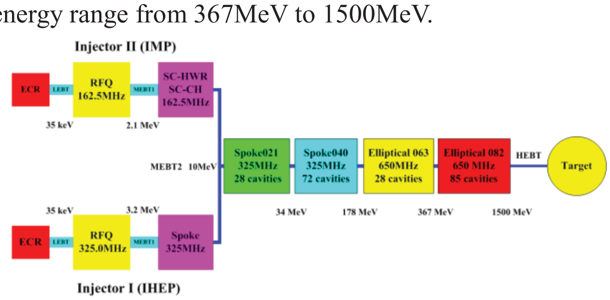

Figure 1: The road map of ADS linac project.

THE DESIGN PRINCIPLE

The 650MHz beta=0.82 superconducting cavity is used to accelerate proton bunches from 367MeV to 1500MeV. In this energy region, the particles still move at a speed lower than the velocity of light. To accelerate 10mA CW proton bunches, we need to follow these principles in the cavity design:

1) Proper cell numbers. Cavity with high cell numbers has low accelerating efficiency while cavity with low cell numbers has short accelerating length. Figure 2 shows the accelerating efficiency for different cell numbers [2] and we choose a five-cell cavity to balance the efficiency and accelerating length.
2) To get higher accelerating gradient, E_{pk}/E_{acc} and B_{pk}/E_{acc} should be low.
3) No hard multipacting barrier caused by shape.
4) Proper beam aperture to damp high order modes.

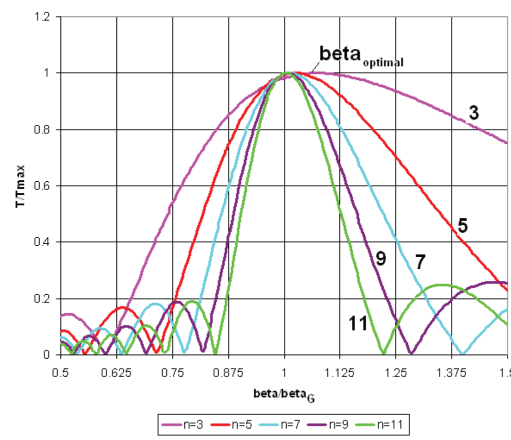

Figure 2: Transit time factor versus a ratio of beam velocity β to geometrical β for different cavity cell numbers [2].

Table 1: The 650MHz beta=0.82 Superconducting Cavity Parameters

Type	Elliptical
Operating frequency (MHz)	650
Working gradient(MV/m)	15
Q_0	1×10^{10}
Beta	0.82
No. of cell	5
Dia. of iris (mm)	100
Cavity length (mm)	1281.7
R/Q (Ω)	514.6
$Q_0 \times R_s$ (Ω)	235.5
E_{pk}/E_{acc}	2.12
B_{pk}/E_{acc} (mT/(MV/m))	4.05
Field flatness (%)	>98

*Work supported by CAS "Strategic Priority Research Program"
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ISBN 978-3-95450-122-9

BuildCavity[3] and Superfish were used to design the cavity shape of the 650MHz beta=0.82 superconducting cavity. The cavity parameters are shown in Table 1. The cell shape parameters are shown in Table 2.

Table 2: The 650MHz beta=0.82 Superconducting Cavity Cell Shape Parameters

Parameters	Center cell	End cell
L (cm)	9.461	9.461
Riris (cm)	5	5
D(cm)	20.0207	20.0207
A(cm)	7.027	7.166
B(cm)	7.027	7.883
a(cm)	1.681	1.667
b(cm)	2.522	2.501
α (°)	7	6.678

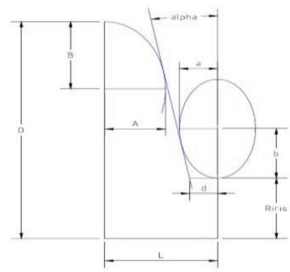

Figure 3: The cell shape parameters' definition.

MULTIPACTING

To achieve high accelerating gradient, one needs to eliminate the hard multipacting barrier in the cavity. Proper cavity shape can avoid that multipacting from happening in cavity. We use Track3P[4] to simulate the multipacting in cavity.

We simulate the multipacting of the 650MHz beta=0.82 cavity for E_{acc} from 1MV/m to 20MV/m with an interval of 1MV/m using a ten degrees slice of the cavity. The simulation results show that no hard multipacting barrier in the cavity.

FABRICATION

We have started the cavity parts fabrication since July 2012. However, we have postponed the fabrication several times since the material delay. Now we have fabricated all the parts of the cavity and the EB welding has been started since April 2013. 9 dumbbells were welded and measured. Other parts' welding is in schedule.

We have carefully cleaned the cavity parts surface before the EB welding. The procedures are as follows:

1) Ultrasonic clean for 15 minutes.
2) BCP for about 5μm. Used acid was used for the BCP procedure. Parts were put in the acid for about 5 minutes at a temperature of 10 degrees Celsius.
3) Drying in clean room for about 24 hours.
4) Encapsulated for EB welding.

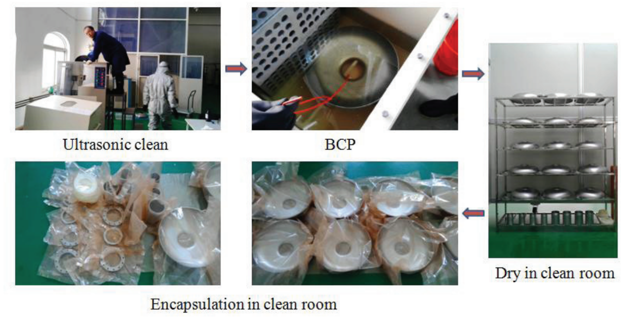

Figure 4: Surface cleaning before EBW.

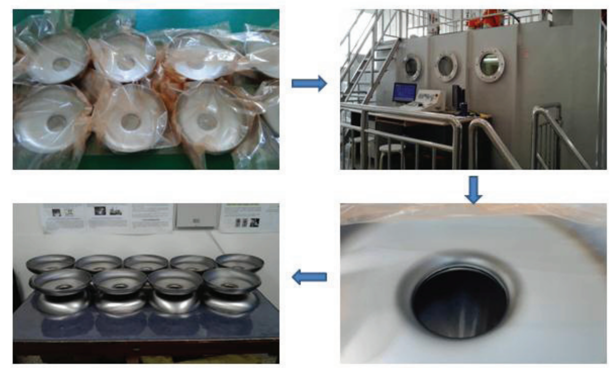

Figure 5: 9 dumbbells were fabricated.

FREQUENCY MEASUREMENT

We have designed and fabricated a half-cell and dumbbell frequency measurement table for the 650MHz cavity. It is also can be used for the 1.3GHz cavity half-cell and dumbbell measurement. For good contacting, there is a rubber O ring under the thin sector plate.

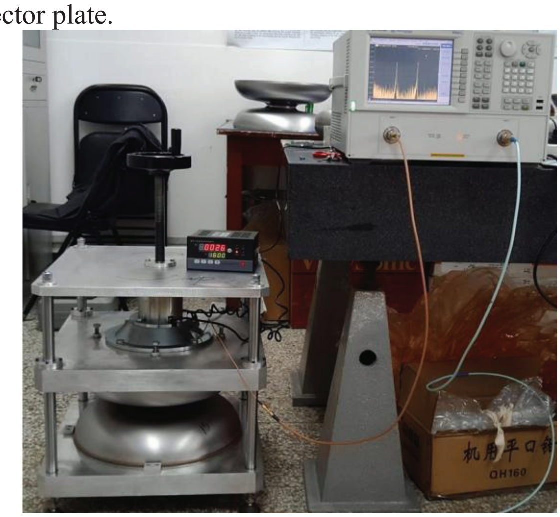

Figure 6: Half-cell and dumbbell frequency measurement table.

We used the perturbation method to measure the half-cell frequency of the dumbbell. A perturbation body of 35.58 mm in diameter was put on the bottom plate near the center of it. The perturbation body should be large enough; otherwise, it will cause little frequency change such as a few hundred kHz which is comparable to the measuring platform system error of about 50 kHz.

Figure 7: The perturbation body.

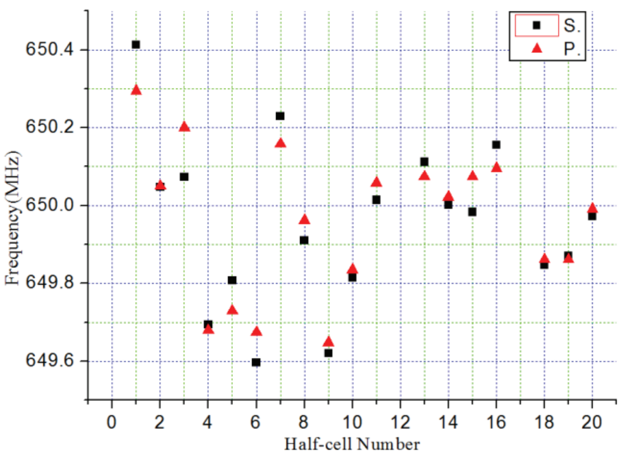

Figure 8: The half-cell frequency measurement of the dumbbell. S. is for the A. Sun method [5] and P. is for the H. Padamsee method [6].

The TM010 0 and π mode of the dumbbell were measured and two calculation methods were used for comparison. The results show that the two methods are well agreed with each other. The frequency range of the half-cells of the dumbbell is between 1 MHz.

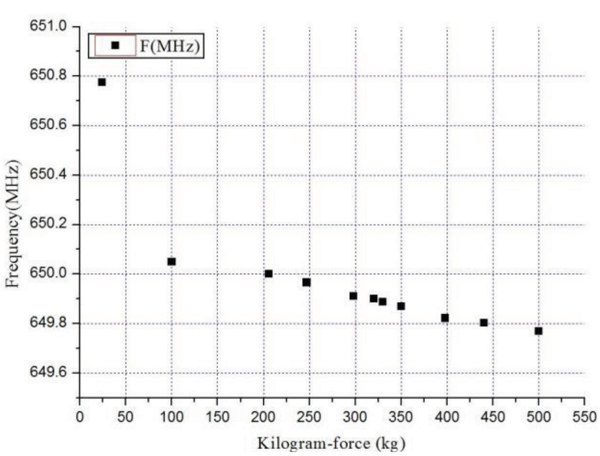

Figure 9: The π mode frequency versus force.

We have measured the frequency change of the dumbbell versus force. From the up picture, we can see that the frequency change at the lower force part is caused by the rubber shape distortion and the frequency change versus force is linear when the rubber shape stopped changing.

SUMMARY

A 650MHz beta=0.82 superconducting cavity has been designed for the ADS main accelerator from the energy range of from 367MeV to 1500MeV. The results show that the cavity has a reasonable E_{pk}/E_{acc} and B_{pk}/E_{acc} and a large diameter of iris. Multipacting was checked by Track3P and the results show no hard multipacting barrier in the cavity. We have finished the cavity parts fabrication for two cavities and EB welding is ongoing. The half-cell frequencies of the dumbbells and the frequency change of the dumbbell versus force have been measured.

ACKNOWLEDGEMENT

We wish to thank the Advanced Computations Department of SLAC for providing the ACE3P code suite and related resources.

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ISBN 978-3-95450-122-9