HIGH POWER CONDITIONING AND FIRST BEAM ACCELERATION OF THE CSNS DTL-1

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Abstract

The CSNS DTLs are divided into 4 cavities. The DTL-1 was transferred and installed in the CSNS Linac tunnel in August of 2015. The RF high power conditioning of DTL-1 started in December 2015 and ended in February 2016. At the end, we finished DTL-1 high power conditioning mission with peak power 1.5MW (1.1 times design value), 1.625% duty factor (650us, 25Hz). And the first beam has been successfully accelerated to the design value 21.6MeV with nearly 100% transmission efficiency. In this paper, the details of conditioning process were presented and one severe RF discharge breakdown was described specifically, which occurred during high power conditioning.

INTRODUCTION

Drift Tube Linac is one of major parts of China Spallation Neutron Source (CSNS), which accelerate H^- particle from 3MeV to 80.1MeV[1]. It consists of 12 mechanical tanks, three mechanical tanks constitute one physical cavity, which is powered by one klystron.

The DTL is made up of tanks, DTs (drift tubes), post couplers, fixed tuners, movable tuners, and other components. Every DTs has a quardupole magnet assembled inside them, which provides focus force for H^- particle. The resonant frequency of DTL can be adjusted by movable tuners while mistuning caused by perturbations during beam commission. The design parameters of CSNS DTL are shown in Table 1.

Table 1: Main Parameters of CSNS DTL

	DTL1	DTL2	DTL3	DTL4
Output energy(MeV)	21.67	41.41	61.07	80.09
Average electric field(MV/m)	2.86	2.96	2.96	3.0
RF driving power(MW)	1.35	1.32	1.32	1.34
Tank length(mm)	8507	8559	8781	8821
Tank diameter(mm)	566.24	566.40	566.43	566.50
DT diameter(mm)	140	140	140	140
Bore radius(mm)	8	10	10	12
No. of cell	64	37	30	26

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HIGH POWER CONDITIONING

It took almost 3 months to do the preparation for high power conditioning, such as rechecking the RF field profile after installation in the Linac tunnel, water cooling system assembling and cable connection, water leakage test and 24 hours full power running of DTs' quadrupole magnet, etc.DTL-1 cavity is shown in Figure 1.

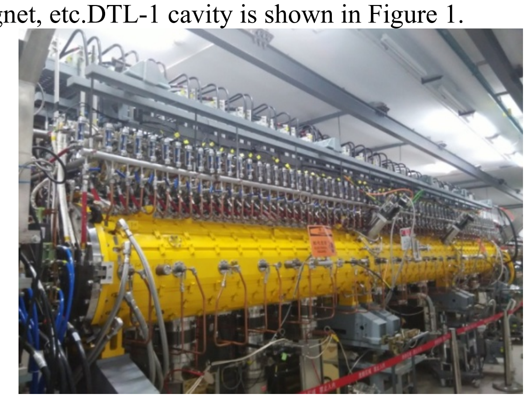

Figure 1: DTL-1 cavity situated in Linac tunnel.

RF power generated by klystron is transferred through a ceramic window and a ridge waveguide, then fed into DTL-1 cavity. The ceramic window guarantees the high transmission of RF power and isolation of cavity vacuum from outside. The ridge waveguide structure was designed deliberated with the power coupling. The measured coupling coefficient of iris hole (with ceramic window) and cavity is 1.33. Figure 2 shows the ridge waveguide structure.

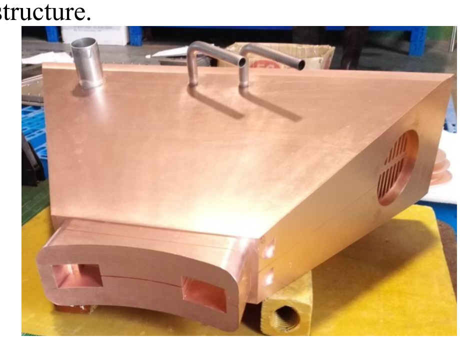

Figure 2: Ridge waveguide structure.

Conditioning Process

The high power conditioning process of DTL-1 took about 2 months, during which first beam acceleration had been done in January 2016. The entire process can be divided into 3 stages.

Conditioning history is shown in Figure 3.

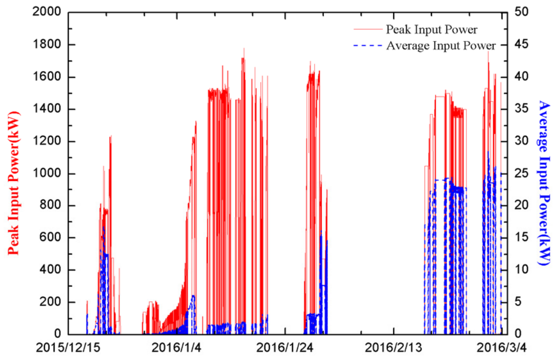

Figure 3: DTL-1 Conditioning History.

Stage 1: Ceramic Window Aging

In the initial conditioning, low power was used to test DTL-1 with peak power 10kW and 1.625% duty factor (650us, 25Hz), we found almost all the RF power was reflected by the ceramic[2], no power was fed into the cavity. The outgas of ceramic window was easily enhanced by input power. Compared with ceramic window, cavity vacuum was dull with increasing input power.

Stage 2: Cavity Conditioning in Low Power Level

After 22 hours aging of ceramic window, RF power was fed into the cavity. The explicit RF signal was got from the pickup. In this period, we increased the input power gradually with low duty factor (200us, 5Hz). Then we set repetition frequency with 5Hz and increased pulse width from 200us to 650us with input power increased to 1.7MW carefully. Cavity vacuum was sensitive with the input power at new high power level and discharge happened frequently in this stage. One severe discharge occurred at input power 1.22MW with 650us and 25/3Hz. After the discharge, cavity was very unstable, discharge continue happening at low power level (below 200kW, 200us, 25Hz). We opened the ridge waveguide to check the RF seal contactor, no obvious damages observed. So we reconditioned the cavity, 200 hours later, the cavity condition became stable at 400kW level and input power was easily pushed to 1.2MW. The discharge happened about once per several hours.

Stage 3: High Power Level Conditioning

The input peak power was increased from 1.2MW to 1.7MW (200us, 25Hz) with step length of 50kW slowly, depending on cavity condition (vacuum condition, sparking frequency, etc). Then we extended the pulse width from 200us to 650us. Conditioning work went smoothly in this stage, 600 hours later (include first beam acceleration), we finally reached the design power level 1.5MW with 1.625% duty factor (650us, 25Hz).

During the conditioning process, several serious RF discharge occurred due to cavity vacuum (vacuum protection threshold 5e-4Pa), especially in high power level. After vacuum breakdown, the cavity needed to be reconditioned and stayed longer at the sparking power point. The VSWR (Voltage Standing Wave Ratio) of ridge waveguide and cavity kept smaller than 1.50 within all the conditioning process.

FIRST BEAM ACCELERATION

The first beam acceleration took place during stage 3 process. Beam was accelerated to 3MeV by RFQ, then transferred by MEBT and injected into DTL-1. The 5mA beam was successfully passed through DTL-1 with almost 100% efficiency. The beam energy reached to the design value 21.6MeV. Two FCT (Fast Current Transformer) monitors, which are located after DTL-1 with a distance, were used to measure the beam energy. By adjusting setting current of DTL-1 quadrupole magnet, 18mA beam (design value 15mA) was observed at CT (Current Transformer) monitor, shown in Figure 4. The accuracy of beam current is within error of CT measurement system.

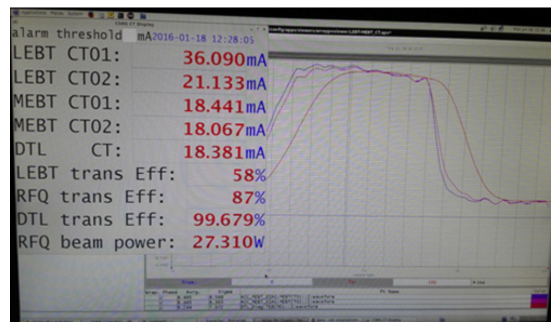

Figure 4: 18mA beam signal at the CT monitor.

CONCLUSION

The CSNS DTL-1 installation in Linac tunnel was finished in December 2015. It took about 2 months to do the high power conditioning work (include beam acceleration and beam commission). The cavity was powered to 1.5MW (peak value) with 1.625% duty factor (design value is 1.05%). And 18mA H^- beam current was successfully accelerated to 21.6MeV with nearly 100% efficiency. High power conditioning of the rest 3 cavities will be carried out soon.

REFERENCES

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