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RF CONDITIONING AND BEAM COMMISSIONING STATUS OF CSNS DTL

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Abstract

The high power RF conditioning of CSNS DTL was finished in April 2017 with peak input power 1.6 MW, 650 us pulse width, 25 Hz repetition frequency. With careful tuning of RF amplitude and phase, beam was accelerated to 80 MeV successfully with maximum peak beam current 12 mA and about 98% transmission efficiency. DTL operate stably at full power level with several trips per day without beam interruption after six months commissioning. The whole RF conditioning process was presented and some details of beam commissioning were described in this paper.

INTRODUCTION

The CSNS DTL is a Alvarez-type Linac, consists of four cavities, accelerate H^- particle from 3 to 80 MeV [1]. Each cavity is powered by individual klystron with 324 MHz operation resonant frequency. The Lattice structure made up of electromagnets inside every drift tube provide transverse focus force for the beam [2]. The main parameters of the CSNS DTL are listed in Table 1.

Table 1: Main Parameters of the CSNS DTL

Tank number	1	2	3	4	total
Output energy (MeV)	21.67	41.41	61.07	80.09	80.09
Number of cell	64	37	30	26	157
RF driving power (MW)	1.35	1.32	1.32	1.34	5.33
Total RF power (MW) (I=30 mA)	1.91	1.92	1.92	1.93	7.68
Accelerating field (MV/m)	2.86	2.96	2.96	3.0	
Synchronous phase (degree)	-35 to -25	-25	-25	-25	

RF CONDITIONGING

The high power conditioning started in December 2015, and finished in February 2017. Due to time limitation, the couplers and ceramic windows of all four cavities were not previously conditioned. The actual effective aging time is about 106 days, the DTL-1 cavity took about 61days due to high frequently arcing and poor vacuum condition. After DTL-1 conditioning process, the first beam had been successfully accelerated to design energy 21.6 MeV by deliberately adjusting of input power amplitude and phase. The rest three cavities took about 45 days finishing conditioning process with 700 us, 25 Hz, peak input power 1.6 MW. The RF conditioning parameters are presented as Table 2.

Table 2: RF Conditioning Parameters

Operation Frequency	324 MHz
Repeation Frequency	25 Hz
Power Width	650 us
Input Power	1.5 MW

Figure 1 shows the whole DTL structure. Before conditioning, the interlock protection systems, include temperature sensors mounted on outside wall, vacuum system read from Cold Cathode Gauges, water cooling system which monitors cooling water flow and VSWR protection system used to shut down RF power when severe arc occurs, are rechecked to ensure cavity operation normally.

Figure 1: The CSNS DTL in tunnel.

The high power conditioning process is illustrated as following,

Firstly, 5~10 kW(650 us, 25 Hz) input power is fed in cavity to see whether cavity operation correctly. The ceramic window is sensitive with the increase of input power, which is almost fully reflected back during initial conditioning process. Half of hour later, power is smoothly transferred into cavity, clear signal can be seen in the oscilloscope captured by pickup.

Secondly, as power comes into cavity, the vacuum fluctuation is big due to outgas from internal wall. Input power was increased gradually according vacuum condition changing, which should rebalance to a stable situation after new high power level. If vacuum condition continues to deteriorate because of arcing inside cavity, then input power amplitude should be reduced until vacuum condition getting stable again. Generally, 5~10 kW increasing power per step is reasonable below 1 MW. For keeping high conditioning efficiency, the klystron fre-

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quency is shifted manually to keep pace with resonant frequency of cavity which drifted away due to ohmic loss by input power.

Thirdly, once input power reached 1 MW, and close to design power level, small power increasing step should be taken, any big arc will do a bad damage to the cavity. Real-time vacuum condition of the cavities should be monitored, interlock systems should be enabled as well. In our case, the VSWR protection threshold is set 20 in one second due to 25 Hz conditioning frequency to protect cavity from arcs, vacuum warning threshold is 5e-5Pa and protection threshold is 1e-4Pa which would trigger interlock system to cut down klystron power. RF power is increased every half hour if no arc was observed. Arcs took place frequently at some power level for CSNS DTL, especially close to 1.5 MW(design value), so we reduce the arc power level a little and make the cavity stay longer at that level until cavity state becoming stable.

During high power level conditioning stage, once a big arc occurred, the cavity state becoming unstable at some power level which is already aged. The cavity should be reconditioned at arcing power level. Sometimes arc took place frequently at high power level close to 1.5 MW, the VSWR protection system frequently cut down input power leading to low conditioning efficiency even after long time aging below that power level. We tried to disable VSWR protection system, and observed cavity vacuum state. As long as cavity vacuum pressure did not exceed 1e-4Pa, then cavity is safe. We believe arcs can eliminate some flaw points inside of cavity.

During DTL-1 conditioning process, several drift tubes were found vacuum leakage, we use Agilent Torr Seal product to block the leak points. Then we repeat the conditioning process for DTL-1. The conditioning process of DTL-2~DTL-4 went smoothly because of better vacuum condition(about 3e-6Pa~1e-5Pa), and the vacuum pressure keep at 3e-6Pa~8e-6Pa while operation at design power level.

The whole conditioning history of CSNS DTL is showed in Fig. 2.

BEAM COMMISSIONING

First beam acceleration had been done after DTL-1finishing conditioning. The H^- ion beam is successfully accelerated to 21.6 MeV measured by two FCT located at temporary beam test line. The transmission was almost 100%, and matches the beam dynamics result very well. Then, after all cavities finishing conditioning, the power amplitude and synchronous phase scan was performed successively cavity by cavity. At last, H^- ion beam was accelerated to 80.1 MeV up to 12 mA with 99% transmis sion efficiency (Fig. 3), which is also verified the simulation result very well.

In the initial operation, the trip rate of the CSNS DTL is several trips per hour. After six month operation, the operation availability of DTL was improved dramatically. The trip rate of DTL-1 is about 1 trip per hour, and several trips for rest three cavities per day (Fig. 4).

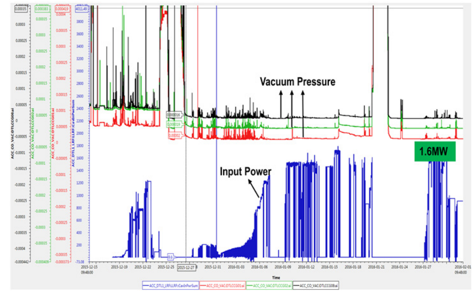

Figure 2a: DTL-1 Conditioning History.

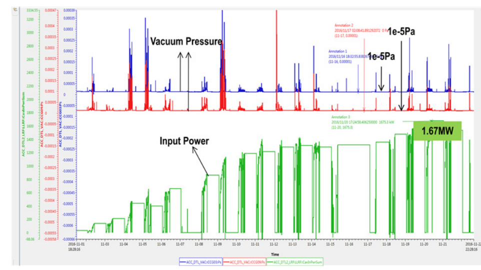

Figure 2b: DTL-2 Conditioning History.

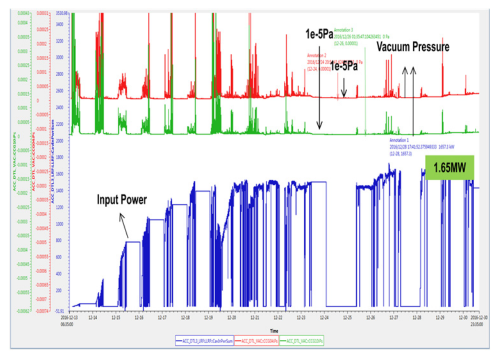

Figure 2c: DTL-3 Conditioning History.

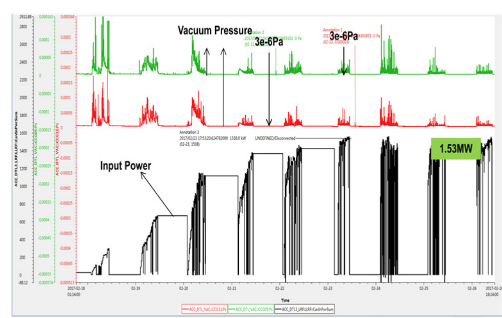

Figure 2d: DTL-4 Conditioning History.


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LEBT CT01:	43.57	mA	LEBT Trans:	30.0
LEBT CT02:	13.09	mA	RFQ Trans:	89.8
MEBT CT01:	11.75	mA	MEBT Trans:	101.5
MEBT CT02:	11.93	mA	DTL1 Trans:	100.3
DTL CT01:	11.96	mA	DTL2 Trans:	100.3
DTL CT02:	11.99	mA	DTL3 Trans:	98.8
DTL CT03:	11.85	mA	DTL4 Trans:	101.8
LRBT CT01:	12.06	mA	LRBT Trans1:	100.8
LRBT CT02:	12.16	mA	LRBT Trans2:	-0.1
LRBT CT03:	-0.02	mA	LDBT Trans:	103.2
LDBT CT01:	12.45	mA	RCS Trans:	60.2
RCS Inj:	0.00/0.09	E12/mA	Ext Trans:	-4229.2
RCS Ext:	0.00/0.13	E12/mA	RTBT Trans:	10.4
RTBT CT01:	0.06	E12	RDBT Trans:	981.8
RTBT CT02:	-0.03	E12	Linac Energy:	81.40
RTBT CT03:	-0.00	E12	Target Power:	-0.00
RDBT CT01:	0.01	E12		

Figure 3: Beam parameters at CT detector.

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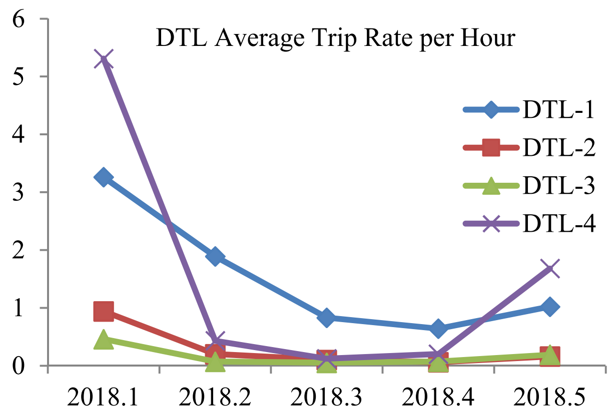

Figure 4: The average trip rate of the CSNS DTL in daily operation (in 5 months).

CONCLUSION

In February 2017, the CSNS DTL finished conditioning (700 us width, 25 repetition frequency, 1.6 MW input power). The scan of power amplitude and synchronous phase of 4 cavities was carried out deliberately. Finally, beam was accelerated to design value (80.1 MeV) with 99% efficiency.

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