STATUS OF THE J-PARC LINAC

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Abstract

Beam commissioning of the J-PARC linac started in November 2006 and 181 MeV acceleration was successfully achieved in January 2007. The linac has delivered beams for commissioning of accelerators and experimental facilities. Trip rates of the RFQ, however, unexpectedly increased in autumn 2008, and that was the primary limitations of the operation days and power ramp up. We tried to recover by improvement of vacuum properties, tender conditioning and so on. By taking these measures, we can lengthen the continuous operation days and stand user operations. We ramped up the beam power and the linac has delivered beams at this power since then without significant troubles. The performance and operation experiences of the J-PARC linac are described.

INTRODUCTON

The J-PARC accelerator consists of a linac, a rapid cycling synchrotron (RCS) and a main ring synchrotron (MR). The RCS provides a 3 GeV beam to the Materials and Life science experimental Facility (MLF) at a repetition of 25 Hz. A part of the 3 GeV beam is injected to the MR and accelerated up to 30 GeV (50 GeV in the second phase). The beam is delivered to the hadron facility or the neutrino facility.

The linac comprises of a negative hydrogen ion source, an RFQ, a DTL and a separated-type DTL (SDTL). The energy is 181 MeV and the peak current is 30 mA at present. The linac beam test started in November 2006 and a 181 MeV beam was successfully accelerated in January 2007. Since then, the linac has been delivered beams for commissioning of the linac itself, downstream accelerators and research facilities. An energy upgrade project to 400 MeV with an Annular-ring Coupled Structure lianc (ACS) was funded. Mass production of the ACS cavities and installation of power supplies are underway[1].

DISCHARGE PROBLEM OF THE RFQ

The most urgent issue of the linac was discharge in the RFQ from September 2008[2]. This has been disrupting operations for user runs and the RCS beam power for the MLF users was limited to 20 kW. We tried to restore the performance of the RFQ and we decided to construct a backup spare RFQ[3]. We improved the vacuum system of the ion source, the LEBT and the RFQ as shown in Fig. 1 in March 2009 and in the summer shutdown of 2009. The key points are as follows;

- The RF interlock setting was changed and pre-injection beam from the ion source was suppressed as low as possible.
- Some cryo-pumps and ion pumps are added.
- Oil rotary pumps used for rough pumping were replaced with oil free scroll pumps.
- A moisture filter was inserted in the hydrogen gas system in the ion source.
- The LEBT chamber was replaced with a new clean one with a divider plate with an orifice for more efficient differential pumping.
- An in-site warming up to 70 deg-C was performed to accelerate degassing.

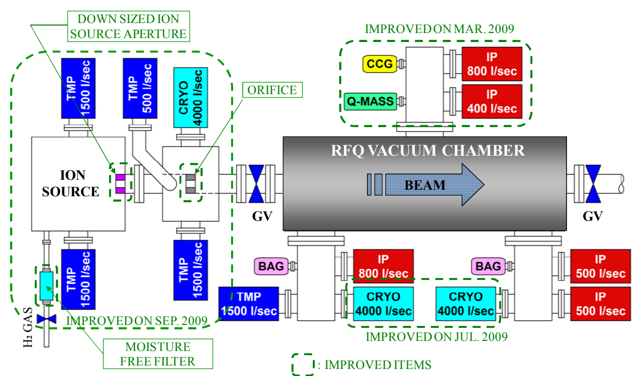

Figure 1: Vacuum system at the front end.

Operational Experience After the Vacuum Improvements

As well as above measures, we did conditioning for several (or more) days. In this way, we managed to clear the important project milestones, so that able to initiate Main Ring acceleration studies and user operation of the Material and Life experimental facilities (MLF) in December 2008.

Since January 2009, the first priority has been to operate on schedule rather than to increase beam power. So we stayed with a conservative regime: peak current of 5 mA, beam pulse width of 0.1 ms, and a repetition of 25 Hz. That corresponds to an MLF beam power of 20 kW, which is the minimum acceptable for users. Even under those conditions, the RFQ disrupted use for a few months. Along with the vacuum improvement, since April 2009 the RFQ vane voltage has been decreased from 102% to 95 % of normal. To reduce unscheduled beam shutdown, conditioning days for RFQ clean up are scheduled in the operational calendar. At first, we set cycles of 2 or 3 days of operation followed by one conditioning day.

In November, based on the stable operation of the RFQ at 20 kW in October, we tried to increase the beam power for MLF user operation; increasing beam pulse length from 0.1 to 0.2 msec, and peak beam current from 5 to 15

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mA, thus giving a 6 fold increase from 20 to 120 kW. We were able to deliver beam to MLF users without incident.

In December we demonstrated a 300 kW operation for one hour to the MLF. The linac and the RFQ delivered the beam with a pulse width of 0.5 ms, which is the full design specification.

In January 2010, we delivered beams to MLF and began trying to extend continuous operation to 3 days and more. Gradually we were able to extend to 6 or 7 days.

Working to extend the continuous operational days, we monitored trend in the number of trips. The day after conditioning, the number of trips was least and it seemed to be increasing with the number of operation days. But the number was decreasing as operational days accumulated. Figure 5 shows the number of trips per day due to the RFQ in June. Most of the time, beam is delivered to the MLF (0.2ms, 25Hz) and NU (0.5ms, 0.3Hz). The blue dots show the success of automatic trip recovery, and red dots show failures where operator assisted recovery was necessary, these are more severe than the automatic recovery cases. We have had many trips on some days, but there seems to be a recovery even when in continuous beam operation. Nineteen consecutive days of operation without degradation have been demonstrated, which means that the performance of the RFQ has been almost restored to what it was.

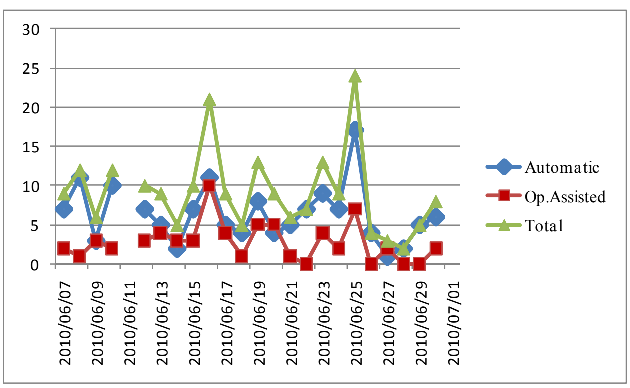

Figure 2: Number of trips per day in the run of June 2010.

RELIABILITY

Figure 3 shows the beam down time by major subsystems not only the linac but also the RCS and the MR. This table summarizes the data for 120 kW@3GeV operation from November 2009 to June 2010. Total scheduled MLF user time was 1,696 hours. The beam availability (defined as the beam on time for MLF users / scheduled beam time) was 92%. There are several reasons for decrease in reliability.

The dominant causes of the linac are RFQ and SDTL. It takes about 1 minute to recover for automatic RF recovery case and 10 minutes for operator assisted recovery case to restart beam operation. As mentioned above, the performance of the RFQ has been almost restored. Even in this case, total number of down time is 600, and the total down time recorded to about 20 hours. When a beam trip occurred, an operator confirmed the reason and reset it. Thus the minimum beam resuming time is 1 minute even in the several seconds RF automatic recovery time. We are considering to shortening a resuming time for insignificant trips such as the RF automatic recovery cases. And also, we still continue to restore the performance of the RFQ to reduce the number of trips.

One of the major causes related to the SDTL was a discharge problem of the coaxial feeder line in run34, June 2010[4]. The downtime due to this incident was 7 hours 20 minutes. This is not occasional case, but we have experienced the similar trouble. We are monitoring temperatures at feeder lines to get a sign.

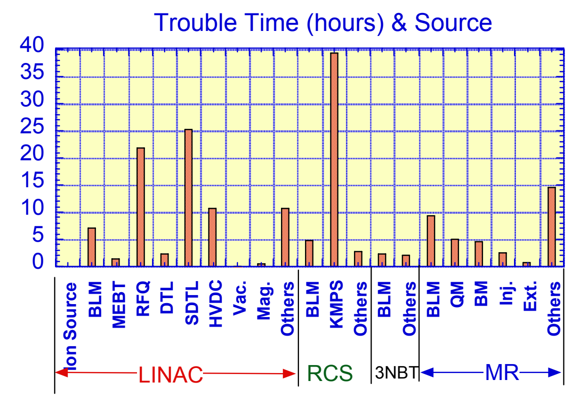

Figure 3: Beam down time by major subsystems.

The HVDC denotes the high voltage DC power supply for klystrons. Number of trips related to high power RF components is shown in Fig. 4. One of the main causes in the recent runs is discharge in an anode modulator. In the anode modulator oil tank, a copper bar was covered by a thin polyethylene insulator and many discharge traces between the polyethylene surface and the inner surface of the tank were observed. To remedy of the problem, we reviewed the arrangement of components for secure the insulation distance in the oil tank[5].

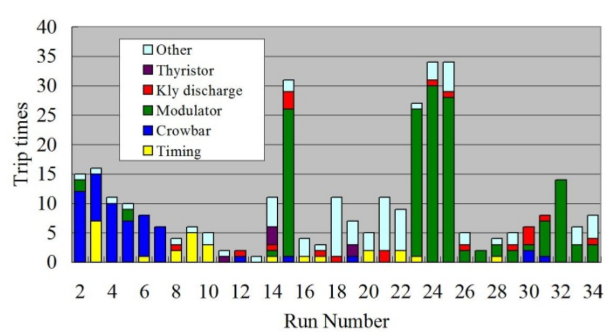

Figure 4: Number of trips related to high power RF components.

The BLM denotes that the beam is tripped by a BLM signal. Some signals are truly by the beam loss, but some are suspect to be false. The suspicious causes are cosmic rays and/or electrical noises. We are taking background data during the summer shutdown without beam. We should take some discrimination procedures between the beam loss signal and some others to improve reliability.

The "Others" is sorted to the other components, which may occur rarely. In this series of runs, the network system failed several times. The components were delivered before the operation of the linac, and some of them may become obsolete. A renew plan should be established.

We can notably show the low trip time due to the ion source[6]. The linac uses a Cs-free, LaB_6-drived multicups H^- ion source. In 2006, we had two filament troubles of short circuit to the neighbouring spirals. Then the filament shape was modified to have a wider gap between spirals from 0.3 to 0.6 mm. We have had no similar troubles since then. Typical ion source operation time is approximately 600 hours for each run. The ion source chamber with a new filament is replaced as preventive maintenance. The ion source failure is mainly caused by ion source peripheral equipments such as vacuum pumps, gauges and so on. We have had no serious unscheduled beam trips due to the ion source and the power supply.

We suffered from unscheduled beam trips due to cooling water flow rate interlocks at the DTL/SDTL section after the maintenance of summer 2009. A slight total cooling water flow rate decrease changed the balance of the flow distribution drastically in the peripheral flow channels. We put many flow and pressure sensors and monitored. We can finally manage the flow rate by controlling the reservoir tank level of the main flow. We have had no unscheduled trips due to the flow change since then.

BEAM LOSS AND RADIOACTIVITY

We are operating with the linac beam power of 7.2 kW at 120 kW for the MLF. Figure 5 shows a comparison of the measured activation levels for 4.5kW and 120kW cases. We have experienced some operational issues such as considerable residual radiation localized at the first bending magnet after the linac, weaker but more widely distributed residual radiation in the beam transport line, and the significant emittance growth in the DTL[7].

The cause of the beam loss at the first bending magnet was identified to be protons captured between the ion source and the RFQ. As a result of a chicane orbit at the beam transport line between the RFQ and the DTL, beam loss has decreased drastically as shown in Fig. 5, where 100 µSv/h at 4.5 kW and 19 µSv/h at 120kW.

The experiments indicated that the beam loss in the beam transport line was caused by H^0 component due to the electron stripping with residual gas[8]. We added some vacuum pumps in the SDTL and the beam transport line in summer shutdown of 2010. We are going to measure the beam loss under the new vacuum conditions.

The cause of the emittance growth in the DTL and the following halo formation has been identified to be longitudinal mismatch at the DTL entrance. They were mitigated by tuning of the buncher cavity amplitudes[9].

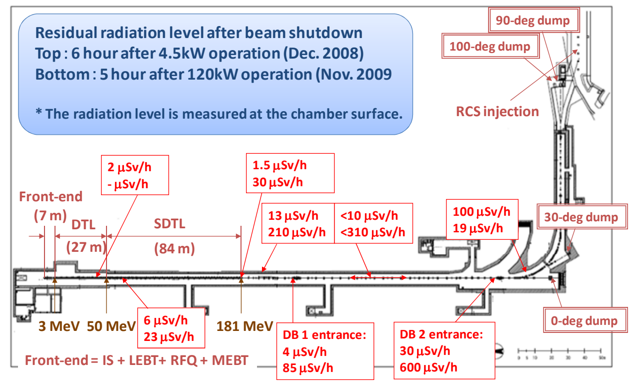

Figure 5: Residual radiation level after the beam shutdown for 4.5 kW and 120 kW @3GeV cases.

SUMMARY

The linac has ramped up the operational beam power to 7.4 kW for 120 kW@3GeV after the performance restoration of the RFQ. Some measures are carried out or planned to improve the availability. Intensive studies and mitigate procedures to reduce beam losses are taken for further ramping up of the beam power.

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