STATUS OF LINACS WITH HIGH-FREQUENCY QUADRUPOLE FOCUSING LU-30 AND LU-30M IN IHEP

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Abstract

There are two RFQ DT proton linacs, named the LU-30 and LU-30M, in the SRC IHEP of NRC "Kurchatov Institute" that are presently in operation. Both are the unique machines employing radio-frequency quadrupole focusing up to 30 MeV at exit. The LU-30 machine now runs as a proton injector to the booster RC PS U-1.5 that feeds the main PS U-70 ultimately. The LU-30M is now run in a stand-alone test operation mode. Such a parallel functioning of these two accelerators allows to use the LU-30M as an experimental facility enabling R&D on new technical decisions and upgrades for the ageing LU-30. On the other hand, the routine operation of the workhorse LU-30 allows for testing of the technical decisions proposed under a heavy non-stop operation during the U-70 runs for fixed-target physics.

INTRODUCTION

The IHEP proton linacs, LU-30 and LU-30M, are the unique machines with Radio–Frequency Quadrupole (RFQ) focusing up to 30 MeV at exit [1, 2]. LU-30 was made as an experimental model. Since 1985 LU-30 has been operating as a proton injector to the booster RC PS U-1.5 on the packet-pulse mode, about 2500 hours per year with downtime (5÷7) %.

The LU-30M was developed from an experience of creation and operation of the LU-30. Emittance of the LU-30M beam reduced to a tenth and the beam transport along the LU-30M is higher then in the LU-30 as figure 1 shows.

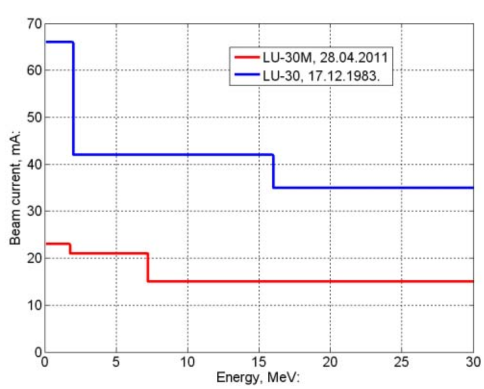

Figure 1: Beam transport in the LU-30 and LU-30M.

The other beam parameters of LU-30M are the same as the LU-30 parameters, except for the beam intensity, which is lower the project level yet. There are substantial differences in design of the accelerators:

- a modification of the electrodes of the initial part (RFQ) LU-30M allowed to halve the RFQ length;
- using the sector H-cavities in the main part LU-30M (RFQ DTL, [2]) some compensation of the decrease in accelerating rate was achieved by realizing the growth in the accelerating voltage along the accelerator;
- a modular design of the anode HV power supplies was developed for higher reliability of the RF-system [3].

Now accelerator LU-30M runs in a stand-alone test operation mode. This mode allows of using LU-30M as an experimental facility enabling R&D on new technical decisions and upgrades for increasing reliability and quality of ageing LU-30.

VACUUM BREAKDOWNS

During LU-30 operation it was noted that the breakdown frequencies for initial and main parts (RFQ, RFQ DTL) LU-30 are almost identical, but the field strength at the surface of the electrodes of this parts differs sufficiently (225 kV/cm and 380 kV/cm). Analytical treatment of the experimental dependence of the relative quality factor on the field strength at the electrodes for RFQ and RFQ DTL showed pronounced distinction between coefficients of local field enhancement for RFQ and RFQ DTL (1100 and 93 accordingly) [4]. This distinction may testify to the various factors that lead to breakdowns. According to paper [5], the values more than 200 can be explained by the presence of films and nonmetallic inclusions on the electrode surface and the smaller values – by the micro irregularities. As a result, we conclude that the products of the ion gun operation may be responsible for the pollution of the RFQ electrodes and the reduced breakdown strength.

BEAM CONDITONING

An injection system with collimators avoiding pollution of the RFQ electrodes by the ion source impurities has been developed. The optics not only effectively separates the impurities but also matches the proton beam to the RFQ in transversal motion. Figure 2 shows it schematically. A diaphragm with a hole of 3 mm in diameter is installed between two magnetic lenses (solenoids), nearby the proton beam crossover. A cylinder of 3.5 mm in diameter is placed in the middle of the second lens to separate the part of the impurity flow coming through the diaphragm hole. In addition the optics filters the transversal phase volume of the proton beam by

ISBN 978-3-95450-170-0

rejecting unconditioned protons. The root-mean-square ellipses of the transversal phase beam volume are presented in figure 3, the required and measured correspondingly.

On testing of the injection system at the LU-30M linac, a possibility of increasing the RFQ electrode field strength (to 450 kV/cm or 3.4 of Kilpatrick criterion) has been demonstrated. For reliable operation LU-30 this injection system will be placed at the input of RFQ LU-30.

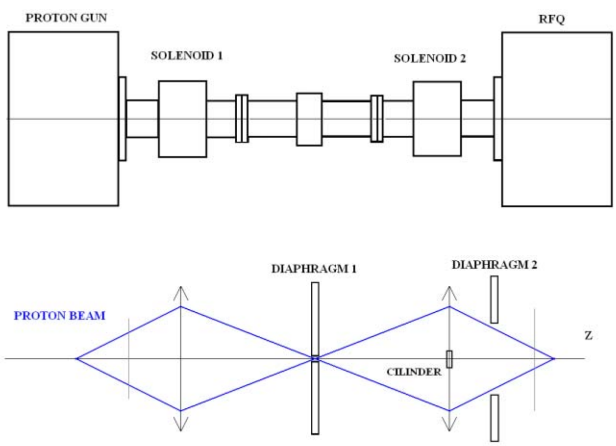

Figure 2: Optic scheme of the matching channel.

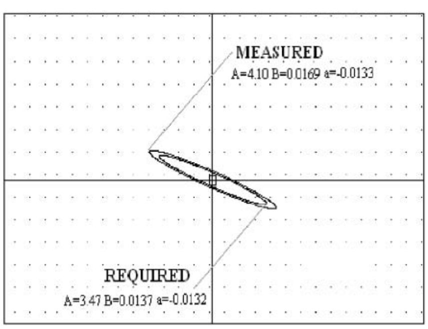

Figure 3: Root-mean-square ellipses of the transversal phase volume of the beam at the RFQ input (grid: 0.98 mm by 43.61 mrad).

FREQUENCY TRIM MODERNIZATION

The frequency trim of resonators at LU-30 and LU-30M is implemented by turning of the copper rings in magnetic field in vacuum. A 90º turn of the ring changes frequency up to 8÷25 kHz, depending on the Q-factor and size of the ring. Turning of the LU-30 rings is carried out by mechanical system with the powerful electric motor through a vacuum seal with plastic plugs and rubber collars. Such a system has the backlash and the susceptibility to mechanical deterioration.

A new system of the ring turning with SHDR-711 step motors and a metallic corrugation vacuum isolation has been developed and tested for LU-30M. Application of the system for LU-30 demanded some modification with using the powerful PL57HD76 step motor and modifying the control electronics, the design of mechanics etc. On figure 4 mechanisms of frequency trim for LU-30M and LU-30 are shown.

Figure 4: LU-30M (left), LU-30 frequency trim mechanics.

The control system of step motors is connected to the personal computer by means of the developed interface. The control program is created in language LabView that allows to supervision of the position of tuning rings to within 1°, and also operatively to change the program of adjustment of frequency. The system of frequency trim with step motors has been installed at LU-30M and LU-30 RFQ. We are preparing now to install it at the RFQ DTL LU-30.

TUNING OF RF BLOCKAGE

During the exploitation of the LU-30 and LU-30M a low efficiency of blocking of the high voltage (HV) modulator circuits against radio frequency (RF) was discovered. Having passed through the modulator outlet, RF voltage could disturb normal work of the low voltage modulator electronics and the measuring system. Since the high power RF systems of the LU-30 and LU-30M were identical, a common cause of the low blocking efficiency was supposed. A scheme of the HV input is shown in Figure 5.

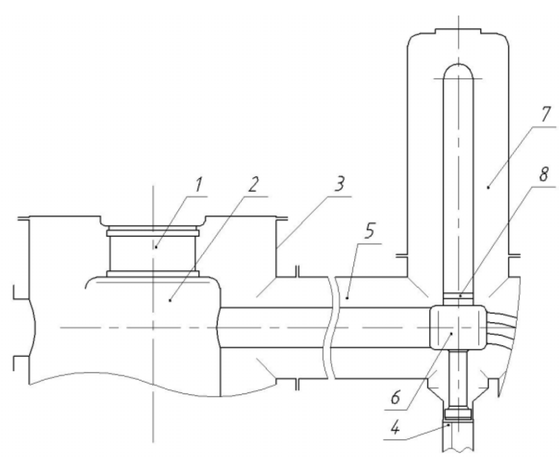

Figure 5: Scheme of the HV input.

The anode circuit consists of the GI-27AM triode (1), an anode block (2), the body (3), the HV modulator cable (4), a coaxial line (5) and rejection filter, that consists of a

ISBN 978-3-95450-170-0

clutch (6), the quarter–wavelength coaxial line (7) and the adjustment ring (8).

A theoretical and experimental studies show that the poor blocking is the result of the difference between the RF system operating frequency 148,5 MHz and the rejection filter resonance frequency (markers 1 and 2 in the figure 6). The filter frequency has been tuned at LU-30M by adjustment of the ring size (8). As a result pronounced frequency difference disappeared (figure 7).

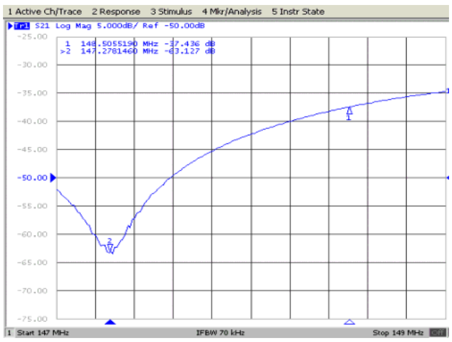

Figure 6: Frequency response characteristic before tuning.

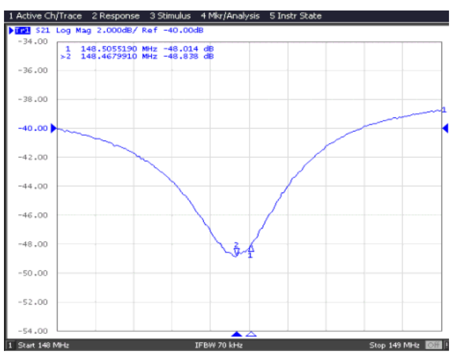

Figure 7: Frequency response characteristic after tuning.

Figure 6 and figure 7 show, that the decreasing of the frequency difference from 1.23 MHz to 48 kHz increases the blocking level of the RF filter from 37 dB to 60 dB. The same works are planned for the high power RF-system at the LU-30. The study [6] shows the necessity of the interference filtration to increase the electronic system reliability at the accelerator complex.

DROOP COMPENSATION

The observed accelerating voltage drooping at the resonators during the beam passing can be partially offset by increasing the output signal of the low power cascade. For that reason a 200 W amplifier was developed and tested. It's based on the UM145-300 "Pallet" module and controlled by an impulse generator.

Figure 8 shows the increase in pulse amplitude of the amplifier's output signal that corresponds to the beam's passage duration of 10 µs. Testing the system of voltage drooping compensation at the LU-30 is under way now.

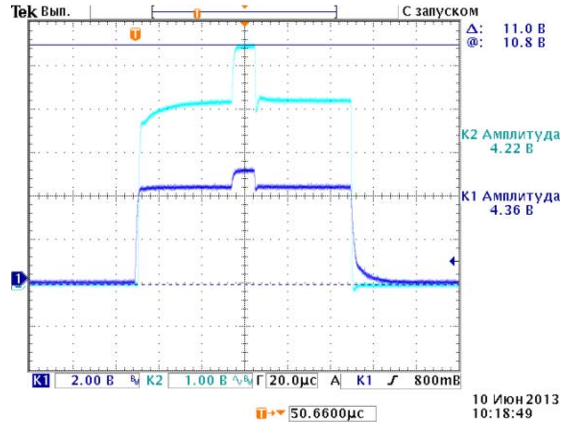

Figure 8: Oscillograms of the power amplifier: output RF impulse (up) and generator impulse (down).

CONCLUSION

It's shown in the paper that simultaneous functioning of two similar accelerators (one operates as a proton injector, another works in the standalone test mode) expands possibilities of increasing the reliability and the beam quality by carrying over the LU-30 the new technical decisions after its testing at the LU-30M. The LU-30M is used as an experimental facility. On the other hand, the routine operation of LU-30 allows a long-term testing of the technical decisions in heavy conditions.

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ISBN 978-3-95450-170-0