Operational experience with heavy ion linac booster at IUAC

B.K.Sahu*, S.Ghosh, A.Rai, P.Patra, J.Karmakar, A.Pandey, B. Karmakar, G.K.Chowdhury, D.S.Mathuria, R.N.Dutt, M.Jain, A.Sharma, S.S.K.Sonti, K.K.Mistry, A.Sarkar, R.Joshi, R.Ahuja, R.Kumar, S.K.Suman, J.Chacko, A.Choudhury, S.Kar, S.Babu, M.Kumar, S.Sahu, J.Antony, J.Sacharias, P.N.Prakash, T.S.Datta, and D.Kanjilal

Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, INDIA

** email: bhuban@iuac.res.in*

Introduction

The superconducting linear accelerator booster having a superbubcher (SB) with a single quarter wave resonator (QWR), three accelerating modules each having 8 QWRs, and a rebuncher (RB) having 2 QWRs, has been delivering heavy ion beams to users since 2008. At present energized ion beams from linac are being delivered routinely for scheduled experiments extending up to weeks. Over the years major efforts were dedicated to improve the operational performance of the SC linac.

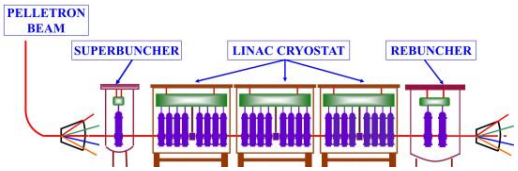

Fig.1. Superconducting booster linac at IUAC.

Planned improvements for linac operation

The accelerating gradients in the resonators obtained in the linac cryostat are in the range of 3 –5 MV/m at 6 watts dissipated power into liquid helium system at critically coupled condition of the power coupler. Although most of the cavity gradients are in this range, still field gradients in a number of cavities in the second and third accelerating module are below 3 MV/m. Effort has been dedicated to improve the accelerating gradients in the resonators. In order to achieve this, the conventional routine procedure like electro-polishing followed by prolonged rinsing with 18MΩ-cm de-ionized water is being followed. Constant effort is also dedicated to increase the operational field of the resonators by bridging the gap between the accelerating fields achieved during Q measurement at 6 W of helium power and during phase locking field of the SC resonator during beam operation. This gap is mainly due to the large stored energy in the resonator and the presence of microphonic vibration coupled to the resonator, along with the slow drift of frequency due to helium pressure fluctuation at higher field gradients. This demands more forward power from the RF amplifier which is above the safe limit of operation (~120 W). A number of steps to reduce the vibration in the central conductor and the niobium bellow tuner have been implemented along with the plan to correct the slow drift at a faster rate to improve the dynamics of control scheme [1].

The central conductors (CC) of all the resonators were made nearly co-axial with respect to the outer cylinder to reduce the frequency jitter. In the past, it had been observed that SS balls can be used as a vibration damper to minimize the frequency jitter due to vibration of central conductor [2]. The optimum number of SS balls with a given diameter necessary to efficiently damp this mechanical vibration mode of central conductor for the indigenously fabricated resonators were implemented.

The phase and amplitude lock in the SC QWR at IUAC is achieved with the help of dynamic phase control using electronic control and mechanical tuner. Mechanical tuner control is meant to correct the slow drift of the resonance frequency by using pure helium gas to flex the niobium tuner bellows. In order to improve the dynamics of this control, an alternate scheme using piezoelectric actuator based tuner has been

developed, tested and finally implemented on all the resonators in the 2nd and 3rd accelerating modules. The control scheme for piezoelectric actuator based control is designed to compensate the slow frequency drift around the central frequency of the resonator and also to damp the low frequency eigen-mode excitations[3]. For the 1st accelerating module a new control scheme using pulse operated proportional valves were designed for gas flow control and implemented in four resonators to improve the frequency correction dynamics of the existing tuners. These two new types of tuner controls reduce a substantial load from the dynamic phase control scheme, thereby reducing the forward RF power requirement.

Linac operation details

Over the years SC linac has delivered heavy ion beams starting from Carbon ($^{12}C^{6+}$) to Silver($^{107}Ag^{21+}$) with time widths of few hundreds of psec on the user target as per the demand by various experimental groups.

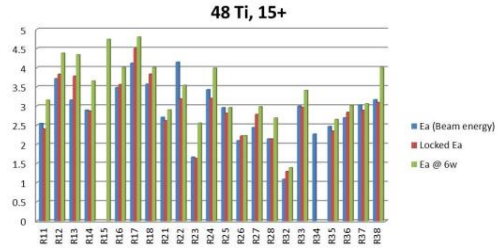

Fig.2. Field gradient of operational resonators

During the last linac operation in 2015 which extended over a few months, 22 out of 23 installed resonators in the three cryostats along with the superbuncher and the rebuncher resonators were used in the acceleration and heavy ion beams were delivered on the target with energy gain of 8.8 MeV/q with time widths of ~ 500 ps at user target. The accelerating phase of the resonators were choosen using optimum phase focussing for better beam transmission and minimum energy modulation. Rebuncher was used along with the accelerating phase combination of the resonators determined by the simulation code for optimising time width of the accelerated beam on user target. The typical RF calibrated operational fields of various resonators along with fields at 6W disspated power into helium system and beam calibrated fields are shown in fig. 2. The details of the beam acceleration over the last two years using three accelerating modules of linac are summarized in table-1.

Table 1: Beam acceleration through linac

Beam	Pell. Energy (MeV)	Linac Energy (MeV)	Total Energy (MeV)	Δt @ Exp. target
$^{48}Ti^{15+}$	168	132	300	580 ps
$^{48}Ti^{14+}$	162	113	275	185 ps
$^{28}Si^{12+}$	130	91	221	RB Off
$^{35}Cl^{13+}$	150	109.5	259.5	RB Off

Future improvements

In order to improve the field gradient of resonators operating below 3MV/m, quality and efficiency of the rinsing procedure is planned. A new high pressure rinsing facility inside a class 100 clean room is designed for the same purpose prior to the installation of resonators in the cryostat. The improved gas flow control scheme will be implemented in remaining resonators of the first accelerating module. An automated phase locking system is being planned for ease of operation.Three capacitive pickups have been installed in the Linac beam line. They have been tested for the measurements of the bunch width and beam energy.

References

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[3] B. K. Sahu et al, Nuclear Instrumentation Methods A 777 (2015) page- 123-130.