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UPGRADES FOR SUBSYSREMS OF 200 MeV H- LINAC AT BNL*

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Abstract

To increase the average current for isotope production by factor of two, we have undertaken several upgrades for 50-year old 200 MeV H^- linac at BNL. Average current will be double by increase the beam pulse length. We are testing DTL tanks reliability by increasing RF pulse length and replacing weak RF joint. We are in the process of replacing 50-year-old ion pumps and a new PLC based vacuum I & C system for the DTL tanks.

INTRODUCTION

The Brookhaven National Laboratory (BNL) 200 MeV drift tube linac (DTL) was built in 1970 [1] with following design parameters for proton: input energy 0.75 MeV, output energy 200.3 MeV, frequency 201.25 MHz, peak beam current 100 mA, beam pulse length (max) 200 µs, RF pulse length 400 µs, pulse repetition rate (max) 10 Hz. Over the 49 years of linac operations, it has gone through several improvements. The major upgrades were; (a) switch to 5 Hz operation [2], (b) change proton to H^- [3], (c) addition of polarized H^- source [4], (d) replacement of the Cockcroft-Walton by Radio Frequency Quadrupole (RFQ) [5], (e) new timing system [6], (f) new 30.48 cm pressurized coax system [6], (g) RF system improvements [6], new 50 kV power supply, eliminating of DC charge control at 60 kV, new RF control system, phase and amplitude servo redesign, (h) new polarized source OPPIS source and its upgrade, and [7,8], (i) reconfiguration of 35 keV and 750 keV transport lines [9,10,11,12,13].

At present linac provides H- beam at 200 MeV to polarized proton program for Relativistic Heavy Ion Collider (RHIC) and at 66-200 MeV to Brookhaven Linac Isotope Producer (BLIP). The RHIC program needs two pulses every AGS cycle (~4-6 sec), one for injection into the AGS booster and other for 200 MeV polarization measurements located in the High Energy Beam Transport line (HEBT). The rest of the pulses from high intensity source are delivered to BLIP. Requirements for these programs are quite different and are following. (1) RHIC: 200 MeV, 600 µA beam current, up 400 µs pulse length, polarization as high as possible and emittance as low as possible, (2) BLIP: 66-200 MeV, 550 µs pulse length, current as high a possible (~60 mA), uniform beam distribution at the target, and beam losses as low as possible. Many of subsystems of the linac are 50 years old and need to be replaced. Two upgrade programs, reliability and intensity [14,15,16], are in progress. Beam raster upgrade was finished in 2016 [18].

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INTENSITY UPGRADE

To increase the isotope production, there is strong desire to increase the linac current by factor of two (Figure 1). An Accelerator Improvement Plan (AIP) was approved for Phase I of intensity upgrade in 2014. Phase I includes 15% (5% in the peak current and 10% in the beam pulse length) increase in average current and evaluations of the linac subsystem for doubling the current by increasing the pulse length [17] for Phase II.

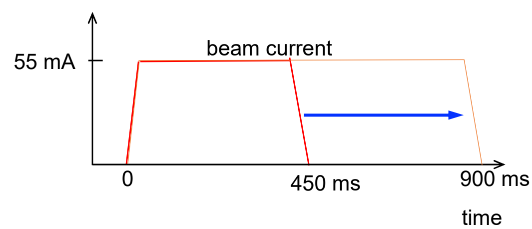

Figure 1: Doubling the average beam current by increasing the beam pulse length.

Table 1 summarizes Linac parameters for intensity upgrade Phase I (2014), operating 2019 and proposed to increase the intensity by factor of two, Phase II. Both the goals of Phase I, (1) increase in 15% current, and (2) evaluation of the Linac subsystem for delivering 250 µA average beam current, were successfully completed on time and within the budget [19]. It was concluded that the Linac can deliver 250 µA with upgrades of subsystem describe in section below

Table 1: Linac Parameter for Intensity Upgrade Phase I and Phase II and Operating Parameters Before (2013) and After (2019) Phase I

	2013	2019	Phase I	Phase II
Peak Cur. (mA)	42	60	45	45
Max. Avg, Cur. (µA)	120	200	140	250
H^- pulse length (µs)	450	590	480	900
RF Pulse Length (µs)	650	710	670	1100
Repetition Rate (Hz)	6.67	6.67	6.67	6.67
RF Duty factor (%)	0.43	0.47	0.44	0.73

Following system will be upgraded: Low- and High-level RF, tanks stamp collars, quadrupole power supply, control, instrumentation, machine protection and vacuum system.

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RF SYSTEM

In order to accommodate the proposed increased pulse width, the RF system required slight modifications. The power supply capacitor banks were increased for the driver amplifier (RCA 4616) and final PA stage (RCA 7835). The pulsed power modulator required new transformers, and to ensure accurate metrology, the pulsed current transducers were modified with DC bias windings. The test system (all RF components except DTL cavity) was successfully operated at a pulse width of 1.1ms

The original analog low-level RF system was replaced with a digital low-level cavity controller system. This cavity controller utilizes the same hardware and topology as all other RF systems within the Collider-Accelerator complex, which provides continuity throughout each of our accelerators. The cavity controller handles phase and amplitude regulation, malfunction status, independent timing parameters, high speed window comparator protection, cavity tuning control loops, and several RF ADC channels for data logging.

DRIFT TUBE TANK

During a shutdown period the DTL cavity was tested at the increased width. Figure 2 depict stem arrangement in the Drift tune tank. The BeCu spring ring had failed at the junction between the drift tube, and the stem collars (12 of 72), one example shown in Figure 3. A CST simulation confirmed higher RF current at this location (Figure 4 and 5), and thermal testing was performed in the lab. The thermal properties of this geometry resulted in an increase in thermal resistance as the collar temperature increases. In extreme cases this resulted in a thermal runaway condition. To mitigate an increasing thermal resistance, methods were developed to interference fit the collars onto the drift tube, however this proved to be labour intensive. A split-collar design has been tested and will be implemented during the next shutdown period.

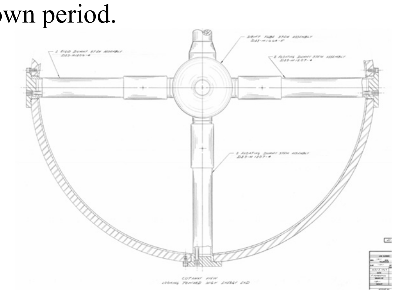

Figure 2: BNL DTL cavity with stems.

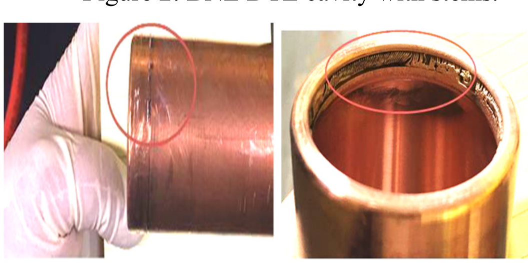

Figure 3: Damaged silver-plated beryllium copper RF spring ring in the collar.

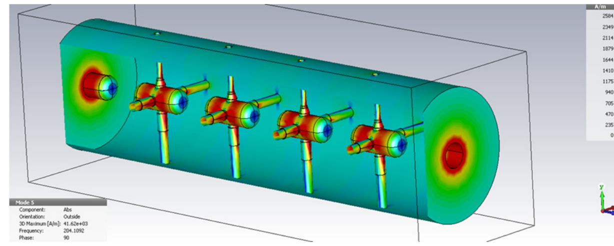

Figure 4: CST simulation of four Drift tube cavity. The RF current at spring ring are ~ 4000 A/m, about 50 W per collar.

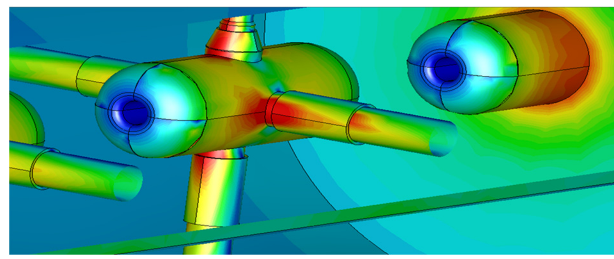

Figure 5: Showing current densities are not symmetric around the stem and collars.

QUADRUPOLE POWER SUPPLY

The present design of power supplies does not enable us to have a flat top of 900 to 1100 µs. The two prototypes were designed, built and are presently running operationally for the BLIP isotope production. The project has been successfully completed on time and within budget. There are couple of issues need to address: Rise time for these supplies is 90 ms, present timing system allows only 50 ms. Capacitor bank charger must ne change to 10A-300V from 4A - 3000 and mechanical layout need to be modified. These are well understood issues. No significant problems are anticipated.

INSTRUMENTATION

Beam instrumentation will be upgraded to monitor increase beam intensity. Following instrumentation will be add/upgraded: (a) beam position monitor (BPM) chamber after DTL tank 9 and between first (BM1) and second (BM2) bending magnet in the BLIP transport line, (b) BPM electronics for the connection to existing BPMs after the DTL cavities 2 through 8 and BPM listed above., (c) Single wire Secondary Emission Monitors (SEM) electronics (20 unites), (d) harp between BM1 and BM2, new current transfers (11 unites) for DTL cavities 2-9, and between BM1 and BM2, (e) new slit and collector emittance monitors (X,Y).

CONTROL AND MACHINE PROTECTION SYSTEM

The Controls System will have all of its Datacon Systems for Linac replaced with newer technology to accommodate the quadrupole power supply upgrade and the data acquisition and controls of devices at Linac. There are two technologies that are being considered. The Front-End

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Computer Remote I/O System (FRIO System) is comprised of VME modules 4140 for analog reference outputs and 3122 for data acquisition. Quad Function Generator modules with Power Supply Interface modules (QFG System) are another option which will be considered depending on the timing needs of devices that are being upgraded throughout the Linac. Both systems are VME based.

The VME 4140 and VME 3122 modules can accommodate up to device channels and 64 device channels, respectively. The 4140 analog output module has a 12-bit resolution and a maximum voltage range of +/- 10V. The 3122 data acquisition module has a 16-bit resolution with a sampling rate of 100 KHz.

A new Machine Protection System will replace the current aging Fast Beam Interrupt system. Improvement in speed, the display and detail of system statuses, and ease of expansion are the goals of the upgrade. There will be over 600 inputs for the MPS. The MPS must be able to interrupt a beam within 1 μs and accommodate pulse-to-pulse modulation.

VACUUM SYSTEM

The ion pumps will be replaced with commercially available off the shelf pumps. These pumps will be DI style pumps with one Tantalum and one Titanium cathode plate. The is type of pump was chosen over the conventional ion pumps because the Linac tank system is assembled using O-rings and is susceptible to small air leaks. The tantalum cathode plates allow for argon pumping from air leaks. 6 pumps will be added to each tank. The elbows which mount the pumps to the tanks need to be reworked to cut off the existing flange that mates to the old ion pumps and have a Confalt flanges installed on the elbow to allow the new pumps to be mounted. The ion pump power supplies will also be upgraded so that each pump will have its own high voltage power supply. The new power supplies are commercially available and have interface options for monitoring and remote control. This will also provide data logging which can detect when there are leaks before a vacuum failure.

Each tank system will have its own vacuum control rack located at each blower station. This will allow all vacuum controls to be local to the roughing station. The upgrade will consist of replacing the Cold Cathode gauge controllers and gauges on the tank and roughing stations. The gauge controllers will interface with control software and provide a feedback loop to Linac controls directly from the controller. The existing control panels will also be replaced with PLC and HMI which will provide local and remote control in addition to data logging. The PLC will also provide interlocks for valves and other equipment as well as MPS. New cables will also be pulled for gauges and ion pumps.

The 5 roughing stations will be replaced with new roughing stations. While we could replace them with new multistage blower pumps, the cost is very high and therefore we will be testing a few options which could result in significant cost savings. NEG pumps will be installed on one tank to check the pump down characteristics for ion pump conditioning. Several configurations of this type could to be evaluated to determine the best pumping characteristic at an economical cost.

REFERENCES

[1] G. W. Wheeler *et al*, "The Brookhaven 200 MeV proton linear accelerator", Particle Accelerator, 1979, Vol. 9, pp. 1-156.

[2] N. M. Fewell *et al*, "Operation of the Brookhaven 200 MeV Linac", in *Proc. Linac 1979*, Montauk, NY, pp 83.

[3] R. L. Witkover, *et al*, "Conversion of the AGS linac to H- Acceleration", in *Proc. PAC 1983*, pp 3010.

[4] Y. Makdist *et al*, "Acceleration of polarized H- in the BNL 200 MeV Linac" in *Proc. PAC 1985*, pp 3166

[5] J. G. Alessi *et al*, "Performance of the new AGS RFQ Pre-injector', in *Proc. PAC 1989*, pp 999.

[6] J. G. Alessi, *et al*, "Upgrade of the Brookhaven 200 MeV Linac", in *Proc. Linac 1996*, pp 773.

[7] A. Zelenski, *et al*, "Optically Pumped Polarized H- Ion Source for RHIC Spin Physics", Rev. Sci. Ins. 73, 2002, pp 888.

[8] A. Zelenski *et al*, "The RHIC Polarized Source Upgrade", PAC 2013, Pasadena, CA, USA, pp 49.

[9] D. Raparia, et *al,* "Proposal for Reduction of Transverse Emittance of BNL 200 MeV linac", in *Proc. Linac 2004*, Lubeck, Germany, 2004, pp36.

[10] D. Raparia, *et al,* "Results of LEBT/MEBT Reconfiguration at BNL 200 MeV Linac*",* in *Proc. PAC09*, Vancouver, Canada, pp 441.

[11] D. Raparia, *et al.*, "Low and Medium Energy Beam Transport Upgrade at BNL 200 MeV Linac", in *Proc. Linac 2010*, Tsukuba, Japan, pp455.

[12] D. Raparia *et al*, "Changes in LEBT/MEBT at the BNL 200 MeV Linac", in *Proc. PAC 2011*, New York, pp1978.

[13] D. Raparia, *et al*, "Improvements at the BNL 200 MeV Linac", in *Proc.Linac 2012*, Tel-Aviv, Israel, pp 969.

[14] D. Raparia, *et al*, "Reducing Current Density for the BLIP Target at Brookhaven 200 MeV Linac", in *Proc. Linac 2014*, Switzerland, pp 850.

[15] D. Raparia, et al, "Reliability and Intensity Upgrade for Brookhaven 200 MeV LINAC" in *Proc. Linac 2014*, Switzerland, pp67.

[16] D. Raparia, et al, "Charged neutralized low energy Beam transport at Brookhaven 200 MeV Linac" Review of Scientific Instruments, 87, 02B935 (2015).

[17] D. Raparia, et al, "200 MeV H- Linac upgrade at Brookhaven" *in Proc. IPAC 2016*, Busan, Korea, pp 968.

[18] R. Michnoff, et al, "The Brookhaven isotope production facility (BLIP) raster scanning system first year operation with beam" in *Proc. IBIC 2016*, Barcelona, Spain.

[19] D. Raparia et al., "Results of Intensity Upgrade Phase I for 200 MeV H^- Linac at Brookhaven", in *Proc. Linac 2016*, East Lasing, MI, U