STATUS OF THE 1.76 MEV PULSED LIGHT ION BEAMLINE AT THE NORTHROP GRUMMAN ADVANCED TECHNOLOGY AND DEVELOPMENT CENTER

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Abstract

The Northrop Grumman Corporation (NGC) Advanced Technology and Development Center (ATDC) beamline has recently been upgraded to provide a 1.76 MeV beam for use in the testing of various types of targets for gamma ray production. The beam is produced by an RF Driven multicusp volume ion source. After transport through a dual solenoid LEBT, the beam is captured and accelerated to 1.013 MeV by an electroformed monolithic RFQ. The DTL boosts the 1.013 MeV output of the RFQ up to 1.76 MeV. A bunching cavity and three permanent magnet quadrupoles match the RFQ output to the DTL. Downstream of the DTL an electromagnetic quadrupole HEBT transports the beam to a diagnostic station housing target testing hardware.

Automatic startup and control algorithms have been developed to simplify beamline operations. A new sequenced autostart has been developed to start up all three RF cavities and initiate amplitude, phase, and frequency control subsystems. The frequency-control system, which uses a sliding-short tuner and an I&Q tune sensor, is currently integrated into the main control system.

This paper will discuss the status of the beamline with emphasis on the energy upgrade, automatic startup and control systems, and the frequency-control subsystem.

Current Beamline Configuration

The current beamline configuration is shown in Fig. 1. The beam is produced in a Berkeley type multicusp volume ion source. The source is 7 cm in diameter and the plasma is driven by up to 20 kW of 2 MHz RF. The amplifier is located at ground and is isolated from the HV at the source body and antenna by an integrated RF matching circuit and isolation transformer. Beam is extracted at 36.5 keV using a triode extraction electrode geometry for a final source beam energy of 32 keV.

The LEBT consists of a pair of water cooled pancake coil solenoids and a pair of x-y steering magnets. The solenoids are capable of peak fields of about 5000 Gauss in the center (limited by the power supplies), and the steerers of 160 Gauss at 10 Amps. In the middle of the LEBT is a diagnostic station. A variety of diagnostics can be housed in the station including a Faraday cup, quartz plate viewscreen, emittance scanner and others.

After the LEBT, an RFQ accelerates the beam to 1.013 MeV in about 1 meter. The RFQ is a twin to the BEAR (Beam Experiment Aboard Rocket) RFQ built for and flown

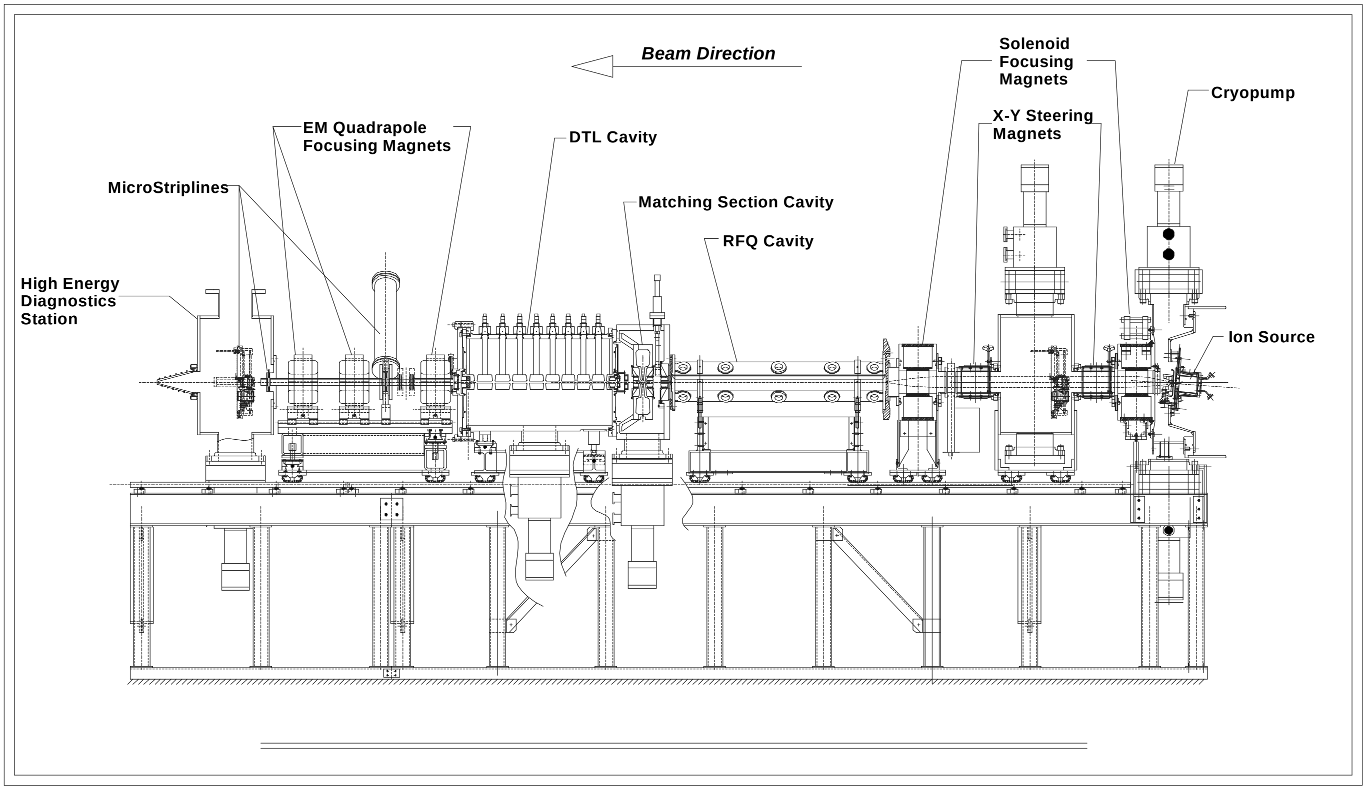

Fig. 1 NGC ATDC Beamline

in space by LANL[1]. It consists if four copper plated aluminum vanes/wall sections which are electroformed together to form a monolithic structure The RFQ was originally designed to operate at 0.1% duty factor. We are currently running it up to 0.7% duty factor. To prevent overheating, cooling bars have been mounted at the vane roots outside the cavity.

The beam is matched to the DTL by a matching section consisting of 3 permanent magnet quadrupoles and a single gap RF cavity. The permanent magnet quadrupoles maintain and adjust the x-y focus of the beam, and the cavity matches the longitudinal focus

The DTL accelerates the beam to 1.76 MeV. It is a 9 gap structure with a $2\beta\lambda$ FO-DO focusing lattice. The DTL and its installation will be discussed at greater length in the next section.

Following the DTL is a HEBT with three water cooled electromagnetic quadrupoles. They transport the beam to the second diagnostic station. This station currently holds our target testing equipment. Targets are being tested which will be used to produce γ rays for a gamma-ray absorbtion contraband detection system[2]. The thermal response and lifetime of the targets are being evaluated under different beam conditions[3].

Energy Upgrade with the 1.76 MeV DTL

The DTL cavity is a room temperature, constant gradient, Alvarez DTL designed for a proton or H^- beam. The focusing lattice is a $2\beta\lambda$ FO-DO. Important cavity characteristics are outlined in Table 1. The DTL cavity is shown in Fig. 2. It has eight drift tubes (nine cells), four post couplers, two tuning slugs, and one tuning bar. There are two large coupling loops, one for the input drive and one for a sliding short tuner. Vacuum windows in the coaxial waveguide are made of Rexolite and are located as close as possible to the cavity (approximately two inches). There are provisions for two RF pickup loops; although, as of this writing, only one is installed. Several vacuum ports penetrate the cavity wall which is also the vacuum wall. Two of these look directly at the high and low energy DT gap and are meant for X-ray end-point measurement of the gap voltage.

The DTL cavity is fabricated from copper plated carbon steel with SS ports. This provides a strong, ridged, inexpensive structure which provides good shielding properties. The endwalls with half drift tubes are made from OFHC copper. The drift tubes and stems are also made from OFHC copper.

After installation of the drift tubes, the DTL was tuned. The cavity was first tuned for flat fields using the bead pull technique. A small dielectric bead is pulled though the cavity, causing the resonant frequency of the cavity to shift. The magnitude of the shift depends on the magnitude of the field at the bead. As the bead is moved, the shift in the resonant frequency of the cavity is measured thus giving a measure of the cavity field. Post couplers are then used to tune the fields to the desired configuration.

The final configuration of the fields after the post couplers have been adjusted and brazed was measured and the field tilt found to be 0.26%. The scatter of about 0.5% is a little larger than we would like but is as good as we can get, given the location of our post couplers.

The installation of the DTL began with the mounting of the matching section cavity, magnets, and vacuum vessel on to the DTL low energy end wall. An interface plate to mate the high energy end wall to the HEBT was then installed and the entire assembly transported to the beamline. The matching section and DTL were aligned with precision

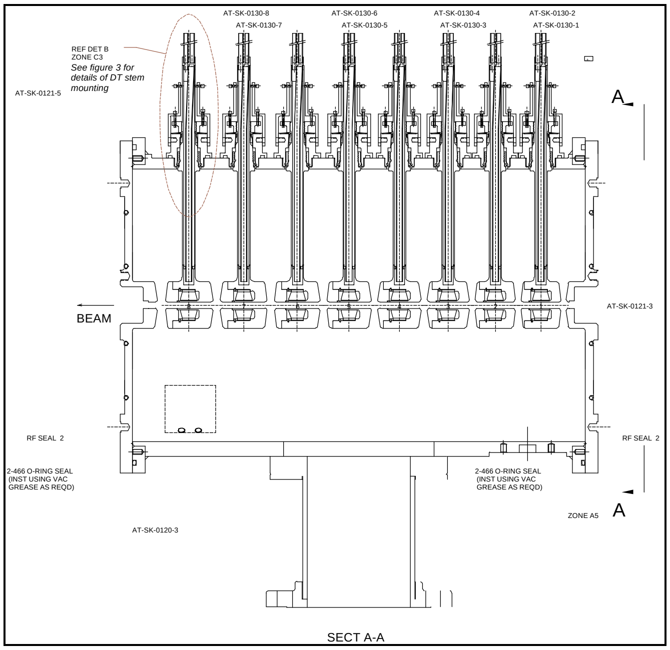

Fig. 2 DTL Cavity

Table 1 DTL Characteristics and Specifications

Frequency (measured)	424.893	MHz	Input Energy	1.013	MeV
Ql (measured)	17,280		Output Energy	1.760	MeV
Coupling (measured)	0.77				
Qo (measured)	30,572		Cavity Power (Superfish uncorrected)	38.88	kW
Qo (Superfish inc. 15% on power in non-endcells)	31,391		Cavity Power (Superfish + 15% on non-endcells + correction for meas'd Q)	43.70	kW
Qo (Superfish uncorrected)	34,975		Beam Power @ 30 mA	22.41	kW
Stored Energy	0.5092	J			
Accelerating Field	1.890	MV/m	Total Power (CP+BP+15%)	76.03	kW
Peak Field (on input end wall DT)	19.293	MV/m			
Gap Voltage (last gap)	94.800	kV			

locating pins. The pins were installed to about 1 mil accuracy on a precision milling machine. The alignment of the DTL to the RFQ is through the matching section vacuum vessel and vacuum end wall. These parts were aligned in the same way as the matching section and DTL. After the MS/DTL assembly was placed on the beamline, it was aligned with, and bolted to, the RFQ. The HEBT was aligned with, and bolted to, the DTL interface plate.

Initial beam operations began by running 150 µsec pulses at 10 Hz. Seventy four percent transmission was easily achieved with a 10.6 mA DTL output beam. During the next run, after adjusting the phasing of the various cavities, we were able to get almost 100% transmission with a 14 mA DTL output beam. Subsequently we have run up to 17 mA beams.

Automated Startup for RF Systems

We have implemented an automatic startup algorithm which brings the cavity system up with a single keystroke. The automatic startup consists of the following three steps:

Step 1: Set initial amplifier controls. Most of the system control variables for the RFQ, MS, and DTL are set in order as soon as the autostart command is given. Control setpoints are stored in a protected file. These initial setpoints generally cannot be changed from inside the control system program. During this step the automatic control loops imbedded in the cavity amplifiers are activated.

Step 2: Tuner initializations. Initialize tuners for MS and DTL, then set tuners to the center of their range.

Step 3: Activate RF. Turn on RFQ RF, wait one minute then turn on MS and DTL RF. The frequency tuning routine is then activated.

The use of this auto startup routine has greatly simplified day to day operation of the system. It reduces the 30 commands required to start the system to one and eliminates the need to have a list of setpoint numbers available at all times. It is especially useful when the system is being operated by personnel who are not experts on the system.

Active tuning using a sliding short.

Tuning for the DTL and MS cavities is performed with a sliding short tuner, an I&Q tune sensor, and a computer control system. The RFQ, which does not employ active tuning, is used as the system reference.

The sliding short tuner is simply a length of coaxial line coupled to the cavity with an inductive loop. The line is shorted at the end. The frequency shift of the cavity, the VSWR looking into the cavity at the drive, and the cavity field linear magnitude are all shown as a function of the position of the tuner in Fig. 3. One can see that only a portion of the tuner position range can be used. As the length of the tuner becomes close to λ/4, it begins to interact strongly with the cavity. At λ/4 it behaves like a second coupled cavity, splitting the mode. We use this tuner to provide approximately±200 kHz of tuning range.

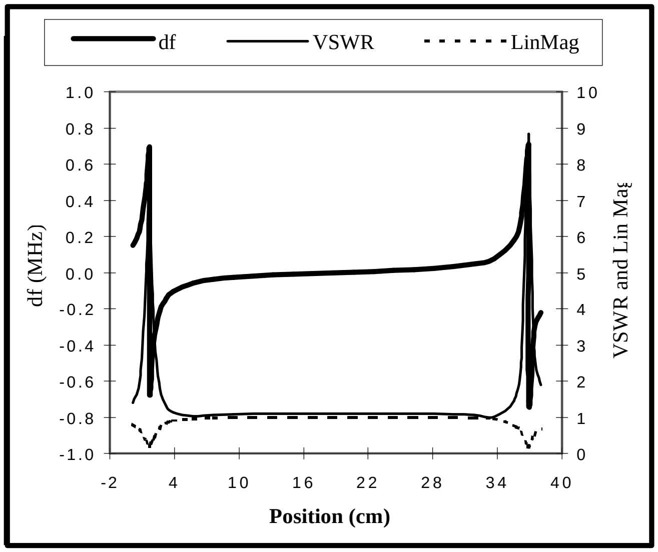

Fig. 3. Measured Performanceof Sliding Short Tuner

The I&Q tune sensor consists of a dual directional coupler, a pair of IQ demodulators, and a reference master oscillator (MO) signal[4]. The forward and reflected signals are fed into the demodulators along with the MO reference signal. They produce four DC signals; Forward In-Phase (I, real), Forward In-Quadrature (Q, Complex), and Reflected In-Phase (I, real), a Reflected In-Quadrature (Q, complex),. The DC signals are fed back to a computer which then calculates the amplitude and phases of the original signals. For active tuning, the only signal analyzed is the reflected phase. The computer system moves the tuner to drive this signal to setpoint, bringing the cavity to the correct frequency.

Conclusion

The beamline is serving as a usefull testbed for the development of accelerator systems technology as well as a tool for generating beam. It will be used primarily to generate beams for target evaluation for near future. It's operation and maintaince provide constant opportunities for the evaluation of accelerator systems. Future applications and upgrades are under consideration.

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