Characterization of the IOTA Proton Source

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Abstract

This project focuses on characterizing the IOTA proton source through changing the parameters of four components of the Low Energy Beam Transport (LEBT). It is important to note that the filament used in testing was emission limited. Because of an inefficient filament, current was limited to 2mA when 40mA is ultimately desired. Through an investigation of the solenoids and trims of the LEBT, we sought more knowledge about the optimum settings for running the IOTA proton source.

IOTA Proton Source

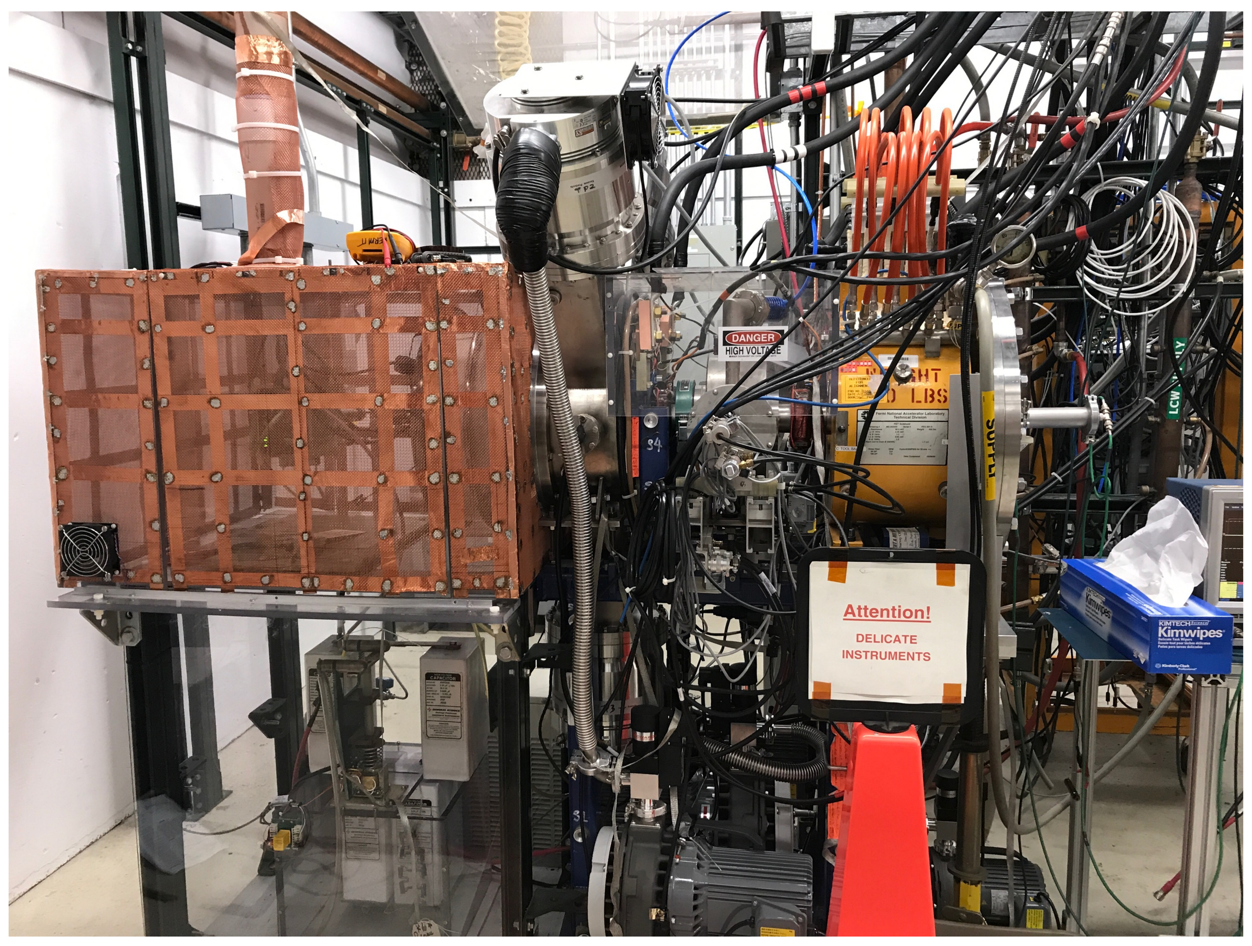

Fig 1: Low Energy Beam Transport (LEBT) of the IOTA source.

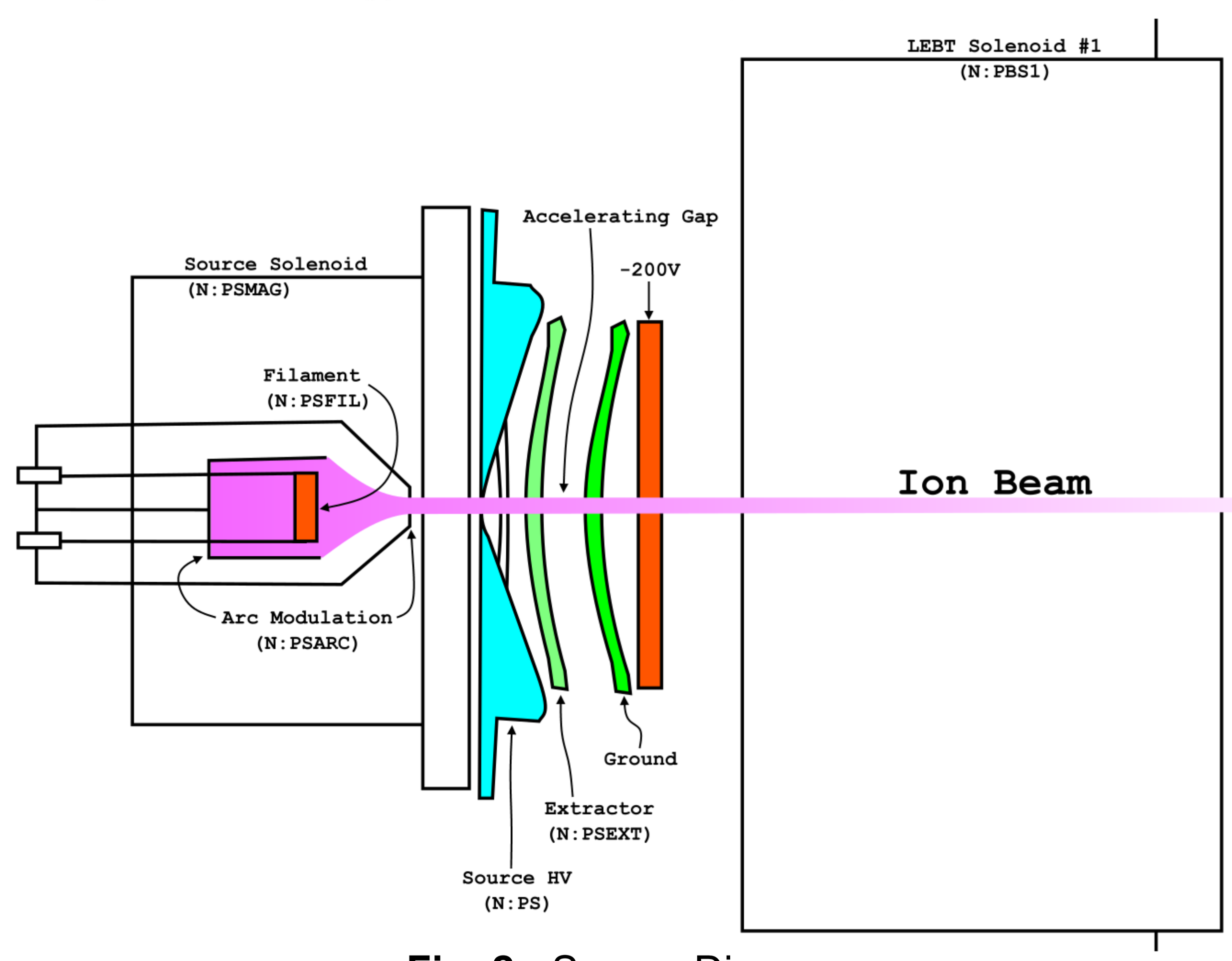

Fig. 2: Source Diagram.

The LEBT will be comprised of a duoplasmatron source of H^+ ions that will be injected into a Radio Frequency Quadrupole cavity (not shown). In the source is a nickel-mesh filament, coated with a mixture of strontium, barium, and calcium oxides. The coated cathode produces an electron arc current in the source. This arc produces a plasma from which H^+ ions are extracted. The inner solenoid, or source lens, focuses the arc through a magnetic field, which allows us to minimize the emittance for injection into the LEBT. The beam is currently fed into a Faraday cup which terminated into a 10 kΩ resistor and displayed on a LeCroy WaveRunner 104Xi oscilloscope.

Methodology

Given the fixed geometry of the source, the method for optimizing the H^+ ion output current was to vary the independent parameters of source pressure, lens solenoid current and arc current. Given the low emissions of the filament the arc current was not able to be varied for this test. The variables were adjusted in small steps, at various lens and beam solenoid current settings. The beam current into the faraday cup was measured.

Results

A consistent beam was achieved while seeing the effects of the extractor current. Our goal was to alter the pressure, solenoid currents, and lens current to see where maximum beam current can be achieved. The blue trace in fig. 2 represents the extractor current. A well tuned source will eliminate the variation of the extractor current and produce a near zero trace of the extractor current, and maximize beam current.

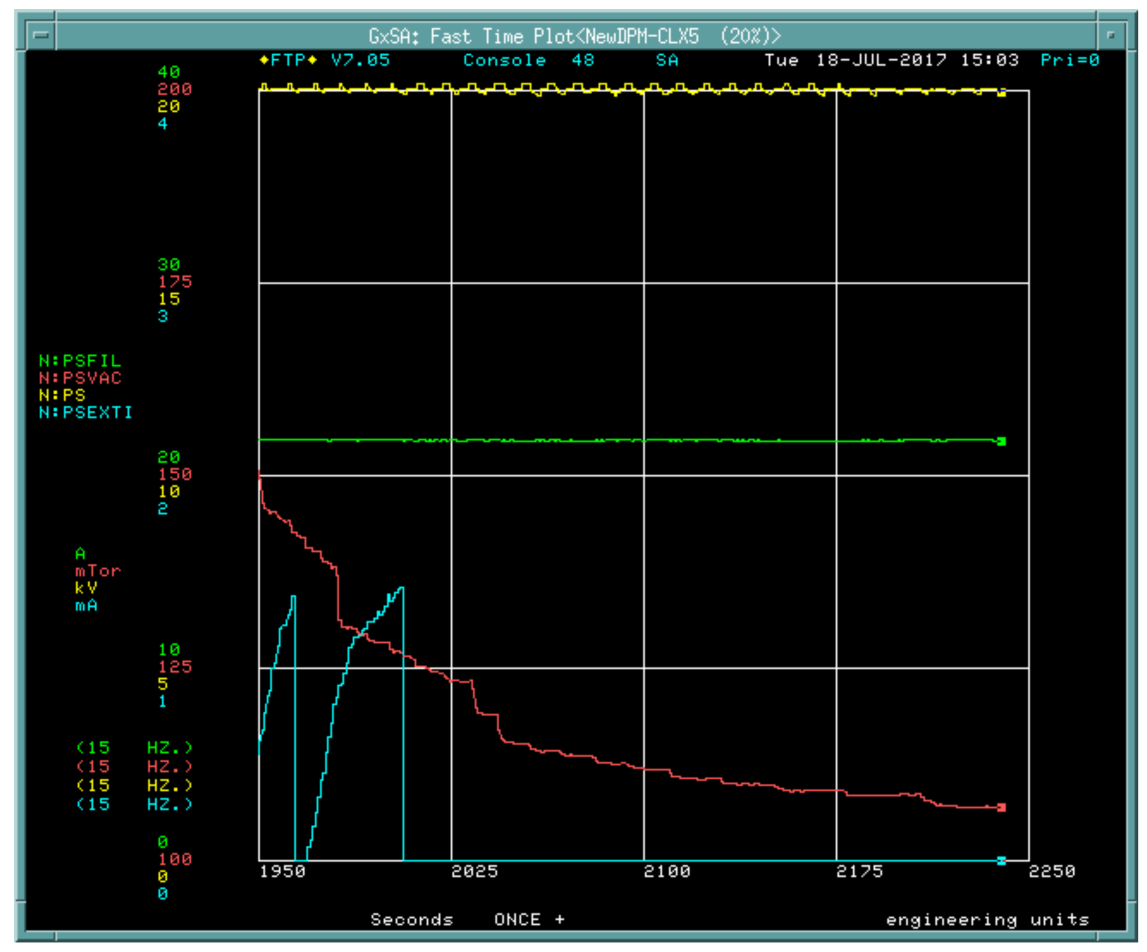

Fig. 3: Extractor behavior as a result of tuning.

Each variable was tested within a safe range of operation, and peaks on plots suggested an optimal parameter to be used in future scans.

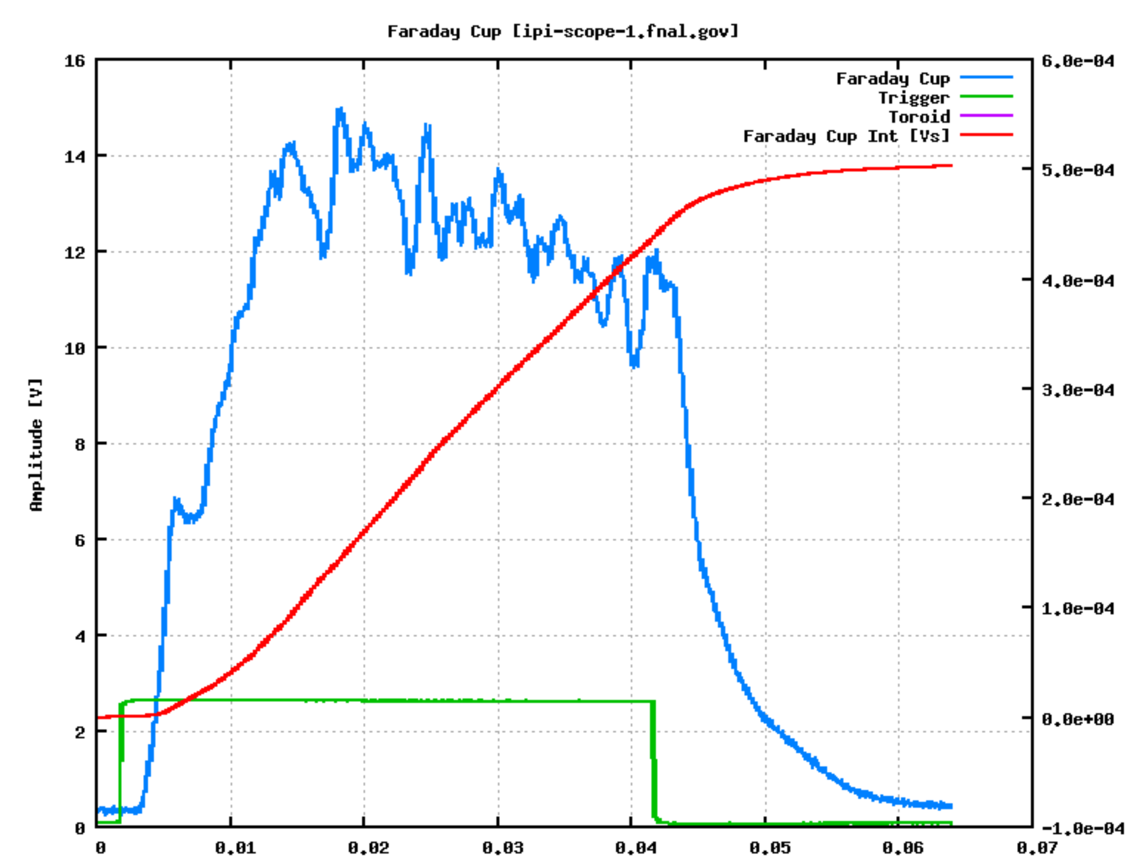

Fig. 4: Waveform outputted on the LeCroy oscilloscope.

Considering that the filament is in poor condition, it was exciting to produce 2 mA of current. Using ACNET's data-logging feature, it is possible to take closer look at these scans by studying multiple devices at once, and isolating a closer time period.

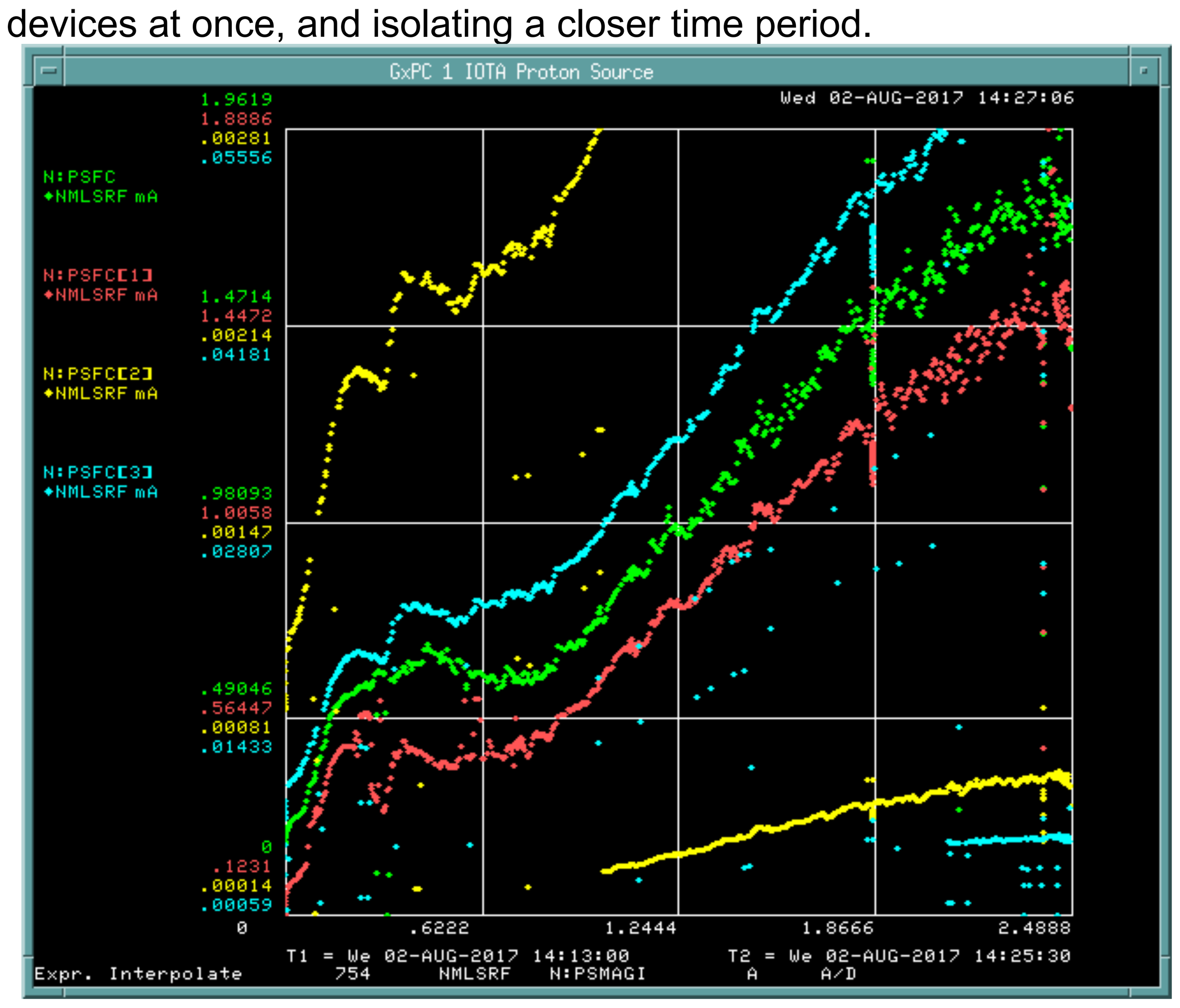

Fig. 5: Datalogging plot of source lens current.

Fig. 5 shows the dependence of the Faraday cup readings on the source magnet current. The green trace is the beam current in mA. The red trace shows the integral of the waveform, which is consistent with the current readings because the whole wave would increase, not just one portion. The blue trace is the extractor current, and the yellow trace is the toroid current. There is currently no explanation for the jump in the yellow trace, though it is a decade change by the program.

Code was also written to use a heat map for scans. Since the beam solenoids affect the beam current in tandem with each other, it is beneficial to scan the beam intensity while alternating both beamline solenoids within the same range.

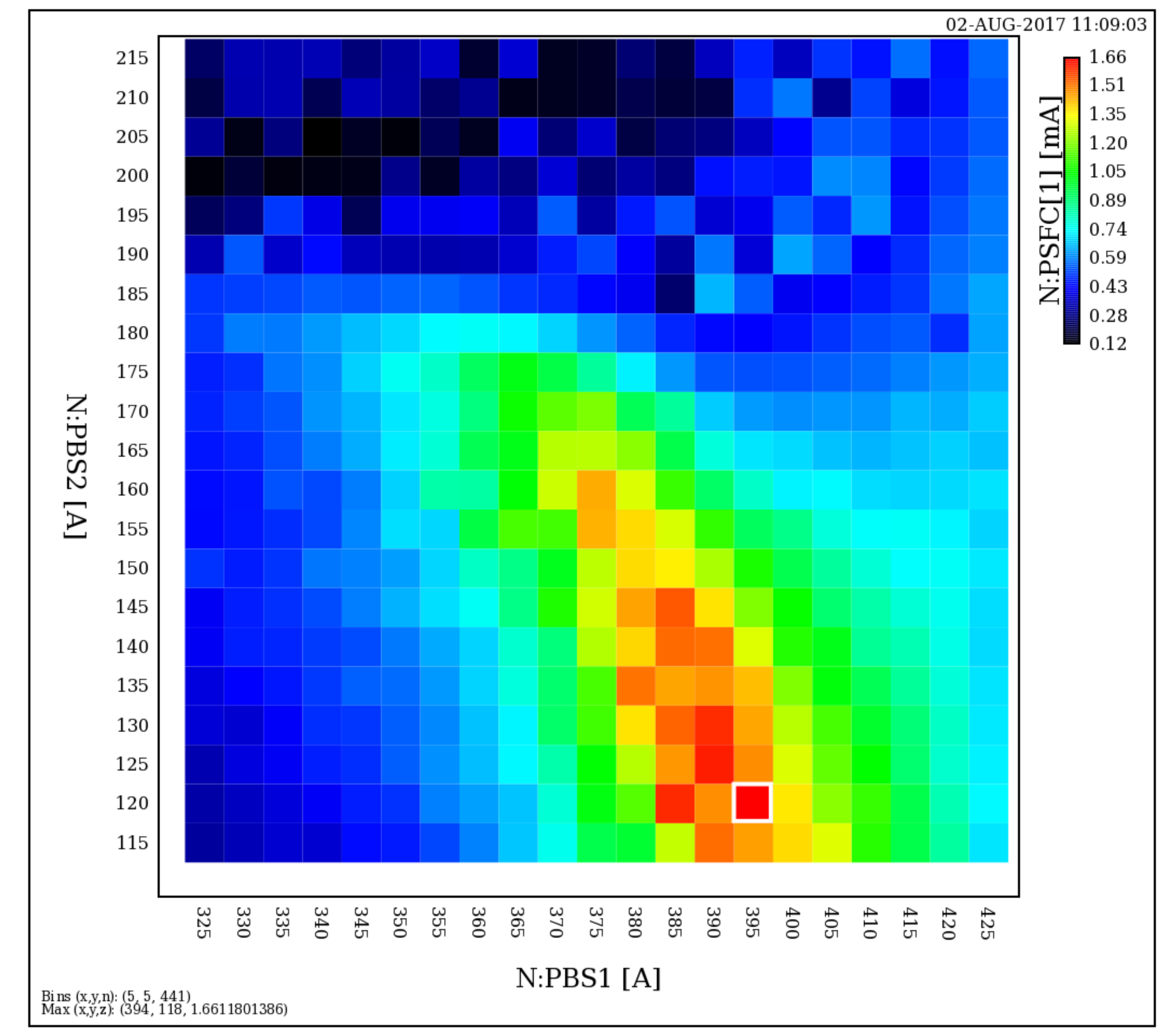

Fig. 6: Heat space display of the beam current dependent on beamline solenoid current.

The highlighted pixel is the area of highest beam current. Once the source was changed to run consistently at 395A and 120A (location of the max current) on the respective beamline solenoid, current leveled at 1.5-1.6 mA. Applying 2.4 A of source solenoid current produced 2 mA of beam current, but at the risk of overheating the source. The setup is not appropriate for the heat that develops after current reaches a safe limit.

Conclusions

There are future improvements planned for the IOTA source, as a replacement filament is being prepared for installation. The LeCroy outputted readings of above 20.8 V, translating to around 2.0 mA of current. Future experiments desire current of about 40 mA. The design for the source calls for 25 A of arc current, and the low achievable arc of 1.98 A limits the number of ions that can be injected. Using the 2.0 mA of beam, I was able to demonstrate that the output current is dependent on the independent variables of gas pressure and solenoid current.

Acknowledgements

I would like to thank my mentor, Kermit Carlson for showing me the workings of the IOTA source and NML as a whole. I would like to thank Dean Edstrom for teaching me about ACNET controls and how to collect data using ACL code. Finally, I would like to thank Eric Prebys for serving as a resource for IOTA and Lee Teng.

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