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PRELIMINARY INTRODUCTION OF THE IOTA BAKE SYSTEM

T. K. Thompson, D. R. Maclean
Fermi National Accelerator Laboratory, Batavia, IL, USA

Abstract

The Integrable Optics Test Accelerator (IOTA) ring is vital to the advancement of accelerator sciences, and a large part of its attractiveness to accelerator physicists is its modularity and the versatility that this function provides. Up until this point, the FAST accelerator has provided electron beam for the studies in IOTA. With the soon to be commissioned IOTA Proton Injector in lieu, the requirement for better vacuum to support future proton studies in the ring have arrived. Our solution is the IOTA Bake System which has the goal of facilitating this requirement.

THE BAKE SYSTEM

IOTA is a modular storage ring designed to be manipulated frequently for the purposes of supporting a variety of scientific studies. The addition of the IOTA Proton Injector (IPI), which will be commissioned in Fall 2025, creates an increased need for operational vacuum levels after inserting or removing elements from the ring. There's also significant value gained from improving the vacuum in regard to the lifetime of particles as they orbit the ring.

According to Associate Scientist, Nilanjan Banerjee [1], if the baking of IOTA can reduce the partial pressure of water by a factor of 10, we predict the lifetime of 2.5 MeV proton beam will increase by a factor of 2. For comparison, residual gas scattering present in 1e-9 Torr vacuum limits proton beam to a lifetime of 7 minutes. Considering the current mean vacuum levels in IOTA is roughly ~6e-10 Torr, it is possible the ring will pump down into 1e-11 Torr range after baking the system.

Figure 1: Breaker-Relay buildout.

The IOTA Bake System in its current state consists of 160 thermocouple channels, as well as a corresponding 160 powered channels to energize the conically wrapped heat tape, and a PLC used for control and operation of the system. A core safety feature of the bake system is the breaker configuration (Fig. 1). 5 A circuit breakers are connected to 10 A solid state breakers that are grouped into fours and are wired in series to a 25 A safety relay that removes power from the four channels if one of the channels trips. Each of the safety relays are wired into a corresponding GFIC breaker.

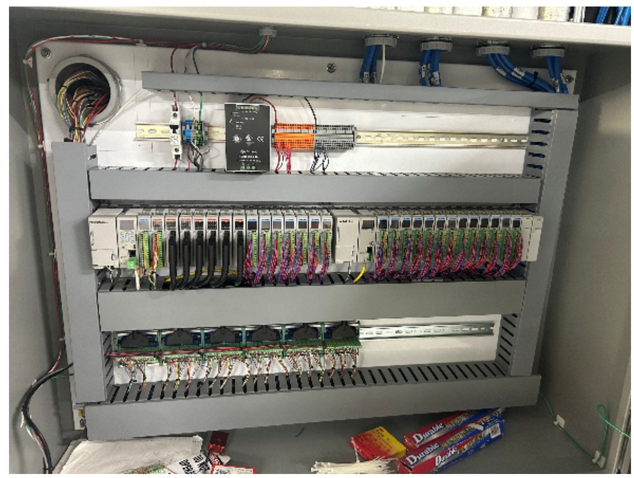

Figure 2: PLC buildout.

The PLC and its associated software is Productivity Suite v4.2.1.8. The buildout consists of twenty P2-08THM thermocouple analog input modules that supports 8 thermocouple channels each, six P2-32TD1P DC output modules that provide thirty-two 12-24VDC sinking outputs for powering the heat tape, as well as a power supply and control module (Fig. 2). The current PLC code was done by Mark Obrycki and has built in soak times to gradually increase the heat safely and also trip limits that open the previously stated breaker and relay chains (Fig. 3).

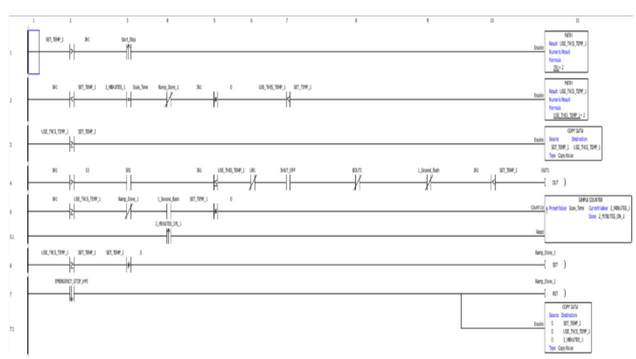

Figure 3: PLC operation code.

The design of the system has the wiring of both the thermocouple and the heat tape power source being wired from

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the PLC to 32-slot outlet power boxes. There are five of each for their respective applications and are cabled to be able to extend to various locations around the ring from the center of it. A topic I'll address later is a necessary addition to the system to fulfil a requirement for secondary heat protection that will cause us to potentially alter this setup.

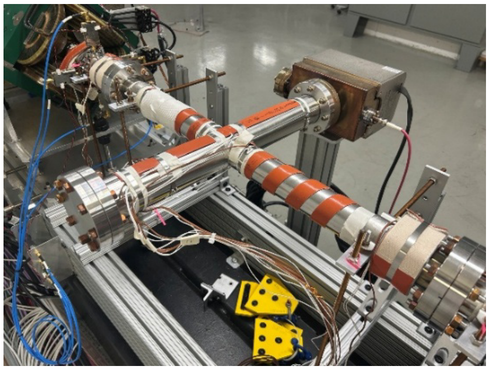

Figure 4: Installed heat tape and thermocouples.

Procedure

The anticipated process for baking IOTA may be revised after testing, but currently:

- Remove magnet and cavity tops;
- Conically wrap the beampipe with heat tape and attach thermocouples to their respective locations, and plug them into their power banks (Fig. 4);
- Insulate the heat tape (Foil, Blankets, TBD);
- Turn off all IOTA ion pumps;
- Take a RGA scan (for comparison);
- Exit the enclosure;
- Start the bake remotely via the PLC;
- Once desired temperature (~100°C) is reached, bake for the allotted time (TBD);
- After completion of the bake, cool down (TBD);
- Connect and turn on roughing pump;
- Once rough vacuum is achieved, turn on the ion pumps;
- Once vacuum has pumped down, take another RGA scan;
- Unplugged powered elements and remove insulating materials;
- Install magnet and cavity tops.

Discussion

Baking IOTA has a few complications. One of which is that the entire ring can not be baked to the desired temperature due to the sensitivity of some of its elements to heat. The issue this raises is that the outgassing of water and residual gases that will be freed from the inner walls of the beampipe due to baking will naturally move towards the "colder" regions. In one of these locations the beampipe aperture is significantly smaller than the rest of the ring which, at minimum, should be noted.

Another hurdle is the secondary heat protection required by *FESHCom ESS Determination D2019-3* [2] that states that heating elements that rely on electricity is its primary source of power must have 2 independent ways of interrupting power in case of failure, and that each element must have 2 independent ways of monitoring. When you consider that this system has 160 channels that all individually meet the spec of this requirement, its clear just how large of a hurdle this is. Engineering Physicist, Daniel Maclean [1], is assisting in the effort to solve this issue.

The next step in the commissioning of this system is to setup a test to determine the effectiveness of baking, and to verify operation of general controls, components, and instrumentation. We hope to learn:

- How much the vacuum will improve;
- An analysis of the effectiveness of water removal at different temperatures;
- How the overall composition of the vacuum changes.

We hope to accomplish the testing this fall, with full operation possible by end of year.

CONCLUSION

The IOTA Bake System has the potential to be an effective tool for the FAST Facility's ability to support future accelerator science. There are obstacles to realize this potential, but I am confident that it will be completed.

REFERENCES

[1] N. Banerjee, A. Romanov, G. Stancari and M. Wallbank, "Proton dynamics scenarios in the Integrable Optics Test Accelerator (IOTA) at Fermilab", in preparation.

[2] FESHCom ESS Determination D2019-3, Electrical Safety Subcommittee, 24 October 2019, revised 26 January 2023