Enhanced Remote Control Capabilities at the Michigan Ion Beam Laboratory

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Abstract—**The Tandem accelerator in the Michigan Ion Beam Laboratory (MIBL) at the University of Michigan has the capability of conducting high current irradiation damage studies using protons as the incident particle. In the last several years, researchers and groups of researchers outside of the university have been requesting time in the facility to conduct irradiations. One solution to the outside user problem is to develop enhanced remote control of the irradiations that is deployed in the lab's watch room and with the lab staff at an off-campus location. In this way, the irradiation can be run day and night and in a mode such that there is always one lab staff member that has access to full control of the experiment parameters**

Index Terms— **Remote Control, MIBL, Remote Irradiation Exxperiments, Remote Experiments**

I. Introduction

This document is a template for Microsoft Word The Tandem accelerator in the Michigan Ion Beam Laboratory (Figure 1) at the University of Michigan has the capability of conducting high current irradiation damage studies using protons as the incident particle.

Figure 1. Michigan Ion Beam Laboratory

Since funded research projects based at the university involve graduate students and since there are at least 3 students involved in this type of research, they are able to "man" the irradiations in this manner. Students are willing to help each other with their irradiations because they will receive help in return when it is their turn. The students undergo significant training in the control of their experiment and in the interfacing of the experiment to the accelerator. This mode of operation has worked well for the last 15 years in which we have been conducting this type of research at MIBL. After the large increase in experiment capabilities at MIBL during the last 4-5 years, researchers and groups of researchers outside of the university have been requesting time in the facility to conduct irradiations. However, since under these circumstances there was not a student who "owned" the research, the mode of operation described for research based at UM is unworkable. Also, training of students to monitor an irradiation is a long and involved process that requires multiple irradiations and many months of effort, which is impractical for outside users. The lab staff is unable to help because they are available only during regular work hours. Over the years, we have refined and improved our monitoring capabilities and moved toward a greater degree of remote control. One solution to the outside user problem is to develop enhanced remote control of the irradiations that is deployed in the lab's watch room and with the lab staff at an off-campus location. With this capability, outside users could be accommodated in the following way: The outside user would undergo a short term, intensive training period (2-3 days). Irradiations would be managed by having the lab staff work split shifts in which one individual keeps an eye on the irradiations from 9 am - 5 pm and the second staff member adjusts his schedule to work from 4 pm to 12 am. The outside user will monitor the irradiation between 12 am and 9 am using the remote monitoring/control capabilities in the watch room. The individual can exercise control over the experiment to a limited extent as permitted by the instructions he/she is given. If any questions/situations arise that are outside of the domain in which he/she is allowed, or has been trained to respond, the procedure will be to contact one of the lab staff at home (by phone) who will have a computer with full monitoring and control capabilities enabled. The staff would be able to either provide advice or to take steps to actively control the irradiation parameters. In this way, the irradiation can be run day and night in a mode such that there is always one lab staff member "on call" that has access to full control of the experiment.

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II. REMOTE CAPABILITIES AT MIBL PRIOR TO THE COMPLETION OF THE REMOTE CONTROL ENHANCEMENT PROJECTS

Before the implementation of the current project, Michigan Ion Beam Laboratory already had some remote control capabilities. These were instrumental in basic monitor / control of an experiment from the outside of the lab. Just by logging into a web site one could control the ion source parameters, could remotely monitor all the aperture currents, the thermocouple temperatures, the pressure in the chamber and selected temperature points on the surface of the samples that were sent from the thermal imager (the end stage computer). These initial remote capabilities could be summarized in the following way:

The Torvis (protons) ion source could be remotely controlled (increase/decrease the beam current or to shut down of the source). This was extremely useful if fine tuning of the source was required at any stage of an experiment. The computer that provided the control was interfaced through Labview / Appletview (Figure 2) via serial ports with the power supplies and was connected to the internet via a high speed LAN. Small variations in the beam current were normal and slight adjustments of the working parameters of the source were required from time to time.

The thermal imager (Stinger – Figure 3) that allows users to view pixel by pixel the surface temperature of the samples during irradiations. Up to 48 areas on the surface could have been remotely monitored for temperature variations. Due to the very large amount of data required in the image processing there was a computer dedicated just for acquiring data from the thermal imager and another one that remotely logged in all the temperatures of the regions of interest.

The end stage computer could monitor remotely the stage and apertures' currents, the thermocouples' temperatures, the vacuum pressure inside the chamber and interprets stores and broadcast live all the irradiation parameters (Figure 4). Input from all of these devices was required to ensure the uniform irradiation of the surface and good temperature control. The samples were heated from behind with a heater cartridge and air cooled with the aid of an air compressor connected to feedthroughs that enter at the back of the stage

Figure 2: Source control GUI 1

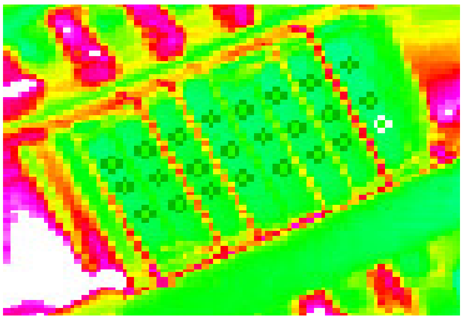

Figure 3: Thermal imager picture

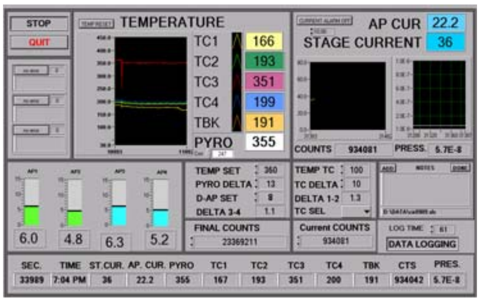

Figure 4: End stage computer – GUI

III. GOALS OF THE PROJECT

There are many other parameters that need to be monitored during an experiment. For example, the temperature drift during irradiation requires an almost instantaneous user input. The change could be caused by a few reasons such as: heater cartridge failure, air compressor failure or change in the ion beam parameters. A variation in vacuum pressure inside the chamber could indicate a malfunction of the cryopump compressor or of a pump in the beamline, requiring immediate user intervention as well. Of critical importance is the balancing of the currents of the four apertures that surround the samples to ensure uniform current distribution. A user located inside the lab could easily correct any drift in current. A remote user needs to have real time access to all these parameters (temperature, pressure and currents) and be capable of turning on / off the heater and the air supply to the cooling lines. Also important is to have the capability to remotely shut down the gate valve that insolates the samples from the rest of the beam line in case of vacuum failure. In particular, the elements of the accelerator system that were targeted for additional remote control were:

1. the heating / cooling of the stage
2. the Faraday cups
3. the gate valves.
4. An extensive web-cam system that would assist in the troubleshooting / surveillance process

In addition to these features, it was decided that important was also to have a power backup support systems for all the computers participating in the data acquisition and control process. Especially during the summer months due to powerful storms, a momentary electrical power failure would cause the reset all the computers. This could easily be avoided by equipping each computer with uninterruptible power supply (UPS) backup system that would prevent the reset of all the programs and loss of data. Each beginning of an experiment is an involved process and a lot of parameters have to be properly setup, procedure that an experienced user can easily accomplish but not a one-time user.

In order to increase the remote capabilities of the MIBL the following equipment was acquired:

- A new computer interfaced via serial port with a motherboard of type Ioplexer equipped with a full set of analog and digital modules. This setup provides remote control of the gate valves, Faraday Cup, and the power supply of the heater and of the air cooler.
- UPS backup power supplies that prevents the controlling computers to reset in case of small power glitches
- An additional computer needed to implement the interactive (vision and sound) web cam system. This additional feature is very useful in case of other equipment failure or in order to remotely help a user by simultaneously monitoring his / her actions (with the web cam) while talking on the phone.

IV. THE IMPLEMENTATION OF THE PROJECT

Due to the fact that the stability of the computer programs is critical to the experiments, the first equipment that was acquired and installed was the UPS (uninterruptible power supplies) back-up system. The following computers were connected to such systems: Torvis source control, irradiation stage monitoring computer, the Stinger (thermal imager) computer, remote temperature recorder/logger computer and the main MIBL-bay computer.

B. The web-cam system was installed next. A PC card with up to nine video inputs was acquired and installed in a new P-IV computer running Win XP with high speed internet connection. The card allows for direct communication and access of the IP address of the computer, provided that the user is permitted to access it (password protected). Once logged into the computer, real time feed from the web cams becomes accessible (Figure 5).

Figure 5. Web-cam system view

The web link can be found at the MIBL web address: http://www.engin.umich.edu/dept/nuclear/research/Mibl/Details.html For the physical installation of the cameras a way was found to completely cover the lab and the lab entrance. There are 6 cameras pointing to different areas of MIBL and 2 cameras that were left “floating”. These last two cameras can be assigned different locations as the application requires

C. Rapid control in case of a vacuum problem or accelerator tank spark could save the samples from being exposed to bad vacuum or uncontrolled beam energy and intensity. A control box was built, that consists of a series of relays that are accessible (controllable) over the internet and allow a fast response (Figure 6). All the relays are powered by a separate 24 VDC power supply and are controlled from a P-IV computer running Win XP. The interface is provided by a motherboard of type Ioplexer (Figure 7) that is equipped with a full set of analog and digital modules that can be addressed from the serial port of the computer. The relay system allow for the control of the gate valves of the beamline and of the Faraday cups used for beam current measurements

Figure 6. Relay control box 1

Figure 4. Ioplexer control modules 1

The controlling software is Labview with Data Sockets for remote access. The program was written such that it allows for the control to be changed from local (in the lab) to remote (online) in conjunction with a series of toggle switches that need to be physically turn on-off in the lab on the control box. LEDs will indicate the status as ONLINE or LOCAL.

Lastly, but perhaps the most important addition to the control of the irradiation experiments is the introduction of computer control of the heating and cooling of the stage where the samples are mounted. The heating is being provided by a DC power supply (TCR 150-4) that is computer controlled with the Ioplexer (Figure 4) and an analog IV10 (0 – 10 VDC) module. The temperature of the stage is read back into the computer via a J-type thermocouple whose signals are fed into another module that is also part of the Ioplexer. The cooling air is programmatically allowed to pass through the cooling lines with a current-to-pressure converter (ItoP) manufactured by Omega Engineering. The cooling air can flow at a rate between 0 – 60 PSI. However, the steady state rate during a typical experiment requires only about 25 psi flow. The signal is provided by a 4-20 mA controller module that is part of the Ioplexer and is controlled from the computer. A P-IV computer running Win XP is used for this purpose, with A Labview interface (Figure 8).

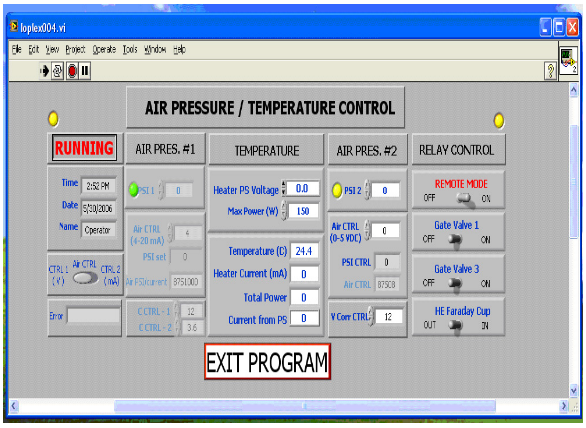

Figure 7. Heating and cooling control 1

A remote user with administrative rights can remotely login into this computer and modify parameters as required by the temperature readings provided by the Stinger (Thermal Imager).

V. SUMMARY

With the enhanced remote capabilities we can better accommodate outside users. During the day and evening hours the lab staff will take two shifts. This would guarantee coverage for almost two thirds of the day. The owner of the irradiation would have to take the night shift. The watch room at MIBL will allow full remote access of the controls needed to operate the accelerator and watch the irradiation parameters.

Any outside user would have to go through a basic training in the use of the accelerator and in the irradiation monitoring procedure. This training would enable him/her to take appropriate action such in the case of an irradiation parameter drifting. In case that staff intervention is needed, or an unknown situation arises and advice is needed as to how to proceed, the owner of the irradiation would contact the MIBL staff that is on-call for additional help. The staff will have access from home to all the parameters of the irradiation, and would provided assistance to the user. In case of a serious problem (included in a hand-out – such as: major power failure) a procedure outlined in the training process would ensure the safety of the samples (heating/cooling ratio) and of the equipment. With the completion of this project we were able to add the following capabilities:

- ❖ Protection of the computers from short power glitches with the addition of UPS backup power supplies
- ❖ Better surveillance of the lab by the addition of a network of web-cams that can be remotely accessed and used in a very flexible way
- ❖ Remote control of the accelerator's gate valves. This can provide additional support and protection in case the vacuums deteriorates and the samples need to be isolated from the rest of the beamline
- ❖ Possibility of automatically insert/remove the Faraday cup in case of small or large variations of the beam
- ❖ Remote control of the heating and cooling of the samples. This capability allows great control and protection in the case of small variations of the proton beam

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Manuscript received August 10, 2006.