C-AD

Radiation

Safety Minutes of RSC Subcommittee of August 1, 2013

Committee

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Subject: Beam Current Monitoring and Limit for ERL Low Power Test

Present: D. Beavis, A. Etkin, L. Hammons, J. Jamilkowski, R. Karol, D. Kayran, T. Miller, M. Minty, J. Reich, C. Schaefer, B. Sheehy, P. Sullivan, C. Theisen, and M. Wilinski

'The low power testing has been discussed[1,2] in previous RSC meetings. The Department has requested a low power test under an exemption so that design issues can be understood and the final design determined before an ARR is conducted. The purpose of this meeting is to examine the devices being used to limit the beam current.

Status of the Gun, Laser, and Five Cell Cavity

The gun and the five cell cavity have undergone cold emission testing. The gun has achieved a maximum voltage of 2 MV and will not exceed this voltage during the low power testing. The five cell cavity has achieved 10 MV in CW and 18 MW in pulsed mode. The cavity will quench when operated in CW mode for periods of time exceeding about 10 minutes due to a thermal issue. It is expected that it will be operated in pulsed mode or for brief periods in CW mode followed by being off for a sufficient period of time to maintain thermal stability.

The laser presently installed is not the final laser system and cannot support the final design value of 500mA but can support operation of a 50 mA beam current. This provides nearly a factor of 10 reduction in potential escalation in beam current when compared to the final design goals.

Current Limiting Controls

A draft of the operating procedure, OPM 2.5.6 Rev. 2, for monitoring the beam current for the low power test is being finalized. The RSC was asked to examine the devices used to monitor and limit the beam current that are listed in section 5.1.1. Section 5.1 lists the following controls:

5.1 ERL Beam Energy and Beam Power Controls

The following limits are the maximum beam energy and beam power allowed for low-power testing. The ERL Operations Coordinator is responsible to comply with paragraphs 5.1.1 and 5.1.5.

5.1.1 The ERL Cathode Laser beam must have a locked, passive attenuator in the laser beam path and a laser duty factor control system to set the laser pulse energy and repetition rate, and an interlocking current measuring device.

5.1.2 Electron kinetic energy must be limited to 3.5 MeV for the superconducting RF gun (reference CASE section 2.1).

5.1.3 The electron beam power leaving the ERL superconducting gun or the 5-cell cavity must be limited to 70W averaged over 1-hour (reference CASE section 2.2).

5.1.4 Electron kinetic energy must be limited to 25MeV to the dump (reference CASE section 2.3).

5.1.5 The electron kinetic energy, the one-hour average beam power or beam current, and the kinetic energy to the dump must be monitored and logged in the ERL logbook at least daily during low power testing to ensure that the limits in 5.1.2, 5.1.3 and 5.1.4 are satisfied.

Requirement 5.1.2 and 5.1.4 are satisfied by the device design. Pickup sensors will measure the achieved voltages and they will be recorded to a computer database.

Requirement 5.1.5 will be monitored by the controls system and recorded to the computer database. The operators will also record the average beam power into the ERL logbook.

Requirement 5.1.3 is achieved with the devices listed in section 5.1.1 and the potential response of the operator.

The three means listed in section 5.1.1 to limit the average beam power to less than 70 Watts are:

1. Passive laser attenuator
2. Laser power to the cathode via duty factor
3. Interlocking current devices

B. Sheehy provided a brief overview[3] of each of the system system that controls the power limit. A brief note was also provided[4] before the meeting.

Members were most comfortable with the passive attenuator in the laser optics, which is essentially a hardware failsafe device. The laser has an adjustable attenuator referred to as an internal attenuator. External to the laser is a manual external attenuator (half wave plate and a polarizer) that can be locked in position when the desired attenuation is

achieved. The controls will then allow the internal attenuator to adjust the intensity up to the 100% level established by the external attenuator. There are only two keys that have been released for the laser room. The ESH coordinator has one and B. Sheehy has the other. No other keys will be released for use during these tests. These two personnel will control access to the laser room and access to the passive attenuator. This was evaluated as sufficient controls to prevent inadvertent changes to the external attenuator.

The laser may not illuminate the cathode until after the attenuation has been measured by the power meter. The external attenuator will provide a minimum of a factor of ten in reduction of the laser light intensity. The beam current is limited to at most 5 milli-Amperes by the existing maximum laser power and the minimum attenuation of the external attenuator.

The following must be checked before beam operation **(ATS-ERL-Aug. 31, 2013-B. Sheehy & A. Etkin):**

1. **HWP and POL rated for the full laser energy density.**
2. **Procedure to measure the laser power with the power meter anytime the external attenuator is changed and before it excites the photocathode.**

The laser operates at 9.4 MHz. There is a laser pulse nearly every 100 ns. Each pulse would generate electrons from the cathode if allowed to be transmitted to the cathode. The number of electrons released is a product of the light intensity which is limited by the external attenuator and the Quantum Efficiency (QE) of the photocathode. An optical switch will be used to limit the number of contiguous pulses that can be transmitted to the photocathode. In addition the optical switch can be opened many times a second. The number of openings (gate frequency) and the number of laser pulses allowed in each gate (width of the gate) will determine the number of pulses allowed to the cathode. The control system will determine the gate width and gate frequency based on a maximum of 70 Watts, or less to provide a safety margin.

The QE of the photocathode is measured when it is fabricated. It will again be measured after it becomes operational. The controls program parameter will be adjusted for the possible change. Most effects cause a decrease in QE with time and contamination usually is the principal culprit.

Configuration management of the laser controls must be documented in a procedure and include the requirement that any change in parameters or software requires both authorization and verification that the setup is correct using the pickoff system prior to transmission to the photocathode. A scaler will be available in the control room to monitor the number of laser pulses allowed by the system. This will enable the operator to monitor the number of pulses. The controls software is a two-layered system. The upper level is a user interface allowing the operator to put inputs into the system. The software then checks that the input values are in the allowed ranges. The lower system provides the machine protection using a National Instruments RIO platform (a field programmable gate array- FPGA). The sections of code programmed specifically for checking the input parameters and for the download of the RIO platform must be checked

by a second programmer to ensure the correct actions are provided by the system. **A procedure must be in place for the configuration management of the control system for the laser. (ATS-C Theisen & J. Jamilkowski-Aug. 31, 2013-ERL)**

Two devices will be used to measure the electron beam current. The first is a Faraday Cup (FC) just after the first vertical bend. The initial setup requires that the vertical chicane be RS LOTOed off and the beam transmitted to the FC for measurement and radiation surveys. The electronics for the FC have been built in house. The second device to measure current is an Integrating Current Transformer (ICT) that is located just after the gun. This device will measure the beam current whether the chicane is on or off. The ICT and Faraday cup will be compared to the laser power and the QE for consistency. A factor of two of better is required. The Faraday cup and the ICT will be cross-checked for agreement.

The ICT can be fired to a maximum frequency of 10 kHz. The width of the integration time can range from 100ns to 6.9 micro-seconds. The transit times in the laser system and the gun are know and can be used to provide a good initial time offset for the ICT window. This also means that if the ICT is used for the current measuring then the gate width of the optical switch cannot be greater than 6.9 microseconds. The pickup between the laser and the external attenuator will be used to determine that the setup is correct. A procedure will establish that the ICT is properly setup for each running condition. **(ATS-ERL-Etkin& B. Sheehy-August 31, 2013)**

The ICT and the FC are not considered failsafe. The FC does have a bias voltage that eliminates some failure modes.

The ICT and the FC will provide an interlock through the Machine Protection System (MPS). The electronics provide an analogue signal that is used by the MPS to provide an interlock. The interlock will occur in less than a second. **A response procedure is required to provide the operators with the correct response to current interlocks and any required authorizations and limitations. (ATS-ERL-L. Hammons&D. Kayran-August 31, 2013)**

An engineering review must be conducted for the ICT and the FC. It should ensure that the device is monotonic for the possible beam currents and device settings. The review should include the procedures used to setup the cross check the devices. **(ATS-ERL-M. Wilinski& J. Sandberg-August 31, 2013)**

The layout of the existing chipmunks was discussed. Each chipmunk has cables about 30 feet long so they can be moved to optimum positions. It was suggested that the chipmunk at the west end of each labyrinth be moved closer to the beam to provide more sensitivity for potential beam faults. In addition, the two chipmunks that are not interlocking will be converted to interlocking (via daisy-chaining to existing interlocking chipmunks) and positioned to interlock if the beam strikes an object with the maximum allowed beam power. One will be positioned to be sensitive to beam faults near the vertical chicane at

the gun energy. The other will be located between the five-cell cavity and the beam dump. It will be sensitive to beam faults downstream of the cavity and potentially the amount of beam on the beam dump. This will provide a means of using the chipmunks to indirectly limit the current. Some adjustments in positions and potential shielding will be needed to make this scheme work. **The committee thought this extra protection was worthwhile for the low energy tests and recommends that the two chipmunks be moved and the other two be daisy-chained for interlocks and mover to appropriate locations to provide protection. (ATS-ERL-D. Beavis& R. Karol-August 31, 2013)**

Maximum External Dose Rate
(note added after the meeting)

It is worthwhile to examine the potential risk for external radiation if only the attenuator provides a minimum reduction in power of a factor of ten, which could result in a possible maximum beam current of 5 mA at 2MV. The dose estimates provided for the G5 test[5] can be used to obtain the dose rate estimates beam striking the beam stop outside four feet of light concrete. For 10 kW of 2 MeV electrons the dose rate is estimated to be .09 mrem/hr. If the shielding of the steel is removed then this would be approximately 20 mrem/hr. This would be the dose rate on the roof. In the isle-way on the side of the power supply house the dose rate would be 0.9 mrem/hr. Therefore, a failure of the system to control the laser pulses and to interlock on beam current from the gun will not result in occupied areas outside the shielding becoming a radiological area. The operators will have a scaler to monitor the laser pulse rate and stop any such fault in a short time. Coupled with the chipmunks located around the facility there is a very small risk that radiological levels could occur outside the facility enclosure for the gun operation.

Acceleration of the electron beam with the five-cell cavity greatly escalates the potential radiation outside the shielding. The increase in potential exposure rates is due to the higher beam power of up to 50 kW provided by the five cell cavity and the reduced effectiveness of the concrete shielding. The estimated external dose rate outside the roof for 50kW of 25 MeV electrons is 30 mrads/hr. In the isle-way on the floor the dose rate is 3 mrads/hr. If the shielding for the side of the dump is ignored to simulate an upstream fault these levels would increase by a factor of 25.

It was noted that if the exemption was approved that the RSC is expected to provide the verification process that was normally provided by an ARR.

References

1. http://www.c-ad.bnl.gov/esfd/RSC/Minutes/9_5.20_12_Minutes.pdf
2. http://www.c-ad.bnl.gov/esfd/RSC/Minutes/10_24_12Minutes.pdf
3. B. Sheehy, "Overview of Power Limitation Controls"
4. Laser Power Limitation to assure electron beam power limitation
5. D. Beavis,"G5 Beam Dump Simulation", Jan. 12, 2012; http://www.c-ad.bnl.gov/esfd/RSC/Memos/G5%20Beam%20Dump%20Simulation.pdf

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RSC minutes file
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