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UPGRADES OF TEMPERATURE MEASUREMENTS AND INTERLOCK SYSTEM FOR THE PRODUCTION TARGET AT J-PARC HADRON EXPERIMENTAL HALL

○K. Agari (KEK), Y. Sato, A. Toyoda, Y. Morino KEK, High energy accelerator research organization, Ibaraki, Japan

Introduction: The Hadron experimental facility (HD-hall) at Japan Particle Accelerator Complex (J-PARC) shown in Figure 1 is designed to handle intense slow-extraction proton beam (750kW-15μA) from Main Ring (MR). The period of beam extraction from the MR to the HD-hall is 2 seconds and the operation cycle is 6 seconds. On May 23th, 2013, 2×10^{13} proton beams were rapidly extracted to the HD-hall in 5 milliseconds due to malfunction of power supply of Extraction Quadrapole magnet in the MR. The production target in the HD-hall was locally damaged because of rapid rise of temperature by beam deposit in extreme short period. In order to detect the damage to the production target, the requirements of temperature measurement system are as follows.

- Upgrade read-out system of the production target temperature.
  - ✓Hundred milliseconds sampling
  - ✓Synchronization with beam extraction
- Make the waveform spectra of target temperature as a function of time to tell the operators the state of the production target.

1. The production target

The production target at the HD-hall is shown in Figure 2 and as follows:

- To be capable for up to 50-kW proton beams.
- Material: Gold and a copper block with coolant stainless pipes.
- Gold:
  - High density(19.3 > Fe: 7.9, Al:2.7 x10^3 [kg/m^3]).
  - High thermal conductivity(318 > Al:237, Fe:80 [W/m^2/K]).
  - Good chemical stability
- A gold structure: $15^W \times 6^H \times 66^L$ [mm].
- The gold structure is divided into 6 pieces to reduce thermal stress.

Thermocouples were attached as follows:

- the gold pieces x12.
- the copper structure x2.
- the water cooling pipes x2 et al.

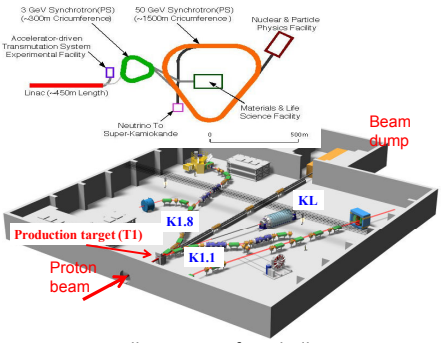

Figure 1: Illustration of HD-hall

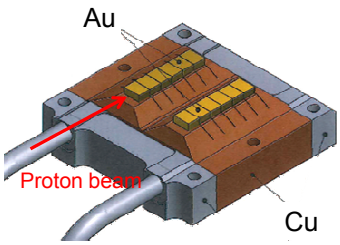

Figure 2: Illustration of the production target

2. Measurement and control device

Before the accident the temperature-measurement cycle of 1 second was too slow to detect the rapid temperature rise. Therefore we have upgraded the measurement system as follows.

- The measurement and interlock system of the target temperature has been developed with A Programmable Logic Controller (PLC) shown in Figure 3.
- The sequence-CPU is described as follows :
  - ✓Measure temperatures with 100 milliseconds sampling.
  - ✓Issue an interlock signal when the temperature exceeds the threshold.
- The EPICS-CPU is described as follows:
  - ✓An embedded EPICS IOC on Yokogawa's FA-M3 PLC platform.[1)]
  - ✓An EPICS-IOC can take data from the sequence CPU via the shared memory.
- The start and stop timing of the measurement is synchronized with the beam extraction cycle, using the gate signal synchronized to the accelerator operation.

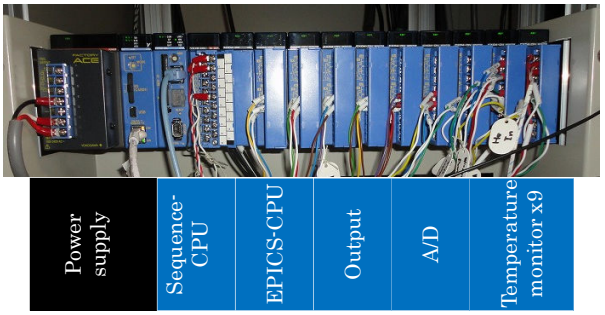

Figure 3: photograph and illustration of the PLC

3. Method to measure temperature data synchronized with beam extraction

- The way of temperature data synchronized with beam extraction is described in Figure 4.
- The EPICS sequencer has been used in order to operate the system synchronized with the beam extraction.

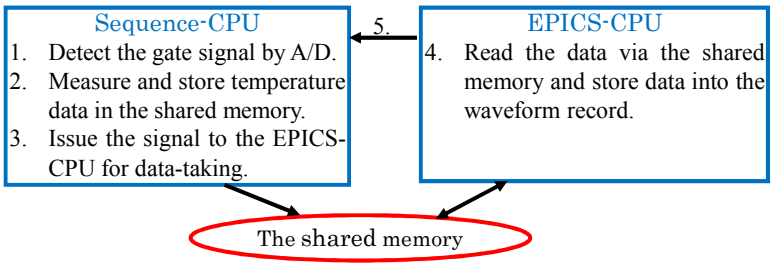

Figure 4: Diagram of how to measure temperature data synchronized with beam extraction

4. Display of temperature data synchronized with beam extraction

Display:

- Program language: wxPython.
- The operators can monitor the current data and inspect the past data if necessary.
- The vertical axis: temperature [degree Celsius].
- The horizontal axis: time [seconds].

Results:

- Maximum temperature:
  - ✓Au piece: 250.0 [degree Celsius] @ the forth from the front piece.
  - ✓Cu block: 51.5 [degree Celsius].
- A smooth temperature rise: 0.6 - 2.6 seconds (on spill).
- A smooth temperature descent: 2.7 – seconds (off spill).

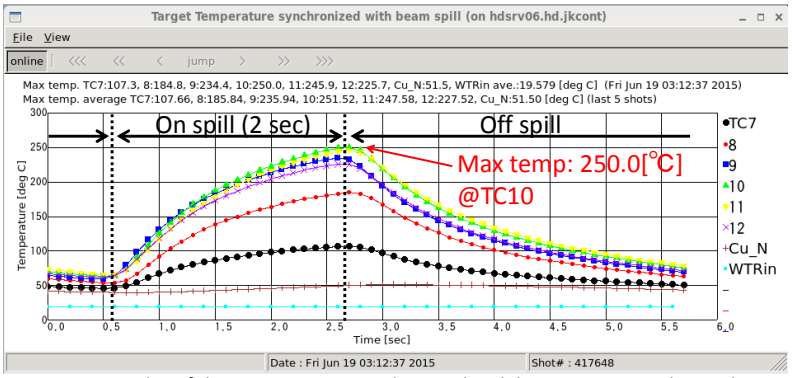

Figure 5: Display of the temperatures synchronized with beam extraction during the typical beam operation of 33kW.

5. Summary

- The measurement and the interlock system of the target temperature has been developed with the PLC.
  - ✓The sequence-CPU module can handle and control the temperature data and the interlock signals.
  - ✓The EPICS-CPU module can handle the data from the sequence-CPU via the shared memory.
  - ✓The waveform records of temperature as a function of time can be referred on the EPICS-CPU.
- The operator can monitor the waveform spectra as a function of time in every beam extraction.
- The upgraded system has been successfully and stably operated with up to 33-kW proton beams.
- The details of trend graphs and an interlock system of the production target are mentioned in our proceedings.

Acknowledgement

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References

[1] http://www-linac.kek.jp/cont/epics/f3rp61/