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STABILIZING THE BEAM CURRENT SPLIT RATIO IN TRIUMF's 500 MeV CYCLOTRON WITH HIGH LEVEL, CLOSED-LOOP FEEDBACK SOFTWARE

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ABSTRACT

In the pursuit of progressively more stable beam currents at TRIUMF's 500MeV cyclotron there was a proposal to regulate the beam current split ratio for two primary beam lines with closed-loop feedback. Initial runs have shown promising results and have justified further efforts in that direction.This paper describes the software to provide the closed-loop feedback, and future developments.

INTRODUCTION

- Three beam lines are presently in use but there are plans for a new fourth beam line
- Extracting multiple beams is relatively straight forward
- Stabilizing the beam currents in multiple beam lines is challenging
- Rare isotope production requires stable beam current:
  - Too much beam over-heats the target
  - Too little beam produces much less isotopes
  - Cycling the beam on and off ages the target
- Closed-loop feedback has been used for more than 8 years for single beam line current stability and position stability
- Current stability existed, using an electrostatic deflector for only one beam line but decreased stability on other beam lines
- A proposal to stabilize the split ratio of two beam lines using a harmonic coil was advanced
- The suggestion uses a Bz magnetic field to alter the split ratio of the two extracted beams

BEAM CURRENT ADJUSTMENT BY HARMONIC COIL

- The cyclotron accelerates H- and uses stripping foil extraction to extract protons
- Trim and harmonic coils exist to alter the beam path of the H- as it spirals out
- The coils provide radial (Br) and vertical (Bz) magnet field components, which move the beam vertically and radially (horizontally) respectively
- The ratio of the currents extracted is determined primarily by the relative position of the circulating/accelerating beam to the position of the two extraction foils
- By moving the beam horizontally using the Bz, current can quickly be re-positioned from one foil to the other
- The harmonic coil is a virtual device comprising six power supplies and related coil windings
- A separate process monitors two extracted currents and calculates the split ratio
- The feedback loop software adjusts the beam position to stabilize the split ratio

DEVICE IMPLEMENTATION

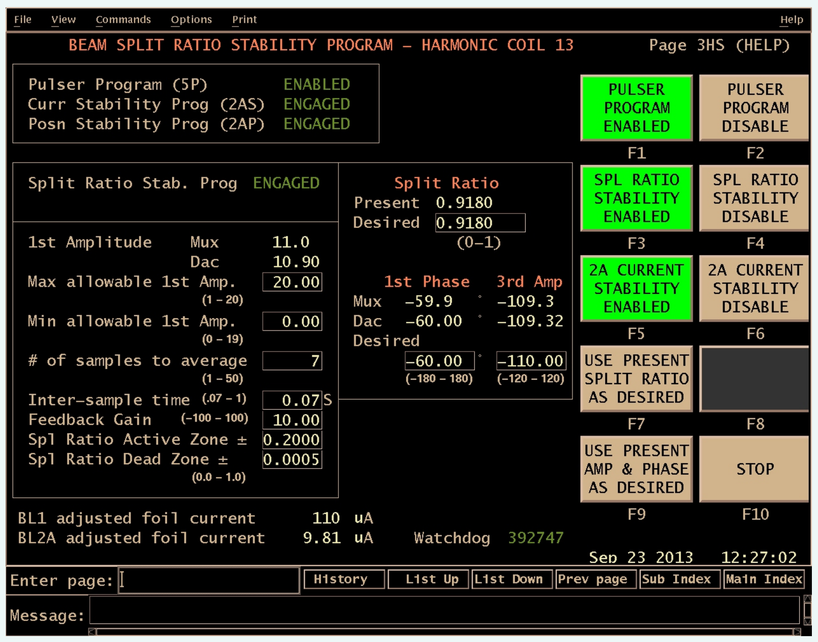
- There are thirteen sets of harmonic coils
- Each set comprises six pairs of coils located in a 6-fold symmetrical manner in the cyclotron tank
- They are used to adjust the local magnet field at a particular radius
- Harmonic coil 13 is the outermost set and was chosen for use in the split ratio stability program
- There are six parameters for this harmonic coil:
  - The 1st harmonic amplitude for Br and Bz
  - The 1st harmonic phase for Br and Bz
  - The 3rd harmonic amplitude for Br and Bz
- Each parameter is implemented as a virtual device

PLANS FOR ENHANCEMENTS

- Install higher resolution DACs to improve control
- Improve software algorithms
- Use the pulser to stabilize the injected current

APPLICATION PROGRAM FEATURES/USER INTERFACE

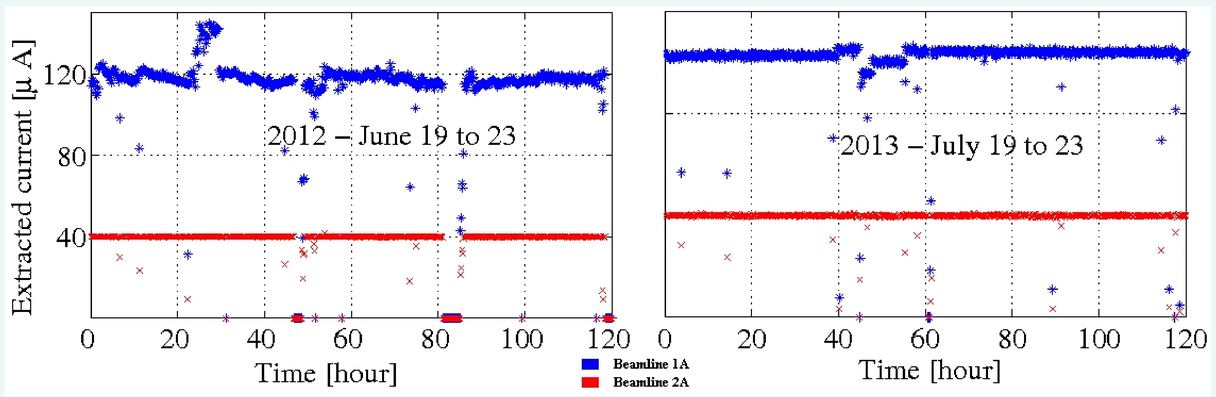
- Application program reads the split ratio, compares it to the target value and adjusts the Bz (horizontal beam position) if necessary
- User interface has three parts:
  - Summary control and monitoring page for stability program
  - Detailed control and monitoring page for virtual devices
  - Control from the main console
- State changes and user changes to parameters are automatically recorded in the master log



XTpage - Control and monitoring of the stability program

OPERATIONAL EXPERIENCE

- Running for almost one year
- Regularly used in normal operation
- Increased stability achieved
- Less beam trips
- Less Operator intervention needed



Results - Current stability before feedback (on left side) and after feedback (on right side)

SUMMARY

- Increased beam current stability has been achieved
- Split ratio stability software is now used in normal operation
- User interface and closed-loop application are well accepted by Operations
- Reliable operation over the last year
- Operation of the Cyclotron is easier because less Operator intervention is needed
- Further enhancements are anticipated

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