SNS BEAM DIAGNOSTICS: PRESENT STATUS AND FUTURE PLANS

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Abstract

The Spallation Neutron Source accelerator systems will deliver a 1.0 GeV, 1.4 MW proton beam to a liquid mercury target for neutron scattering research. The accelerator complex consists of an H- injector, capable of producing one-ms-long pulses at 60 Hz repetition rate with 38 mA peak current, a 1 GeV linear accelerator, an accumulator ring and associated transport lines. The accelerator systems are equipped with variety of beam diagnostics. The beam diagnostics played important role during beam commissioning, they are used for accelerator tuning and monitoring beam status during production runs. The requirements to the various diagnostics systems are changing in the process of beam power ramp up. This talk will give an overview of the evolution of the major SNS beam diagnostics systems: commissioning, operation, power ramp up, and power upgrade.

INTRODUCTION

The SNS accelerator complex consist of an H^- injector, capable of producing one-ms-long pulses with 38 mA peak current, chopped with a 68% beam-on duty factor and a repetition rate of 60 Hz to produce 1.6 mA average current, an 87 MeV Drift Tube Linac (DTL), a 186 MeV Coupled Cavity Linac (CCL), a 1 GeV Super Conducting Linac (SCL), a 1 GeV Accumulator Ring (AR), and associated transport lines. After completion of the initial beam commissioning at a power level lower than the nominal, the SNS accelerator complex is gradually increasing the operating power with the goal of achieving the design parameters in 2009. Results of the initial commissioning and operation experience can be found in [1]. The SNS Power Upgrade Project (PUP) [2] aims at doubling the beam power by increasing SCL and AR beam energy to 1.3 GeV and peak current in the linac to 59 mA. The SNS baseline design included diverse suite of beam diagnostics [3], which, in main part, were brought on line simultaneously with other accelerator systems and played crucial role in fast and successful SNS commissioning and power ramp up. As the SNS operation is shifting more and more toward neutron production for users the roles and requirements for the beam diagnostics are changing as well. This paper describes the status and development plans for the major beam instrumentation systems.

BEAM INSTRUMENTATION ROLES

The beam time in the SNS operational schedule is divided in free parts: neutron production, machine tune up for production, and machine study periods.

Neutron Production Period

The neutron production period currently takes 80% of the scheduled beam time and this fraction is increasing steadily. The most important performance metric during this period is beam availability. Therefore only systems directly involved in beam delivery are of high importance. Beam instrumentation systems triggering the Machine Protection System (MPS) fall in this category. These include the Beam Loss Monitors (BLMs), distributed along the accelerator, the beam-in-gap detector (CHUMPS) in the Medium Energy Beam Transport (MEBT) line responsible for detection of the MEBT chopper failure, the Differential Beam Current Monitor (DBCM) protecting the MEBT chopper target, the beam dump current detectors (NCDs) protecting beam dumps from excessive power, and the beam current on target monitor (BCM25) monitoring beam power delivered to the neutron target. These systems have to operate at the beam rate up to 60 Hz and if any one fails the beam in the machine is inhibited.

Machine Tune Up Period

The machine tune up period is required after each maintenances period and currently takes about 10% of the scheduled beam time. If any one or even several systems fail operation is still possible. The most important performance metric during this period is accuracy of data, easy of use (user friendliness), and speed. Operators should be able to perform tune up as quickly as possible with as little support from diagnostics experts as possible. The main systems for machine tune up are the Beam Position and Phase Monitors (BPMs) and the Wire Scanners (WSs). These systems have to operate at a reduced pulse rate of 1-2 Hz. The BLMs are also used for the fine tuning of the losses.

Machine Study Period

About 10% of the scheduled beam time is dedicated for the machine study. All available diagnostics could be used during this period. If any one or even several systems fail operation is still possible. The most important performance metric during this period is accuracy of data. Physicists usually do measurements often with help from diagnostics experts. Some of the diagnostics systems for machine study can be of experimental nature or in prototype stage of development. Beam halo and transverse profile measurements in the ring are examples of such systems. These systems are required to operate at a reduced pulse rate of 1-2 Hz.

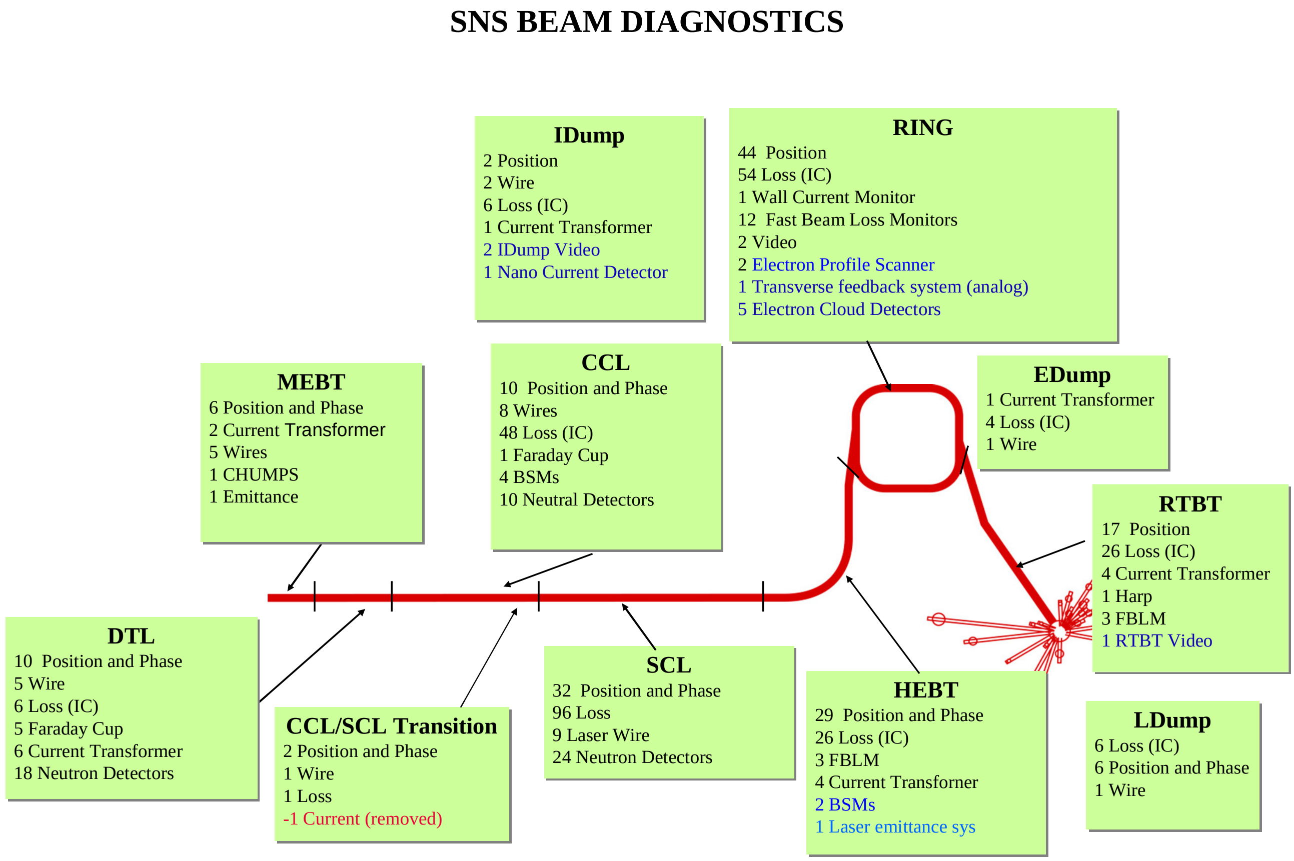

Figure 1: SNS Beam Diagnostics.

Beam Loss Monitors

The SNS BLM system consists of 362 radiation detectors measuring secondary radiation due to beam loss. BLMs are used as MPS device to shutdown the beam if the integral loss is above threshold. SNS uses ionization chambers (IC) as its main BLM device. This is due to their simple design and immunity to radiation damage. In addition to ICs we use several type of PMT based detectors. The data acquisition system is VME based. The BLM system has been quite reliable and caused less than 10 hours of beam down time during last year. To further improve reliability we are developing new front-end electronics with independent hot swappable modules with individual high voltage power supplies in each module.

Beam Position and Phase Monitors

Beam phase measurements are the main tool for linac tune up. Position measurements are used for trajectory correction in the linac, ring injection set up and centering beam on dumps and target. BPM system utilizes strip line pick up electrodes in all parts of the accelerating complex. Narrow band RF front-end electronics is used in the linac and the HEBT, base band front-end electronics is used in the ring and the RTBT. All BPM systems use PCI digital interface. In the near term we plan to add more BPMs in the transfer lines and upgrade timing system. In longer term we plan to redesign the data acquisition electronics to mitigate part obsolescence and PC compatibility problems.

Transverse Beam Profile Measurements

Conventional stepping wire scanners are used for measuring transverse beam profile in the normal conducting linac and beam transport lines. The wire scanners deliver reliable profiles with dynamic range of about 100, which is sufficient for the beam core matching bunt not sufficient for beam halo and loss study. We are investigating possibilities to increase the dynamic range to 10^3 - 10^4 by upgrading the front-end electronics and/or by modifying the wire scanner design.

A laser based transverse profile measuring system, or Laser Wire (LW) is used in the SCL. The LW delivers reliable data on a quite day but often suffers from laser beam position jitter due to environmental noise. A typical variation of the laser beam position during a day is shown in Fig. 2. We have identified the main sources of the vibrations and will implement mitigation measures during the next shutdown. The LW has a capability of measuring profiles with high time resolution allowing observing beam size variation within a single mini-pulse as shown in Fig. 3.

There was no base line diagnostics for measuring beam profile in the SNS ring. We installed and successfully tested a prototype of non-perturbing Electron Beam Profile Monitor EBPM [4]. The EBPM has a capability of measuring profiles with high time resolution allowing observing beam size variation within a single turn in the ring mini-pulse as shown in Fig. 3. An ionization profile monitor is under development as an alternative device of measuring transverse beam size in the ring.

A conventional slit/grid device is used for measuring transverse phase space footprint of the beam in the Medium Energy Beam Transport (MEBT) line. Its performance has been improving steadily.

A non-perturbing laser wire based transverse emittance measuring station will be installed in the High Energy Beam Transport line by the end of 2009 [5].

Measuring the beam halo is considered to be important for increasing beam power and reducing beam loss. There is no a dedicated beam halo measuring device at the moment. We developed a current measuring system for HEBT scrapers capable of measuring an intercepted beam charge down to 10^{-5} level. This system can be used for transverse halo evaluation or can become a basis for a dedicated halo monitor.

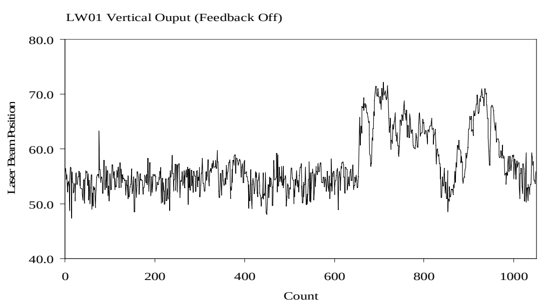

Figure 2: Laser beam position (arbitrary units) vs. time (1 sec/count) in the SNS Laser Wire system.

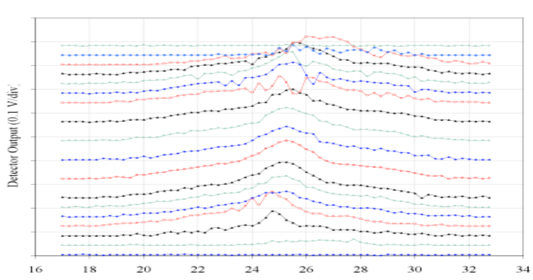

Figure 3: Transverse beam profile in the SCL measured with 20 nsec steps within a single mini-pulse.

Longitudinal Beam Profile Measurements

There are two types of diagnostics in use for longitudinal bunch profile measurements. A Laser Bunch Shape Monitor (LBSM) is installed in the MEBT, four Bunch Shape Monitors (BSMs) are installed in the CCL, and two BSMs are installed in the HEBT [6]. These measurements proved to be useful for linac set up, troubleshooting and machine study. The BSMs have very large dynamics range up to 10^4-10^5 as illustrated by a typical bunch profile measurement shown in Fig. 4 and Fig. 5

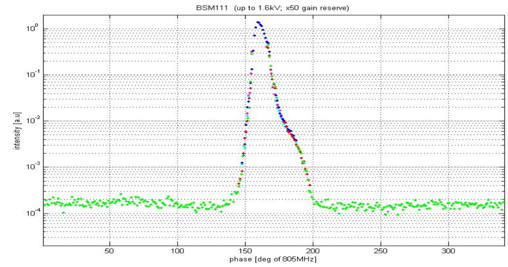

Figure 4: Longitudinal bunch profile measured in CCL.

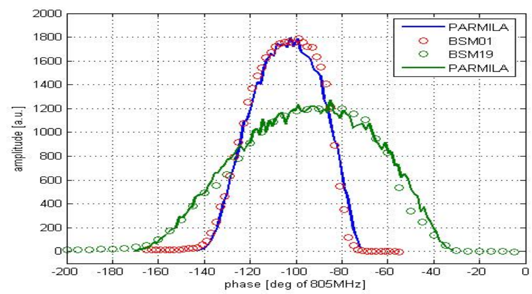

Figure 5: Longitudinal beam profiles measured in the HEBT compared to simulation.

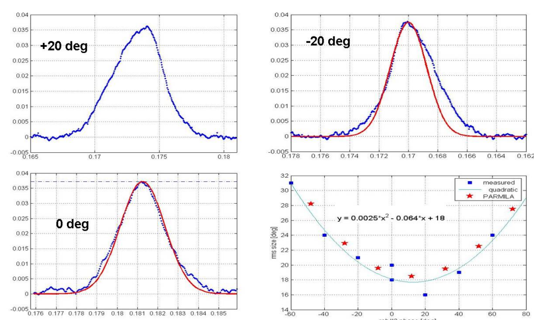

Figure 6: Bunch profile measurements in the SNS MEBT. Plots on top are for the buncher phase shifted from the nominal set point. Bottom left is for the nominal buncher setting. Bottom right is comparison of RMS bunch width vs. buncher phase dependence with the PARMILA simulation.

ACKNOWLEDGEMENT

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