ACCELERATOR OPERATION AT THE GSI HIGH CURRENT INJECTOR

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Abstract
The operation of the new high current injector (HSI) is characterized by up to a factor of hundred higher beam intensities and the enlarged possibilities of the time sharing operation between two ion source terminals feeding the HSI and the High Charge State Injector (HLI). The increased beam power of a single Unilac pulse is now able to damage sensitive accelerator components. New operation hard- and software tools controlling the accelerator and monitoring the device settings and beam properties had to be developed and integrated in the already existing concept. Based on the beam parameters the data supply of all devices with proofed initial settings and the check of device properties are automatically done by software programs. The interlock system was advanced by the survey of transmission losses and it also reduces the beam power automatically while beam diagnostics is measuring. The paper deals with the new requirements, the ideas of solving them and the first operation experiences.

1. INTRODUCTION

GSI is the heavy ion research center in Germany operating with the linear accelerator Unilac (universal linear accelerator), the synchrotron SIS (Schwerionensynchrotron) as a circular accelerator and a storage ring ESR (experimental storage ring) on the fields of nuclear and atomic physics, plasma physics, material research and biophysics. The SIS was designed as a high intensity machine with a large magnet aperture. In contrast, the original Unilac was not dedicated as a synchrotron injector, fulfilling all requirements due to high intensities (especially for a mass number higher than 150). To serve the SIS up to the inherent space charge limit for all ion species including uranium a new High Current Injector was installed and commissioned step by step in 1999 replacing the more than 25 years old Wideröe section of the GSI Unilac. [1]

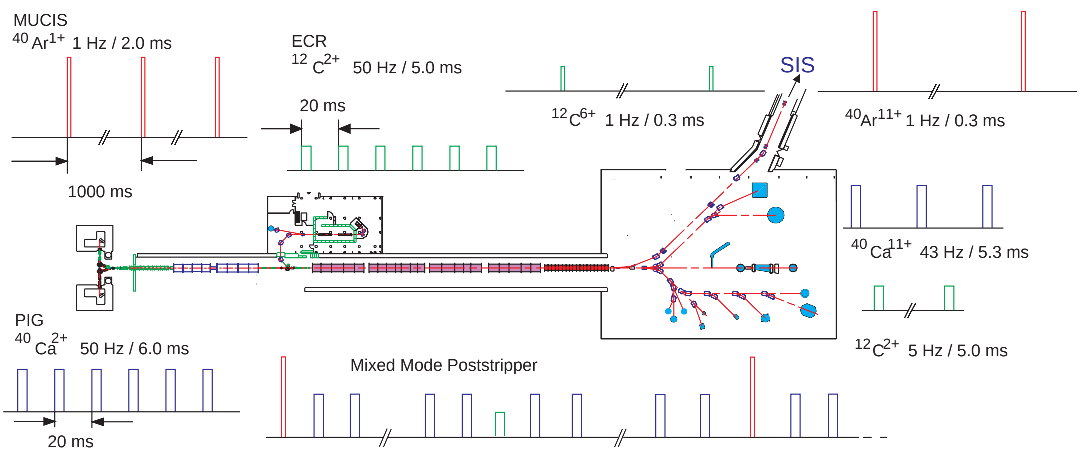

Fig. 1: Example of Three Beam Operation with four users (December 2000)

With the new injector the operation possibilities are considerably enlarged. Pulse to pulse availability of every ion source is now possible. Two ion source terminals feed the HSI: One is housing a Penning Ion Gauge (PIG) already in operation at the former Wideröe injector (for all kinds of ions at medium and low intensities) and the other one serves for the production of high intensity, heavy ion, low charge state beams. Optionally the Multi Cusp Ion Source (MUCIS) for gases or the MEtal Vapor Vacuum Arc ion source (MEVVA) for metals is installable. Afterwards the ion beams are accelerated up to 1.4 MeV/u in the new HSI, before injection into the Alvarez the modified gas stripper section provides for the essential charge state. The other 1.4 MeV/u injector, the HLI (Hochladungsinjektor) fed by an Electron Cyclotron Resonance (ECR) ion source at low intensity, high charge states and high duty cycle allows Alvarez injection directly without stripping. After the upgrade of the Unilac a multi-pulse mode from the different injectors is possible. Figure 1 shows typical operation parameters (in the 4th beam time period 2000): the $^{12}C^{6+}$ ion beam to SIS for therapy (from HLI), a high intensity $^{40}Ar^{11+}$ beam to SIS for the fragment separator (MUCIS) and Xe (PIG) to the Unilac experimental hall were simultaneously in operation on pulse to pulse basis.

2. MACHINE DESIGN FEATURES FOR THE HIGH CURRENT OPERATION

The increased beam intensity leads to a very high pulse power of the beam up to 1.5 MW in the gas stripper section. Connected with the short stopping range of the ions at Unilac energies even a pulse of 100µs length is able to melt metal surfaces. Hence the damage of accelerator components becomes a serious problem [2].

2.1 Passive Damage Prevention

Sensitive devices are shielded by especially designed apertures and slits; the cooling of the beam stoppers was improved. By decreasing the impinging angle on the surface in design layout, the exposed area is increased while the thermal energy density decreases.

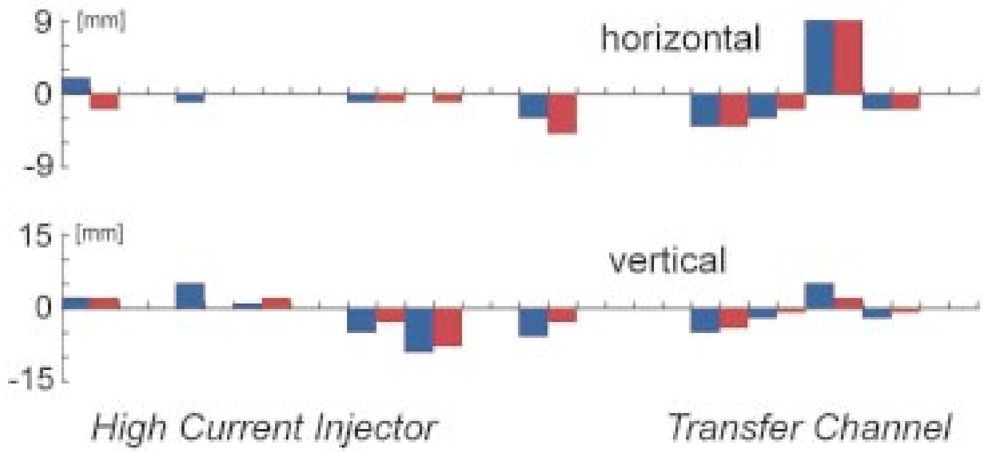

Fig. 2: Online monitoring of beam position with the pick-ups at the HSI and transfer channel; the measured positions and a stored reference is represented.

2.2 Beam Diagnostics

Due to the high beam power and the short stopping range the use of non-destructive beam diagnostics reached more importance. The beam intensities are high enough to detect the beam signal with the less sensitive high current diagnostic. A damage of the measurement system due to direct impact of the ion beam is prevented [3].

Instead of Faraday cups now beam transformers (33 in the Unilac) measure the intensity and 24 segmented capacitive pick-ups along the linac instead of profile harps are used to qualify beam position – the pick-ups are likewise usable for an accurate determination of beam energy. Residual gas monitors deliver information about beam profiles. Because of their size (length is 250 mm) they are only used at special matching points. Beyond several expert systems are available to measure the six-dimensional phase space distribution along the Unilac.

2.3 Interlock-System

The established interlock system has been upgraded and enlarged: the beam loss along the whole machine is monitored by beam transformers to prevent the damage of components. At some key positions the difference of the charge values between two subsequent measurement points is carried out. If this value is higher than a threshold value the pulse length will be reduced with the chopper before HSI-injection. This system is also working with special beam loss data while profile measurements with grids – beside the dynamical pulse length reduction the repetition rate is also decreased.

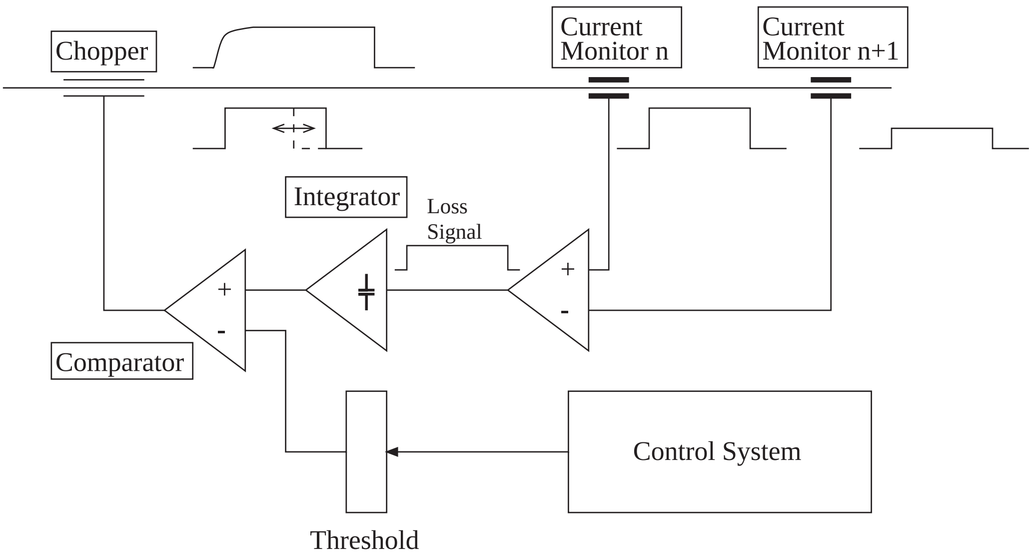

Fig. 3: Principle of beam loss control

Routinely the status of all accelerator components is permanently monitored. If any malfunction is detected the beam is switched off by the beam choppers selectively for the corresponding users. A special software gives the operator information about the affected device and the failure.

3. OPERATION STRATEGY

The philosophy of 'prevention of a possible damage of accelerator components' impacts not only safety aspects in the technical construction, it also affects the operation of the accelerator. An unexpected vacuum leak is always connected with a longer undesired loss of beam time. To support the installed interlock system, which should guarantee the safe operation, the control software checks all actions done by the operation crew. The following basic rules have to be fulfilled without fail:

- before a beam pulse is accelerated all devices get their operation settings based on the beam parameters
- requested changes of beam parameters lead to a new calculation of the device settings based on the actual one

- the measurement of beam parameters with destructive diagnostics has to be prepared by reducing the pulse length and repetition rate
- Online monitoring of steering by capacitive pick-up probes

4. OPERATION EXPERIENCES

The installation of the high current injector enlarges the operation possibilities considerably. Quite a lot of operation work is done automatically, as preparation of an initial data set or as save procedures. That reduces the necessary time for accelerator tune up drastically, but the risk to destroy the actual machine setting by a maloperation is increased. Essential 'current dependent settings' were calculated before and have to be verified during operation. A few device properties lead to interference between the single beams: several dc magnets in the poststripper section, phase of bunchers and single gap resonators, limited pulse to pulse operation of HSI magnets. This fact causes mainly operation problems, which reduces availability during multi-beam-operation. The operation experiences of the last year led to many changes of the operation procedures and automatic actions in software programs. The last high current beam time with argon from the HSI was quite successful – during three weeks the Unilac served for the synchrotron without any re-tuning and without any failure, only ion source changes were regularly done. The beam time was performed while the carbon beam was delivered for the cancer therapy.

5. ACKNOWLEDGEMENTS

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References

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