STATUS REPORT ON THE GSI SYNCHROTRON FACILITY AND FIRST BEAM RESULTS

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Abstract

An account is given on the assembly phase of the SIS 18. The status of components and subsystems is reviewed. During an aperture test in November 1988 first beam results were obtained. A load test on the public grid with the SIS magnet power supply revealed that a mechanical power buffer has to be installed in future.

Introduction

The GSI Synchrotron facility, which was described in earlier conference papers[1,2], is under construction since end of 1986. Because of the extended preparatory phase for the technical design and the administrative procedures, the project developed smoothly. The envisaged time schedule and budgetary allowance were met. No changes in the parameter list or in component design were applied meanwhile.

Unilac Modification

The Unilac control room was reconfigurated and accommodates now three separate consoles for the linac, the synchrotron and the storage ring. The console installation and control media are available and operative.
The energy switching program of the linac beam is completed and occasional in use during routine operations. While the cautiously provided switching of the quadrupoles at the front end and exit of the Alvarez tanks turned out to be not important, the switching of the steering magnets is quite essential.
The transfer line between the linac and the synchrotron is completed since November 1988 and connected to the new control system. In beam times requiring only modest operators interaction, the beam is occasionally sent into the transfer line for acquiring experience with the control and adjustment of the low duty-cycle beam and with matching to the SIS injection requirements.
The high current injector, originally included in the framework of the new project, was postponed because of manpower shortage for design and engineering effort. Instead, a "low current" injector, replacing the existing prestripper part of the Unilac, is under construction. A high charge-state ECR source allows for a short linac section and a complete elimination of the stripper. When this installation becomes available in mid of 1990, the present prestripper section will be at the disposal for high intensitities of light ions (up to Argon) and for a phased modification schedule. The original intensity goal of the SIS 18 for very heavy ions will therefore not be reached before mid of 1992.

Record on the SIS 18 assembly phase

In spring of 1988 the ring tunnel became available for component installation. The dipoles were available in due time and it was possible to position the magnets such that the residual errors in magnetic length, which were unavoidable either at low or at high fields, cancel approximately in each period. The triplet and quadrupol assembly was slightly behind schedule due to occasional problems with the smooth fitting of the vacuum chamber with its heater jacket.
All components, magnet chambers, pumping and diagnosis chambers were subjected to repetitive baking cycles with residual gas monitoring prior to acceptance for final installation. The kicker tanks needed 4 weeks of baking treatment until an acceptably low outgassing of the ferrite material was obtained. Similar material, specified by the vendor as UHV compatible as well, was then subjected to a heat treatment at 900 °C for 5 hours and the base pressure of 10^{-9} Torr was then reached immediately in the assembled kicker unit .
Though various hardware groups contributed to the large amount of UHV components, there was only one person responsible for the ulitmate vacuum pressure and the strategy, how to assure it. This individual gave the clearance for manufacturing drawings, acceptance test procedures, baking treatments and the final installation authorisation. This smell of burocracy was highly efficient in the design and assembly phase. For routine maintenance activities an extended number of technicians is in the process of volonteering for the procedures and implications of the UHV environment.
It was lately discovered that the vacuum chambers of the dipoles, undergoing 20 mm of lengthening during the heating cycle, did not bounce back reproducibly after cool down and the chamber ends tended to remain displaced occasionally on either side. All magnet yokes were fitted with fixtures, limiting the chamber extension at both ends to + 10 mm. An excursion beyond this margin, which was possible because of generous bellow travel, would have resulted in exceeding the travel of rf shields bridging bellows and pumping chambers on the vacuum side.
During the assembly of the Unilac, 16 years ago, there was the agreement that every component group was responsible for their own cable laying. This resulted in partly overcrowded cable trays and in an unequal quality in positioning perfection. For the SIS assembly, a centralized cabling strategy was decided, managing three classes of interference susceptibility. In the opinion of a few individuals this resulted in an unpleasent burocracy and partly inflexible timing in the availability of completed connections. However, the crafts work finally was quite satisfactory and one third of the space in the cable trays is still in reserve.
As with every new accelerator, there was the traditional debate on the grounding philosphy. The choice was made not to have insulating gaps in the vacuum duct. Every component is tightly connected to a copper bar, running along the tunnel wall. The ceramic chambers for the bumper magnets are metallized on the inner side and bridged by metallic straps on the outer side. Beam diagnostic probes and preamplifiers, which are expected to operate at the electronic noise level for the occasional very low intensity beams, are floating in respect to the vacuum chamber and are grounded via the signal cables to the potential in the electronic equipment room. It is not yet clear, whether this precausion is necessary, because a real field test with power signals on the rf cavities and kicker units was not yet endeavoured .
After the final assembly of the vacuum chamber and the usual leak testing, a thorough check-out of the components, as they are, versus the design drawings took place. This resulted in a small number of modifications applied to both, components and drawings. Thereafter the heater jackets were put in their final configuration and the cabling of about 800 heater circuits proceeded. Though there was one ring period under controlled bake-out operation up to 300 °C without any indication of developing leaks, the bake-out temperature of the whole machine will cautiously by limited for the next time to 180° C in order not to run any risk in respect to the tight running-in schedule. A pressure within the range of $1 \cdot 10^{-10}$ Torr was reached and is deemed adequate for machine commissioning in the first half year.
During the past year several checks of the alignment targets in the ring tunnel revealed a non uniform settling of the tunnel segments in the order of 2 mm per month. In one area this sag accumulated such that flanges had to be reopened in order to give a major lift to the magnets. Fortunately after the wintertime this development came to a halt, which was not expected by the slope of the settling curve. A thorough alignment check-out is

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planned for July of 1989, when a scheduled major shut down is planned in the middle of the running-in phase.
In March 1989 the acceptance tests of the four freely programmable magnet power supplies will be performed. A current accuracy during the whole cyle of $\pm 2 \cdot 10^{-4}$ is expected by a GTO thyristor and transistor shunt regulation scheme. In order to obtain a "zero" time lag ($\pm$ 20 μs) between command signal and actual current, a feed-forward signal accounting for predictable errors (inductance drop, resistance rise, eddy current effect) is generated by the control computer for each cycle.
In April the 5 months running-in period will follow with multi turn injection tests, closed orbit corrections, rf trapping and acceleration and fast and slow extraction tests at the end. A beam dump close to the extraction channel is in preparation. The high energy beam transport to the first experimental cave and to the storage ring will not be available before December 1989. The relatively long running-in-period is determined by the limited availability of the Unilac for light ion beams, which are of no demand for the on-going low energy nuclear physics program. On the other hand, light ions at low charge states are selected for the start-up of the synchrotron, because higher beam intensity and quality are available without lifetime problems with the ion source and without other break-down risks of the Unilac. In this early machine studies ample of time should be available for the clean-up of hardware and software deficiencies. During two days of the week the operators can devote their entire attention to the properties of the new machine.

First beam results

On November 23rd a first Argon beam was injected into the SIS 18 in honour of the 80th birthday of Ch. Schmelzer, the founder of the GSI Laboratory. This venture, not officially foreseen in the assembly schedule, was pragmatically declared as an aperture test. It gave the useful confirmation that no obstacle was blocking the vacuum chamber and that all magnets were connected with the right polarity. A few missing components were substituted by temporary pipes, the magnet currents were available only without precision regulation and without calibrated readback. The "first turn inspection box" with profile grids and faraday cup, and 12 positron monitors and the DC beam transformer were operational, though with analog read-out only.
The 5.9 MeV/u beam with 5 μA was easily tuned downstreams the transfer line to the injection point, 170 m away from the end of the Unilac Alvarez section. The beam stability was excellent. Inflector magnet and electrostatic septum were set to theoretical values, and after the service of the first bumper magnet was substituted by the excitation of the correction coil of the first dipole, the beam immediately went around at the assumed theoretical set values of the dipole and quadrupole fields and then was stopped in the first turn box.
Due to the low momentum spread of the Unilac beam, the bunch structure of the linac survived in the ring and gave useful readings of the beam position. The large beam oscillations, 30 mm horizontal and 10 mm vertical, were attributed to an incorrect injection angle. The alignment of magnets seemed to agree with the geodetically recorded values of $\pm$ 0.5 mm. The analysis of the Q values indicated an error of 0.2. The transmission in the ring was nearly 100 %. A beam loss by a factor of 2 at the injection point gave the indication of still imperfect matching conditions in this area.
This first beam test was not repeated thereafter, because the scheduling of the Unilac experiments implied for the operators a difficult tuning of low intensity beams, and a honorable list of incomplete or improvised items had to be worked off.

The episode of the power grid tests

It was envisaged to draw the magnet power swing of + 30 and - 28 MW directly from the public grid. An analysis of the network impedance at the connection point of the GSI substation to the 110 kV line resulted in still tolerable voltage fluctuations, when a dynamic compensation of the reactive power, generated by the thyristor controlled rectifiers, is applied. This study was jointly done with the power company. However, a firm reply to such an unusual load characteristic was never obtained. There was a glimpse of fear that near-by generating stations could run out of control due to the fluctuating amount of real power. Since a large nuclear power plant contributed to the local grid, an over-cautious attitude was met with the power company, though the demand for the state of the art tolerance of $\pm$ 5 % periodical fluctuations did actually not exist. Considering this uncertain situation, the reactive power compensator was not ordered. It would have been worthless, when a mechanical power buffer should become unavoidable.
In the long term planning of available generating plants and network configurations, one week in July of 1988 was reserved by the power company for an extensive load test. Magnets, cabling, power supplies, still without precision regulation, and computer control were ready just in due time. A large variety of repetition rates, ramp shapes including sinusoidal waveforms, were applied to the power grid at slowly increasing peak values. The grid configuration could be branched such that the fluctuating power arrived selectively at two nearby generating stations. There was no problem with the nuclear plant, even in the peak of the resonance response of the turbine governors. The SIS noise was just measurable in the angular oscillation of the generator shaft. When the load was channeled to a conventional plant, considerable but still admissible disturbances were recorded. However, during this load management, ist was overlooked that a small generating plant of a private paper mill was unadvertedly in connection to the line. This plant got heavily disturbed by the SIS cycle and an immediate complaint was received by the headquarters of the line experiments. No further tests were made to determine, whether a particular repetition rate would alleviate the interference.
This episode was taken up by the power company to refrain from a general authorisation of the SIS operation directly from the public network. It was put forward that several small private generating stations could eventually be connected to the grid and that the power company is legally obliged to support this energy contribution.
There are two ways out of this situation: a) The connection of the GSI to a nearby 220 kV line, which is sufficiently stiff and interconnects only large generating plants. This solution was discarded so far, because of the high investment and operating cost. b) The installation of a mechanical power buffer on the GSI site. Quotations for a classical motor-generator set with floating frequency of the output voltage were on hand since long. Again, the investment cost and the maintenance effort for a synchronous generator were discouraging.
Instead, a new scheme is being worked out by a study with simulations of the involved transient behaviour: a large asynchronous motor, in the 30 MVA range, is connected directly in parallel to the 20 kV power line and to the magnet power supplies. The energy exchange from the inertia and variable speed of the rotor is controlled by feeding the rotor with a current of the frequency difference between the mains and the angular velocity of the rotor field. Such an asynchronous motor is a standard product and can sustain considerable load chocks without preventive maintenance. The frequency generator of 0 to 5 Hz with its feed forward control will be a challenging development task. Specifications have been worked out for tendering the whole energy storage device. Installation is scheduled for end of 1990.

In the meantime the SIS 18 cycle at 40 % of the peak load is tolerated by the power company, involving a particular network branching, which cannot be made surely available all the time.

References

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[2] D. Böhne et al., "Status Report on the SIS/ESR Project at GSI", in Proceedings of the 13th International Conference on High Energy Accelerator, edited by A.N. Skrinsky, Novosibirsk Aug. 1986, pp 204 -208.