STATUS OF THE CRYRING-PROJECT

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Abstract

CRYRING [1] is a facility for research in atomic, molecular and nuclear physics. It uses a cryogenic electron beam ion source, CRYSIS, together with an RFQ linear accelerator as injector into a synchrotron/storage ring for very highly charged, heavy ions. The status of the project as of May 1990 will be described.

CRYSIS

The ion source [2] has been installed in the E-hall as part of the CRYRING-project, see figure 1. During the remounting many improvements have been made. The capacity of the He-system has been increased to speed up the cooling down and to improve the reliability. Work has been done on the electron beam resulting in a substantial increase in the transmission. Most components have been connected to the computer control system. The longitudinal potential well is controlled by fast function generators, giving increased flexibility. The cryostat and source vacua will be fully separated to avoid He contamination in the ion beam. The first tests with ion beam have recently been performed. The total number of charges per pulse was then found to be $5 \cdot 10^9$ which is more then previously achieved. The injector isotope separator INIS has also been moved to its position close to CRYSIS to allow injection of singly charged ions, which gives more ions of the chosen species and a larger variety of species possible to inject.

RFQ

The RFQ [3] has been built and installed. The first tests with beams of protons, deuterons and $^3He^+$ have been made, showing a proper operation. The test beams for the RFQ and later for the ring are produced in MINIS, a copy of the INIS ion source put on a 50 kV platform. In order to reduce the energy spread a debuncher is being installed after the RFQ.

The RING

Some parameters of the ring when operated at the main working point [4] are given in table 1.

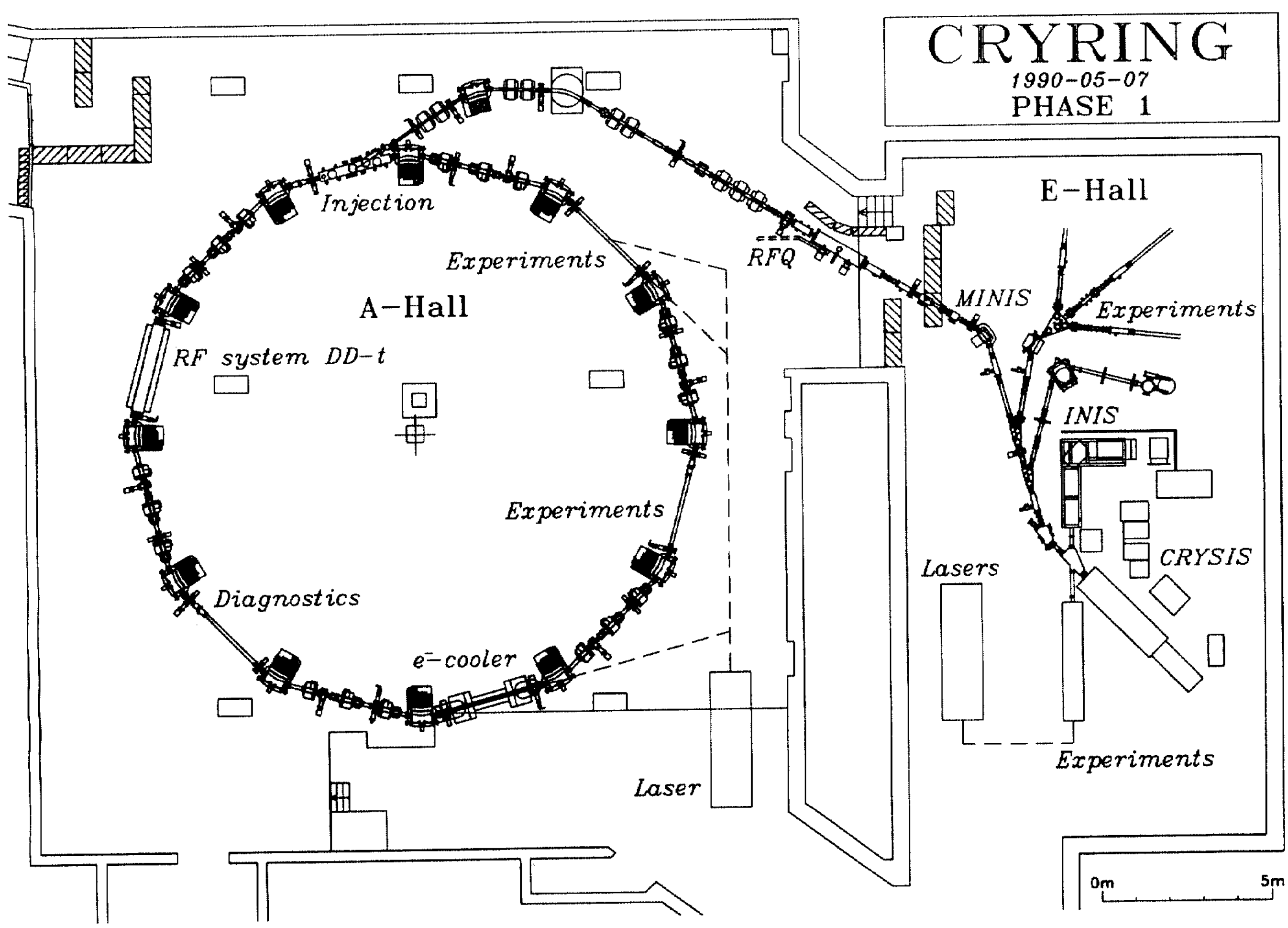

Fig 1. Layout of the CRYRING project, phase 1.

Table 1. Main parameters of the ring.

Circumference	51.63	m
Q_x	2.30	
Q_y	2.27	
$\Delta Q_x/(dp/p)$	-1.3	
$\Delta Q_y/(dp/p)$	-3.2	
ϵ_x at inj.	200π	mm·mrad
ϵ_y at inj.	100π	mm·mrad
$\Delta p/p$ at inj	$\pm 5\cdot 10^{-3}$	
$\beta_{x,max}$	6.3	m
$\beta_{y,max}$	6.5	m
$D_{x,max}$	2.1	m
E_{inj}	0.3	MeV/u
for $q/A < 0.25$	0.3 q/A	MeV/u
E_{max}	$96\ (q/A)^2$	MeV/u
T_{ramp}, fast	150	ms
T_{ramp}, slow	1	s
$T_{flattop}$	>150	ms

Magnets

The alignment of the ring magnets is based on distance measurements with calibrated invar wires and a KERN distometer. The dipoles have been positioned better than ±0.1 mm in all dimensions. The tilt is smaller than ±0.1 mrad. The quadrupole positions are correct within ±0.2 mm transversally and ±1 mm longitudinally. They have a tilt smaller than ±0.3 mrad. The quadrupoles are positioned relative to the dipoles and have less accurately stacked laminations, hence the bigger errors. Their longitudinal position is not critical. All dipoles are equipped with backleg windings, two of which will be used to correct the orbit through the electron cooler. The twelve sextupoles have been delivered and will be positioned shortly. Correcting dipoles have been designed and parts ordered and delivered. The assembly will shortly start. In Figure 2 one typical magnet straight section is shown.

Main power supplies

The fast ramping (150 ms ramp time and 500 ms cycle time) planned for CRYRING meant that existing mains feeding was underdimensioned. A new building has been erected, with a 10.5 kV distribution system, dipole transformer, a 1000 kVA transformer for pulsed power, and a harmonic filter. The dipole, two quadrupole and electron cooler power supplies have been installed. The system has been tested under practically full-load conditions with sufficiently low flicker and harmonic disturbances. The magnet currents are well within specified accuracy during the full cycle in all running modes tested so far.

Table 2. Data of CRYRING ring magnets.

DIPOLES		
bending radius	1200	mm
yoke length	631	mm
bending angle	30	degrees
gap height	80	mm
max field	1.2	T
$\lvert\Delta B/B\rvert$ ($\lvert r-R\rvert < 50$ mm)	$< 10^{-4}$	
number of turns	36	per pole
resistance	0.014	Ω
inductance	0.022	H
peak current	1097	A
QUADRUPOLES		
aperture diameter	125	mm
yoke length	238	mm
effective length	283	mm
max field gradient	5.0	T/m
$\lvert\Delta g/g\rvert$ ($r < 50$ mm)	$< 5\times 10^{-3}$	
$\lvert\Delta g/g\rvert$ ($r < 30$ mm)	$< 10^{-3}$	
number of turns	24	per pole
resistance	0.045	Ω
inductance	0.0061	H
peak current	336	A
SEXTUPOLES		
aperture diameter	125	mm
yoke length	170	mm
effective length	203	mm
max field parameter	27	T/m^2
$\lvert\Delta G/G\rvert$ ($r < 50$ mm)	$< 3\times 10^{-1}$	
$\lvert\Delta G/G\rvert$ ($r < 30$ mm)	$< 2.4\times 10^{-2}$	
number of turns	162	per pole
resistance	1.45	Ω
inductance	0.33	H
peak current	10	A

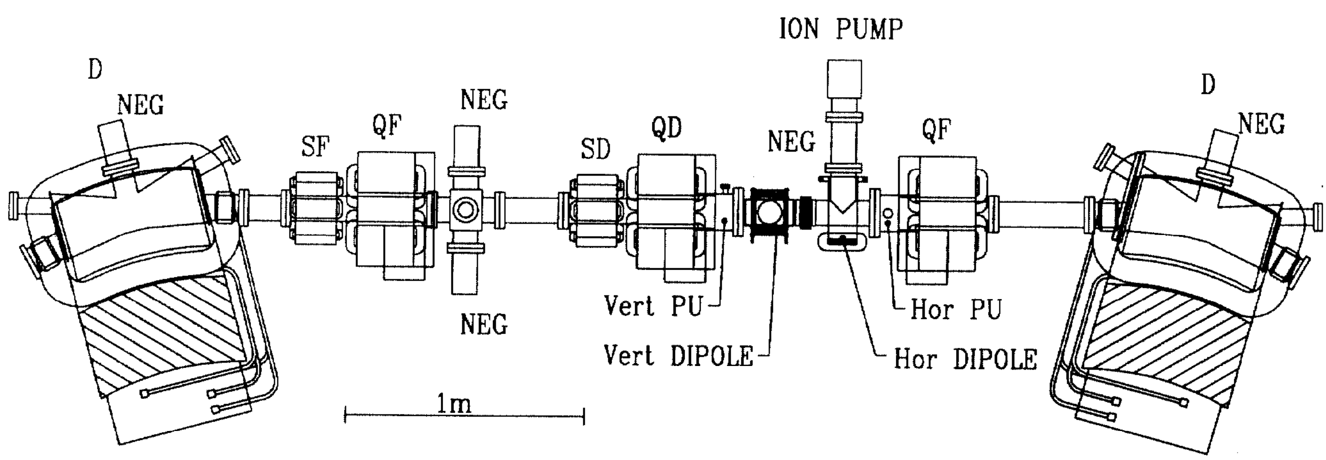

Fig 2. Magnet straight section of CRYRING

Injection

The shortest CRYSIS pulse is $\sim 50\ \mu s$, which corresponds to about 8 turns in the ring at injection energy. The full pulse can be accepted by the ring with multiturn injection. The necessary displacement of the closed orbit is done locally in the injection straight section by four pairs of electrostatic plates [5]. The plates will be fed by two ramped voltages of maximum ± 30 kV, (originally one voltage of 60 kV was anticipated). The voltages will be ramped to zero in 50 - 100 μs. A power supply which provides this and is based on the solution in reference [6] has been ordered and delivered.

RF system

The RF system will be non-resonant, a driven drift tube, as described in reference [7]. At the expense of higher power consumption and larger space requirements, a much simpler construction with wider frequency range and possibilities to modify the shape of the accelerating voltage will be achieved. The system has been tested in an almost full scale model. The final version has been designed and is under construction.

Electron cooler

The data of the CRYRING electron cooler [8] are shown in table 3.

Table 3. Parameters of the CRYRING electron cooler

Electron energy	2 – 20	keV
Perveance	0.1 – 5	$\mu A/V^{3/2}$
Electron current	10 – 3000	mA
Beam diameter	40	mm
Magnetic field	≤ 0.3	T
Ramping speed	up to 0.1 T: ≤ 0.8	T/s
	above 0.1 T: ≤ 0.3	T/s
Cooling length	1.1	m

The electron cooler will cool ions with energies up to the highest in CRYRING, corresponding to 13.5 keV electrons. At electron energies up to 20 keV it will work as an electron target for atomic physics experiments . The electron gun will use adiabatic acceleration, implying that electron current, electron energy and magnetic field can be varied independently. The magnet system has been delivered. Field mapping is going on. Due to the low injection energy it is impossible to correct the influence from the cooler magnets on the ion beam if the cooler is run at fields used for cooling. Therefore the field can be ramped with the same speed as the ring magnetic fields up to 0.1 T. The maximum field can only be reached in 1 s. The vacuum system, gun and collector are designed.

Vacuum system

The ultimate vacuum has to be in the low ptorr range [1]. All available techniques and methods to achieve this are applied. Only vacuum fired 316LN stainless steel is used and the whole vacuum system is bakable to 300 °C. The pumping will be done by turbo-molecular pumps during baking, otherwise by ion pumps and NEG strips as shown in fig 2. The eddy current heating inside the heat insulation of the dipole chambers call for cooling. The whole vacuum system will therefore be water cooled to about 12 °C, which will give a better final vacuum.

DIAGNOSTICS

The beam intercepting devices in the transfer lines are Faraday cups for intensity and strip detectors for beam profile measurements. In the ring, nine horisontal and nine vertical electrostatic pick-up units, a beam current transformer and a Schottky noise detector will be used for non-destructive measurements. The strip detector system has been tested in the INIS and CRYSIS beams. The arrangement of a pair of electrostatic pick-ups is shown in figure 2. The assembling of the pick up electrodes and vacuum chambers has started. The ADC units [9] and the synchronous rectifiers are ready. The design of the preamplifier has also been completed. All information from beam diagnostic devices will be processed by a dedicated VME computer.

COMPUTER CONTROL

The control system [1] is to a high degree the same as that of LEAR, CERN. For specific equipment like parameters of CRYSIS/INIS, existing power supplies in the transfer lines and a new multi-output HV system new hardware and/or software had to be developed. The control system for CRYSIS/INIS has been in operation for one year. The ring main power supplies have been operated from the control system with fast ramping. The RF and RFQ computer controls are manufactured and ready for use. Local control of subgroups of parameters have been implemented using terminal stations with limited menus. The software has been modified to allow the use of hardware with 16-bit unsigned ADC's and DAC's.

Summary

The first parts of the CRYRING project are now (May 1990) becoming operational. Experiments using the beam from INIS have been running since the fall of 1989. CRYSIS is working in its final position and experiments are being set up. The RFQ is installed and working with test beams from MINIS. The transfer lines are underway. The main magnets of the ring are installed and positioned. The installation of the vacuum system will start late this summer. The present time schedule aims at injection tests before the end of the year and installation of the electron cooler in the summer of 1991.

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