The Heavy Ion Accelerator Facility VICKSI

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General Description of VICKSI

The accelerator facility VICKSI [1] (Van-de-Graaff Isochron Cyclotron Kombination für Schwere Ionen) at the Hahn-Meitner-Institut in Berlin is a combination of either one of two electrostatic injectors, a 6 MV single ended Van-de-Graaff or an 8 MV tandem, with a fourfold symmetry separated sector isochronous cyclotron (fig.1). VICKSI can accelerate ions with masses ranging from 1 to about 130. For fully stripped ions (up to mass 30) energies of up to 32 MeV/nucleon are available, decreasing to 4 MeV/nucleon for ions with mass 100 (fig.2). VICKSI has been in routine operation with the V.-d.-Graaff injector since 1979. In 1986 the tandem became operational as a second injector. The whole system is computer controlled.The beam quality is excellent: the relative energy width is better than 5×10^{-4}, the pulse length is shorter than 1 ns and the minimal beamspot size with full intensity is 0.5 x0.5 mm² at the target. The annual operation time is about 7000 h. About 35 % of the available beamtime for experiments are used by guest groups from Germany and Central Europe, 10 % of the beamtime are taken for beam development, and the rest is used by in house groups for fundamental research in the atomic-, nuclear- and solid state physics fields.

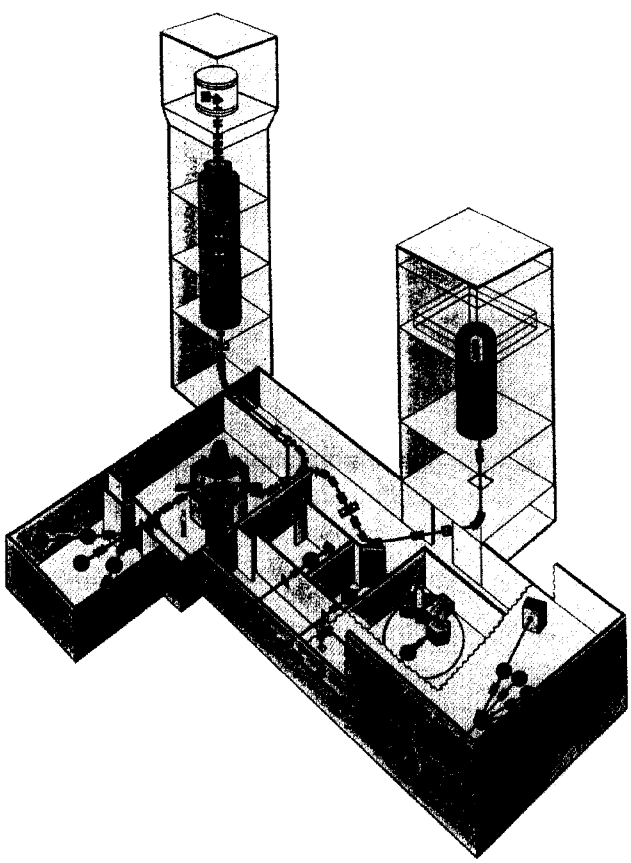

Fig.1: Layout of the VICKSI facility. The tandem injector is located in the left tower.

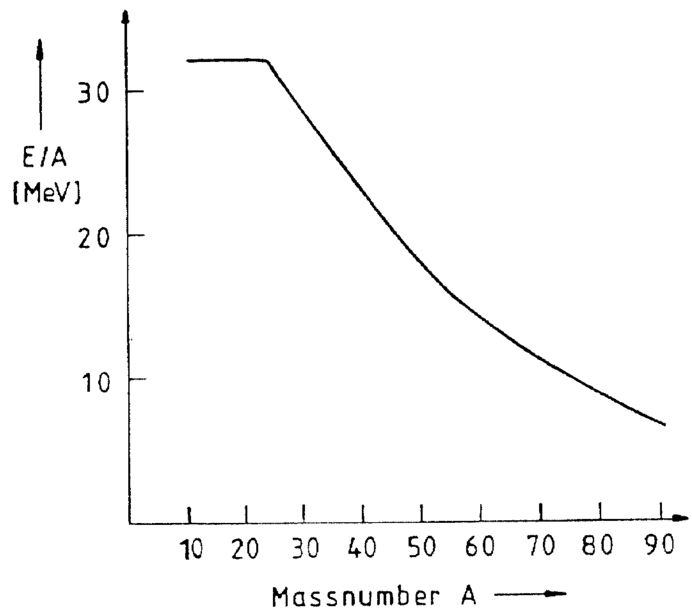

Fig.2: Energy - mass curve for the VICKSI accelerator.

Van - de - Graaff Injector

The single ended Van-de-Graaff[2] is a HVEC CN machine with a maximum terminal voltage of 6 MV. It had been in operation in the institute as a stand alone machine since 1964 and was rebuilt in the midseventies for conversion into a heavy ion injector for VICKSI. A bakable NEC accelerating tube and a newly designed larger high voltage terminal with ion source, charge state selection, prebuncher and 3 einzellenses were built in. The standard ion source is a reliable cold cathode PIG source with axial extraction. For Li-beams a field emitting source is used. The lifetime of the sources generally exceeds 2 weeks. Ion currents of up to 20 µA can be accelerated in the injector without difficulties. The charge transport to the terminal is done by a commercial rubber transport belt[3], which can be sticked together with the belt in place. So there is no need to disassemble the whole machine every year to change the belt as it was necessary with the old HVEC belt. Last year a fast capacitive voltage regulation system has been installed for the Van-de-Graaff, which caused a remarkable increase in the stability of the terminal voltage. All components in the high voltage terminal are computer controlled via an infrared data transmission system.

Tandem Injector

Due to the low maximum terminal voltage of the Van-de-Graaff the bending limit of the cyclotron cannot be reached for beams produced with this injector. Therefore the original plans for VICKSI included a second injector. Due to financial and manpower reasons these plans had to be postponed to 1984 when a vertical tandem[4] could be installed as a second injector with a max. terminal voltage of 8 MV. It was manufactured by Nuclear Electrostatic Corp., Madison,Wisconsin, USA, and has been in routine operation since 1986. We have two negative ion sputter sources, a Hiconex 834 and a Middleton SNICS source, which are run on a 200 kV injector platform. The beamline between platform and tandem contains two electrostatic lenses and a double drift buncher system. In the tandem high voltage terminal, where the negative ions are stripped to multiply charged positive ones, a charge selection system using an offset quadrupole triplet deflects the ions with wrong charge states. A second stripper behind the tandem produces the required charge state for further acceleration in the cyclotron. The power for the elements in the high voltage terminal is provided by two rotating shafts driven from the ground ends. Charging of the high voltage terminal is done by two pellet chains, which are able to transport about 200 μA.

Injection Beam Lines and Bunching System

The beam lines from the two injectors to the cyclotron are telescopic and meet at about 10 m before the cyclotron to use the same adaptation system for matching the beam to the cyclotron acceptance.
To achieve the designed energy resolution of 5×10^{-4}, the length of the beampulses injected into the cyclotron has to match a phase window of $\pm 3°$ in relation to the phase of the accelerating RF. To get as much beam intensity as possible into this phase intervall, the dc-beam out of the ion source is bunched with a time focus at the stripper location and rebunched with a second buncher, which is halfway between the stripper and the cyclotron, to have a time focus at the center of the cyclotron. About 50 % of the dc-beam can be bunched into pulses with less than 1 ns in length at the time foci[5].

Cyclotron

The isochronous cyclotron was designed and built by Scanditronix AB, Uppsala, Sweden, in close cooperation with the Hahn - Meitner - Institut. It consists of four 50° wide sector magnets and two quarter wave RF-resonators with a dee angle of 36° located in opposite valleys. In each magnet there are 12 trim coils to achieve the required radial field distribution for isochronism. For both the injection and the extraction channel three elements, two magnets and one electrostatic deflector, are installed in the cyclotron vacuum chamber. The maximum beam energy is given by :

$$E = 134 \times Q^2/A \ \ [\mathrm{MeV}]$$

Q = charge number
A = atomic mass number

The energy gain factor, i.e. the ratio of the extraction to the injection energy, is 17.3. To achieve the desired beam quality, an extensive diagnostic system has been included in the cyclotron. There are two radial probes to measure the total beam current and the radial beam width. These probes are used for the optimisation of the energy width and for the centering of the circulating beam. On the symmetry line of the extraction valley there are 10 capacitive phase probes to measure the radial variation of the revolution frequency to optimize the isochronism. In general the turns of the circulating beam are well separated from injection to extraction radius. Therefore a single turn can be extracted with a very narrow energy width and with an efficiency of almost 100 %.

Beam Lines to the Target Areas

A modular system of doubly focussing 90°-dipole magnets and telescopic units of two quadrupole triplets transports the beam from the cyclotron to the target areas. 17 locations are available for experiments. Normally a non-dispersive mode of beamline settings is used, but special modes (e.g. doubly dispersive or time compression optics, or emittance matching to experimental requirements) are possible as well. The beam quality is mainly monitored at the various focus places along the beamlines, where standard diagnostic tools such as beam profile monitors, slits and faraday cups have been installed. Beam parameters at the target positions can easily be adapted to the special needs of the experiments. Different pulsing facilities (see below) provide the right time-structure of the beam, the position of the beam is fine-tuned by steerer magnets and the size of the (rectangular) beam spot may be widened homogeneously by means of high frequency wobbler coils.

Pulsing System

Many experiments require a short beam pulse at the target and then no beam for a longer time interval than that given by the cyclotron RF (50 to 100 ns). Therefore VICKSI provides three pulse suppressing systems, one in each injection beam line and one behind the cyclotron. The former let one pulse pass at a chosen repetition rate and deflect the unwelcome beam to a stopper, the latter deflects the small fraction of the beam, which happens to be extracted from the cyclotron after a turn differing from the one of the main stream. These systems can be run in two modes , the „slow" mode for repetition rates of up to 500 kHz, and the „fast" or „RF" mode for repetition rates ranging from 1 to 10 MHz. The suppression rate, i.e. the ratio of unwanted to wanted beam, has been measured to be smaller than 1×10^{-6}.

Accelerator Control System

The VICKSI control system is presently based on PDP-11/44 and PDP-11/84 (Digital Equipment Corp.) processors as control computers and the parallel and serial CAMAC system standards as control interface. Operator consoles use the parallel CAMAC highway, accelerator equipment is interfaced to serial CAMAC loops. As detailed descriptions of the design concept and control philosophy have been given in earlier publications [6-9] only the main features will be repeated here.

The interface hardware and the control software are strictly standardized. The hardware is commercially available or has been made commercially available by tendering with exact specifications of the requirements. The interfacing standards reflect the software design aspects as e.g. the operation protocol which represents the vertical top-down path through the different control system levels.

To be able to standardize the software and to simplify its development all control system information is held in a central data base with entries for each accelerator or physics parameter in engineering or physical units. The data base and the corresponding shareable libraries reside in the transport level of the control system software scheme to hide the hardware access from the man-machine interface and application programs level.

The operator interface that has been provided is easy to use and reflects site and operating aspects. Touch panels lead the operator to the various subsystems, to beam line sections and to sets of distinct device or parameter names, for which the specific control and monitoring variety is displayed on the down-most 'service-page'. This also applies to control procedures or to groups of parameters, which may be controlled simultaneously if their correlating algorithm has been implemented and been given a parameter name. Parameter names may also be directly used if the system is accessed by the interpreter [10] which has been implemented to facilitate e.g. operator intervention or tests in case of failures or for machine physical investigations. As soon as accelerator or physics parameter names have been entered into the system data base, the interpreter handles them as predeclared variables implying automatic process access in acquisition or control depending on the syntactical context.

The control system has been operational since the commissioning of the VICKSI subsystems with mainly two internal changes to make it faster and even more flexible. It has proven its easy extensibility when new accelerator subsystems have been added. Unfortunately enhanced graphics are still missing and are felt to be quite a drawback with regard to present state of the art man-machine interfaces. This disadantage will be eliminated by the prospective upgrade of the control system which is essential to be able to cope with the increasing extensive use of the control system by different groups (e.g. to run the two injectors in parallel for different applications). The major change (within the next two years) will be the implementation of a computer network to decentralize the access capabilities and to make the system extensible with respect to computing power.

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