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STATUS OF THE VICKSI TANDEM INJECTOR PROJECT

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Abstract

The VICKSI accelerator facility is being enlarged by the addition of an 8 MV tandem as second injector. This will allow the acceleration of ions up to mass 30 u to energies of 32 MeV/A and furthermore will produce a variety of ions which are not available from the present Penning ion source installed in the terminal of the existing injector.

At present installation and testing of all subsystems are in progress and we anticipate completion of the project before the end of this year. Routine operation with the tandem injector can start in early 1985.

Introduction

The VICKSI accelerator combination went into operation in 1978[1]. Descriptions of its properties and performance have been given earlier[2,3,4]. Therefore we will only briefly explain the reasons for adding a second injector. The maximum energy available from VICKSI is determined by two limits. One limit is given by by the bending power of the cyclotron magnets, which is

$$E_{max} < 128 \cdot \frac{Q^2}{A}$$

with Q being the charge state of ions with mass A to be accelerated in the cyclotron and with 128 as the K-factor. The cyclotron has a fixed injection- and extraction-radius which means that it acts as an energy multiplier with a multiplication factor of ~17. This leads to the second energy limit determined by the 6 MV maximum terminal voltage of the existing CN-injector:

$$E_{max} < Q_s \cdot 6 \cdot 17 \text{ MeV} \approx Q_s \cdot 100 \text{ MeV}.$$

Q_s being the charge state of the ions extracted from the ion source of the present injector.

Already the early operation since 1978 showed, that the real energy limit for VICKSI is determined by the maximum energy available from the existing injector. Therefore an additional injector which raises the energy limit to that determined by the bending power of the cyclotron magnets is very desirable.

One further limitation of the present accelerator combination is given through the Penning ion source in the terminal of the injector. It can only produce ions from gases and for many ion species it is severely intensity limited for higher charge states. With modern sputter ion sources used with tandem accelerators the variety of ion species which can be accelerated in the tandem-cyclotron combination will be greatly increased.

The maximum required terminal voltage for the tandem injector was determined by taking into account the stripping efficiency of a gas stripping process in the tandem terminal and a gas- or foil-stripping process in front of the cyclotron and imposing an intensity limit of 1 pnA beam on target. A maximum useful terminal voltage of 8 MV was calculated. Actually this voltage is only needed for ions around a mass of 55 u, for higher and lower masses, terminal voltages between 6.5 MV and 7.5 MV are sufficient.

The tandem project was first put forward in 1979. It was partially approved in 1980 and it received full approval in 1981. After that a contract was placed with Electrostatics International, Inc., (NEC/EII) for an 8 UD Pelletron accelerator.

Status of the Project

Building

Due to limitations given through existing buildings the tandem had to be a vertical machine. A tower with a height of 37 m had to be erected next to the cyclotron building (fig. 1). The building permit was received in the beginning of 1982 and in April 82 the groundbreaking for the tandem tower took place. In April 83 the tower had reached the full height and installation work in the interior started. Several steel platforms were mounted as well as electrical power, cooling water, heating systems and the elevator. By the end of October 83 the building was essentially ready and the installation of the ion source platform, the beam lines and the tandem injector could start.

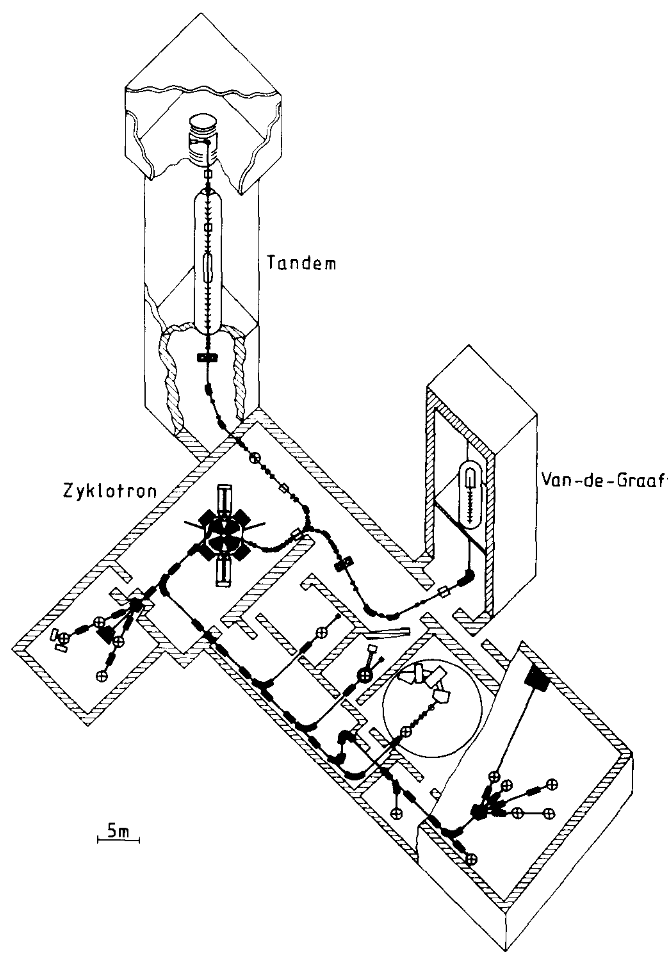

Fig. 1: Layout of the VICKSI-facility with 6 MV type CN Van-de-Graaff and 8 MV Pelletron Tandem injectors

Gas Handling System

The gas handling system of the existing Van-de-Graaff was completely rebuilt and enlarged to be able to handle the two electrostatic machines. To accommodate the additional gas volume of the tandem an extra storage tank was added. A new helium leak tight compressor was installed to minimize SF_6 losses during gas transfers as well as a roots blower combination to extract all SF_6 from the accelerator tanks before opening. Each accelerator has its own purifying and drying circulating system and a third system can be used to dry the gas in either of the storage tanks.

The gas handling system has been operational on the CN-injector for well over one year now and for the tandem accelerator also several gas transfer cycles have been completed successfully. The turn around time for the CN-injector with its ~34 m^3 tank is about 3.5 h, while one transfer from storage tank to accelerator or reverse takes about 3 h for the tandem.

The 8 UD Pelletron

The tank of the tandem accelerator was built by a German company. The NEC design for the tank had to be slightly modified to meet German safety regulations and also to make use of prefabricated parts. The tank is 15 m high and has an inside diameter of 3.1 m. Manholes are provided at the low energy end, the terminal and the high energy end of the machine. 25 windows allow the inspection of almost every part of the machine. An annular service platform is installed in the tank, which rests on the bottom of the tank during operation.

The column of the 8 UD accelerator consists of 9 sections (diameter: 1.07 m) at the low energy end, of the terminal (length: 3.05 m, diameter: 1.12 m), and of 8 sections in the high energy end. One of the sections half way down the low energy column is a dead section housing a vacuum pump and an electrostatic quadrupole triplet lens. The terminal is equipped with a gas/foil stripper assembly, an offset quadrupole charge state selector and an electrostatic matching lens. Furthermore the necessary pumping is provided in the terminal as well as an aperture/Faraday-cup arrangement for beam diagnosis. Isolation valves, one at each end of the terminal, allow for separation of the terminal vacuum from the vacuum in the low energy- and high energy-acceleration tubes.

In the high energy column two pellet-chains are provided to deliver up to 100 µA of charging current each. Power to the terminal and dead section is delivered through rotating shafts driven from either end of the column. Potential grading along column and accelerating tubes is done through open corona systems.

Before delivery the complete column was erected in the tower at the NEC plant and tests concerning the pellet-chains, the rotating shafts, and all equipment in the terminal and the dead section have been performed. The column was then dismantled and shipped to Berlin where it arrived in October 83. In the second half of November we started to mount the accelerator in the tank and by christmas the column was erected. By the end of February 84 all the wiring had been completed and voltage tests on the column could start. At different pressure levels the terminal voltage was raised until sparks occurred. At each pressure several sparks were produced. They allways occurred at the same voltage and no "conditioning" could be observed. At a SF_6 pressure of 6 bar a voltage of 10.6 MV was reached. This voltage figure was derived from the column corona current which had been calibrated at other NEC accelerators. The calibration should be accurate to ±5 %.

With the voltage tests completed, the installation of the accelerating tube was started in the middle of March this year. Presently preparations for vacuum pumping and heating of the tubes are in progress.

Ion Source Platform

The ion source platform was also ordered from NEC. It was delivered in August 1982. The 200 kV deck is a cylindrical design of 3.5 m diameter supported on 8 legs in upper and lower insulated stacks. Included in the platform order were two ion source modules equipped with a Hiconex 834 and a SNICS ion source respectively. On delivery the platform was erected in a laboratory in Berlin and first experience with the ion sources has been obtained. With both sources beams of carbon and sulphur ions with microampere intensities have been produced. On the platform the necessary focusing and steering elements are provided as well as a 90^0 double focusing analysing magnet with ME = 7.5 u. The 200 kV preacceleration tube is a NEC general-purpose type. Potential grading along the upper and lower legs and along the tube is done with resistors.

After completion of the tandem tower the platform has been moved to the ion source room on top of the tower. It is essentially ready for further ion source tests and operation.

Beam Line between Injector and Tandem

The low energy beam line between the injector and the tandem is designed to provide good beam diagnostic of the beam from the injector and to bunch the beam before injection into the tandem. All necessary diagnostic elements like Faraday cups, slits, and beam profile monitors are provided as well as an emittance measuring device. Two electrostatic quadrupole triplet lenses for focusing and a double-drift harmonic bunching system are also included in this beam line.

All elements for this line are delivered and tested. The installation is proceeding and it is scheduled to be completed by the end of May.

The Bunching System

In front of the tandem two bunching units will be located which are separated by a drift length of .75 m. The first unit operates on the cyclotron frequency and the second at double that frequency. We expect to bunch 60 % of the dc-beam intensity. The bunching units are driven by broad band RF-amplifiers of 300 W and 150 W respectively. The units are ready and tested at full power in the laboratory and they are awaiting installation in the beam line.

Between the tandem and the cyclotron a third buncher is located to provide a time focus at the cyclotron center. This unit is in principal identical to the bunchers in the existing injection line with some modification to alleviate installation and service. It will share the control-electronics and the power amplifier with one of the bunchers in the CN injection line through the use of an appropiate switching system. This unit is mechanically finished and presently being tested in the laboratory.

The Beam Line between Tandem and Cyclotron

Behind the tandem a magnetic quadrupole triplet will focus the beam into a gas/foil stripper assembly. An achromatic bending system consisting of two 45^0 bending magnets and two quadrupole doublet lenses will bend the beam into the horizontal plane, where a quadrupole triplet telescope will transport it to a switching magnet joining the existing beam line 8 m in front of the cyclotron. All magnetic and electrical components for this transport system are in house. The support structure for the bending unit is under construction and due for delivery in the first week of May. The horizontal part of the beam line is already assembled and under vacuum, while presently the vertical part with the triplet lens and the stripper is being assembled. The whole transfer line is due to be installed, aligned, electrically connected to the power supplies and the control system, to be ready for beam transfer in the middle of July.

The Control System

All elements of the new injector, the ion source platform and the beam-transfer system will be connected to the existing control system[5,6] through an additional serial CAMAC loop. All necessary hardware is in house and tested and the accelerator elements are connected to the control system as they are installed in their final location.

Time Schedule and Conclusion

The time schedule for the remaining part of the project is as follows: during May vacuum pumping, heating, leak testing of the 8 UD accelerating tubes and installation work on the other systems will continue. In June we hope to start conditioning the tube of the 8 UD with hopefully a first beam through the tandem in the first half of July. During July and August all other systems will be tested and run in to be able to make the acceptance tests with beam for the 8 UD in September. Thereafter tests with beam for the whole injector system will take place with injection into the cyclotron from time to time. During the last quarter of this year we plan to familiarize ourselves with the operation of the new injector system, establish and optimize the setting procedures and train the operators. By the end of this year the project should be completed, so that planned operation of VICKSI with the 8 UD as injector can start at the beginning of 1985. This is a delay of about 6 months against a time plan drawn up when the project was approved in 1981. Most of this delay is due to the time we had to wait for the building permit of the tower. During the whole project and particularly now it is apparent that the available manpower is a major constraint especially as we operate the existing facility practically without interruption. In light of this fact the delay of half a year appears quite acceptable.

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