STATUS OF ISL

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Abstract

During the last couple of years the scientific activities at the former VICKSI [1] facility have been switched to applications of ion beam techniques in medicine, modification of materials, and materials analyses. The nuclear physics programmes were no longer supported. With the new activities, the requirements on the accelerator specifications, beam guiding systems, and target areas have changed as well. The facility got the new name ISL[1] (Ionen-Strahl-Labor). Within a period of 6 years the facility has been rearranged. Major projects in this reorientation process were the installation of a new RFQ accelerator operating as injector for the cyclotron and the installation of a medical beam line to treat ocular melanoma with fast protons.

1 INTRODUCTION

Besides the limits set by the cyclotron specifications, the characteristics of the facility in terms of ion species and ion energies are determined by the ion sources and the injectors. With the development of powerful ECR ion sources, the original VICKSI concept of a high energy injector and a stripper before injection into the cyclotron became partly obsolete. In particular, this concept did not allow the production of very heavy ions and higher currents, two strong demands arising from the anticipated scientific programme. Stripping efficiencies for the necessary charge states become extremely low, and foil stripper live times decrease drastically with higher beam currents and heavier ions. To achieve the new goal - higher currents and heavier ion masses - a new injector has been installed. In addition, several measures were taken to improve the reliability and short as well as long term stability of the facility

2 NEW ACCELERATOR EQUIPMENT

The layout of the facility is shown in fig. 1. Two injectors, a 5.5 MV Van de Graaff and a RFQ, can alternatively inject their beams into a separated sector cyclotron. The first injector needs a stripper between both accelerators. Three low energy target areas can be supplied with van de Graaff beams. High energy beams are available at 12 stations. A so-called dual beam line allows irradiations of samples with both low and high energy beams simultaneously or consecutively. A special room is dedicated to eye tumour radiotherapy with fast protons.

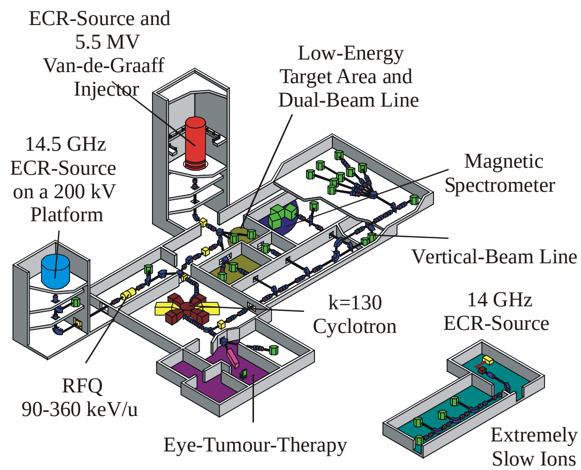

Figure 1 : Layout of the facility

2.1 *Van de Graaff Injector*

A first important step in the accelerator upgrade programme was the installation of new ion source operating on the high voltage terminal of the 5.5 MV Van de Graaff injector. It is a 5 GHz ECR ion source [2], fully equipped with permanent magnets operating at moderate RF power (100 Watts). After some improvements of the ion source extraction system and the fast high voltage regulation system [3] this injector produces a very stable ion beam.

2.2 *RFQ Injector*

To reach final energies of 1.5 to 6 MeV/n after the cyclotron, ion charge to mass ratios between 1/8 and 1/5 are necessary. These values can be achieved by powerful ECR ion sources for almost all ions. Possible accelerators acting as injectors for the ISL cyclotron are either a small compact injector cyclotron or a RFQ structure. After considering both solutions in detail [4,5] the RFQ option was chosen. In collaboration with A. Schempp a RFQ design [5] fulfilling the demands of continuous mode operation and the necessary energy variation has been developed. Basic features of this design are: i.) a relatively high injection energy, ii) a separate bunching system with

[1] http://www.hmi.de/isl/ * diseased 4. April 2000

CP600, *Cyclotrons and Their Applications 2001, Sixteenth International Conference,* edited by F. Marti

the cyclotron frequency in front of the RFQ and iii.) frequency variability and 2-stage operation of the RFQ allowing a total energy variation of a factor of 4. The layout of the RFQ injection system is shown in figure 2.

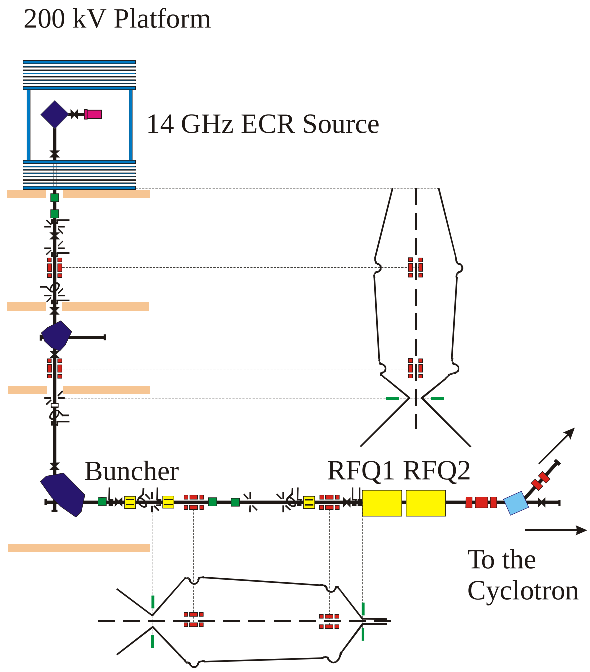

Figure 2 : RFQ injection.
Ions from the ECR source are preaccelerated, bunched and injected into the RFQ. The beam envelopes are shown at the left-hand side and at the lower part of the figure.

The RFQ is described in detail in ref. [6] and [7]. It was manufactured by the German company NTG (Neue Technologien) under the supervision of the Frankfurt Group [8] and was delivered to HMI by the end of 97. After an installation period of 5 months, the first beam was accelerated in May 98, two hours after the power had been switched on. This confirmed the basic correctness of the design and the construction of the electrodes immediately. In fall 1998, the first beam was injected into the cyclotron. The first tests disclosed the basic tuning problems connected with the existing design. The injection of the RFQ beam into the cyclotron imposes severe constraints on the energy stability of the beam from the platform, the phase relation between the buncher and the RFQ, and the phase relation of the two RFQ stages with respect to each other. Small deviations in phase influence both the energy and the rotation of the phase ellipse at the exit of the RFQ. The long flight path from the RFQ to the cyclotron (shown in detail in fig. 3) amounts to more than 10000^0 in cyclotron RF-phase. Thus, small changes in energy at the exit of the RFQ lead to considerable phase shifts of the beam pulses arriving at the first acceleration gap of the cyclotron.

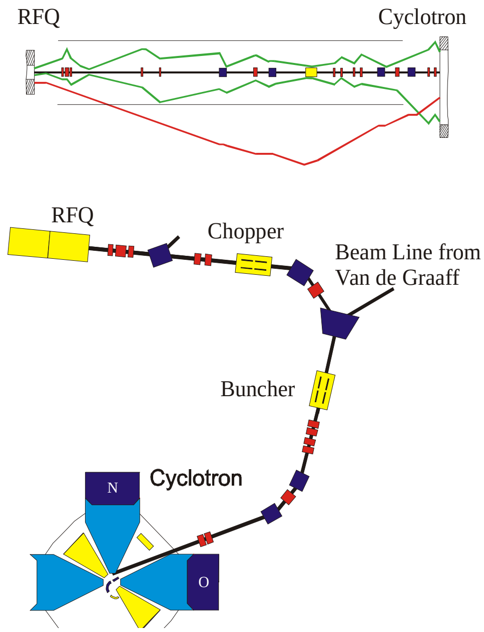

Figure 3: Beam transport from the RFQ to the Cyclotron
The upper part shows the beam envelope and the time evolution of the beam pulses. The total path length from the RFQ to the cyclotron is about 20 m.

In a series of detailed measurements properties of accelerated and transported beams have been investigated [9]. An example of energy shifts depending on the RFQ1-RFQ2 phase relation is shown in figure 4. With comparable transmissions (see insert in fig.4) completely different energy distributions are observed. It is obvious that both phase settings require a different tuning of the beam guiding elements in the injection path from the RFQ to the cyclotron. The strong interdependence of the longitudinal and transversal phase space impedes a fast tuning. To overcome the problems a very careful and accurate calibration of all parameters is necessary. This work is currently under way. Total beam transmissions from the ion source to the target of 15 to 20% are usual though tuning times are sometimes rather long. The maximum transmission observed so far was 30%. These numbers include the 50% bunching efficiency of the bunchers in front of the RFQ. With these transmission values the system provides an excellent injector solution for the cyclotron, in particular for very heavy ion beams.

3 SCIENTIFIC PROGRAMME

Ion beams at ISL are more or less exclusively used for ion beam applications in different fields of research and technology. The major active fields are medical applications (~15%), modification of materials (~35%), and materials analyses (~25%). More than 60% of the beam time is given to outside users.

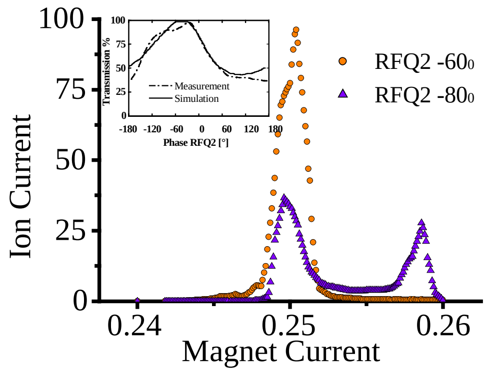

Figure 4: Selected energy spectra for different phases of RFQ2

3.1 Medical applications

In cooperation with the medical partners from the university hospitals of the Freie Universität Berlin and the Universität Essen radiotherapy with fast protons is applied to ocular melanomas. Starting in July 1998 [10] 200 patients have been treated up to now. In addition to routine therapy, research and development aiming at improvements of treatment planning is performed.

3.2 Materials Analyses

The materials analyses activities involve both the heaviest and the fastest ions available. At high energy ERDA (elastic recoil detection analysis) heavy ions with energies up to 2 MeV/n are utilised [11] to analyse the composition profile of thin layers. With fast protons (68MeV) employing high energy PIXE (Proton induced X-ray emission) [12] heavy elements in or hidden underneath thick layers are determined.

3.3 Modification of materials

Effects of the high energy deposition involved with the heavy ion impact such as strong electronic excitations [13] and the subsequent modification of the solid state structure [14] are studied to uncover the track formation process. The irradiation of polymer foils for microfilter production is the strongest field of direct applications.

4 OPERATIONS

The accelerators operate 18 to 19 days per month with three major shutdowns in spring, summer, and fall. Until 1998 increased shutdown periods were necessary for the renewal of the infrastructure and the installation of the RFQ. For the proton therapy 10 five-day periods per year are foreseen. Details of the operation statistics are displayed in figure 5.

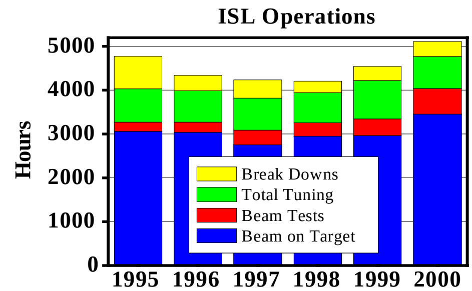

Figure: 5 ISL Operations

An average of 3000 h/year of beam time on target has been delivered during the last six years. The increase of beam time after 98 reflects the .start of the RFQ operation.

5 FUTURE PLANS

Ion source development is the major issue for the near future. This involves a new 10 GHz ECR source on the Van de Graaff terminal and a second platform with 14.5 GHz ECR source for the RFQ injector.

For the study of modifications of materials two new target areas are foreseen, one of them allowing in-situ X-ray diffraction analysis of irradiation induced structural modifications.

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