EXPERIENCE AT THE ION BEAM THERAPY CENTER (HIT) WITH 2 YEARS OF CONTINUOUS ECR ION SOURCE OPERATION

T. Winkelmann, R. Cee, T. Haberer, B. Naas, A. Peters, S. Scheloske
Heidelberger Ionenstrahl-Therapie Centrum (HIT), D-69120 Heidelberg, Germany

ABSTRACT
Radiation therapy with heavy ions is an upcoming cancer treatment method with the advantage of minimized normal tissue damage. The facility of the Heidelberg Ion Beam Therapy Center (HIT) [1] is the first dedicated proton and carbon ion therapy facility in Europe. HIT is located at the radiological university hospital in Heidelberg (Radiologische Universitätsklinik Heidelberg, Germany). The acceptance tests with beam started in 2006, when sources, low energy beam transport system (LEBT) and the lineal accelerator (LINAC) were commissioned [4], followed by synchrotron [5] and high energy beam transport system (HEBT) in 2007 and 2008. The first turn of the synchrotron was achieved in February 2007, the first beam in the treatment place was seen in March 2007. Beam performance for protons and carbons had reached a level enabling patient treatment at the two fixed beam patient treatment places by December 2007, at the experimental area by April 2008. Gantry commissioning started at January 2008 [6]. The beam production at HIT consists of two 14.5 GHz permanent magnet ECR ion sources from PANTECHNIK [7]. The 7 MeV/u injector linac [2] (Figure 2) comprises of the LEBT, a 400 keV/u radio frequency quadrupole accelerator (RFQ) [8], and a 7 MeV/u IH-type drift tube linac (IH-DTL) [3,8,9]. The linac beam is injected in a compact 6.5 Tm synchrotron [10] with a circumference of about 65m to accelerate the ions to final energies of 50 – 430 MeV/u which is the key to the enormous variety of beam parameters provided by the HIT accelerator. The beam is distributed by the high energy beam transport line (HEBT) to the four beam stations. There are two horizontal fixed beam stations for patient treatment. In station three the beam is guided along an isocentric gantry. The fixed beam station for quality assurance is dedicated to development and research activities. All places are fully equipped for a 3D raster scan volumetric conformal irradiation.

OPERATION OF THE ION SOURCE

During the first two years of operation mainly carbon ions were used by 60 %, followed by hydrogen (38 %), helium (1 %) and oxygen (1 %). The continuous operation runtime of the two sources are 330 days per year 24 h 7 days a week operation, our experience with two years of continuous operation will be presented, with special emphasis on stability and breakdowns of components. In addition, an outlook of further planned developments at the HIT ECR ion sources will be given.

Table 2: Specified ion species and intensities behind the 90% analysing magnet.

<table>
<thead>
<tr>
<th>Ion</th>
<th>I / epA</th>
<th>I / epA</th>
<th>U_{peak} / kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>H²⁺</td>
<td>1000</td>
<td>1000</td>
<td>16</td>
</tr>
<tr>
<td>He¹⁺</td>
<td>500</td>
<td>500</td>
<td>24</td>
</tr>
<tr>
<td>C⁶⁺</td>
<td>150</td>
<td>200</td>
<td>24</td>
</tr>
<tr>
<td>O²⁺</td>
<td>150</td>
<td>150</td>
<td>21.3</td>
</tr>
</tbody>
</table>

DEVELOPMENTS

After 2 years of permanent operation the ceramic isolator showed relevant evaporation. Pantechnik supplied us with a longer first electrode (puller electrode) to make an overlap of 3mm to minimize the evaporation, see Figure 7. In order to increase the lifetime of the extraction system components we are presently running particle optics simulations for a reduction of evaporation.

Based on particle optics simulations performed by HIT a new extraction system was designed. As a next step COBRA simulations will be performed jointly with GSI to study the properties of the new design. The goal for this new design is a better long time stability in combination with extended maintenance intervals. The beam transport with a smaller emittance and better isolator shielding could be achieved by simulations. This new design will also allow an optimized position of the pumps, we found out that the durability is better when the turbo pump run in vertical plane.

OUTLOOK

Figure 4: Spectrum of one of the ECR ion sources. The peak at Br = 0.0386 Tm corresponds to the desired 16²⁺ for carbon operation.

Figure 5: 3D-Model of the first extraction system that HIT bought with the source, design by PANTECHNIK S.A., Caen, France [7].

Figure 6: Isolator after 3 weeks of CO₂ operation of the first extraction system that HIT bought with the source (e.g. Figure 5).

Figure 7: The new design of the extraction system by PANTECHNIK S.A., Caen, France [7]. The puller electrode got an overlap with the focus electrode.

The following developments are planned:
- A new extraction system for a stable beam and better focusing will be build.
- Intensity gain can be obtained by varying the microwave frequency within a narrow range around the centre frequency.