THE 7-GAP-RESONATOR-ACCELERATOR FOR THE
REX-ISOLDE-LINAC*

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Abstract

The REX-ISOLDE-Experiment which is presently being
under construction at CERN is intended to investigate ex-
otic, very neutron rich, radioactive nuclei. A linear accel-
erator will deliver radioactive beams which are produced
by the isotope separator ISOLDE, with energies between
0.85 and 2.2 MeV/u. The Linac will consist of a RFQ-
accelerator, an interdigital H-Structure (IH) and three 7-
gap-resonators for variable final energy [1].

Assuming an acceleration voltage of one 7-gap-resonator to
be 1.75 MV at 90 kW rf power, the design velocities of the
three resonators were chosen to be 5.4%, 6.0% and 6.6% of
the velocity of light. Three downscaled models (1:2.5) were
built in order to optimize the shuntimpedance and the field-
distribution for the operating frequency of the amplifiers of
101.28 MHz.

The development of the resonators was accompanied by
extensive MAFIA calculations. It could be demonstrated
that spiral-resonators like 7-gap-resonators can be calcu-
lated with MAFIA. Important quantities like frequency,
shuntimpedance, quality factor and field distribution were
compared between simulation and measurement.

The first two power type resonators (5.4% and 6.0%) are
finished, frequency tuning and low power measurements
were done. The Q-values are about 5560 and 5280, respec-
tively, the shuntimpedance 71 MΩ/m and 68 MΩ/m, respec-
tively, and are in very good agreement with the model mea-
surements. After preparation for high power tests a beam
test for the voltage calibration is planned. In this paper the
status of the production of the 7-gap-resonators is reported.

1 INTRODUCTION

The high energy section of the REX-ISOLDE Linac
(see fig.3) consists of three 7-gap resonators similar to
those built for the new high current injector at Heidelberg
[2]. Each resonator has a single resonance structure which
is shown in fig.1. It consists of a copper half shell to which
three copper arms are attached on each side. Each arm
consists of two hollow profiles, surrounding the drift tubes
and carrying the cooling water. Copper segments on both
sides of the half shell allow to tune the resonator to the
rf frequency of 101.28 MHz. A tuning plate corrects the
detuning effects due to the temperature changes of the tank
or half shell during operation. The rf power will coupled
into the resonator near one of the three legs, where the
magnetic flux is maximum. Assuming a realistic resonator
voltage for each resonator of approximately 1.75 MV for
90 kW rf-power (duty cycle 1:10), the design velocities
were chosen to 5.4%, 6.0% and 6.6% of the velocity of light [3].

2 OPTIMIZATION AND TUNING

Three down scaled models were built in order to optimize
the field distribution of the push pull mode used for acceler-
ation and to tune the eigenfrequency. Therefore the drift
tubes and the arms of the models are movable in the half
shell. The capacity between the arms is changed by rotation

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* Work supported in part by the German Federal Ministry for Edu-
cation, Science, Research and Technology (BMBF) under contract No.
06HD802I and No. 06LM868I(2).
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of the arms against each other. Fig. 2 shows the phase shift distribution along the beam axis before and after optimization. The result of the optimization is a flat field distribution between the inner drift tubes. All field measurements were made with the bead perturbation measurement method. A small perturbation bead influences the electric field of the resonator. This causes a phase shift $\Delta \phi$ between the signals of the signal generator and the resonator. This phaseshift is proportional to the square of the unperturbed electric field.

Fig. 4 (left) shows the frequency of the three models as a function of the position of the tuning plate. Driving the tuning plate results in a variation of the capacity between the resonance structure and the plate and therefore a frequency shift. The copper segments are used to tune the resonators to the frequency of the amplifiers by changing the inductance of the resonance structure. Fig. 4 (right) shows the linear behavior of the frequency as function of the thickness of the segments attached to the ends of the half shell. Table 1 summarizes the measured main parameters of the three model resonators [4].

<table>
<thead>
<tr>
<th>Parameter</th>
<th>5.4%</th>
<th>6.0%</th>
<th>6.6%</th>
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</thead>
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<tr>
<td>$f$ (MHz)</td>
<td>253.2</td>
<td>253.2</td>
<td>253.2</td>
</tr>
<tr>
<td>Q-value</td>
<td>3315 ± 30</td>
<td>3340 ± 30</td>
<td>3180 ± 30</td>
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<tr>
<td>$Z$ (M$\Omega$/m)</td>
<td>113 ± 7</td>
<td>105 ± 6</td>
<td>106 ± 8</td>
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Table 1: Measured parameters for the (2.5:1) model resonators, $f$ = frequency, $Z$ = shuntimpedance

3 POWER TYPE RESONATORS

Two of the three power type resonators are already finished. Fig. 5 shows the 5.4% power type resonator with resonance structure and plunger prepared for low level rf measurements. After tuning the eigenfrequency of the push-pull-mode to the operation frequency of the amplifiers (101.28 MHz) the Q-values were determined to 5560 (5.4%) and 5280 (6.0%) respectively. The shuntimpedances are 71 M$\Omega$/m and 68 M$\Omega$/m. With an rf power of 90 kW we can expect a resonator voltage of 1.9 MV for both resonators. The resonators are now ready for high power and beam tests. Fig. 6 shows the first delivered rf-amplifier which provides an rf power of 100 kW with a duty cycle of 10%. Table 2 summarizes the results of the low level rf measurements of the power type resonators.

4 MAFIA SIMULATIONS

The development of the resonators was accompanied by extensive MAFIA calculations [5]. To investigate the eigenfrequency and voltage distribution in the gaps MAFIA is a
Table 2: Measured parameters for the power type resonators, \( f \) = frequency, \( Z \) = shunt impedance, \( N \) = power consumption, \( U_0 \) = resonator voltage (extrapolated)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>power type resonators</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>5.4%</td>
</tr>
<tr>
<td>( f ) [MHz]</td>
<td>101.28</td>
</tr>
<tr>
<td>Q-value</td>
<td>5560 ± 110</td>
</tr>
<tr>
<td>( Z ) [( \Omega )/m]</td>
<td>71 ± 7</td>
</tr>
<tr>
<td>( N ) [kW]</td>
<td>90</td>
</tr>
<tr>
<td>( U_0 ) [MV]</td>
<td>1.90 ± 0.1</td>
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</tbody>
</table>

very powerful calculation code. It could be demonstrated that the frequency of the 7-gap-resonators can be calculated with an accuracy of better than 1% for the push pull mode. The calculated quality factor Q and shunt impedance \( Z \) are always a factor of about two too high [3]. The power losses inside a 7-gap-resonator are also calculated in order to check the cooling water requirements. These investigations have shown that about 75% of the rf power is dissipated at the resonance structure half of which is lost at the arms, which therefore have to be cooled very effectively.

5 BEAM DYNAMICS

Beam dynamic calculations were made to optimize the transmission of the beam to the target [3]. Final energies between 0.85 and 2.2 MeV/u with nearly 100% transmission can be realized. The acceptance of the three resonators in the x-plane is 1.2 \( \pi \) mm mrad (norm.) and in the y-plane 3.0 \( \pi \) mm mrad (norm.). The bunchlength of the fully accelerated beam (2.2 MeV/u) is 2.4 ns at the target, which can be further improved – if necessary – by a rebuncher before the target. Fig. 7 shows the calculated envelope of both transverse directions between the last resonator and the target. Because of the relatively wide transit time factor of the 7-gap-resonators they can be used to vary the output energy of the linac. Even a deceleration of the beam from the IH-structure from 1.1 MeV/u down to 0.85 MeV is feasible.

6 REFERENCES