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 exotic, very neutron rich, radioactive nuclei. A linear accelerator 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 calculated 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, respectively, the shuntimpedance 71 MΩ/m and 68 MΩ/m, respectively, and are in very good agreement with the model measurements. 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].

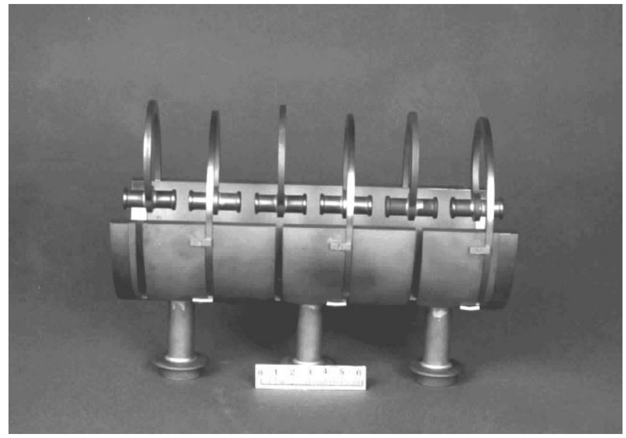

Figure 1: Resonance structure of the 6.0% model (2.5:1)

2 OPTIMIZATION AND TUNING

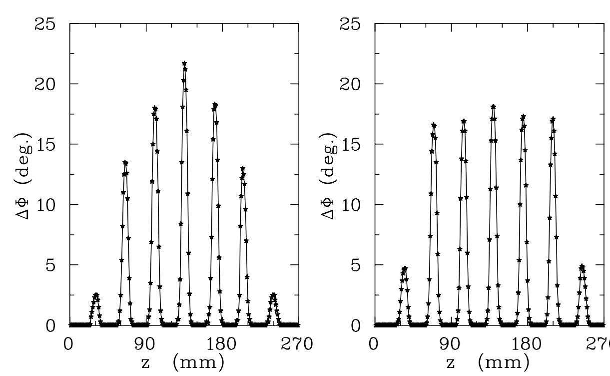

Figure 2: Phase shift distribution (square of the E-field) of the detuned (left) and optimized (right) 6.0% resonator model (push pull mode).

Three down scaled models were built in order to optimize the field distribution of the push pull mode used for acceleration 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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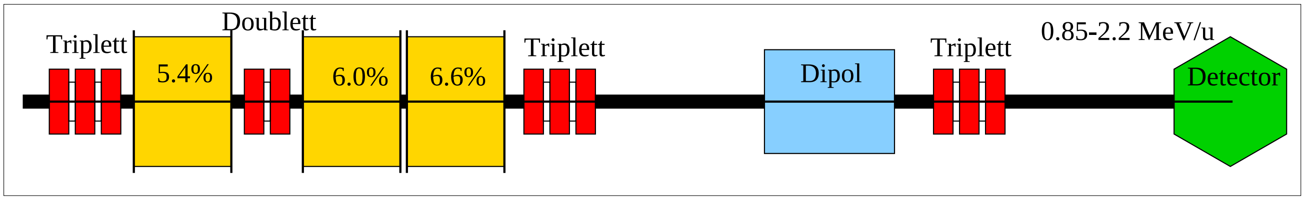

Figure 3: Lay-out of the 7-gap-resonator-accelerator forming the high energy part of the REX-ISOLDE-Linac

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

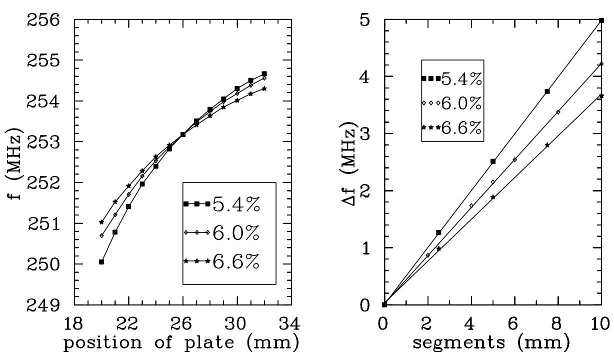

Figure 4: Frequency of the models (2.5:1) as function of the position of the tuning plate (left) and thickness of the segments (right).

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].

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

Parameter	model resonators		
	5.4%	6.0%	6.6%
f (MHz)	253.2	253.2	253.2
Q-value	3315 ± 30	3340 ± 30	3180 ± 30
Z (MΩ/m)	113 ± 7	105 ± 6	106 ± 8

Table 1: *Measured parameters for the (2.5:1) model resonators, f=frequency, Z=shuntimpedance*

Figure 5: The 5.4% power type resonator prepared for low power rf measurements

shuntimpedances are 71 MΩ/m and 68 MΩ/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

Parameter	power type resonators	
	5.4%	6.0%
f [MHz]	101.28	101.28
Q-value	5560 ± 110	5280 ± 105
Z [MΩ/m]	71 ± 7	66 ± 6
N [kW]	90	90
U_0 [MV]	1.90 ± 0.1	1.90 ± 0.1

Table 2: *Measuered parameters for the power type resonators, f=frequency, Z=shuntimpedance, N=power consumption, U_0=resonator voltage (extrapolated)*

Figure 6: The first of three 100 kW amplifier delivered in December 1998. Left RF part, middle HV rack, right control rack

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 shuntimpedance 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 π mm mrad (norm.) and in the y-plane 3.0 π 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.

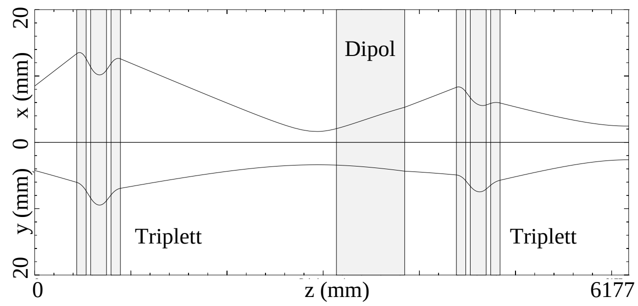

Figure 7: Calculated envelope in x and y direction between the last resonator and the target.

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