9th International Particle Accelerator Conference IPAC2018, Vancouver, BC, Canada JACoW Publishing
ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPAF079

SCALED ALVAREZ-CAVITY MODEL INVESTIGATIONS FOR THE UNILAC UPGRADE

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Abstract

The 1:3 scaled aluminum model of an Alvarez-type cavity with 10 gaps was used for comparison of simulations with measurements for the frequency and the electric field on axis. The scaled frequency is 325.224 MHz and an Alvarez cavity has a small frequency tuning range. With this scaled model it was possible to apply different stem configurations for each drift tube to damp parasitic modes and to increase the field stability. The new drift tubes have an optimized free-formed profile on the end plates in order to increase the shunt impedance. In special the assembly, positioning and alignment of the drift tubes can be tested and the frequency change can be investigated in this respect.

INTRODUCTION

The existing Universal Linear Accelerator (UNILAC, Fig. 1) at the GSI (Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany) is together with the synchrotron SIS18 the main injector for the upcoming FAIR project (Fig. 2) [1]. The existing Alvarez-DTL has been in operation for more than 40 years and accelerates protons up to uranium in pulse-to-pulse-switch mode at 50 Hz for parallel operation with different energies on target. FAIR imposes new requirements for the UNILAC in terms of beam intensity, quality and high availability. An extensive upgrade

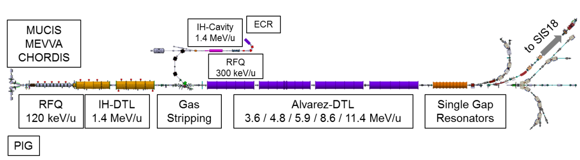

Figure 1: Schematic overview of the GSI UNILAC.

program at the UNILAC has already started to address these FAIR-requirements [2]. The Alvarez-DTL will be replaced by a upgraded Alvarez (Table 1) with a new adapted beam dynamics, an optimized drift tube geometry, to reach a homogeneous surface field and an increased shunt impedance per surface field [3–5]. A test bench with a 10-gap aluminum 1:3 scaled Alvarez-type model for low power RF-measurements is used to investigate the frequency, mode separation, voltage distribution on the beam axis and the field tilt sensitivity [6]. This scaled model will be used to crosscheck the frequency deviation between simulation and measurement.

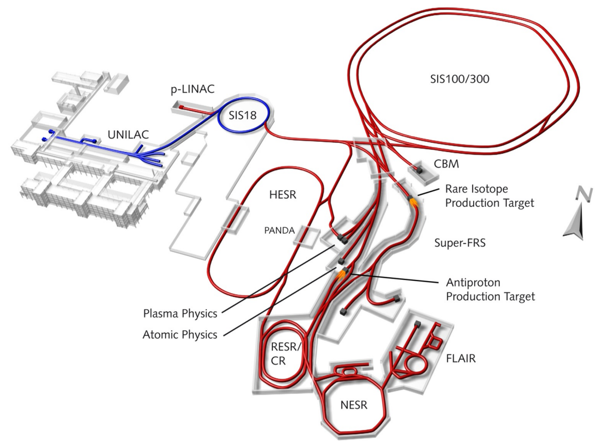

Figure 2: Schematic overview of FAIR.

Table 1: Parameters for the Upgraded UNILAC

Parameter	Unit	Value
RF-frequency	MHz	108.408
A/q		≤ 8.5
Max. Current	mA	1.76×A/q
Synchronous phase	deg.	-30 / -25
Input beam energy	MeV/u	1.358
Output energy	MeV/u	3.0 – 11.4
Hor. emittance (norm., tot.)	µm	≤ 0.8
Ver. emittance (norm., tot.)	µm	≤ 2.5
Beam pulse length	ms	≤ 1.0
Beam repetition rate	Hz	≤ 10
Alvarez-cavities	#	5
Drift tubes / cavity	#	21 – 54
Drift tube length	mm	109.9 – 327.0
Drift tube diameter	mm	180 – 190.3
Aperture	mm	30 / 35

1:3 SCALED ALVAREZ-MODEL

The simplified scaled Alvarez-model was used primarily to investigate the stabilization scheme (tilt sensitivity) [6, 7]. The frequency difference between the CST STUDIO SUITE-simulation [8] and the measurements is another important topic be investigated for the new Alvarez-DTL. The model shown in Fig. 3 has nine drift tubes and the stems can be

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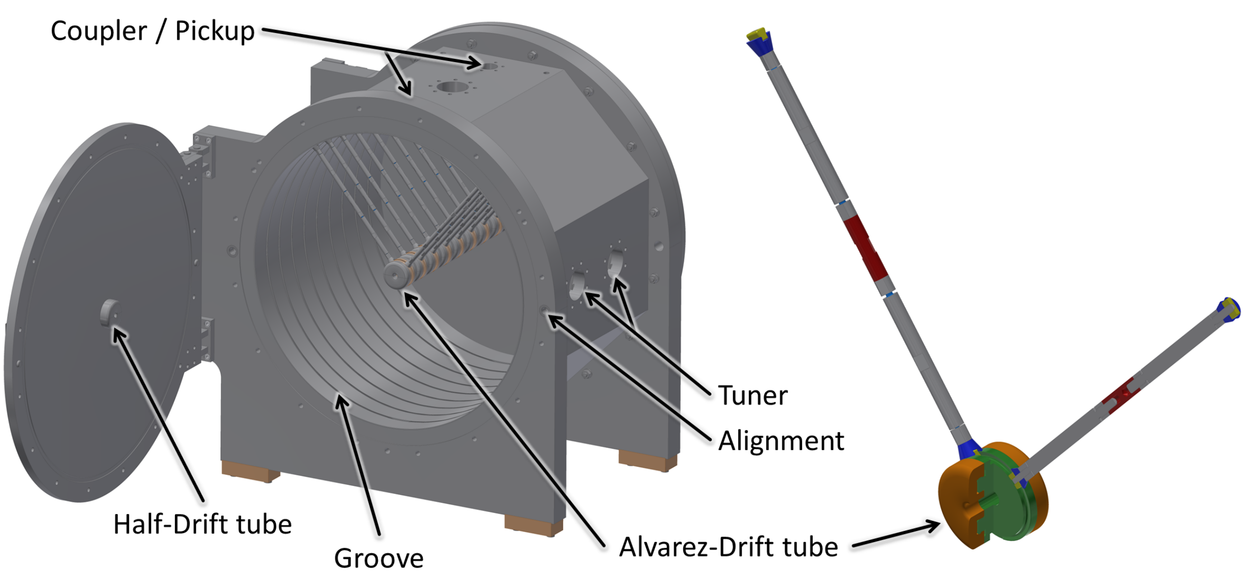

Figure 3: CAD-model of the 1:3 scaled Alvarez-model with nine drift tubes. The drift tubes are installed on the top of the tank and the stems can rotate individually in the groove. The tuners are on the side and the coupler and pickup are installed on the top. The material of the scaled tank and the (half-) drift tubes are aluminum; the stem components are stainless steel.

Table 2: Parameters of the 1:3 scaled Alvarez-Model

Parameter	Unit	Value
RF-Frequency	MHz	325.224
Gaps	#	10
Gap length	mm	12.7 – 13.5
Drift tubes	#	9
Drift tube length	mm	38.1 – 40.8
Drift tube diameter	mm	60.0
Aperture	mm	10.0
Tank diameter	mm	634.5
Tank length	mm	525.7
Q - Factor		45000

rotated by 360° individually for each drift tube (Table 2). Inside of all drift tubes and also at the position of the drift tube is a groove inside of the aluminum tank and the stems are mounted with slot nuts for the individual positioning of the stems. For the investigation of the tilt sensitivity and for optimization of the electrical field distribution along the beam axis, its possible to change the gap between neighboring drift tubes by unscrewing the end plates. The endplates of the drift tubes have an optimized profile to increase the shunt impedance per surface field [9]. The tank has three inductive plungers and both end plates of the scaled cavity can be opened easily for fast stem movement between the measurements. The scaled model can be extended with a second scaled tank up to 21 gaps, but for the frequency investigations and a better comparability the ten gap model was used, because of the eleven gaps of the First-of-Series Alvarez-DTL. For the extended version a special suspension is needed to mount the stem and the drift tube into the tank.

The angle between the stems for the FoS Alvarez-DTL are fixed to 90° as well as for the frequency investigations of the scaled model.

RF-simulation

In the simulation with CST the scaled model was simplified as much as possible for the frequency investigation. All irrelevant geometries, like the screws or the groove, are not implemented (via CAD-file import) into the simulation to reduce the Mesh-Pull Away Effect. The scaled model has a parallel shift of the frequency of $\Delta f = 2$ MHz, when all these unimportant geometries of the components are implemented [6]. But the volumina of the groove or the holes for the coupler and the pickup must be considered to compare the frequency between the simulation and the measurements. The mesh-type (tetrahedral/hexahedral) or the component-background-option (vacuum / PEC) shows no significant differences at the frequency deviation ($\Delta f = 20$ kHz). A mesh-sweep is limited by the RAM of the simulation computer (in our case: 128 GByte) and in a optimum case the frequency converged to a plateau (mesh: 1.5M/tetrahedral; background: vacuum). The plateau can be archvied faster, when a symmetry can be used to increase the mesh by a factor of e.g. two in an Alvarez-DTL.

The Alvarez-DTL with an operation frequency of 108.4 MHz at the UNILAC, a large frequency shift like in the scaled model with all details cannot be compensated with inductive plungers. The main challenge is to hit very precisely the frequency, because of its not foreseen to make any rework at the tank of the FoS Alvarez-DTL. The FoS Alvarez-DTL has a large volume with many and repetitive very complicated shapes like the profile of the end plates at the drift tubes. The FoS cavity will have eight frequency

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plungers (±200 kHz) and an additional possibility to decrease the frequency with a statical plunger at the support port (–80 kHz) [4].

The mode separation as a function of the angle between the two stems of a drift tube and the field-tilt sensitivity investigations are described in detail in [6, 7, 10].

Measurements

The alignment of the drift tubes has been made with a rod inside of the aperture along the short tank (10 gaps). The rod was mounted at one endplate and a frame was at the opposite side; dowel pins were used for the adjustment of both parts of the tank.

The coupling loop and the pick-up are mounted on the top and a vector network analyzer (VNA, Rohde Schwarz ZNB 4) was used to couple critically the RF. The frequency can be changed in the scaled model with three aluminum plungers with a diameter of 60 mm. The frequency range depending on the position of the inductive plungers (Fig. 4) has a shift of 875 kHz (2.7 ‰) between the simulations and the measurement.

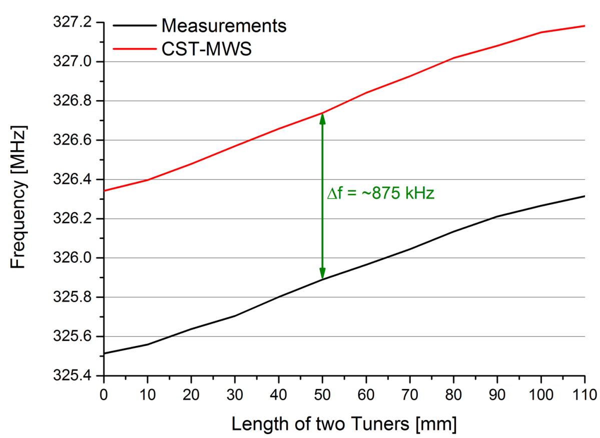

Figure 4: Simulated and measured frequency of the scaled Alvarez model depending on the position of the plungers.

The voltage distribution (Fig. 5) on the beam axis from the CST-MWS simulation is compared with the bead pull measurements and has just a minimal deviation [6]. The dynamic tuners have no significant effect on the voltage distribution on the beam axis, because of the distance to the beam axis and as the short tuners have just an inductive effect.

The misalignment of the drift tube in longitudinal direction (parallel to the beam line) was tested during the measurements. A nylon cord was attached at a drift tube and the frequency change dependence of the misalignment along the beam axis is approximately $\Delta f/\Delta z = 100$ kHz/mm.

The alignment at the Alvarez-DTL will be performed optically by a telescope and a target is placed both at the entrance and exit of each drift tube to adjust the x- and y-plane. The distance between neighboring drift tubes will be measured via laser rangefinder at the new Alvarez-DTL.

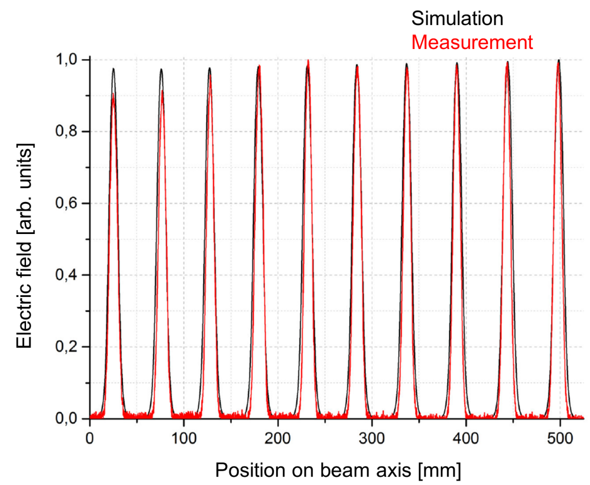

Figure 5: Simulated and measured electric field distribution on the beam axis of the scaled Alvarez model at the resonance frequency (taken from [6, p. 69]).

OUTLOOK

The experience with the comparison between the simulation and the measurement of the 1:3 scaled Alvarez-model can be directly included into the design of the new Alvarez-DTL for the UNILAC at GSI. It can be assumed that in the new Alvarez-DTL approximately three static tuners per meter must be used to compensate the differences of the frequency between simulation and the reality. In the next step the extended version of the 1:3 scaled Alvarez-model with 21 gaps will be used to further investigate the deviations between simulated and measured frequencies. The challenge w.r.t. mesh density in the simulation increased in the extended tank, because of the fixed boundary conditions of the PC-hardware.

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