DEVELOPMENT OF CH-CAVITIES FOR THE 17 MeV MYRRHA-INJECTOR *

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Abstract

MYRRHA is conceived as an accelerator driven system (ADS) for transmutation of high level nuclear waste. The neutron source is created by coupling a proton accelerator of 600 MeV with a 4 mA proton beam, a spallation source and a sub-critical core.
The IAP of Frankfurt University is responsible for the development of the 17 MeV injector operated at 176 MHz. The injector consists of a 1.5 MeV 4-Rod-RFQ and six CH-drifttube-structures. The first two CH-structures will be operated at room temperature and the other CH-structures are superconducting cavities assembled in one cryo-module. To achieve the extremely high reliability required by the ADS application, the design of the 17 MeV injector has been intensively studied, with respect to thermal issues, minimum peak fields and field distribution.

INTRODUCTION

The development of MYRRHA (**M**ulti-purpose h**y**brid **r**esearch **r**eactor for **h**igh-tech **a**pplications) is important to investigate advanced technologies for future power generations. Mainly the transmutation of long-lived radioactive waste of nuclear power plants will be studied in this test reactor. Furthermore the reactor will contribute to the present material research and can replace the expiring molybdenum reactors, which are essential for nuclear medicine.

The operation of the reactor requires an extreme reliable proton accelerator. Breakdowns of the cw proton beam will cause thermal stress in the reactor core and decrease its lifetime. Therefore the design of the LINAC and mainly the proton injector part has to be very safe (less than 11 beam trips of $t > 3$ per year).

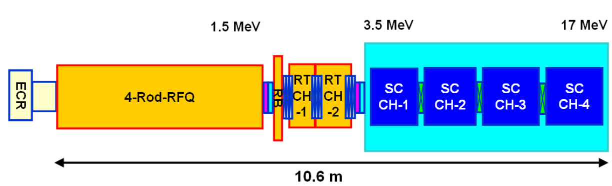

Figure 1: Overview of the MYRRHA injector.

A KONUS (combined zero degree structure [1]) beam dynamics design leads to a short and effective injector section of 10.3 m. In the new 176 MHz layout a cheap and reliable 4-rod-RFQ can be used instead of the 4-vane-RFQ, which was planned for the 352 MHz layout [2] [3].

The output energy of the 4-rod-RFQ will be 1.5 MeV and the following two room temperature CH structures will increase the beam energy to 3.5 MeV. CH structures are excellent candidates to accelerate proton beams with a fixed velocity profile. The main acceleration (of the injector) to 17 MeV will be applied in the four superconducting CH-DTL. Compared to conventional low-β proton LINACS, the superconducting CH structures deliver higher acceleration gradients. Hence the number of cavities can be reduced.

RT CAVITY DESIGN

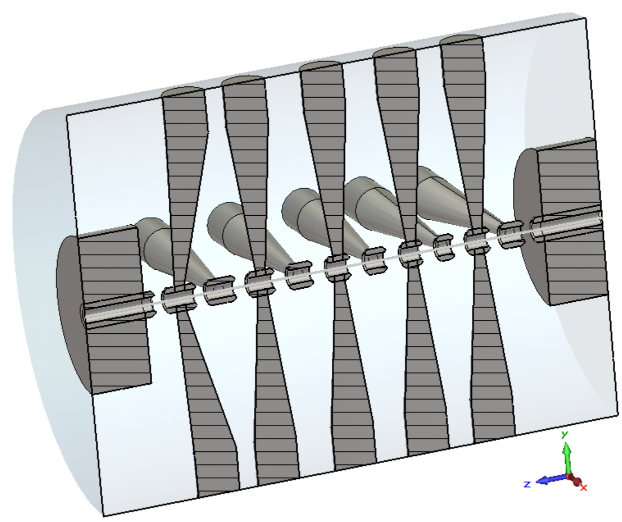

Figure 2: An overview of the first room temperature CH-DTL (MAX – RT CH-1).

Table 1: Parameter list of the first room temperature CH-DTL of MAX (MAX – RT CH-1)

Parameter	RT CH-1
Frequency [MHz]	176
Q-Factor (85% MWS)	15100
U_{eff} [MV]	1.02
E_a [MV/m]	1.87
U^2_{eff}/P_{sim} [MΩ]	85.74
Z_{eff} [MΩ/m]	133.38
P_{sim} [kW]	12.13
P_{real} (85% MWS) [kW]	15.86
Length [mm]	546.37
Diameter [mm]	560

Presently a good design of the first room temperature

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cavity was found. The new 176 MHz layout combines a compact geometry with a high impedance of $85.74\,\mathrm{M\Omega}$. This means losses of only $29\,\mathrm{W/m}$ with an acceleration gradient of $1.87\,\mathrm{MV/m}$. The increase of the proton energy accounts $1.02\,\mathrm{MeV}$.

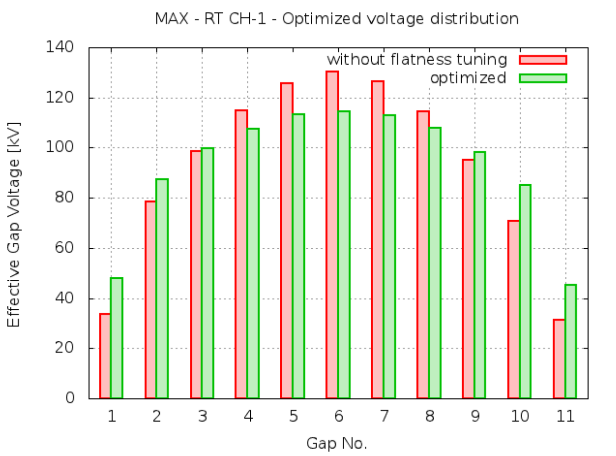

Figure 3: A flat voltage distribution ensures a good heat distribution and therefore a good heat disposal.

Three inclined stems and optimizations of the gap-to-cell-length-ratio (g/l) improve the flatness of the electric field distribution (Figure 3). This leads to a well balanced thermal power distribution over all stems and consequently to a comfortable heat disposal. Voids at the end drift tubes (Figure 2) provide cylindrical housings for quadrupole triplet lenses and increase the shunt impedance by supplying extra space for the magnetic field in the end cells.

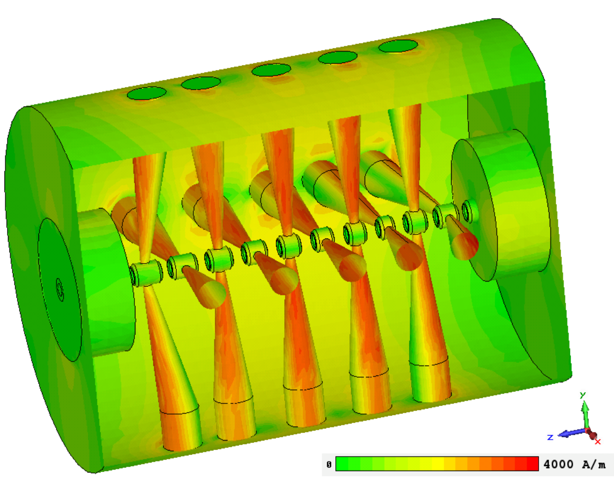

Figure 4: The map of the surface currents on the cavity walls is correlated with the thermal losses [4].

The thermal losses of $15.86\,\mathrm{kW}$ in the room temperature CH-1 have to be cooled. Approximately 60 % of the surface currents are located on the stems (Figure 2). The sixth stem has the highest surface currents with $3500\,\mathrm{A/m}$ and dissipate heat of $0.83\,\mathrm{kW}$. To cool this amount of heat $100\,\mathrm{ml/s}$ are necessary.

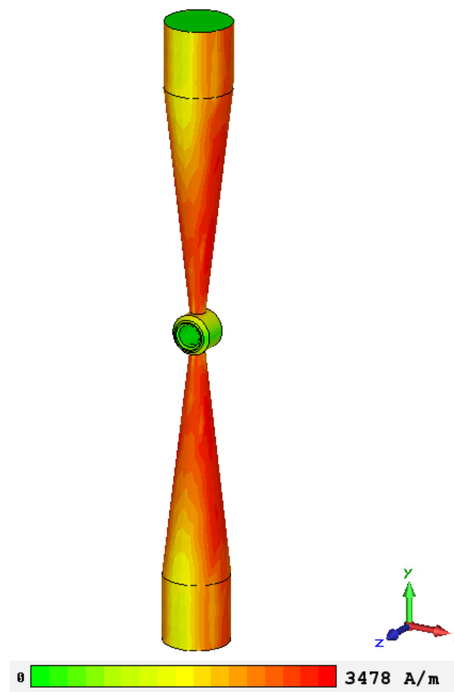

Figure 5: The sixth Stem has the highest thermal losses.

Exemplarily the temperature of the sixth stem in thermodynamic equilibrium is calculated (Figure 6). Stems and drift tubes are built of stainless steel with a thickness of $2\,\mathrm{mm}$. The thermal losses are dissipated on the roughly $2\,\mu\mathrm{m}$ copper layer. The thermal conductivity of the stainless steel and the heat transfer coefficient to the cooling water build up a temperature gradient. In average the temperature difference between the surface and the cooling water is below $2\,\mathrm{K}$. At the hottest spot it amounts $11\,\mathrm{K}$.

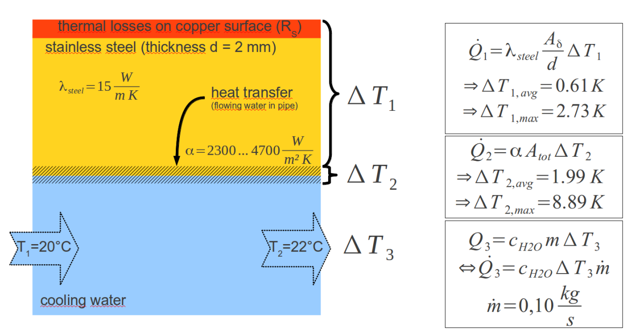

Figure 6: Thermal losses on the copper surface have to be cooled. The calculations are regarding a heat transfer over a 2 mm thick layer of stainless steel. 100 ml/s of water are necessary to cool the sixth stem.

Table 2: Parameter list of the first superconducting CH-DTL of MAX (MAX – SC CH-1)

Parameter	SC CH-1
Frequency [MHz]	176
U_{eff} [MV]	3.83
G [Ω]	60.18
R_a/Q_0 [Ω]	2747
R_aR_S [Ω^2]	165323
E_a [MV/m]	4.52
Max. E-Field [MV/m]	30.1
Max. H-Field [A/m]	19670
E_{peak}/E_a	5.93
Length [mm]	846.32
Diameter [mm]	580
Aperture [mm]	30

SC CAVITY DESIGN

Four superconducting (sc) niob cavities are responsible for the main acceleration in the injector part (13.5 of 17 MeV). The first sc CH-DTL has an effective gap voltage of 3.83 MeV. Elliptical stems fixed on the four girders are a good compromise between low magnetic peak fields [5] and a mechanical integrity [6]. Inclined end stems increase the gap voltage in the end cells like in the room temperatrue CH. A larger end cell length flattens the electric field distribution, too. The Optimization of the every geometric parameter yields an E_{peak}/E_a below 6.

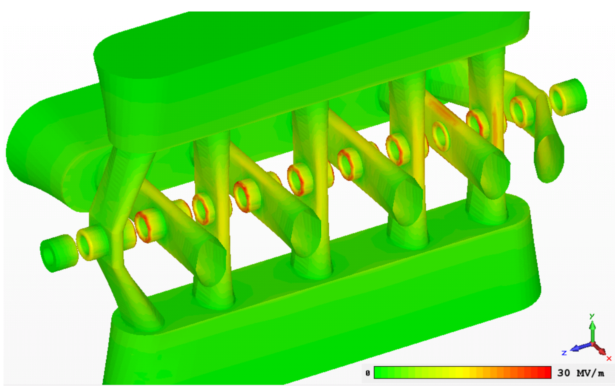

Figure 7: The electric peak fields on the surfaces limit the acceleration gradient. The impact of emitted electrons would cause heat and increase the risk of quenching.

OUTLOOK

The simulations are promising a very safe cavity design of the first CH structures of each type. Because of very low thermal losses in the room temperature cavity, a layout with higher acceleration gradient will be simulated. This will increase safety margin in the superconducting part.

In the next simulation step capacitve static tuner will be considered. Also dynamic tuners are necessary to keep the resonance frequency.

ACKNOWLEDGEMENTS

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