DEVELOPMENT OF A COUPLED CH STRUCTURE FOR THE GSI PROTON INJECTOR*

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Abstract

The FAIR facility, under development at GSI, needs a new dedicated proton injector for the production of intense secondary $\bar{p}$ beams. This injector will accelerate protons from 3 to 70 MeV at a current of 70 mA, and due to the high voltage gain and shunt impedance will be based on CH cavities powered by 6 2.5 MW, 325 MHz klystrons. An innovative coupling cell containing one drift tube of length $N\beta\lambda$ was developed to combine multicell drift tube modules of the CH-type (H_{211} mode). In order to study this coupling mechanism a 1:2 scaled model of the second resonator of GSI proton injector was fabricated at IAP and it ready for testing. The according full scale prototype, a 3 meter long coupled resonator from 11.7 MeV to 24.1 MeV is under development and will be power tested with a 2.5 MW klystron at GSI early in 2009.

This paper describes in detail the coupled structure together with a general overview of the R&D results achieved on the CH-DTL's cavity.

THE NEW PROTON INJECTOR FOR FAIR

A significant part of the experimental program at FAIR is dedicated to antiproton physics. For the experimental demands an ultimate intensity of up to $7 \cdot 10^{10}$ cooled $\bar{p}/h$ is required: taking into account the $\bar{p}$ production and cooling rate, this corresponds to a primary beam of $2 \cdot 10^{16}$ protons/h. Such an intensity is much beyond the capabilities of the existing GSI UNILAC and, for this reason, a dedicated proton injector has to be built [1]. This 325.2 MHz proton accelerator will be the the first linac entirely based on CH-structure: this new kind of cavity is in fact characterized by higher shunt impedance in the low-medium beta range when compared with conventional DTL's; moreover, it is well demonstrated that H-mode cavities in combination with KONUS [3] beam dynamics can provide high voltage gains resulting in a compact and efficient design. [2].

Due to the availability of the new 324 MHz, 2.5 MW klystrons developed for the JPARC facility, it was decided to base the FAIR Proton linac on the frequency of 325.2 which is exactly three times the resonating frequency of the existing UNILAC: the adoption of the JPARC klystrons to this frequency at a duty factor of 0.028 % can in fact be easily performed: in this way the GSI linacs will be operated further at multiples of 36.14 MHz. The high level of power available from those klystrons has pushed the development of coupled structures in order to get an efficient power matching between the linac and the power supplies: each coupled cavity is powered via a single feeder by one 2.5 MW klystron.

The general layout of the FAIR Proton Linac is shown in Fig. 1: the beam is extracted at 95 keV from an ECR source and then bunched and accelerated by an RFQ up to 3 MeV where the main linac starts. Three coupled CH modules bring the beam up to the energy of 36 MeV where 60 cm of drift space are reserved for an extended diagnostics section. After this drift, other three coupled modules accelerate the protons up to the final energy of 70 MeV where the beam enters the transfer line towards the SIS 18.

Table 1: The main parameters of the FAIR proton injector

Energy [MeV]	3-70
Peack Current [mA]	70
Frequency [MHz]	325.2
Repetition rate [Hz]	≤ 4
Duty Factor [%]	0.028
Beam Emittance (trans. norm) [mm mrad]	≤ 4.2
Momentum spread	$\leq 10^{-3}$

THE COUPLED CH-DTL

The starting point to develop a coupled CH-DTL is the end cell geometry described in [4]: big half drift tubes are used to make the end cell resonant and to host the magnetic lens needed to focus the beam: the analysis of the magnetic flux in the end cell shows how the magnetic field lines surround the last half drift tube similar to the field distribution of a cavity exited in E_{010} mode (Fig. 2).

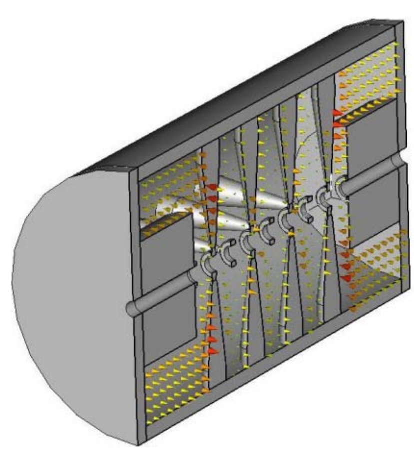

Figure 2: The magnetic field on CH-DTL's middle plane.

If one now to puts together two CH-cavities of that typ

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Figure 1: The layout of the FAIR proton injector.

and replaces the endwalls by a massive stem supporting the lens, the magnetic field points parallel and antiparallalel to the beam axis in the accelerator modules and is surrounding the focusing element in the coupling cell like in Alvarez DTL's. Finally, the radius of the coupling cell can be easily modified in order to match the desidered resonating frequency.

The result is a very compact structure which presents many advantages when compared to other solutions based on the coupling cells adopted by the Side Coupled Linac: the construction is very simple, requiring only the insertion of the magnetic lens inside the coupling element and the module can be easily opened to perform any kind of maintenance. Moreover, there is a large experience with this kind of tube installation inside IH cavities. Fig. 3 illustrates an example of coupled CH's while Fig. 4 shows the magnetic flux within a yz plane at half the radius of the coupled module making this magnetic coupling concept transparent.

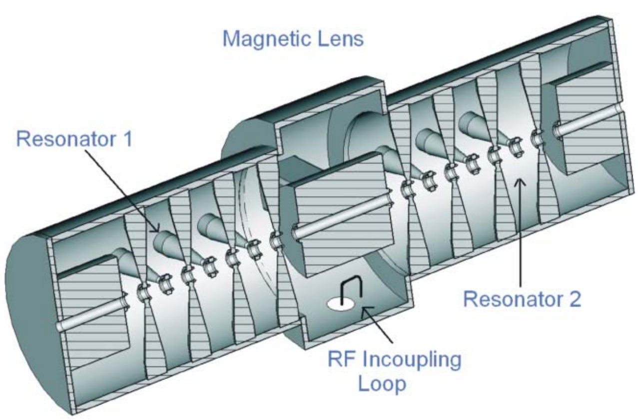

Figure 3: The coupled CH-DTL.

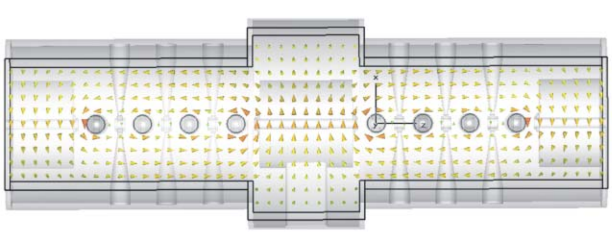

Figure 4: The coupled CH-DTL.

The validity of such a solution in terms of RF properties was tested with Microwave Studio by simulating two identical CH resonators, 322 mm diameter, each made of 8 cells with period $\beta\lambda/2$ 45 mm, coupled by an intertank section with length $5\beta\lambda$;the radius of the coupling cell was set at 220 mm in order to match the resonant frequency of the GSI Proton injector. Besides non coupled resonant modes or modes far away from the operating resonance frequency, the RF simulations showed the presence of two modes which are dominating our coupling scheme:

- the 0 mode, resonating at 325.2 MHz, which is characterized by the oscillation in the E_{010} mode of the coupling cell: the RF currents on the lens outer cylinder are oriented along the bam axis resulting in a coupling cell of length $N\beta\lambda$. Fig. 5 shows the electric field distribution along the cavity axis demonstrating the capabilities of this mode to accelerate at a rather flat gap field distribution.

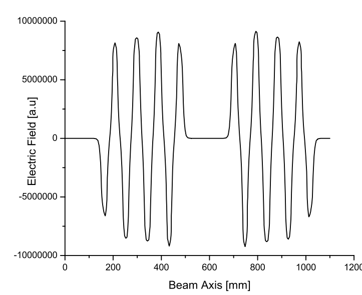

Figure 5: The electric field distribution for the 0 mode.

- The first parasite mode, the π mode which resonates at 328 MHz, is charachterized by a weak oscillation of the coupling cell as shown in Fig. 6: this is a very important feature of the coupling scheme since it gives a natural hint where the structure must be coupled with the power supply. If the incoupling loop is in fact placed in the coupling section the parasite mode could be only weakly exited and the risk of feeding this mode during operation is strongly reduced.

THE SECOND RESONATOR OF THE FAIR PROTON INJECTOR

The second resonator of the FAIR proton injector will bring the beam from 11.6 MeV to 24.1 MeV within less

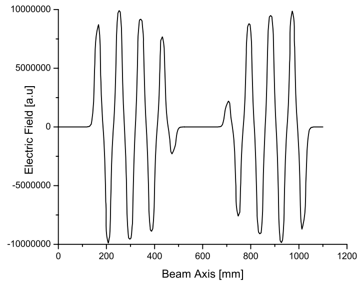

Figure 6: The electric field distribution for the π mode.

than 3 meters. The β profile of the accelerating gaps was defined by use of the LORASR simulation code [5] and the RF properties were investigated with Microwave Studio: Tab. 2 illustrates the main parameters of this structure while Fig. 7 and Fig. 8 show the electric field distribution of the working mode and of the closest mode. Again, the parasite mode only weakly excite the coupling cell reducing a potential overlap during operation. The choice to investigate the second module is justified by the fact that the final design of the RFQ is still not fixed. In this way still some freedom is left in order to change the first module whose, at moment, only the initial and the final energy are fixed.

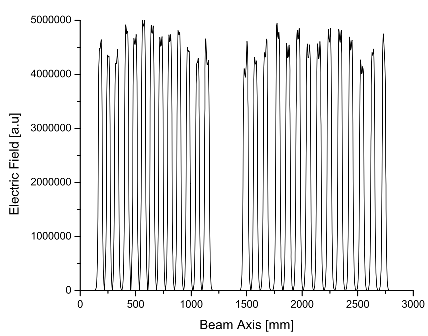

Figure 7: MWS electric field simulation for the second resonator of the FAIR proton injector.

At the moment, the frequency difference between the working mode and the first parasite mode is 1.3 MHz which, compared to the 750 kHz bandwidth of the klystrons gives some safety margin against a possible overlap.

Nevertheless, in order to investigate this coupling concept and to improve the separation between the modes a scaled model was built at IAP: this model will be used not only to improve the coupling constant, but as well to study the effect of mobile plungers on the field distribution. The experience gained on this model will then be transferred on the production of the full scale prototype which is foreseen to completed within 2008: this first module will be finally tested in the new test-stand of GSI with at full power with a 2.5 MW klystron of the same type of the FAIR proton injector.

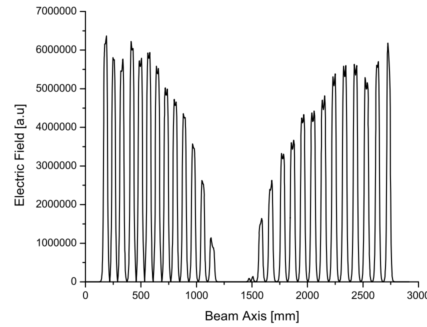

Figure 8: MWS electric field simulation for the first parasite mode of the second resonator of the FAIR proton injector.

Table 2: The main parameters of the second resonator of the FAIR proton injector

Energy [MeV]	11.6 - 24.1
No. of gaps	14 + 13
Total Voltage [MV]	15.33 (7.2+8.1)
Q_0	15300
ZT^2 [MΩ/m]	60
Length [m]	3

ACKNOLEDGMENTS

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