Abstract

The RF-System for SuSe consists of two large cavities in opposite valleys. The cavities are driven in the TE 101-mode and have a radial increasing voltage distribution. The maximum accelerating voltage per cavity is 1 MV at a power consumption of about 170 kW. A frequency variability in the range between 59 MHz and 74 MHz is possible in reducing the gap between the capacitively loaded lips, the fine tuning is done with two cylindrical perturbing objects. The cavities were optimized with the aid of the recently developed three-dimensional cavity calculation program CAV3D and measurements on several models in the scale 1:5, 1:8 and 1:2.5. A full scale power model is in construction. It will be tested with existing facilities at the Munich tandem laboratory, the large vacuum chamber HEKE and the RF power-generator for the post-accelerator SchweIN. A later application of this test cavity as part of a mass-separator is under consideration.

Introduction

SuSe is a project study at the Munich Accelerator Laboratory for a superconducting sector cyclotron to access the medium energy range up to 300 MeV/u for heavy ions. The RF-System for SuSe has to fulfill the following conditions: A maximum accelerating voltage of 2 MV per turn at the extraction radius of 2.40 m with a moderate power consumption, a frequency variability in the range between about 59 MHz and 74 MHz for harmonic numbers between 5 and 16 and a radially increasing voltage distribution. At the injection radius of 0.4 m, the voltage should be at least 20 percent of the maximum voltage to allow an injection system without stripping, i.e. with an electrostatic deflector. Furthermore, the accelerating cavities have to fit in the narrow place between the main coils, and only two valleys can be filled with cavities in order to have space for the injection and extraction paths. From space and power consumption reasons, a conventional dee system is not appropriate. Therefore, a high Q-value cavity system is chosen, as a radially increasing voltage distribution is also very naturally for a cavity. The RF-system consists of two large cavities in opposite valleys. They are driven in the TE 101-mode and have the radially increasing voltage distribution. The frequency variation is possible in reducing the gap between the capacitively loaded lips; the outer part of the accelerating lips is movable and can be turned around a vertical axis at r = 1.20 m (fig. 1). The fine tuning is done with two plunge tubes at the top and the bottom of the cavity. The frequency variation with the movable lips has two main advantages. First, at narrow acceleration gap the frequency is low and the transit time factor high, just as it is needed for the slower, heavier ions which are accelerated at high harmonic numbers. Second, the cavity with wide acceleration gap is well adapted for the fast, light ions, which are accelerated at high frequencies and low harmonic numbers and need the highest voltage. As the acceleration gap is wide, nevertheless the electric field remains at moderate values.

Model studies and calculations

The form of the accelerating cavity was optimized with the aid of the recently developed three-dimensional cavity calculation program CAV3D and perturbation-body measurements on several models in the scale 1:5, 1:8 and 1:2.5. In comparison with the published version, the program now is improved with the aid of a penalty method. The eigenvalue problem is now

$$\left( \Delta + k^2 + s \cdot \text{grad div} \right) H = 0,$$

where $k = \omega/c$ is the eigenvalue and $s$ is a penalty parameter chosen between zero and 1.5. With this penalty method, solutions without physical meaning, i.e. div H = 0, can be shifted away from the correct solutions. This is very helpful in some cases where the frequencies of physical and unphysical solutions are very close together and the field solutions are mixed and not clean. Nevertheless, the mesh size in the computer code cannot be chosen very small and the accuracy is not good enough to completely replace the method of building cavity models. But it is a very helpful tool for getting a feeling and to see what happens if one changes something at the cavity geometry. So, beside an older 1:5 scale model, which is not very well fitted to the geometry of the SuSe magnets, two further models were built, one in the scale 1:8 and one in the scale 1:2.5. The 1:8 scale model can be quickly changed and was used to optimize the cavity geometry, together with CAV3D calculations. As an example, fig. 2 shows the geometry and the stairlike CAV3D approximation of the cavity with narrow acceleration gap and the measured and calculated voltage distributions. The surfaces of this small cavity model are not very good, so absolute measurements of the shunt impedance are not possible but are done on the large 1:2.5-scale model after a galvanic polishing procedure. It turned out that it is not so easy to get enough voltage at the injection, especially with narrow acceleration gap. Curve a in fig. 3 shows the measured percentage $U_{inj}/U_{max}$ versus the frequency of the first version of the 1:8 scale-model. The frequency range is large, but the injection voltage too low in the whole range. To enhance it, essentially three changes were
made. First the cavity cross-section in the machine center was expanded into the neighbouring valleys as far as possible with larger "ears". Second, the cross-section was not kept constant in vertical direction but widened 0.7 m above and below the particle plane in the narrow region with "cheeks" (cf. fig. 1). Third, the capacitive plates at the acceleration lips were made smaller with increasing radius (fig. 2). The curves b in fig. 3 show the resulting Uinj/Umax versus the frequency for several positions of the plunge tubes. With the aid of the "cheeks" and "ears", more magnetic flux can be fed into the machine center, so 18 percent of the maximum accelerating voltage are reached at the injection radius at the lowest frequency of 59 MHz.

A full scale power model is in construction. It will be built from unmagentic stainless steel sheets electro-plated with copper before welding. The welding joints can be coppered later by tampon galvanizing. It will be tested with existing facilities at the Munich tandem laboratory, the large vacuum chamber HEXE (fig. 4) and the RF power-generator for the post accelerator SchweIN.

A later application of the power model as a velocity filter is under consideration. It can be shown\textsuperscript{4,5}, that for the deflection of a pulsed beam transported through a SuSe-like cavity in radial direction the following formula holds:

$$F_y = \frac{Z e}{A m_{\text{r}} v^2} E_0 L \frac{\Delta v}{v}.$$ 

Here, Ze is the charge of the beam, Am\text{r} the relativistic mass, v the velocity, E\text{r} an effective electric field strength and L the distance between target and cavity center. In practice, E\text{r} is about 75 percent of the maximum voltage, divided by the gap size. For a conventional Wien velocity filter, the same formula is valid but with E\text{r} being the true electric field strength and L the length of the filter. In comparison with an electrostatic Wien filter, the RF cavity has the advantage of a higher possible electric field strength without sparking and a shorter geometric length.

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### References

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