IMPROVEMENT OF RFQSIM

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Abstract

RFQSIM has been developed at IAP to simulate multiple particles dynamic of RFQs which includes simulations of high current applications, decelerators, debuncher and rebuncher e.g. for the medical application. The latest work to improve RFQSIM include the option to change the modulation and or the aperatur of the simulated RFQ to produce the same acceleration and or focusing efficiency as the two term potential gives for different electrode geometries. Additional work was done to improve the graphical analysis during runtime as well as the change of all routines to be compatible with the Fortran F95 standard. The maximum number of particles to be simulated was increased to 200k. The paper shows examples of results for the high current application like the of the p-linac and the new HLI injector for GSI and for transition sections.

THE TWO TERM POTENTIAL

The basic equation to describe the potential in a RFQ uses the first two coefficients of the multipol expansion and is therefore known as the two term potential (eq 1) [1].

$$\psi(r,\theta,z) = A_0 r^2 \cos(2\theta) + A_{10} I_0(kr)\cos(kz) \quad (1)$$

$$\varphi(r,\theta,z) = \frac{V_0}{2} A_0 r^2 \cos(2\theta) + A_{10} I_0(kr)\cos(kz) = \frac{V_0}{2}\phi \quad (2)$$

Using this formula one has to keep in mind, that a real structure can not be exactly build according to the two term potential because of its hyperbolic shape. Doing so would cause a risk of sparking and big consumption of HF-power in a region far away of the beam axis.

REAL SHAPE OF THE ELECTRODES

The surface of the electrodes which is close to the beam axis has a shape similar to a hyperbolic surface and the part of the electrodes with a bigger distance to the beam axis differs a lot from the ideal hyperbolic shape. The difference between the real and the hyperbolic shape of the electrodes becomes only effective in a region away from the beam axis and it has therefor a bigger influence on particles which are at the edge of the bunch e.g. the halo.

The method which was now implemented in RFQSIM to take the described effect into account is based on Ken Crandell's work which is also used in PARMTEQM [2]. After the RFQ structure is generated a new subroutine "ModRFQ is called which uses the acceleration and or focusing efficiency to find a new apertur and or modulation which produce the same acceleration and or focusing efficiency. For doing that one has to give the program the type of modulation and the ρ/r_0 ratio. To find the right apertur and modulation the program uses some files in which the multipol coefficients for constellation of cell length, ρ/r_0, apertur and modulation are noted. These files are similar to the ones PARMTEQM uses.

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ADDITIONAL WORK

Additional work done on the program include the increased number of particle the program can handle. The number was increased from 20k to 200k to have the option to produce an output distribution which contains more particles to fit the requirements for simulations of future structures e.g. halo and loss studies.

In order to avoid future errors while working on the source code some features of Fortran 95 like modules in which common variables are defined are used.

Also the variables were changed from four byte real variables to eight byte real variables to have a greater accuracy. Due to the newer compiler this does not lead to a bigger computation time.

The program frame was changed from an old DOS program to a normal windows like program. This also included an improvement of the graphics which are shown during the simulation. It now plots the x, y, ϕ_s and W_s versus the cell number showing the particles density in each plot using different colors. The density scheme is fixed, so that the same color always means same particle density.

EFFECTS OF THE IMPROVEMENTS

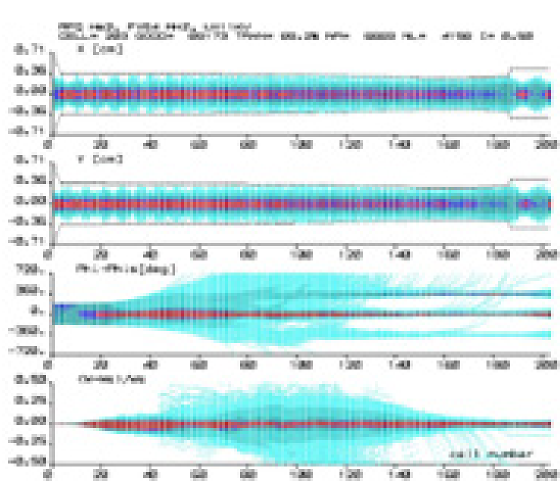

Figure 1: Simulation with 100k particles

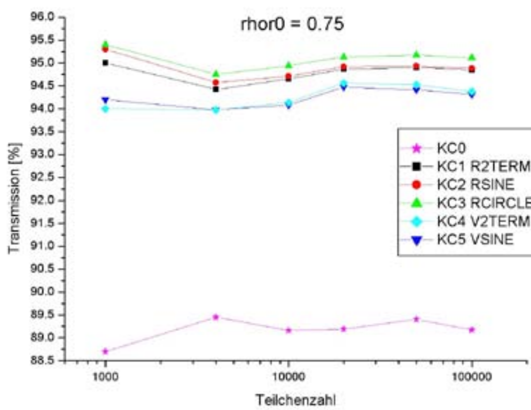

Figure 2: Transmission vs. number of particles with ρ/r_0 ratio of 0.75

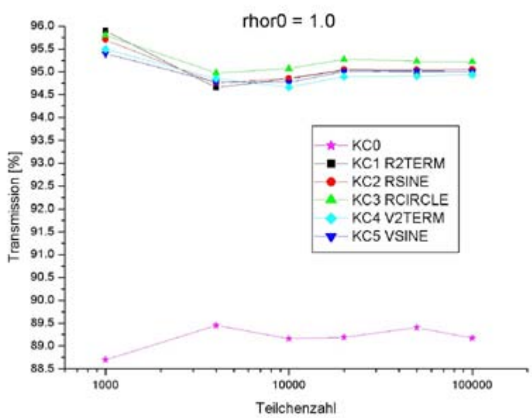

Figure 3: Transmission vs. number of particles with ρ/r_0 ratio of 1.0

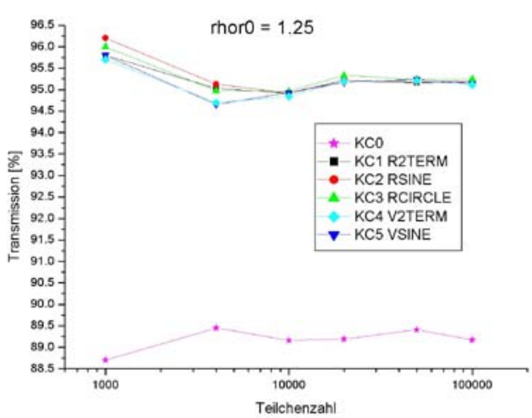

Figure 4: Transmission vs. number of particles with ρ/r_0 ratio of 1.25

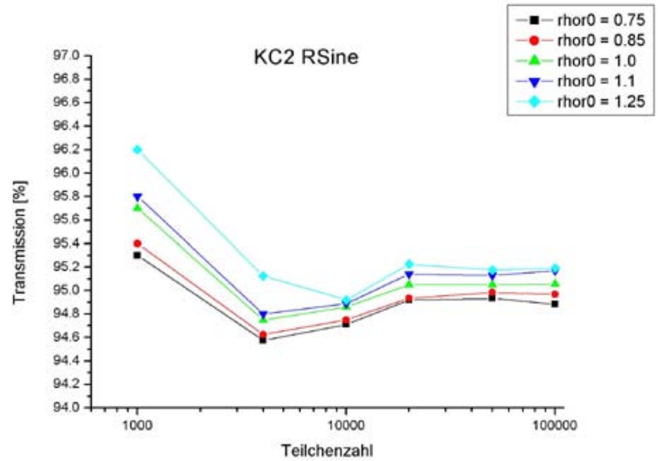

Figure 5: Transmission vs. number of particles for different ρ/r_0 ratios

Figure 1 illustrates how the simulation process is shown by the program. The simulated RFQ is on older version of one channel of the Frankfurt funneling RFQ. It is a low current He accelerator running at a frequency of 54 MHz. The following three figures show the influence of the multipols by the described method for different values of the ρ/r_0 ratio and the effect of using more particles. Using more than 30k particles does not have a impact on the transmission, but taking the harmonics into account has an impact on the transmission. It is noticeable that the transmission is higher for the rod electrode geometry if the ρ/r_0 ratio is small and the difference to the two term potential is big. When the ρ/r_0 ratio gets bigger the difference between the different geometries becomes very small (figure 4). Figure 5 illustrates the influence of the ρ/r_0 ratio for a 4 rod sinusoidal geometry.

CONCLUSION

The development of RFQSIM has been done by numerous authors (e.g. H. Deitinghoff, J. Thibus, J. Madlung, A. Bechtold) for our RFQ projects and special application like funneling and deceleration. The program was a melange of very old parts written in Fortran 2 and newer ones which are now brought to the same Fortran 95 levels giving us a transparent simulation tool which can easily be adapted to future problems.

REFERENCES

[1] K.R. Crandall and R.H.Stokes and T.P.Wangler, " RF Quadrupole Beam dynamics Design study, Proceedings of LINAC79, Montauk, Sept. 10-14, 1979, 205-216 (1979).

[2] K. R. Crandall and T. P. Wangler and L. M. Young and J. H. Billen and G. H. Neuschaefer and D. L. Schrage, "RFQ Design Codes, Los Alamos National Laboratorym, 2005

[3] Johannes Maus, "Berücksichtigung höherer Multipole in RFQSim 200k, Int-Rep IAP-JM 907-1, 2007