THE DATA LIBRARY FOR ACCELERATING STRUCTURES DEVELOPMENT. RF PARAMETERS OF THE DRIFT TUBE ACCELERATING STRUCTURE

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Abstract

The Drift Tube (DT) accelerating structure is very well known, developed and widely used in existent proton linacs. Nevertheless, in the development of new projects all time arise the problem to estimate rf parameters of the structure for particular case given. This paper is the first report about activity in the creation of the data library for accelerating structures development. Basing on particularities of codes, which were developed early in INR (CPU time to calculate in 2D approximation one variant of the cell is several seconds with modern computer) and later were added with the shell to change automatically cell dimensions and tune to the frequency given, we store one time extremely large number of variants. The ranges of the cell dimensions overlap all known and another reasonably interesting variants of the DT structure application (both with focusing lenses inside drift tubes and without lenses). The main (cells dimensions, quality factor, shunt impedance, transit time factor) and additional results (the distribution of rf losses and so on) are stored in the file and provide the data base for further treatment. Using the data base obtained, we can with scaling and interpolation consider and compare, without additional calculations, rf parameters of the structure at different frequencies and with different limitations, finding either optimal or compromise solution for the structure.

Introduction

All times in design of the accelerating structure there is the problem to find reasonable compromise between different requirements. It may be internal problem in the structure design - how to choose dimensions to have effective shunt impedance Z_e as high as possible and to keep electrical field at the surface E_{smax} (usually in parts of the Kilpatric limit E_k) in reasonable limits. The increasing of an aperture radius is good for beam dynamic, but leads to the reduction in the Z_e. The manufacturing processes will be simpler if a set of dimensions will be constant through the structure, but it means that will be deviation from optimal parameters.

As a role, dependencies of parameters from dimensions qualitatively are known, but, if the problem arises to have a number (to estimate "the price" of the solution), the designer needs to do estimation or additional calculations.

To simplify the design procedure for the DTL structure, this work has been performed.

The Data Base Storage

Several years ago the set of very powerful 2D codes [1] was developed in INR. With modern "middle power" computers, like DEC ALFA 2000, one run takes of order $3 \div 5$ sec CPU time from mesh generation to physical postprosessing with high precision of results. Later, this set of codes was added with several simple codes to provide the system, which allows to perform automatically the set of similar calculations.

The idea and realization of the data base are not so complicated. The cell of the accelerating structure may be specified with several independent parameters (for example length, aperture radius, gap ratio and so on) and one dependent - to tune the cell for the operating frequency given f_0.

Two options of the DTL structure have been considered (Fig. 1). The first one is a conventional DTL with the possibility to place focusing lenses inside drift tubes. The second option has small drift tubes without lenses and is intended for high frequency DTL application - Bridge Coupled DTL (BCDTL) [2].

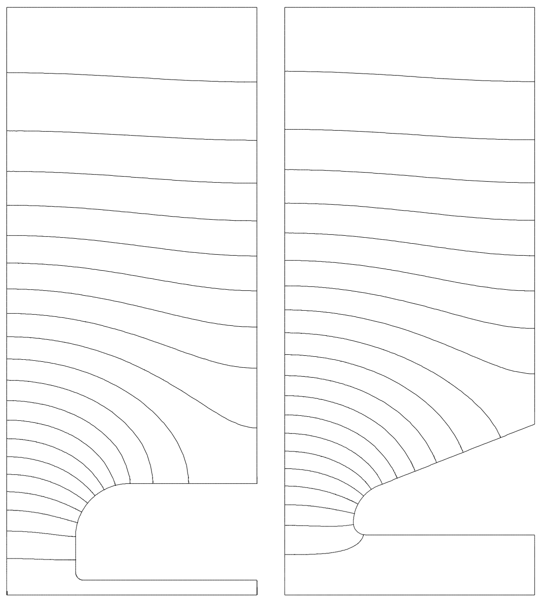

Figure 1: The field distribution and drift tube shape for the conventional DTL option and for the BCDTL one.

The cell of the DTL for both options is specified with six independent parameters and the cell radius R_c as dependent one. The limits of the independent parameters in normalized type (in parts of operating wavelength λ_0) are listed in Table 1.

Several steps with each parameters were done during the data base storage. As a role, the dependencies of the structure rf parameters vrs dimensions are smooth enough and not so many points are needed to approximate any curve using cubic spline interpolation. It is evident, that accuracy of this interpolation is better for larger number of points. But, if we have M independent parameters and are going to do N steps with each parameter, number of variants to be calculated is M^N. As the results of the compromise between accuracy of the interpolation and the total number of variants for calculations, from 4 to 7 steps for each parameter were chosen, depending on influence of the parameter given on the structure rf characteristics.

Table 1
The ranges of the DTL cells dimensions.

	Conv. DTL	BCDTL
β	$0.05 \div 0.57$	$0.05 \div 0.57$
Aperture rad. a/λ_0	$0.0023 \div 0.0223$	$0.01 \div 0.09$
Low. DT rad. r_1/λ_0	$0.002 \div 0.01$	$0.002 \div 0.01$
Upp. DT rad. r_2/λ_0	$0.004 \div 0.04$	$0.0066 \div 0.036$
DT radius r_t/λ_0	$0.033 \div 0.067$	
DT angle ϕ		$0.0^\circ \div 30.0^\circ$
Gap ratio	to 0.5	to 0.5

It is not so difficult to develop algorithm for this work and to pass this long routine job to computer, for which it is directly intended. The system takes one variant, tunes it to frequency specified, stores results and goes to next variant automatically.

The results of this job are M-dimensional arrays in direct access file.

For every variant are stored:

a) the cell dimensions,

b) general parameters of the structure - transit time factor T, quality factor Q, effective shunt impedance Z_e, maximum electric field at the surface - $E_{smax}/(E_0T)$ ratio, maximum magnetic field at the surface - $H_{smax}/(E_0T)$ ratio. The surface of the cell is divided in several segments. For each segment are stored:

c) the relative part of rf losses (with respect to losses in total cell),

d) frequency shift due to possible displacement of this segment,

e) maximum electric field at the segment - $E_{simax}/(E_0T)$ ratio.

As the particularities of the DTL structure, frequency shift and additional rf losses in the stem together with additional rf losses in the end wall are calculated and stored.

The Data Treatment and Applications

The data base stored is the main value of the system.

The procedure of the application is also simple. First of all, the designer should specify DTL option and the operating frequency. The data base will be extracted, scaled to the frequency specified and the available ranges of the cell dimensions will be displayed.

There is a large variety of the data base applications for the DTL design. The simplest one is the comparison of different DTL variants. For this purpose the designer should specify the cells dimensions under interest. After each specification, using standard methods of the cubic spline interpolation, dimensions of data arrays will be reduced at 1. At the end of this procedure the values of rf parameters, corresponding to the cell dimensions specified, will be displayed.

For example, at Fig. 2 and Fig. 3 the plots of Z_e and E_0T for different BCDTL operating frequencies, assuming $a = 15$ mm, $r_1 = 3$ mm, $r_2 = 7.5$ mm, $\phi = 0$ are shown. If the dimensions of the drift tube are fixed, especially aperture radius, the increasing of the operating frequency do not leads to the increasing in shunt impedance.

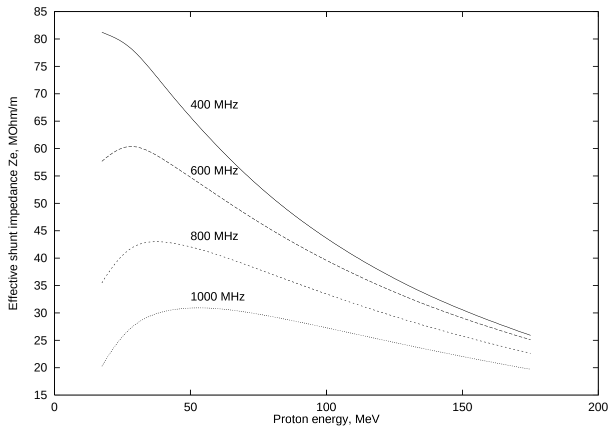

Figure 2: The effective shunt impedance of the BCDTL option for different operating frequencies.

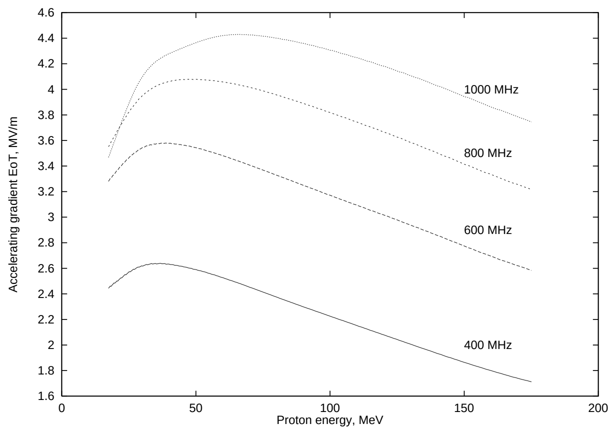

Figure 3: The accelerating gradient E_0T of the BCDTL option for different operating frequencies.

Two dimensional plots are efficient tool to provide general picture for the DTL parameters behavior vrs cell dimensions. For example, at Fig. 4 and Fig. 5 the surfaces of Z_e and E_0T, available for BCDTL option assuming $a = 15$ mm, $E_{smax} = 1.5E_k$, $r_1 = 3$ mm, $r_2 = 7.5$ mm, $f_0 = 700$ MHz, are plotted. Comparing these two surfaces, one can see, that conditions to get maximum shunt impedance practically coincide with ones to have a large $E_0 t$ value.

More interesting and important case of application is to find optimal parameters with restrictions. Usually, the aperture radius is restricted from below with the beam dynamic requirements. The maximum electric field at the surface - E_{smax} should be also specified in the beginning of the design. Then, to simplify the manufacturing process, the designer can specify the set of another parameters, for example, cavity radius R_c, lower and upper DT radii r_1, r_2, and find maximum of Z_e, determining simultaneously the deviation from global maximum (without limitation in parameters specified for manufacturing simplification).

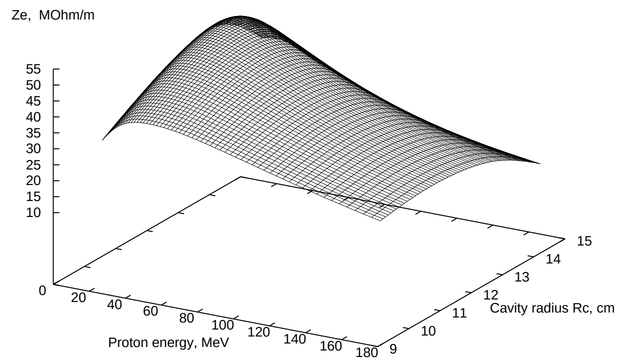

Figure 4: The Z_e surface for the BCDTL option.

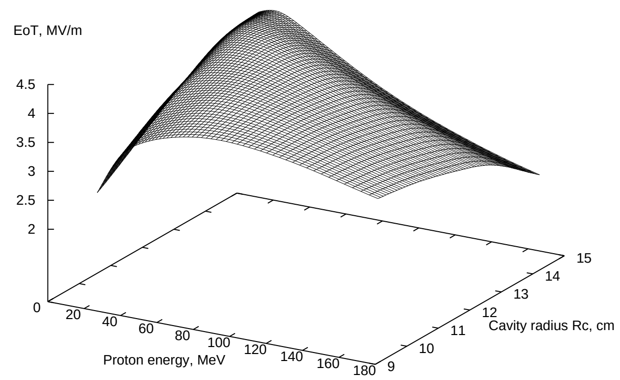

Figure 5: The $E_0 T$ surface for the BCDTL option.

It is possible to consider also the segmentation of the structure into accelerating cavities, taking into account additional rf losses. At Fig. 6 the plots of the effective shunt impedance for regular (a) BCDTL cell ($f_0 = 600$ MHz, $E_{smax} = 1.5 E_k$, $a = 10$ mm), average Z_e for 6 cells BCDTL cavities taking into account rf losses in end walls (b), in end walls and stems with radius $r_s = 9$ mm (c) are shown. Additional rf losses strongly reduce efficiency of the structure, especially for low proton energies.

Because the code source for data base treatment is open, it can be added with any possibility proposed.

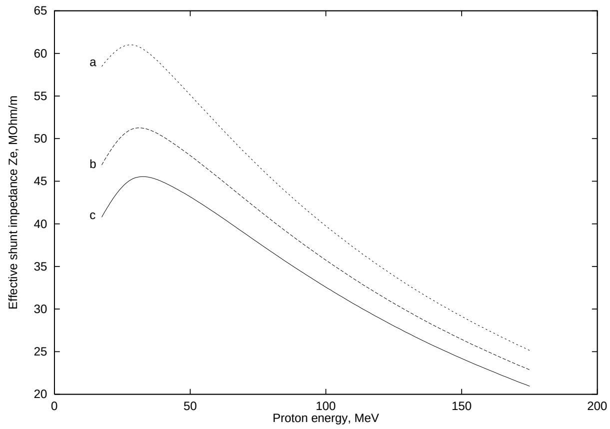

Figure 6: The effective shunt impedance for the BCDTL, a) - “ideal” structure, b) - 6 cells tank without stems, c) 6 cells tank with stems $r_s = 9$ mm.

Conclusion

The data base for rf parameters of the DTL structure has been developed. The large number of calculations has been performed one time and stored. The application of this data base allows for the designer to work more creatively, providing him more time to choose the best solution.

Acknowledgments

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References

[1] I.V. Gonin et al. 2D codes set for RF Cavities design. Proc. of the 1990 EPAC Conference, 1990, p. 1249.

[2] R.W. Garnett et al. Design and Simulation of a Bridge-Coupled DTL Structure..., Proc. of the 1992 Linac Conference, 1992, p. 802.