Design of Mode Converter Based on Genetic Algorithm

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Abstract—*As a high-power power source, the output mode of the gyrotron is usually TE_{0n} mode. As a part of high power output system, modal converter plays a very important role. This paper mainly introduces the method of converting TE_{01} mode to TE_{11} mode. The traditional TE_{01}-TE_{11} analog converter is calculated by coupling wave theory and designed by axis function. In this paper, based on the iterative method, genetic algorithm is used to optimize the parameters of the axis function to obtain a more efficient modal converter. The genetic algorithm can optimize the function in the global scope, and the result is more accurate and effective.*

Keywords—*converter, mode, genetic algorithm, axis*

Introduction

As a new type of electronic vacuum device based on the principle of free electron stimulated radiation, gyrotron has the advantages of high efficiency, wide bandwidth and high peak and average power. It is widely used in military and scientific research fields. The output mode of the gyrotron is generally TE_{01} mode or several mixed modes of TE_{0n} mode. In order to facilitate long-distance transmission, the output mode is usually converted into HE_{11} mode through mode conversion. There are two common transformation sequen - ces[1]:(1)TE_{0n}-TE_{01}-TE_{11}-HE_{11};(2)TE_{0n}-TE_{01}-TM_{11}-HE_{11}. In this paper, based on the study of the first transformation sequence, the given coupling structure function is optimized by genetic algorithm, and an optimal initial value is obtained. Then the iterative method is used to further optimize the structure, and finally a mode converter with compact structure and high conversion efficiency is obtained.

Fundamentals And Simulation Results

Through observation, it can be found that the coupling coefficients between the modes are closely related to the curvature in the curved smooth circular wave-guide, and the other parts except the curvature can be regarded as the constants composed of wave pattern and radius and become the wave pattern parameters.Then the coupled wave equations can be expressed as：

$$\frac{dA}{dz} = [-j\beta(z) + C(s,z)]A \tag{1}$$

Where A is the amplitude of the plural form of each mode; β is the phase constant; C is the coupling matrix; s is the structural parameter, represents the curvature of the wave-guide axis.

In order to achieve compact structure and high conversion efficiency, the coupling structure is generally adopted as follows:

$$y(z) = e_1 \cdot r \cdot \cos\left(\frac{2\pi}{\lambda_{B1} \cdot (1+\delta_1)} \cdot z\right) - e_2 \cdot r \cdot \sin\left(\frac{2\pi}{\lambda_{B2}(1+\delta_2)} \cdot z\right) - e_3 \cdot r \cdot \sin\left(\frac{2\pi}{\lambda_{B3} \cdot (1+\delta_3)} \cdot z\right) \tag{2}$$

Where e_1, e_2, e_3 represents the disturbance amplitude and r represents the wave-guide radius. In the curved wave-guide,TE_{01} is strongly coupled to TE_{11}， also coupled to TE_{12} and TE_{21}, which leads to inefficient modes. Therefore, these two patterns should be considered when designing the coupling structure. λ_{B1}, λ_{B2}, λ_{B3} are the beat frequency steps between TE_{01} and TE_{11},TE_{12},TE_{21} respectively. δ_1, δ_2, δ_3 represents the phase re-matching factor.

We use genetic algorithms to optimize these parameters. Genetic algorithm,as a global optimization algorithm,is a method to find the optimal solution by simulating the natural evolution process. After the initial population is given, the fitness function is solved to determine whether the requirements are met. If not, the fitness function is solved by optimizing the selection,crossover and mutation operators, and a new value is obtained. Until the end condition is satisfied exit,get the optimal value. In this problem,the initial population is the optimal range of parameter values, and the fitness function is the coupled wave equation. Fig.1 is a block diagram of the genetic algorithm[2].

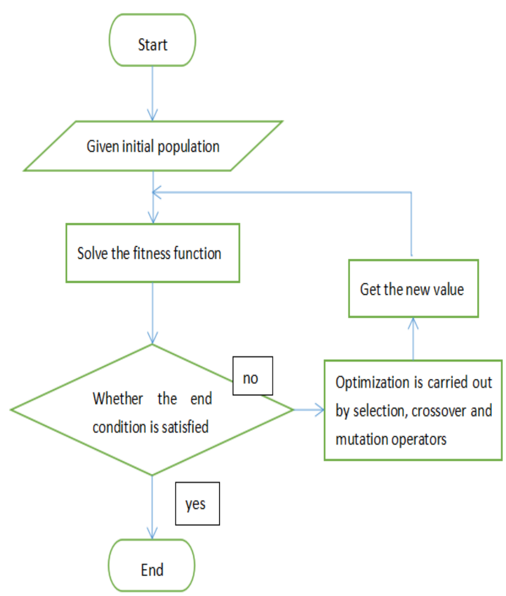

Figure 1. Flow chart of genetic algorithm

After the optimized initial parameter value is obtained through optimization, iterative optimization is carried out.

The coupled wave equations are solved by calculating the curvature value of a point on the axis. If the efficiency fails to meet the requirements, the curvature is corrected, and the correction amount is:

$$\Delta cur(z) = \Delta S \cdot t \qquad (3)$$

Where ΔS is the gradient and t is the step size of iteration.

The initial value of parameters optimized by genetic algorithm is shown in Table 1:

Table 1. Optimized parameter values

e_1	e_2	e_3	δ_1	δ_2	δ_3
0.1643	0.0252	0.0090	-0.0120	-0.0024	0.0262

Then, the structure is further optimized by iterative method, and the curvature is changed to make the structure more compact. Fig.2 is the axis position curve of the mode converter after iterative design. It can be seen that its input and output ports are parallel, which is actually used in assembly.

Fig.3 shows the relative conversion efficiency of each mode after numerical calculation. It can be seen that the relative power of TE_{11} mode reaches 98.7% at the end of output.

In order to further verify the efficiency of our designed pattern converter, we conducted modeling experiments in CST. Fig.4 is the sweep frequency curve of the mode conversion efficiency of the output port of CST simulation. It can be seen that, at 32GHz, the conversion efficiency of TE_{01} to TE_{11} mode reaches 98.5%, which is almost the same as the numerical simulation result. Moreover, in the 31.643GHz to 32.887GHz frequency band, the efficiency reached more than 90%, the relative bandwidth is 3.89%.

In the CST, the field detector can be used to view the field distribution of the longitudinal section of the mode converter, as shown in the Fig.5, and the field distribution of the input and output ports, as shown in the Fig.6.

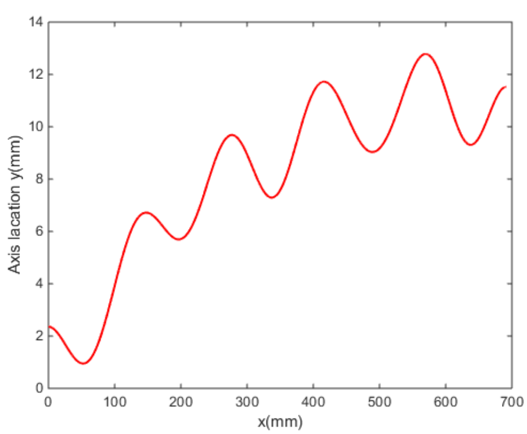

Figure 2. Axis position of mode converter

Conclusion

The optimization effect of the genetic algorithm on the function parameters under global conditions enables us to obtain more effective initial values, and then through iteration we can design the desired pattern converter. The length of the wave-guide is 691.52mm, the wave-guide radius is 14mm, and the efficiency reaches the maximum around 32GHz, and the bandwidth is wide enough. The next step is to further optimize the algorithm and design a shorter and more compact mode converter.

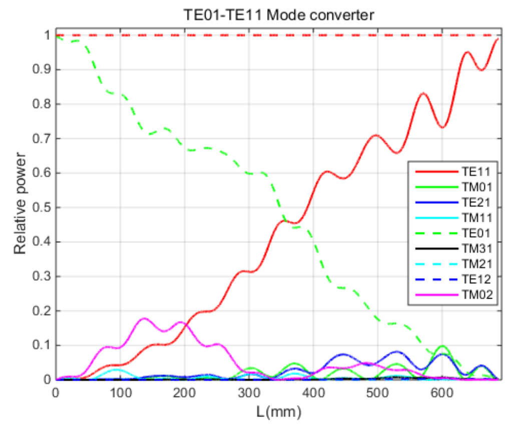

Figure 3. The relative efficiency of the mode converter

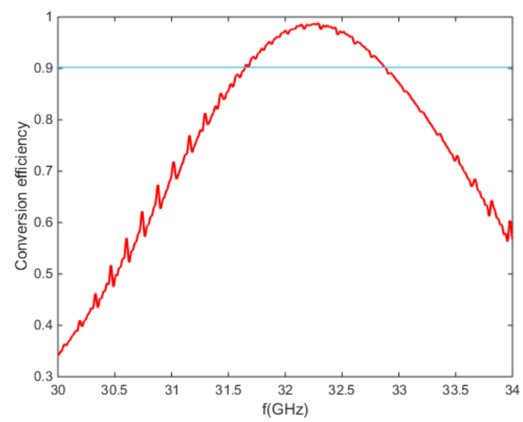

Figure 4. Mode conversion efficiency

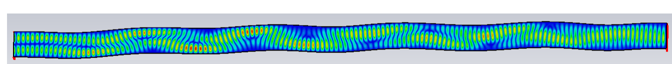

Figure 5. The field distribution of the longitudinal section

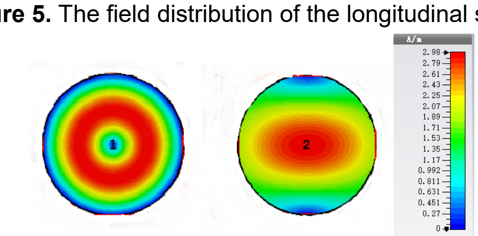

Figure6. The field distribution of the longitudinal section

References

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