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EXPERIMENTAL STUDY OF LONG COUPLED HELIX RESONATOR

Z. X. Liang, W. G. Li, K. Li, W. S. Qian and C. C. Han
Department of Technical Physics, Peking University
Beijing, China

Abstract

Experimental tests of a coupled normal temperature low β helix resonator with six-half-wavelength are described. The frequency shift and dynamic instability of the resonator are studied experimentally. The mechanical vibration caused by ponderomotive effect has been controlled. This resonator can run stably at a RF power of 50 KW , frequency of 27 MHz, duty factor of 1/6, and the maximum voltage gain is more than 1.1 MV. Some measures have been taken to increase the stability of the helix. The resonator tested is a model for heavy ion booster following a small van de graff accelerator.

Introduction

A heavy ion post accelerator after an electrostatic accelerator has been proposed.[1] It consists of two normal temperature long coupled helical resonator and one splitring loaded resonator. In order for pretest, an accelerating cavity with six-half-wavelength coupled helices with β lower than the first section's has been designed and constructed on the base of two half-wavelength coupled helical resonator.[2,3] The instability of the resonant mode for long coupled resonator, the distribution of the field, the overall tunning and the stability at high power levels are studied. It is convenient for this that some adjustable components and measurement parts are installed in the cavity. This paper briefs the results of the experiments.

Parameters of the Resonator

A stainless steel tube with a diameter of 6mm, thickness of 0.5 mm were winded into helices after pressing axially to 4 mm and copper plated. Six helices were assembled into a 240 mm diameter tank. The parameters of the resonator are listed in table 1. Where D is diameter, S pitch, L total length, f_o resonant frequency, Z_s electrical length.

Table 1. Parameters of the resonator

helices			f_o	Q_o	Z_s	L_e
D mm	S mm	L mm	MHz		MΩ/m	mm
80-90	5.5-6.4	1005	27.37	890	19	1035

Field Distribution

Probes located at every wave crests of the radial field are used to pick up signals so as to monitor the relative changes of the field distribution at different power levels.

Six moveable plug are installed at every wave crest of the helices. The length of the helices can be trimmed for about 10 mm by means of moving a slide, that means gaps between helices can be adjusted in the range of 10 mm. All of these fine variations can be considered as a small frequency pertubation of corresponding helix. According to pertubation theory of a coupled network, the field distribution will be change considerably due to the trimming mentioned above. It is effect can just be used for regulating the field. The measured field distribution at low power condition is shown in Fig. 1. The 1st and 7th peaks are smaller because of influence of end effect. In order to get higher energy gain the 4th, 5th and 6th peaks are regulated higher than others.

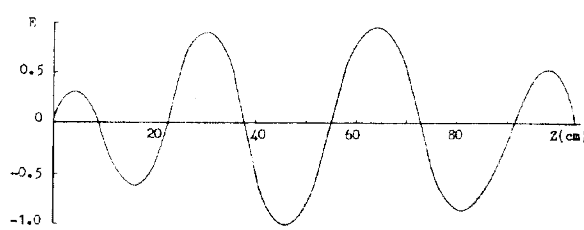

Fig. 1. Field distribution of helices

As a tunning ring can not give a wide tunning range and it may considerably influence the field distribution, it is no good to be used in a long coupled resonator. Hence a long aluminium plate movable along the radial direction and in parallel with the axis has been developed as a tunning component. In order to maintain the field distribution, the tunning plate must provide same frequency shift for different he-

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lices. In terms of the chromatic dispersion, the width of the tunning plate must be varied with the diameter of the helix.[4] The overall resonant frequency can be changed by adjusting the width of the plate along axis and the -mode field distribution maintains constant. Experimental results show that to keep constant field distribution the first two helices with diameter of 90 mm corresponds with width of 110 mm, length of 480 mm, the following four helices with diameter of 80 mm, with width of 60 mm, length of 620 mm. When the tunning plate moves along radial direction for 12 mm, the resonator's frequency changes about 340 KHz.

Experimental Apparatus and Results

The layout of the high power experiments is shown in Fig. 2. The vacuum of the tank is better than 2×10^{-5}. Some static frequency shift, dynamic unstable threshold power and harmful resonant frequency have been tested without amplitude regulating system and automatic frequency tunning loop.

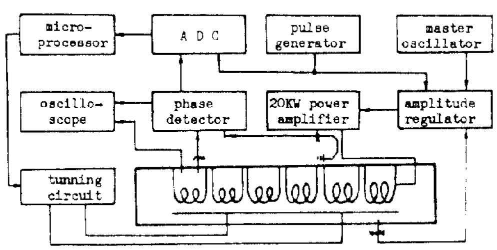

Fig. 2. The layout of the experiments

A power level P versus resonant frequency f has been done at duty factor of 1/6. As shown in Fig. 3, a static frequency shift $\Delta f_s / P = -17$ KHz can be seen.

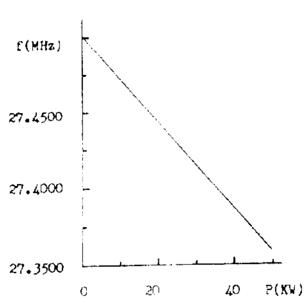

Fig. 3. The static frequency shift curve

The dynamic unstable threshold power was measured at different duty cycles with a sensitive phase detector. From the results listed in table 2, a unstable threshold power is about 10 KW in average.

Table 2. The tested threshold power value

duty cycle	1/2	1/3	1/4
pulse power (KW)	19.9	30.0	40.0

Some harmful frequency such as 20.2, 40.8, 60.2 and 80.0 Hz have been observed. So long as the pulse repitition rate avoids those harmful frequency and their harmonics, it is possible to damp mechanical vibration.

Six modes of axial electric field have been measured for six $\lambda/2$ coupled helices resonator. The frequencies are 27.37, 28.42, 29.86, 35.90, 48.19 and 52.85 MHz. The cavity tuned to 27.37 MHz i.e. for π-mode. The separation between π-mode and its neighbouring-mode is about 1.05 MHz, which is much larger than the half width of the resonant curve, so the mode can keep stability. The resonator at π-mode can run stably at high power of 50 KW, duty factor of 1/6 condition.

From probe signals located at the five peaks of the field slight changes of field distribution have been observed. The experimental results are listed in table 3.

Table 3. The relative field value at different power

P (KW)	E_2	E_3	E_4	E_5	E_6
5	0.84	0.92	1.00	1.01	0.85
10	0.79	0.92	1.00	1.02	0.85
15	0.75	0.91	1.00	1.02	0.84
20	0.74	0.90	1.00	1.03	0.83
25	0.73	0.89	1.00	1.03	0.83
30	0.71	0.89	1.00	1.04	0.84
35	0.70	0.88	1.00	1.04	0.84
40	0.70	0.88	1.00	1.04	0.84

These slight changes of the electric field at different power levels indicate that the six coupled helices have different mechanical distortion at high power levels.

An amplitude control system with gain of 40 dB, band-width of 30 KHz is used. It is capable to damp considerably the disturbances caused by external electrical and mechanical pertubations. It is suitable for wide power level range and easy for regulating on the resonator. A microprocessor controlled automatic frequency tunning loop[5] with an adjustable sensitivity of less than 1° was installed which is capable of following the resonant frequency within ± 150 KHz during power feeding of 0-50 KW, duty factor of 1/6. With the two automatic control systems the six coupled helices resonator can run stably for long period at average electrical field strength of 0.75 MV/m. This resonator can be used for accelerating 0.2 Mev/A of proton and deutoron and the maximum energy gain W_{max} is 0.86 Mev.

Conclusions

As terminal effects was not considerd in the designing of this coupled helices, it makes the resonant frequency of the 1st and 6th helices higher. In addition, the less coupling factor and the defect of mechanical technology restrict the field regulation, and make the measured Q-value and shunt impedance lower than the designed value. To enhance the threshold power a stainless steel tube of ϕ10x1.0 mm is used for the proposed long coupled resonator. A field of 1 MV/m is to be expected.

Acknowledgements

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