FABRICATION OF HOM-FREE LINEAR ACCELERATING STRUCTURE USING CHOKE MODE CAVITY FOR JAPAN LINEAR COLLIDER

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Abstract

In order to eliminate the wake field instabilities in the accelerating structure, a choke mode type damped cavity has been proposed for Japan Linear Collider (JLC). It was first suggested by T. SHINTAKE at KEK and was fabricated by Nihon Koshuha CO., LTD. . An S-band 0.5m-long structure was tested at Accelerator Test Facility (ATF) at KEK. The maximum an axial electric field gradient is already obtained 50.6MV/m with an input rf power of 100MW and 1μs pulse width. The structure consists of twelve regular cells with an input and an output couplers, which has traveling wave $3\pi/4$ resonant mode and a constant impedance geometry. This paper will report the low power measurement results and fabrication techniques.

Introduction

The Japan Linear Collider (JLC) project of the first phase (JLC-I) aims to build a new high energy electron-positron collider for this 300-500 GeV [1]. In order to get high luminosity, acceleration of multibunched, high peak-current and low-emittance beam is most important R&D issue to realize JLC. Eminence-growth due to the long-range wake field is very serious problem. The new type damped structure; Higher Order Mode (HOM)-free linear accelerating structure using choke mode cavity (SHINTAKE Structure) was devised by T. SHINTAKE at KEK. It effectively damps higher-order modes induced by accelerating beam and this effectiveness was demonstrated in low-power tests [2]. Besides, in order to fit within realistic total length of entire accelerator and from the viewpoint of beam dynamics, the requirement of accelerating gradient is several times higher than conventional structure. Thus the requirements for such a structure are:

1) No discharge should occur even at high power operation,

2) there should be less dark current even at high power operation.

In order to carry out the high power test of SHINTAKE structure and the beam accelerating test, a hot model has been fabricated. An S-band frequency (2856MHz) was chosen for this operation test. This is because the high-power rf source has been already developed and there are many results of high power test of the conventional accelerating structure. This paper describes the fabrication technique and low power test results of the hot model and lastly introduce the high power test results performed at KEK. Incidentally, the detail of the hot model design was already published by T. SHINTAKE [3].

Fabrication of hot model of SHINTAKE structure

The structure of the 0.5m-long hot model is shown in Figure 1, the main parameters in Table 1 and the exterior view in Photo 1. The hot model installed in the vacuum chamber. The structure has an active length of 0.551m and is composed of 12 regular cells and 2 coupler cells. Length between each cell was fixed by 6 pipes (diameter: 30mm, length: 34.36mm) which also serve as cooling water channel. In order to achieve deviation of resonant frequencies of each cell to 100kHz or less, it was manufactured as follows: first, the inner diameter (2b), length (d), thickness of disk (t) and aperture (2a) of each cell were processed to the precision of ±10μm; finally the cavity inner diameter of each cell was processed while measuring the resonant frequency. This corresponds to the phase difference of ±0.4 degrees. The actual process is as follows: detuned cavities as shown in Figure 2 were manufactured and set to ultrahigh precision machines to perform the resonant frequency measuring ($\pi/2$ mode) and machining at the same time. Also the ambient temperature, humidity and the temperature of cavity were always measured during the frequency measurement and machining, and the resonant frequency was corrected accordingly. As the result, the deviation in resonant frequency of each cell could be kept within ±80kHz. The adjustment of the coupler cells was also made by using the detuned cavities, measurement and machining being done by using the same method.

The material of Oxide Free Copper (OFC) was class 1 of Hitachi Cable Co., Ltd. The surface cleaning was done by ultrasonic cleaning with pure water after degreasing, followed by heat treatment under the vacuum condition. Since all the surface of the SHINTAKE structure is subjected to ultrahigh vacuum of the order of 10^{-9} Torr, it was processed to have the superfinish with the target of 0.1S or less in coarseness grade. The lubricant employed at the time of superfinish processing was not machine oil but ethanol.

The vacuum brazing was performed in 3-stage process: firstly the input coupler section, 6 upstream regular cells, 6 downstream regular cells and output coupler section were respectively connected; secondly the input coupler and upstream 6-train regular cell block, downstream 6-train regular cell block and the output coupler were connected respectively; lastly the cavity and two regular cell blocks were connected. Since the brazing for each cell was made only with 6 pipes of 30mm diameter, repetition of heat treatment gave little distortion, and the length between cells was maintained within ±5μm of the design value even after the final brazing.

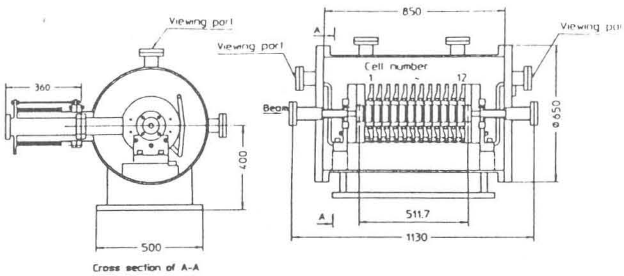

Fig. 1 Structure of HOM-free accelerating structure using choke mode cavity (SHINTAKE structure).

Table 1. Main parameters of the SHINTAKE Structure

Operation frequency	2856	MHz
Phase shift per cell	$3\pi/4$	Constant Impedance
Number of cells	14	12 regular cell + 2 coupler cell
Structure diameter	280	mm
Active length	511.7	mm
Cavity diameter (2b)	82.94	mm
Cavity length (D)	39.36	mm
Diameter of aperture (2a)	24.00	mm
Disk thickness	8.0	mm
Shunt Impedance	42.0	MΩ/m
Quality factor (Q_0)	12000	
Vg/C	0.0084	
Attenuation parameter	0.16	naper/m
Accelerating gradient at input 100MW	46.1	MV/m

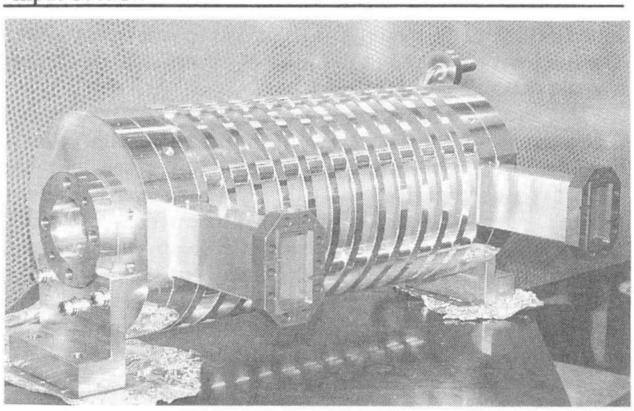

Photo. 1 Exterior view of SHINTAKE structure

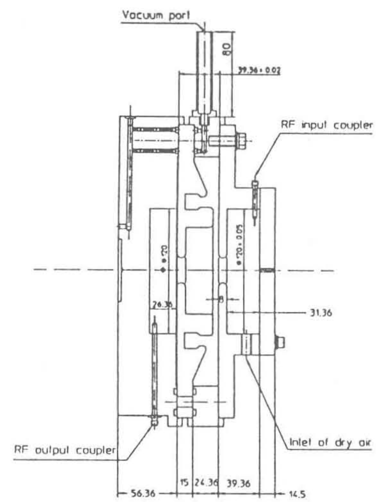

Fig. 2 Structure of detuned cavity for measurement of $\pi/2$ mode resonant frequency and processing.

Low Power Test and Results

The resonant frequency and phase shift of each cell after the brazing, were measured by using magnetic short method and nodal shift method, respectively. All the measurements were performed in the air. Each cell was numbered in order from the upstream.

Figure 3 shows the $\pi/2$ mode resonant frequency of each cell after the brazing as measured by the magnetic short. It is known that the resonant frequency of each cell has the variance of ±80kHz before brazing and ±250kHz after brazing. This corresponds to ±1.0 degree of phase angle which is acceptable. Thus we have confirmed that the fabrication method adopted can provide the sufficient precision of frequency.

Figure 4 shows the phase variation of each cell as measured by the nodal shift method. $3\pi/4$ mode being used, the phase shift per cell is 135 degrees (270 degrees for round-trip). The measured phase shift of each cell falls in the range 126.5 to 142.5 degrees and is rather scattered, but the mean value is 134.5 degrees. The large dispersion is considered to be due to the standing wave in the cavity caused by the insufficient adjustment of the coupler cells. The attenuation parameter obtained from the attenuation of No. 2 and No. 10 cells is 0.16 (naper/m) which agrees well with the calculated value of 0.16.

The input VSWR is 1.423 at 2854.588MHZ which is the frequency under the atmosphere at the time of measurement. This is considered mainly due to the defective adjustment of the coupler. However, the power reflection caused by this is 4%, which causes no problem for the high power test of this time.

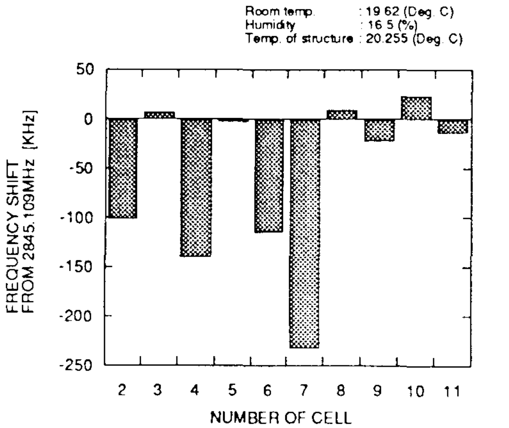

Fig. 3 Resonant frequency of each cell after brazing.

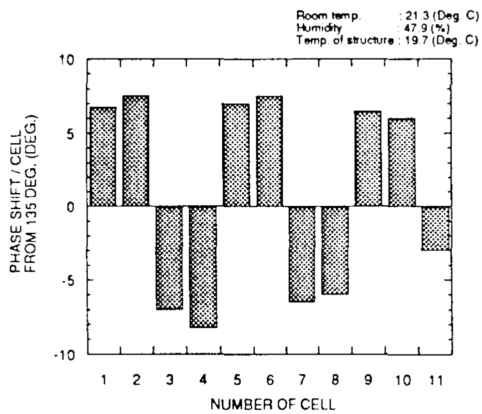

Fig. 4 Phase shift of each cell.

High Power Test and Beam Acceleration Test

The SHINTAKE structure was subjected to the high power test at KEK [4]. During the RF processing of about 100 hours, the input power of 100MW and average accelerating gradient of 46.1MV/m were obtained without problems. The input and output power of the structure at that time are shown in Figure 5. Moreover, accelerating of multibunched beams with this input power, succeeded in obtaining the energy gain of 26.2MeV which is nearly the expected design value.

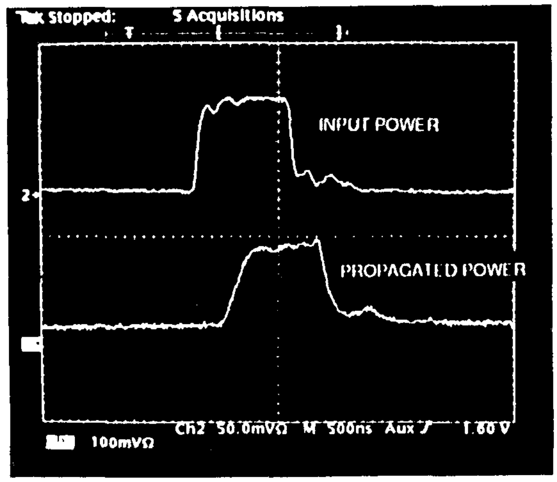

Fig. 5 Rf pulse waveforms of input and output power for high power test of SHINTAKE structure.

Conclusion

Form the results of the hot model fabrication and the high power tests carried out lately, we have confirmed that there is no problem in practical use of SHINTAKE structure for Japan linear colliders, and have established the fabrication method. We shall hereafter study the development of its mass production techniques and the adjusting method of coupler cells.

Acknowledgments

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