MEASUREMENTS OF HIGHER ORDER MODE IN AN X-BAND ACCELERATOR*

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Abstract

In this paper, a cage of metallic wires is used as a perturbing object to measure the longitudinal electric fields of higher order modes (HOMs) in an X-Band accelerating structure. The cage is made by sputtering copper film onto nylon thread through a specially designed fixture. The "form factors" of cage are calibrated in a pillbox cavity. By using of a cage and a cylinder, the longitudinal electrical fields on TM110 mode in an X-Band accelerating structure are determined by perturbation technique. This results are compared with the calculated ones from URMELT code. And the measurements with cage produce the true field profiles.

1. INTRODUCTION

Research and development on the next generation electron linear collider (NLC) aiming at TeV energy are underway[1]. In order to achieve the desired luminosity for physics experiments, a multi-bunch operation is considered; therefore, the long-range wake field must be suppressed. For this purpose, many types of structures have been studied [2], such as damped structure, detuned structure and damped detuned structure and choke-mode cavity. The amplitude of the wake field on each HOM is in proportion to its *R/Q*. In this paper, the most dangerous HOMs — TM_{110} mode in an X-Band accelerating structure is studied and measured.

Experimental determination of *R/Q* is usually accomplished by the Slater's perturbation technique[3]. Different from the accelerating mode TM_{010}, dipole modes not only have longitudinal electric field but also have other field components at the position of the perturbation. In order to separate axial electric field from other components, a very thin metallic needle should be demanded ($d << l$, d and l are the diameter and length of a needle). But for such a thin and short needle ($l << \lambda_0$), the frequency shift would be too small to produce relevant data.

Another technique is to measure three components of each $\vec{E}$ and $\vec{H}$, corresponding to the perturbation along the bead pull. So six independent equations relating them must be solved simultaneously at each point. The most convenient perturbing objects are a needle, a sphere and a disk. This measurement procedure, although theoretically being possible, would make rather severe demands on the accuracy of the form factors of each object.

In 1987, at DESY, one of the authors proposed a new type of perturbation object — metallic cage[4]. It combines the advantages of high sensitivity and high directivity. It had been used to measure *R/Q* of the dipole modes in superconducting cavity of HERA successfully[5]. In 1994, a cage was also made on S-Band and was used to measure the longitudinal and transverse electric fields of dipole mode in an S-Band model cavity accurately.[6]

In this paper, TM_{110} mode in an X-Band accelerating structure is measured. The cage on X-Band is made by sputtering technique. In 1996, this technique had been used to make a hollow cylinder to measure the *R/Q* of TM_{010} on X-Band accelerating structure. The fabrication and calibration of cages are described in section II. In section III, the longitudinal electric fields on TM_{110} in an X-Band accelerating structure are measured and are compared with those calculated one from URMELT code.

2. FABRICATION AND CALIBRATION

2.1 Fabrication

In X-Band NLC, the operating frequency of main linacs is 11.424GHz. The most dangerous dipole mode is TM_{110} mode. Its typical frequency is about 15.6GHz. In order to achieve enough frequency shift as well as small K_i / K_1 (K_i are the form factors of a perturbing object), a metallic cage was developed (shown in Fig.1)[4]. According to the boundary conditions of cage, if each metallic wire is thin enough ($d << l$), the cage is only sensitive for perturbing the axial electric field; Moreover, when the number of the metallic wires increases enough, the amount of the perturbing will approach that one of a cylinder with the same D and l. We can find that the type of perturbation

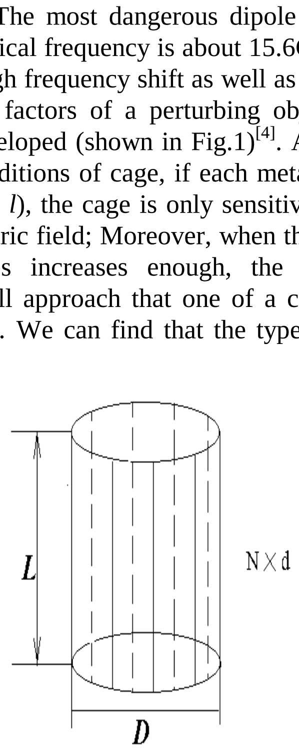

Fig.1 Layout of a cage

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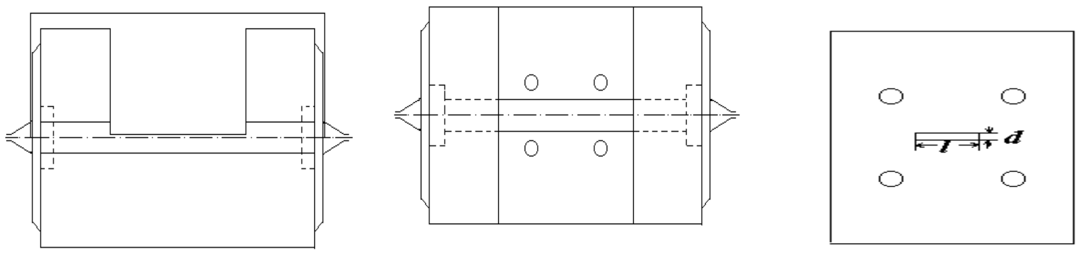


(a) longitudinal view (b) vertical view (c) mold plate

Fig.2 The fabrication fixture

object has the advantages of high sensitivity and high directivity.

In this paper, the cages with *D=0.56mm, l=2mm, d=0.01mm, N=6~12* are chosen and made by magnetron sputtering metal onto a nylon thread.

A specially fixture is designed (shown in Fig2.). The nylon thread is threaded through the fixture and is fixed by a pair of the coaxial tongs with turntable at the sides of the cylinder. Pulling rod, the nylon thread can be rotated about the axis. In the middle region of the fixture, a half part is cut down; therefore, a platform is formed on which a mold plate is put. The cage length and the wire diameter are defined by the mold plate and can be adjusted as needed. Sputtering N wires, the pull rod will be rotated 360°/*N* each time.

2.2 Calibration

To calibrate the form factors K_i / K_1, of perturbing objects, a pill-box is made with dimensions of *2R=21.64mm, L=17.494mm*, in which the resonant frequencies of TM_{010} and TE_{111} modes are 13GHz and 12.23GHz. Choosing four suitable arrangements, an object can only perturb one of the field components. For a calibrated object and a metallic sphere, the related frequency shift are Δf_i and Δf_{0i}, the unperturbed frequency are f_i and f_{0i} , their form factors are K_i and K_{0i}. Using the sample relation $K_{01} = K_{02} = 2K_{03} = 2K_{04}$, So, K_i / K_1, of the calibrated perturbing object can be written as

$$\begin{aligned} \frac{K_2}{K_1} &= \frac{\Delta f_2}{\Delta f_1} \cdot \frac{\Delta f_{01}}{\Delta f_{02}} \cdot \frac{f_1}{f_2} \cdot \frac{f_{02}}{f_{01}}, \\ \frac{K_3}{K_1} &= \frac{\Delta f_3}{\Delta f_1} \cdot \frac{\Delta f_{01}}{\Delta f_{03}} \cdot \frac{f_1}{f_3} \cdot \frac{f_{03}}{f_{01}}, \\ \frac{K_4}{K_1} &= \frac{\Delta f_4}{\Delta f_1} \cdot \frac{\Delta f_{01}}{\Delta f_{04}} \cdot \frac{f_1}{f_4} \cdot \frac{f_{04}}{f_{01}}. \end{aligned} \tag{1}$$

Several cages have been measured. The thickness of the wire is about 7000A°. The form factors are about $K_2 / K_1 < 3\%$, $K_3 / K_1 < 3\%$, $K_4 / K_1 < 2\%$. In the pill-box model cavity, the frequency shift on E_z is about 36MHz and approaches that one of a hollow cylinder with the same outer size.

3. EXPERIMENTAL RESULTS

The metallic cage is used to measure TM_{110} mode in the X-Band accelerating structure provided by KEK. The structure consists of 32 cells and 2 couplers. At the beginning, in order to avoid the influence of couplers, the TM_{110} mode is excited and detected by a pair of probes off-axis (shown in Fig.3). The field profiles of TM_{110} modes of 4-cell are calculated by URMELT-code. In this structure, TM_{110} mode is backward wave one. As space is limited, only TM_{110}-3pi/4 mode are shown in Fig.4.

In Fig.4, the measured results with cage and cylinder are also be given. They show that the measurements with the cage are similar to the calculated one from URMELT code. But the measured results with a cylinder are different due to the other components perturbed.

The different field components of TM_{110}-3pi/4 mode are shown in Fig.5. On some points the E_z is near zero while the other components are strong or the E_z is maximum while the H are also maximum; therefore, the frequency shift decreases. So, if K_i / K_1 is not small enough, the longitudinal electrical field can't be measured accurately.

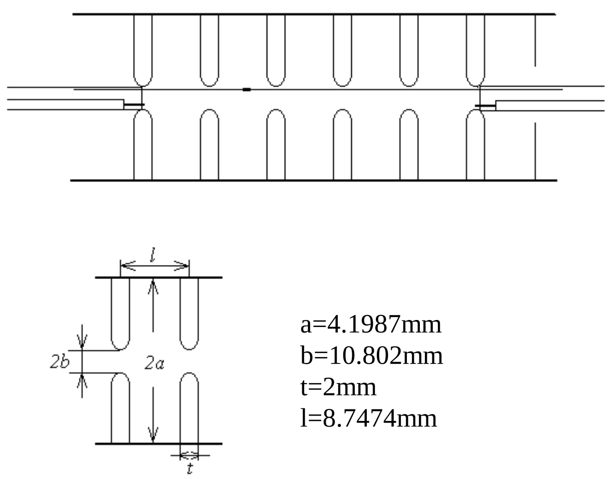
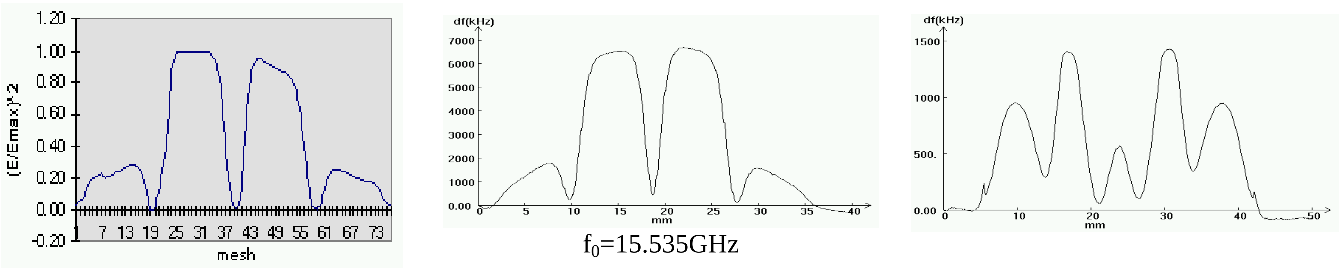
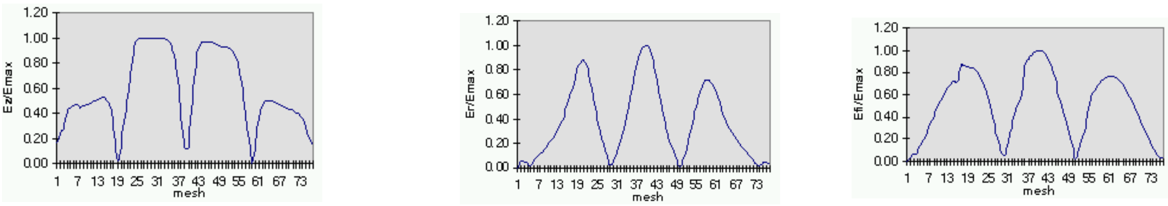


Fig.3 The measured accelerating structure

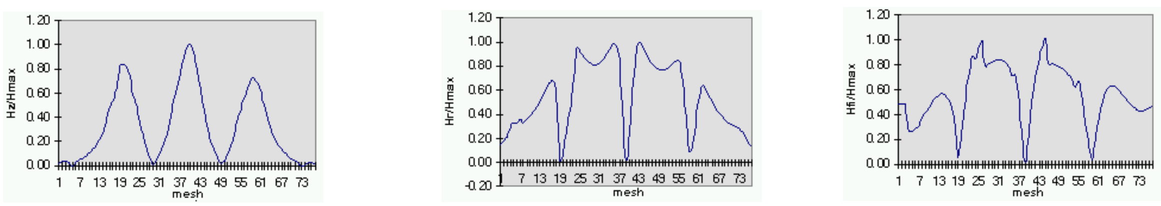


(a) calculated from URMELT code (b) measured with a cage *(D=0.56mm, l=2mm, d=0.01mm, N=10)* (c) measured with a cylinder *(D=0.56mm, l=2mm)*

Fig.4 The field profiles of TM_{110}-3pi/4 mode in 4-cells



(a) E_z, E_{zmax}=489V/M (b) E_r, E_{rmax}=247V/m (c) E_{fi}, E_{fimax}=532V/M



(d) H_z, H_{zmax}=579A/M (e) H_r, H_{rmax}=362A/m (f) H_{fi}, H_{fimax}=215A/M

Fig.5 The field profiles of TM_{110}-3pi/4 mode in 4-cells from URMELT code

4. CONCLUSTIONS

A metallic cage suitable for HOM measurement in X-Band is made by magnetron sputtering copper film onto a nylon thread. The typical size of the cage is *D=0.56mm, l=2mm, d=0.01mm, N=6~12*. The form factors K_i / K_1 of a cage can be small than 3%. The longitudinal electric fields of TM110 mode in X-Band structure are measured by the cage and are similar to the calculated one from URMELT code. Next step the microfabrication of the cage need to be modified. Accurate *R/Q* measurements require a precise knowledge of the form factors of the cage. We aim at measuring the *R/Q* of dipole mode in an X-Band long chain accelerating structure.

5. ACKNOWLEDGMENTS

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