

MICROWAVE QUALITY ASSURANCE EFFORT FOR R&D ON THE NEXT LINEAR COLLIDER AT FERMILAB*

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Abstract

To build the Next Linear Collider, about 5000 accelerator structures are needed in the design considered here which has 206 disks per structure. In order to explore the feasibility of making these structures in an industrial environment (that is, outside a national laboratory setting), 12 copper disks were fabricated by a diamond turning factory. Both mechanical inspection and microwave measurement results of these disks are presented.

1 INTRODUCTION

As part of the Next Linear Collider (NLC) collaboration, the NLC structures group at Fermilab has started an R&D program to fabricate NLC accelerator structures in cooperation with commercial companies in order to prepare for mass production of rf structures. In a recent design proposed by SLAC, the NLC would consist of a total of about 5000 RDDS (Rounded Damped Detuned Structure) accelerator structures. Each structure consists of 206 cells with very tight tolerances. For example, in order for the detuning mechanism to suppress long range dipole wakefields as designed, the first dipole mode frequency of each cell must vary smoothly and the frequency deviation from the designed value must be less than 1 MHz. This requires a 1 μm mechanical tolerance on the contour of each cell. For the fundamental mode (i.e., the accelerating mode), the accumulated phase error through the structure must not exceed 5 degrees. To meet this requirement, simply controlling the mechanical tolerance to 1 μm is not enough, and thus sorting of cells or a feed forward correction scheme have been proposed [1]. Other tolerances on flatness, parallelism etc. are also very tight in order to achieve the phase slip and frequency requirement.

Due to these tolerance requirements, quality assurance (QA) is one of critical steps for this program. The full scope of QA includes many topics such as single cell and full structure QA, rf and mechanical QA, etc. So far 12 RDDS disks (61 mm O.D.) have been fabricated by the diamond turning company Contour Manufacturing & Metrology Inc. The 12 RDDS disks are identical (cell #50 in a structure) so they can be used to identify quality of diamond turning and potential difficulties or problems in QA. Microwave measurements (non-contact) were done with all 12 disks first, and then six of them were mechanically inspected. These measurement results are listed and discussed in the following sections.

2 MECHANICAL INSPECTION RESULTS

Six disks (C001 – C006) were mechanically inspected using an optical non-contact measurement system at Zygo, and a contact measurement system at Zeiss. Shown in Figure 1 is the surface map of a disk measured by an interferometer manufactured by Zygo. Data on flatness, parallelism, O.D, and thickness of these six cells are listed in Table 1.

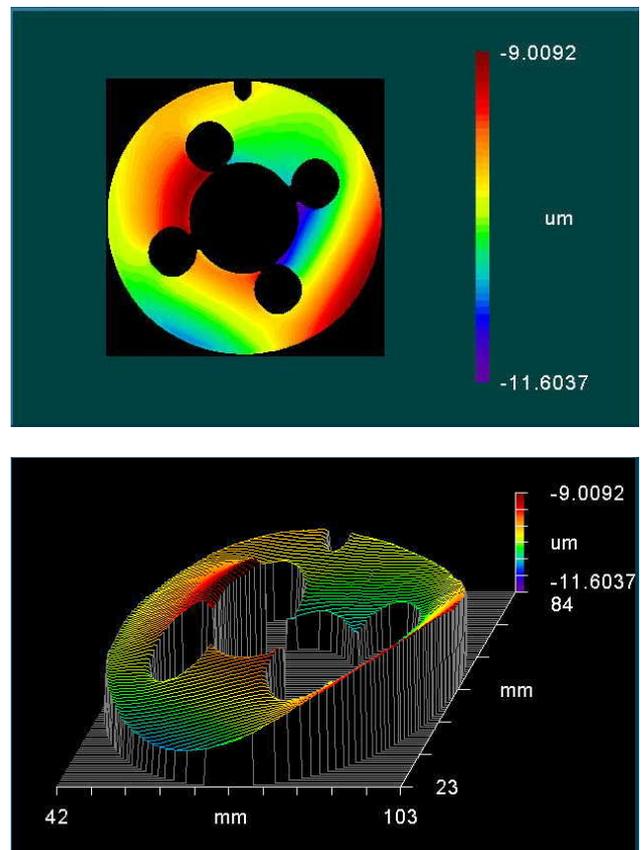


Figure 1: Surface map of a disk (optical measurement).

Shown in Figure 2 are contours (green: measured, blue: designed, red: tolerance) of the six disks measured by contact measurement at Zeiss. Each column in Figure 2 has four contours of a disk measured at four different cross sections (90 degrees apart.)

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Table 1. Measured mechanical properties (*: designed tolerance) All dimensions are in mm.

Disk #	Flatness 0.0005*	Flatness (opposite side)	Parallelism 0.001*	Thickness 8.74377 +/- 0.001 *	O.D. 61.000 +/- 0.001 *
C001	0.00139	0.00059	0.00279	8.73739	60.99900
C002	0.00056	0.00112	0.00145	8.73605	61.00012
C003	0.00051	0.00105	0.00258	8.74148	60.99944
C004	0.00082	0.00066	0.00221	8.74004	60.99988
C005	0.00047	0.00054	0.00363	8.73734	61.00013
C006	0.00118	0.00044	0.00329	8.73870	61.00006

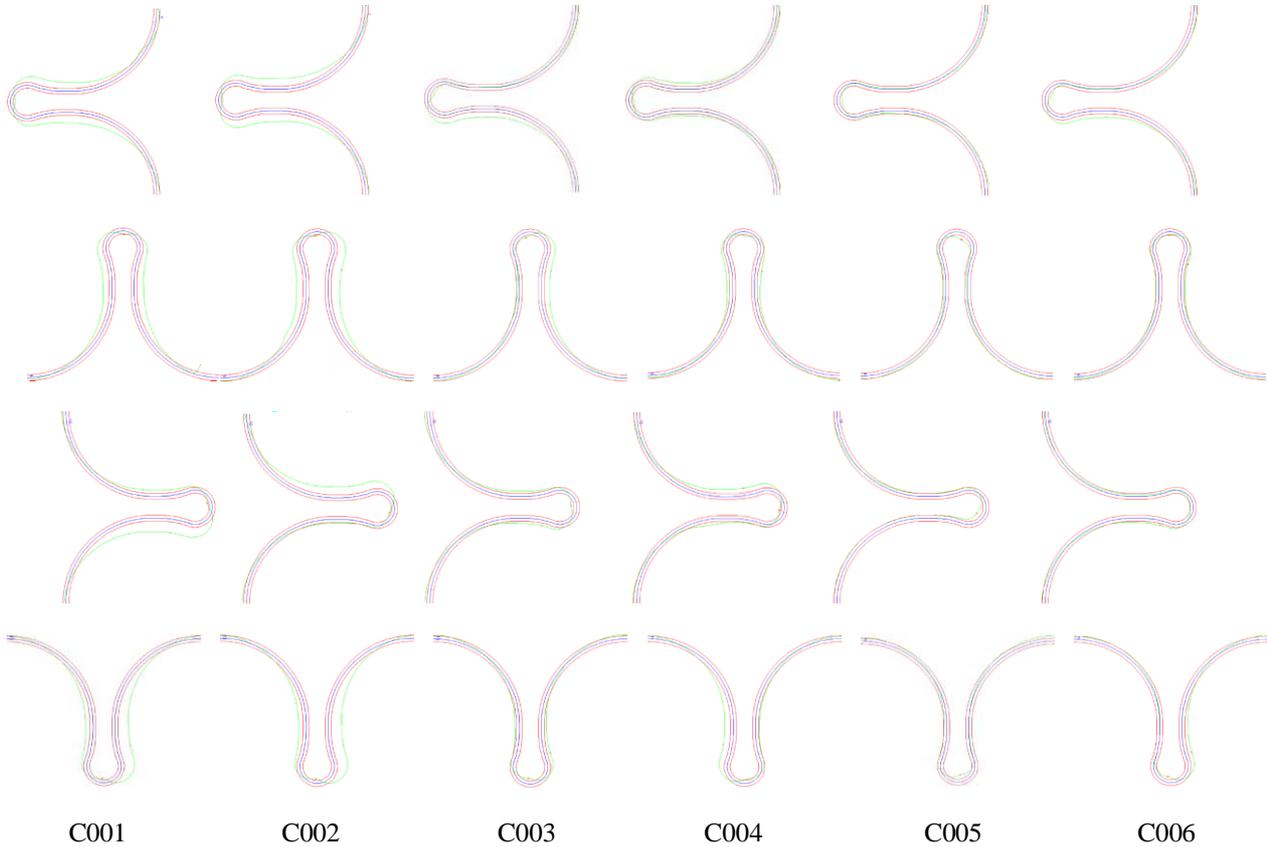


Figure 2: Contour of six disks (each column is one disk, green: measured, blue: design, red: tolerance).

The results show that deviations from the design contour are in three dimensions and are not symmetric about any axis. Therefore it is not meaningful to characterize the contour error as simple deviation from a single parameter such as $2a$ (diameter of the bore) or $2b$ (diameter of the cell) etc.

3 MICROWAVE MEASUREMENT RESULTS

Single cell resonant frequency measurements were done by putting shorting plates on each side of a disk and measuring the transmitted or reflected signals through two tiny probes on the shorting plates. The shorting plates are flat plates with chokes for non-contact measurement or without chokes for contact measurement. The non-contact shorting plate is copied from SLAC [2]. There is a 2.5 mil

gap between the shorting plates and the disk for non-contact measurements.

Shown in Figures 3, 4, 5 and 6 are the resonant frequencies of the first four modes. Each disk was measured, rotated by 90 degree and measured again. This procedure was repeated four times until the disk was returned to the original orientation. The measured frequencies at each position are marked as 0° , 90° , 180° and 270° . Since RDDS disks have 90-degree symmetry by design, the 90-degree rotation does not affect the resonant frequency if the disk is “perfect”. This procedure is primarily for detecting imperfections of disks other than errors in $2a$ or $2b$.

4 DISCUSSION

The mechanical inspection shows that these disks do not meet the design tolerance. Taking contour errors in all

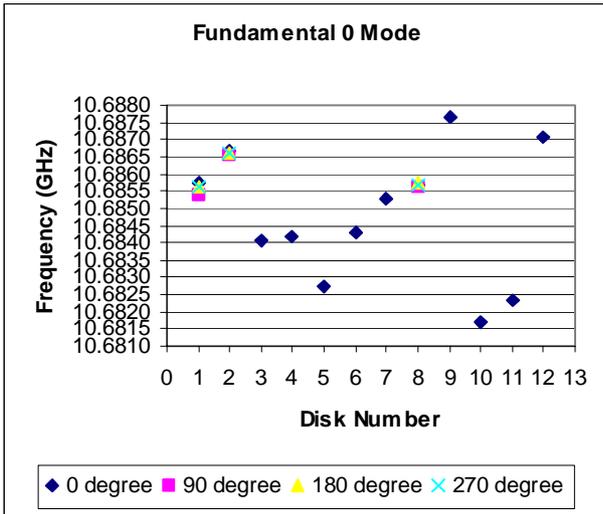


Figure 3: Resonant frequency (monopole 0 mode)

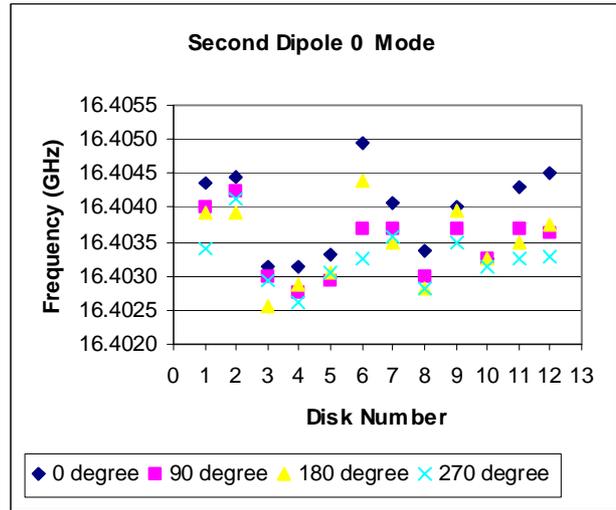


Figure 5: Resonant frequency (second dipole 0 mode)

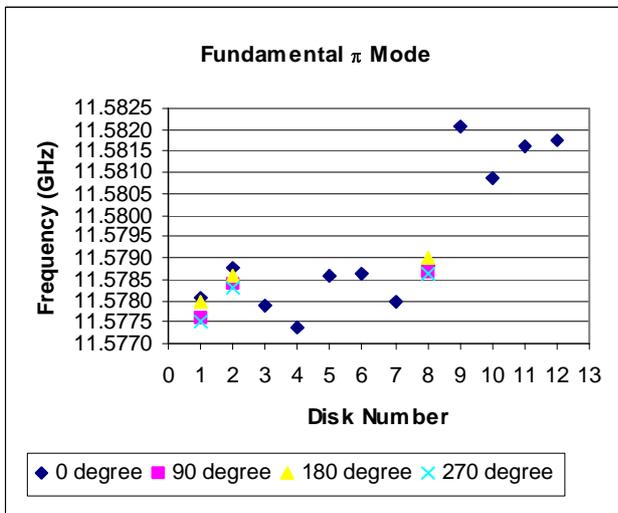


Figure 4: Resonant frequency (monopole π mode)

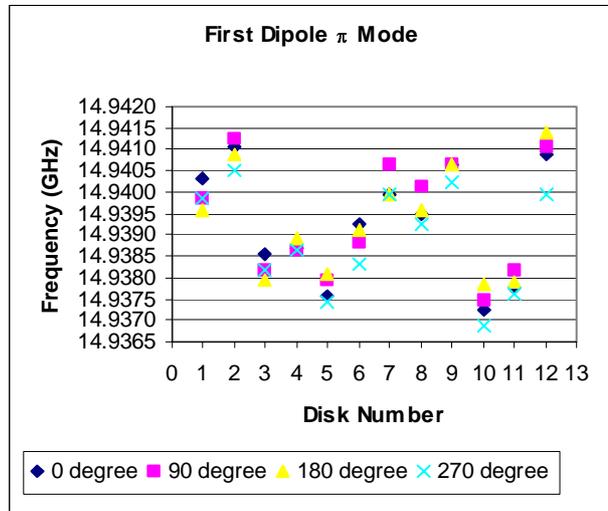


Figure 6: Resonant frequency (first dipole π mode)

four cross sections into consideration, the six inspected disks can be divided into 3 groups: disk # 5 is the best one, disks # 3, 4 and 6 are next, and disks # 1 and 2 are the worst. The frequency changes of the monopole 0 mode and the first dipole mode of these six disks are similar to the changes in their contour errors. Therefore the frequency variations of these two modes among disks are likely caused mainly by contour errors in these disks.

The change in resonant frequency when the same disk was rotated is more or less an indication of other qualities of the disk such as flatness and parallelism. This is true in particular when the monopole 0 mode frequency changed a little (disk #2 and #9). In these cases, the little change in the monopole 0 mode frequency is an indication that the electrical center of the disk is almost the same as the geometric center (center of outer circle) and the roundness error at critical places of the disk is close to zero. Therefore the frequency spreads in other modes (such as the monopole π mode) are mainly due to errors in the flatness and parallelism since the π mode and other modes are more sensitive to these parameters.

A frequently asked question is: Can microwave measurements be used as feedback to correct the machining process? The results of these six disks indicate that the frequency spread between rotations of a single disk may be used as an indicator for quality control of flatness and parallelism, and frequency comparison between a measured disk and a standard disk may be used as a guide to modify the 2b parameter to obtain the right frequency. However, microwave measurements can not tell the details of contour errors of a disk, even though this may be the information the machining process really needs as feedback. More R&D on fabrication and measurement of disks are needed if the present RDDS design is to be used as the basis of the NLC main linacs.

5 REFERENCES

- [1] ISG Progress Report, April 2000
- [2] R.H.Miller *et al*, "Microwave Quality Assurance for Single Cells of the Next Linear Collider," LINAC 2000