CONCEPTUAL DESIGN OF AUTOMATED SYSTEMS FOR SRF CAVITY OPTICAL INSPECTION AND ASSEMBLY*

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Abstract

The International Linear Collider (ILC) will require ~16,000 Superconducting Radio-Frequency (SRF) cavities at an accelerating gradient of 31.5 MV/m. One of the critical issues that needs to be addressed is the insufficient yield of high-gradient cavities that meet the requirement. This paper describes the design and initial tests of a cavity inner surface optical inspection system. Combined with a full-featured 9-cell cavity temperature mapping system being developed at LANL, we hope to be able to correlate the cavity heating and the surface condition causing it.

INTRODUCTION

LANL restarted SRF cavity activities in 2007 with funding to help identify problems with the 9-cell cavities for the ILC. This effort included initial development of a 9-cell cavity temperature mapping system [1] and conceptual designs for automated surface inspection and assembly systems [2]. Unfortunately, the ILC funding was not enough to complete the T-mapping system and development was suspended. In 2008, with new funding from the Defense Threat Reduction Agency (DTRA), SRF cavity activities were again restarted. Recently, the hardware for the T-mapping system was completed; T-mapping system software is currently being developed [3]. Regarding the surface inspection system, the first phase system (i.e., some parts will be manually positioned) has been designed. Fixtures to hold a ~6mm diameter videoscope have been fabricated and tested using videoscopes from 2 companies. This paper describes the design of this surface inspection system and presents some preliminary inspection results. Since LANL will be performing R&D for both 1.3 GHz and 805 MHz cavities, this system can be used to inspect both sizes of cavity.

INSPECTION SYSTEM DESIGN

Figure 1 shows the concept of the surface inspection system. A ~6 mm diameter videoscope is inserted into a T-shaped fixture contained in a stainless steel pipe. At first, this T-shaped fixture is facing upward so that the scope does not stick out of the pipe. The pipe is inserted into the cavity along its beam axis and the T-shaped fixture rotates to position the scope horizontally pointing to the equator region when it is straight. The videoscope can be articulated remotely to look at the vicinity of the area up to ~90 degrees as shown in Fig. 1.

Figure 2 shows how the cavity is mounted on the inspection system. A cavity stiffening ring will be clamped with the 2 half circles (shown in dark blue in Fig. 2), and the cavity will be supported by a plate (shown in light blue). This plate will rotate smoothly on a Teflon sheet. In the first phase, the cavity will be manually moved, but in the second phase, an actuated motion system will be incorporated to automate the rotation and up/down motions.

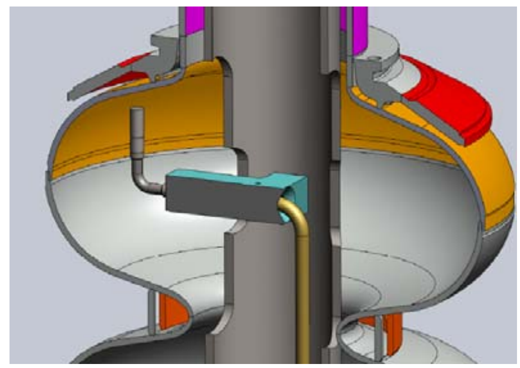

Figure 1: Conceptual drawing of the surface inspection using a videoscope.

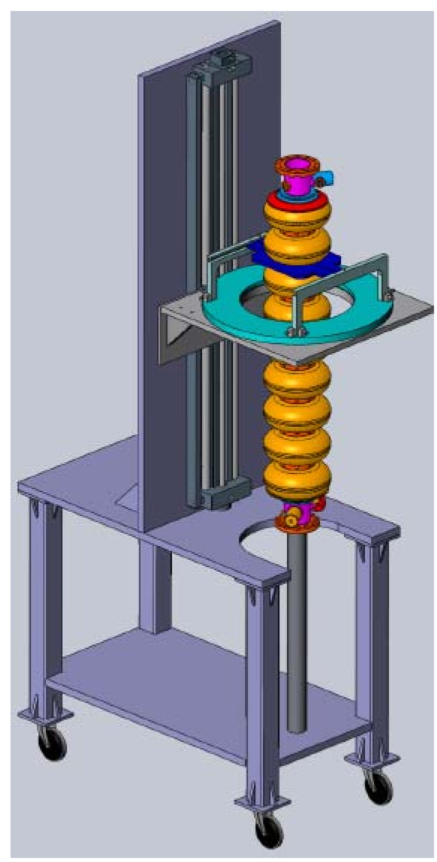

Figure 2: Cavity inspection hardware with a 1.3 GHz 9-cell cavity. The videoscope and the motors for moving the cavity are not shown here.

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The first region to be inspected is the equator region. Figure 3 shows this regular position.

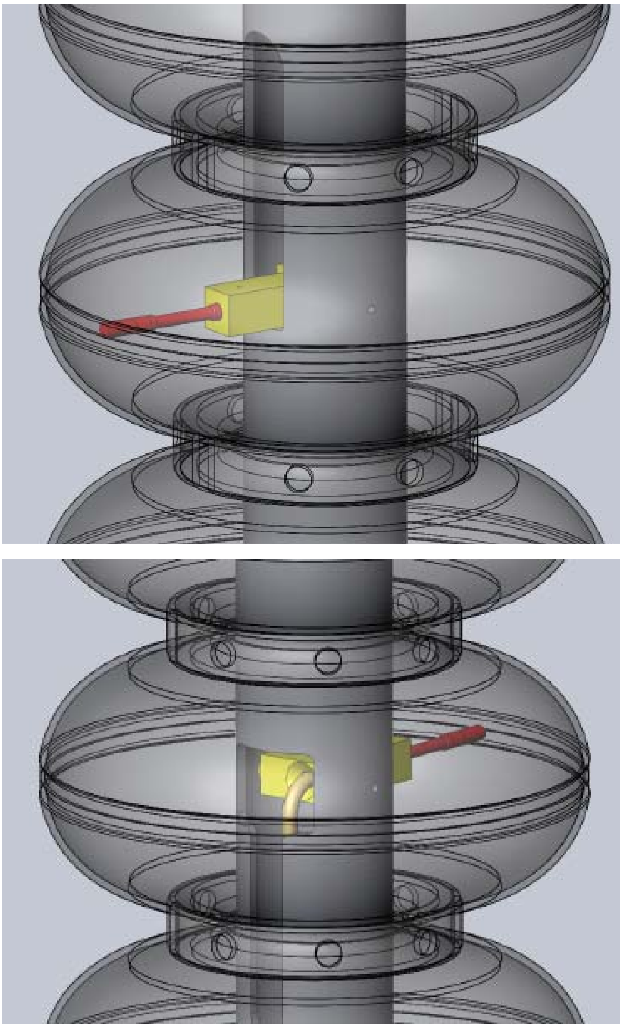

Figure 3: Schematic of a 6 mm videoscope inserted in the cavity. The closest distance to the cavity will be 4-7 mm depending on the scope you choose.

CHOICE OF A SCOPE

The design incorporates a videoscope that consists of a small CCD chip enclosed in a small diameter tube of typically 4-8 mm in diameter with a remote articulation function. Although videoscope manufacturers do not publish the resolution of their scopes, the best resolution seems to be around 50 microns judging from an image of a scale, shown in Fig. 4, and assuming about 1/5 of the distance between 2 clearly seen lines is the resolution.

TEST OF A CRUDE SYSTEM

The T-shaped fixture was fabricated and attached to a stainless steel pipe. Then, a 6 mm diameter videoscope was inserted into the fixture as shown in Fig. 5. This pipe was inserted into an 805 MHz, β=0.8, single-cell cavity shown in Fig. 6. In Fig. 6, also shown is an indirect light source needed to look at the interior clearly without a glare from a point light source.

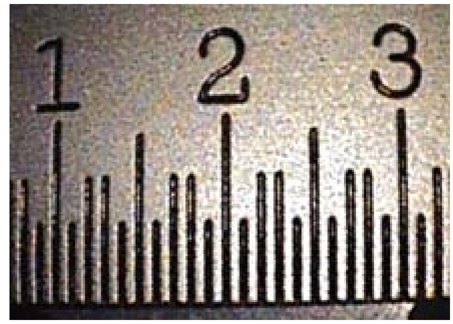

Figure 4: An image of a scale using a 5 mm videoscope. The smallest increment between lines is 254 microns.

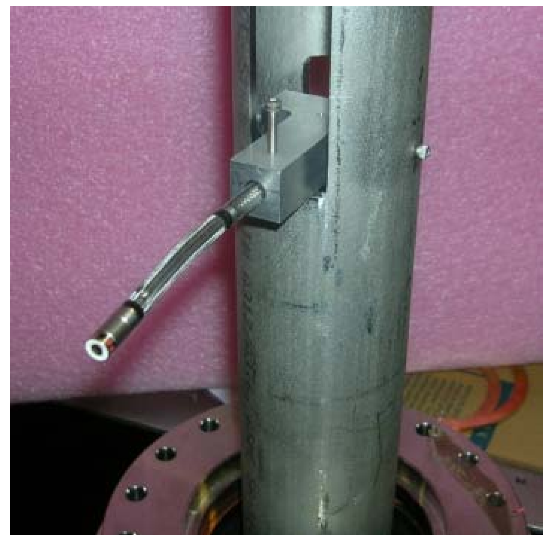

Figure 5: A 6 mm diameter videoscope set in the fixture.

Figure 6: A 805 MHz single-cell cavity inspected.

Figure 7 shows the Q_0 versus peak surface electric field (E_{peak}) for this cavity, measured in 1993. It was quench limited at about E_{peak}=35 MV/m [4], but there was no surface inspection system available at that time and the relationship between the surface condition and the cavity performance limitation was not studied.

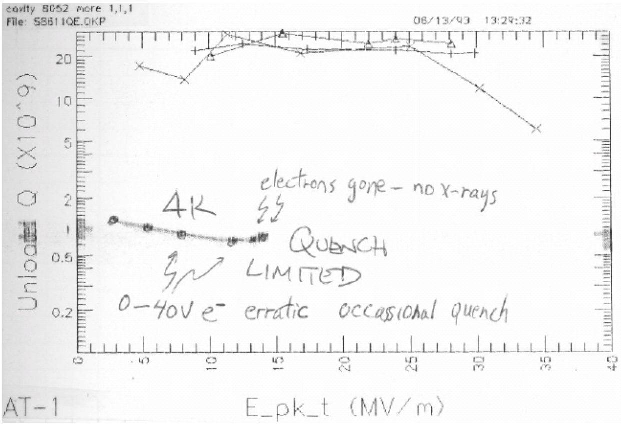

Figure 7: 805MHz single-cell cavity Q_0-E_{peak} curve measured on 13 August 1993.

An inspection of the equator region and its vicinity was performed using the remote articulation function of the videoscope. Several imperfections and defects were found, as shown in Figs. 8 through 10. The largest and most outstanding defect was the one shown in Fig. 9, which is located about 25 mm away from the equator. This defect could be the cause of the quench.

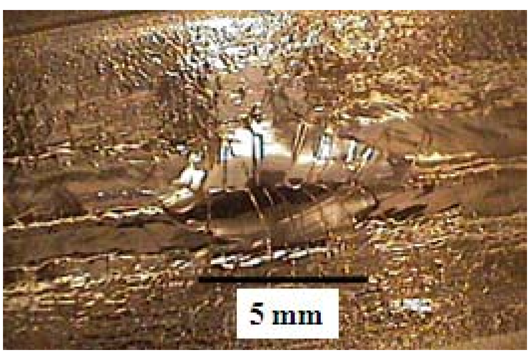

Figure 8: Starting or ending point of electron beam welding.

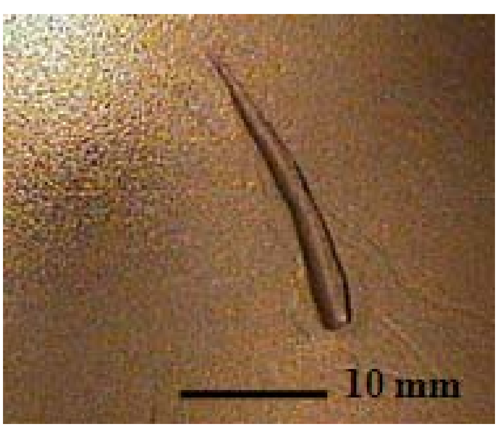

Figure 9: A defect about 25 mm away from the equator.

Figure 10: Scratches near the equator.

FUTURE PLAN

The inspection system will be refined and used to inspect a 1.3 GHz 9-cell cavity after locating hot spots with T-mapping system in July 2008. Then, a more automated system will be developed so that the scope can accurately be positioned at the coordinates specified by the T-mapping system. Also, there are plans to develop an ultrasonic system to detect inner surface defects from outside, without venting or contaminating the cavity.

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