STUDY ON NONDESTRUCTIVE INSPECTIONS FOR SUPERCONDUCTING CAVITY

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Abstract

The temperature mapping (T-map) and X-ray mapping (X-map) are powerful inspection methods to locate a hot spot during the vertical RF tests for superconducting cavity. We also developed SX-map (X-map system beneath the stiffener rings between cavity cells) with the same scheme as the XT-map system. Our mapping system got useful results on finding a defect in vertical RF tests of superconducting 9-cell cavity. We have been studying to apply the mapping technology to the superconducting spoke cavities.

INTRODUCTION

The nondestructive inspection is important and necessary for the survey of the interior surface on R and D of superconducting (SC) cavity [1, 2]. The upper limit of the accelerating gradient of the SC cavity seems to be affected by the condition of the interior surface. Main causes of limiting accelerating gradient are thought to be the quench at local heat source and field emission due to defects such as scratches, dust particles in tens of µm and roughness of a few hundreds µm. These defects must be located and removed after the searching at local area of the interior surface. So the nondestructive inspections are essential manufacturing processes.

Among varieties of the inspections, the multi-point thermometry mapping measurements (T-map) and the multi-point X-ray radiation mapping measurements (X-map) are useful tools to survey the defect locations during the vertical RF tests. XT-map system under development in collaboration between Kyoto University and KEK is a combined function system of T-map and X-map for the 9-cell niobium cavity in the International Linear Collider (ILC) [3]. The same scheme is applied to the Stiffener-X-map strips that installed beneath the iris stiffener rings of the elliptical SC cavities

MAPPING SYSTEM

Among various X-map and T-map methods in some other laboratories, our mapping system has the following features, which are still under improvement.

- Use of low-cost components
- High-resolution survey
- Reduction of number of wiring signal cables
- Easy installation

The schematic drawing of the XT-map and the Stiffener-X-map is shown in Fig. 1. Figure 2 shows the newest prototype (XT-map ver.4 and Stiffer-X-map ver.2). Only commercially available components are assembled on Flexible Printed Circuits (FPC) sheets for the T-map and X-map. Almost all components are low-cost on market. The XT-map boards and the Stiffener-X-map boards consist of sensors, amplifiers and multiplexers. The huge amount of sensors (T-map:1024/cell, X-map:256/cell, X-map:32/iris) are installed in this system. In order to cover with many dense sensors on exterior surface of a cavity, the XT-map circuit board is shaped into a double-leaf as shown in Fig. 3. The reduction of the number of wiring signal cables has been achieved by the daisy-chained sensor-circuit boards and the signal multiplexers at the cryogenic area.

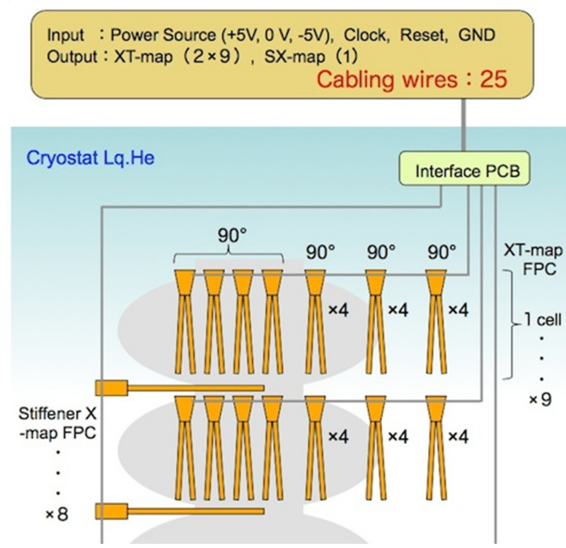

Figure 1: The inter-connection for the XT-map system and Stiffer-X-map

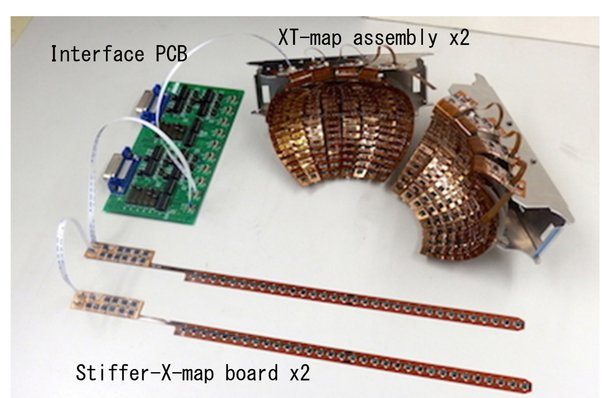

Figure 2: New FPC assemblies for Ver.4 XT-map (1/4 cell) and the Ver.2 Stiffer-X-map (2 iris). These have sensors, amplifiers and multiplexers on FPC sheets (polyimide film with several layers).

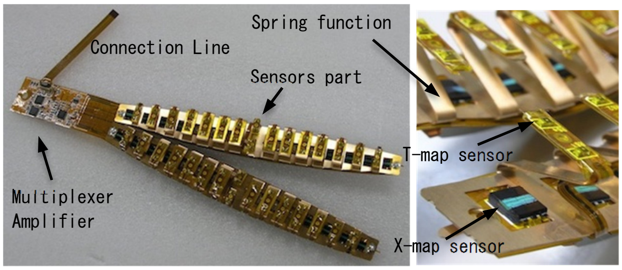

Figure 3: The Ver.4 XT-map assemblies. It is comprised of the double-leaf-shaped FPC sheets, the phosphor bronze sheets for the spring action and a fixing device for SC-cavity. 16 XT-map sheets can cover the whole one-cell.

Ruthenium oxide (RuO_2) chip resistors instead of the carbon resistors are adopted as typical cryogenic temperature sensor. In our preliminary study on RuO_2 chip resistors, we confirmed that the resistors have enough sensitivity for detecting the temperature rise around 4K [4]. PIN photodiode is adopted as X-ray sensor in consideration of performance, package size, cost, and availability on market [5]. Although both the sensors adopted have less sensitivity compared with sensors used in other T-map and X-map systems for example carbon resistors, or big size photodiodes on the market, these sensors have enough sensitivity for our mapping system sensor with the on-board amplifiers and integrators.

9-CELL CAVITY

XT-Map

A preliminary quench detection test using a ver.3 assembly of XT-map was performed on a SC 9-cell cavity which was known to have a quench location by a previous vertical test at KEK. As shown in Fig. 4, four XT-map circuit boards were installed on 1/4 area (from 45 to 135 degrees) of a cell, where a heat generation was expected. Figure 5 shows a typical measurement results of actual quench events detected by the mapping system with 1kHz sampling rate (a scan of 9-cell cavity takes about 1 sec). The thermal contact scheme of this old system was not very good, because the thermal sensors directly soldered on the FPC touched to the cavity surface through a tension of the FPC sheet pulled from both the ends. Although there were some sensors with bad thermal contacts, the quenches were detected well enough with the rest of sensors owing to the super-multipoint measurement. Our T-map system can work at a rate more than 2kHz sampling [6].

Because some measurement points had insufficient thermal contact between T-map sensor and the exterior surface of cavity, we developed the new XT-map board (Ver. 4) with independent spring actions as shown in Fig. 3. It should be noted that the chip resisters have naked soldering electrodes at both ends, which have to be electrically insulated from the cavity conductor surface. Among several kinds of insulation materials, which included STYCAST 2850FT with high-performance at the cryogenic temperature, a polyimide tapes (thickness:35μm) had been adopted as the electric insulation between sensor and the cavity exterior surface, based on the measured thermal conductivity in actual T-map condition (cryogenic temperature, contact pressure, in liquid helium, etc). In addition to polyimide tapes, we are studying other electric insulation materials for the new XT-map sensors considering ease of installation, thermal conductivity, radiation resistance and cost [7].

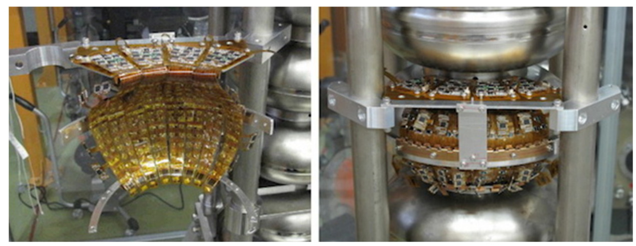

Figure 4: The installed XT-map assemblies (1/4 cell) for the quench detection at KEK. This ver.3 XT-map FPC boards assembly did not have spring action.

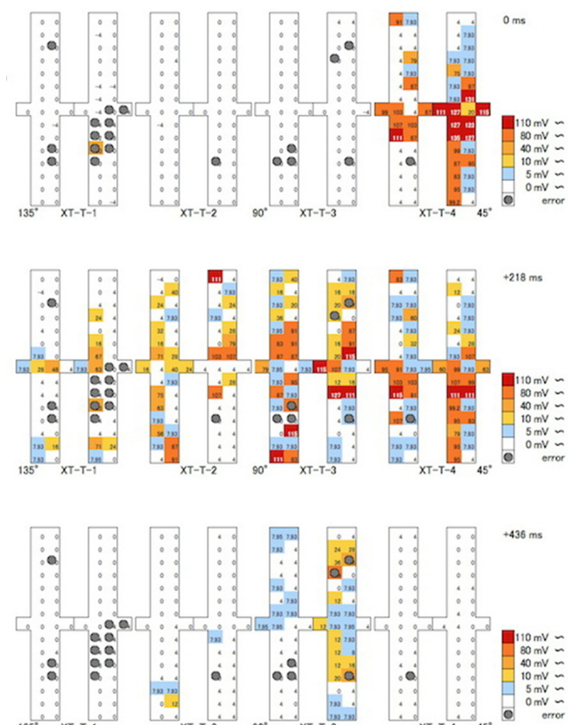

Figure 5: Typical measurement results of the quench detection test of XT-map during the vertical test. The circles are quench location previously observed by KEK T-map. The temperature rise time was estimated about 0.5sec from the scan period of 0.216 sec.

Stiffer-X-Map

X-ray measurement around iris zone of cavity is difficult in the 9-cell SC cavity because of the stiffener ring. Therefore a special X-map system (Stiffer-X-map) is developed so that X-map sensors can be installed under the stiffener rings as shown in Fig. 6. This Stiffer-X-map

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consists of 10 strips at 8 irises and 2 end flanges, where each strip has 32 photo diodes with integrating amplifiers and a multiplexer. Stiffer-X-map can detect clear signals without the attenuation of X-rays through the stiffener rings (Nb).

The data acquisition system was prepared. A USB connected PC oscilloscope converts the multiplexed sensor voltage train transmitted through a single signal lines with a clock signal. The acquired data is processed in a notebook-PC. A screen shot of the measurement software is shown in Fig. 7, when Stiffer-X-map detected the infrared light from fluorescent room lamps in the setting as shown in Fig. 8. We will test this Stiffer-X-map system in the vertical RF test in this year.

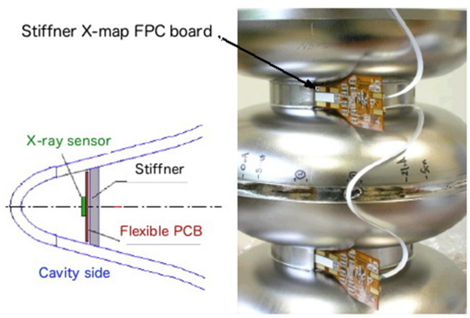

Figure 6: Stiffener-X-map test circuits and its installation. The ribbon shaped FPC boards (Ver.1) are installed under the stiffener ring.

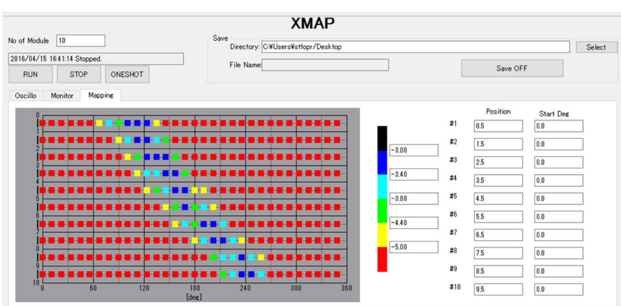

Figure 7: The screen shot of a real time measurement with Stiffer-X-map. This screen shot is a result with the setting as shown in Fig. 8. The red output signals indicated saturation by infrared light from fluorescent room lamps.

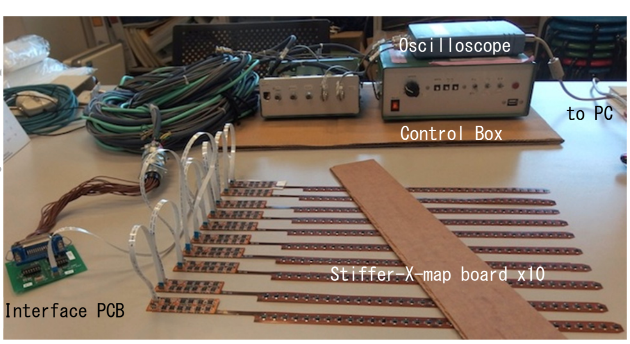

Figure 8: The hardware setting for Stiffer-X-map. In order to confirm the operations, a shade bar was placed on Stiffer-X-map sensor FPC boards (Ver.2).

SC SPOKE CAVITY

Based on the success of Stiffer-X-map, we are trying to apply the techniques for the SC spoke cavities.

A 325MHz superconducting spoke cavity is under development for electron accelerators [8]. Our XT-map system should also be available for SC spoke cavities. As shown in Fig. 9 T-map sensors can be designed for an installation at the end-plate corner that has a risk of multipactor [9]. T-map sensors can cover the corner area with density of about one sensor per 1cm^2.

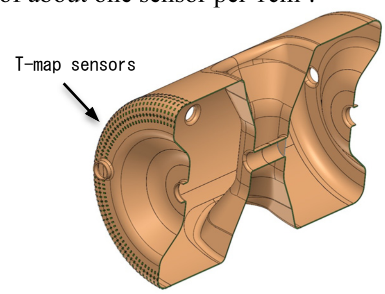

Figure 9: The measurement points for the spoke cavity.

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