A WIRE POSITION MONITOR (WPM) SYSTEM TO CONTROL THE COLD MASS MOVEMENTS INSIDE THE TTF CRYOMODULE

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Abstract

A system able to measure, on-line, movements and vibrations of the Cold Mass (CM) during cool down and steady state operation has been developed and installed inside the first TTF Cryomodule. The system includes two independent lines, with 18 WPMs each, and an improved version of BPM type.
read out and data analysis. Laboratory tests on a shorter prototype have shown that the system is able to monitor the CM displacements with a few micron sensitivity, the absolute error being less than 50 microns in the range of +/- 2.5 mm. Fast read out and FFT technique allow also to detect and analyze possible CM vibrations.

1 INTRODUCTION

The TTF facility will consist of four 12 m long cryounits each with eight 9-cell superconducting cavities operating at 1.3 Ghz and one focusing quadrupole. Beam tests will be carried out at about 500 MeV.
The test program for the first cryounit of TTF includes measures of the cryomodule alignment stability and reproducibility during cool-down/warm up operations.
The required alignment tolerances for the elements inside a cryomodule are 0.5 mm for the RF cavities and 50 μm for the quadrupole. After final assembly inside the cryomodule, the stability of the axis position must be monitored on line during thermal cycles with a resolution of 10 μm. Fig. 1 shows a cross section of the first cryounit.

2 METHOD

The stretched wire alignment system has been discussed in detail in literature since it has been used for the precise measurement of transport components in beam lines [(1)]
Taking as a reference such an experience we have designed a measuring system able to monitor on line positions and vibrations of objects from room temperature down to LHe temperature[(2)]. Desy laboratory has designed the components necessary to install this measuring apparatus inside a cryomodule to monitor the RF cavity axis stability.
The measuring system consists of detectors, called WPMs (Wire Position Monitors), similar to beam position monitors. Each one contains 4 antennas and the differential signal strength received from opposite pairs is the quantity of interest. The WPMs receive their signal from a stretched wire excited by a 140 Mhz RF signal and centered inside a tube. The wire provides the fixed reference with respect to the lab frame while the detectors are fixed to the CM elements to monitor.
The TTF design foresee two sets of 18 transducers fixed along two straight sections inside the cryomodule to provide a complete 3D analysis of the displacements. The system had to take into account many constrains due to the peculiar operating conditions. The most important have been the wide range of temperature (from room temperature up to the operating 2K), the need to contain the overall power consumption at 2K (few Watts) and the fact that the system, after the final assembly, will be inaccessible.

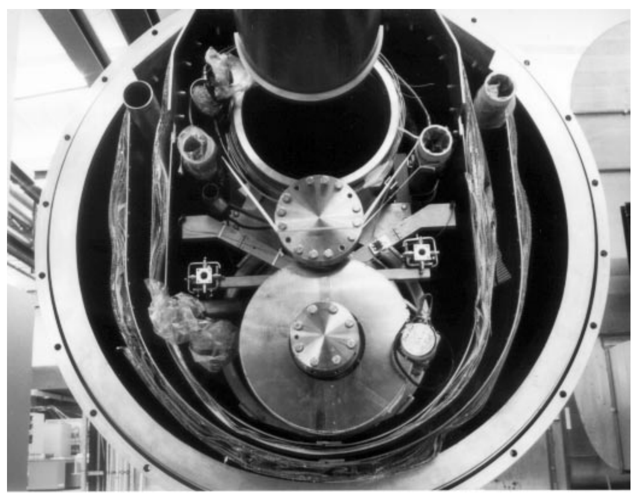

Figure 1 - Cross section of the cryounit

3 DETAILS OF THE APPARATUS

3.1 The WPM

A schematic layout of two WPMs with their supporting frames, is shown in fig. 2.
The detector is of the stripline kind with four electrodes matched to 50 Ω and symmetrically placed at 90° each other. The downstream end of each stripline (relative to RF propagation) is terminated to 50 Ω and the clear aperture is of 12 mm. The wire-stripline coupling and the

crosstalk between adjacent striplines have been measured as 39 dB and >55 dB respectively.

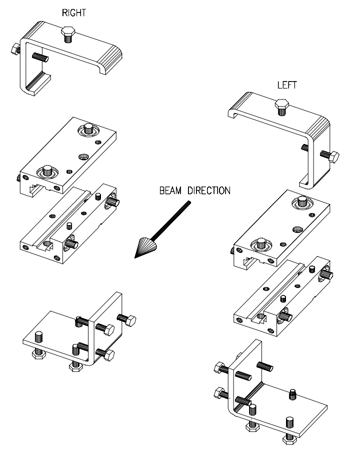

Figure 2 - Schematic layout of two WPM

3.2 The wire and the coaxial tube

The wire employed is a 0.5 mm diameter beryllium copper wire coated with EV-13 to provide electrical insulation. The choice of the material has been imposed by the need to use amagnetic materials and the possibility to stretch the wire with an high tensile stress (of the order of 100 Kg/mm^2). This will reduce, under the operating conditions, the overall sag of the wire at 2.07 mm.

3.3 RF coaxial cable and connectors

The choice of the connectors and RF coaxial cables to transport the signal from WPM to the external of the cryomodule has been a major technological challenge.
The radioactive environment and the cryogenic compatibility have posed severe limitations on materials for connectors and cables. The final choice has been to use a Suhner cable mod. P02182 and special designed SMA connectors and 50 Ω terminations with PEEK dielectric and amagnetic spring.

3.4 Read out electronics

The electronics which handles the signals coming from the WPMs has been developed according to the VXI format, in order to improve noise immunity and to take advantage of the larger board size. Each board will accommodate the components for the control of two WPMs.
The RF signal sensitivity is of -65 dBm with a dynamic range of 40 dB and a linearity of the order of 0.1% in a 20 dB range[3]. The BPM detector cannot process the signal in less than 50 μs, so the maximum rate of acquisition is of the order of 20 Khz for a single stripline. Under operating conditions the acquisition rate for a whole set of detectors is of 1 Khz.

3.5 Data acquisition and analysis system

On line control of the detector electronics and handling of data acquisition from each one of the two structures is performed by a VME 68040 CPU fitted inside each VXI crate. Raw data acquisition, averaging and corrections with polynomial curve are performed at this level. A local storage of data has been provided before a transfer will occur toward a dedicated NFS server. This machine allows to share data between consumer processes.
A PC with a LabVIEW based application provides console functionality for the whole system. On line monitoring of each set of WPM along with analysis of the displacement of each WPM versus time may be done using a menu driven interface. Advanced data processing (frequency analysis, power spectrum of any instability, etc.) is available as a powerful tool to analyze the possible vibrations of the structure.

LABORATORY MEASUREMENTS

A test fixture has been constructed for studying the response of the single WPM or of a string of 3 WPMs. The detectors are assembled on a two axis translation stage and can be positioned anywhere within their aperture with respect to the fixed wire. The absolute accuracy of the positioning system is repeatable to about 4 μm. The electronics reading chain is the same as the final one. The more relevant aspects which have been investigated are the following:

- mapping of the response of the WPM over its aperture
- reproducibility of the measurements after a mechanical disassembling of the detector
- tolerance to errors in mechanical positioning of the detector on its support arm
- long term stability
- characterization of the full set of detectors.

The dependence of the response with respect to the position of the wire can be described by a 3rd order bidimensional polynomial, where the even and cross terms of the 2D polynomial expressions take into account mechanical tolerances and inter-electrode coupling. A mapping of each WPM has been performed in order to determine the polynomial coefficients. These coefficients have been computed fitting the experimental data using Mathematica. The results of these fits shows that the functions describing the wire vertical (Y) and horizontal (X) positions have a strong dependence on the odds terms, whose coefficient has higher weight than the even ones. Moreover odd term coefficients are almost equal for all WPMs, while even term coefficients vary in a random way either when we change the monitor or repeat the measurement of the same device after a disassembling. This suggests us to describe a WPM using only odd terms. A simulation based on a 2D electrostatic model of the WPM has been performed to investigate this behavior. In this model the wire is simulated by a point charge and the signal induced on an infinitely long microstrip is computed. The results have shown that the functional dependence of the picked up signals with respect to a generic wire position can be described by a superposition of Arcsinh(x,y) functions, whose expansion may be stopped at the 3rd order. A graph of the error in position measurement is shown in figure 3. An error of less than 40 μm has been measured within a 2.0 mm range. The same set of coefficients has been applied to the analysisi of the measures for all the WPMs. The error in the reconstructed position has been of the order of 50 μm in the range of +/- 2.0 mm.

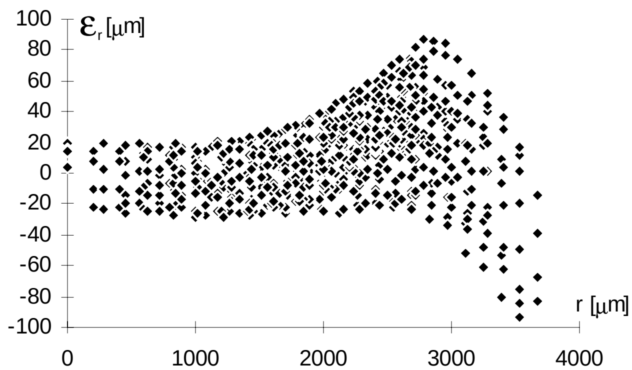

Figure 3 - Errors in position measurements

Tests carried out over a period of 2 month of operation on the 3 WPMs string have shown no significant deviation in the readings (less than .1 mm), assuring a good long term stability of the system.

Misalignment effects of the order of 1.0 mm over the detector dimensions have been studied. The mapping of the response function have shown negligible modifications with respect to that taken with the detector in the reference position. This makes the assembling procedure inside the cryostat less critical.

INSTALLATION AT DESY

In February 1997 the measuring system has been installed into the first cryounit at Desy. A close view of a WPM assembled on its support arm is shown in fig. 4.

The WPMs has been assembled following the catenary sag at each position with a precision of the order of 20 μm. The performance of the WPM system has been assessed measuring the sag of the cryostat under its own weight releasing the central post support on the alignment fixture. Fig. 5 shows the reconstructed position of the detectors in this circumstance. Once the normal position of the cryostat has been recovered the monitors return to their rest measurements within an error of 5 μm.

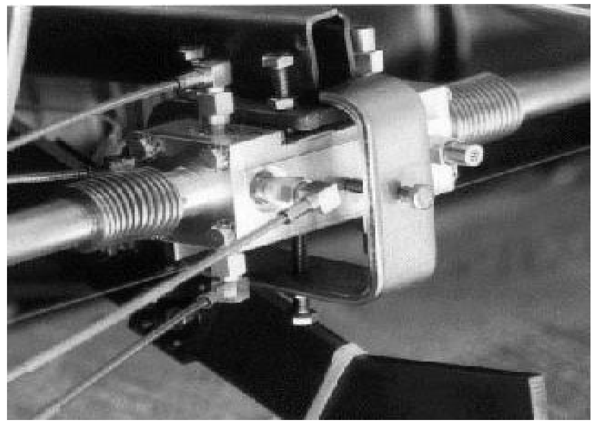

Figure 4 - A WPM installed in the cryounit

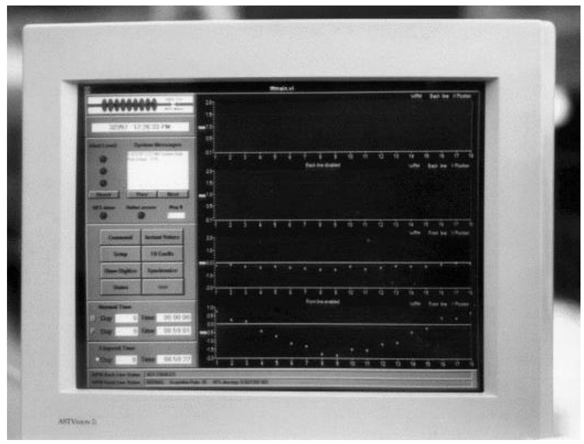

Figure 5 - Console front panel

CONCLUSIONS

We have developed a system able to measure displacements over a range of 6 mm with resolutions up to 10 μm. Components have been designed and tested for operation at 2 K. The final system has been installed in Desy and it will be operative during the first cooldown in May 1997.

REFERENCES

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