A Microstrip Based Position System for the Alignment of the TTF Cryostat

D. Giove, A. Bosotti, C. Pagani and G. Varisco, INFN Milano
LASA, Via F.lli Cervi 201, Segrate (Mi), Italy

Abstract

The cryostat designed for the superconducting cavities of the Tesla Test Facility (TTF) is quite a complex structure with strict requirements on the alignment of the different components at the LHe temperature. A system able to measure on-line misalignments on the full length of the cryostat module (12 meters long) during cool down and operation procedures seems a very useful tool in order to verify structural analysis computation. A microstrip based system using a stretched wire has been designed for this purpose in our laboratory. Desy will provide the stretching system for the wire and the support system for the position transducers. In this paper we will present and discuss the design based on warm and cold tests on a prototype.

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 TTF includes measures of the cryomodule alignment stability and reproducibility during cool-down/warm up operations.

In the TTF cryostat the cavities are suspended and aligned off a large 300 mm diameter helium gas return pipe. Three support posts, derived from the SSC magnet cryostat design, provide the warm to cold support transition from the outside of the cryostat to the helium gas header. Cavities are first assembled and aligned with a standard optical system in an alignment fixture. 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 will be on line monitored during thermal cycles with a resolution of 10 μm.

Method

On line monitoring of the relative position of the different elements inside a cryomodule will be accomplished using a stretched wire alignment system. A detailed discussion of this method may be found in the literature, since it has been already used for the precise measurement of transport components in beam lines (1) . Taking as a reference such an experience, (2) we have designed a measuring instrument able to work at LHe temperature.

In our system two sets of 18 transducers, called WPMs (Wire Position Monitors), will be fixed along two straight sections inside the cryomodule to provide a complete 3D analysis of the displacements. They will be assembled on titanium support arms (designed by Desy), in order to bind their position to the cold mass (RF cavities and a quadrupole). Each WPM is similar to a beam position monitor. It 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 tube is the outer conductor in a coaxial structure which presents a constant impedance to the signal and which shields the signal from external interferences. The wire is stretched by means of an external system (designed at Desy) which will also provide the reference to the wire.

The design of the TTF system had to take into account a lot of constrains due to the peculiar operating conditions. The most important have been the wide range of temperature (from room temperature up to the operating one of 2°K), the need to contain the overall power consumption at 2°K (few Watts) and the fact that the system, after the final assembly, will be inaccessible.

Details of the apparatus

The main elements of the apparatus are the WPM, the wire and the coaxial tube, the RF cables from the WPM up to the exit connectors, the read out electronics and the data acquisition and analysis system. In the following we will describe the characteristic choices for each one of these elements. A more detailed description is available in Ref . 3.

The WPM

A schematic layout of two WPMs with their supporting frames, is shown in fig. 1. It 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 aperture has been imposed by the prevision about the displacement of the supports during the cool down: Δy=1.6-1.8mm and Δx=0.3-0.6mm respectively for cavities and quadrupole.

Striplines are 2.6 mm width and 64 mm long. The characteristic impedance of a stripline measured alone is 50 Ω (SWR has been measured less than 1.1 from room up to LHe temperature). The wire-stripline coupling and the crosstalk between adjacent striplines have been measured as 39 dB and >55 dB respectively.

The choice of the material for the WPMs and for the electrodes has been the consequence of measurements on prototypes from room up to LHe temperature. Brass, titanium and aluminum has been tested. For thermal compatibility and weight considerations, the use of standard microstrip for electrodes has been discarded, while solid aluminum (copper and silver plated) has been chosen both for the WPM body and electrodes.

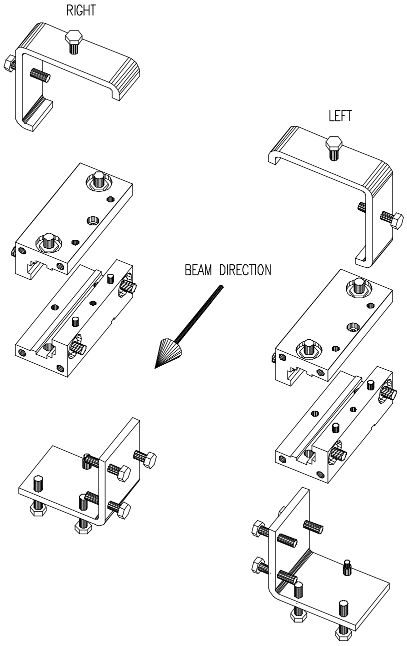

Fig. 1 Schematic layout of two WPMs with their supporting frames

The wire and the coaxial tube

The wire employed is a 0.5 mm diameter beryllium copper wire. 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. Power loss on the wire is of the order of 0.2 dB at room temperature and it will be negligible at LHe temperature.

The coaxial tube has an internal diameter of 12 mm and is made of copper.

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.

Radioactive environment have limited the choice of dielectric materials for connectors and cables. Capability to work at cryogenic conditions with low power loss at LHe temperature (taking into account that the whole length of the coaxial cables inside a cryomodule will be of the order of 400 m) and good RF behavior have limited the choice of available cables.

The actual design has been based on a coaxial cable of 2.70 mm diameter with center conductor of copper clad stainless steel wire and dielectric of Kapton tape. Attenuation at room temperature is of 0.25 dB/m and operation up to -270°C has been proved. The computed heat load at 2 K for each cable is 18 mW. This figure will give an overall load of 2.6 W.

Connectors will follow a special mechanical design to fit to the cable.

50 Ω terminations will be fitted directly on the WPM. This would reduce the number of cables, and related problems. Terminations has been tested from room up to LHe temperature and negligible variations of SWR has been measured at 140 Mhz.

Read out electronics

The electronics which handle the signals coming from the WPMs has been designed according to the BPM electronics used at Sincrotrone Trieste (4) .

The RF signal exciting the wire has a fixed frequency of 140 Mhz and a power of 10 dBm. The detector electronics is composed of three parts: the RF input, the IF/AGC/integrator and the timing/ADC/DAC. Two main features of the detector are responsible for its stability and linearity. The first one is the choice to switch all the four inputs coming from a single WPM to a common readout electronics with a four channel PIN diodes multiplexer. The second one is the use of AGC circuitry in order to keep the highest electrode detected signal at the same output level in the full dynamic range. This guarantee the highest linearity and the best S/N ratio in ADC conversion (it has been measured of the order of 0.5 bit).

A characteristic of the whole design is that the electronics is completely controlled by an external CPU which provides gain control, synchronization signals and data handling capabilities. Such a feature reflects in a simpler analog electronics and provide and easier way to calibrate and control the board. The detector electronics 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 interface toward the CPU (which is an Eltec Eurocomm 17, 68040 based @33 Mhz with FPU) is based on VME.

The amplitude detector (which has been modified with respect to the Trieste design, and is a XR 2208) has a very good linearity (< 0.1%) in a 20 dB range. An input amplifier stage has been added obtaining an RF signal sensitivity of -60 dBm with a dynamic range of 30 dB. 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 is of 1 Khz, and the CPU performs an on line averaging of the readings. The algorithm has been designed to reject the natural oscillations of the wire (of the order of 4 Hz) and to control the rms deviation of the readings.

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 the VXI crate. Raw data acquisition, averaging and corrections with polynomial curve are performed at this level. A local hard disk stores data as a first level security.

Using an NFS based structure, data are transferred on a dedicated NFS server which provides functionalities of sharing data between consumer processes. These may be those of the consoles of the monitoring apparatus or, eventually, one of the control system of TTF.

Local consoles will be based on Pcs employing LabVIEW as basic software. They will provide on line monitoring functionalities, with the capability to display displacement versus time for a whole structure or for a single WPM. Further data processing (frequency analysis, power spectrum of any instability, etc.) will be possible too. Data storage will be accomplished as a second security level.

Measures

A test fixture has been constructed for mapping the response of single WPM. The wire is mounted in a fixed position and the RF signal is applied to it. The WPM is assembled on a two axis translation stage and can be positioned anywhere within its aperture. The absolute accuracy of the positioning system is repeatable to about 4 µm. The structure is 1.2 meters long, with the WPM mounted between two sections of pipe which presents the correct boundary conditions.

The electronics reading chain is the same as the final one.

The whole process is controlled by a LabVIEW dedicated program.

As expected, the dependence of the response with respect to the position of the wire can be described by a 3rd order polynomial, with a small coupling between the coordinate planes. The even and cross terms of the 2D polynomial expressions take into account mechanical tolerances and inter-electrode coupling. So doing accurate measurements over 50% of the mechanical aperture is guaranteed.

In order to determine the coefficients of the two bidimensional polynomial curves, which will characterize each WPM, a two steps mapping system has been followed.

The first step provides two data sets from orthogonal axis through the electrical center of the WPM. Each data set refers to a back and forward path, in order to measure the absolute response and the repeatability of the system. Data have been taken every 10 µm over a range of +/- 3 mm.

The second one provides measurements on square paths of increasing distance from the electrical center of the WPM.

Using Mathematica, the data from previous measurements have been used to compute the coefficient of two dimensional polynomial curves. An excellent measure over a large portion of the WPM aperture has been obtained, as shown in fig. 2. Over the 50% of the aperture, we have got less than 10 µm of error, mainly due to mechanical uncertainty both for the x and for the y coordinate. The electronics contribution is less than 1 µm.

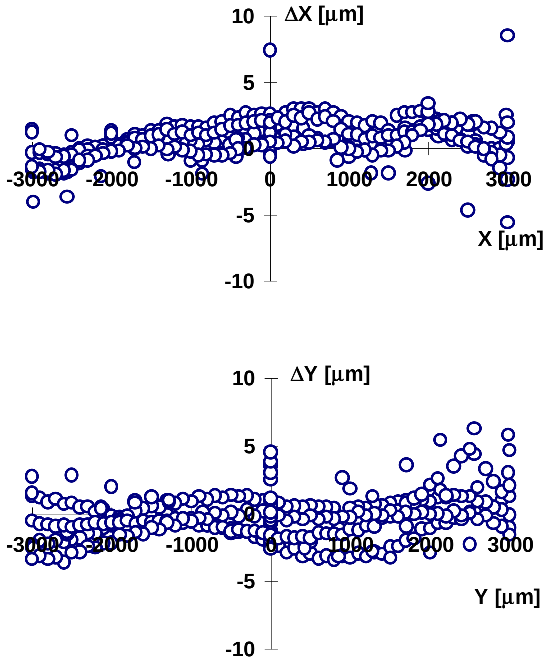

Fig. 2 Error in position measurements

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 is under construction and it will be ready for the installation in a TTF cryomodule by the end of July 1995.

Acknowledgments

We are particularly grateful to M. Bonezzi, D. Corti, M. Fusetti, P. Spada and S. Tizzoni for their contribution .

References

[1] V.E. Bressler et al., Overview of the Final Focus Test Beam Alignment System, Proc. PAC 1991, p. 2736

[2] F. Peters, private communication

[3] D. Giove et al., The On Line Monitoring System for the Cold Mass of the TTF Cryostat, Tesla Report, to be published

[4] R. De Monte et al., Elettra BPM System (Hardware and Software): First Results, Proc. EPAC 1994, pag. 1530