ANALYSIS OF THE COLD MASS DISPLACEMENTS AT THE TTF

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Abstract

Some of the TTF cryomodules have been equipped with wire position monitors (WPM) in order to monitor on line the displacements of the cold mass to verify alignment stability and reproducibility. Based on the operation experience of the first prototypical cryomodules, equipped with up to 36 WPMs distributed in two strings, on the last generation cryomodules a single string of 7 sensors has been installed. Here we review and analyse the data collected so far to prove that the proposed cryomodule design is consistent with the TESLA alignment requirements.

INTRODUCTION

The production of affordable cryostats is one of the goals of the TTF project. Each cryostat contains 8 superconducting RF cavities cooled to 2 K, a quadrupole magnet package cooled to 4.5 K, thermal shields at 70 K and 4.5 K, magnetic shielding, cryogenic service pipes and all associated instrumentation. The axes of the 8 cavities must be aligned to the ideal beam axis to within ± 0.5 mm and that of the quadrupole package to within ± 0.3 mm, with an acceptable maximum tilt limited to ± 0.1 mrad. These alignments, performed when the system is warm, must be preserved after cool down and during operation. Furthermore the cryostat has been designed to prevent that the RF pulsing at 5 or 10 Hz could excite its vibration frequencies.

A Wire Position Monitor (WPM) system has been developed for on-line monitoring of the cold mass during cooldown and operation [1]. The analysis of the WPM measurements allows checking the alignment reproducibility between successive cooldown cycles. The first prototypical cryomodule was equipped with two sets of 18 WPMs, fixed along two straight sections inside the cryostat. Such a high number of monitors was justified by the need to provide a complete 3D analysis of the displacements. The data acquired by the WPM system has contributed to optimise the cooldown and warm up procedures and to the further development of the cryomodule design (second and third generation) [2]. The WPM design was simplified too, to improve linearity and easiness of mounting inside the modules. The new cryomodules are equipped with a single chain of seven monitors screwed through a support to a stainless steel arm which is welded to the gas return pipe (GRP). A picture of the cryomodule cross section showing the WPM position and the supporting arm is shown in Fig. 1, while in Fig. 2 the drawing of the cryomodule # 4 is shown, together with the longitudinal monitor positions.

Figure 1: The WPM position in the cryomodule.

The current WPM system has been optimized for a string of 3 cryomodules directly connected together (with a single stretched wire through the system), as originally planned in the TTF linac. However, the TTF schedule has been revised, and only two cryomodules (#4 and #5) are now connected in a single string. This results in a slight mismatch of the sensor position with respect to the optimal compensation of the wire sag.

WPM systems have been successfully operated to monitor displacements at the sub-μm level, but here the relaxed TESLA tolerances do not require these accuracies, which would be hard in a cryogenic environment, due to the uncertainties in the sensor calibration and in the cables attenuation.

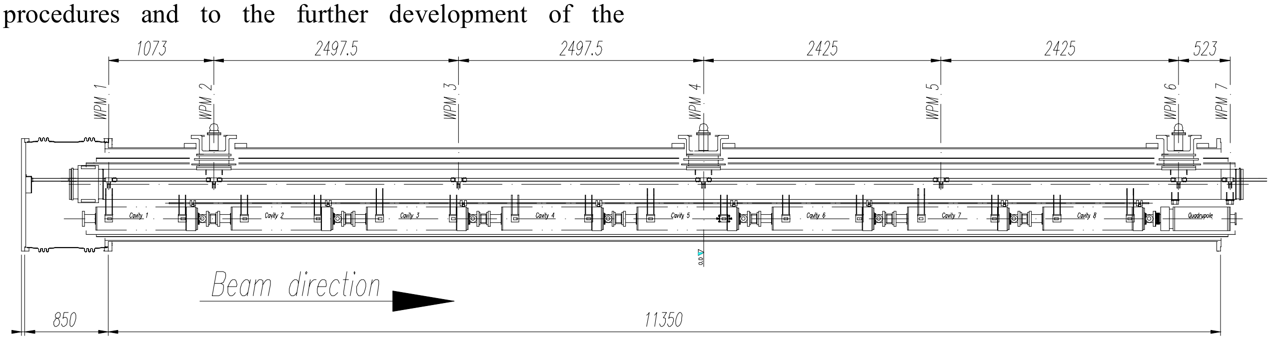

Figure 2: The longitudinal positions of the WPM sensors in cryomodule # 4.

WPM SYSTEM DESCRIPTION

Each WPM has the structure of a beam position monitor, of the microstrip directional coupler type, and it is inserted in a 180 Ω coaxial line fed by a 140 MHz RF signal. The inner conductor is a stretched wire and four symmetric microstrips, attached to the WPM's body, are sampling the applied RF signal. Heat treated Cu Be (2%) has been chosen for the wire, as a good compromise between RF losses and tensile stress. With a wire diameter of 0.5 mm, we have sag of 13 mm with a stretching load of 18 kg (~ 10^9 Pa) along the full length of approximately 25 m. Both the body of the monitors and the microstrips are made by silver plated bulk aluminium, to limit the monitor weight, while providing good RF contact and brazing capabilities. The WPM clearance is now of circular shape with a diameter of 28 mm and the length is 65 mm. A WPM view from the top of the module is shown in figure 3, where the copper berillium tubes that acts as external connector can be seen together with the Cu Be bellows used to compensate the different thermal contractions during cool down.

The principle of operation of the WPM is similar to the directional coupler BPM. The quantity of interest is the difference signal between two opposite microstrips, which is function of the wire (or beam) displacement from the monitor axes. The measure is then normalized to the sum of the two opposite electrode signals, to be independent from the magnitude of the RF signal travelling on the wire. The WPM read out signals are converted into positions via a two dimension 3rd order polynomial, to take into account the non-linearity arising when the wire is displaced more than 1 mm from the sensor centre.

The sensors and cables were calibrated at room temperature conditions. The operation in the cryomodule at a range of cryogenic temperatures, depending on the sensor position and cable path, induces a spread in the cable attenuations that limits the overall sensitivity.

The electronics that handles the signals coming from the WPMs has been designed according to the BPM electronics developed at ELETTRA [1]. The system is interfaced with the DOOCS-based TTF control system via a VME board computer.

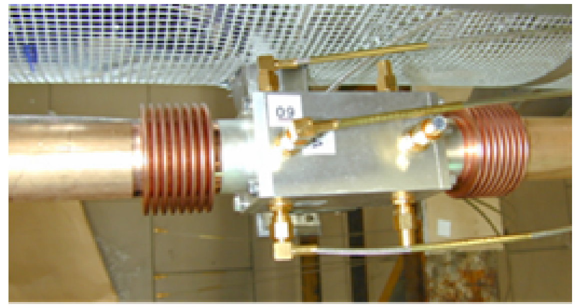

Figure 3: Top view of a WPM sensor.

CRYOMODULE STRING COOLDOWNS

Two thermal cycles of cryomodules # 4 and # 5 have been monitored. The first thermal cycle is complete (cooldown and warmup). The cooldown operations started on the June 19, 2003, to be completed on July 24, 2003, when stable 2 K temperature on the cold mass was reached. The cryomodule was kept cold until September 24, 2003, when the warm up operations started to reach a stable room temperature conditions on October 9, 2003, when a 1000 mbar pressure inside the cryomodule was re-established. Before the second cooldown, the cold mass was re-aligned both in horizontal and vertical directions. The second cooldown started on March 8, 2004 and a stable condition at 2 K has been kept since April 7, 2004. At 2 K the isolation vacuum is of the order of 10^{-5} mbar.

In Figure 4 and 5 the horizontal and the vertical displacements for the cooldown of the modules, with respect to 300 K @ 1000 mbar stable condition positions, are shown. The figures show the cryomodule support positions (posts), the quadrupole position and the gray area correspond to the required TESLA alignement with respect to the nominal position. The displacements are relative to the initial positions at the beginning of each cooldown operation, and hence are referred to the two different initial absolute value positions.

A systematic error of about 0.1 mm must be added to the measurements, to account for the detectors and cables

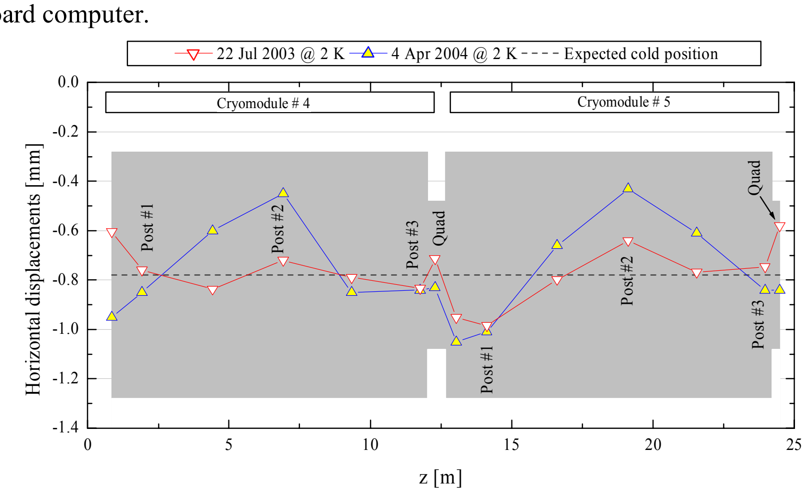

Figure 4: Horizontal displacements measured by the WPM system.

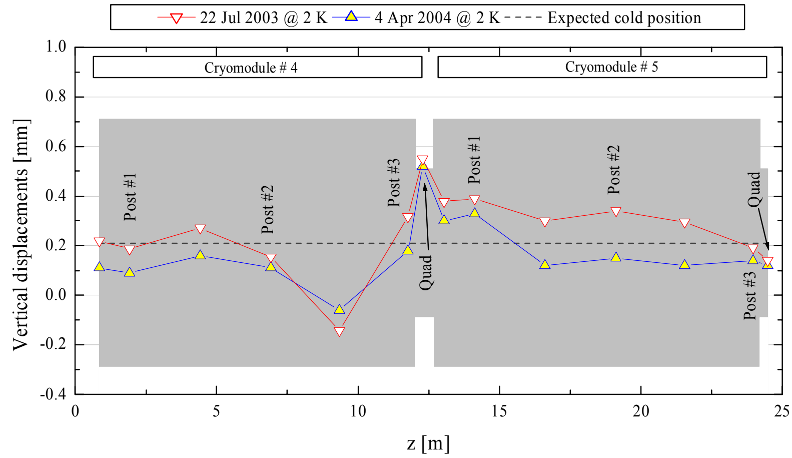

Figure 5: Vertical displacements measured by the WPM system.

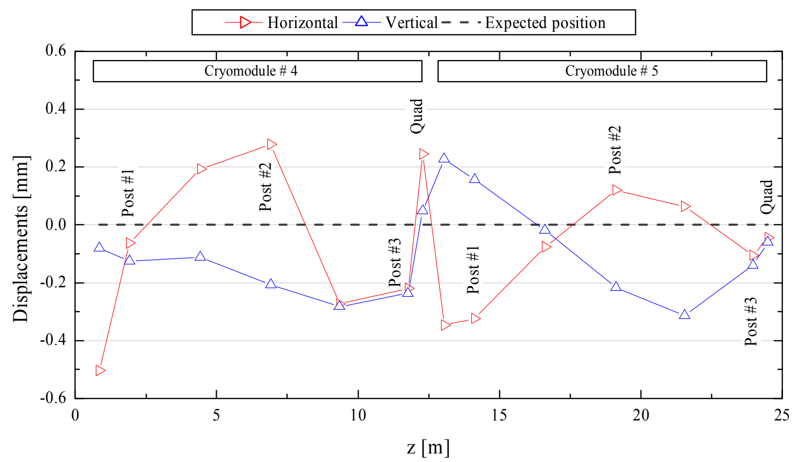

Figure 6: Horizontal and vertical displacements after warmup.

calibration errors and the fact that the detectors are not working in their optimal region, due to the missing third cryomodule of the string, as was originally planned. Finally, Figure 6 shows the horizontal and vertical positions restored in the October 2003 warmup. Table 1 summarizes the measurement results with respect to specifications.

Table 1: Result Summary.

TDR Specifications (rms)		
Cavities	x/y	± 0.5 mm
Quadrupoles	x/y	± 0.3 mm
WPM results (peak)		
Cavities	x	+ 0.35/- 0.27 mm
	y	+ 0.18/- 0.35 mm
Quadrupoles	x	+ 0.2/- 0.1 mm
	y	+ 0.35/- 0.1 mm

CONCLUSIONS

The cold mass displacements seem to be consistent with TESLA specifications. The analysis shown in Figs. 4 and 5 is a further confirmation of the opportunity to move the quadrupole package at the central post position, in order to benefit from the reduced displacements and tilt angles. The residual horizontal bending suggests to further minimize forces acting at the GRP ends for the TESLA cryomodules. A check will be done at the next warm up for the horizontal bending shown in Fig. 6.

The WPM line will be extended to module # 6, of the same generation of # 4 and 5, when it will be connected to the string. Finally the electronic system will be equipped with a digital receiver board [3] to detect low frequency vibrations of the cryostat with the WPMs.

ACKNOWLEDGEMENTS

We wish to acknowledge the support of M. Bonezzi, INFN Milano, and the MKS1 group at TTF, in particular K. Jensch, for assembly, installation and operation and G. Grygiel from MVP group for WPM set-up in DOOCS.

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