MAGNETIC PERFORMANCE OF THE NEW ALBA MAGNETIC MEASUREMENTS BENCH FOR CLOSED STRUCTURES

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Abstract

ALBA has designed and built a new magnetic measurement bench for closed structures, presented elsewhere. This bench has been fully built in-house and has been magnetically characterized at ALBA, showing excellent performance in terms of repeatability and accuracy. In the case of homogeneous fields, the accuracy reaches 40 µT, and in the case of undulators characterization, the accuracy of period determination reaches 0.5 microns. After this characterization, the bench has been moved to CIEMAT premises, and has been used to magnetically characterize a superconducting cyclotron that is being built there. In this paper we present the results of magnetic characterization of the bench as well as the first results of cyclotron measurements.

MECHANICAL & CONTROLS DESIGN

As described elsewhere [1], new ALBA magnetic measurement bench has a stroke of 1.2 m in the longitudinal direction, 0.23 m in the horizontal and 0.09 m in the vertical, enough to measure the usual in-vacuum closed structures. Figure 1 shows a drawing of the mechanical structure of the bench.

Regarding accuracies, the bench has excellent checked mechanical performances: positioning along the three axes has a maximum mechanical error of 10 µm. Regarding angular errors, they are lower than 40 µrad, being the roll angle error <35 µrad and the pitch angle error <25 µrad. These low values are obtained thanks to a high flatness (better than 7 µm) and straightness (better than 8 µm). Regarding the vibrations, maximum amplitudes of the belt holding the Hall sensor are smaller than 0.15 µm. Maximum torsion error is also very low, smaller than 3 µrad.

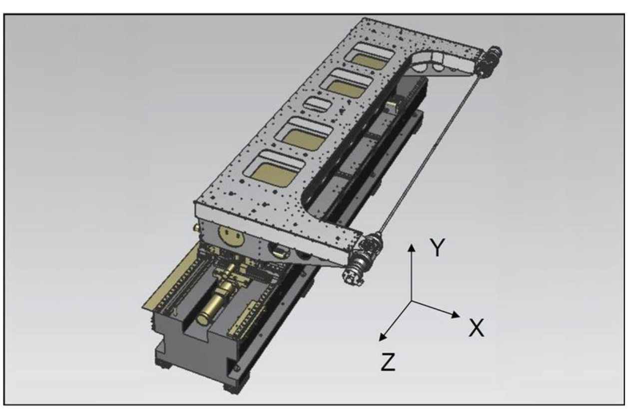

Figure 1: Mechanical design of ALBA Hall probe bench for closed structures.

MAGNETIC PERFORMANCE

On September 9th 2016 the bench was ready to carry out test measurements at ALBA experimental Hall, as shown in Figure 2. In order to test its performance we have used two magnetic structures producing different field distributions.

Figure 2: Measurement bench already built and placed at ALBA experimental Hall, ready for tests

Measurement of Uniform Field

In first place we measured a pure permanent magnet dipole used to align Hall probes in ALBA magnetic measurements laboratory [2]. This magnet produces a highly homogeneous (±50×10^{-6} T) vertical magnetic field in its central region. The experimental setup is shown in Figure 3. In order to measure a non-zero field value in all three directions, the dipole was slightly misaligned with respect to the Hall sensor.

Figure 3: Experimental setup for measuring a constant field. Hall probe (inside red circle) is mounted on the stretched belt, passing through the aperture of the dipolar magnet.

We repeated 20 longitudinal scans through the dipole and studied the repeatability in the measurement. Results

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are summarized in Figure 4. The resulting standard deviation of the determined field components have been $7\cdot10^{-6}$ T, $4\cdot10^{-5}$ T and $7\cdot10^{-6}$ T for B_x, B_y and B_z respectively, leading to a relative repeatability better than 10^{-4} for the major component (B_y) and $\sim5\cdot10^{-4}$ for the minor ones (B_x and B_z).

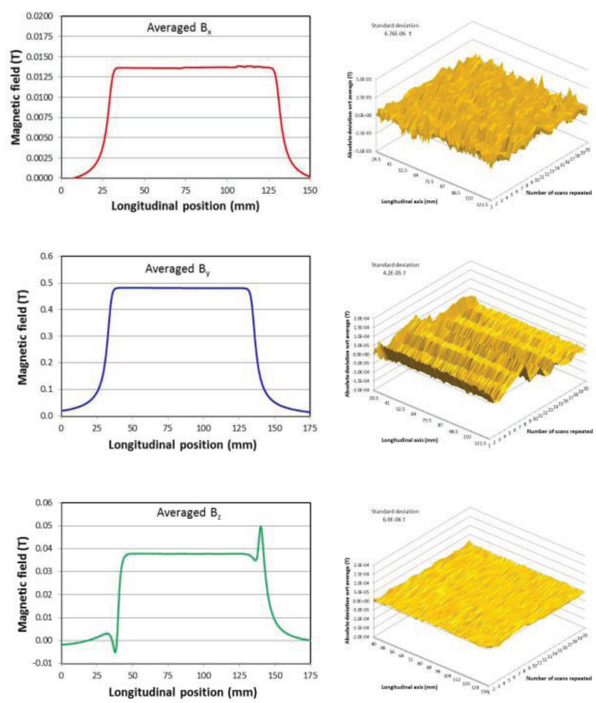

Figure 4: Average value and error distribution for the three components of the magnetic field inside alignment dipole.

Measurement of Variable Magnetic Field

Second, we characterized the bench for variable magnetic fields using an undulator segment. The used device had a period length of 21.3mm and contained 19 periods, for a total length of half a meter. It was characterized in the past with a conventional bench, so its features are well known and for this reason was used as reference. The experimental setup is shown in Figure 5.

As in the case of the dipole magnet, 20 longitudinal scans over the undulator were carried out and the repeatability of the obtained results was analyzed.

Results are summarized in Figure 6. The resulting standard deviation of the determined field components have been $6\cdot10^{-6}$ T, $5\cdot10^{-5}$ T and $5\cdot10^{-5}$ T for B_x, B_y and B_z respectively, leading to a relative repeatability close to $1\cdot10^{-4}$ for the major components (B_y and B_z) and $\sim5\cdot10^{-4}$ for the minor one (B_x).

Regarding the physical parameters of the undulator extracted from the measured data, the *rms* error in the location of the pole positions is slightly smaller than 1 µm, and the calculated optical phase error is reproducible within 0.01°.

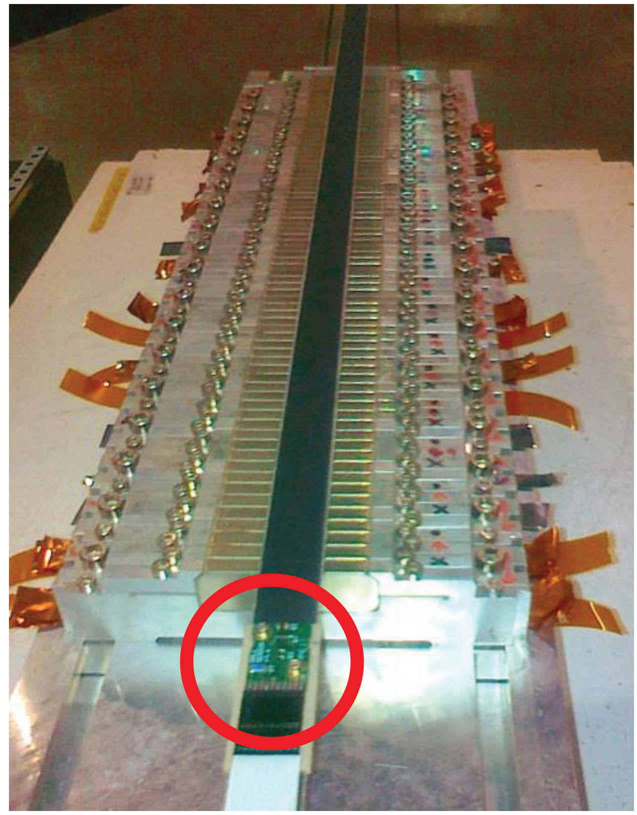

Figure 5: Experimental setup for measuring a variable field. Hall probe (red circle) is mounted on the belt, passing on top of the magnet array.

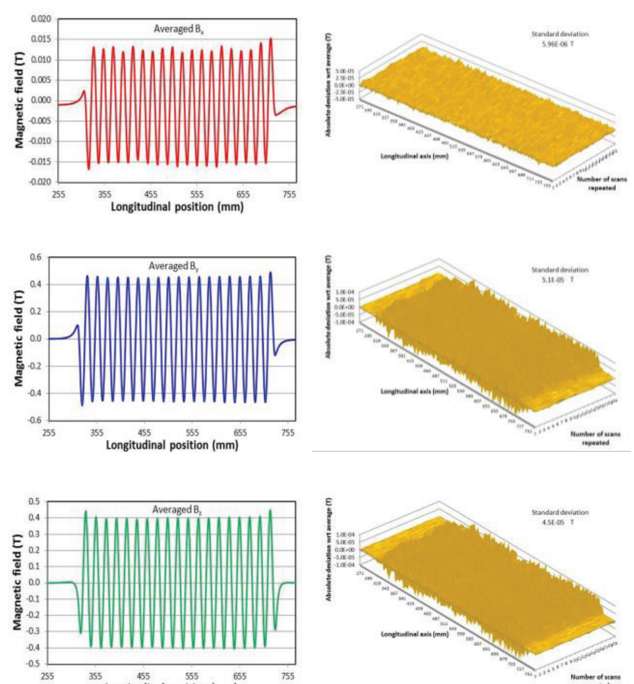

Figure 6: Average value and error distribution for the three components of the magnetic field measured on the undulator segment.

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FIRST APPLICATION

After its performance validation at ALBA, on October 24th 2016 the bench, along with its stand-alone control system based in Tango, was moved to CIEMAT premises in Madrid for the measurement of a superconducting compact cyclotron being developed there [3].

The cyclotron will generate a central field of 4 T using NbTi coils operating at a nominal current of 110Amp. The aim of the Hall probe measurements with the new bench is to check the magnetic field distribution inside the good field region of the cyclotron magnet.

Figure 7 shows some pictures of the bench during the first test measurements of the cyclotron. So far only room temperature measurements at low currents (up to 100mA) have been done, but it is expected to carry out measurements at liquid Helium temperature and high currents soon.

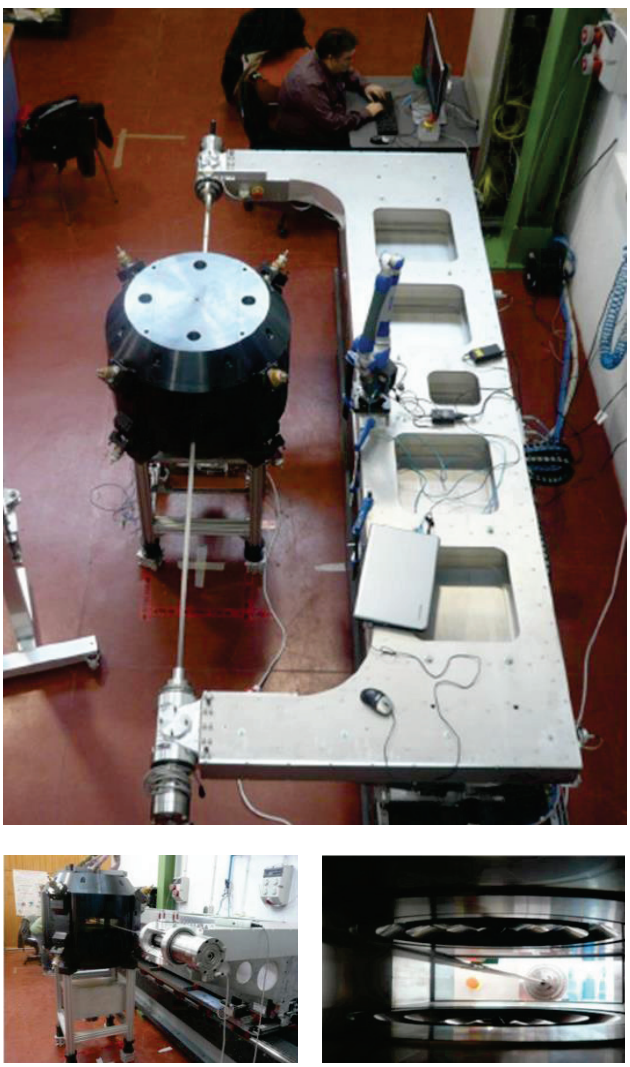

Figure 7: Pictures of the bench at CIEMAT premises measuring the compact superconducting Cyclotron. It can be seen the stretched belt passing through the gap of the device.

Measurements made so far show good agreement with the theoretical predictions. As an example, Figure 8 shows the field profile expected at low current (100mA) determined from OPERA simulations as compared to a real measurement. Deviations from the theoretical model are smaller than 1 mT for the whole measured volume, with most of the points in the interest area deviating by much less than 0.5 mT.

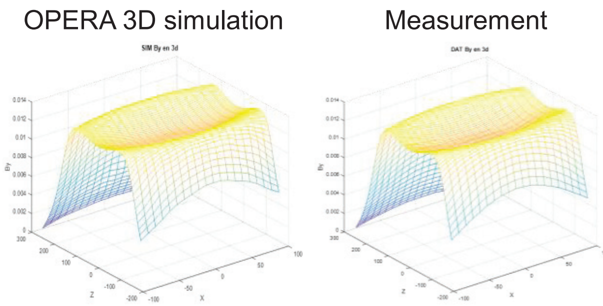

Figure 8: First results of CIEMAT cyclotron measurement at room temperature and low current (100mA), showing a good agreement between simulation made with OPERA 3D (*left*) and data measured with the new bench (*right*).

CONCLUSIONS

New magnetic measurement bench developed at ALBA performs according to specifications, and it is suitable to measure with high accuracy closed structures.

Validation tests carried out at ALBA indicate that the system has a performance comparable to conventional Hall probe systems in terms of probe positioning and field determination.

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