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NEW SMALL DIAMETER ROTATING COIL SHAFT FOR CHARACTERIZING NEW GENERATION OF MULTIPOLAR MAGNETS

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Abstract

The proliferation of ultimate-light source facilities around the world has yielded the need of accurate characterization of small gap magnets. This also applies to multipolar magnets. Clearance diameters down to 10 mm for quadrupoles and sextupoles become to be used and need to be accurately measured. At these small gaps, the high order multipoles influence on electron beam dynamics is high, and it should be well characterized in order to guarantee a feasible operation of the accelerator. To face this challenge, ALBA magnetic measurement laboratory has developed a new rotating coil shaft with a diameter of 10 mm able to be introduced inside narrow-gap multipolar magnets. In this paper we present the design as well as the manufacturing of such a device.

INTRODUCTION

Rotating coils have been widely used to characterize the purity of multipolar fields [1]. The rotation of the coil inside such fields induces an electromotive force directly related to the magnetic field, depending only on the coil geometry and the rotation speed. The usual scheme of coils, shown in Fig. 1, allows the cancelation of main component and enhands the visibility and measurability of high order harmonics. ALBA has used this type of coils to measure a number of magnets, as published elsewhere [2]. and has a set of rotating coils allowing the measurement of apertures larger than 25 mm. So far this was enough for our needs. However, the evolution of Storage Rings towards ultimate light sources is imposing new requirements. Apertures are becoming smaller and the harmonic content of magnetic fields become more relevant at small gaps. Therefore, high accuracy measurements of small apertures magnetic multipolar fields become a need.

The combination of high accuracy in the measurement and small diameter is challenging. Difficulties for designing, manufacturing and testing this kind of coil are multiple: first, the small diameter forces the use of small coils, yielding to small signal. Therefore, an improvement in signal measurement should be done. Second, the coil should rotate at constant velocity and without exentricity; therefore the coil should be assembled in a very rigid shaft. And last but not least, being the coil and shaft light, it can be affected by vibrations; therefore, the driving force should not introduce vibrations that can perturb the measurement.

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ENGINEERIGN DESIGN AND MANUFACTURING

Coils

The rotating coil bench at ALBA can determine the integrated field harmonics of accelerator magnets with lengths up to 0.5 m. Driving system is a step motor driven by IcePAP controller [3]. Data acquisition is made by a Keysight 34470A digital multimeter [4].

The coils for the shaft have been produced using the multilayered-PCB technology that has been previously employed at ALBA. For the two shaft we have used the usual compensation scheme in order to obtain the desired dipole-quadrupole bucking, with 4+1 identical radial coils centered at different radial positions, as described in [5]. Multi-PCB (10 layers in this case) allows manufacturing coils with 30 turns in total, providing signal enough to measure with high accuracy. The configuration scheme of the shaft is shown in Fig. 1, and the corresponding geometrical parameters are listed in Table 1. PCB is shown in Fig. 2. A similar shaft has been manufactured with a diameter of 20 mm.

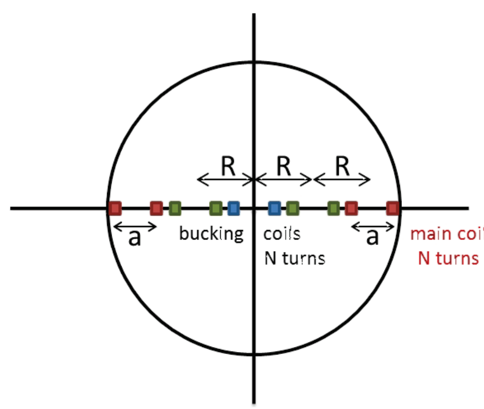

Figure 1: Configuration diagram of the shafts manufactured with ∅ 10 mm and ∅ 23 mm diameters.

Table 1: Parameters Of The Two Manufactured Shafts

Shaft diameter	Circuits position	Turns per layer	Layers	Length
10 mm	R = 1.9 mm A = 0.9 mm	N = 3	10	550 mm
23 mm	R = 4.6mm A = 2.3mm	N = 9	20	550 mm

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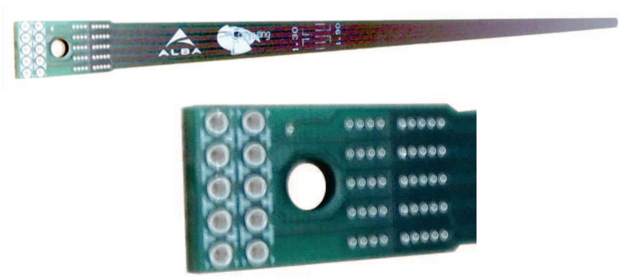

Figure 2: Multilayered PCB with the 5 coils.

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The measured FEM is channeled to a standard connector, as shown in Fig. 3, that will be embedded into the shaft structure.

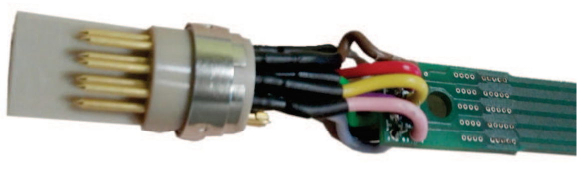

Figure 3: Connection of PCB.

Rigidity

A critical point during the measurement is the rigidity of the shaft. A change in the axis due to PCB deformation (sag, twisting, etc.) induces and uncontrolled perturbation in the measurement. PCB itself is not a rigid solid piece. Such small device (0.5 m long x 0.01 m wide) is flexible and is easily deformed. To avoid this, the PCB has been glued to a rigid Al_2O_3 ceramics. The resulting shaft is so rigid that avoids 10μRad / 10 μm twist and deformations dues to its own weight.

Ceramic solution has been adopted because, despite its fragility, it is very rigid, not affected by temperature and its weight low enough to not perturb the rotation. The shaft is shown in Fig. 4, 5 and 6 (design) and 7 (manufatured).

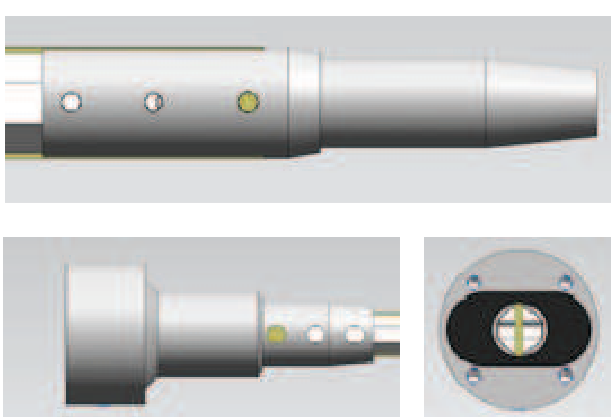

Figure 4: Mechanical design of rotating parts.

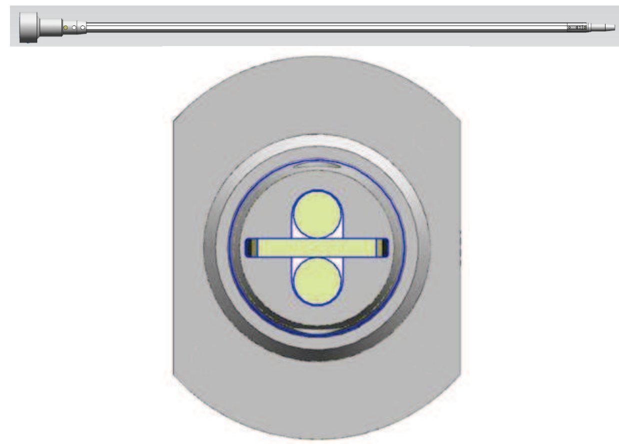

Figure 5: Lateral view (top) and cross-section (bottom) of the shaft.

The characteristics of the shaft are:

- Epoxy Glued sandwich of 2 ceramic ribs and PCB.
- Epoxy Glued aluminium ends
- Connector interface and coil end is the same piece.
- Piece has room for cables and soldering spots.

In order to assemble the set of ceramics, PCB, connector and ring bearings (∅ = 10 mm; (∅ = 23 mm)) a special tool is needed, to guarantee the straightness of the set. We show in Fig. 6. the tool developed to this end.

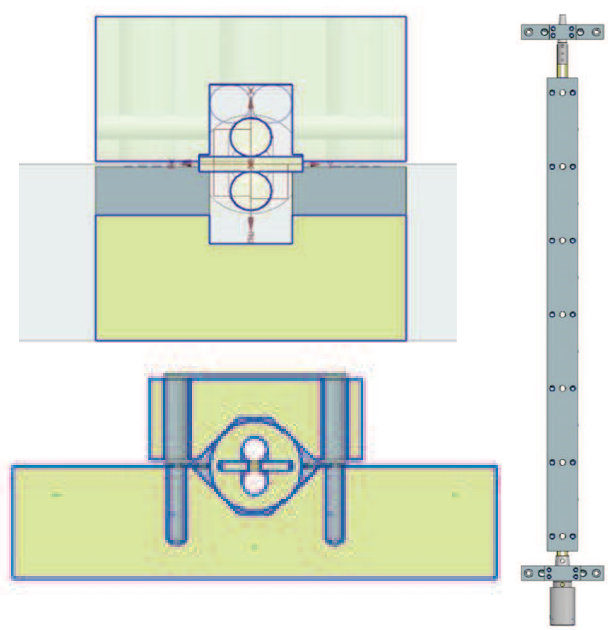

Figure 6: Assembling tool.

The assembling protocol is:

- Position and hold the components with high precision (~10 μm).
- Solder cabling before gluing
- Low viscosity epoxy is applied
- Alumina material used for rigidity.

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Figure 7: Manufactured shaft.

SUPPORT DESIGN AND MANUFACTURING

Another important issue is the positioning of the shaft axis with respect to the magnet to be measured. This position determines the misalignment and tilt angle of magnetic axis of the magnet, and the accuracy should be within 30 µm. This implies the possibility to move and correct position using high precision translator tables. We will use commercial devices, as shown in Fig. 8. The complete set up is shown in Fig. 9.

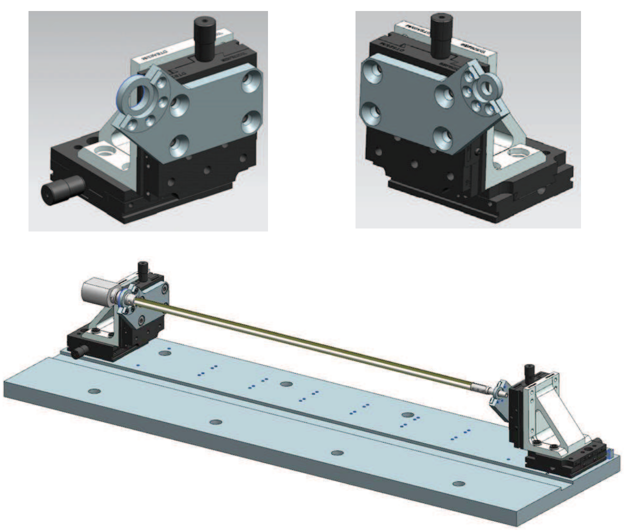

Figure 8: Positioning tables.

The characteristics of the set up are the following.

- Coil has independent and precise supporting setup.
- Horizontal and vertical range is ±12 mm allowing alignment of the shaft with the geometrical axis of the magnetic structure.
- High precision positioning of both ends. It will be based on commercial positioners.
- Rotation with standard steel bearings.

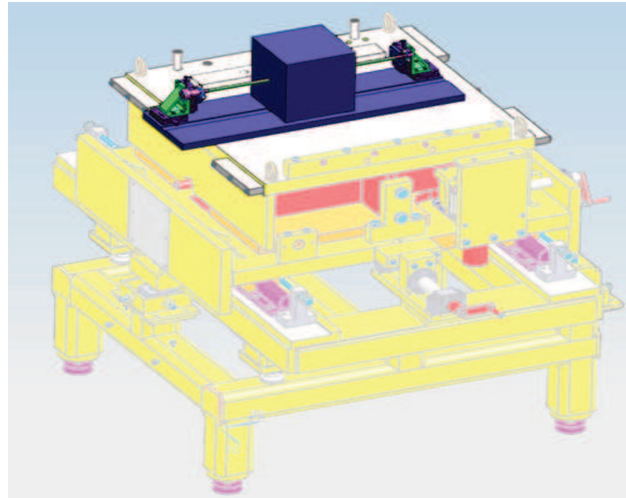

Figure 9: Complete setup for supporting and driving the rotating shaft with coils.

CONCLUSION

The manufacturing of rigid and small diameter shafts is feasible, using ceramic alumina bars glued to multilayer PCB as structural component. Alumina is light, it does not add inertia to the set-up, avoiding twisting and minimizing the sag. This solution will reduce the systematic errors in measurements, allowing the accurate characterization of small aperture multipolar magnets, that will be used in low emittance rings.

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