CHEAP, GOOD, FAST: HOW A PERMANENT MAGNET ARRAY WAS USED TO PROVIDE A DETECTOR MAGNETIC FIELD FOR FAST

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The FAST experimental group approached us for assistance with the design and manufacture of a coil pair required to produce a weak but homogeneous magnetic field in their target block. The required field could not be achieved using the Helmholtz coil configuration because of space limitations. Our preliminary studies showed that, although the proposed design nearly fulfilled the homogeneity conditions required on the three principal planes, the field quality in the corners of the rectangular target region was insufficient and that the coil design and realisation would not be as easy as at first sight. Further studies finally led to an alternate design based on commercially available permanent magnetic ferrite blocks. This design fulfils the homogeneity requirements throughout the target volume, was much cheaper and was also faster to make.

INTRODUCTION

The FAST experimental group approached us for assistance with the design and manufacture of a coil pair required to produce a weak but homogeneous 80 Gauss magnetic field in their target block, which is a 160 mm cube. They had performed initial studies using a pair of coils filling the only available space. The optimal solution using the Helmholtz coil configuration was not possible because of space limitations. Furthermore, the coil design and realisation using available power supplies was not trivial. Since the coils had to be completely enclosed in a light-tight cover, direct or indirect water cooling would have been required.

PRELIMINARY STUDIES

Our preliminary homogeneity studies showed that, although the proposed design nearly fulfilled the conditions required on the three principal planes, the field quality at all extremities of the rectangular target region was insufficient (Fig. 1).

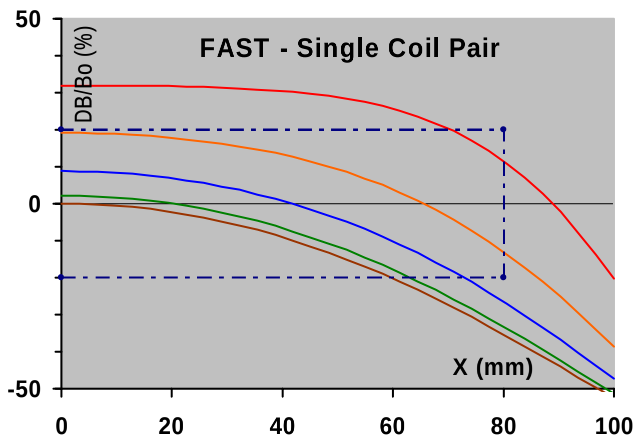

Fig. 1: Field homogeneity on five planes spaced at 20 mm through the target block for the single coil model. The planes are chosen to be on the cube diagonal, which represents the worst case, and projected onto the X-axis. The dotted area represents the specified homogeneity limit of ±20 %.

In a first attempt to improve the homogeneity, smaller negatively excited coils were placed in the free space inside the main coils (Fig. 2). This improved the homogeneity but reduced the main field level, thus leading to higher currents and power levels in the main coils. We then realised that what we were trying to do could also be done using permanent ferrite magnets. The simple linear model for a piece of ferrite is a current sheet around its edge at right angles to the magnetic field direction. A piece of ferrite with a central hole could then be modelled with a second negative current sheet along the inside edge. The outside current sheet is even closer to the Helmholtz configuration because it is at a larger diameter than the extended real coil.

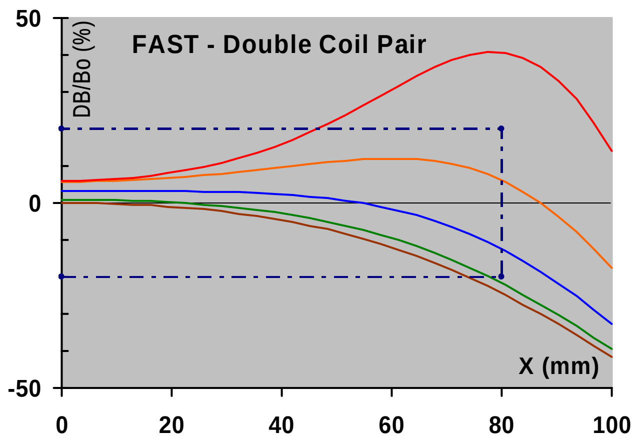

Fig. 2: Field homogeneity on five planes spaced at 20 mm for the double coil pair model.

STUDIES WITH FERRITE

Initial calculations using ferrite showed that the solution was viable and could fulfil all the requirements. The next step was to find readily available ferrite blocks. Many manufacturers have stopped ferrite production and are not interested in producing the small quantities involved. We could finally find a manufacturer in the Czech Republic and ordered suitable rectangular blocks in different thicknesses. Further studies were performed using the Tosca 3D magnetic field code. A calculation performed for the actual prototype model is shown in Fig. 3.

A FERRITE BLOCK MODEL

Fig. 4 shows the non-magnetised ferrite blocks laid out on an aluminium carrier plate. Two such plate assemblies spaced 260 mm apart are required.

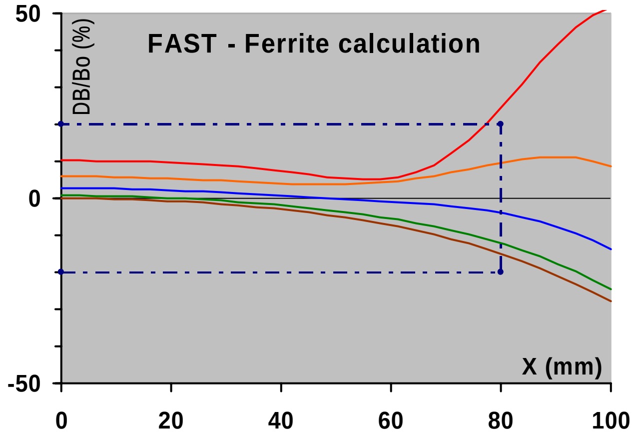

Fig. 3: Field homogeneity on five planes spaced at 20 mm calculated for the ferrite prototype.

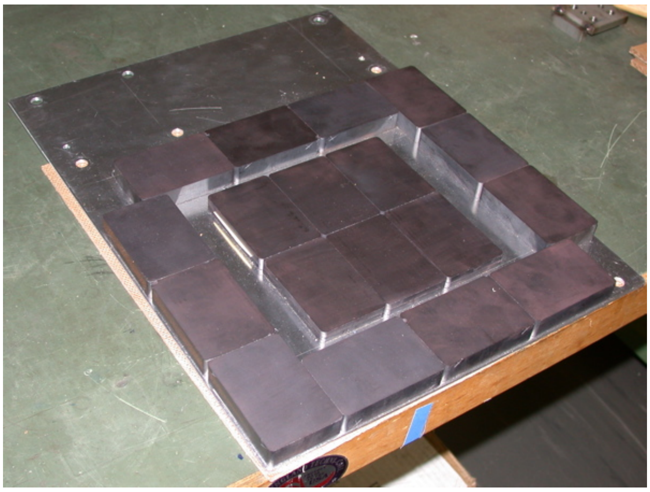

Fig. 4: An array of non-magnetised ferrite blocks arranged on the aluminium plate. The outer thick ring provides the main field. The inner thinner blocks improve the homogeneity.

During initial magnetisation tests, we noted that not all blocks reached the same magnetisation level. However, for the first prototype measurements, we decided to first fix the magnets on the carrier plate and magnetise them all together using our calibration magnet. The ferrites have to be held firmly in place, since they repel each other through magnetic forces. For the measurements, they were stuck on with double-sided sticky tape and clamped using a second aluminium plate bolted to the carrier plate. Nevertheless, one morning, we found a ferrite block that had been pushed out and landed on the floor. For the final assembly, we plan to magnetise and measure each block separately, so that a symmetrical array structure can be achieved. However, this will require some special clamping devices to counteract the repulsive magnetic forces. The magnetic fields produced by the prototype pair of ferrite arrays were measured using our standard measuring facility.

As can be seen in Fig. 5, the measurements confirm the calculations except for an asymmetry appearing at the very top of the target block region.

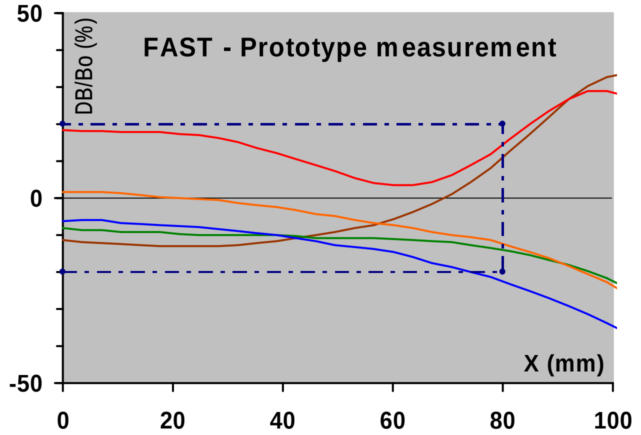

Fig. 5: Field homogeneity on five planes spaced at 40 mm measured on the ferrite prototype.

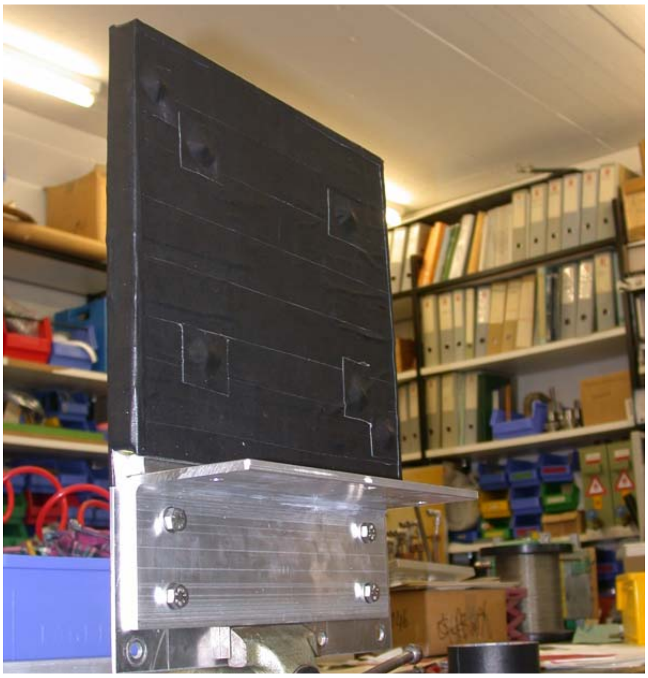

Fig. 6: One of the two ferrite assemblies ready for installation.

INSTALLATION

For the first tests with beam, the prototype plate assemblies were secured with strong black tape and installed through the two prepared slits in the base of the FAST experiment. The results of these preliminary tests are encouraging.

CONCLUSION

This example demonstrates that sometimes unconventional solutions can be applied to simple problems under specific circumstances. In general, the use of hard ferrite material is not attractive because of its invariance.