On Permanent Magnet Material Testing.

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Abstract. Note describes two experiments made to explore basic properties of permanent magnet (PM) material and to obtain "first hand" experience.

In the first experiment, magnetic moments of NdFeB permanent magnets (PM) were fine tuned. The magnetic moment spread among 17 PM magnets was reduced by a factor of 5 from 2.8% to 0.5%. The note describes setup used for magnetization and presents result.

The second experiment measured irreversible demagnetization caused by temperature under different conditions. Understanding of this process is very important, because all components of in-vacuum undulators undergo baking, i.e., exposure to high temperature for UHV conditioning. It was found that simple tricks can significantly increase the allowed baking temperature.

1. Permanent Magnet magnetization.

Apparatus previously used for electromagnet coil pulse testing, was converted to magnetize PMs. Two major changes were the rewiring of high voltage capacitors to increase total capacitance and the insertion of a high-voltage diode between output terminals. The latter made the output pulse unipolar. A spool of gauge #18 copper wire was used as the magnetizing coil. To enhance magnetic field, the spool was placed in the box assembled from ferrite blocks. Modified apparatus and magnetizing coil in ferrite box are depicted on Figure 1.

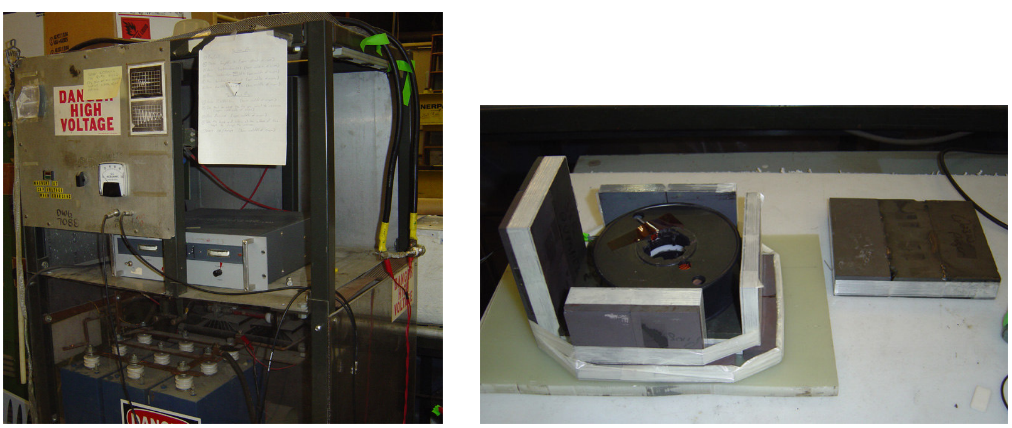

Figure 1. Pulse current apparatus and magnetizing coil.

The measured field maximum as a function of capacitor voltage is shown on Figure 2.

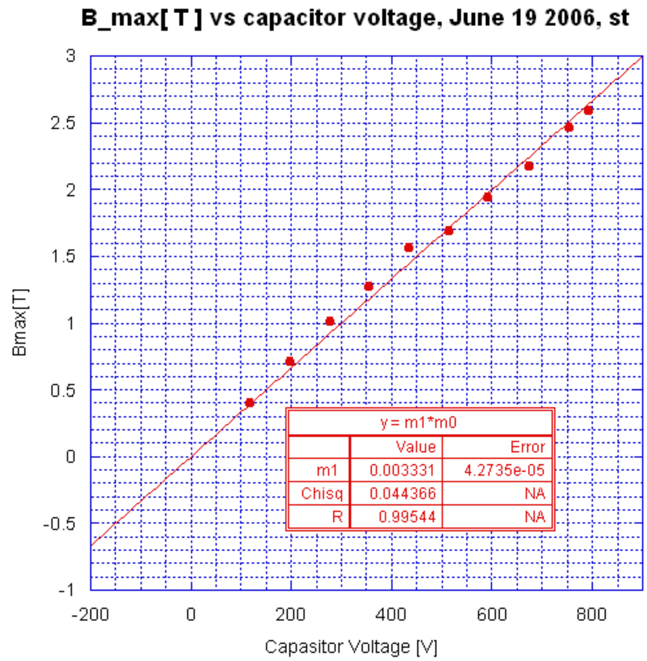

Figure 2. Magnetizer calibration.

The field was measured by integrating the voltage induced by magnetic flux in a pickup coil with known area. The pulse duration was approximately 5ms. The measurement indicated that the 2.5T field needed for magnetization of NdFeB blocks can be reached at ~800V.

This setup was used for fine-tuning of magnetization of 17 permanent magnet H-blocks[1], left over from the 12.5mm period undulator prototyping. First, blocks were magnetized to saturation by ~2.5T field and then the magnetic moment of the blocks with higher than average moment, was slightly reduced by applying ~0.2T of reversed field. Magnetic moments measured before and after this procedure are presented on Figure 3. Solid circles show magnetic moments measured before remagnetization. They have relatively large spread ~ 2.8%. After magnetization (see open circles) the spread became 5 times smaller, ~0.5%.

[1] Permanent magnet block dimensions were 1"x 0.5"x 0.125". H-block refers to block magnetized in 0.125" direction.

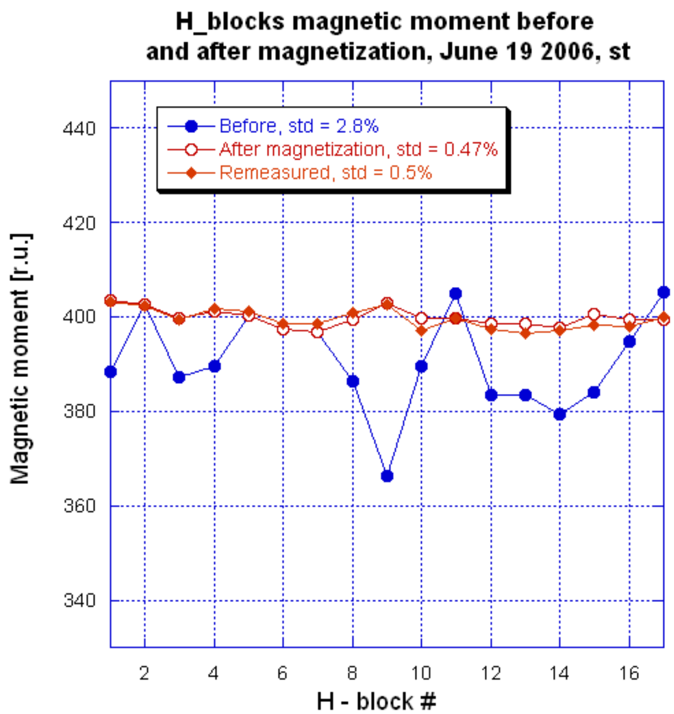

Figure 3. Magnetic moment of H-blocks before and after remagnetization.

As a conclusion it should be said that the small magnetic moment spread will significantly facilitate the tuning of the assembled magnetic arrays.

2. Irreversible demagnetization caused by temperature.

To satisfy UHV condition, all in-vacuum undulator components undergo baking. Thus the effect of PM magnetization loss caused by high temperature should be seriously considered during PM material selection and should be taken into account in undulator magnetic design.

In simple experiments described below, "first hand" experience was obtained and some useful tricks have been learned. A PM rectangular block with dimensions 1" x 0.5" x 0.125" made of N40 material from "Stanford Materials." was used in the experiment. It was magnetized in 0.125" direction. The block was tested under two different conditions. In the first case, it was single (see Figure 4(left)) while in the second, the block was inserted in the middle of a 5-block stack (Figure 4(right)).

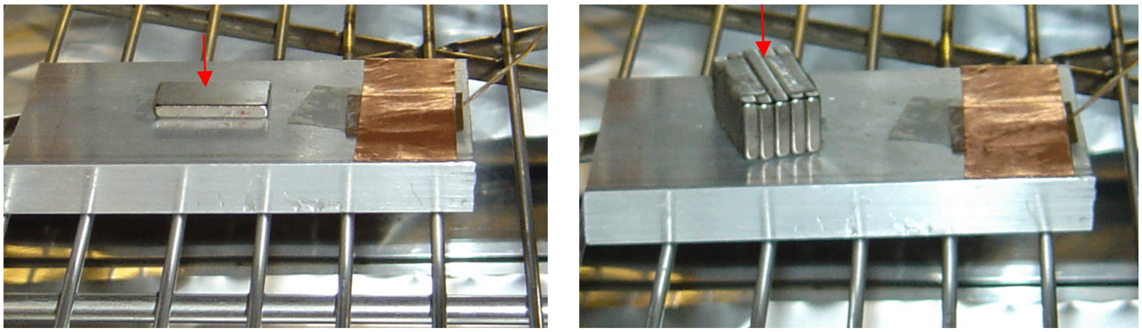

Figure 4. Left - single PM H-block . Right - 5-block stack, the tested block in the middle. Arrows point to tested block.

The local magnetic field distribution was calculated with program POISSON for single PM block and for 5-block stack as shown on Figure 5. The tested block location is at x=0. In both cases, the field is parallel to magnetization. As can be seen in Figure 5, the field is ~4 times stronger when the tested block is inserted in the stack (6.2kGs) than when block is separate (~1.6kGs).

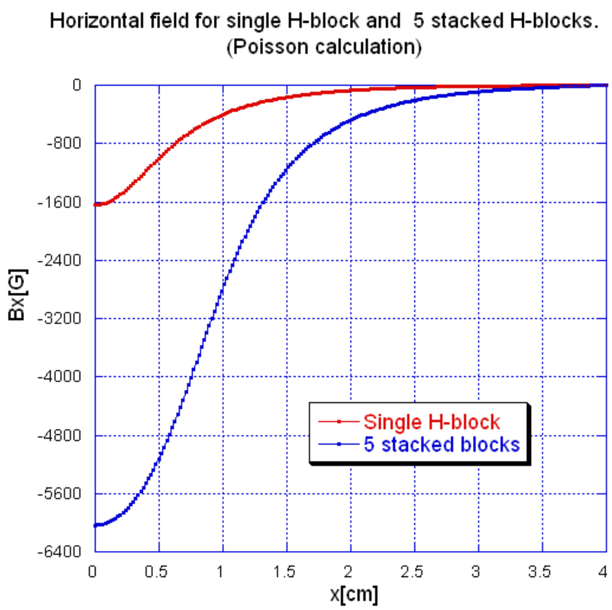

Figure 5. Horizontal field versus horizontal position for 1) separate PM block and for 2) block inside of 5-block stack. x=0 corresponds to the center of tested block.

The measurement of irreversible demagnetization caused by temperature is shown on Figure 6. It indicated significant difference for these two cases.

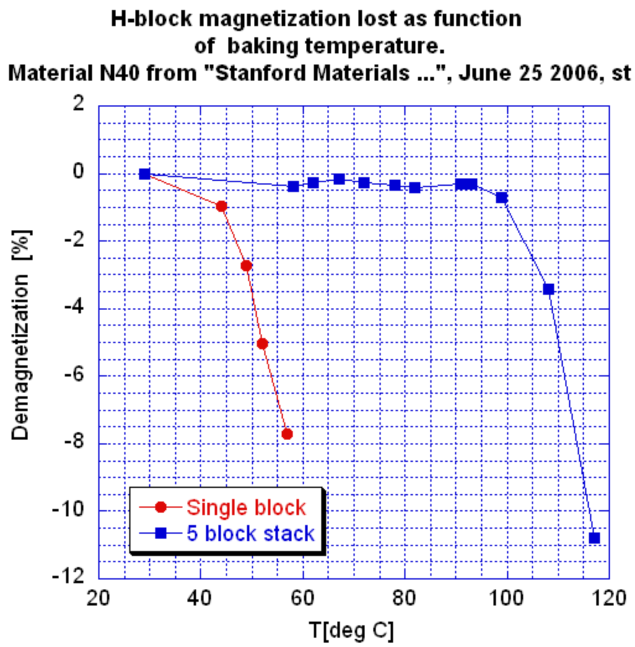

Figure 6. Irreversible demagnetization as function of baking temperature for single block (circles) and for block placed in the middle of 5-block stack.

In the case of the single block, irreversible demagnetization occurred at ~40deg C. When in the stack, this happened at temperature ~100deg C. Comparing this data (demagnetization temperature ~40deg at 1600G field and 100deg at 6200G field) with characteristics of NEOMAX PM materials available on web: http://www.neomaxamerica.com/ one can conclude that the N40 is very similar to NEOMAX-42. For the latter the irreversible demagnetization temperature is ~40 deg C for 1600G field and ~ 110deg C for 6200G.

Two conclusions can be derived from the above measurement. First, the effect of the magnetization loss of PM material with temperature can be and should be measured "in house" for any material chosen for undulator building. Second, because of strong dependence of the demagnetization on the local field, it can be appropriate to temporarily chsnge the local field for period of baking in order to avoid magnetization loss.

3. Conclusions and acknowledgements.

The above experiments provided "first hand" experience in PM material handling. They also:

- Demonstrated possibility of fine-tuning PM block magnetization in house. More uniform magnetization among PM blocs will facilitate the tuning of the assembled device.
- Showed that by changing the local field one can significantly increase the baking temperature without magnetization loss. This field change can be temporal, i.e., just for a baking period

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