Damage of NdFeB Permanent Magnets under Neutron Irradiation at the Brookhaven Linear Isotope Producer

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Abstract

High brilliance in the next generation light sources such as the NSLS II is obtained from the high magnetic fields in insertion devices (ID). The beam lifetime is limited to 3h by single Coulomb scattering in the Bunch (Touschek effect). This effect occurs everywhere around the circumference and there is unavoidable beam loss in the adjacent low-aperture insertion devices. This raises the issue of degradation and damage of the permanent magnetic material by irradiation with high energy electrons and corresponding shower particles. It is expected that IDs, especially those in-vacuum, would experience changes resulting from exposure to gamma rays, x-rays, electrons and neutrons.

The demagnetization effect of a spallation-generated irradiation field consisting primarily of fast neutrons, gamma rays and electrons on a set of NdFeB magnets has been studied experimentally using the 112 MeV, 95 μA primary proton beam of the Brookhaven Linear Isotope Producer (BLIP). The source of the magnet irradiation field was an isotope producing target array upstream of the magnets which consumed the proton beam.

Five permanent commercially available magnets with dimensions of 5cm x 4.75cm x0.7cm were irradiated and studied during this investigation in this investigation. Integrated magnet doses ranging from several 50 Mrad to 1.8 Grad were achieved during the experiment. The magnetic intensity of each of the magnets was measured with a Hall probe prior and following irradiation. The magnetic field intensity of the un-irradiated magnets while spatially variable was of the order 0.2 Tesla on average.

Detailed information on dose distributions as well as on particle energy spectra on the NdFeB magnets was obtained in realistic simulations with the MARS15 Monte-Carlo code while ORIGEN and CINTER-90 codes were employed to verify the isotopic content. The actual photon spectrum indicating the dominance of Co^{60} was obtained using a high sensitivity germanium detector.

Post-irradiation measurements of the magnetic intensity immediately after irradiation revealed that demagnetization in excess of 97% has occurred in the geometrical center of the NdFeB magnets and in excess of 82% over the edges of the magnets. Given that past studies have shown that demagnetization attributed to electron and gamma fluences that are similar to the lower end of the range of this study only accounts for a few percent of the magnetic intensity prior to irradiation, the dramatic loss observed in this study is assessed to be the result of the neutron fluence. Following a 4-year cool-down period photon spectra and magnet intensity were re-evaluated. The new data indicate slight restoration of the magnetic intensity.

The comprehensive results of the NdFeB demagnetization study, including the experimental data and the simulation efforts, as well as the identified path forward will be presented.