Optimal Larmor precession magnets: application to neutron spin echo

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ABSTRACT: Resolution characteristics of neutron spectrometers using Larmor precession of the neutron spin are presently limited by magnetic field homogeneities of a special type. The line integral of the modulus of the magnetic induction $B\int^L |B|\, dl$ along a neutron trajectory of length L is a measure of the amount of precession performed by the neutron. Hence, it should be precisely the same for all neutrons of the same energy in a diverging beam. We present an analytical solution to the variational problem $\int^L |B|\, dl =$ constant for the case of cylindrical magnets coaxial to the beam axis. This solution describes the best irrotational field shape along the beam axis z. The optimal homogeneity is significantly better than for a simple solenoid of comparable dimensions. Improved neutron economy can be achieved because our magnets can be made much shorter than solenoids. For realistic lengths **L** and beam radii **r**, it is, however, not good enough for high-resolution spectroscopy. Therefore, we studied a way to correct both for the residual inhomogeneities of cylinder magnets and the line-integral variations caused by pathlength differences, which result from finite angular beam divergence. Such corrections can only be done by introducing current distributions in the beam. Their optimal distributions can also be calculated analytically, and we present a way of implementing them in practice. In addition, we discuss the application of the same correction technique to other magnets, demonstrating that it is useful in general for cylinder-symmetric magnets such as solenoids. With magnets designed and corrected this way, the Larmor phase angle is a unique measure of the neutron energy and the resolution of spectroscopic methods using Larmor precession, such as LPS, which allows spectrum determination before or after scattering, or more sophisticated techniques, such as NSE and NMS*, for example, is not influenced by corrections or other limitations caused by imperfect magnets. With the two novel concepts of optimal magnets (OFS) and pathlength corrections described here, the resolution properties of Larmor precession techniques can be pushed to their intrinsic limits. As further results of the correction technique introduced here, wider angular divergencies can be used, resulting in substantially improved neutron economy.

*Spectroscopy techniques using Larmor precession (LPS) are:
NSE: neutron spin echo, NSM: neutron spectral modulation and just LPS.

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