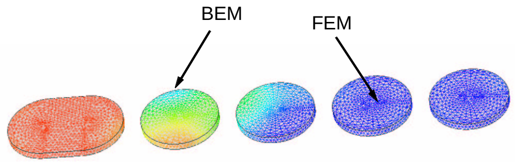
Numerical Methods in Micromagnetic Simulations

D. Suess, H. Forster, W. Scholz, R. Dittrich, V. Tsiantos, T. Schrefl and J. Fidler
Institut für Angewandte und Technische Physik, Vienna University of Technology

INTRODUCTION

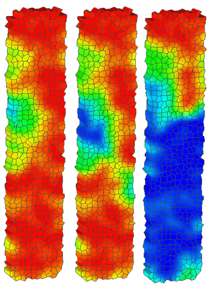
Numerical micromagnetics is an essential tool to optimize magnetic storage media and sensors. The application of these devices requires a profound knowledge of the reversal mechanism. Due to the ambition to calculate problems of increasing size the problem of a non-linear increase in CPU time has to be tackled. Therefore more efficient numerical methods are developed which allow to reduce the computing time. We calculate the time evolution of the magnetic polarization towards equilibrium using the Gilbert equation of motion.

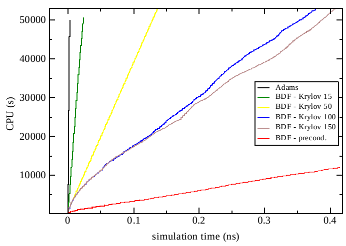
FEM / BEM



The finite element method is applied for the spatial discretization. The strayfield problem is treated with a hybrid finite element / boundary element method [1]. This method has the advantage that no finite elements are needed outside the magnetic particle to consider the boundary conditions.

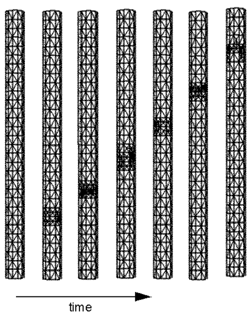
PRECONDITIONING

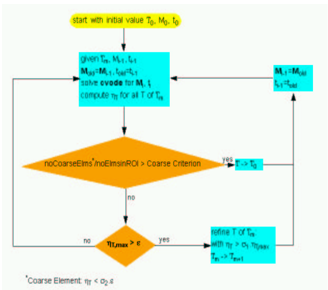




For the time integration we have tested different options of the cvode package [2]. For a granular Co-nanoelement with a damping constant $\alpha = 0.1$ we found that the implicit BDF method is much more efficient than the Adams method. The CPU time for the BDF method strongly depends on the maximum dimension of the Krylov subspace of the linear system which has to be solved in every Newton step. An increase of the maximum dimension of the Krylov subspace from the default value of 5 to 300 decreases the CPU time by a factor of 7, which leads to an overall speedup of a factor 60 as compared to the Adams method. The use of preconditioning for the time integration leads to a further speed up of a factor of 6.

MESH REFINEMENT





The CPU time for solving the system is mainly determined by the number of finite elements. In order to keep the number of finite elements small but also to resolve the micromagnetic details we introduced an adaptive refinement scheme. The mesh is refined in regions with non-uniform magnetization, whereas elements are taken out in regions with nearly uniform magnetization. Numerical studies showed that the adaptive mesh algorithm reduces the total CPU time by more than a factor of 4 [3]. The combination of mesh refinement and preconditioning for time integration keeps the number of linear iterations small and thus drastically decreases the CPU time.

[1] D. R. Fredkin, T. R. Koehler, IEEE Trans. Magn. 26 415 (1990) 415
[2] S. D. Cohen, A. C. Hindmarsh, CVODE: User Guide, LLNL, Technical Report UCRL-MA-118618, 1994.
[3] T. Schrefl, H. Forster, D. Suess, W. Scholz, V. D. Tsiantos and J. Fidler, Advances in Solid State Physics, Springer Verlag, July 2001, in press.

Work supported by the Austrian Science fund (Y-132PHY).