Progress on FY2008 First Quarter Milestone

Summary

The first quarterly milestone for the FY2008 JOULE theory milestone states that MIT shall "*Finish parallelization and testing of the newest TORIC-LH solver that directly couples the slow wave polarization of the lower hybrid (LH) wave*". This milestone was essentially accomplished in that the matrix inversion and solution algorithm part of the solver was parallelized and it was confirmed that results for the (E_θ, E_ϕ) components of the electric field solution from the parallel code were identical to the solution obtained with a serial version of the solver. This work was performed by Dr. John Wright at MIT and a description of the new code and parallel matrix inversion algorithm can be found in a paper that has been submitted for publication to *Communications in Computational Physics* entitled "Full wave simulations of lower hybrid waves in toroidal geometry with non-Maxwellian electrons". At present Dr. Wright is debugging parallel code related to an algebraic reconstruction of the radial component of the electric field (E_r) and the power reconstruction, which should be completed by the end of January, 2008.

Background for Milestone

When we examine the required resolution for LH simulations even for smaller research tokamaks, we quickly conclude that a parallel version of the field solver is needed both for memory requirements and for reasonable executions times. The worst case for poloidal resolution is at wave caustics where the radial wavenumber (k_r) vanishes and the perpendicular wavenumber is $k_\perp \approx (m/r)$, where m is the poloidal mode number. Assuming a perpendicular wavelength of $\lambda_\perp \approx 1$ mm and taking $k_\perp = 2\pi/ \lambda_\perp$ and r = a =20 cm we get m-values of $-1200 \leq m \leq +1200$, or a total number of poloidal modes of $N_m \approx 2400$. If we take $\lambda_r \approx 1$ mm as a typical radial wavelength and require 2 cubic elements per wavelength, the requirement is for 400 radial elements for the same minor radius. Given that the TORIC code is restricted to approximately 200 radial elements with 127 poloidal modes with 2GB of memory, parallelization is clearly required. Using out-of-core techniques can extend the resolution about another factor of two in each dimension, but then the processing time becomes burdensome (due to problem size, not the out-of-core disk access).

Description of First Quarter Work

The previous ion cyclotron version of the TORIC code had already been parallelized with parallelization done in the poloidal dimension for matrix inversion of the resulting block tri-diagonal system with ScaLAPACK. Parallelization along the radial dimension was done during processing of the solution for power and current drive deposition. The added complication introduced by the LH version is associated with the elimination of the equation for E_r - the diagram in Fig. 1 illustrates the issue. For the purposes of the construction of the stiffness equation it is most efficient to have each electric field component and its derivative on the same CPU. During the elimination and post calculation of E_r we need to invert the sub-matrix representing the coefficients of E_r in the stiffness matrix. Since ScaLAPACK only can do this for stride one distributed matrices, the matrix must be reordered so that the needed coefficients are logically continuous. Successful reordering of the stiffness matrix in the new parallel LH solver was accomplished in the first quarter and the solution from the new solver was confirmed to be correct.

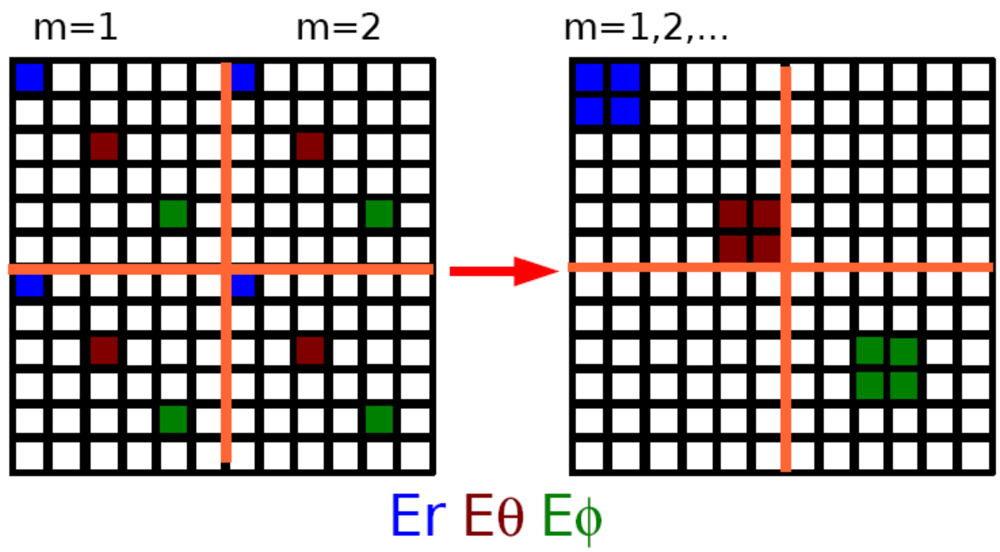

Figure 1: Diagram of the reordering of matrix elements needed for elimination of E_r in the lower hybrid algorithm. The red solid lines separate the stiffness matrix into four CPU regions. For construction and solution each CPU has all field components at a mesh point or points for most efficient communication as in the left example. On the right, the matrix has been reordered so that each field components representation is logically continuous in the distributed matrix.