PARAMAGNET Documentation

Release 6

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November 23, 2017

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INTRODUCTION

The PARAMAGNET is a 3D plasma physics code for the simulation of magnetized collisional plasmas with full electron transport in a Cartesian geometry.

Physics

The code uses a MHD model for the plasma with the full Braginskii electron transport coefficients for the anisotropic heat flow, resitivity and thermoelectric coefficient.

This plasma model is coupled to a paraxial laser model via inverse bremmsstrahlung and the ponderomotive force.

These two modules are separate and can be solved independently.

Numerical Methods

The plasma solver uses a fully implicit finite difference scheme. This produces a large nonlinear matrix problem that is solved using the Jacobian-Free Newton method with a GMRES linear solver provided by the PETSc library.

The laser solver uses finite differences. This produces a sweeping across the z direction where a linear problem has to be solved at each slice of the domain along z. To solve this linear problem the Alternating-Direction-Implicit method is used in compination with a direct complex tridiagonal matrix solver.

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DEPENDENCIES

PETSc

PETSc is a library of linear and nonlinear solvers that are required to run the PARAMAGET code. The core solvers lie at the heart of the plasma solver within PARAMAGNET and so must be installed. In order to do so go to the PETSc website https://www.mcs.anl.gov/petsc/ and follow the download and installation instructions. The version used in the code was **3.6.3** and so it is best to download this version.

OpenMP

The PARAMAGNET code uses OpenMP parallelisation for parts of the code and so a version of OpenMP must also be installed. The download and installation instructions can be found on the website https://http://www.openmp.org/. OpenMP is a shared memory model parallel library and so it can only be used for a single node.

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SIMULATION SETUP

Initialisation

To setup a simulation changes must be made to the `Initial.cpp` file and the `Global.cpp` file. The `Global.cpp` file contains the globally defined variables in the code.

The `Global.cpp` file contains:

- Physical State: variables where the temperature, density, domain size, time period and ionisation state is set
- Collisional Parameters: these should not be changed
- Mesh Variables: change the number of timesteps and mesh size
- Laser Variables: change the peak intensity and wavelength, also one can turn off the ponderomotive and inverse bremmsstrahlung terms if needed
- Output Variables: change the variables to output and how many timesteps should be Output
- Boundary Conditions: choose between periodic and outflow boundary conditions

The `Initial.cpp` file contains:

- Initial Condition: this sets the initial state of the plasma in normalised units.
- Initial Laser: this sets the laser profile at the z=0 boundary

OpenMP

To run in parallel one first has to specify the number of OpenMP threads that the program will use. Set this with the command: `export OMP_NUM_THREADS=N` with N as the number of shared memory processes needed.

Compilation

To compile the code run the command: `make MAGNET` The makefile should take care of the compilation and linking process. Within the makefile one must set the compiler variable to a C++ compiler available on the computer.

Running

To run the code use the command: `./MAGNET`

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OUTPUT

The PARAMAGNET code produces two kinds of output, plain ASCII text files for each variable that is output by the code and VTK output files.

ASCII Output

The plain ASCII text file output can be used for analysis in Matlab or Python. There is a file for each variable, density, temperature etc.

VTK Output

The VTK file output can be used for analysis in Paraview or Visit. This is useful for 3D visualisation and to quickly look at the output of the code. The format used for the VTK output is the legacy .vtk ASCII format. It works and was simple to code up but more modern and sophisticated formats exist in the VTK family.

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