Scalable and Efficient Solution of Full Maxwell Electromagnetics - Multifluid Plasma Systems by AMG-based Approximate Block Factorization Preconditioners[#]

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ABSTRACT

The mathematical basis for the continuum approximations of multifluid plasma physics systems is the solution of the governing equations describing conservation of mass, momentum, and total energy for each fluid species, along with Maxwell's equations for the electromagnetic fields. This PDE system is non-self adjoint, strongly-coupled through source terms and first-order off diagonal operators, highly-nonlinear, and characterized by physical phenomena that span a very large range of length- and time-scales. To enable accurate and stable approximation of these systems a range of spatial and temporal discretization methods are commonly employed. In the context of finite element spatial discretization these include nodal and discontinuous Galerkin methods of the fluid sub-systems, and structure-preserving approaches for the electromagnetics system. For effective time integration of the longer time-scale response of these systems some form of implicitness is required. Two well-structured approaches, of recent interest, are fully-implicit and implicit-explicit (IMEX) type methods. The requirement to accommodate disparate spatial discretizations, and allow the flexible assignment of mechanisms as explicit or implicit operators, implies a wide variation in unknown coupling, ordering, the nonzero block structure, and the conditioning of the implicit sub-system. These characteristics make the scalable and efficient iterative solution of these systems extremely challenging.

In this context this talk considers the development and evaluation of scalable iterative solvers based on approximate block factorization and physics-based preconditioning approaches. These methods reduce the coupled systems into a set of simplified systems to which multilevel methods are applied. A critical aspect of these methods is the development of approximate Schur complement operators that encode the critical cross-coupling physics of the system [1-3]. To demonstrate the flexibility and performance of these methods we consider application of these techniques to full Maxwell electromagnetics interacting with multifluid models for challenging prototype plasma systems.

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