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Block preconditioning methods for asymptotic preserving scheme arising in anisotropic elliptic problems

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The aim of this work is to introduce a numerical method to cope with the multiscale nature of confined plasma physics. These investigations are focused on fluid plasma description under large magnetic field. The difficulties in this context stem from intense magnetization of the plasma, inducing a severe anisotropy, possible quasi-neutrality breakdowns, which may occur locally in the plasma and, eventually, the drift regime which prevails for the description of the electrons. These characteristics bring small parameters compared to the scale of the studied device. This work is therefore devoted to highlighting the difficulties specific to this context and to developing numerical methods efficient to cope with this multiscale nature of the physics within the framework of asymptotic-preserving methods[1].

The discretization of the asymptotic-preserving methods introduces a block matrix systems, where efficient and robust iterative solvers for these linear systems are very challenging. We therefore focus on a toy model containing the main difficulties. Then a block preconditioning method is introduced to solve the linear algebraic systems of a class of micro-macro asymptotic-preserving (MMAP) scheme. The MMAP method was developed by Degond *it et al*.[2] in 2012 where its corresponding discrete matrix has a 2 x 2 block structure. Motivated by approximate Schur complements, a series of block preconditioners are constructed. We first analyze a natural approximate Schur complement that is the coefficient matrix of the original Non-AP discretization. However it tends to be singular for very small anisotropic parameters. We then improve it by using more suitable approximation for boundary rows of the exact Schur complement. With these block preconditioners, a preconditioned GMRES iterative method is developed to solve the discrete equations. Several numerical tests show that block preconditioning methods can be a practically useful strategy with respect to grid refinement and anisotropic strengths[3].

The applications targeted are related to the linear plasma device facility HIT-PSI[4]. For example, the proposed numerical scheme could deal with plasma beam colliding with neutral particles in the quasi-neutrality and low Mach regimes (see Figure 1), and also with the collisionless isothermal sheath (see Figure 2).

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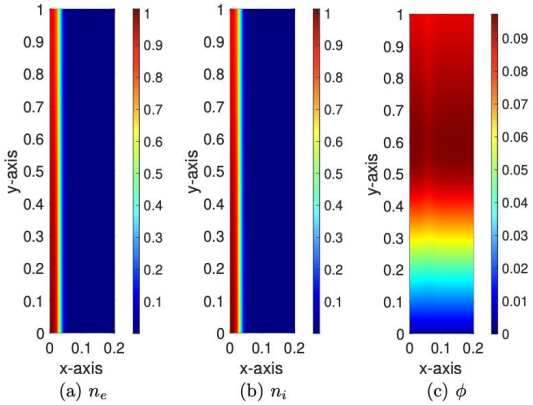

Figure 1 Physical quantities in 2D domain for the test of the collision with neutral particles.

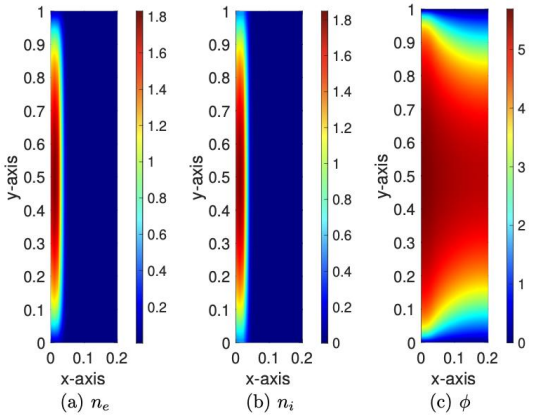

Figure 2 Physical quantities in 2D domain for the test of the collisionless isothermal sheath.