Explicit local time stepping for Maxwell's equations

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The accurate and reliable simulation of electromagnetic wave phenomena is of fundamental importance in a wide range of engineering applications, such as wireless communication, photonic crystals, radar technology, and near field scanning optical microscopy. In the presence of complex geometry, adaptivity and mesh refinement are certainly key for the efficient numerical solution of Maxwell's equations. Hence to address the wide range of difficulties involved in the numerical simulation of time-dependent electromagnetic waves, we consider symmetric interior penalty (IP) discontinuous Galerkin (DG) methods for the spatial discretization, which yield a block-diagonal mass matrix with fixed block size determined by the number of degrees of freedom per element only. Hence, when combined with explicit time integration, the resulting time-marching schemes are truly explicit. Locally refined meshes, however, impose severe stability constraints on explicit time-stepping schemes, where the maximal time-step allowed by a CFL condition is dictated by the smallest elements in the mesh. When mesh refinement is restricted to a small region, the use of implicit methods, or a very small time step in the entire computational domain, are very high a price to pay. To overcome the stability restriction, we consider local time-stepping schemes, which allow for arbitrarily small time-steps precisely where small elements in the mesh are located. Numerical experiments validate the theoretical results and illustrate the efficiency of the proposed time integration schemes, which are fully explicit and energy conserving.

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