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Computation of resonant modes in cavities with a Discontinuous Galerkin time domain approach

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ABSTRACT

Recent advances in manufacturing techniques, such as electron beam lithography, make it possible to manufacture resonators on the scale of the wavelength of light. It has been demonstrated that such devices have well defined resonances and high quality factors. However, the typical scale and the geometric complexity introduce several challenges for numerical simulation.

Behaviour of these resonators is described by Maxwell's equations of classical electromagnetics. For metallic devices, the frequency dependence of material parameters becomes significant and should be accounted for using the Drude or Drude-Lorentz models, see an example of a computation in a dispersive cavity in Figure 1. Frequency domain solvers [1] are traditionally employed to find the resonant frequencies and associated modes, but as the scale and geometric complexity of the devices increases, the large eigenvalue system that must be solved becomes computationally prohibitive.

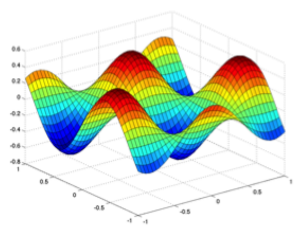

Figure 1: A component of the electromagnetic field in a square cavity filled with a dispersive material.

We propose to use the Discontinuous Galerkin (DG) method with explicit time marching, which only requires solving a block diagonal system of equations for each time step [2]. The resonant frequencies, quality factors and mode shapes can then be recovered by a periodic sampling of the solution in time using the Fast Fourier Transform or similar, more advanced, techniques. Quantities of interest, such as resonant frequencies, quality factors and mode shapes are then obtained from the spectrum by curve fitting. Additionally, the ease of parallelisation of the DG method is particularly attractive to allow the sampling of a signal of the required duration in reasonable computational time.

We discuss in detail the implementation of a parallelised DG electromagnetic solver, capable of full 3D simulation of dispersive metallic cavities. We present a study on the sampling rates and duration of the sampled signal required to obtain a given spectrum resolution. We validate the method by assessing the optical properties of resonators for problems with known solutions. Finally, we present results for a realistic metal-coated semiconductor nanocylinder resonator.

References

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[2] Sevilla, Ruben, Oubay Hassan, and Kenneth Morgan. "The use of hybrid meshes to improve the efficiency of a discontinuous Galerkin method for the solution of Maxwells equations." Computers & Structures 137 (2014): 2-13.