A DPG Maxwell approach for studying nonlinear thermal effects in active gain fiber amplifiers

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Fiber lasers that are operated at high power levels suffer from undesired nonlinear effects such as Transverse Mode Instability (TMI). Indeed, TMI is a major obstacle in power-scaling of continuous-wave, weakly guided, large mode area, active gain, silica fiber amplifiers. A better understanding of these relevant nonlinear coupling effects is beneficial in the design of new fibers. To that end, we propose a three-dimensional Discontinuous Petrov-Galerkin (DPG) finite element approach for studying a novel nonlinear full vectorial Maxwell model. The model incorporates both amplification (or laser gain) as well as thermal effects via coupling with the heat equation. The high-frequency nature of this nonlinear wave propagation problem requires the use of high-order discretizations to effectively counter numerical pollution. The DPG methodology provides a suitable framework for this. In particular, we apply the ultraweak DPG formulation to the Maxwell system, carrying desirable properties in the high-frequency regime. The ultraweak Maxwell system is then coupled with the primal DPG formulation of the heat equation. The derived DPG formulation comes with a host of advantageous properties, including mesh-independent stability and a reliable built-in a-posteriori error estimator enabling *hp*-adaptivity. We present numerical results for this coupled system, modeling fibers with up to several hundred wavelengths. For that, we emphasize the importance of high-order discretization. Our qualitative results provide new insight into the nonlinear effects of laser gain and thermal fluctuations on the propagation of guided modes in the fiber amplifier.

Acknowledgement

This work is partially supported by AFOSR FA9550-17-1-0090.

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