SCALABLE SIMULATION OF FIBER LASER MODEL WITH DPG

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ABSTRACT

Development of increasingly high-power fiber laser systems is of interest for a range of applications including manufacturing, medicine, and military defense. Power scaling of fiber lasers is limited by a complex trade-space of deleterious nonlinear effects including transverse mode instability (TMI)—a phenomenon in which interference of fiber modes induces an oscillatory thermal profile, resulting in chaotic transfer of energy between modes and degrading beam coherence. Modeling and simulation can provide valuable tools for exploring fiber designs that mitigate nonlinear effects; unfortunately, many simplified models fail to accurately predict high-power performance, explaining the need for high-fidelity modeling of fiber laser systems.

A coupled vectorial Maxwell and heat model under a DPG finite element discretization was recently used to simulate TMI in a step-index continuous-wave active-gain fiber laser amplifier in [1]; however, the computational expense of resolving highly-oscillatory electromagnetic fields limited the scale of simulation to < 1 cm of fiber. In the present work, the Maxwell model is supplanted by an *equivalent* vectorial envelope model that significantly eases discretization requirements; enabling three-dimensional simulation of TMI in full-length fibers with $> 1\,000\,000$ optical wavelengths. This model is currently limited to fibers with simple cross-sections due to relatively poor scaling of available solvers under transverse refinement; we thus detail progress on a distributed implementation of a scalable DPG multigrid solver [3] to enable simulation of more complex fiber geometries, including fiber bending effects.

The fiber laser model and DPG-MG solver are implemented in *hp*3D[1]—an open-source scalable *hp*-adaptive finite element software [2].

[1] https://github.com/Oden-EAG/hp3d

References

[1] Henneking, S., *A scalable hp-adaptive finite element software with applications in fiber optics*, Ph.D. thesis, The University of Texas at Austin (2021).

[2] Henneking, S. and Demkowicz, L., *hp3D User Manual*, arXiv:2207.12211, Jun. 2022.

[3] Petrides, S. and Demkowicz, L., *An adaptive multigrid solver for DPG methods with applications in linear acoustics and electromagnetics*, Comput. Math. Appl. 87 (2021), pp. 1999–2017.

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