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Adaptive DPG-based Multigrid Solver for Bent Optical Fiber Simulations

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Development of increasingly high-power fiber lasers is of interest for a range of applications including manufacturing, medicine, and military defense. High-power optical fibers are typically designed with larger fiber cores, decreasing the intensity of core fields and associated non-linear effects, but allowing higher-order modes to propagate. These high order modes can be problematic and are responsible for inducing transverse-mode instability (TMI) at high optical intensities. Mechanical bending of optical fibers facilitates transfer of energy from core-guided modes to cladding modes and, due to the strongly mode-dependent behavior of bend losses, can be used to filter high-order modes. Computational modeling can be used to investigate the interaction of bend losses with non-linear effects including TMI, but can be prohibitively expensive due to the extremely high-frequency of propagating fields. This work focuses on the development and application of a distributed multigrid solver [1] based on the Discontinuous Petrov-Galerkin (DPG) finite element method to simulate non-linear optical effects in bent optical fibers.

The DPG methodology provides a number of benefits including pre-asymptotic stability, a built-in robust error indicator, and Hermitian positive-definite discrete systems. In particular, pre-asymptotic stability implies that DPG methods are not subject to the minimum discretization requirements for stability of Galerkin and other classical methods in the context of high-frequency wave propagation [2]. When used in concert with the robust error indicator, DPG can start from an arbitrarily coarse grid and adaptively refine only where the signal is supported; representing a significant cost savings for modeling the highly localized fields in optical fibers. Finally, because DPG produces Hermitian positive-definite discretizations (even for indefinite continuous operators as in the case of high-frequency wave propagation), a scalable multigrid solver can be employed that leverages the hierarchy of grids produced during adaptive refinements.

REFERENCES

[1] S. Petrides and L. Demkowicz, An adaptive multigrid solver for DPG methods with applications in linear acoustics and electromagnetics. *Computers & Mathematics with Applications*, Vol. **87**, pp. 12-26, 2021.

[2] J.M. Melenk and S. Sauter, Wavenumber explicit convergence analysis for Galerkin discretizations of the Helmholtz equation. *SIAM J. Numer. Anal.*, Vol 49(3), pp. 1210–1243, 2011