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Schwarz Domain Decomposition with the Modal Transmission Condition Applied to an In-Vacuum Undulator at PETRA III, DESY

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Finite element non-overlapping Domain Decomposition Methods (DDMs) based on the Schwarz method are promising iterative techniques for addressing large-scale electromagnetic wave problems in the frequency domain. The convergence of these methods highly depends on the transmission conditions (TCs) employed between subdomains. Typically used TCs, which are based on free space open boundary conditions, face issues when applied to guided wave problems, such as those encountered in in-vacuum undulators (IVUs). Higher-order variants struggle with convergence around cutoff frequencies of modes at interfaces, while zeroth-order TCs fail completely for evanescent waves. Superior convergence is obtained by considering the physics of the waves travelling through the interfaces, which leads to the modal transmission condition (MTC).

In this contribution, we extend the MTC to include a particle beam through the domain interfaces, making the method applicable to problems encountered in particle accelerators. We apply this enhanced MTC to the electromagnetic simulation of an in-vacuum undulator at PETRA, DESY. The Schwarz domain decomposition method allows the problem to be divided into several subproblems, which can be distributed across nodes of an HPC cluster. The MTC enables particularly efficient use of HPC resources by significantly reducing the number of iterations required, while adding only minimal computational overhead compared to a zeroth-order free space TC.

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