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A Differentiable Interferometer Simulator for the Computational Design of Gravitational Wave Dectectors

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Recent advances in optimization techniques have opened up a promising path towards computationally exploring the vast design space of new gravitational wave detectors. Formulating a highly expressive, continuous search space of potential topologies, defining a clear objective function and evaluating detector candidates with an interferometer simulator allow for computational methods to discover novel and unconventional detector blueprints that compete with designs based on human ingenuity. One current bottleneck of such optimizations is the numerical gradient approximation which makes it necessary to run the simulator multiple times per evaluation. To address this bottleneck, we present a new differentiable frequency domain interferometer simulator implemented in Python using the JAX framework. Our implementation closely follows the established Finesse simulator and offers functionality to simulate plane waves in quasi-static, user-specified setup configurations including quantum noise calculations and optomechanical effects. JAX's GPU support and just-in-time compilation ensure fast runtimes, while its automatic differentiation feature enables gradient-based optimizations that can easily support the large-scale digital discovery of novel gravitational wave detectors.

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