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Combination of Machine Learning with Finite Element Time Domain Methods for the Ultrabroadband Simulation of Nonlinear Optical Processes

Nonlinear optical phenomena are the basis for a wide range of applications such as novel optical sources and measurements or diagnostic techniques. With growing complexity of physics and models, advanced discretization techniques and optimal performance properties of algorithms are of increasing importance for the simulation of nonlinear optical phenomena. Here we confirm the accuracy and efficiency of the concepts developed in the field of applied mathematics and show their application to problems of practical relevance.

Firstly, we investigate the accurate full broadband simulation of complex nonlinear optical processes. We develop a mathematical model and numerical simulation techniques without employing ad hoc approximations such as slowly varying envelopes. The techniques are used to elucidate THz generation in periodically poled Lithium Niobate (PPLN) including optical harmonic generation.

Secondly, we investigate the potential of using machine learning to accelerate simulations by exploiting knowledge based on data of our numerical experiments. Our approach takes advantage of the crystal structure through neural networks that learn the propagation through one period of the layers in the PPLN. We further use prior physical knowledge about the PDEs governing the wave propagation in PPLN. Based on examples from fluid mechanics, we show cross-disciplinary perspectives for the combination and coupling of machine learning and numerical simulation techniques and give an outlook on how this can be used in nonlinear optics.

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