Nonlinear Vector Finite Element Simulation of Optical Photonic Devices

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Continual research of new optical devices for use in the communication industry has led to the possibility of using the nonlinear optical response of various materials. Using these nonlinear effects, researchers have been designing switches, logic gates, and frequency generators with increasing complexity in both functioning and geometry. The high degree of complexity in functioning makes analysis of these devices through analytical approximation incomplete. Significant progress in understanding these devices has been made through the use of simulation using nonlinear Finite Difference Time Domain (FDTD) schemes. While the FDTD schemes are highly computationally efficient, the increasing geometric complexity of these devices is becoming a problem for the FDTD approach given its highly restrictive geometry constraints.

We present a nonlinear Vector Finite Element Method (VFEM) scheme that involves discretizing Maxwell's equations using Nedelec edge and face bases. The VFEM scheme is capable of simulating instantaneous third order nonlinear processes such as the the kerr effect, and four wave mixing. The VFEM scheme is also capable of handling the complicated 3 D geometries found in many of the newer optical photonic devices with a high degree of accuracy. Also, our VFEM scheme includes methods for reducing the high computational cost of nonlinear finite element methods, thereby making larger simulations possible.

In addition to presenting this new scheme, we will also present a series of tests to show that the scheme is capable of simulating the intricacies of optical photonic devices. These tests include simulations of classical nonlinear optical effects that can be compared with analytical approximations. The tests also include some comparisons to FDTD schemes on less complicated geometries. Finally, with a reasonable degree of confidence in the accuracy of the scheme, we will present novel simulations of some optical photonic devices.