Modified Padé Approximant Operators for Efficient Time-Domain Beam Propagators

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The usefulness of the recently introduced modified Padé approximant operators for the solution of time-domain beam propagation problems is presented. We show this both for a wideband method which can take reflections into account, and for a split-step method for the modeling of ultrashort unidirectional pulses. The resulting approaches achieve high-order accuracy not only in space but also in time.

Introduction

Many Time Domain Beam Propagation Methods (TD-BPMs) are based on the slow-wave approximation, and ignore the second order derivative with respect to time. If this derivative term is included, it is commonly approximated by rational real Padé approximant operators [1]. These incorrectly propagate evanescent modes in the frequency domain leading to additional errors and instability problems. We proposed modified Padé approximant operators to overcome these problems [2]. Here TD-BPMs based on the modified Padé operators are used to investigate an optical grating and to simulate ultra-short pulse propagation in a Y-branch waveguide structure.

Results

For the grating problem the relative error (RE) of the field profile at a reference point, i.e. the error with respect to the field profile obtained at the smallest time step used of 0.1fs, is calculated as a function of time. Fig. 1 shows this error for the conventional (cPade) and modified (mPade) Padé schemes with various time step resolutions (0.5fs, 1fs, 2fs). The REs obtained using the modified Padé(1,1) operator are much smaller than those obtained by the conventional one for the same accuracy, with an associated reduction in computational effort.

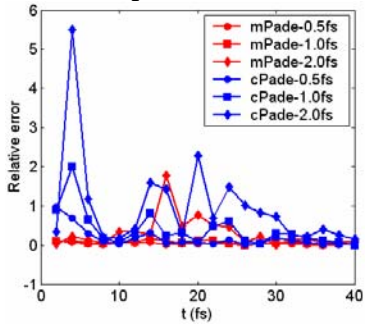

Fig. 1. Relative error of the field monitored at the reference point calculated by the modified (red lines) and conventional (blue lines) Padé-based TD-BPM with various time steps using the field at 0.1 *fs* as a reference

Calculations for pulses propagating in a Y-branch waveguide using conventional and modified Padé-based TD-BPM with various propagation step resolutions also show that REs obtained using the modified approach are much smaller than those obtained by the conventional one for the same propagation step.

References

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