Numerical analysis of partially coherent pulses applied to resonance gratings

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Introduction

Coherence properties of temporally partially coherent non-stationary fields modified by optical elements are rather unexplored in light sciences. Analytical models beyond the free-space propagation are rare and for relatively demanding optical elements, resonance gratings, the coherence analysis is only possible by numerical means. For this purpose rigorous electromagnetic methods are a feasible and efficient way to obtain accurate results.

Implementation and results

We compare Fourier Modal Method (FMM) [1] and Finite Difference in Time Domain method (FDTD) [1] and calculate the degree of temporal coherence of a non-stationary field after a resonance grating of Ref. [2]. For modelling the temporal properties we use the Gaussian-Schell –model (GSM) and independent-elementary- pulse representations [3]. The resonance grating reshapes the spectrum and hence the time pulse of the 50 fs elementary Gaussian source field as shown in Figs 1(a) and 1(b).

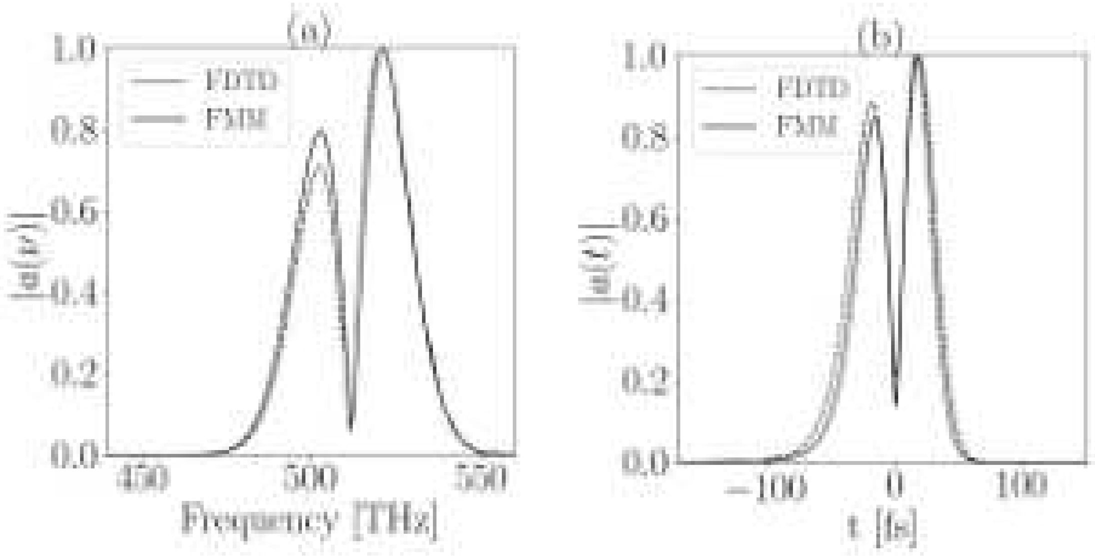

Figure 1. The normalized magnitudes of the transmitted elementary pulses in (a) frequency and (b) time domains calculated with FMM (dotted line) and FDTD (solid line).

We notice small differences in spectral and temporal shapes between FDTD and FMM. This is due the difference between the operating domain pulse propagation of the methods. Also the numerical dispersion plays a role in FDTD.

Temporal coherence properties of the transmitted non-stationary field can now be determined by making a Gaussian weighted superposition of the mutually independent and fully temporally coherent elementary pulses $a(t)$ at different time instances t_1 and t_2. For independent-elementary- pulse representation the complex degree of coherence γ reads:

$$\gamma(t_1, t_2) = \frac{\int_{-\infty}^{\infty} g(t) a^*(t - t_1) a(t - t_2)\, dt}{\sqrt{\int_{-\infty}^{\infty} g(t) |a(t - t_1)|^2\, dt \int_{-\infty}^{\infty} g(t) |a(t - t_2)|^2\, dt}},$$

where the asterix denotes complex conjugation and $g(t)$ is a Gaussian weight function. In Fig. 3 we present the degree of temporal coherence of the GSM pulse after a resonance grating calculated with FMM. FDTD gives similar result.

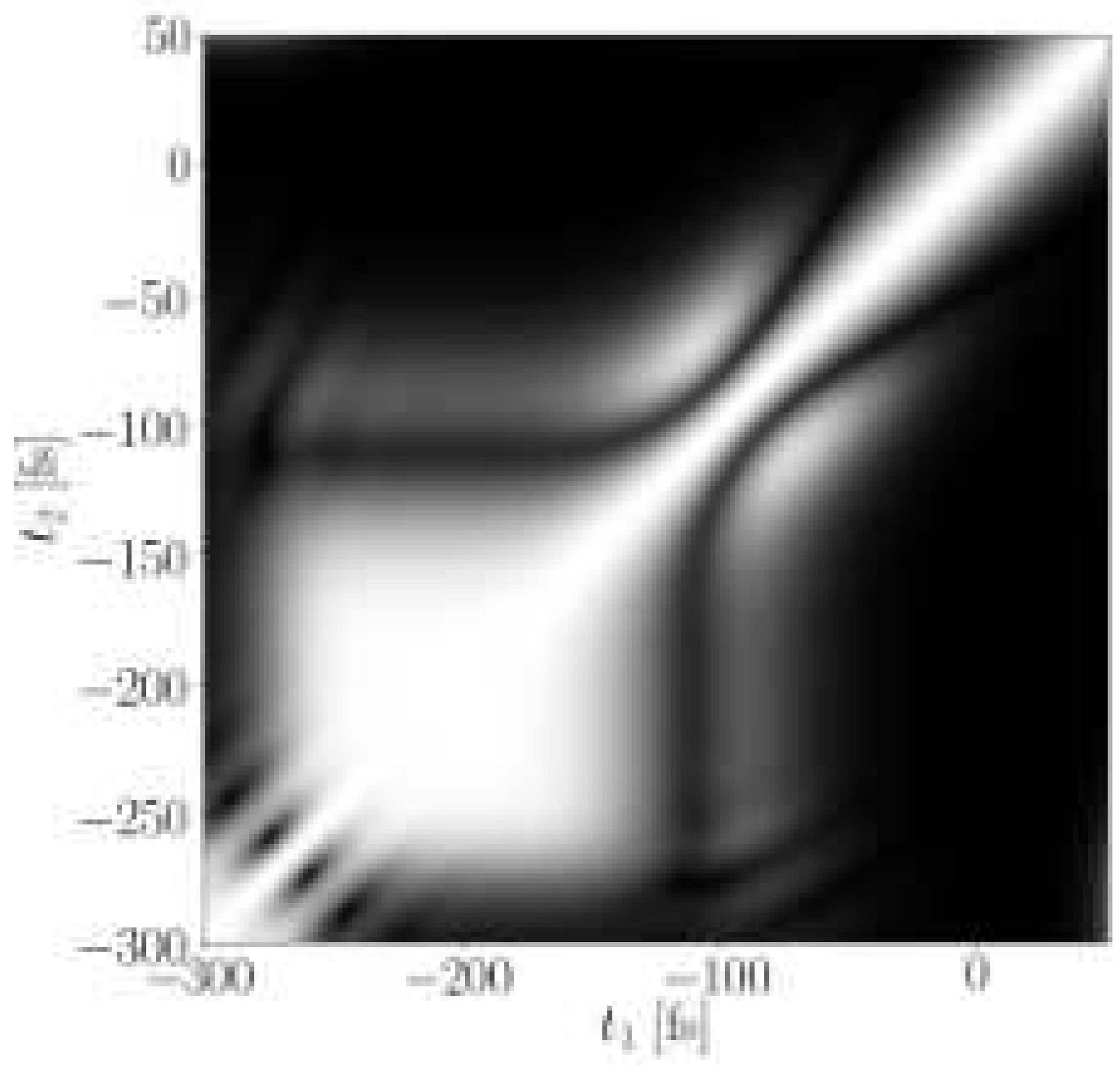

Figure 2. The complex degree of coherence for transmitted partially temporally coherent 50 fs GSM-pulse incident to the resonance grating.

As a conclusion FMM and FDTD are suitable for modelling the temporal coherence properties of partially coherent pulses incident on resonance gratings when special features of the operating domain pulse propagations of the methods are taken in to account [4].

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