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Optimization of Parameters of Input Pulses for Passive Photonic-Crystal-Based Electromagnetic Energy Compressors

Electromagnetic (EM) energy compression is a process of converting long-duration low-amplitude input pulses into much shorter output pulses with significantly higher amplitude. There are two primary approaches to this: active and passive compression [1]. Active compressors accumulate the input in resonant cavities over a relatively long accumulation stage, followed by a rapid release of the accumulated energy as a very short, high-power output pulse [2]. Passive compression, which is the focus of this study, occurs when an input pulse increases in amplitude and decreases in duration as it travels through a waveguide with specific geometric and/or material properties [3]. This is achieved by exploiting the dispersion of waveguides, which causes different frequency components to propagate with different velocities, and by tuning the frequency modulation of an input pulse so that these components arrive synchronously at the output. EM energy compressors are used in particle accelerators, radars, data transmission, energy transfer, plasma heating, biophysical applications, EM launch systems, essentially, in any field that requires high-power electromagnetic pulses (EMP).

Accurately computing the time signature of input pulses is crucial for the efficient passive compression of EMP. In this work, we employ the time reversal method (TRM) for these computations. TRM is based on the possibility to change the sign of the time variable in the Maxwell's equations, enabling the reconstruction of a pulse's evolution up to its arrival at the output with a set-in-advance temporal profile, regardless of the type of dispersion elements used [4]. In this work, we detail the specific aspects of TRM application and address the optimization of the excitation pulse's parameters through the linearization of its frequency modulation.

A 2D photonic crystal with a waveguiding defect is considered as a test-bed dispersive waveguide. The absence of metal components (the crystal is constructed of sapphire rods) makes it particularly inviting for compressing microwave pulses.

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