Temporal coherence filter for non-stationary light

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Introduction

The coherence of pulse trains is of major interest in a large variety of experiments, ranging from high precision metrology to material processing. Methods of measuring [1] and generating [2] partially coherent pulse trains have been realized in the past. However, there currently exists no method to increase the temporal degree of coherence of non-stationary light.

Theory

We consider the effect an external Fabry-Perot resonator has on a train of pulses. A schematic representation of the resonator with mirror reflection coefficients \( r_1 \) and \( r_2 \) is shown in Fig. 1 below.

The incident pulse train can be described with the electric field representation as

\[
E(t) = \sum E_n(t + n\Delta t),
\]

where each realization \( E_n \) is potentially different and \( \Delta t \) is the pulse separation. Apart from the obvious spectral sampling, it is of great interest to inspect how a non-stationary field behaves when consecutive pulses are superimposed within the cavity. This type of situation occurs when the resonator round-trip time is some multiple of the input laser repetition rate, in which case the intracavity field at the beginning of the \( N \)th round trip is described by

\[
\bar{E}(t') = t_1 \sum_{n=1}^{N} (r_1 r_2)^{N-n} E_n(t'),
\]

where \( t_1 = 1 - r_1 \). The intracavity field can have greatly enhanced temporal coherence properties when compared to the input field, thus acting as a coherence filter.

Simulations

We simulate the effect of the external resonator with supercontinuum pulses that have a very low degree of temporal coherence. We input the pulses to a Fabry-Perot resonator with mirror reflectivities \( r_1 = r_2 = r \) and assume that \( \Delta t \) is equal to the cavity round trip time. We then compute the complex degree of temporal coherence for the incident and intracavity pulses, using the equation

\[
\gamma = \frac{\langle E^*(t_1) E(t_2) \rangle}{\langle |E(t_1)|^2 \rangle^{1/2} \langle |E(t_2)|^2 \rangle^{1/2}}
\]

The resulting absolute values of the temporal degree of coherence are shown in Fig. 2.

From Fig. 2, it is clear that the degree of temporal coherence increases rapidly inside the cavity as \( r \) is increased.

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