Observation of large “fast light” pulse advancement without distortion

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Abstract: We observe pulses advanced by 15% of their width and experiencing only minor distortion using laser-driven potassium atoms in a novel configuration that avoids competing nonlinear optical effects.

There is currently great interest in tailoring the dispersion of gasses of atoms using intense laser fields. For example, it is possible to create spectral regions of large anomalous dispersion so that the group velocity is greater than $c$ or less than zero (“fast light”). One experimental technique for studying fast light pulses uses a continuous-wave bichromatic Raman pump laser beam to tailor the dispersion properties of an atomic vapor [1]. It does this by creating two gain features with similar frequencies. Between these gain features, the phase velocity dispersion is anomalous and the group velocity dispersion can be minimized. As a result, a pulse traveling through the medium will experience “fast light” propagation with little distortion if its frequency falls between these two gain features.

While a recent experiment has achieved extremely fast group velocities [1], the pulse advancement was small (less than 2% of the pulse width). Large advancement is necessary to carefully study the propagation of discontinuities imposed on the pulse envelope. These discontinuities are thought to be the carriers of information and are therefore expected to propagate with velocity $c$ [2], but this has not been verified experimentally in “fast light” optical pulses.

In an effort to obtain large pulse advancement, we have found that the induced modulation instability (IMI) causes temporal modulation of the pumping field. As the bichromatic gain becomes larger (leading to greater “fast light” pulse advancement), the IMI leads to Raman-pump distortion, which in turn leads to pulse distortion [3].

In order to achieve large advancement with little distortion, we employ a new experimental method in which the pulse passes through two spatially distinct gain regions [4]. Each of these regions is illuminated by only one of the Raman pumping beams, as shown in Fig 1a. By passing through both regions, the pulse experiences the required anomalous dispersion. However, because the two Raman pumps never exist in the same location, the IMI can be avoided.

Using this new technique, we can now achieve unprecedented “fast light” pulse advancement while introducing only minor distortion. In preliminary experiments, we have advanced pulses by 15% of their width, introducing very little distortion, as shown in Fig. 1b. The large advancement and small distortion of this technique make it possible for the first time to explore experimentally the propagation of discontinuities on optical pulses with velocities faster than $c$.

We will discuss “fast light” pulse propagation and its limitations, and present our progress in observation of the propagation of discontinuities on dramatically advanced optical pulses in an effort to test proposed definitions of the information velocity [2].

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References
4. This method was suggested by L.J. Wang in private communication.
Fig. 1. (a) Dual-zone setup used to generate “fast light” pulses. (b) Plot of pulse intensity as a function of time for vacuum and advanced pulses. The vertical lines mark the centers of the pulses. The pulses have been averaged 25 times.