Negative group velocity in a coherence-free cold atomic medium

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We have observed superluminal propagation of a light pulse through an atomic medium in which the fast light arises from the intrinsic anomalous dispersion associated with an atomic absorption line. Steep dispersion is associated with narrow absorption resonances, and fast light conditions in atomic media have most often been achieved by exploiting very narrow ground-state coherence resonances; however, in this work our aim has been to demonstrate fast light in a coherence-free medium, using the anomalous dispersion that results from linear atom-light interaction. Such a simple system should aid understanding of the underlying mechanism responsible for superluminal propagation, which remains a subject of some debate despite its apparent phenomenological simplicity.

The pulse advance was observed in a cloud of cold ^{85}Rb atoms in a magneto-optical trap. The atomic medium was first characterized using a radiofrequency heterodyne technique [1] in which a bichromatic beam with frequency components offset by typically 80 MHz is split so that one bichromatic beam passes through the atomic medium while the other does not. The output of a radiofrequency mixer in which the two beat signals are combined depends on the optical phase shift experienced by either frequency component as it is scanned through an atomic resonance.

To observe the pulse advance directly, an AOM was used to generate a 35 ns-long optical pulse (Fig.1a) which propagated through the MOT [2]. The frequency of the light was tuned to the transmission minimum on the 5S$_{1/2}$(F=3) $\rightarrow$ 5P$_{3/2}$(F=4) transition, where the rf heterodyne technique indicated a spectral region of up to 40 MHz of negative and constant dispersion. This places a lower limit on the pulse lengths that can be used, and is an order of magnitude wider than that typically associated with ground-state coherences. Although it is well established that fractional advance of a light pulse is harder to achieve than the same fractional delay, the observed pulse advance of 3.6 ns relative to an off-resonant control pulse (Fig.1b) represents a significant fractional advance of around 10% for a pulse attenuated by approximately 50%, and corresponds to a negative group velocity -c/360, in good agreement with the value of anomalous dispersion of $dn/d\nu \approx$-1.3$\times$10^{-12} Hz^{-1} determined with the rf heterodyne technique.

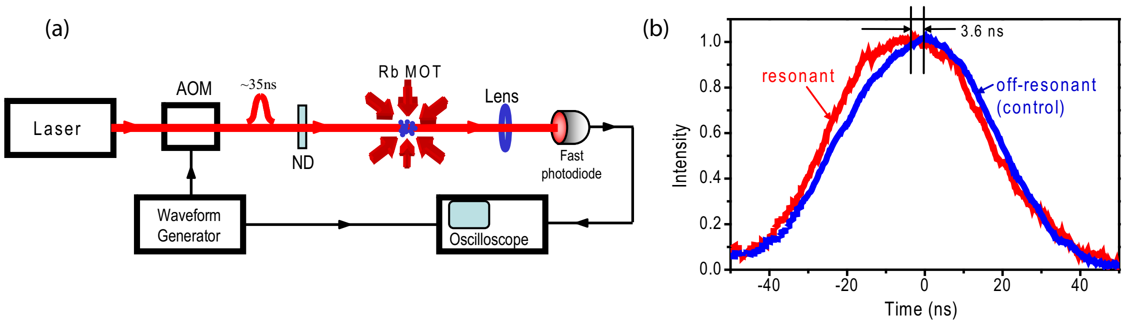

Fig. 1: (a) Experimental arrangement for observing pulse advance. (b) Normalised resonant and off-resonant pulses after propagation through the ^{85}Rb MOT. The linearly polarised probe was resonant with the 5S$_{1/2}$(F=3) $\rightarrow$ 5P$_{3/2}$(F=4) transition. Attenuation of the resonant pulse is less than 50%

References

[1] A.M. Akulshin, S. Barreiro and A. Lezama, Phys. Rev. Lett. **83**, 4277 (1999).

[2] W.G.A. Brown, R.J. McLean, A.I Sidorov, P. Hannaford and A.M. Akulshin, J. Opt. Soc. Am. B **25**, C82 (2008).