

🌀 Focusing Light Beams To Improve Atomic-Vapor Optical Buffers

Atomic-vapor optical buffers could be made to perform more nearly optimally.

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Specially designed focusing of light beams has been proposed as a means of improving the performances of optical buffers based on cells containing hot atomic vapors (e.g., rubidium vapor). There is also a companion proposal to improve performance by use of incoherent optical pumping under suitable conditions.

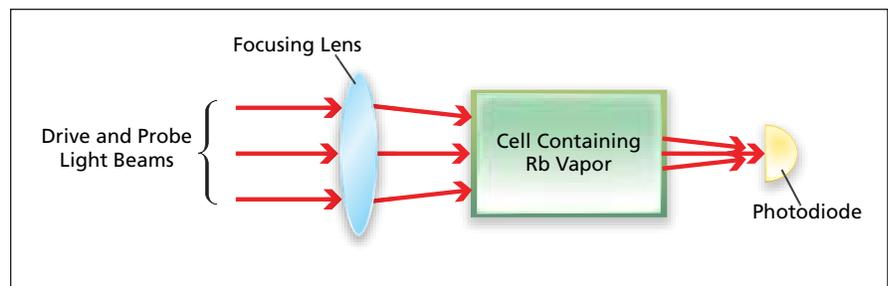
Atomic-vapor optical buffers (of which there are both cold- and hot-vapor types) are photonic devices based on a "slow light" phenomenon that involves quantum effects that occur in vapors of rubidium and other elements under suitable conditions. Atomic-vapor optical buffers have been extensively discussed in the literature as means of optical storage and optical processing of information.

Regarding the proposal to use focusing: The utility of atomic-vapor optical buffers as optical storage and processing devices has been severely limited by nonuniform spatial distributions of intensity in optical beams, arising from absorption of the beams as they propagate in atomic-vapor cells. Such nonuniformity makes it impossible to optimize the physical conditions throughout a cell, thereby making it impossible to optimize the performance of the cell as an optical buffer. In practical terms simplified for the sake of brevity, "to optimize" as used here means to design the cell so as to maximize the group delay of an optical pulse while keeping the absorption and distortion of the pulse reasonably small.

The basic limit of the group delay in the presence of Raman amplification of a probe light beam in a hot-atomic-vapor cell is set by the absorption of a drive light beam with consequent gradual decrease of the width of an electromagnet-

ically induced transparency (EIT) resonance along the propagation direction. One possible approach to compensation of the absorption, represented by the present proposal, is to focus the light (see figure) in such a way that the net effect of the focusing and absorption is

light systems. However, prior studies of those systems did not quantitatively answer the question of whether the performance of an atomic vapor or other medium that exhibits EIT with Raman gain is superior to that of a medium that exhibits EIT without Raman gain.



Light Would Be Focused into and through a hot vapor of rubidium or other suitable atoms. The focusing lens would be designed to produce a beam profile in which focusing would compensate for absorption to yield constant intensity.

that its intensity does not vary with position in the cell. Theoretically, such compensation should lead to fractional group delays longer than those of similar cells in which collimated light is used. It has also been determined theoretically that focusing by a thin spherical-surface lens describable by the geometric-optics approximation would not suffice; it would likely be necessary to use a thick lens of more complex design based at least partly on wave optics.

Regarding the proposal to use incoherent optical pumping: For reasons too complex to describe here, residual absorption of light is one of the main impediments to achievement of desirably long group delays in hot atomic vapors. The present proposal is directed toward suppressing residual absorption of light. The idea of improving the performance of slow-light optical buffers by use of incoherent pumping overlaps somewhat with the basic idea of Raman-based slow-

It is known from prior research that incoherent optical pumping results in (1) suppression of absorption or even amplification of a probe light beam on the one hand, and in (2) destruction of the atomic coherence and broadening of the EIT resonance on the other hand. Suppression of absorption improves the delay-line performance of an atomic-vapor cell, while the destruction of atomic coherence degrades its performance. These considerations were taken into account in a theoretical study performed in support of the proposal to use incoherent optical pumping. The study yielded equations showing that incoherent pumping increases group delay within certain ranges of design and operational parameters.

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