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Atomic vapor cells meet integrated optics

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Integrated optics and compact packaging enable on-chip atomic spectroscopy for a variety of advanced applications.

The demonstration of slow, fast, and stopped light[1] has helped generate considerable interest in quantum interference effects. In addition to producing intriguing physical phenomena, these effects will be valuable for future optical communications. Buffers using slow-light modules will be important elements in all-optical data networks. Cryptography systems may also be expected to use quantum interference effects for photon creation and detection. But if slow-light buffers and quantum cryptography are to be practical in real-world applications, we must create miniaturized, stand-alone quantum interference modules. This is the aim of research involving on-chip atomic vapor cells integrated with optical waveguides

Slow-light effects are a product of a medium with large, frequency-dependent gain or absorption features that then give rise to large dispersion characteristics. Our work employs quantum interference effects in atomic vapor to create large dispersion. At present, atomic vapor can provide excellent dispersion characteristics, but it usually requires a large system footprint. In classical optical setups, which beam a laser through a transparent vapor cell, there is also a constant trade-off between focal depth and beam width. By using on-chip hollow-core optical antiresonant reflecting optical waveguides (ARROWs), we are able to direct light down vapor-filled cores, maintaining large optical intensities over long distances. This is particularly beneficial for nonlinear optical effects that can be exploited for single-photon generation and detection. In addition, ARROW-based platforms also require only a small footprint (1×1cm).

ARROWs are constructed by growing alternating layers of silicon oxide and silicon nitride around a sacrificial core on a silicon wafer. The alternating dielectric materials with specific thicknesses confine and guide light through antiresonance. After etching out the sacrificial core, we are left with a hollow channel into which we can introduce various gases and liquids for optical experiments. Solid waveguides etched into the silicon on either side of the hollow core allow us to couple light in and out using optical fiber (see Figure 1).

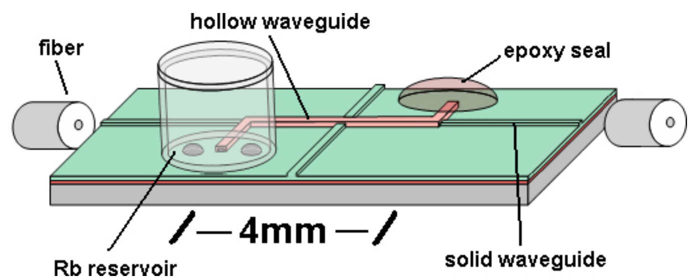

Figure 1. A rubidium (Rb)-loaded ARROW atomic vapor cell.

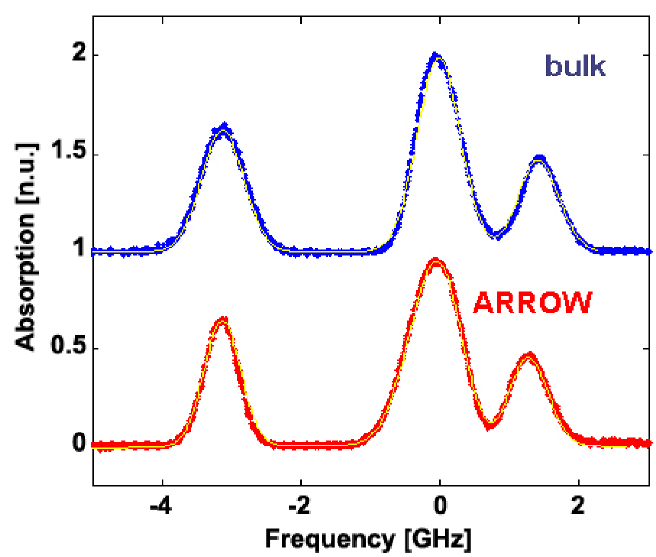

Figure 2. Absorption spectrum comparison between a commercially available Rb atomic vapor cell and its Rb ARROW counterpart.

We have experimented with rubidium (Rb) as an atomic vapor in our hollow ARROW cores. We use this element because it provides the long electron coherence times required for

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quantum interference effects. It is, however, highly reactive with air, and we have developed introduction and packaging techniques to prevent it from oxidizing to ensure high atomic vapor densities in our cells. To date our most successful packaging involves a nonreactive epoxy and copper tube crimping. Copper tubes, sealed to silicon chips, serve as reservoirs for solid Rb droplets. The crimping method allows us to evacuate the tubes in a controlled atmosphere glovebox before sealing them off. By evacuating our cells to several tens of millitorrs, we can eliminate pressure from broadening the Rb absorption spectra.

With these techniques we have successfully performed Rb absorption spectroscopy in our on-chip ARROW atomic vapor cells, including saturated absorption spectroscopy[2] (see Figure 2). In the near future we hope to demonstrate electromagnetically induced transparency and other nonlinear optical effects in our devices, bringing us closer to a more versatile and practical atomic vapor cell for use in advanced communication systems.

More information about our on-chip atomic vapor cells will be available at presentations at Photonics West 2008.[3–5]

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References

1. E. Parra and J. Lowell, "Toward applications of slow light technology," *Opt. Photon. News* **18**(11), pp. 41–45, 2007.
2. W. Yang and D. Conkey, "Atomic spectroscopy on a chip," *Nat. Photon.* **1**(6), pp. 331–335, 2007. doi:10.1038/nphoton.2007.74.
3. H. Schmidt *et al.*, "Quantum interference effects in rubidium vapor on a chip," (6904-14), 2008. Paper accepted at Photonics West 2008, in San Jose, CA.
4. J. Hulbert *et al.*, "Sealing techniques for on-chip atomic vapor cells," (6904-23), 2008. Paper accepted at Photonics West 2008, in San Jose, CA.
5. A. Hawkins *et al.*, "Fabrication methods for compact atomic spectroscopy," (6898-39), 2008. Paper accepted at Photonics West 2008, in San Jose, CA.