

Chip-Scale Atomic Devices Based on Microfabricated Alkali Vapor Cells

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We describe recent progress in the development of millimeter-scale instruments based on alkali atom vapor cells implemented with microfabrication techniques. Because of their small size and correspondingly low power requirements, these “chip-scale” atomic clocks and magnetometers have the potential to bring atomically precise instrumentation to portable, battery-operated systems such as GPS receivers, remote sensors and wireless communication devices. In addition, wafer-level processing and assembly potentially allows for very low cost per instrument if high volumes are produced.

At the heart of the chip-scale atomic devices being developed in our group is an alkali vapor cell, shown in Figure 1(a). It is fabricated by injecting alkali atoms into a small etched hole in a Si wafer, and then bonding glass on the upper and lower surfaces to seal the cell [1]. These cells can be integrated into stacked physics packages [2], shown in Figure 1(b), in which a low-power semiconductor laser is used to probe the frequency of various atomic transitions. Finally, the physics package can be integrated with low-power RF oscillators and miniature control electronics to create a complete instrument, shown in Figure 1(c). Frequency references fabricated in this manner have been shown to be able to support a fractional frequency stability of 4×10^{-11} at 1 second and near 10^{-11} at one hour of integration. Magnetometer sensors can have sensitivities in the range of a few $\text{pT}/\sqrt{\text{Hz}}$.

We will describe the design, fabrication and performance of these types of instruments as well as the underlying optical and atomic physics on which their operation is based. Applications for such instruments will be discussed as well as prospects for further improvement, with regard to size, power and performance.

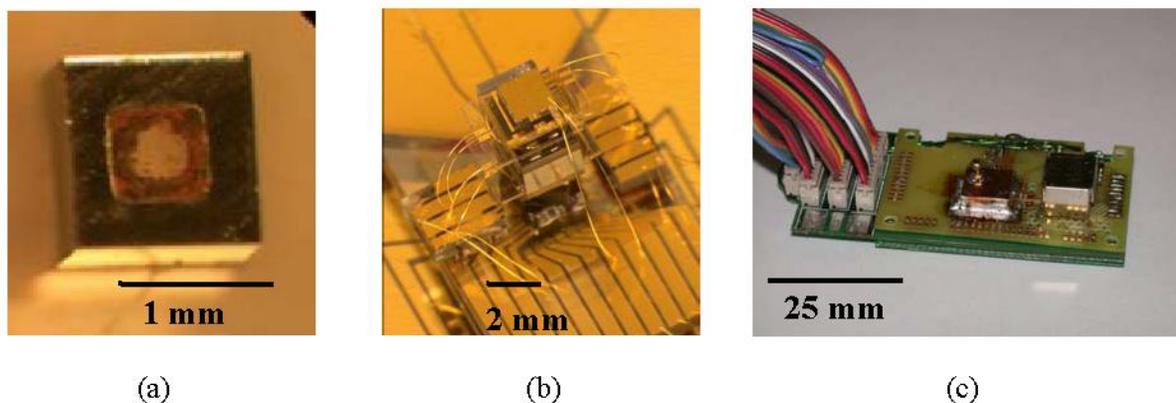


Figure 1 (a) Microfabricated alkali vapor cell. (b) Chip-scale atomic magnetometer physics package. (c) Complete atomic frequency reference.

1. L. A. Liew, S. Knappe, J. Moreland, H. Robinson, L. Hollberg, and J. Kitching, "Microfabricated alkali atom vapor cells," *Appl. Phys. Lett.* 84, 2694-2696 (2004).
2. S. Knappe, V. Shah, P. D. D. Schwindt, L. Hollberg, J. Kitching, L. A. Liew, and J. Moreland, "A microfabricated atomic clock," *Appl. Phys. Lett.* 85, 1460-1462 (2004).