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Chip-Scale Atomic Devices[1]

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We describe recent efforts to develop millimeter-sized devices based on atomic spectroscopy for highly precise timing and sensing applications. At the heart of these structures are miniature alkali vapor cells, fabricated using techniques common in micro electro mechanical systems (MEMS). These cells allow atoms to be confined along with a buffer gas in volumes of order 1 mm^3 and allow for optical access to the cell interior. Atoms in these cells are excited using light from modulated vertical cavity surface-emitting lasers and magnetic fields generated by microfabricated current loops. To date physics packages have been developed for atomic clocks with an instability below 4×10^{-11} at an integration time of one second while magnetic field sensors with a similar structure demonstrate a sensitivity near 40 $pT/\sqrt{Hz}$. These physics packages have volumes of order 10 mm^3 – about the size of a grain of rice – and require less than 200 mW of electrical power to run. We anticipate that in the future complete systems, including control electronics, will be possible with volumes near 1 cm^3, and a power requirement near 30 mW. Applications for such units include global positioning system receivers, wireless communication devices, detection of improvised explosive devices and remote monitoring.

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