Supplementary Figure 1: **Schematic image of the suspended SiN device.** (a) A schematic of the Si-chip and optical fiber mounted on the V-groove. (b) Probe light enters the system via optical fiber (I) and couples into the free end of a tapered SiN waveguide (II). The guided light transmits through the supporting tether array (III). At the center of the window, the waveguide is tapered into a double-nanobeam, and then tapered (IV) into the nominal APCW section (V) where atom-light interaction occurs. At the end of the window, the waveguide is tapered out and terminated into the substrate (VI). Two support rails are added symmetrically parallel to the APCW for structural integrity (one rail is illustrated in VII). The insets at the bottom are SEM images of (IV) the tapered section, and (V) the ‘alligator’ photonic crystal. Scale bars in (IV) and (V), 2 µm and 500 nm, respectively.
Supplementary Figure 2: Schematic image of light coupling into the APCW. Propagation and adiabatic tapering of the guided mode from optical fiber (I), through the adiabatic tapering waveguide (II), into the double-beam APCW section (V, VI). Note that the roman numerals match those of Supplementary Figure 1.
Supplementary Figure 3: Calculated effective mode area $A_m(r_A)$ for an atom at $r_A = (0, y, z)$ at the central $x = 0$ plane of a unit cell. Masked areas in gray represent dielectric regions of the APCW. The dashed line represents $A_m(r_{eff}) \sim 0.44 \, \mu m^2$ which we extract from measurements shown in Fig.4.
Supplementary Figure 4: Device characterization. (a) Schematic of the setup for device characterization. FBS: fiber beam splitter with $T = 50\%$ and $R = 50\%$. HWP: half waveplate. QWP: quarter waveplate. OSA: optical spectrum analyzer. PD: photodetector. (b) Measured reflection spectrum near the band gap. Gray and red curve show the original data and smoothed data, respectively. Blue dashed lines correspond to the Cs D$_1$ and D$_2$ resonances. (c) Measured reflection spectrum near the Cs D$_2$ line (black curve) and envelope fit (gray curve).
Supplementary Figure 5: **Schematic of a 1D transfer matrix model of the device.** Forward- and backward propagating waves in the structure are coupled to each other through partial reflection from the fiber end-face, tether, and matching mirrors, and also evolve under propagation losses. Their effect on the total reflected and transmitted fields ($E_r, E_t$) can be modeled through a set of four independent transfer matrices $M_{fiber}$, $M_{tether}$, $M_1$, and $M_2$ (depicted by the dashed lines), which together determine the transfer matrix $M_{tot}$ of the entire system.
Supplementary Figure 6: Guiding potential for Cs $F = 4$ hyperfine ground state. (a) Casimir-Polder potential $U_{\text{CP}}(r)$ and (b, c) total potential $U_{\text{tot}}(r) = U_{\text{CP}}(r) + U_{\text{dipole}}(r)$ are plotted at $r = (0, y, z)$ at the central $x = 0$ plane of a unit cell. The dipole potential $U_{\text{dipole}}(r)$ is calculated for $m_F = 0$ state, using the $E_1$ mode at (b) $k_{A,x} = \pi/a$ with total power of 1 $\mu$W and (c) $k_{1,x} = 0.99k_{A,x}$ with total power of 0.6 $\mu$W, and both with 10 GHz blue-detuning from $F = 4 \leftrightarrow F' = 4$ transition frequency of the D$_1$ line. The curved arrow in (b) [(c)] illustrates a characteristic trajectory of an atom (solid circle) guided into the trap center [reflected off the bump] in the total potential between the gap.
Supplementary Figure 7: **Schematic of the setup for reflection measurements.** VBG: volume Bragg grating. FBS: fiber beam splitter with $T = 99\%$ and $R = 1\%$. HWP: half waveplate. QWP: quarter waveplate. APD: avalanche photodetector.
Supplementary Figure 8: **Reflection measurements and theoretical fit.** (a) Simulated reflection spectrum of the optical pathway to and from the APCW derived from the transfer matrix calculation. Blue dashed line shows the Cs D$_2$ line. (b, c) Measured reflection spectra (circles) with free-space density of $\rho_0 \sim 2 \times 10^{10}$ cm$^{-3}$, where the reflectivity with no atoms $R_{0\text{off}} \simeq 3\%$. These are the data same as Fig.3c. Error bars for the data points reflect 1 s.d. estimated from the statistical uncertainties. The full curves are fits with (b) uniform-absorption model (i) and (c) losses localized to the matching mirrors (ii). From the fits, we deduce (b) $(\Gamma_{1D}/\Gamma', N, \delta_0/\Gamma_0) \simeq (0.31 \pm 0.05, 1.5 \pm 0.2, 0.56 \pm 0.06)$ and (c) $(\Gamma_{1D}/\Gamma', N, \delta_0/\Gamma_0) \simeq (0.41 \pm 0.04, 0.9 \pm 0.1, 0.25 \pm 0.06)$. The shaded band gives uncertain arising from the position of the matching cavity.