doi:10.1038/nature10319

SUPPLEMENTARY INFORMATION

Transitions between ground state hyperfine levels of a single $^{171}Yb^+$ ion confined in a miniature Paul trap (diameter of 2 mm) are driven with microwave radiation close to 12.64 GHz [1] which is generated by mixing the signal from a fixed frequency source at 6.3 GHz with an rf signal whose frequency, amplitude, and phase are adjustable.

$^{171}Yb^+$ is produced from its neutral precursor by photoionization using a diode laser operating near 399 nm. Laser light near 369 nm driving resonantly the $S_{1/2}$ F = 1 $\leftrightarrow$ $P_{1/2}$ F = 0 transition in Yb^+ is supplied by a frequency doubled Ti:Sa laser, and serves for cooling and state selectively detecting the ion. State-selective detection is achieved by collecting scattered fluorescence on the $(S_{1/2}, F = 1 \leftrightarrow P_{1/2}, F = 0)$ resonance which allows for discriminating population in states $S_{1/2}, F = 0$ (no fluorescence) and $S_{1/2}, F = 1$ (resonance fluorescence is detected). Initialization in the state $S_{1/2}$ F = 0 ($|0\rangle$) is done using 369 nm light tuned to the $S_{1/2}$ F = 1 $\leftrightarrow$ $P_{1/2}$ F = 1 transition. A diode laser delivers light near 935 nm and drives the $D_{3/2} \leftrightarrow [3/2]_{1/2}$ transition to avoid optical pumping into the metastable $D_{3/2}$ state during the cooling and detection periods.

SUPPLEMENTARY LEGENDS

The STIRAP sequence carried out when varying the holding time T (Fig. 2) is characterized by these parameters: pulse separation of $6/f_\Omega$, pulse width of $5/f_\Omega$ and $\Delta t = \frac{1}{10 f_\Omega}$, where $f_\Omega = \Omega/(2\pi) = 36.5$ kHz. The microwave frequency on the $|+1\rangle - |0\rangle$ resonance was 12.6528121 GHz, and on the on the $|-1\rangle - |0\rangle$ resonance it was 12.6328272 GHz; a static magnetic field $B = 0.714$ mT defines a quantization axis. Each measurement point consists of 300 repetitions.

The parameters for the data shown in Fig. 3a) are as follows: The microwave frequency on the $|+1\rangle - |0\rangle$ resonance was 12.6533088 GHz, and on the $|-1\rangle - |0\rangle$ resonance it was 12.6323327 GHz; the microwave Rabifrequency $\Omega = 31.8 \times 2\pi$ kHz; the rf frequency driving transitions between dressed states was set to 10.49676 MHz; a static magnetic field $B = 0.749$ mT defines a quantization axis. Each datapoint is

the average of 50 (up to 40 ms) or 25 repetitions (over 500 ms).

For the Ramsey measurement shown in Fig. 3b), $f_\Omega = \Omega/(2\pi) = 37.3$ kHz. The microwave frequency on the $|+1\rangle - |0\rangle$ resonance was 12.6530938 GHz, and on the on the $|-1\rangle - |0\rangle$ resonance it was 12.6325472 GHz; a static magnetic field $B = 0.730$ mT defines a quantization axis. 0 ms - 30 ms: 20 repetitions per datapoint; 500 ms - 1000 ms: 40 repetitions.

[1] Hannemann, T. *et al.*, Self-learning estimation of quantum states. *Phys. Rev. A* **65**, 050303 1-4 (2002).