A laser-cooled optical beam clock for portable applications

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The doubly-forbidden $^1S_0 \to {}^3P_0$ optical transition of neutral ytterbium has been used to demonstrate some of the world's most stable atomic clocks [1]. However, the experimental systems required to address it have, until this point, been prohibitively large and complex for integration within a deployable device. In our ytterbium clock, we combine the robust design considerations of thermal beam clocks with modern techniques including laser cooling and agile FPGA-based frequency stabilisation and control, to address this 10 mHz wide transition in a rack-mountable device.

The frequency reference for our portable optical clock is generated via Ramsey-Bordé spectroscopy [2] (Figure 1 (a)). This is, to our knowledge, the first measurement of the ytterbium clock transition to be made on an atomic beam, and represents a key milestone towards a robust, portable device. Stabilisation of our clock laser to the 9-kHz fringes produces an atom-shot noise limited short-term clock stability (Figure 1 (b)). This measurement was carried out in the radio frequency domain, made possible by our integrated fibre-frequency comb which transfers the clock laser stability to useful clock outputs.

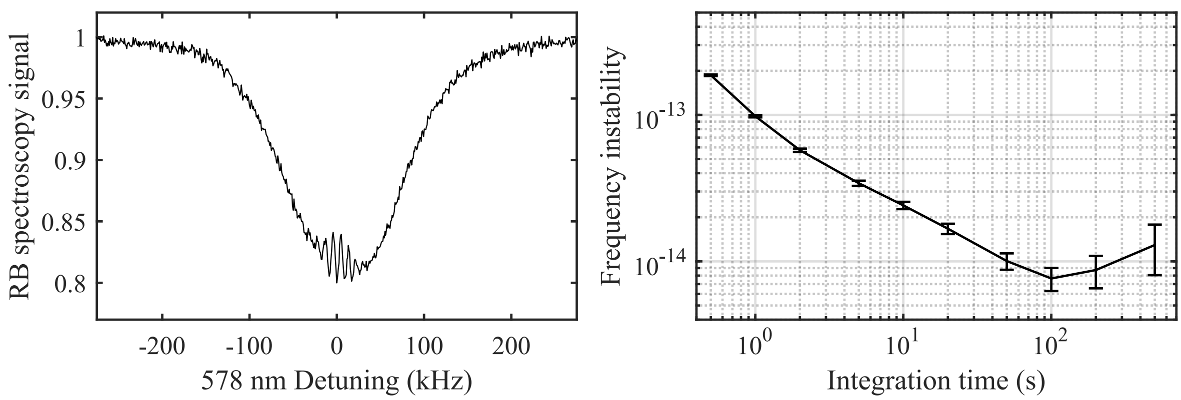

Figure 1: **Left:** Ramsey-Bordé (RB) spectroscopy of the $^1S_0 \to {}^3P_0$ Yb transition measured on a transversely-laser-cooled thermal ytterbium beam **Right:** Preliminary clock instability measured in the radio frequency domain.

[1] N. Hinkley, J. A. Sherman, N. B. Philips, M. Schioppo, N. D. Lemke, K. Beloy, M. Pizzocaro, C. W. Oates, A. D. Ludlow, *Science* **341**, 6151 (2013).

[2] Ch. J. Bordé, Ch. Salomon, S. Avrillier, A. van Lerbeghe, Ch. Bréant, D. Basse, and G. Scoles, *Phys. Rev. A* **30**, 1836 (1984).