An optical lattice clock breadboard demonstrator for the I-SOC mission on the ISS

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The I-SOC (Space Optical Clock on ISS) mission\(^1\) is an ESA mission whose main goal is testing the Einstein Equivalence Principle and performing relativistic geodesy from space. It will be based on a strontium lattice clock on the ISS, which will be compared with ground clocks using advanced frequency link technologies, optical and microwave. The space clock will have $1 \times 10^{-17}$ fractional inaccuracy, and ground clocks intercomparisons will be possible at the $10^{-18}$ level.

As a breadboard demonstrator for the I-SOC optical clock, a modular and transportable Sr optical lattice clock (Fig. 1, left) has been developed\(^2,3\). The modular design allows to implement new laser subunits for testing purposes. The compact size of the system (970 liters) allows easy transportation by van. Low power consumption is achieved using novel solutions\(^4,5\). All the lasers needed for atom cooling and trapping are stabilised to a robust frequency stabilization system\(^6\).

The atomic package was developed and operated in Birmingham and then relocated without problems by van to PTB (Braunschweig). Here the performances of the atomic package, operated with the $^{87}\text{Sr}$ isotope and magneto-optically induced spectroscopy, were evaluated using a stationary reference cavity for the 698 nm clock laser\(^7\), and a stationary Sr clock as frequency reference\(^8\), demonstrating an instability of $2.5 \times 10^{-16} \tau^{1/2}$, averaging down to the $2 \times 10^{-17}$ level (Fig. 1, right). The transition linewidth was 1.1 Hz.

Some systematic effects have already been determined at the $< 5 \times 10^{-16}$ level, a full uncertainty budget at the $1 \times 10^{-16}$ level is expected by mid-2017. In the near future, we will implement operation with the $^{87}\text{Sr}$ isotope, which is preferred as atomic frequency standard, aiming at the goal inaccuracy of $1 \times 10^{-17}$.

Finally, we will integrate a transportable clock laser cavity (fractional instability of $8 \times 10^{-16}$ at 300 ms\(^9\)) with the goal of implementing a fully transportable clock apparatus having a frequency instability $< 1 \times 10^{-15} \tau^{1/2}$.

References