Abstract

The optical frequency standards clearly surpass in terms of accuracy and stability the microwave Cs primary standards, whose performance limits the realisation of the second as defined in the International System of Units (SI). In 2006 several atomic optical transitions have been recommended as secondary representations of the second, and recently a roadmap towards the redefinition of the SI second on an optical transition has been delineated defining requirements and targets.

Among the optical clocks realising a secondary representation of the second, lattice clocks based on neutral ^{171}Yb have demonstrated feasibility and performances competitive with the best frequency standards realised to date. Several research laboratories around the world develop such frequency standards, including metrology institutes in Japan, USA, Korea, China and Italy.

These frequency standards exploit an optical lattice to trap hundreds of neutral atoms, and probe the narrow $^1S_0$-$^3P_0$ clock transition with a ultra-stable laser at the frequency of 518 THz.

The work presented in this thesis has been carried out with ^{171}Yb lattice frequency standards developed at the National Metrology Institute (NMI) of Italy, the Istituto Nazionale di Ricerca Metrologica (INRIM), and at the Institute of Physical and Chemical Research (RIKEN), in Japan, where I have been guest researcher.

The thesis discusses in details the evaluation of the systematic frequency shifts of the Yb clock transition frequency due to external perturbations. The INRIM Yb clock has been characterised with a fractional uncertainty of 2.8×10^{-17}, while the RIKEN Yb clock with an uncertainty of 6.0×10^{-18}.

Furthermore, several frequency measurements are presented: at INRIM we measure the absolute frequency of the ^{171}Yb clock transition directly against a Cs fountain, which is the Italian primary frequency standard employed for the steering of the Italian time scale. The frequency is evaluated with an uncertainty of 5.9×10^{-16}. We also perform an optical frequency ratio measurement of the Yb clock against the ^{87}Sr transportable lattice clock developed at the NMI of Germany (PTB), with a final fractional uncertainty of 2.8×10^{-16}. At RIKEN we measure the frequency ratio between the Yb clock and the RIKEN ^{87}Sr lattice clock with a fractional uncertainty of 1.1×10^{-17}.