Dual-Spectral Thermometry and Emissivity Calibration Techniques for Minimizing Trap-Associated Blackbody Radiation Shift in Optical Ion Clocks

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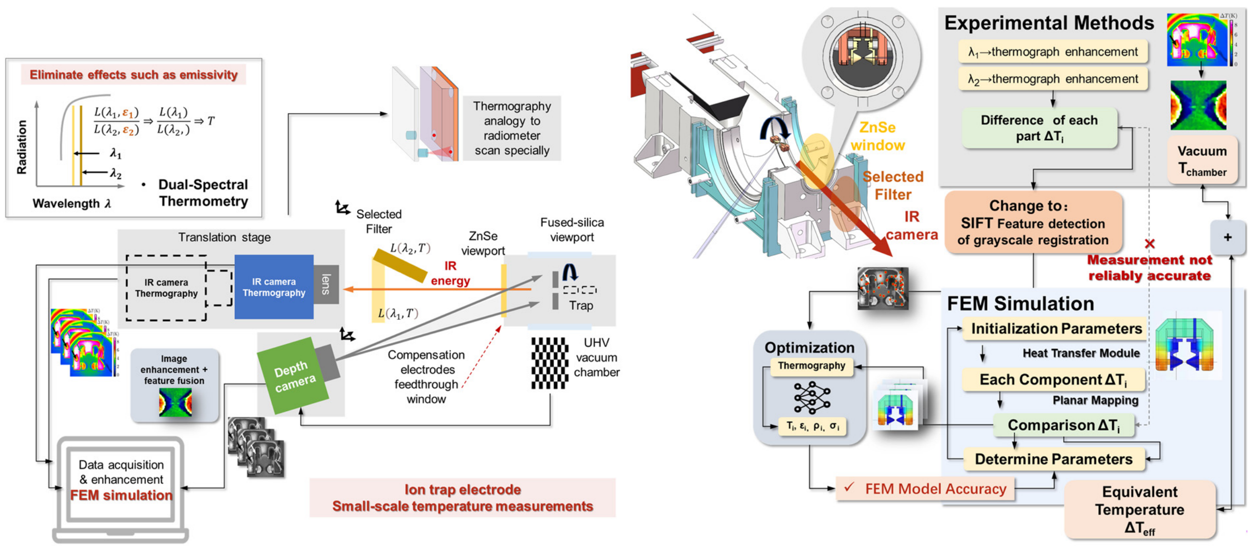
The frequency shift of blackbody radiation presents a significant challenge for optical clocks due to its impact on uncertainty. The shift is affected by polarizability and equivalent temperature of atom and ion positions, with polarizability having been the focus of detailed studies domestically and internationally. However, the accuracy of equivalent temperature remains a pressing concern due to limitations in non-contact temperature measurement and emissivity[1].

To meet the SI roadmap for the second redefinition, the uncertainty of a single optical clock must be better than 2E-18, and the blackbody radiation frequency shift uncertainty should be less than 1E-18. In particular, the ytterbium ion's E3 clock transition requires equivalent temperature uncertainty of less than 500 mK. Current methods, based on thermal imaging and finite element modeling, are insufficient. We propose a novel approach incorporating dual-spectrum thermometry and depth fusion enhancement to develop a measurement system that reduces the emissivity of gold-plated electrodes. This system accurately measures the small-scale temperature field of the ion trap. Through training emissivity registration between the model and the measured thermal image, the evaluation of radiation temperature at the ion becomes more precise. This, in conjunction with high-precision polarizability data, further reduces the uncertainty associated with the blackbody radiation frequency shift.



(a) (b)

Fig. 1: Experimental Schemes: (a) dual-spectral thermometry and image enhancement methods for temperature profiling of ion traps. (b) registration and optimizing training for FEM simulation to enhance the accuracy of equivalent temperature.

[1]Abdel-Hafiz M, Ablewski P, Al-Masoudi A, et al. arXiv preprint arXiv:1906.11495, 2019.