Collisional frequency shift systematics in trapped-ion optical clocks

Amar Vutha[1], Tom Kirchner[2] and Pierre Dubé[3]

[1]*University of Toronto, Toronto, Canada*
[2]*York University, Toronto, Canada*
[3]*National Research Council Canada, Ottawa, Canada*

Optical atomic clocks using trapped ions are some of the most accurate instruments ever constructed, with 18 digits of accuracy [1]. A significant source of systematic uncertainty in these clocks is the collisional frequency shift (CFS), due to collisions between the clock ion and residual background gas molecules. Despite the ultra-high vacuum systems used in these clocks, the residual background gas pressure leads to a sizeable systematic error.

While conservative, worst-case estimates of the CFS are straightforward to calculate [2], more accurate estimates are necessary in order to reduce the CFS systematic error in state-of-the-art ion clocks. Over the last couple of years we have developed a systematic framework, based on a quantum channel description of the scattering process, for evaluating the CFS in trapped-ion clocks [3,4,5]. We have also incorporated the quantized motion of the trapped-ion within the same unified framework, to evaluate recoil heating of the ion and the resulting relativistic Doppler shift of its resonance frequency.

I will describe the basic problem from an experimentalist's point of view, and then motivate the methods that we have developed to answer questions at this interesting intersection between ultra-precise atomic clocks, scattering theory and quantum information. I will present some recent results obtained using this framework, which lead to significantly tighter bounds on the CFS systematic uncertainty for Al^+ and Sr^+ atomic clocks.

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