ABSTRACT

Current experimental progression demand the time to be most precise. For that purpose, we have the modern state-of-art atomic clock, which uses the resonance frequency of two atomic states as a frequency reference. Making the transitions insensitive to the environment or input light(s) is a challenge to improve the accuracy of the experiments. Further, we need to reduce the kinetic motions of the atoms or ions and protect them from the ambient fields. Trapping and cooling are necessary not only for atomic/ionic clock but also for quantum computation, quantum gates, atom interferometry, etc. Trapping and cooling of atoms or ions, especially inside a cavity, are such mechanisms governed by mainly two-photon processes. Proper knowledge of dynamic polarizability can remove the ambiguity coming from the energy shift (Stark-shift) induced by the external light source. The scalar part of the static (no light) polarizability is a measure of the Black-Body-Radiation (BBR) shift. The study of dynamic polarizability can also serve the tune-out wavelength, which is important for state insensitive trapping scheme. Here our goal is to calculate one- and two-photon dynamic polarizability of the states used for clock transition. We follow the systematic approach given below to fulfill our goal. We employ correlation exhaustive relativistic coupled-cluster (RCC) theory to calculate dipole matrix elements necessary for the calculation of polarizability.

• The primary aim of this work is to test the correlation exhaustiveness of our RCC method and calibrate its implementation in our program. We choose rubidium-like ions (Y III, Zr IV, Nb V, Mo VI, and Tc VII) due to their relatively simple but highly correlated electronic structure. We find some anomalous correlation trends in the energy values of $4\ ^2F$ states and $5^2D - 4^2F$ matrix elements of the ion. The

calculated parameters are extremely important for astrophysical interests. Most of the parameters of Tc VII ions are calculated for the first time in literature. We have calculated the dipole matrix elements for Y^{2+} and Ba^{+} ion, which are used to calculate dynamic polarizability further.

• Ba^{+} and Y^{2+} ions are the ideal candidates for ionic clock due to their well-understood atomic structure and the existence of two meta-stable states. The transitions between forbidden transitions mediate the transition between the ground state and the first two excited states. ground state and first two excited states are mediated by forbidden transitions. Here we presented the dynamic profile of polarizabilities for the clock states and extracted magic wavelength and tune-out wavelengths from these. The calculated static values of scalar polarizabilities are a measure of Black-Body-Radiation shift.

• Recent investigations show that a two-photon optical clock can be better than single-photon in terms of stabilization and accuracy. We employ a two-photon model to calculate dynamic polarizabilities of the clock states and extract magic wavelengths from these. As an intriguing application, we investigate its importance on an ion-atom mixture of heteronuclear ($^{137}Ba^{+}$-^{87}Rb) binary systems. We achieve more flexibility in the spin-changing process with a two-photon source which can be applied to other atomic mixture systems to generate entanglement between two different atoms and control the singlet-pairing process.

Key words: Trapping and cooling, Polarizability, Black-Body-Radiation, Electron-correlation, Magic and tune-out wavelength, Relativistic coupled-cluster theory, Atomic transition