DAMOP14-2014-000480

Abstract for an Invited Paper
for the DAMOP14 Meeting of
the American Physical Society

Optical atomic clocks and metrology

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The atomic clock has long demonstrated the capability to measure time or frequency with very high precision. Consequently, these clocks are used extensively in technological applications such as advanced synchronization or communication and navigation networks. Optical atomic clocks are next- generation timekeepers which reference narrowband optical transitions between suitable atomic states. Many optical time/frequency standards utilize state-of-the-art quantum control and precision measurement. Combined with the ultrahigh quality factors of the atomic resonances at their heart, optical atomic clocks have promised new levels of timekeeping precision, orders of magnitude higher than conventional atomic clocks based on microwave transitions. Such measurement capability enables and/or enhances many of the most exciting applications of these clocks, including the study of fundamental laws of physics through the measurement of time evolution. Here, I will highlight optical atomic clocks and their utility, as well as review recent advances in their development and performance. In particular, I will describe in detail the optical lattice clock and the realization of frequency measurement at the level of one part in 10^{18}. To push the performance of these atomic timekeepers to such a level and beyond, several key advances are being explored worldwide. These will be discussed generally, with particular emphasis on our recent efforts at NIST in developing the optical lattice clock based on atomic ytterbium.