Ultrasensitive laser spectroscopy, Optical atomic clocks and optical frequency synthesizers

Jun Ye

JILA, NIST and University of Colorado, Boulder, CO 80309-0440, USA

Ultrasensitive detection enables us to explore novel regimes and new techniques in optical-based information and measurement science. The importance of this topic is illustrated with the three examples in the talk, covering diverse areas of molecular dynamics, quantum measurement and control, and optical frequency metrology.
The real time monitoring capability makes it possible to explore quantum measurement and feedback in the context of cavity quantum electrodynamics (cavity QED). Precision optical frequency metrology is also intrinsically related to high resolution and ultrasensitive laser spectroscopy. In the talk I will report the current state-of-art laser stability along with the recent progress in optical frequency measurement. We have successfully implemented precision phase control of an ultrawide bandwidth optical frequency comb generated by a Kerr-lens mode-locked femtosecond laser. A frequency network spanning an entire optical octave (> 300 THz) has been established, with millions of frequency marks stable at Hz level repeating every 100 MHz. Optical-based atomic clocks and optical frequency synthesizers are now a reality, with a single ultrastable laser providing phase coherent references throughout the optical spectrum and down to the microwave/radio frequency domain. Besides its utility in precision metrology, a phase stable femtosecond comb represents a major step towards ultimate control of light field as a general laboratory tool. An example is the study of resonantly enhanced multi-path quantum interference in a two-photon transition in cold Rb samples. The multi-pulse interference in the time-domain givens an interesting variation and generalization of the two-pulse based temporal coherent control of the excited state wavepacket.