Control and Applications of Extreme Timing Enabled by Femtosecond Lasers

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Lower-noise and higher-stability mode-locked lasers and frequency combs are becoming more important and useful sources for a variety of applications ranging from spectroscopy to signal processing. In this talk, I will overview our recent progress in ultra-stable and ultra-low-noise mode-locked lasers and their applications. First, we realized ultralow noise mode-locked fiber lasers. One of the most powerful methods for noise reduction is dispersion engineering toward zero dispersion. It has enabled 100-attosecond-level timing jitter from Er- and Yb-fiber lasers. Second, in order to stabilize the noise of free-running mode-locked lasers, we have developed all-fiber-based, alignment-free stabilization methods. By using an all-fiber Michelson interferometer with a km-scale fiber delay line, we can stabilize multiple optical frequency combs to the equivalent timing stability of the fiber delay. The comb-line frequency instability and timing jitter could be stabilized to few times 10^{-15} and ~1-fs, respectively, within 1-s. Finally, I will show some of new application areas, which our group has opened up in recent years, such as synchronization of ultrafast electron diffraction (UED) facilities, ultralow-noise all-fiber microwave synthesizers, ultrafast and nm-resolution time-of-flight (TOF) sensing, on-chip clock distribution networks (CDNs), and metrology of three-dimensional semiconductor devices, to name a few.