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Rapid thermal sensors with high resolution based on an adaptive dual-comb system

Key words: Interferometers; Fiber sensors; Laser spectroscopy

Corresponding author: He-ping Zeng
E-mail: hpzeng@phy.ecnu.edu.cn
ORCID: http://orcid.org/0000-0002-9153-3050

Motivation

- Fabry-Perot (FP) cavities or frequency combs are often adopted to detect the spectral shift of fiber Bragg gratings (FBGs). Even with high resolution in static sensing, the system still encounters challenges in stability and practicability with bulky and complex continuous-wave (CW) systems.
- The traditional dual-comb system can also demodulate the FBG, but the system requires precise locking of the repetition frequency and carrier-envelope-phase offset frequency, greatly improving system complexity.

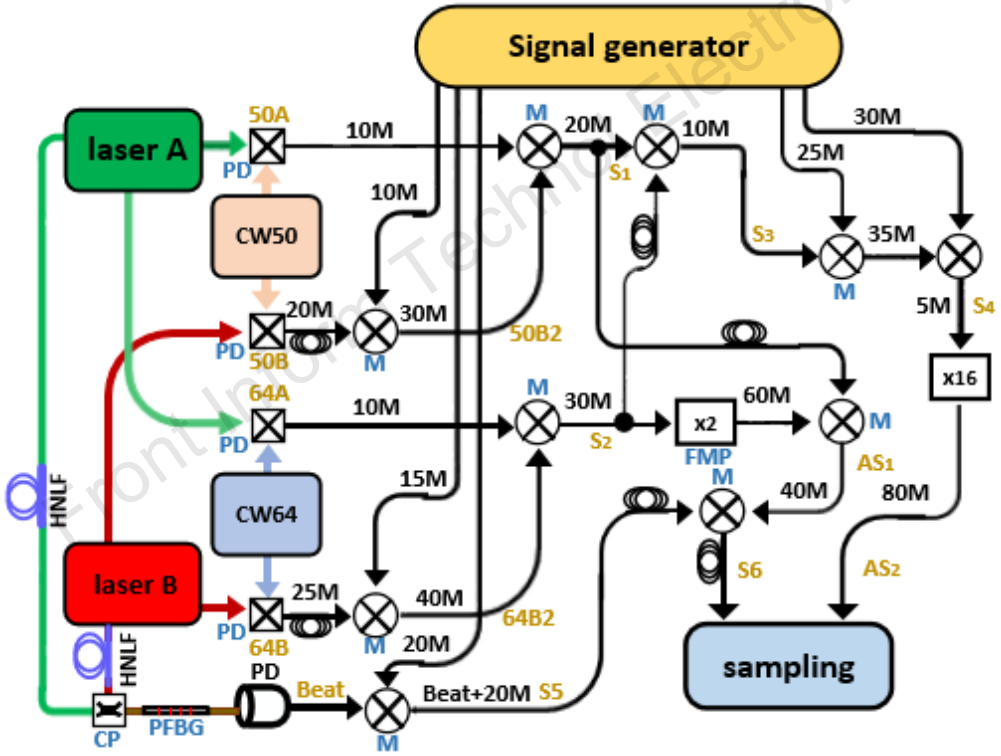
Main idea

- Adaptive dual-comb spectroscopy is extremely simplified by removing the requirement of strict phase-locking feedback loops from the dual-comb configuration. Instead, two free-running fiber lasers are adopted as the light sources.

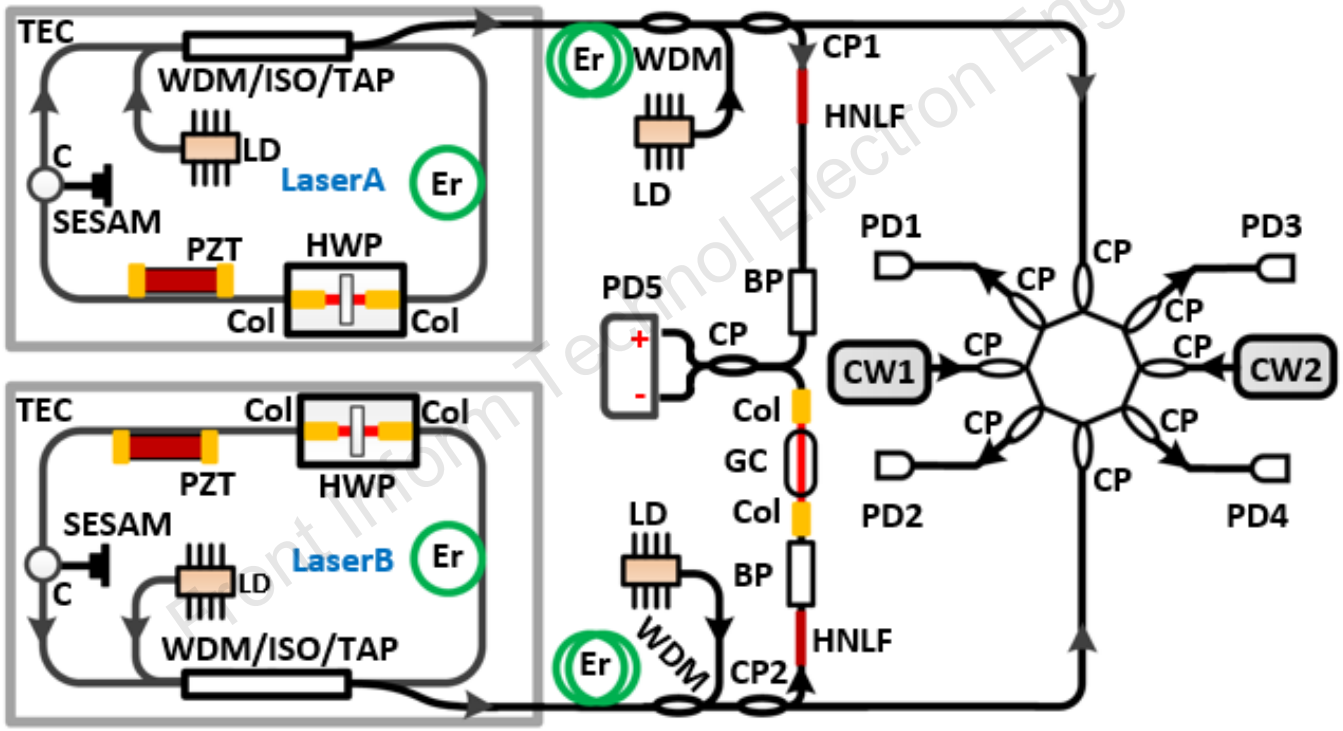
- Because of good compensation of fast instabilities with adaptive techniques, the optical response of the PFBG is precisely characterized through a fast Fourier transform of interferograms in the time domain.

Method

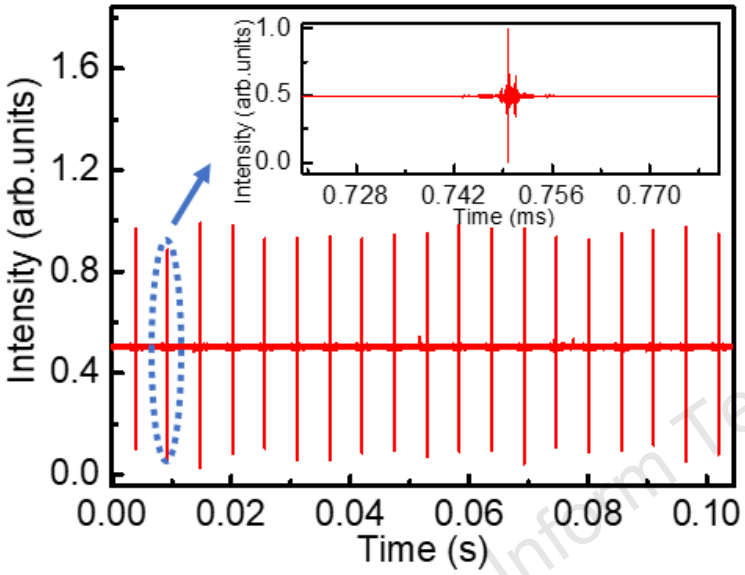
1. Adaptive processing circuit

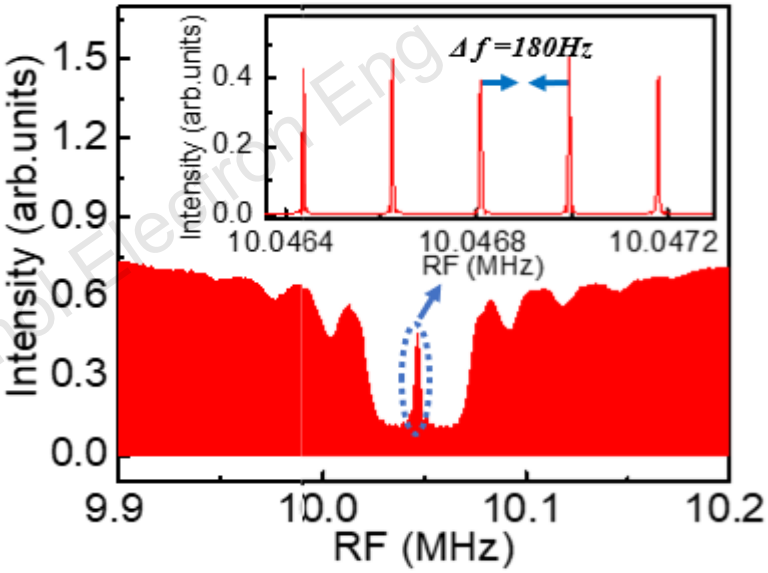


2. Experimental setup



Major results





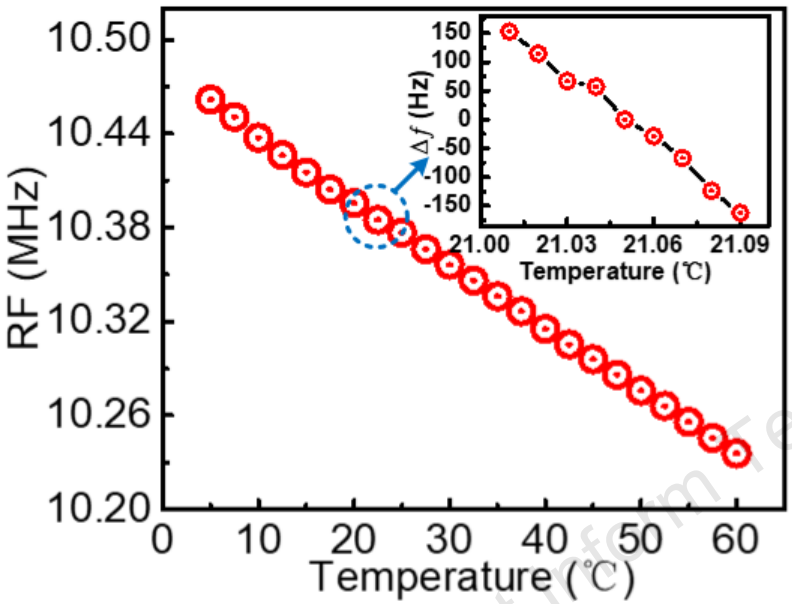
104-ms sampled time-domain signals

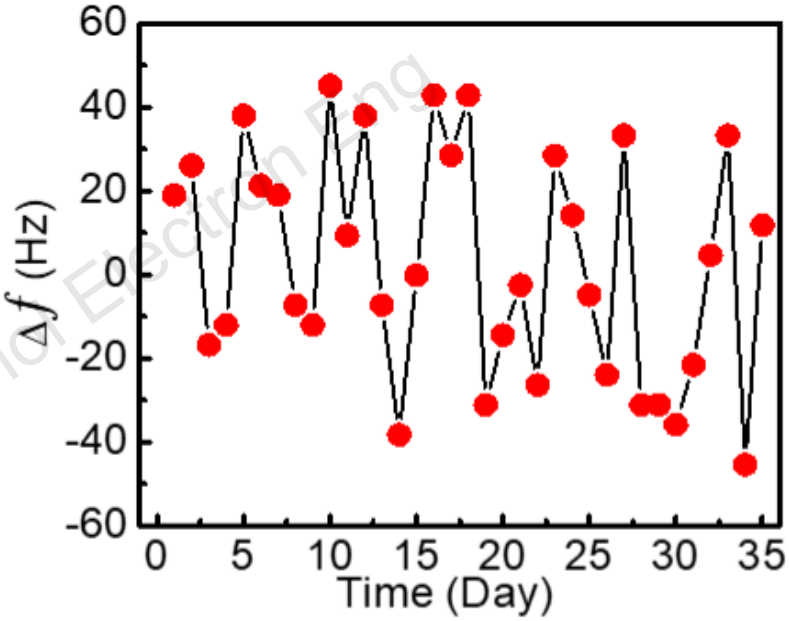
Single-shot acquisition is accomplished within 104 ms with 6.3 MHz apodized optical resolution at a refresh rate of 180 Hz

Spectral profile of the PFBG

Both side wings and the deep notch of PFBG are finely depicted by comb lines in the radio-frequency domain from 9.9 to 10.2 MHz

Major results (Cont'd)





Relationships between radio-frequency positions and temperature settings

During slight temperature tuning around 21 ℃, the gain is about 3.8 kHz/℃

PFBG center reflection peak stability measurement

The frequency jitter range is within 90 Hz and the ambient temperature change is 0.02 ℃

Conclusions

- Advantages of the dual-comb system are retained in the adaptive sampling system, including broad spectra, high resolution, and fast acquisition speed.
- Fast instabilities between comb lines are well compensated for without extra tight phase-locking of combs.
- Single-shot acquisition can be accomplished rapidly within tens of milliseconds at a spectral resolution of 0.1 pm, corresponding to a thermal measurement resolution of 0.01 ℃.
- The optical spectral bandwidth of the measurement exceeds 14 nm, which indicates a large dynamic temperature range.