A Tampering Risk of Fiber-Based Time-Frequency Synchronization and Its Countermeasure

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In the past decades, fiber-based time-frequency (TF) synchronization techniques have been widely studied and played an important role in a wide range of applications[1,2]. Due to the fundamental position of TF synchronization system, its security has become an important issue that must be considered in advance. It is worth noting that the most disastrous attack would not disrupt the normal operation of applications relying on TF synchronization but could lead to incorrect or biased results.

We propose a frequency tampering method called "frequency lens", as shown in Fig.1(a), and a hybrid fiber-based time synchronization and vibration detection method as its countermeasure. By inserting a frequency lens-enabled frequency tampering module (FTM) in the 200 km fiber link, the recovered 100 MHz signal can be altered within ±100 Hz. The relative stability of the recovered frequency is maintained at the same level as normal, i.e., $2.2\times10^{-14}/1$ s and $2.2\times10^{-14}/10^5$ s.

The attack operations against fiber-based TF synchronization are often accompanied by abnormal vibrations. In the time synchronization system, the Rayleigh backscattering generated by time pulses can be used to achieve vibration detection, as shown in Fig.1(b).

This method does not affect the time-synchronization performance. In the multi-user experimental demonstration, time deviation results are better than 4 ps/1 s and 1.5 ps/10^4 s. Meanwhile, the system can accurately detect and locate abnormal vibrations occurring on the link. These vibration-detection results are useful for providing early warnings and implementing trouble-shooting measures.

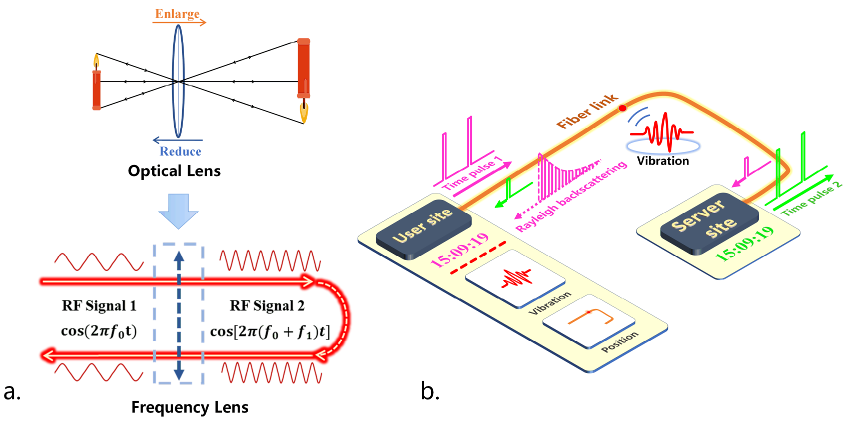

Fig. 1: (a) Schematic diagram of the frequency lens inspired by the optical lens. (b) Principles of the hybrid fiber-based time synchronization and vibration detection method.

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[1] F. Riehle, "Optical clock networks," Nat. Photonics, vol. 11, no. 1, pp. 25–31, 2017.

[2] Lisdat, C., Grosche, G., Quintin, N. et al. "A clock network for geodesy and fundamental science," Nat. Commun., vol. 7, no. 1, p. 12443, 2016.