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Design and prototyping of a new synchronization system with stability at femtoseconds

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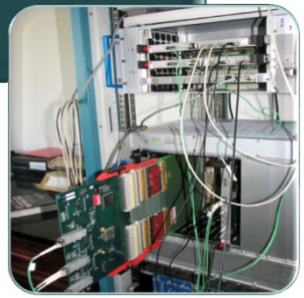
Outline

- System design
- Preliminary result
- Future plan

10-year development history of electronic timing system at SSRF

Sep. 2007
Development began.



Dec. 2009
Version-I development completed.

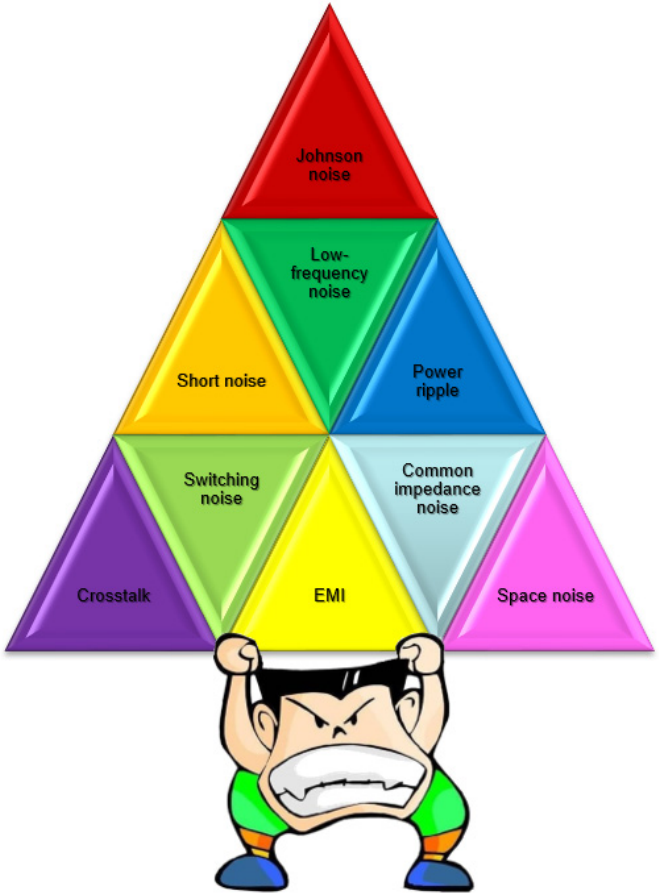
Aug. 2010
1st test on site succeeded @ PLS-II

Jul. 2012
Version-II development completed.

Dec. 2014
Standalone modules for Brazil Sirius delivered.

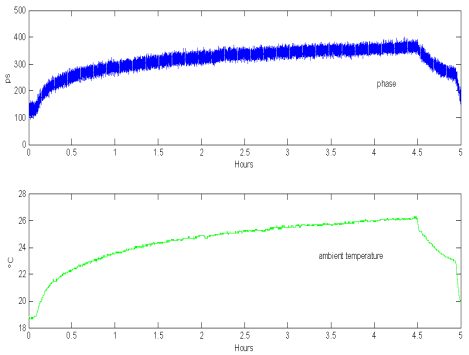
Mar. 2015
Development of femtosecond timing system began.

Jun. 2016
Implemented at damping ring of SuperKEKB.

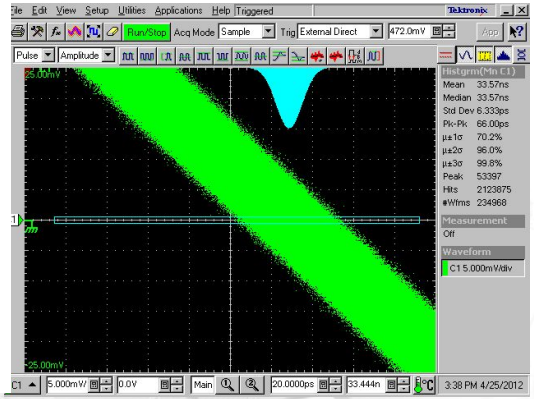


- The development of the electronic timing system has encountered its bottleneck.

Phase shift ~ 35 ps/℃



Jitter ~ 6 ps



The goal of the system

- The short-term jitter of the transmitted RF signal: 10fs;
- The long-term drift: 40 fs.

System design

Very fine phase delay is detected based on the theory of Michelson interference.

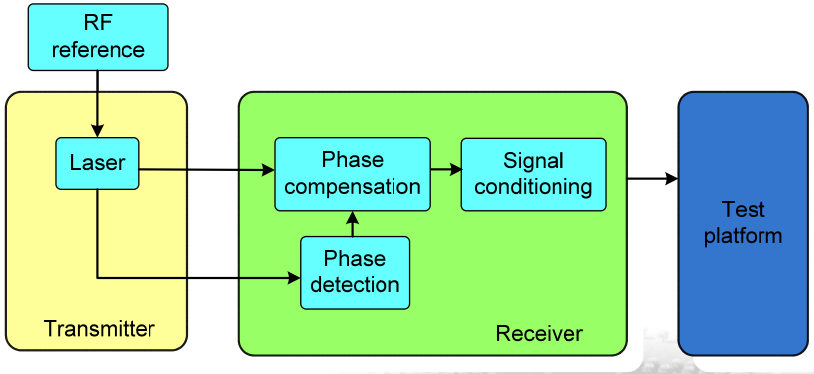
RF reference is recovered from fiber link, not rely on LLRF.

Feature

Full fiber optic network. Fanout distributed RF reference to devices around big facility.

Traditional event timing system is integrated to improve the stability.

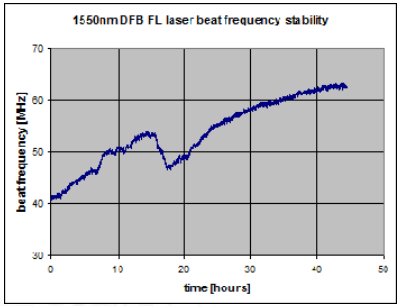
System design



- A CW laser with narrow linewidth and low temperature drift provides carrier signal;
- Phase drift is detected in the homemade electronics based on the interference theory;
- Phase is compensated by optical delay modules according to PID algorithm;
- Homemade electronics as test platform measure the stability of the transmitted signal.

System design

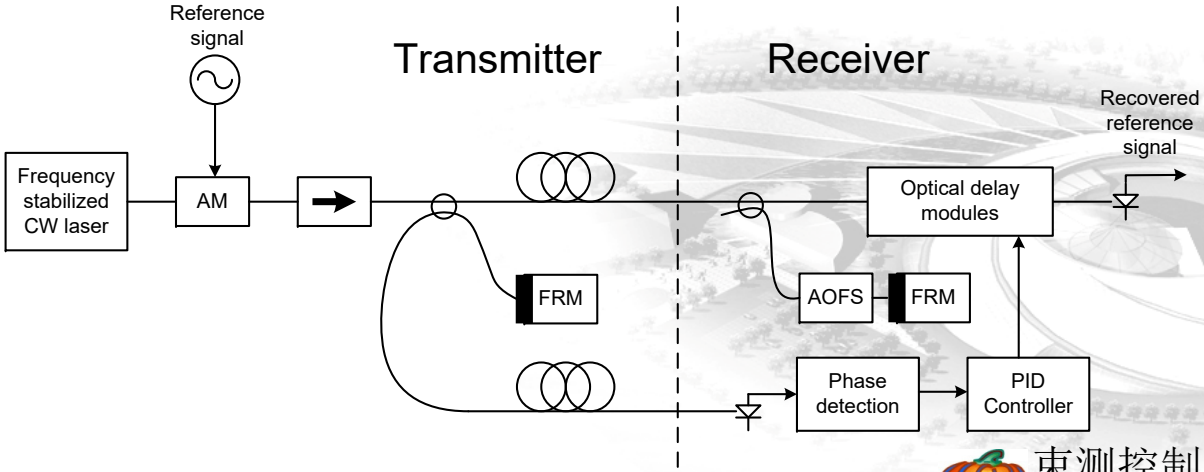
- The CW DFB fiber laser
  - Linewidth ~ kHz;
  - Wavelength ~ 1560nm;
  - The output is locked to achieve a stability higher than 2×10^{-9} over a long term.



The change of ambient temperature brings slow drift of the laser frequency.

System design

- Optical part of the system is based on the theory of Michelson interference
  - Optical network provides THz bandwidth, low attenuation and electric isolation;
  - Since the carrier phase in THz converts to beat frequency phase in MHz, the detection accuracy is improved by 6 orders of magnitude;
  - Ordinary single-mode fiber but not PM fiber is utilized to reduce the cost.

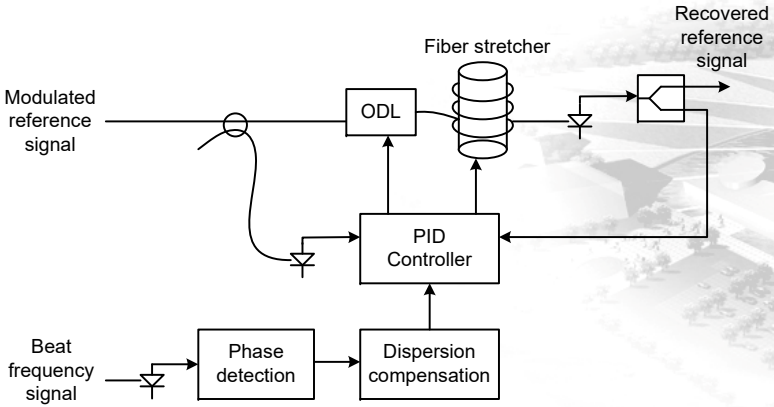


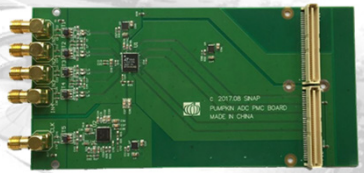
System design

- Hardware module design
  - Transmitter
    - Modulate RF reference to laser carrier.
  - Receiver
    - Both of detection and compensation are in receiver;
    - Hardware based PID algorithm allocates delay amounts to 2 delay modules;
    - RF signal conditioning and amplification.
  - Fanout
    - Expansion of signal channels.

System design

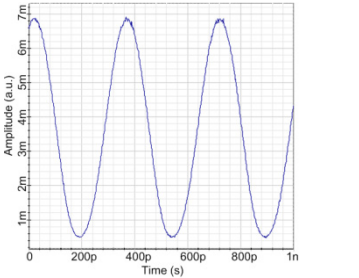
- Feedback quantities are calculated accurately in consideration of detected phase drift, group delay fluctuation and so on.
  - Phase drift of RF reference is detected accurately in beat frequency signal;
  - Each fiber will be tested to obtain the dispersion parameters, and the feed forward compensation is applied to the correcting value;
  - PID controller guarantees accurate outputs to the executive devices.

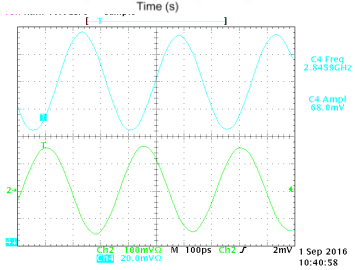


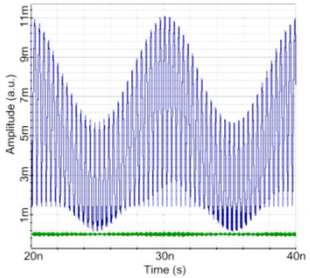


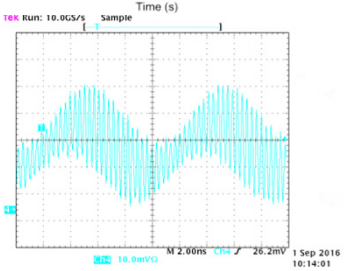
Preliminary results

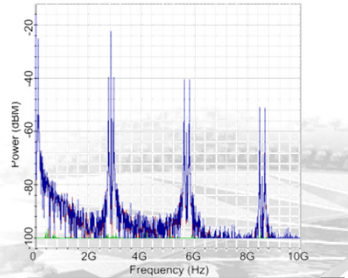
- The results agree with the simulation.
  - The recovered RF signal was lock to the original RF signal at the transmitter;
  - The beat frequency signal was observed.

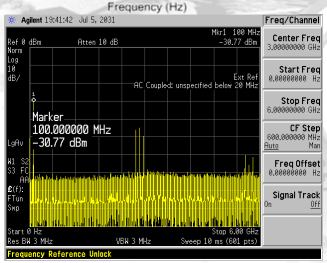






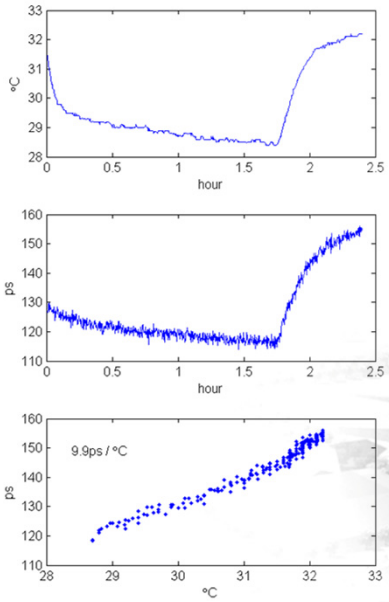




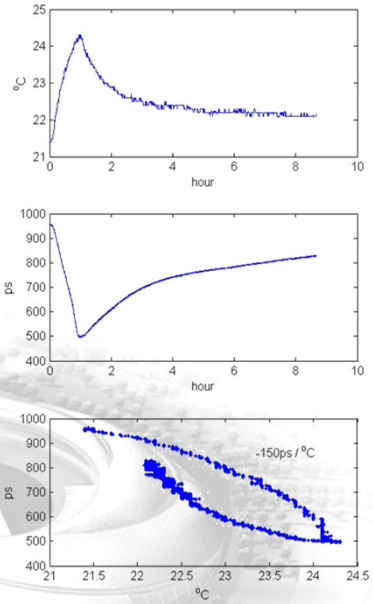


Preliminary results

- The phase drift of optical modules due to ambient temperature change. (including laser, analog modulator, fiber coupler and photodiode but not long fiber).

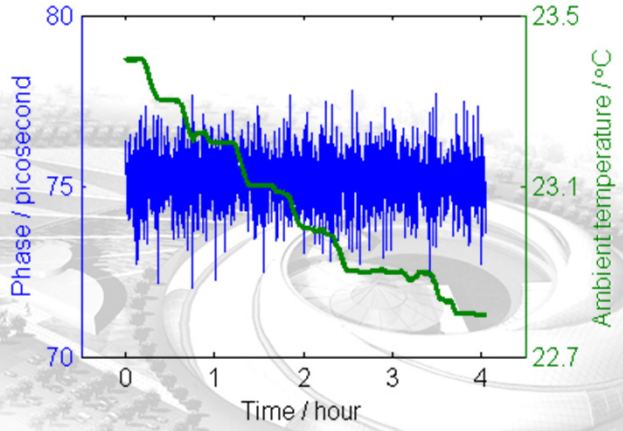


- The phase drift of optical modules due to ambient temperature change. (including laser, analog modulator, fiber coupler photodiode and a fiber of 2km).



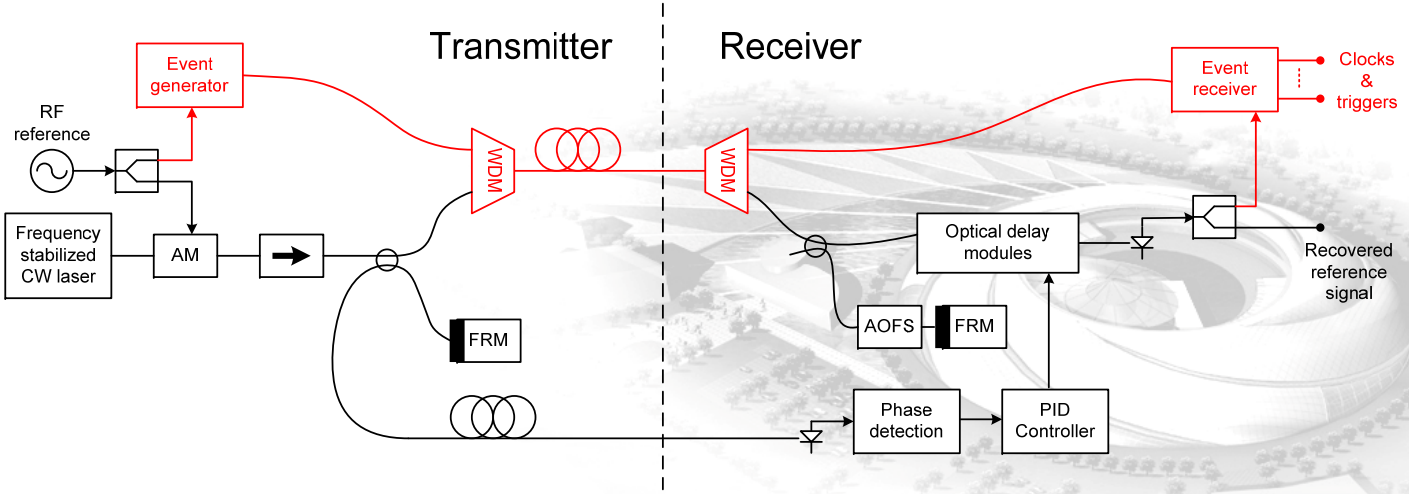
Preliminary results

- A software-based feedback scheme suppressed the phase drift to around ~800fs, where only the coarse delay line was utilized.



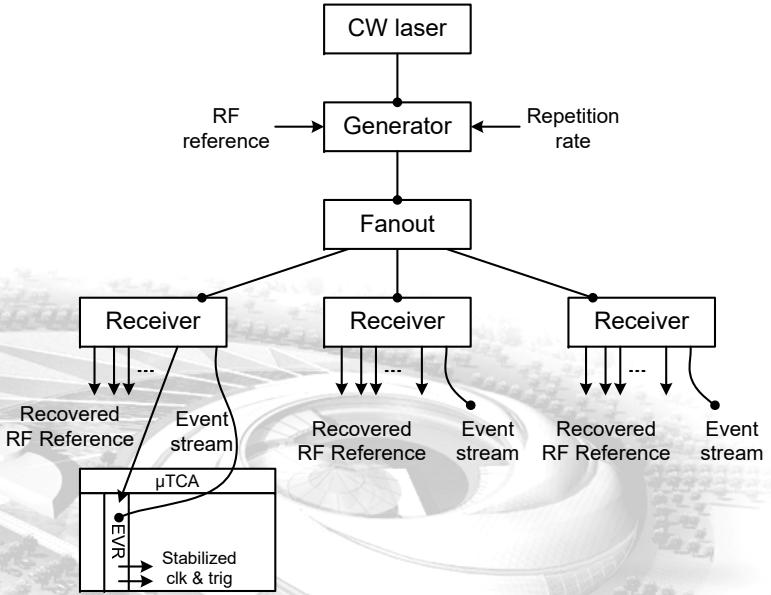
Future plan

- Integration of event timing system.
  - Timing events are transmitted along the same fiber;
  - Timing events could be stabilized against temperature change.



Future plan

- Integrated system structure.
  - The generator transmits modulated RF reference and event stream through one fiber;
  - The fanout distributes RF reference and event stream, and compensates phase drift of uplink;
  - The receiver compensates phase drift of uplink, and recovers electric RF reference and optical event stream;
  - EVR modules in μTCA chassis output stabilized clocks and triggers.




THANKS.
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