Large-Scale Timing Distribution and RF-Synchronization for FEL Facilities

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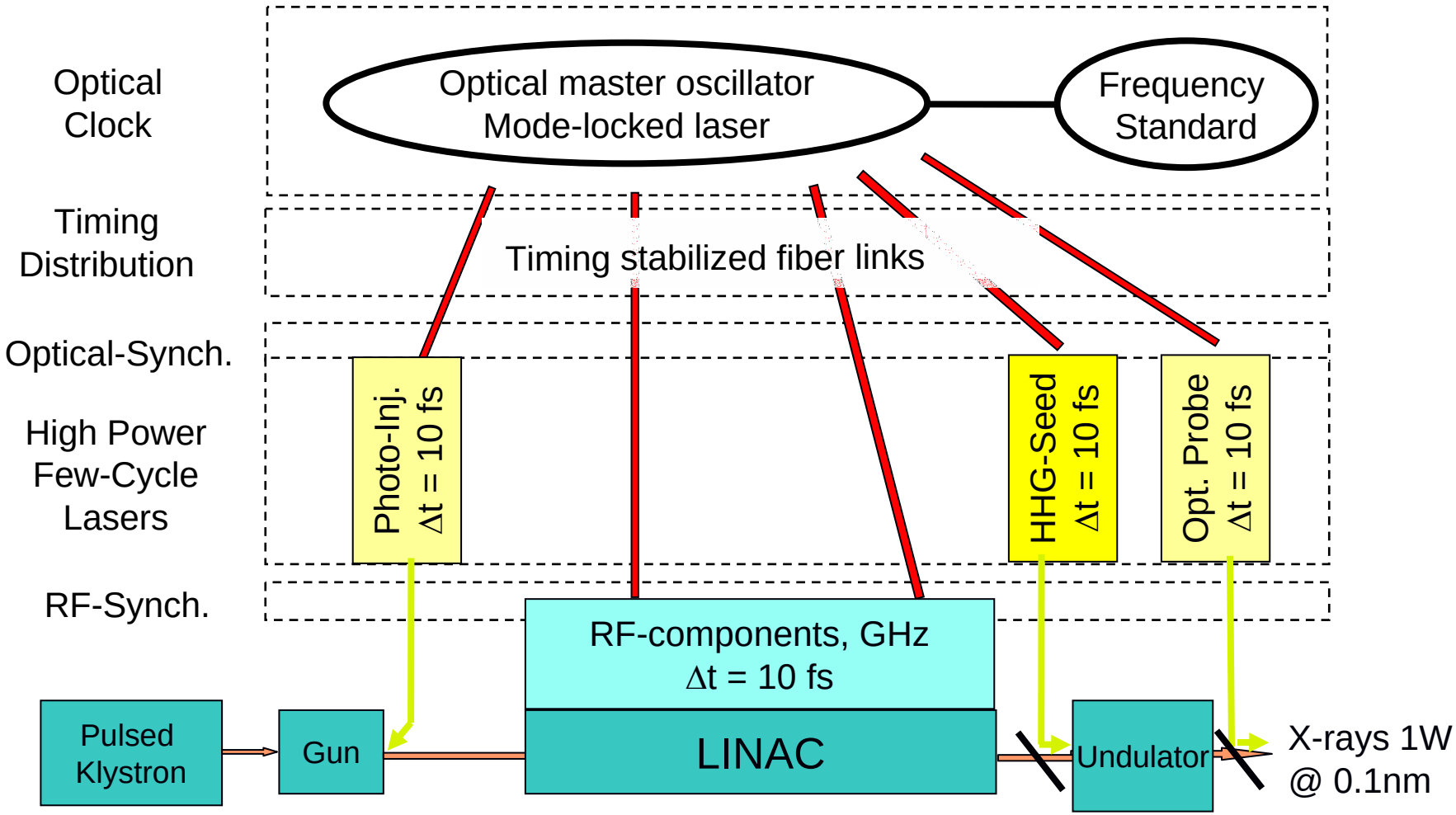
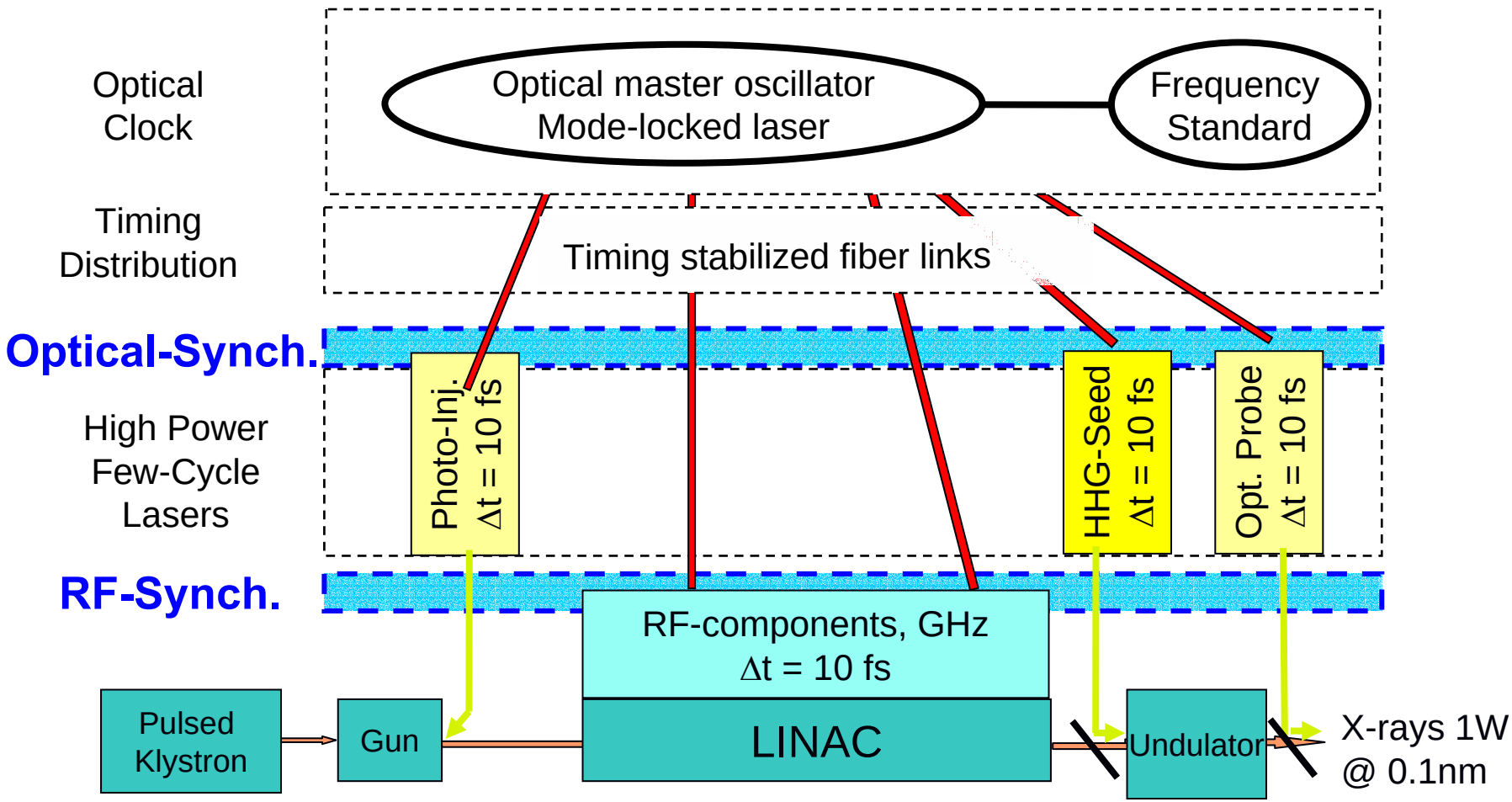
Schematic Outline of MIT X-Ray Laser Project



RF-synchronization module for RF-optical & optical-optical synchronizations

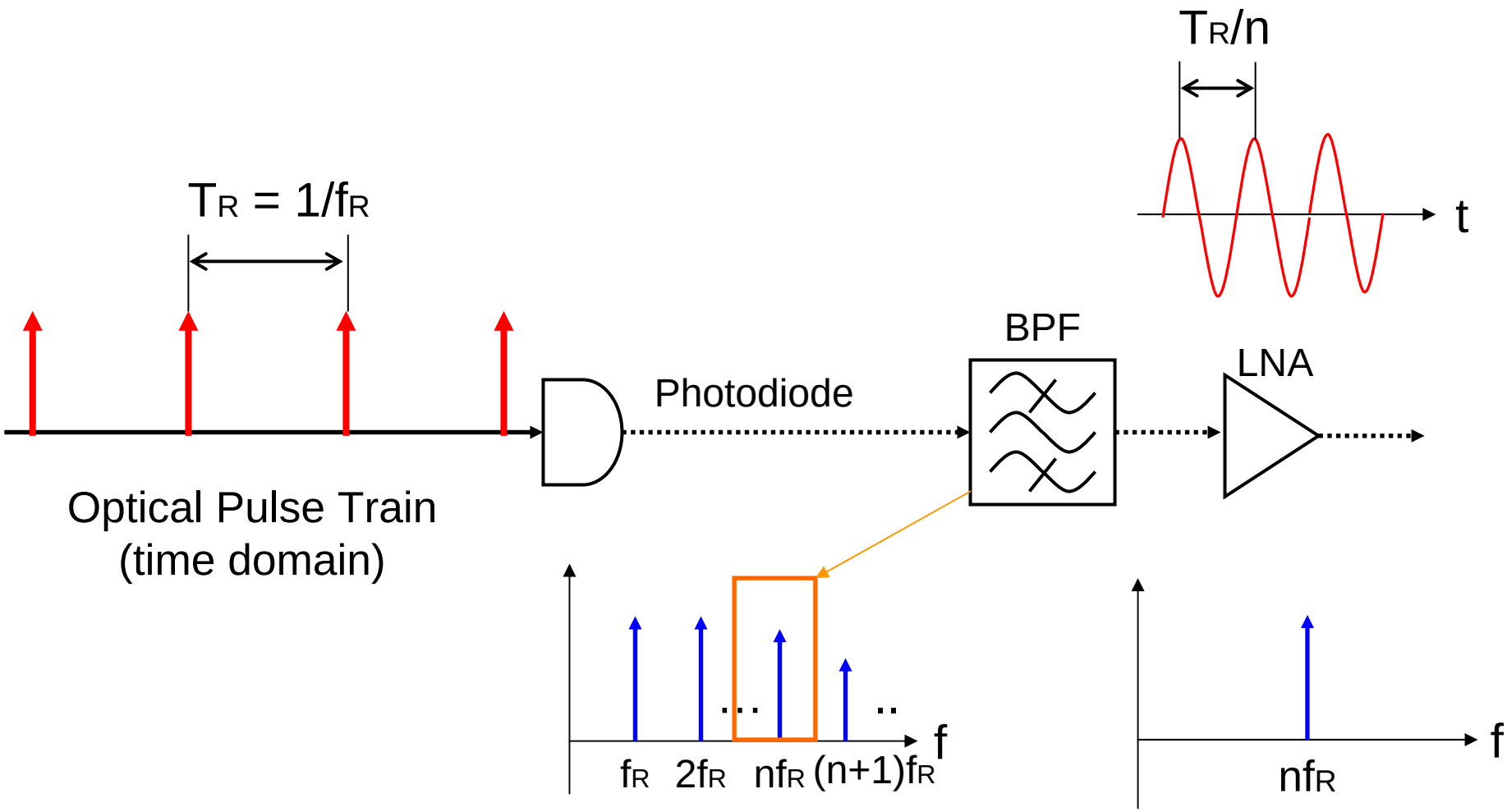
Timing stabilized fiber links and optical master oscillators

RF-Optical and Optical-Optical Synchronizations



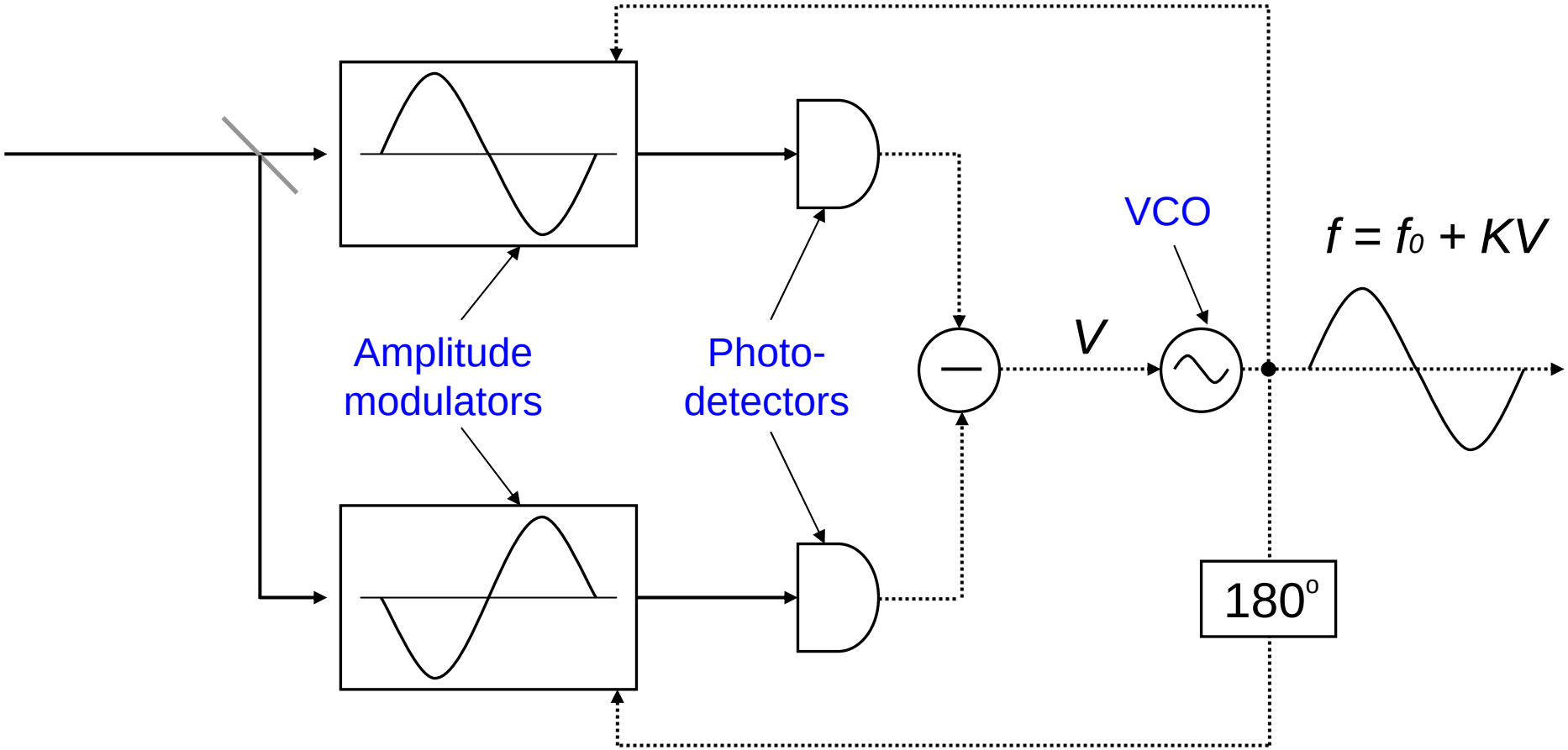
Sub-femtosecond synchronization is preferable: Δt< 1 fs

Direct Detection to Extract RF from Pulse Train



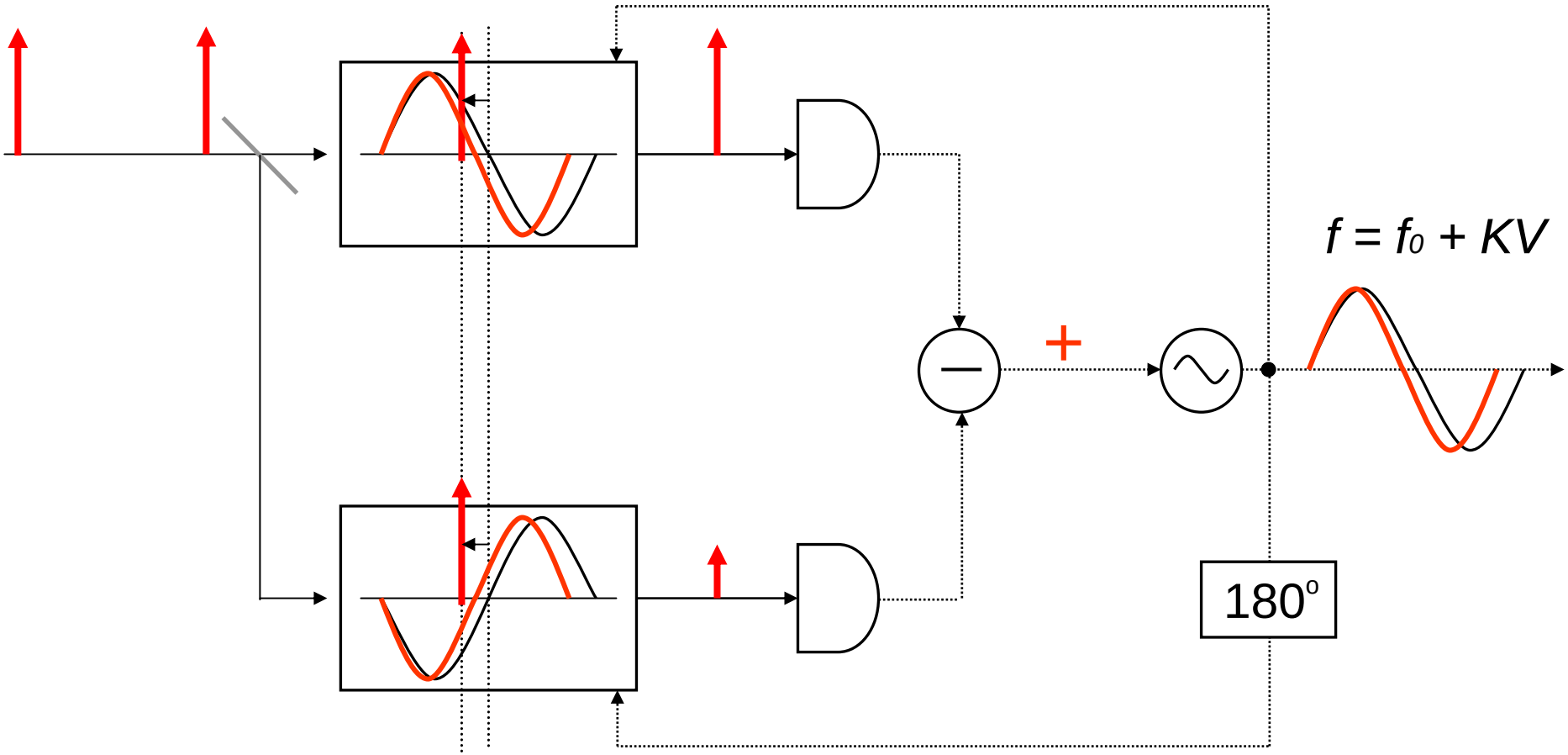
Amplitude-to-phase conversion introduces excess timing jitter.

RF-Synchronization Module

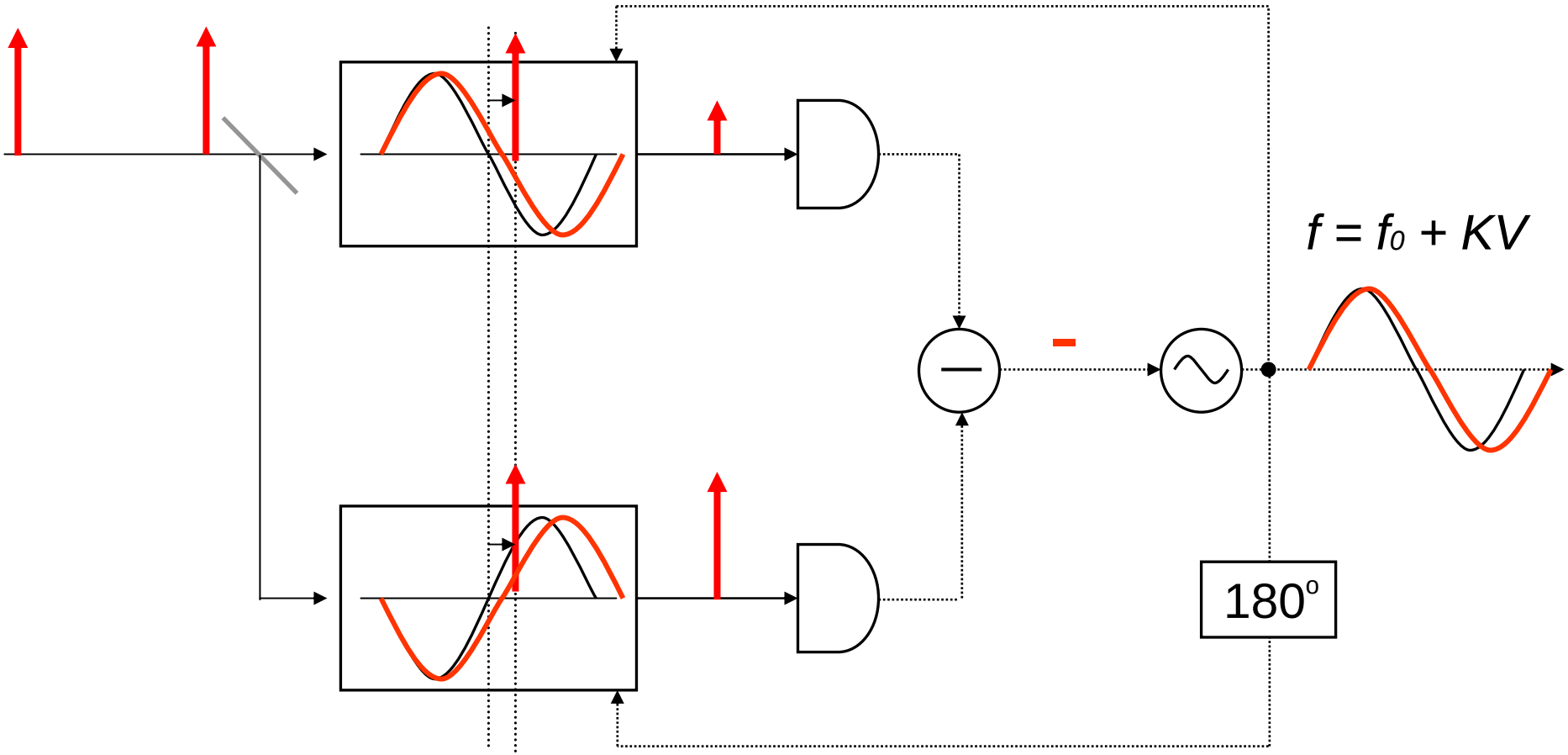


Transfer of timing information into intensity imbalance in optical domain

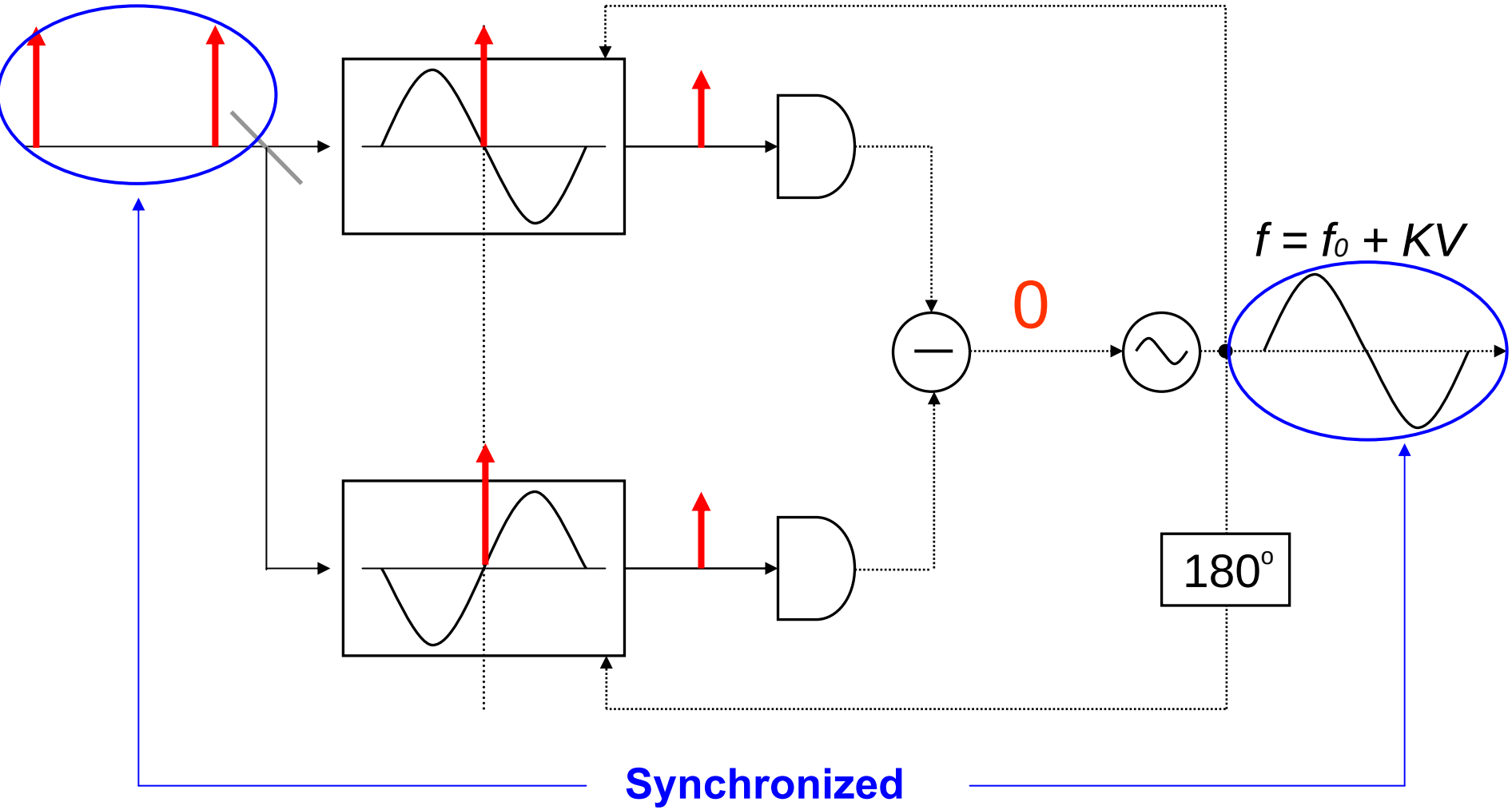
RF-Synchronization Module



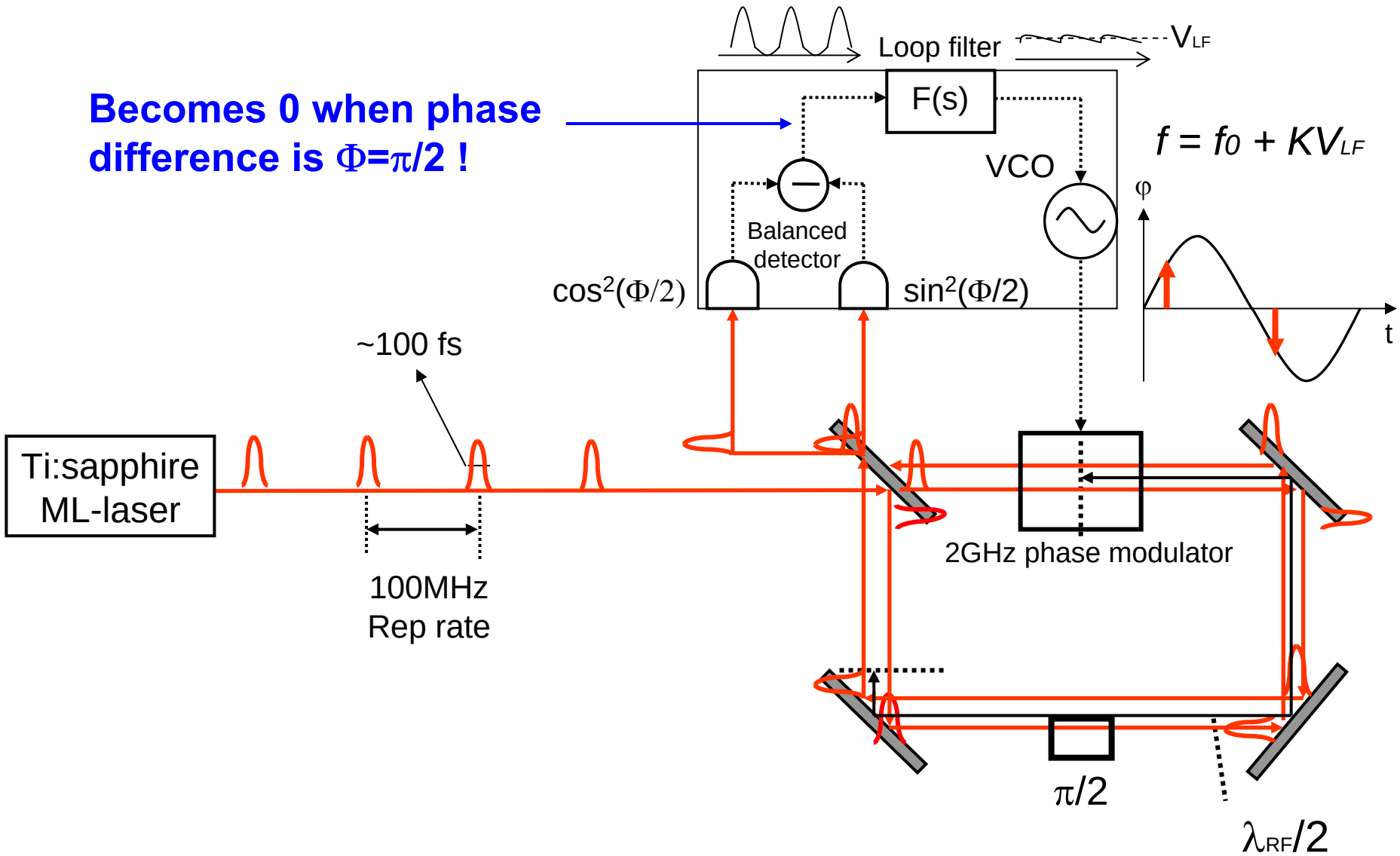
RF-Synchronization Module



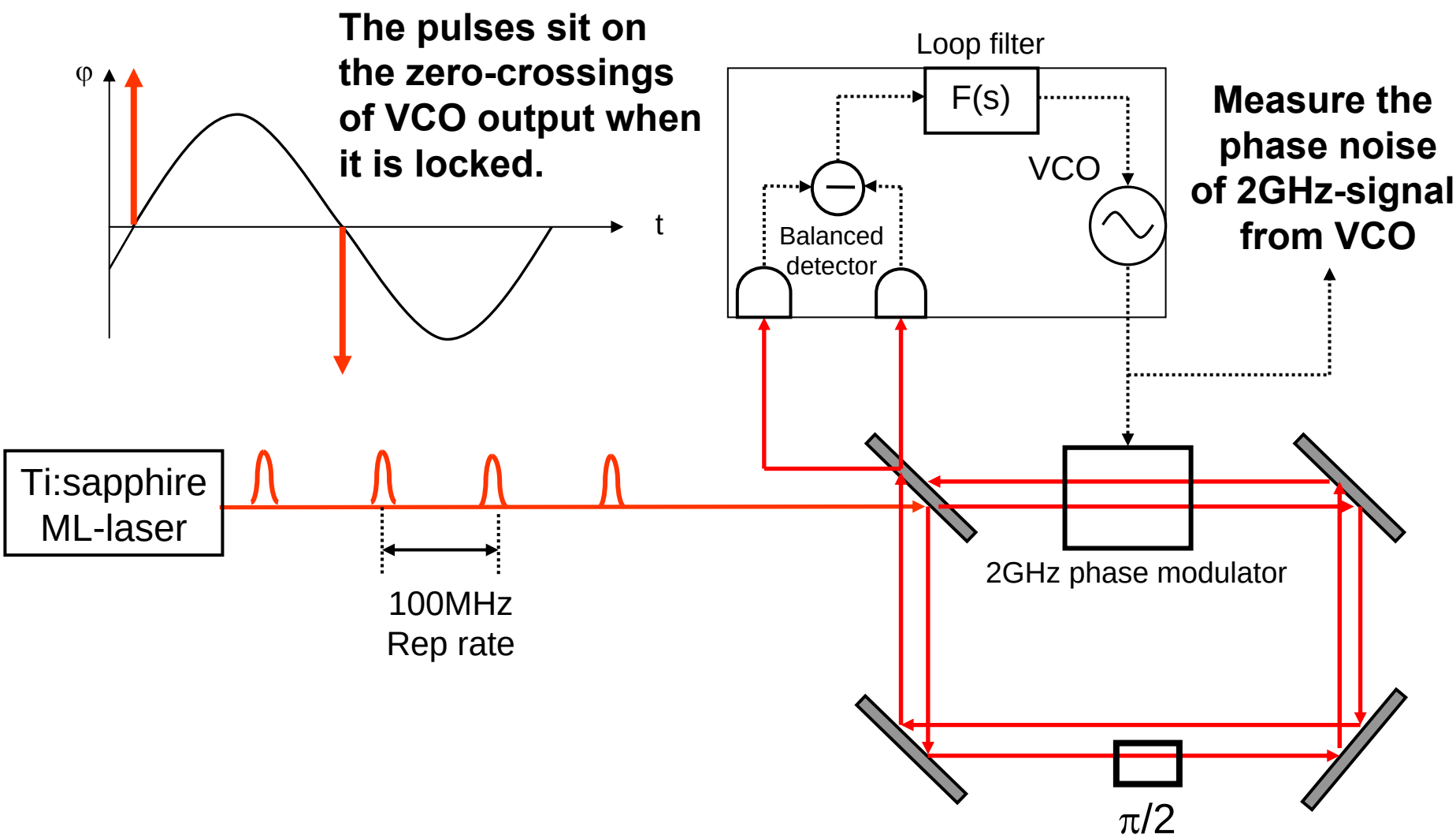
RF-Synchronization Module



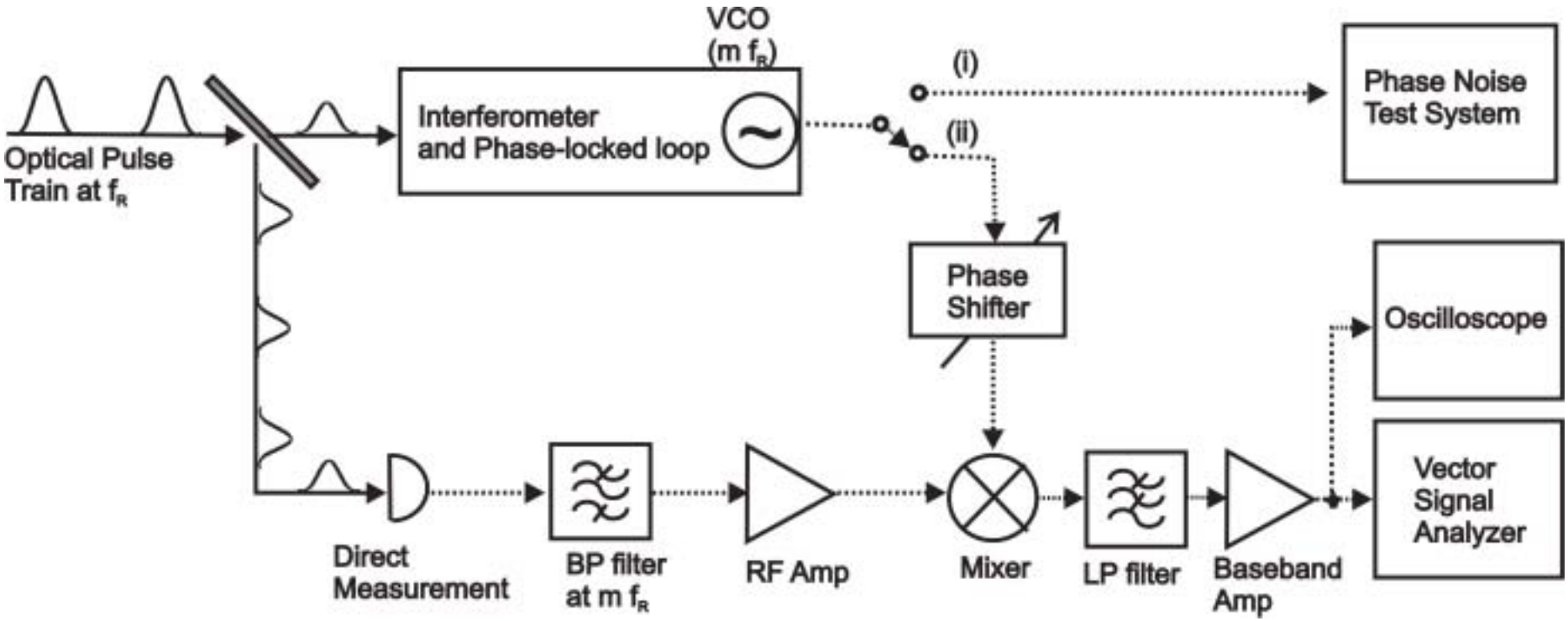
RF-Synchronization Demonstration Experiment



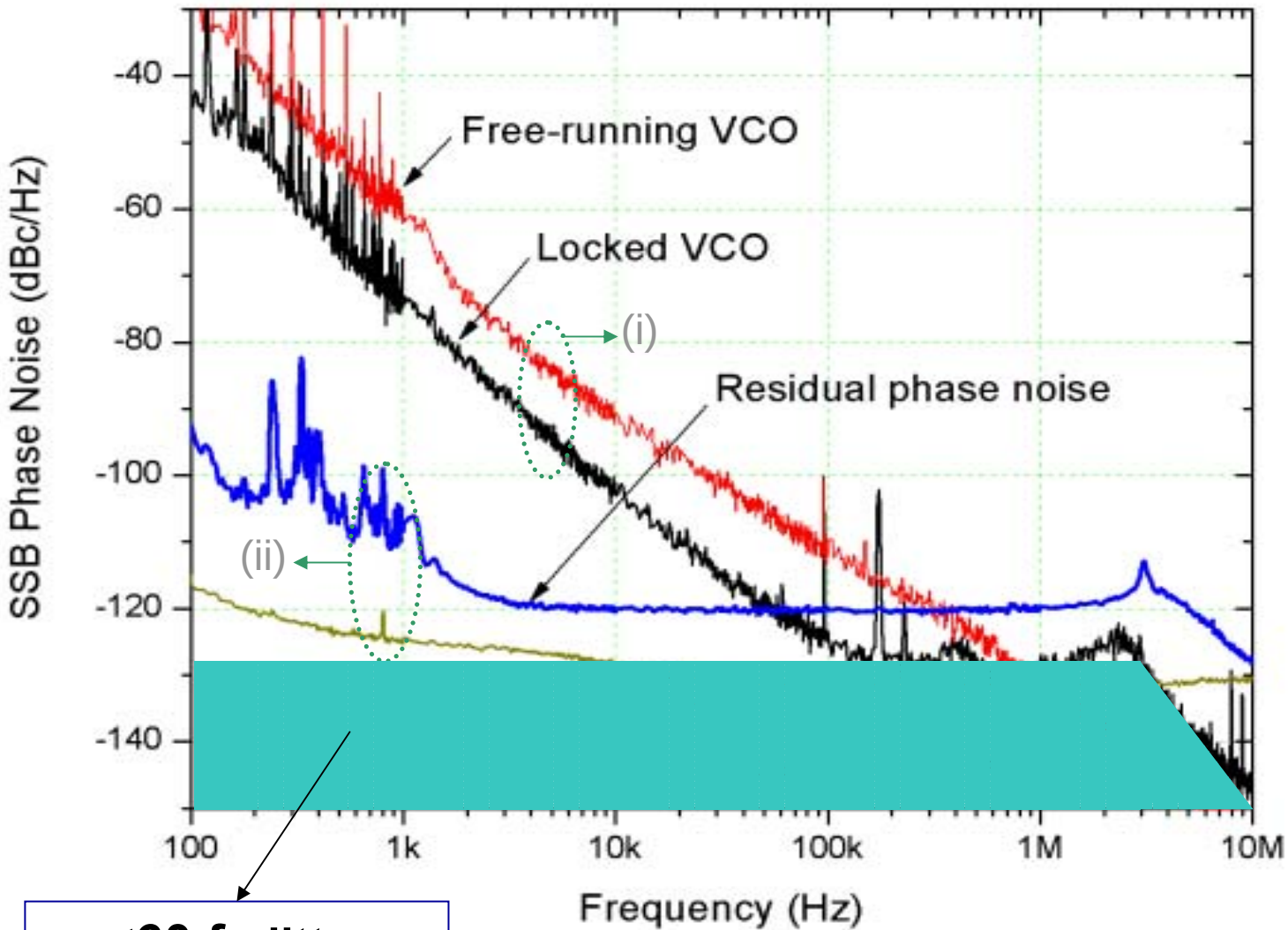
RF-Synchronization Demonstration Experiment



Phase Noise Measurement



Phase Noise Measurement Result



<60 fs jitter
(100Hz-10MHz)

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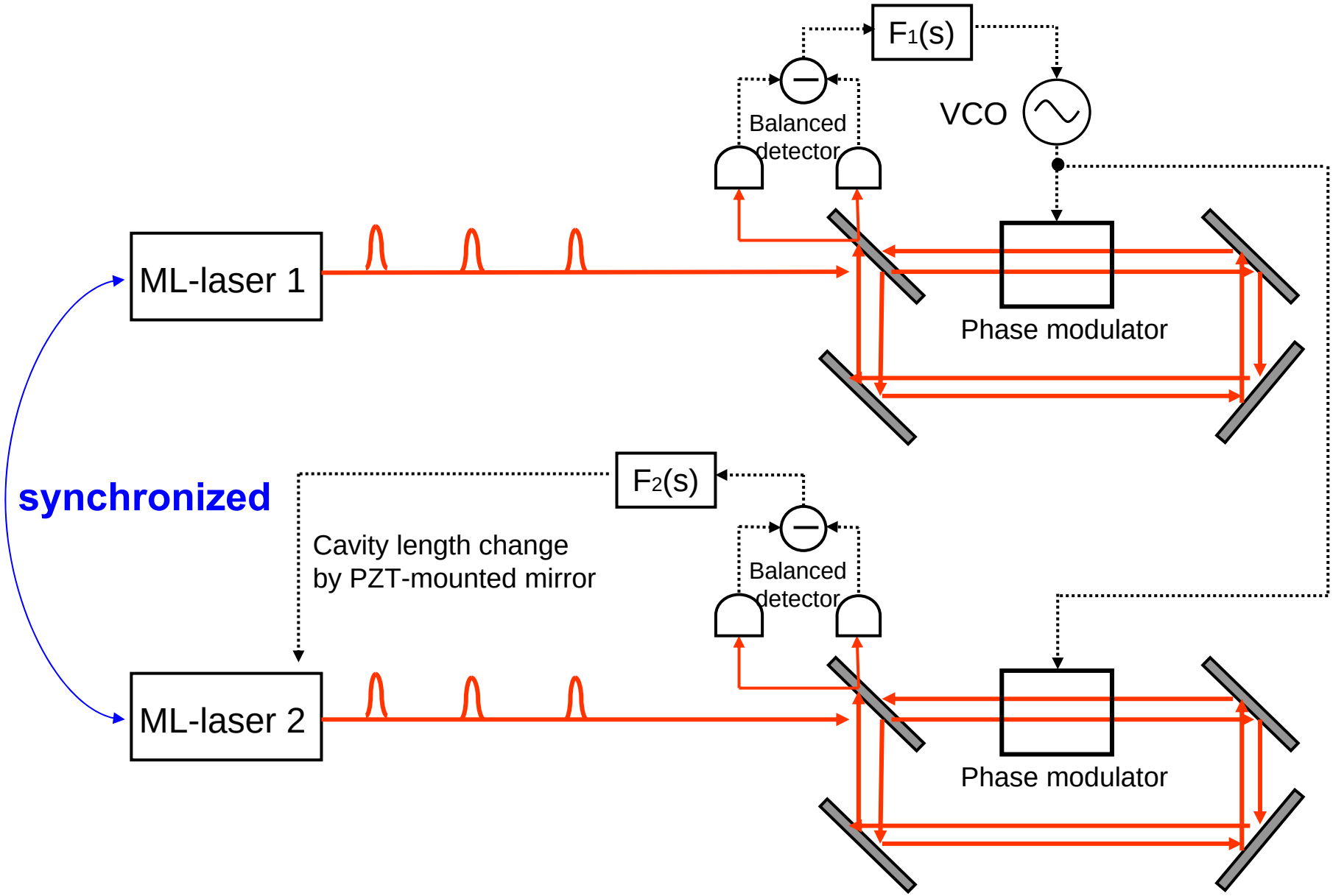
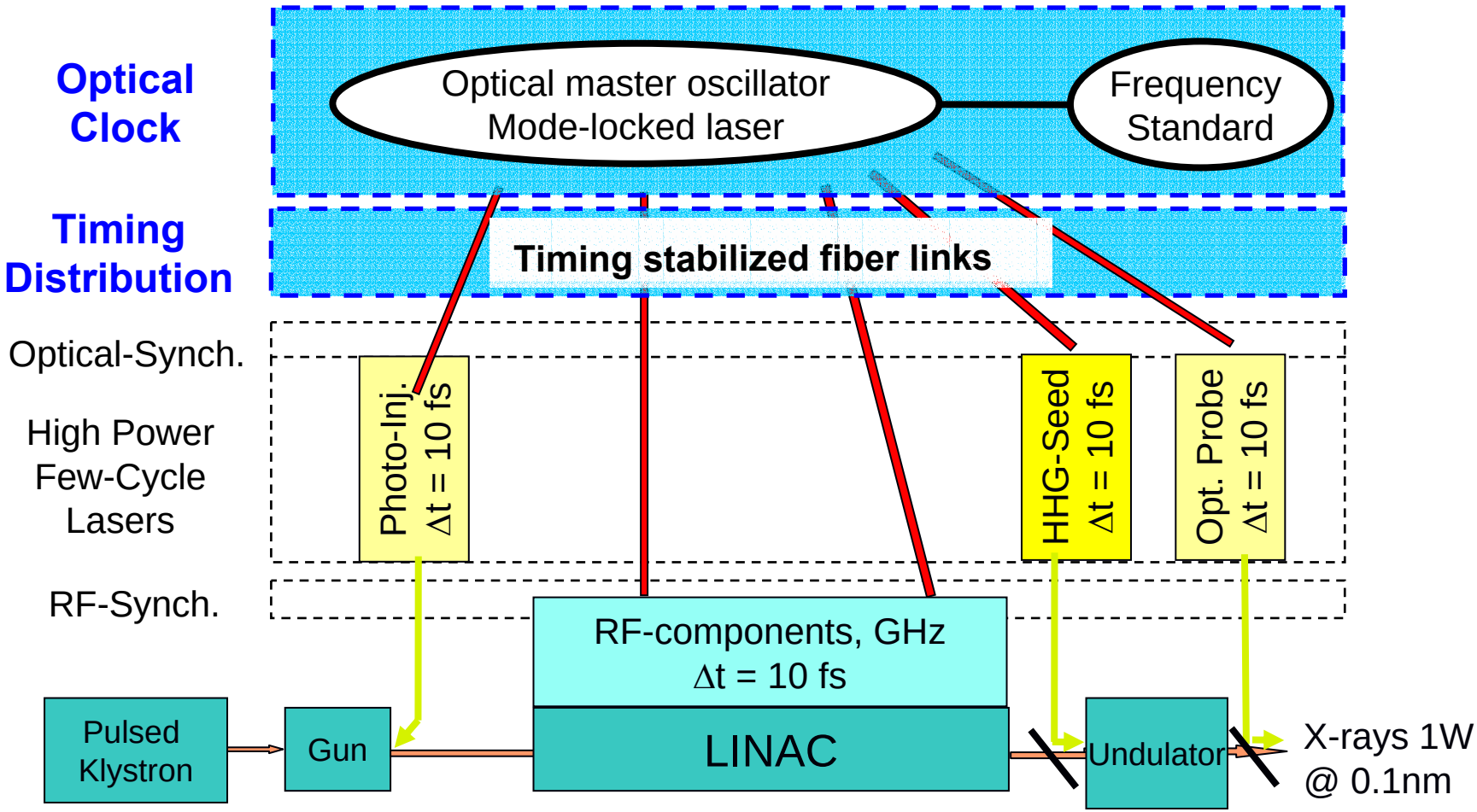
Optical-to-Optical Synchronization



RF-synchronization module for RF-optical & optical-optical synchronizations

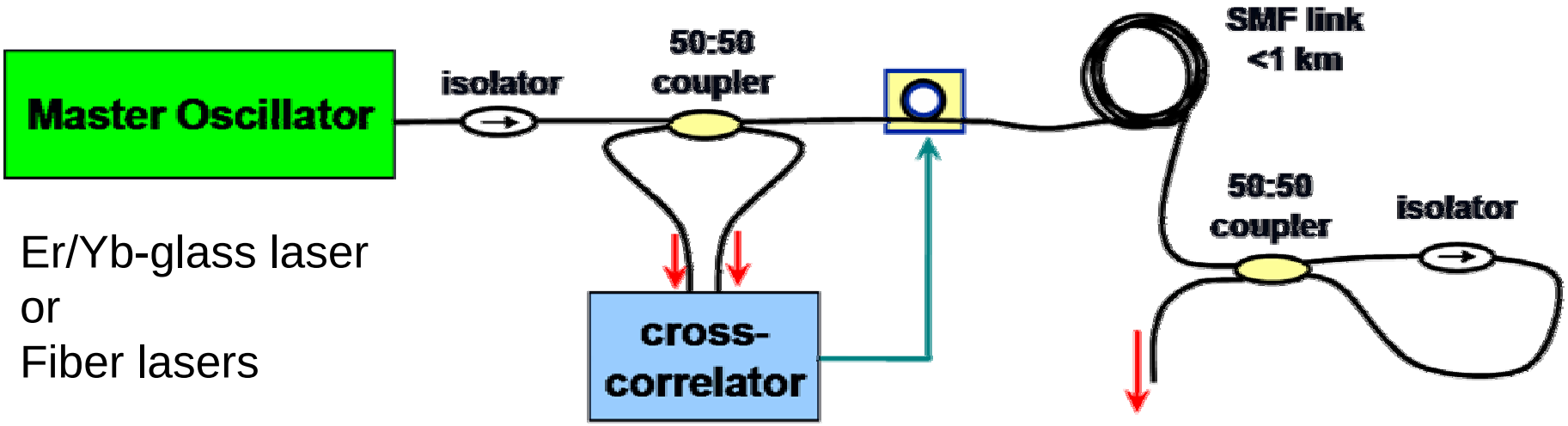
Timing stabilized fiber links and optical master oscillators

Timing Distribution and Optical Master Oscillator



Max timing jitter in each section Δt: 10 fs ~ 3mm

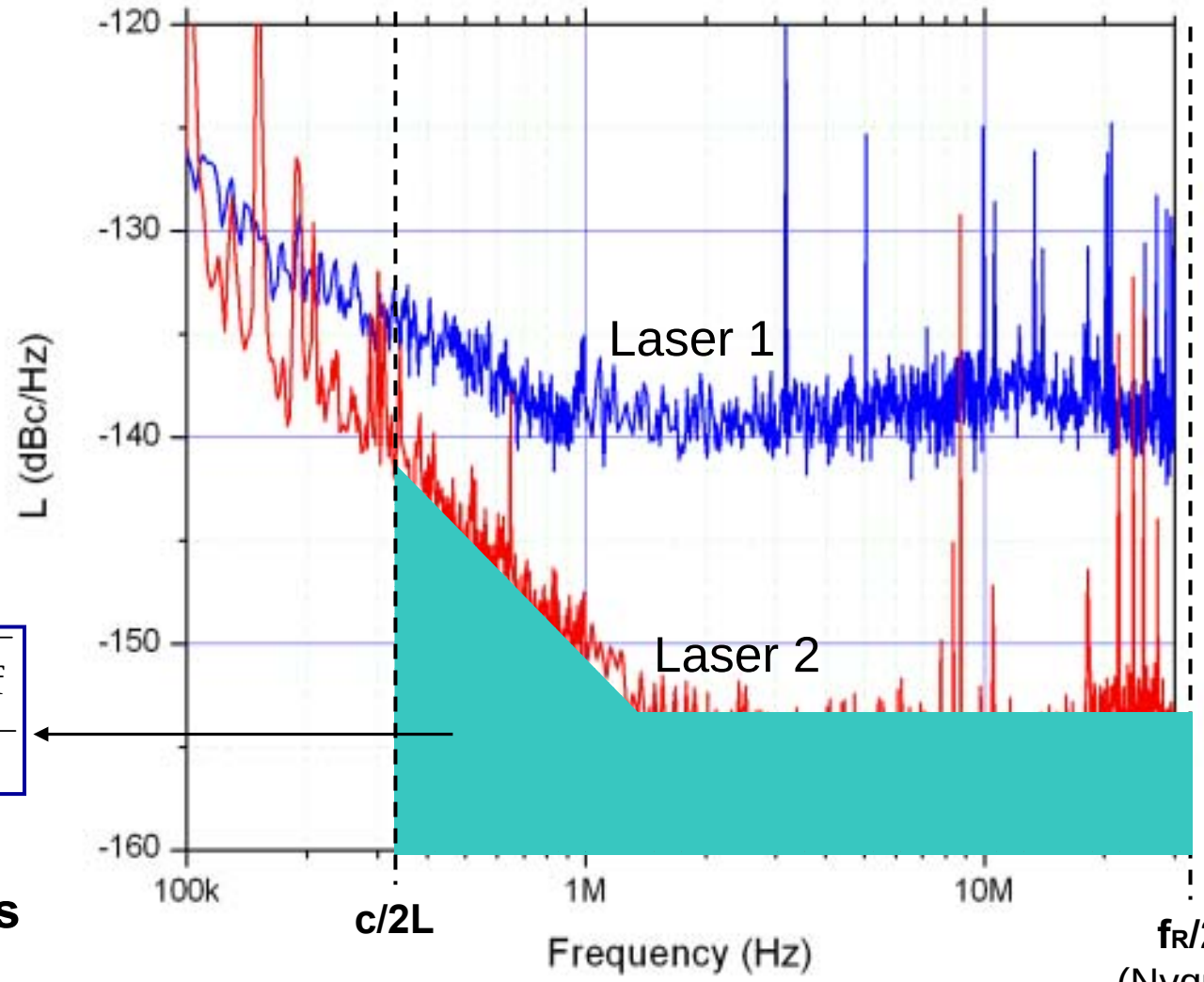
Timing Stabilized Fiber Links



Er/Yb-glass laser
or
Fiber lasers

Assuming no fiber length fluctuations faster than 2nL/c.

Jitter Requirement for Optical Master Oscillator



$$\Delta t_{rms} = \frac{\sqrt{2\int_{f_1}^{f_2} L(f)df}}{2\pi f_0}$$

should be less than 10 fs

Conclusion and Outlook

- Scalable timing distribution and synchronization schemes for future accelerator and free electron laser facilities are introduced.
- Modular RF-synchronization scheme, which is robust against photo-detector nonlinearities, is demonstrated. This module is applicable to both RF-optical and optical-optical subsystems synchronizations (currently sub-100 fs level, but scalable to fs-jitter level in the near future).
- The technical requirements for timing distribution links and optical master oscillators are addressed. Timing stabilized fiber links driven by ultra-low jitter mode-locked lasers are under development.