Summary of Discussion
Timing and Synchronisation

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Phase and Amplitude Detectors

- Diode for amplitude detection (typ. noise 50 μV (rms) in 1 MHz BW, temperature compensation needed for long term stab.)
- Phase detection:
  - Digitizing with 16 bit ADC => .01 deg S-band
  - Drifts dominated by cables, not by double balanced mixer.
  - Mixer overdriven to obtain highest sensitivity, 10 deg. dynamic range typical.
  - Large phase changes (360 deg) found empirically, not by precision phase measurement.
  - combination of low resolution (0.1 deg) 360 deg. detector with overdriven mixer (res. < 0.01 deg.) appears attractive.

Optical vs. Electrical distribution

- Fiber
  - BW higher, not prone to EM noise
  - temperature drift similar to coaxial cable (5-10 ppm/deg. C)
  - Polarization maintaining fiber difficult. Requires length compensation. Microphonics ? Availability ?
  - Noise floor of fiber optic transmitters and receivers ? Limit power to few mW (thermal issues)
  - Pulse length of the order of 1 ps to avoid higher order dispersion
  - use of shorter pulses desired for diagnostics
  - effects of radiation on fiber (Scintillation noise, darkening)
  - Microphonics on fibers (bifringence caused by stress -> path-length variation)
  - SLAC experience: rf-fiber-rf adds noise

- Coax.
  - SLAC main drive line (476MHz) noise floor -135dBc@10kHz and -85dBc@100Hz
  - No problem with ground loops (12” copper strip along line)
  - Integrated interferometer compensates 2/3 of 30 ps diurnal changes.
  - No problem with microphonics, should be able to reach 10 fs stability over few hundred meters.
  - Temperature stabilized fiber < 1ppm/ deg. C possible at optimum temperature (0.1 deg. C stability has been achieved)

Choice of Master Oscillator and what is the Reference – Bandwidth ?

- Laser oscillators:
  - Fiber laser ~50-100 MHz 100's fs pulses
  - Er:Yb glass – MO lasers
  - Ti:Sa for seeding at ~ 5 fs, ~100 MHz
  - Yb glass photo cathode laser
- RF oscillators
  - SC cut quartz xtl 3-30 MHz, multiplied to 476 MHz, 10 kHz off-set -157 dBC/Hz
  - Sapphire loaded cavity 10 GHz VCO
  - Dielectric resonators (DRO's) VCO
- Reference should be rf (crystal oscillator) for low frequencies.

Distribution Frequency Choice (Hi or Low)

- Highest frequency for resolution vs. losses
  - locking at higher frquencies gives higher sensitivity of mixer
- ~ 50 - 100 MHz optimum (timing jitter !) for laser
- Timing jitter increases with frequency – need experimental verification.
- Higher frequencies derived from harmonics (filter !)

Consequences of Bunch Repetition Rate

- High rep. allows for continuous beam based diagnostics and feed-back on subsystems
- For pulsed machine first pulses (20-30 us, dumped) can be used for fast feedback stabilization
- LCLS different scheme, requirements tightened for first bunch.

Stability Achievable on Different Time Scales

- What needs to be stable on different time scales ?
- Expect that stability degrades rapidly from 1ms – 10 ms – 100 ms – 1s, some experience at SLAC with klystrons, stability seems to degrade fast for time scale from 1 ms to 1 s
- much longer time scale (shutdown) requires significant time for restart (all subsystems need hours to stabilize in temperature)

Laboratory Experiment vs. Beam Based

- Different environment (klystron modulators, heavy machinery (vibrations) etc.
- Grounding and shielding schemes
- EMI and EMC issues need to be solved

Design architecture for XFEL laser timing and synchronization

- Master oscillator – noise floor of laser (e.g. Ti:Sa) vs xtl oscillator. Bandwidth of interest.

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Note:

Mode locking laser less reliable, going out of lock. Mode locking initiation mechanisms help, but temp sensitive.

Laser synchronized to RF master oscillator, output of laser then used as source of LLRF for accelerator.

- Balanced detector
  - Optical
  - low noise balanced with sufficient BW
  - single ended detectors
- RF
  - overdriven mixers

Note: Optical components critical for performance:
- Phase Modulators
- Couplers
- Cross correlators
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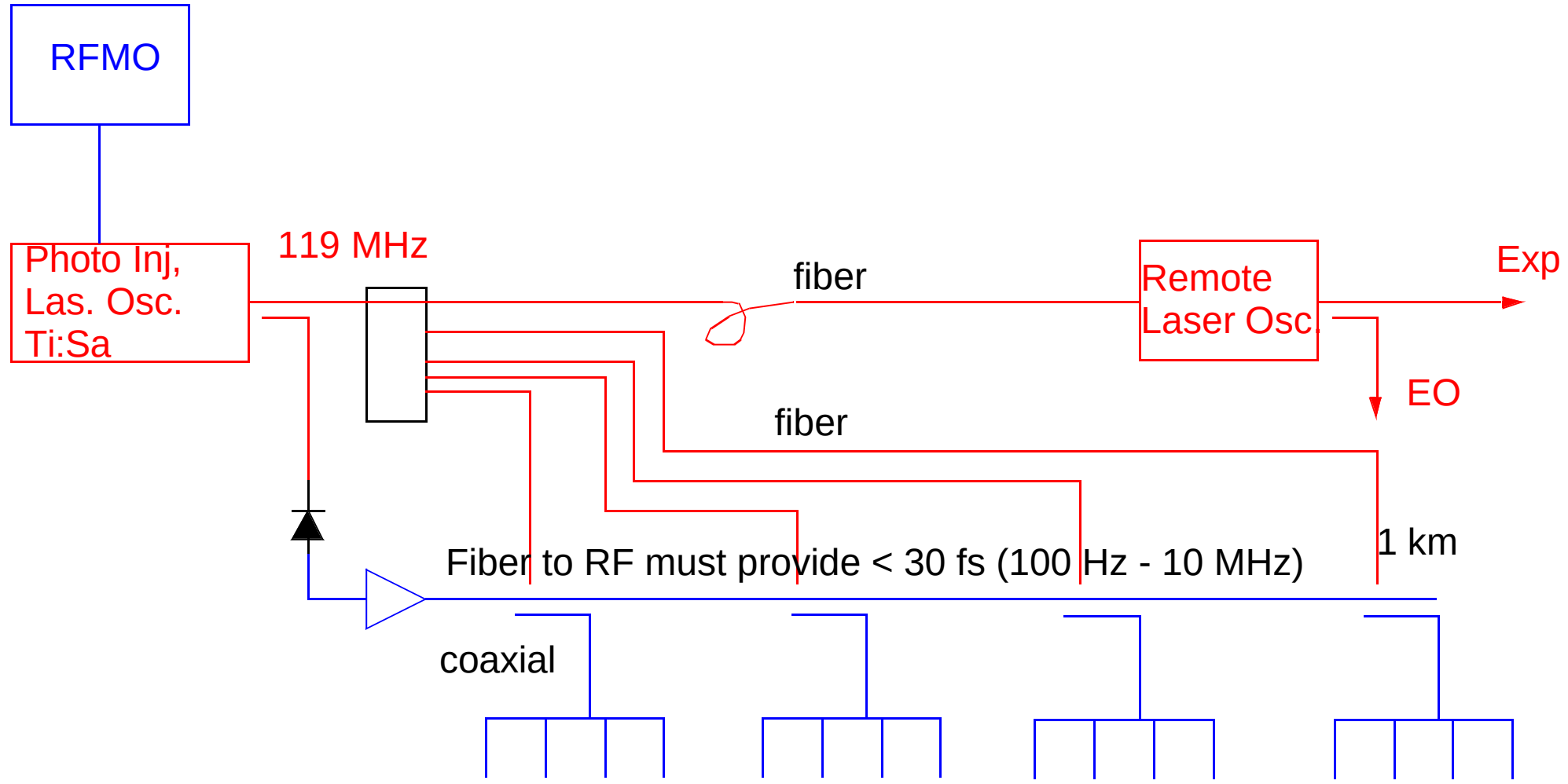
- Distribution system – for both LLRF and remote lasers over 100's of m.
  - Fiber
    - stabilized at 1500 nm dispersion managed, single mode, polarized and unpolarized versions
    - free space – short distance, same optical table
  - Coax
    - Temp. stabilized rigid coax (2856 MHz 1 km 1 5/8")

Distribution for LCLS



Recommendation: Add redundant optical distribution for monitoring