Frequency Scanned Interferometer Demonstration System

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Physics Goals

- To Carry out R&D toward a direct, quasi real time and remote way of measuring positions of critical tracker detector elements during operation.
- The 1-Dimension measurement precision of absolute length is O(1 micron).

- Assumption: Thermal drifts in tracker detector on time scales too short to collect adequate data samples to make precise alignment.

Background

* RASNIK system: used in L3, CHORUS and CDF
* Frequency Scanned Interferometer(FSI): used in ATLAS [*A.F. Fox-Murphy et al., NIM A383, 229(1996)*]

* Focusing here on FSI system for NLC tracker detector
* Basic idea: To measure hundreds of absolute point-to-point distances of tracker elements in 3 dimensions by using an array of optical beams split from a central laser. Absolute distances are determined by scanning the laser frequency and counting interference fringes.

Length Measurement and Precision

- The measured length can be expressed by

$$R = \frac{c\Delta N}{2\bar{n}_g \Delta \nu} + \text{constant end corrections}$$

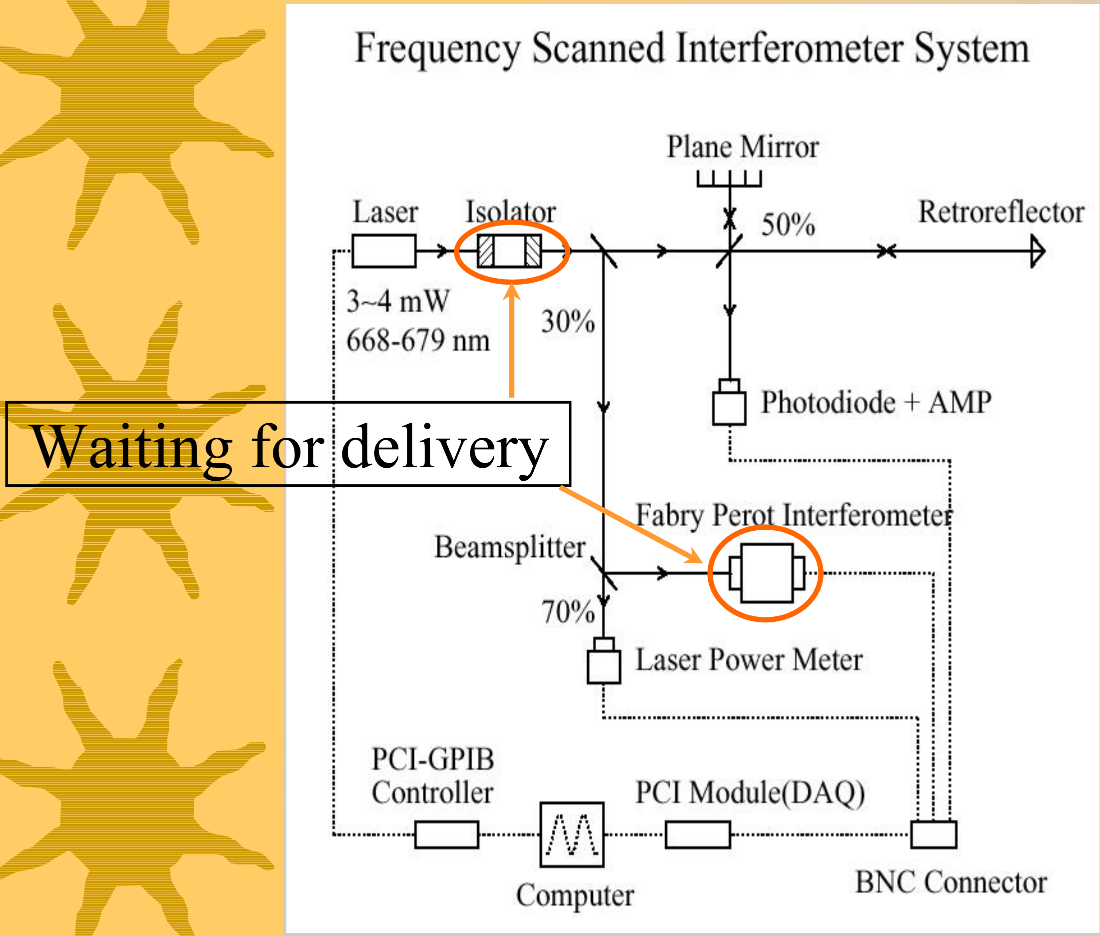
c - *speed of light*, ΔN *– No. of fringes*, $\Delta \nu$ *- scanned frequency*
n_g *– average refractive index of ambient atmosphere*

- Assuming the error of refractive index is small, the measured precision is given by:

$$(\sigma_R / R)^2 = (\sigma_{\Delta N} / \Delta N)^2 + (\sigma_{\Delta \nu} / \Delta \nu)^2$$

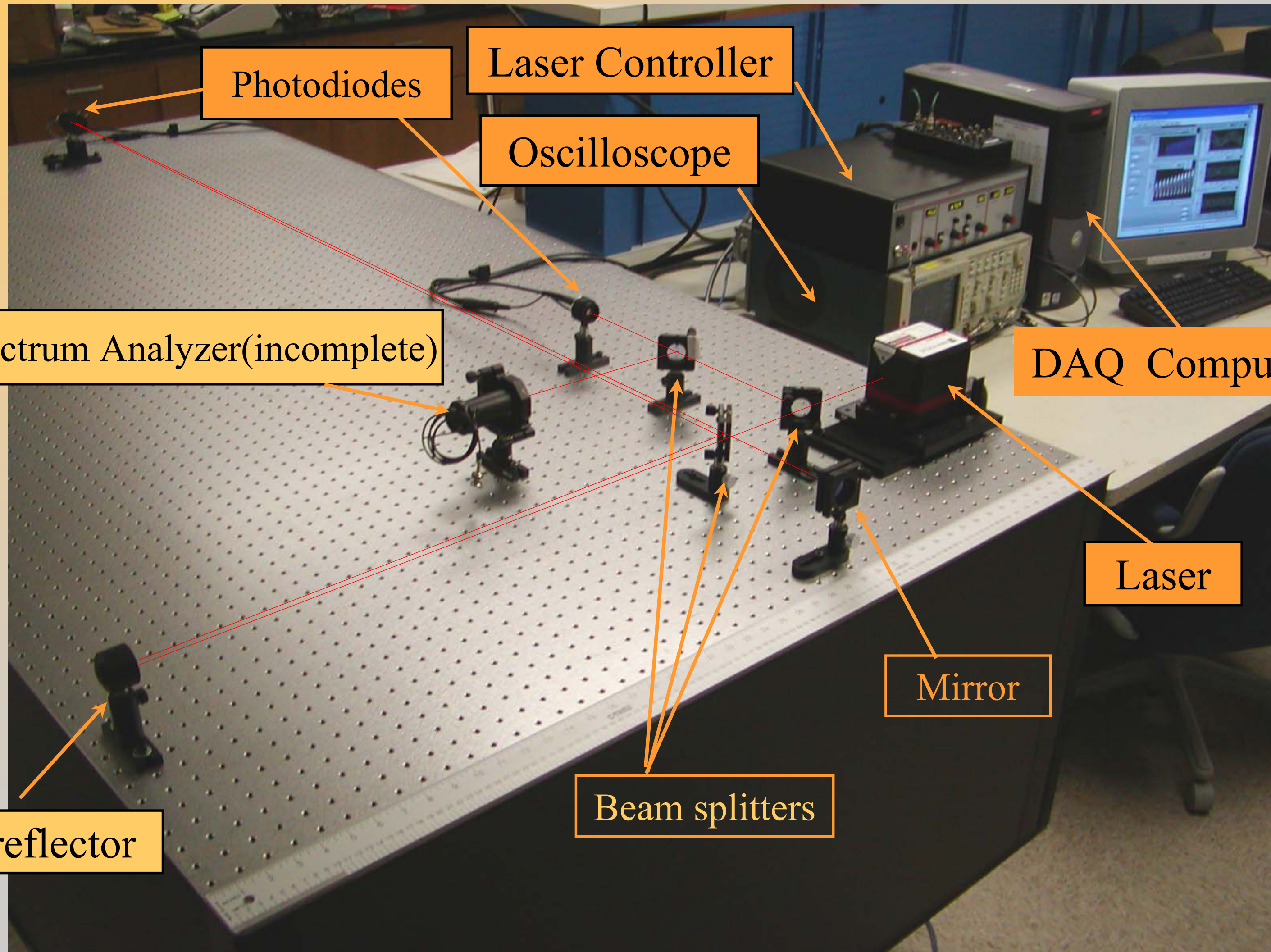
Example: R = 1.0 m, $\Delta \nu = 6.6$ *THz*, $\Delta N \sim 2R\Delta\nu/c = 44000$
To obtain $\sigma_R \cong 1.0\ \mu m$, *Requirements:* $\sigma_{\Delta N} \sim 0.02$, $\sigma_{\Delta \nu} \sim 3$ *MHz*

FSI Demonstration System



- **Tunable Laser: New Focus Velocity 6308, 3-4 mW, 668-679 nm.**
- **Isolator: Leysop FOI 5/57 with polarisers to eliminate the optical feedback.**
- **Retroreflector: Edmund, D=2", angle tolerance: ±3 arc seconds.**
- **Photodiodes: 3 Thorlabs PDA55, DC-10MHz, Amplified Si Detector, 5 Gain Settings.**
- **Fabry-Perot Interferometer: Thorlabs SA200, high finesse(>200) spectrum analyzer to determine the relative frequency precisely, Free Spectra Range (FSR) is 1.5 GHz, with peak FWHM of 7.5 MHz.**
- **PCI Card: NI-PCI-6110, 5 MS/s/ch, 12-bit simultaneous sampling DAQ.**
- **PCI-GPIB Card: NI-488.2, served as remote controller of laser.**
- **Computers: 1 for DAQ and laser control, 3 for analysis.**

FSI Demonstration System



FSI Laser & DAQ Control Panels

- ***Laser Control Panel***

  set: start and stop wavelength, forward and backward scanning rate, power constant mode etc.

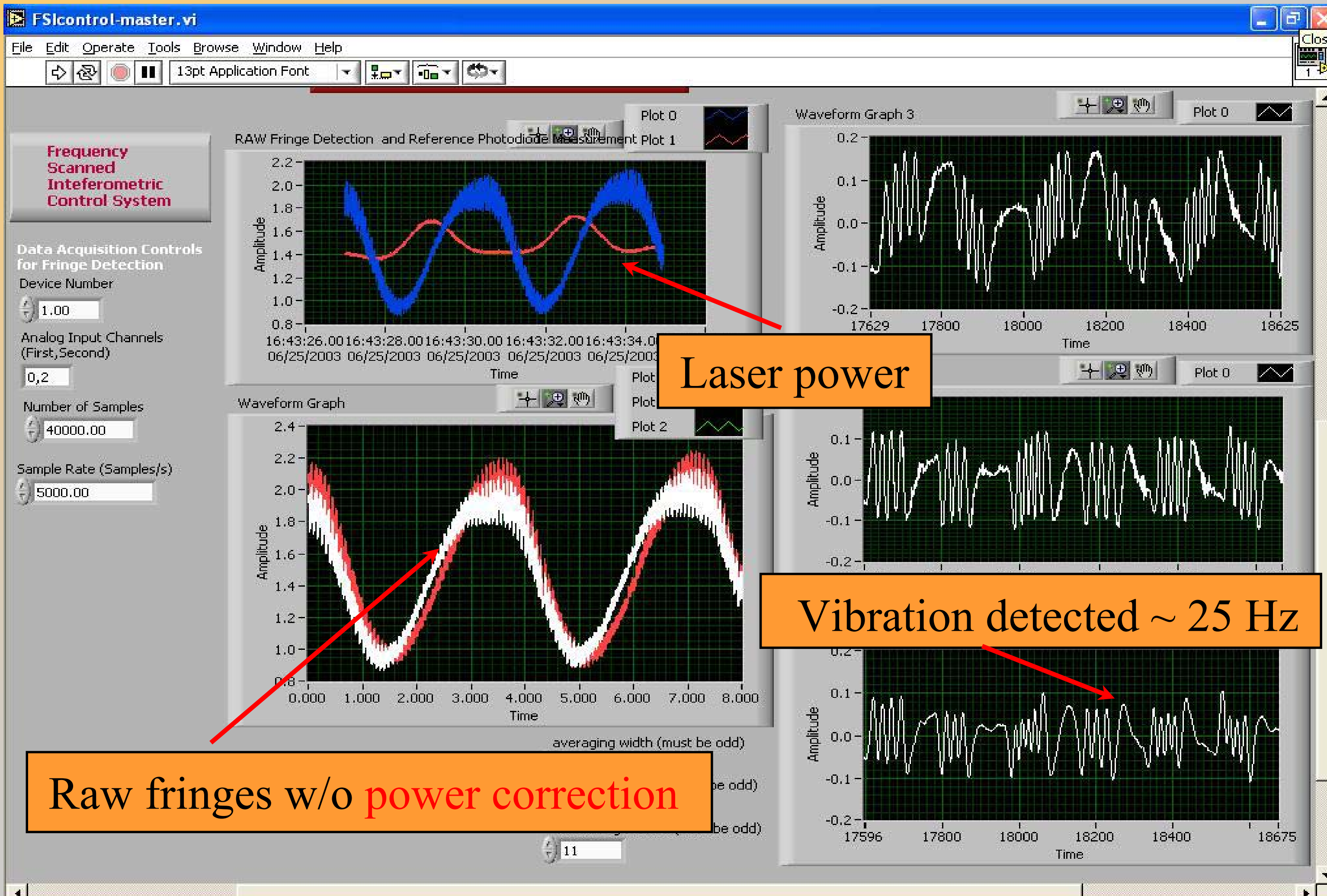
- ***DAQ Control Panel***

  set: device No., input signal channels No., sampling rate, total samples collected etc.

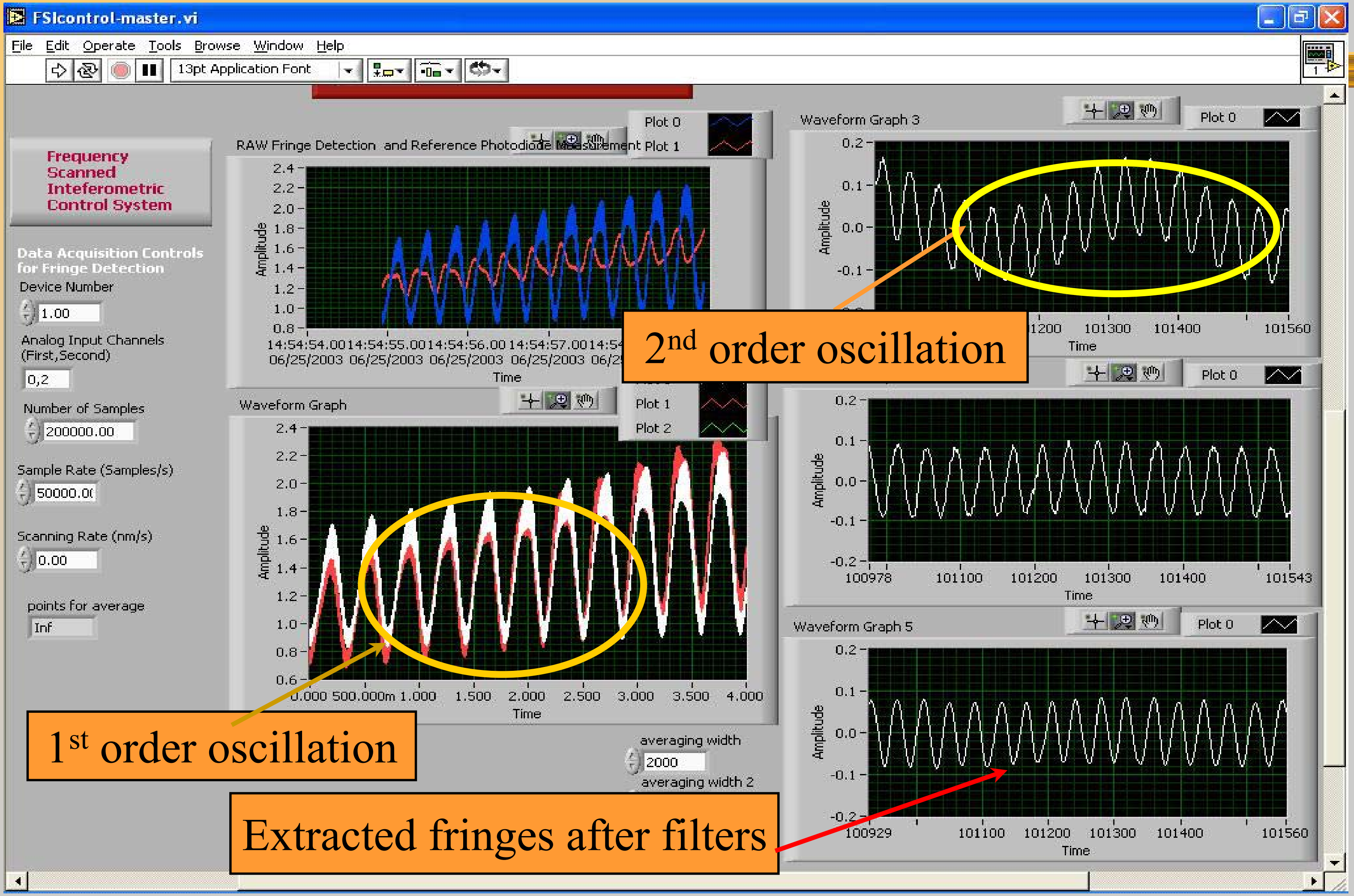
  show: laser power, scanned frequency, raw fringes, extracted fringes after filters, fringes No., extracted vibration etc.

- ***Tentative Operation(preliminary results)***
  - Low Scanning Rate(<0.1nm/s): good for measuring vibrations.
  - Medium Scanning Rate(0.5 – 1 nm/s): good for length measurement.
  - High Scanning Rate(>1 nm/s): fringe instability increased.

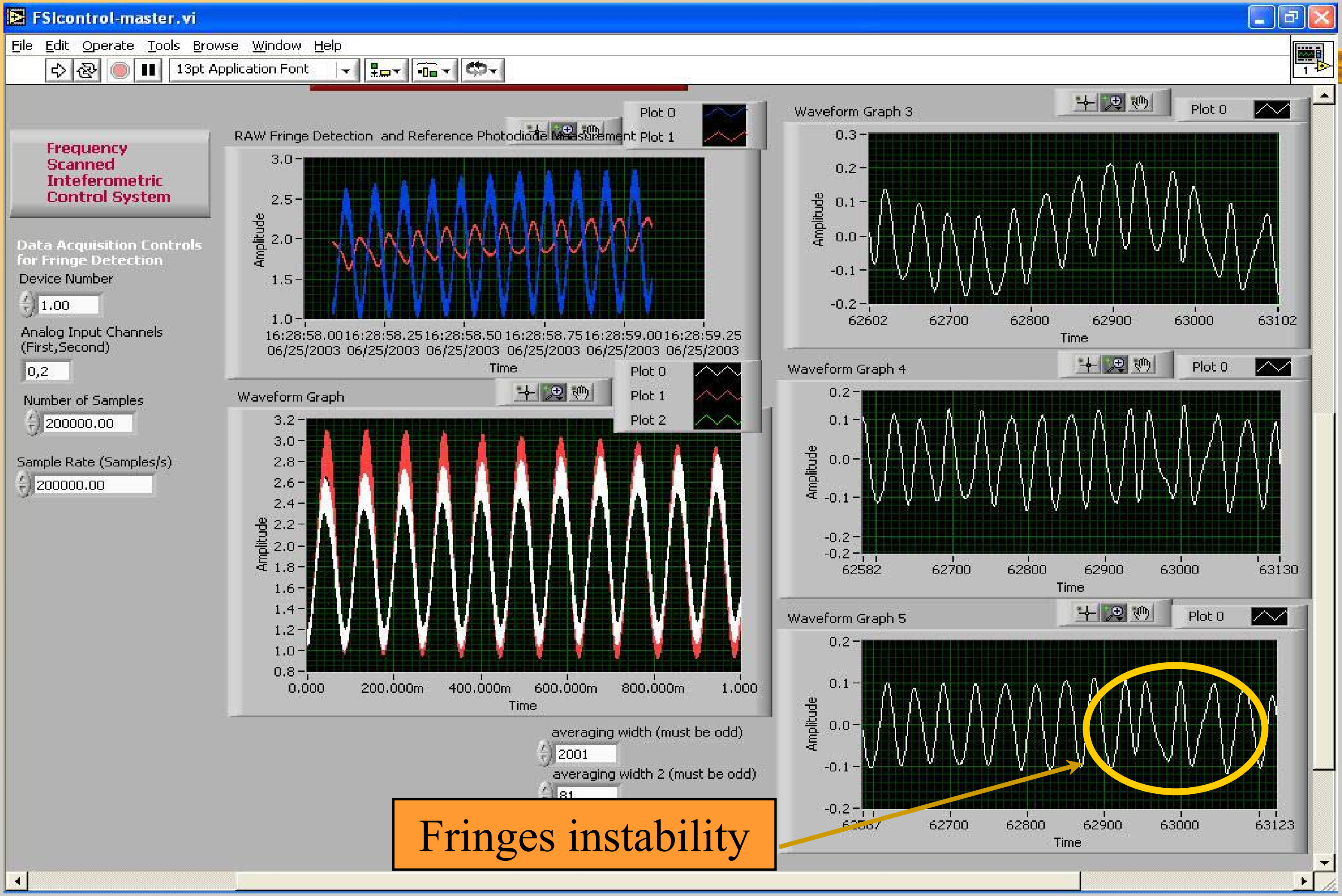
Scanning Rate is 0.05 nm/s



Scanning Rate is 0.5 nm/s



Scanning Rate is 2 nm/s



Phase Shift Technique

- Fringe phase at time t: $\Phi(t) = 2\pi[OPD^{true} + 2x_{vib}(t)]/\lambda(t)$, $x_{vib}(t) = a_{vib}\cos(2\pi f_{vib}t + \phi_{vib})$
- Fringes number are, $\Delta N = OPD^{measured} \bullet \Delta\nu/c$

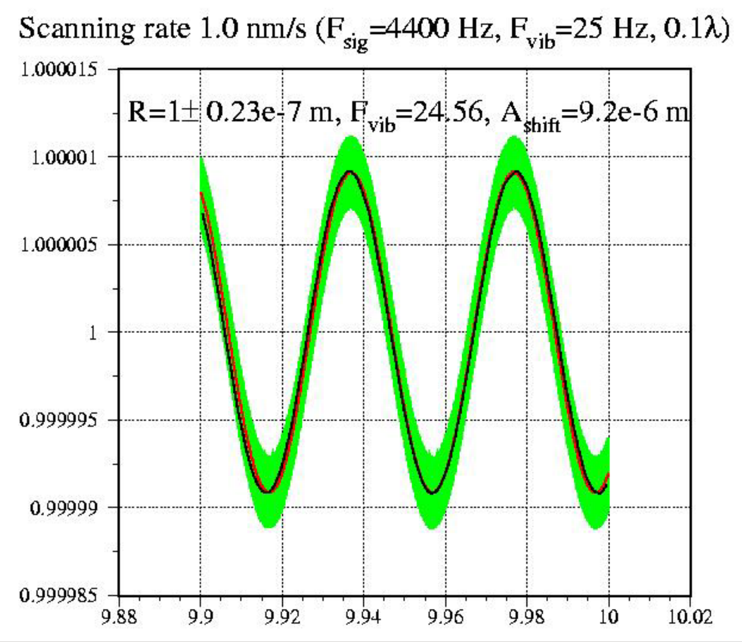
  $\Delta N = [\Phi(t)-\Phi(t0)]/2\pi = OPD^{true}\bullet\Delta\nu/c + [2x_{vib}(t)/\lambda(t) - 2x_{vib}(t0)/\lambda(t0)]$
- Measured OPD can be written as,

  $OPD^{measured} = OPD^{true} + c/\Delta\nu \bullet [2x_{vib}(t)/\lambda(t) - 2x_{vib}(t0)/\lambda(t0)]$

  if t_{slot}=t-t0 fixed, 2^{nd} term can be written as,

  $A_{shift} \bullet \sin(2\pi f_{vib}t' + \phi)$

- If we fix the measurement window t_{slot} and shift the window to measure many OPDs, then the vibration effect will show up. True OPD, vibration frequency can be derived by fitting the measured OPDs. MC simulation result is shown in the plot.



Discussion & Outlook

- 1st and 2nd order oscillations depend directly upon scanning rate, we have strong evidence that they are due to back reflection from the interferometer into the lasing cavity. We expect the Faraday isolator on back order to fix this problem.
- Also waiting for Fabry Perot spectrum analyzer to complete the demonstration system.
- Fringe phase shift caused by vibrations can be extracted through phase filter and can be corrected by offline analysis.
- Very preliminary measurements with newly arrived equipment (<1 month since most deliveries) look encouraging. We expect a successful demonstration of the system. But much work to do !