Successful Tests of Laser Doppler Vibrometer at PolyTec, Inc.

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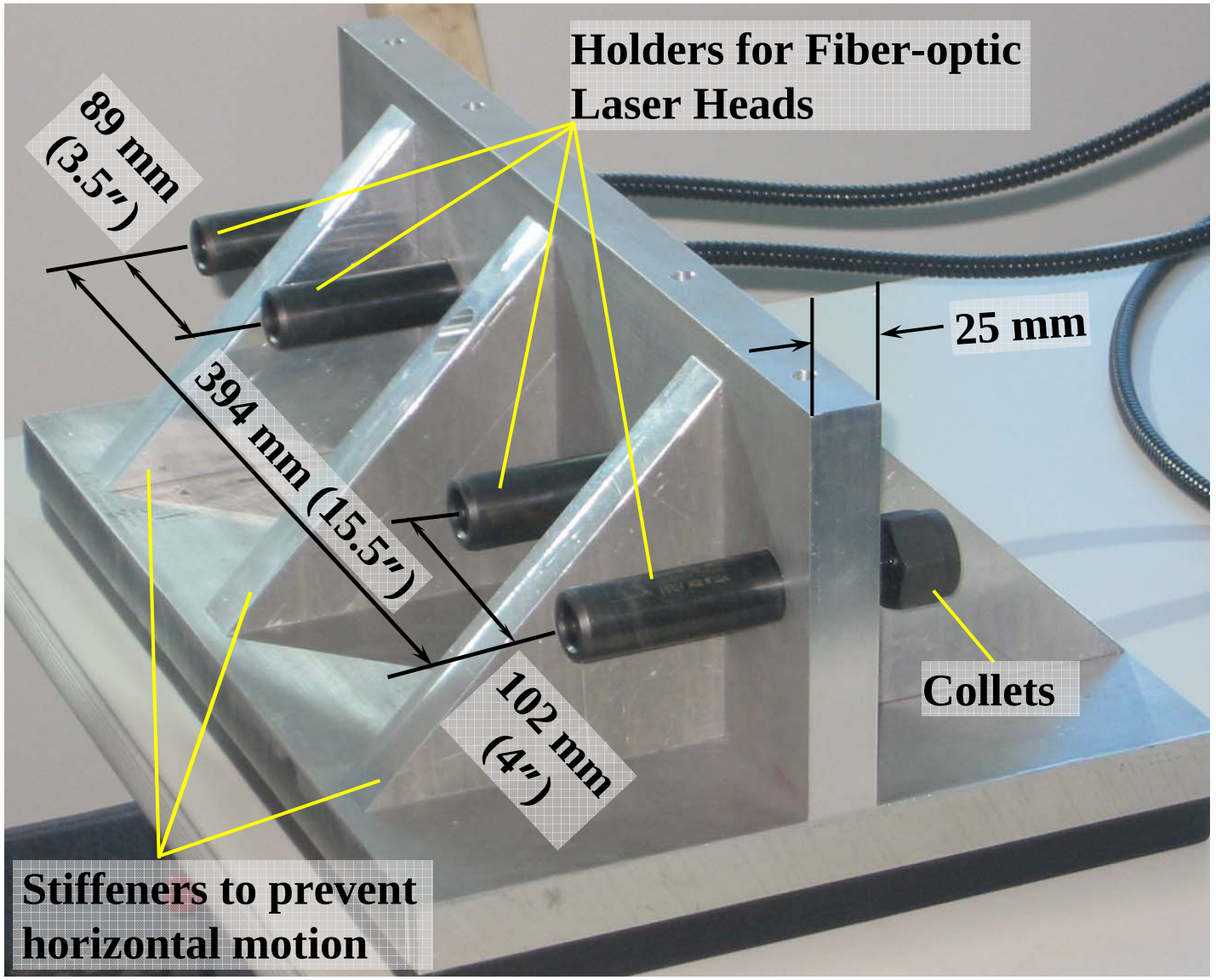
Introduction

- Two demonstration runs of the PolyTec Laser Doppler Vibrometer system were carried out at BNL earlier.
- **1st test in April'04:** nearly two orders of magnitude more vibrations of the CQS test stand seen with the laser system, as compared to typical geophone spectra. (No simultaneous geophone data acquired in this run.)
- **2nd test in August'04:** studied the influence of laser head motion. Agreements within a factor of 2 were obtained with the geophone data for 5-10 nm motion above ~20 Hz.
- The laser system was shown to be potentially useful, provided the issue of laser head motion is addressed.

Plans for Further Tests

- Further tests were planned to better characterize the laser system, paying particular attention to the problem of laser head motion.
- It was decided that the best approach will be to make differential measurements using a dual optical fiber laser head, instead of using a single beam laser head.
- Errors due to head motion are minimized, as long as the two fiber optic heads ***have the same motion***.
- A special laser mount was designed and built at BNL to carry out these tests.
- The tests were carried out at PolyTec, Inc. in Auburn, MA, on February 11, 2005.

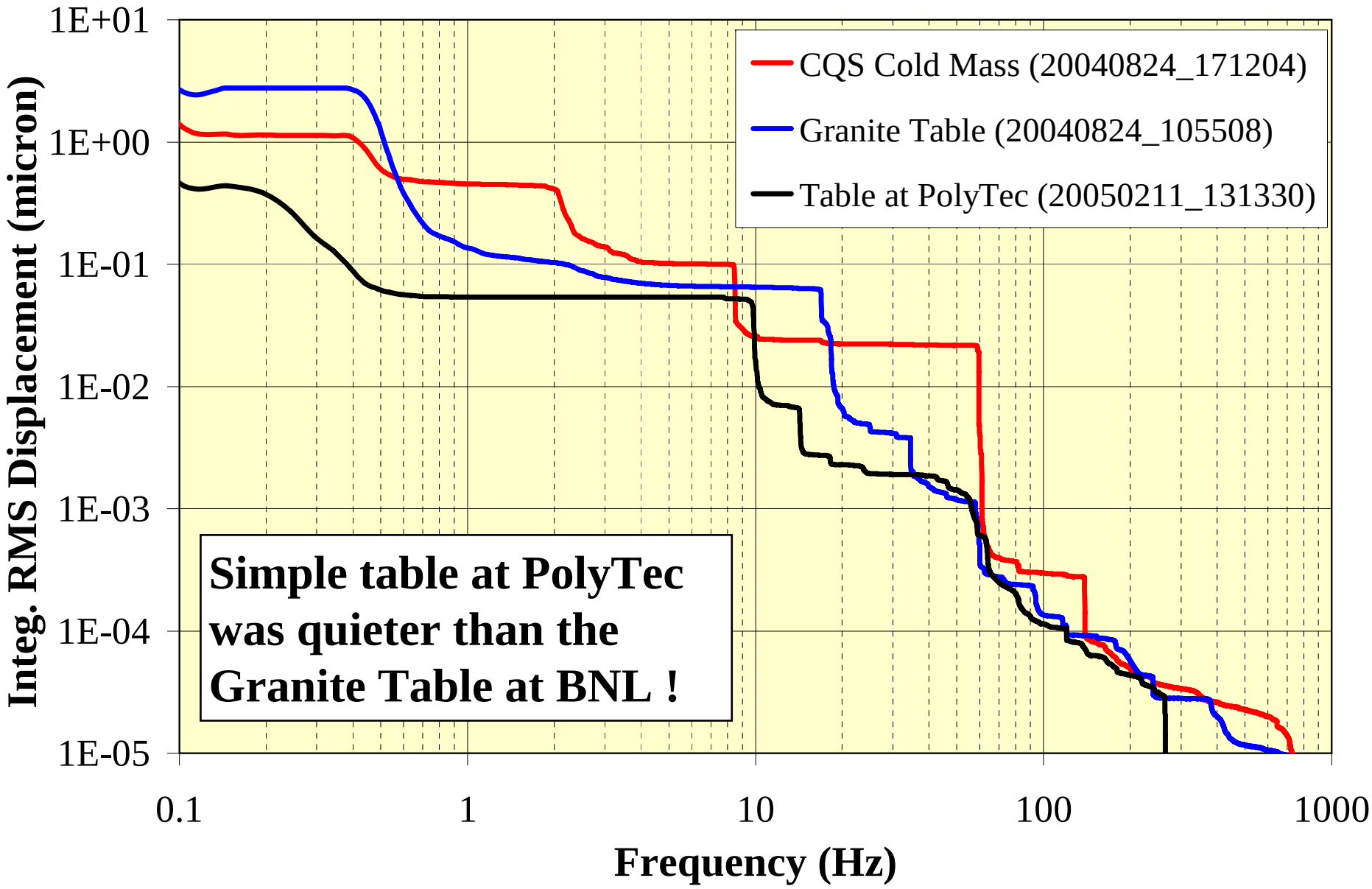
Laser Holder for Tests at PolyTec, Inc.



Improvements during Feb'05 Tests

- Quieter environment at PolyTec as compared to BNL.
- Better laser equipment was used:
  - OFV-5000 controller (OFV-3100 in Aug'04)
  - VD-06 velocity decoder (VD-02 in Aug'04)
- Fiber-optic laser heads in a custom built holder:
  - Easier to keep steady than a "big box" laser head.
- Amplifier with gain of 200X used with laser analog output (1 mm/s per Volt becomes 5 μm/s per Volt):
  - Limit bandwidth to 1 kHz
  - Improve signal to noise ratio
- Data acquisition and analysis using BNL LabView programs with improved features and user interface.

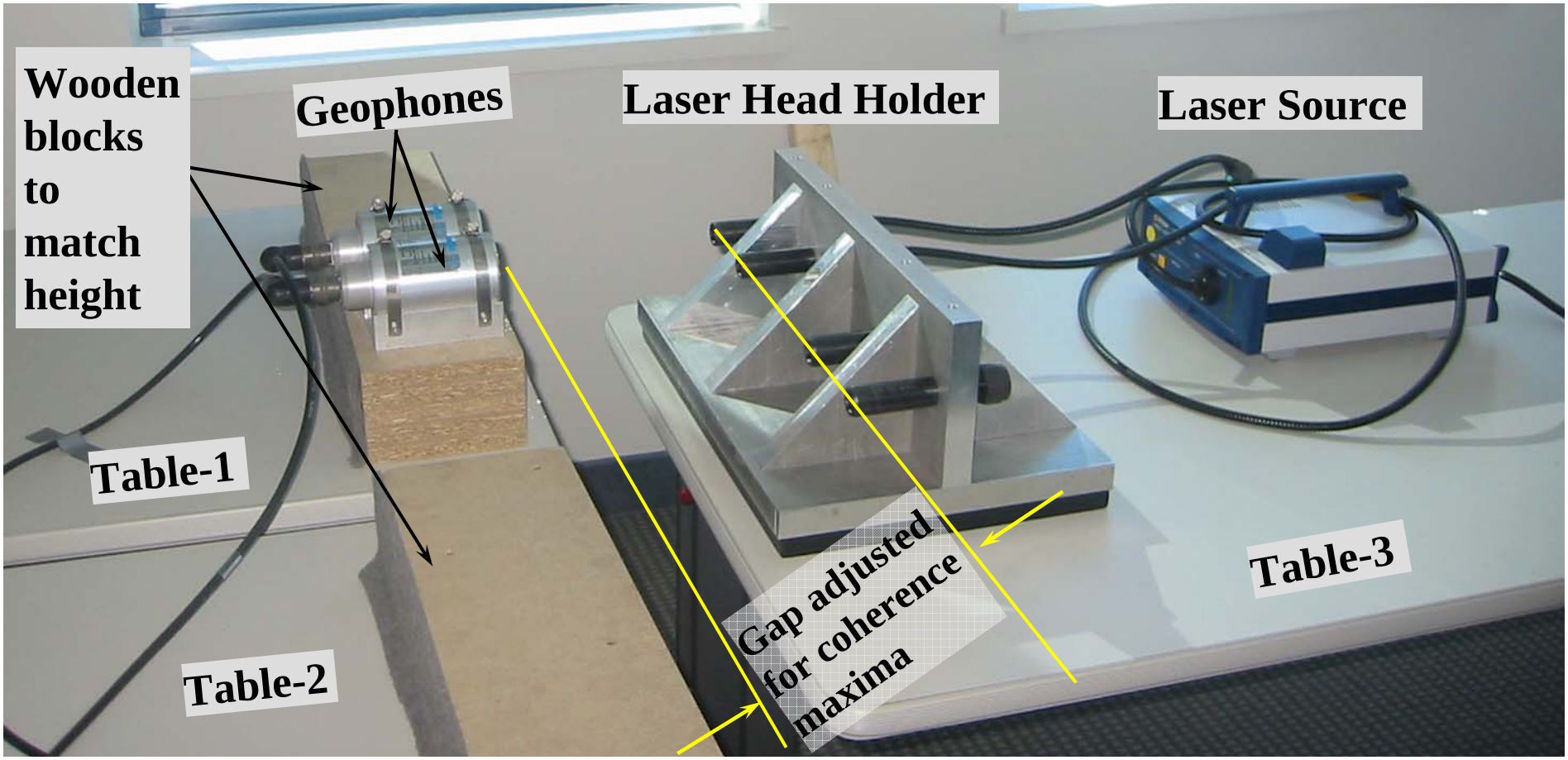
Horiz. Motion at Various Locations at BNL and PolyTec



Experimental Setup at PolyTec

- Two tables were placed side by side, with horizontal geophones.
- The laser head, along with the custom built mount, was placed on a third table nearby.
- The laser beams were set up to measure directly the faces of the geophones.
- The differential data from the laser was compared against the differential motion computed from the two geophone signals.
- The tests were carried out for two different separations of the geophones.

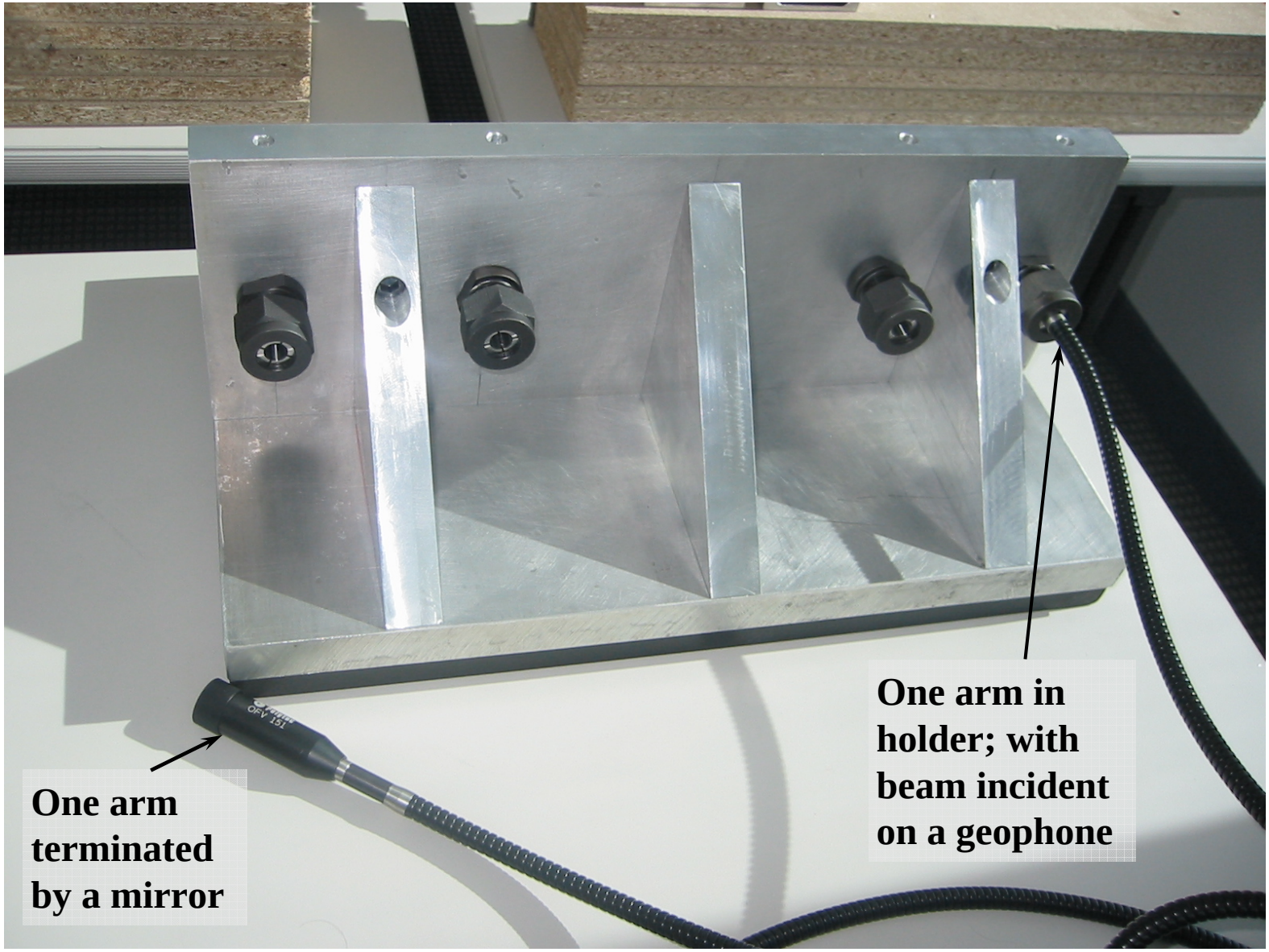
Setup for Tests at PolyTec, Inc.



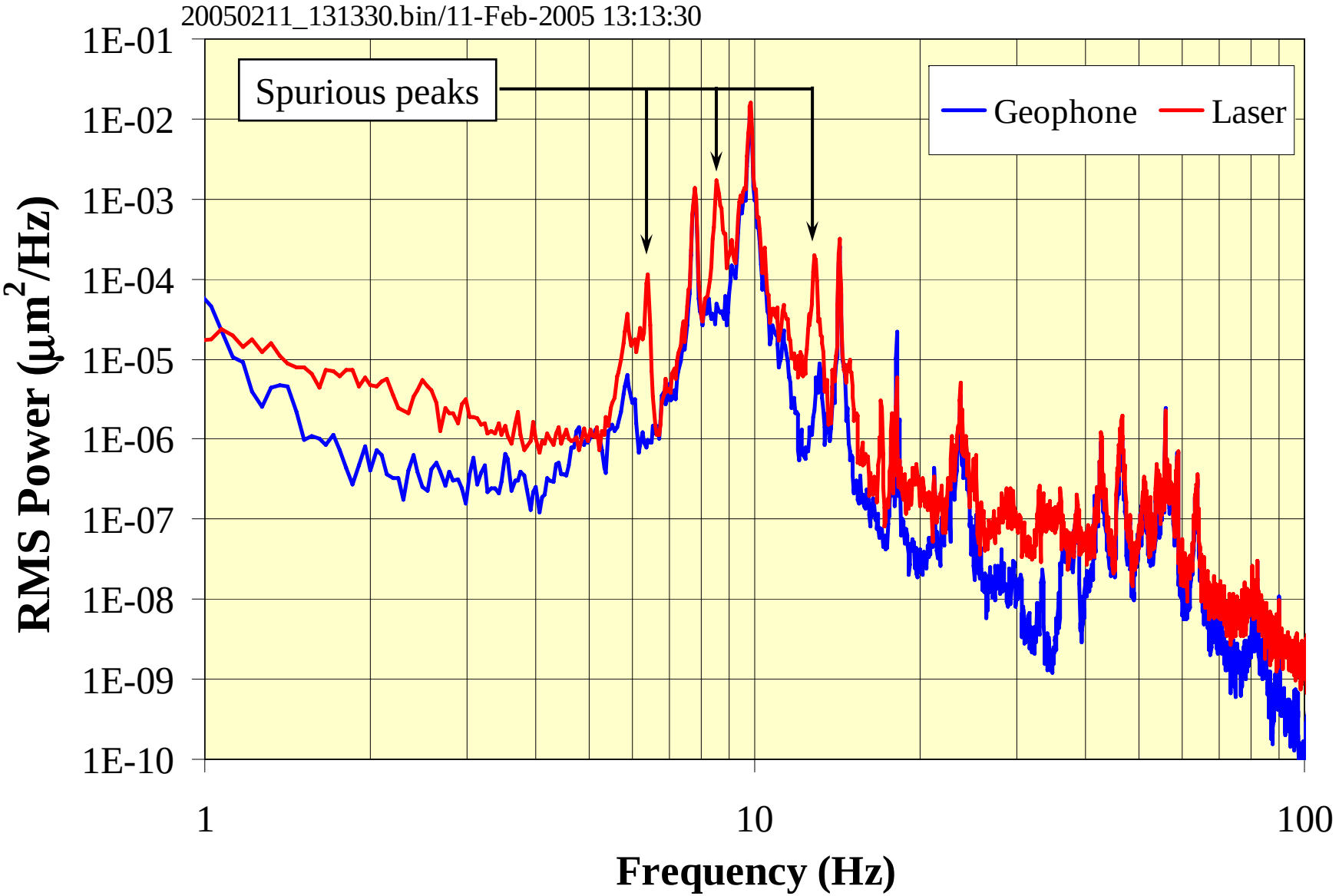
PolyTec Test #1: Single Beam Mode

- One of the fiber-optic heads was terminated by a small mirror.
- The system in this mode works as a single beam vibrometer.
- The single beam was used to measure the vibration of a single geophone.
- The spectra from the geophone and the laser output were compared.
- This test was done to verify general similarity between geophone and laser signals, and to ensure that there are no large motions of the laser holder.

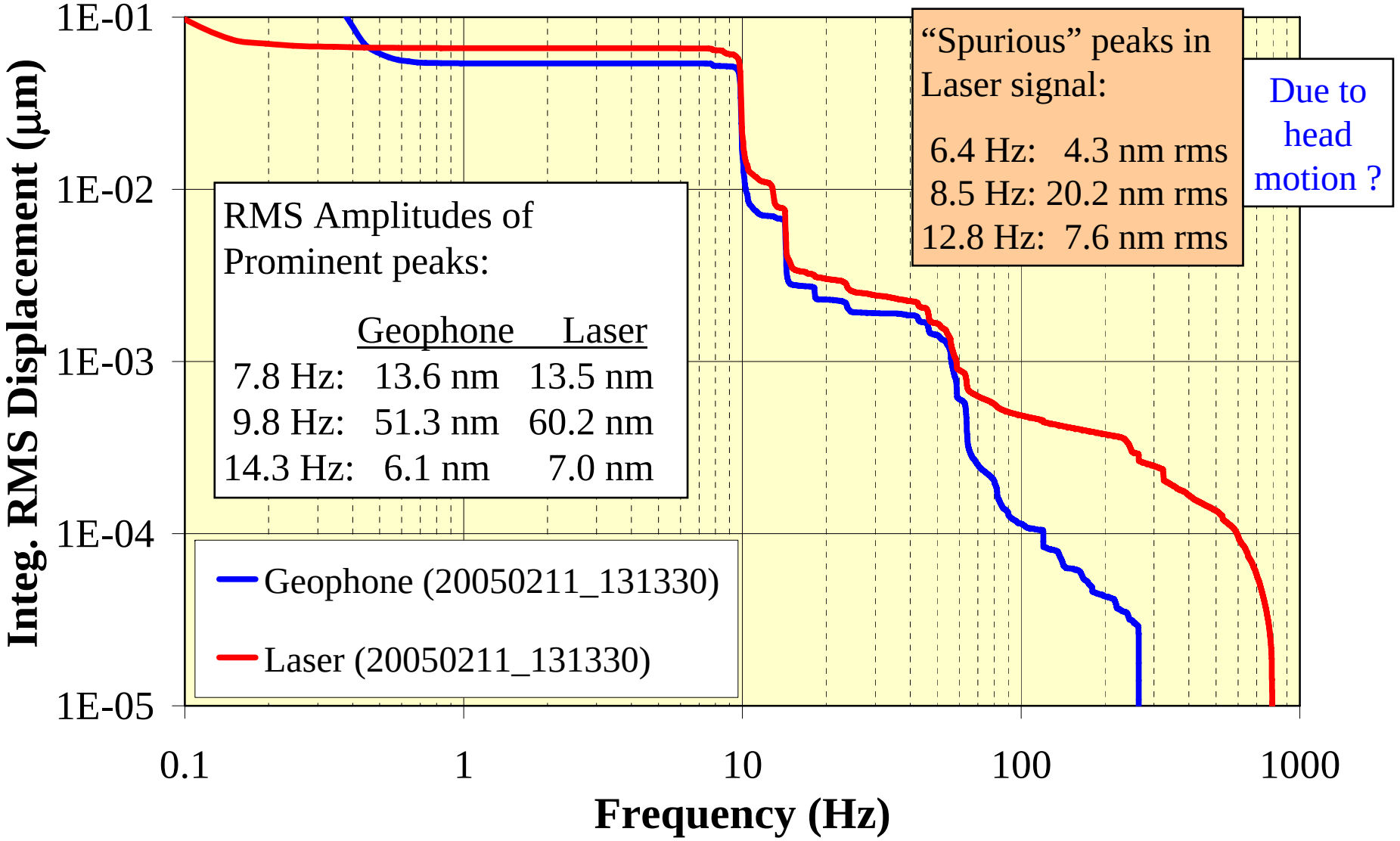
Dual Laser Head in Single Beam Mode



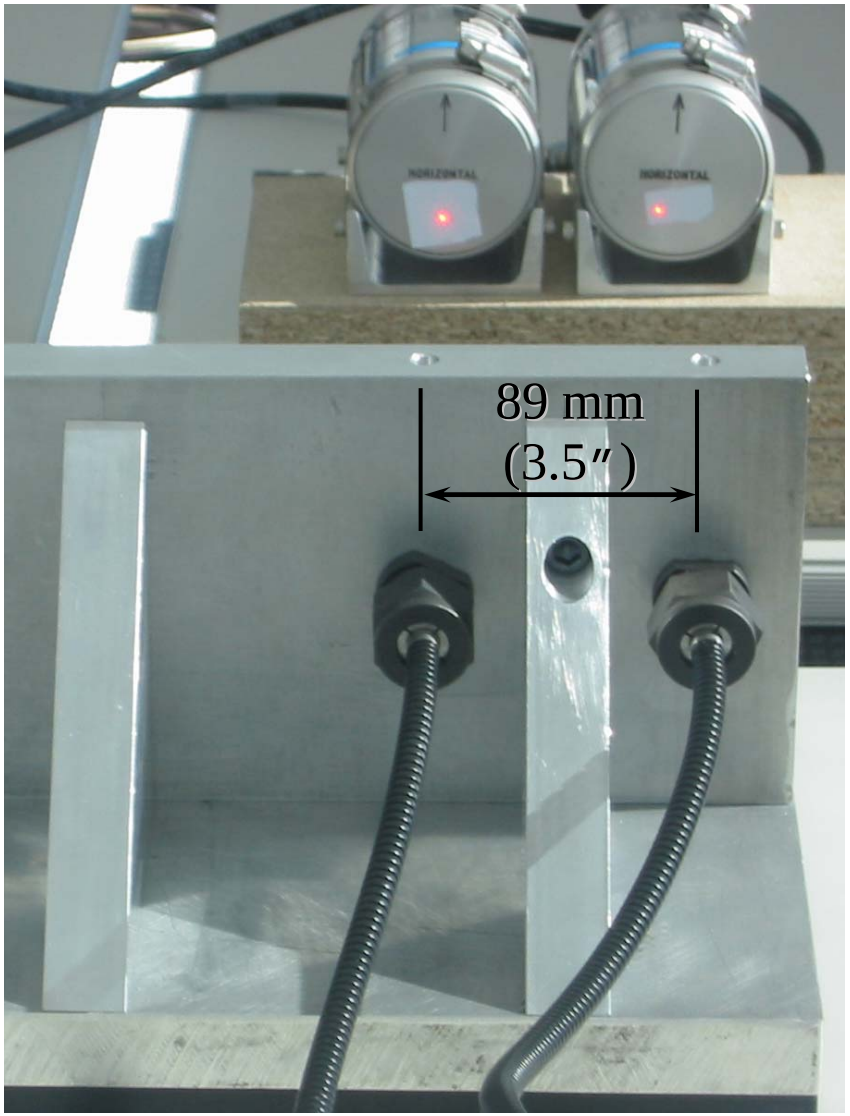
Geophone Vs. Laser in Single Beam Mode



Laser Vibrometer in Single Beam Mode Vs Geophone



Test #2: Dual Beam with small separation

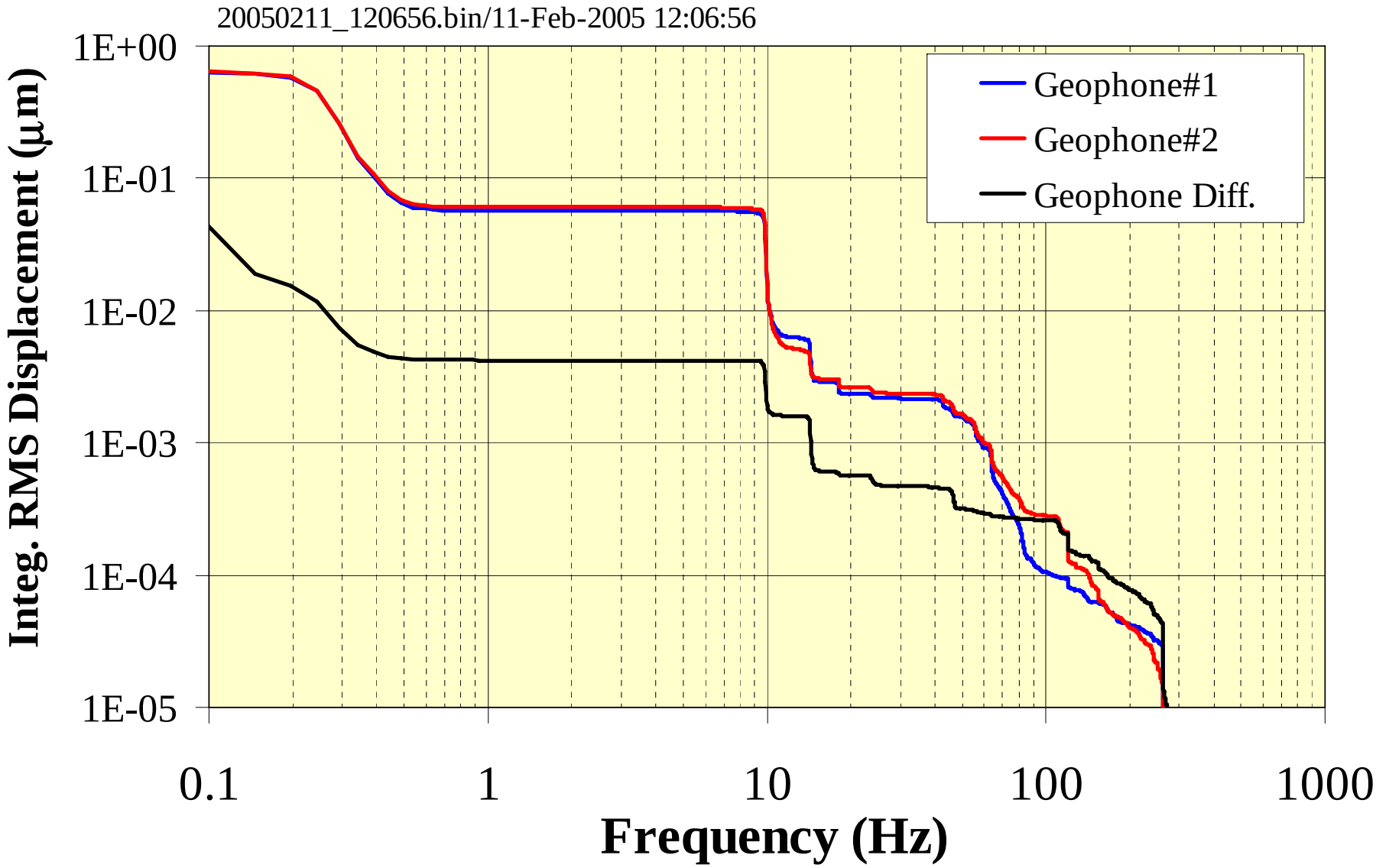


Geophones close to each other:
– good correlation
– reliable subtraction
– smaller relative motion

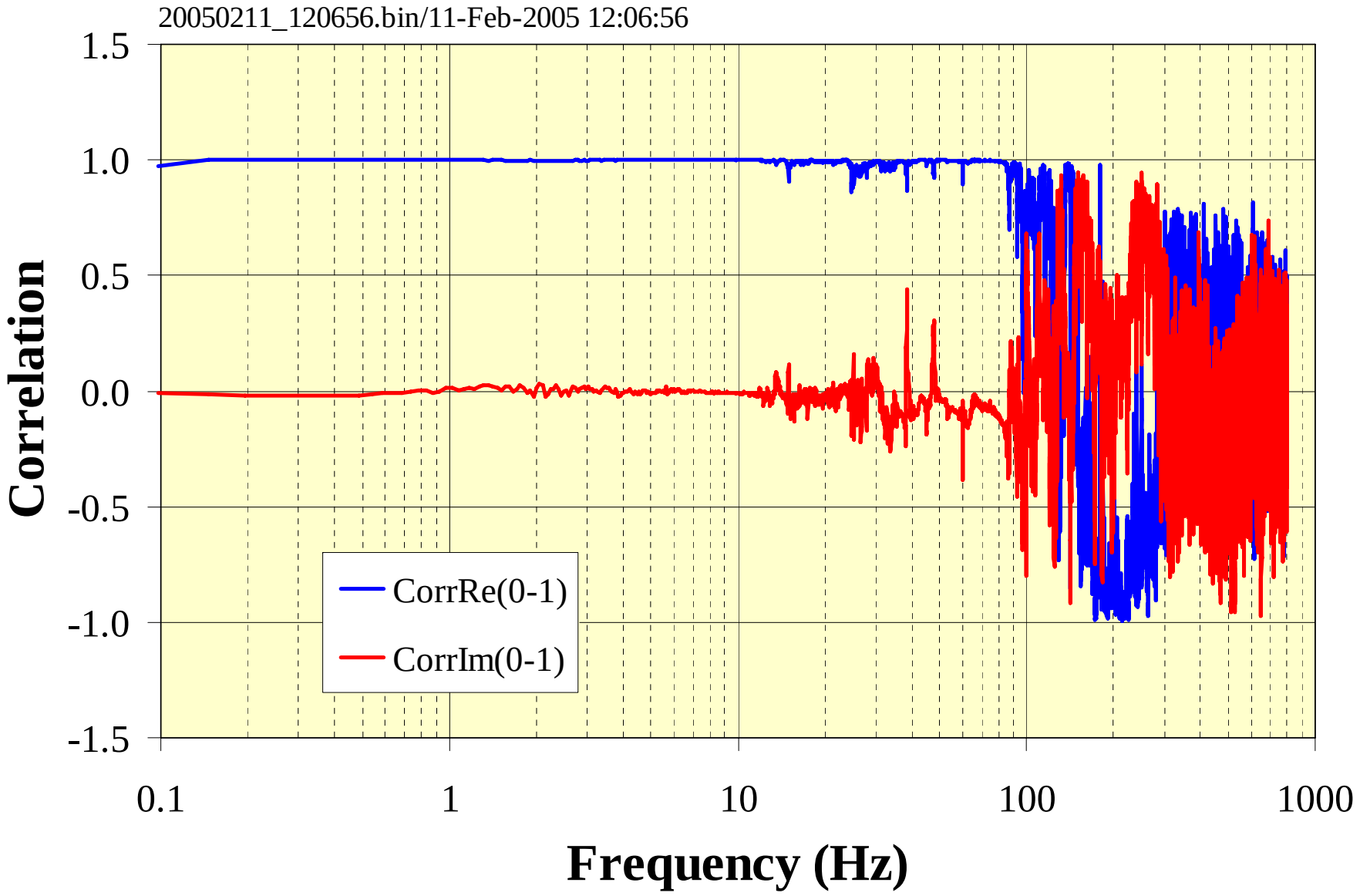
Two beams of the dual head incident on the two geophones:

Small separation ⇒ motion of the two arms are more likely to be similar.

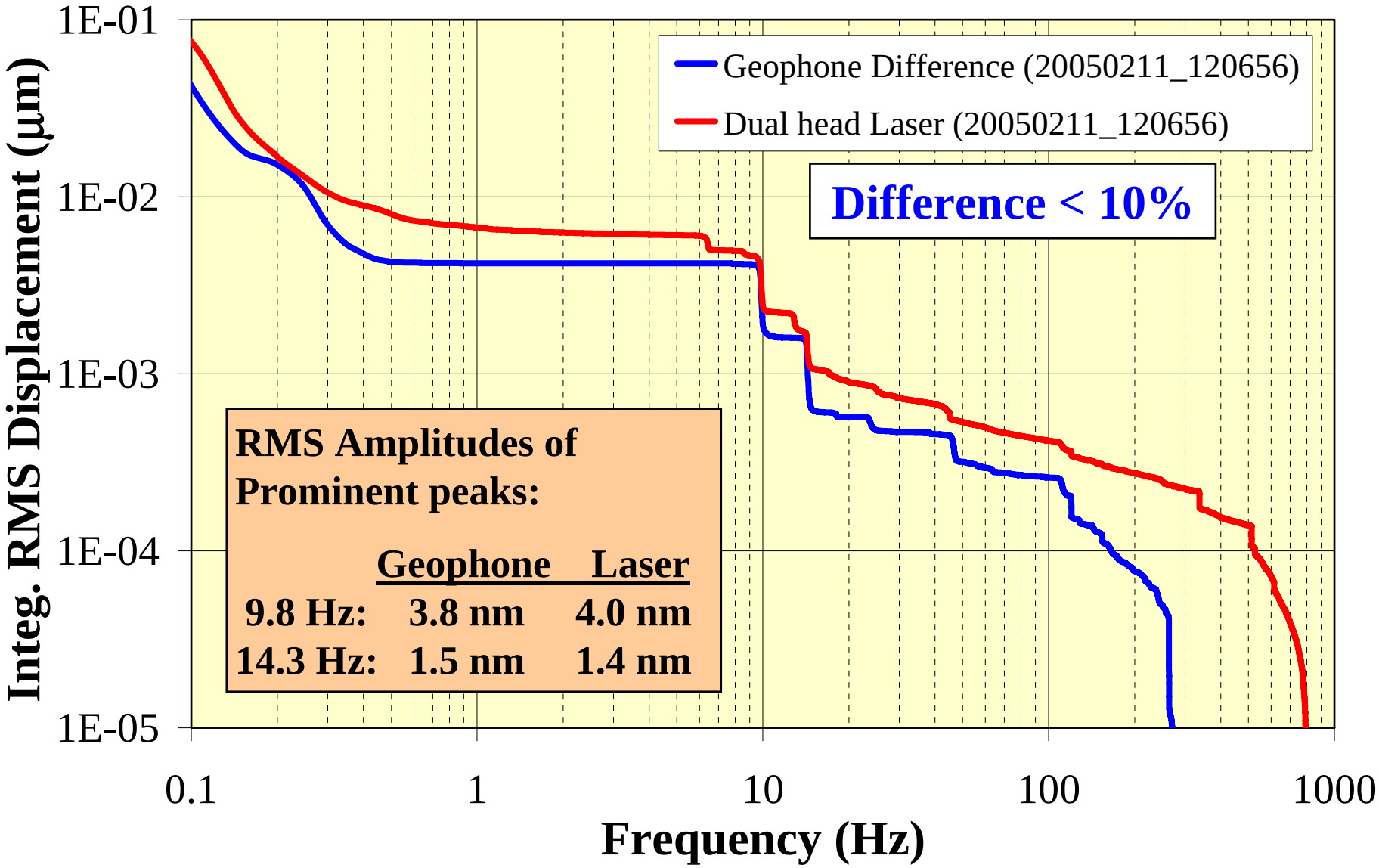
Geophone Spectra: 89 mm Separation



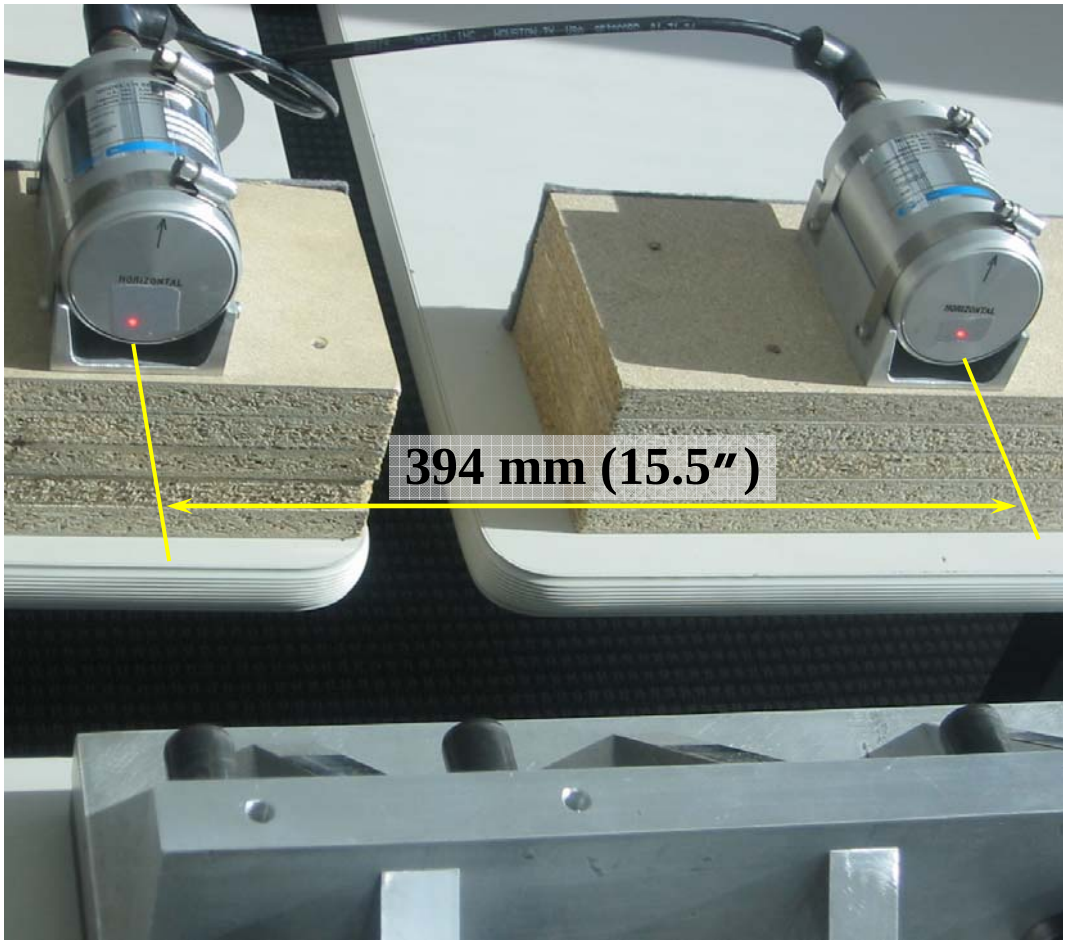
Geophone Correlation: 89 mm Separation



Geophone Vs. Laser: 89 mm Separation



Test #3: Dual Beam with larger separation

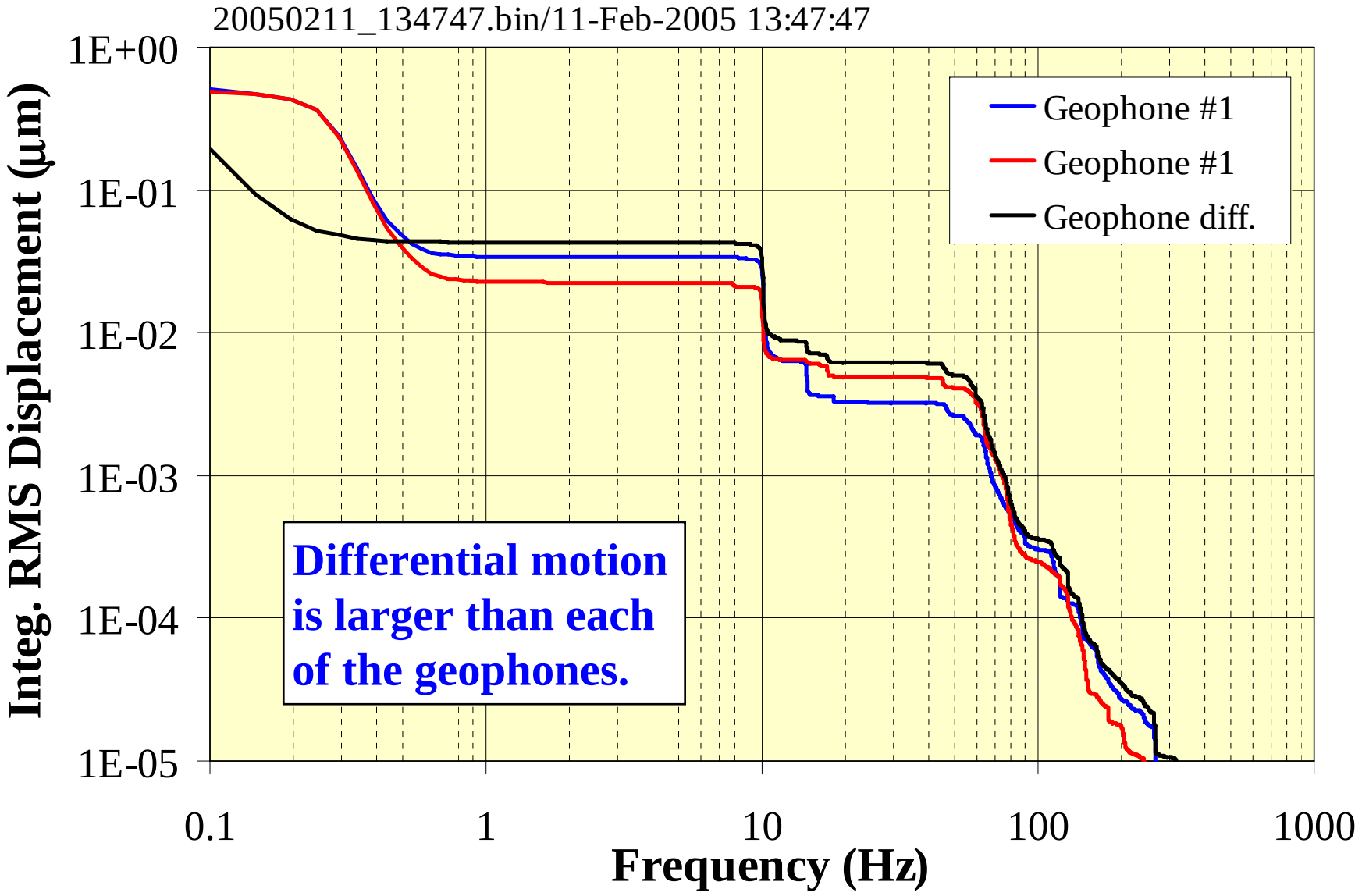


Geophones on separate tables:
– not so good correlation
– poor subtraction
– larger relative motion

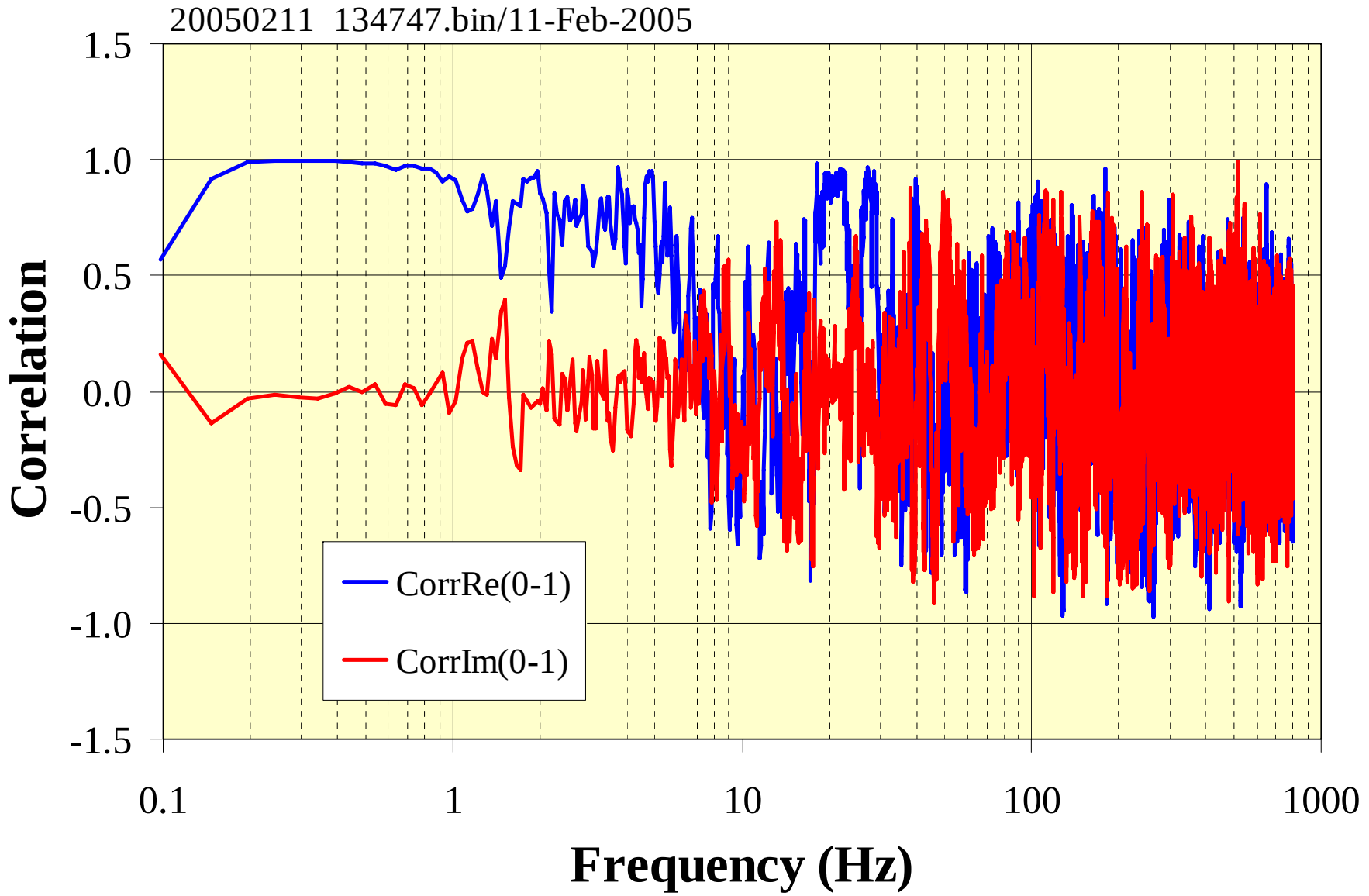
Two beams of the dual head incident on the two geophones:

larger separation ⇒ motion of the two arms may not be identical.

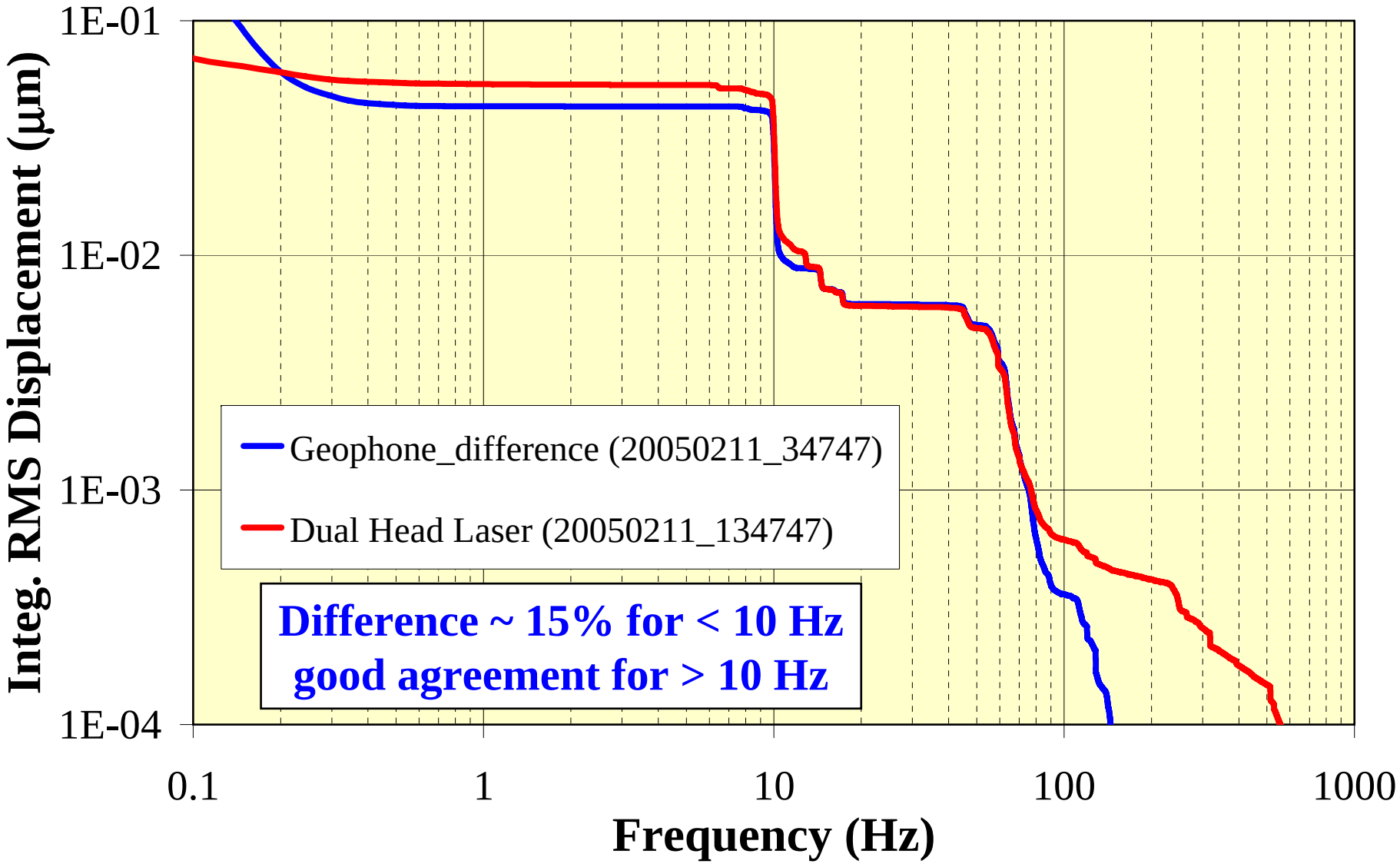
Geophone Spectra: 394 mm Separation



Geophone Correlation: 394 mm Separation



Geophone Vs. Laser: 394 mm Separation



Geophone Vs. Laser: 394 mm Separation

RMS Amplitudes of Prominent Peaks:

	Geophone	Laser
7.8 Hz:	7.7 nm	9.1 nm
8.2 Hz:	6.7 nm	8.9 nm*
10.0 Hz:	40.1 nm	47.2 nm
14.5 Hz:	4.9 nm	5.2 nm
16.2 Hz:	1.7 nm	1.7 nm
17.2 Hz:	3.1 nm	3.3 nm
18.2 Hz:	0.6 nm	0.5 nm

* Calculation affected by neighboring peaks (7.8 and 8.5 Hz)

“Spurious” Peaks in the Laser Spectra

Laser Vibrometer Tests at PolyTec, Inc. on Feb. 11, 2005

Frequency	RMS Amplitudes		
	Single Beam Mode (Run 131330)	Dual Beam Mode: 89 mm separation (Run 120656)	Dual Beam Mode: 394 mm separation (Run 134747)
6.4 Hz	4.3 nm	3.4 nm	13.5 nm
8.5 Hz	20.2 nm	1.7 nm	9.2 nm
12.8 Hz	7.6 nm	1.4 nm	5.3 nm
17.0 Hz	0.8 nm	0.3 nm	1.9 nm

Spurious peaks appear to be due to head motion, which is compensated to a great extent in the differential mode, particularly at the smaller separation.

Summary

- Good agreement between geophone data and the PolyTec dual beam Laser Doppler Vibrometer system has been demonstrated.
- Dual beam system used in a single beam mode, in conjunction with geophone data, could give an indication of spurious peaks, possibly due to head motion.
- Spurious peaks are significantly suppressed in the differential mode, particularly at smaller separations.
- The laser spectra have higher background above 100 Hz. Perhaps a better filtering is needed to cut-off higher frequencies.
- No further evaluations of the laser system are deemed necessary at this point.