Fit-Based Analysis of PDV Data

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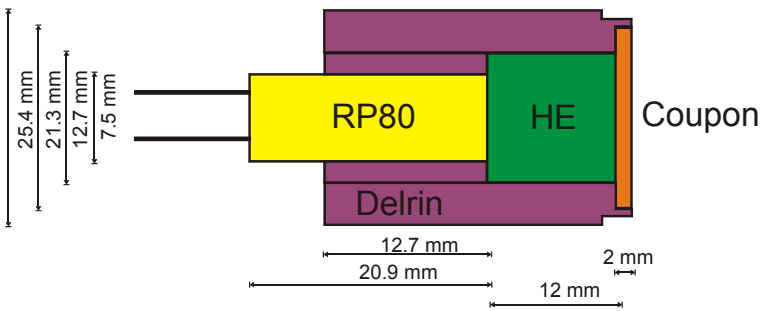
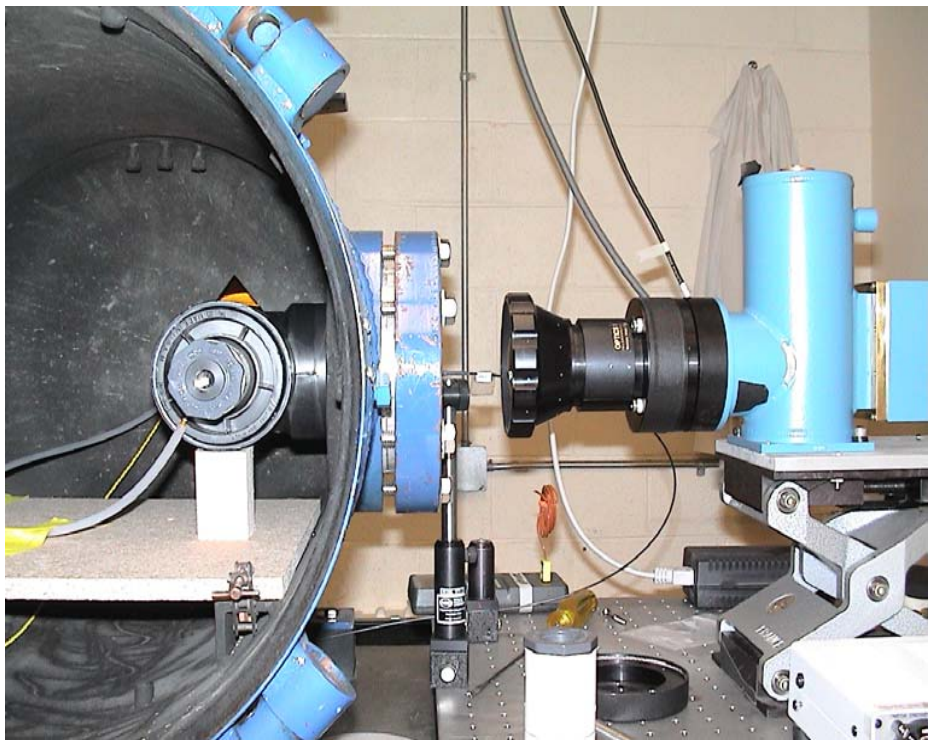
PDV Sample Data: Shot Details

- Molybdenum coupon, 40 mm dia. x 1.56 mm thick
  - Polished outer surface
  - Collaboration with Sarah Stewart-Mukhopadhyay (Harvard)
- PBX 9501 explosive





PDV: Implementation

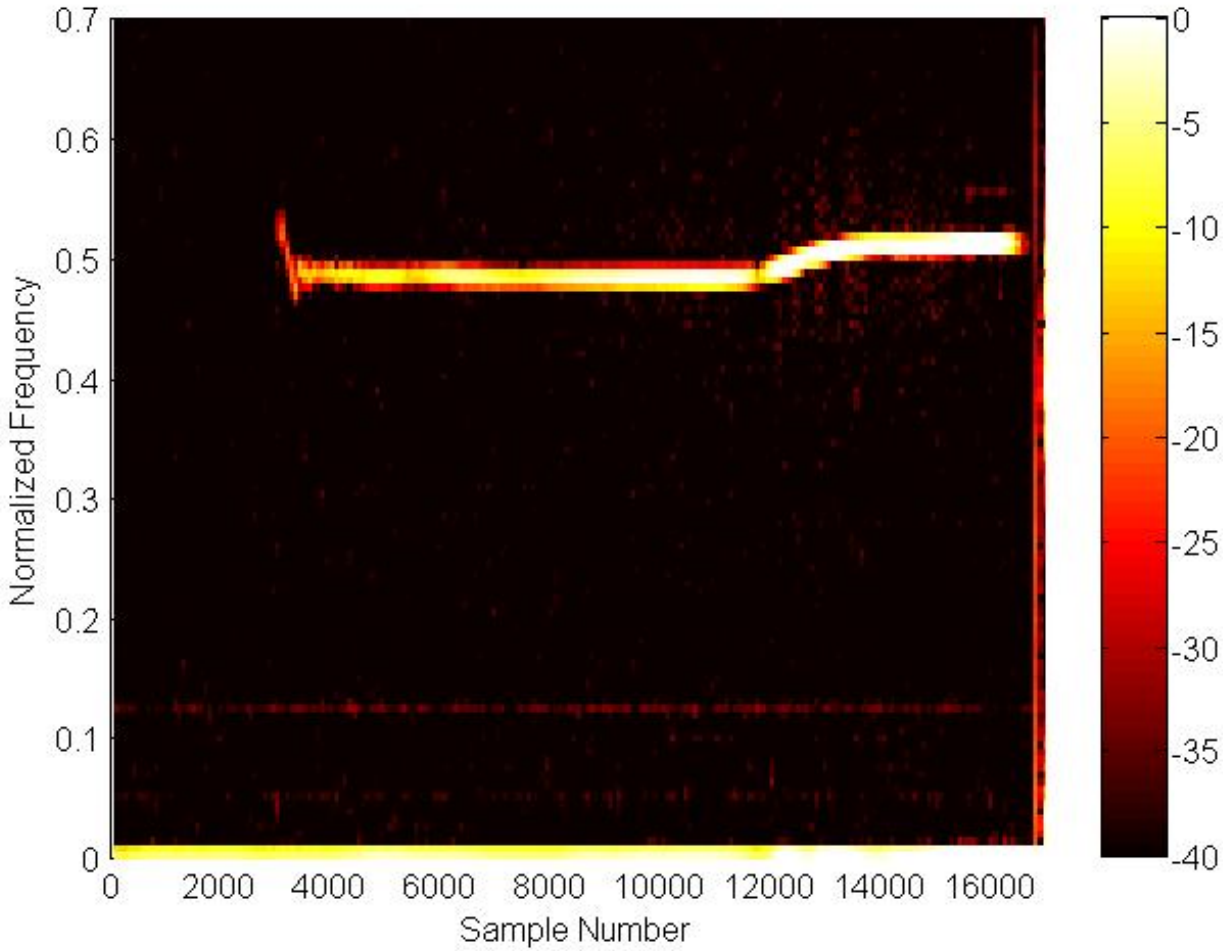
- DFB-pumped EDFA laser
  - 250 mW
  - 1550.000 nm ± 0.3 nm absolute accuracy, ± 0.005 nm wavelength stability shot-to-shot → 200 ppm accuracy
- Single mode fiber
  - 9 μm core/125 μm cladding SMF-28 fiber
  - 6° angle polish
  - Narrow hypodermic needle for support – 0.018" o.d.
  - 5 – 16 mm initial standoff from surface
- Adjustable retroreflector for unshifted light – -3 dBm
- Miteq detector – 13 GHz bandwidth
- Textronix TDS6604 oscilloscope
  - 6 GHz analog bandwidth
  - 20 Gsamples/s, 50 ps/point

PDV Data: Methods of Analysis

- Need to transform amplitude v. time to frequency (velocity) v. time
- Usually use Gabor transform – Short Time Fast Fourier Transform (STFFT)
  - Bin the data by time
  - FFT on each data bin
  - Gives time and frequency resolution
- Compare to:
  - Forward analysis
  - Moving fit

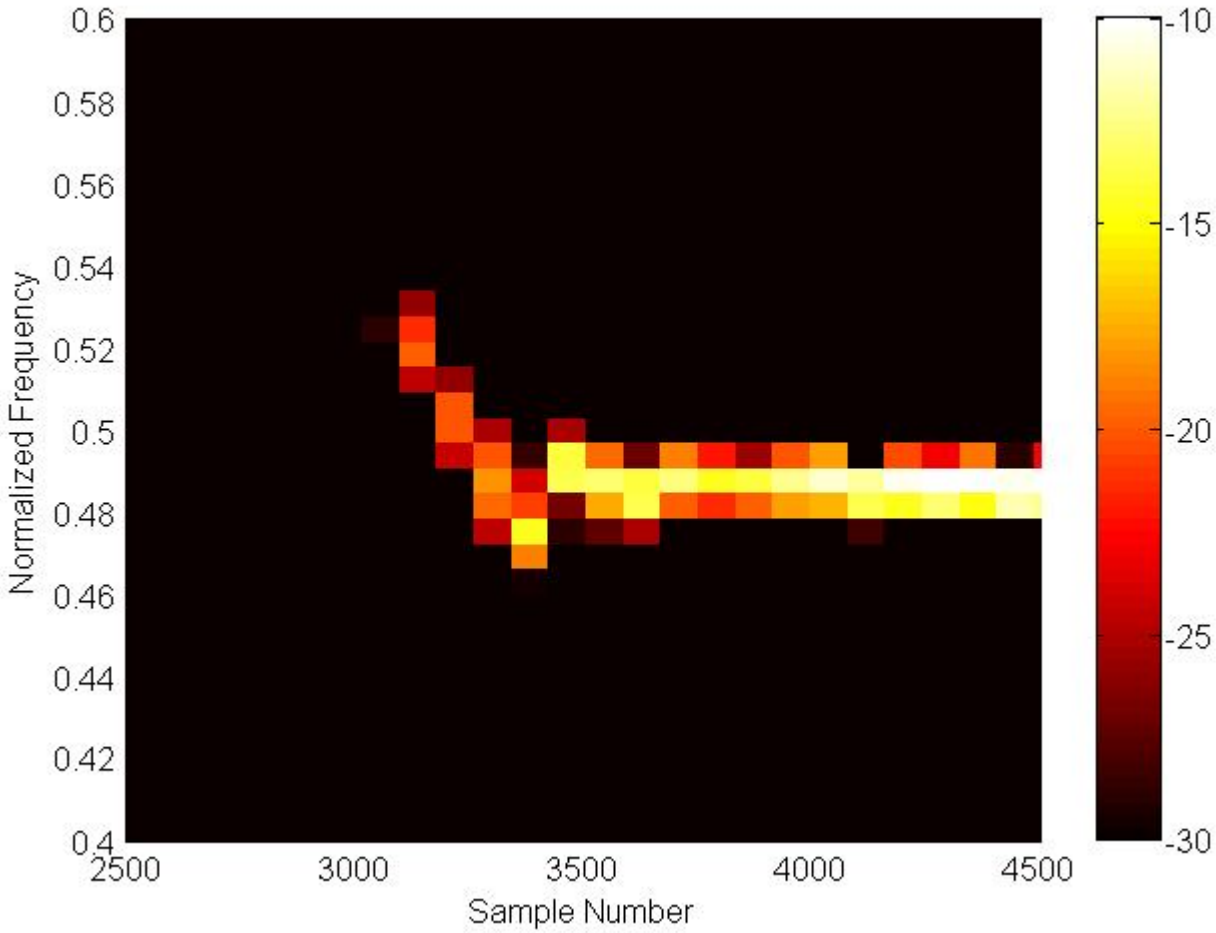
PDV Sample Data: Spectrogram

1024 pts.
50% overlap
Hamming
window



PDV Sample Data: Pullback and Ringing

1024 pts.
50% overlap
Hamming
window



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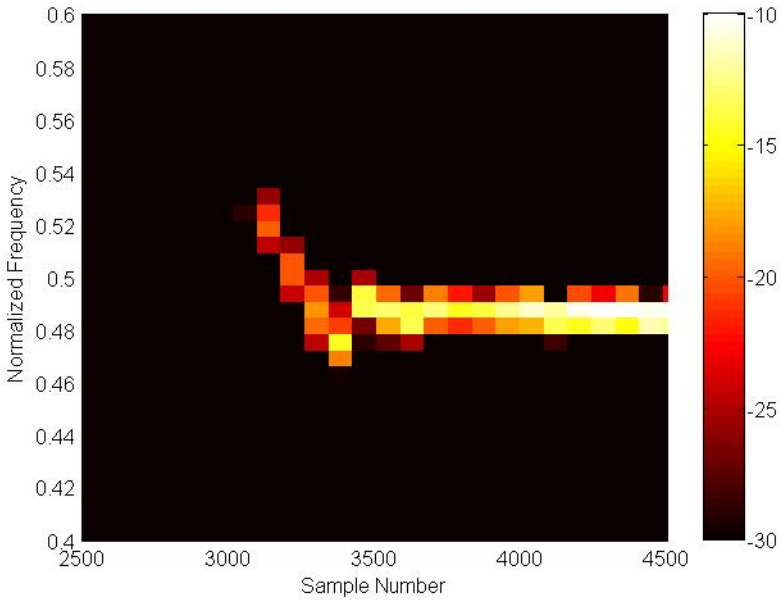
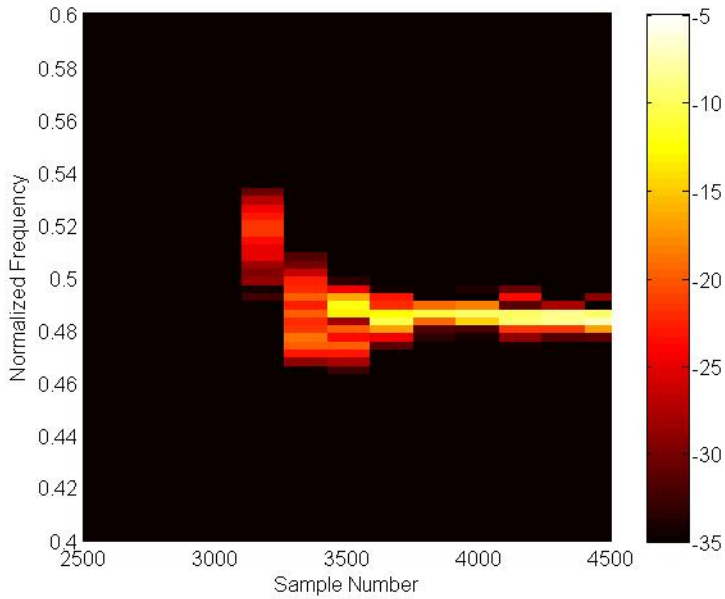
STFFT: Tradeoffs

- FFT uses bins of 2^N points
  - Larger bins → better frequency resolution
  - Smaller bins → better time resolution
  - Overlap solves some problems
- No clear recipe for maximum resolution
- Accuracy as well as precision problems (possibly)

STTFT Tradeoff: Example

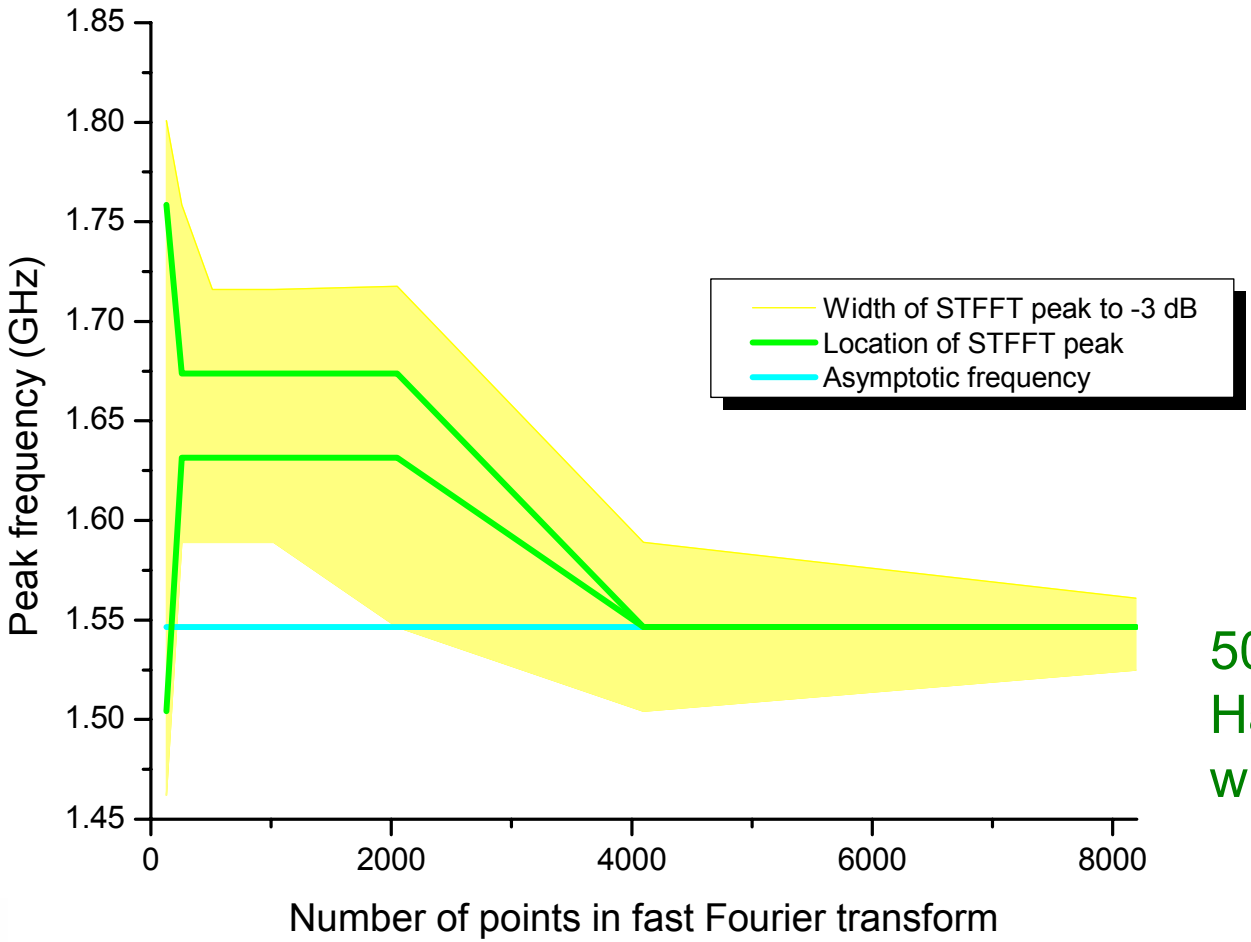


1024 points



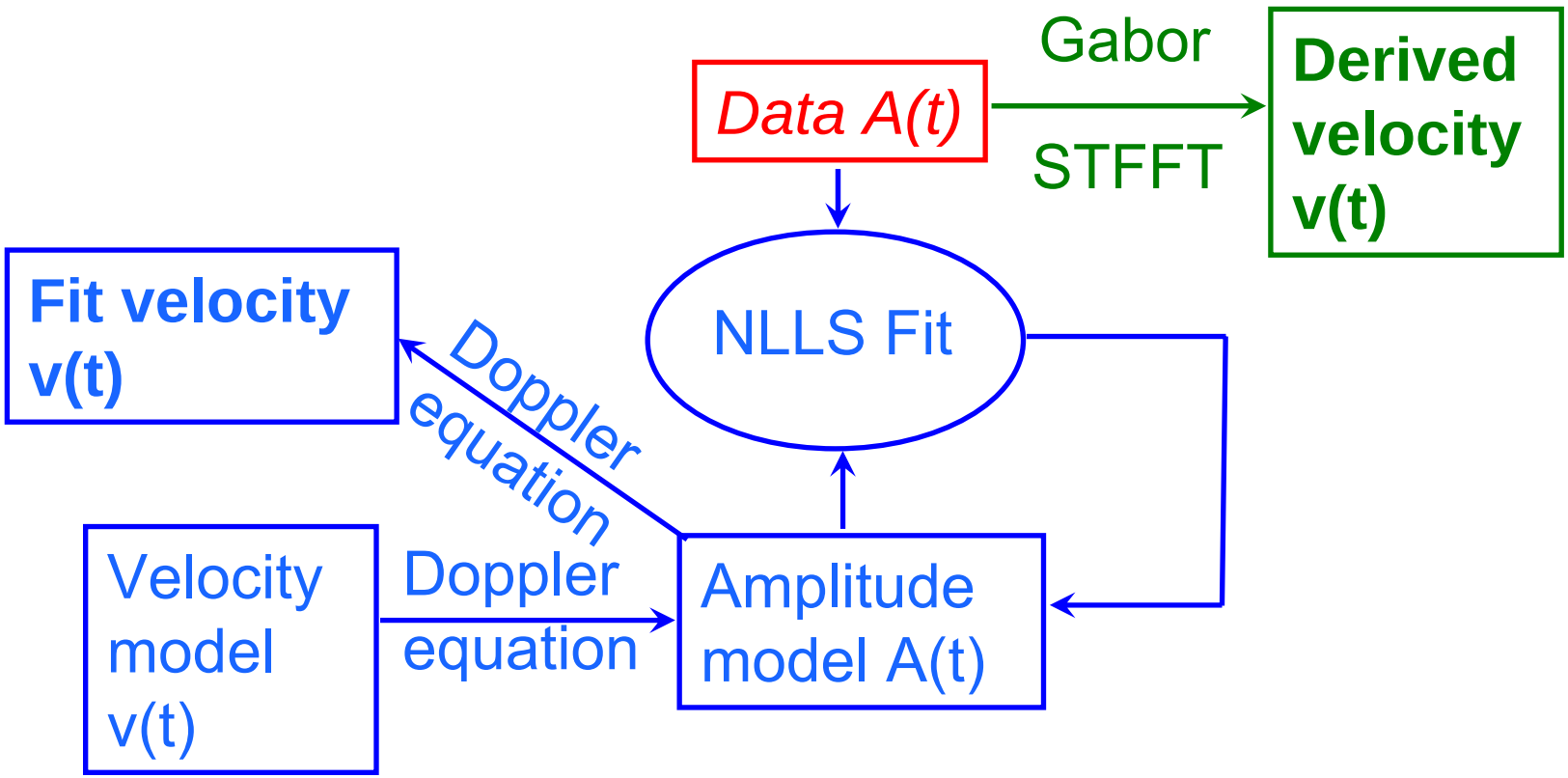
2048 points

STFFT : Precision *and* Accuracy Problems?



50% overlap Hamming window

Forward Analysis: Concept



Forward Analysis: Execution

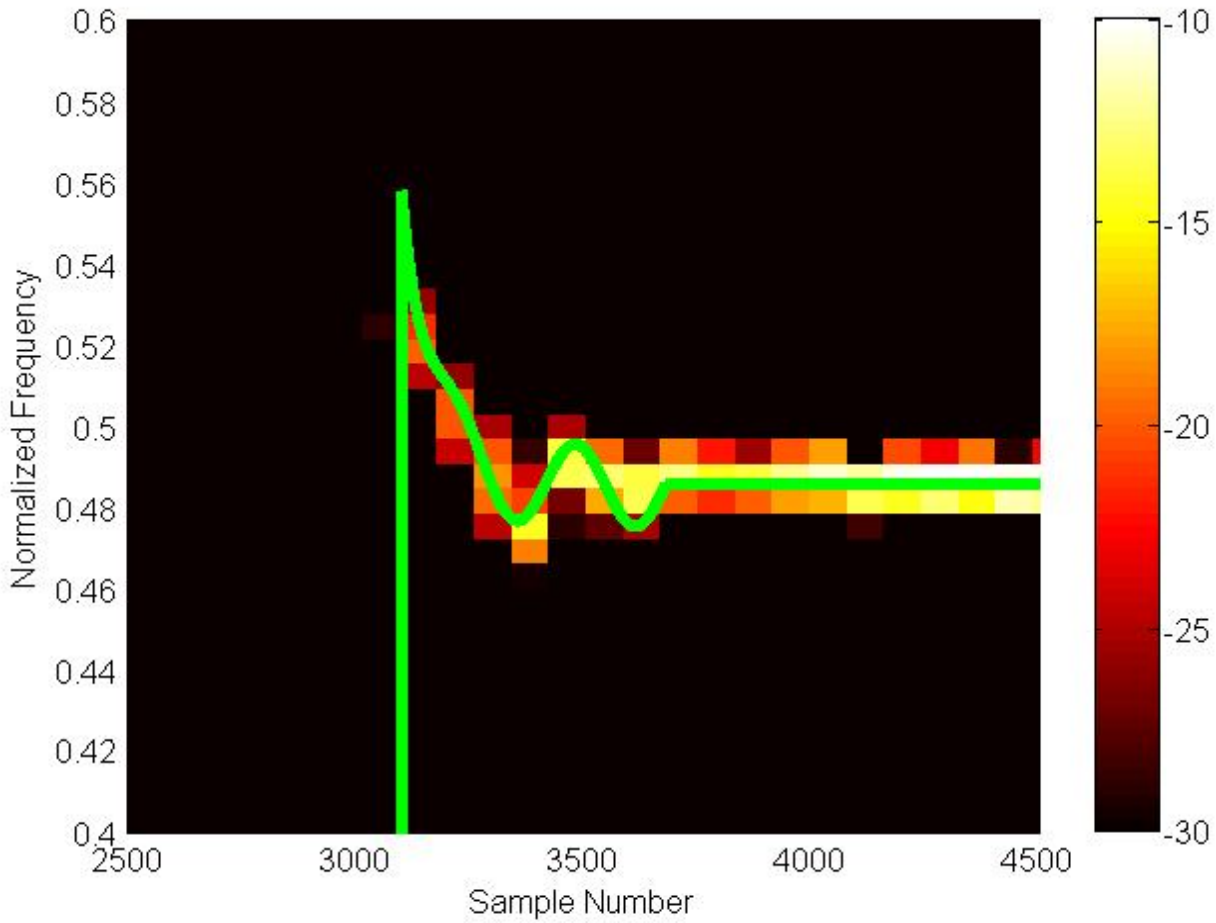
Modeled Feature	*Modeling Function*	*Adjustable Parameters*
Precursor wave	Two linear functions	Starting positions (and phase sin time domain), slopes, intercepts
Shock wave	Heaviside function	Starting position (and phase in time domain), amplitude
Pullback	Exponential decay	Starting position, amplitude, decay rate
Ringing	Single cycle sine wave	Starting position, ending position, amplitude, frequency, phase, decay rate
Probe impact	Heaviside function	Position (output forced to zero after this time)
Harmonics	All of above	Integer frequency multiple, amplitude (held constant over all harmonics)

Forward Analysis: Execution

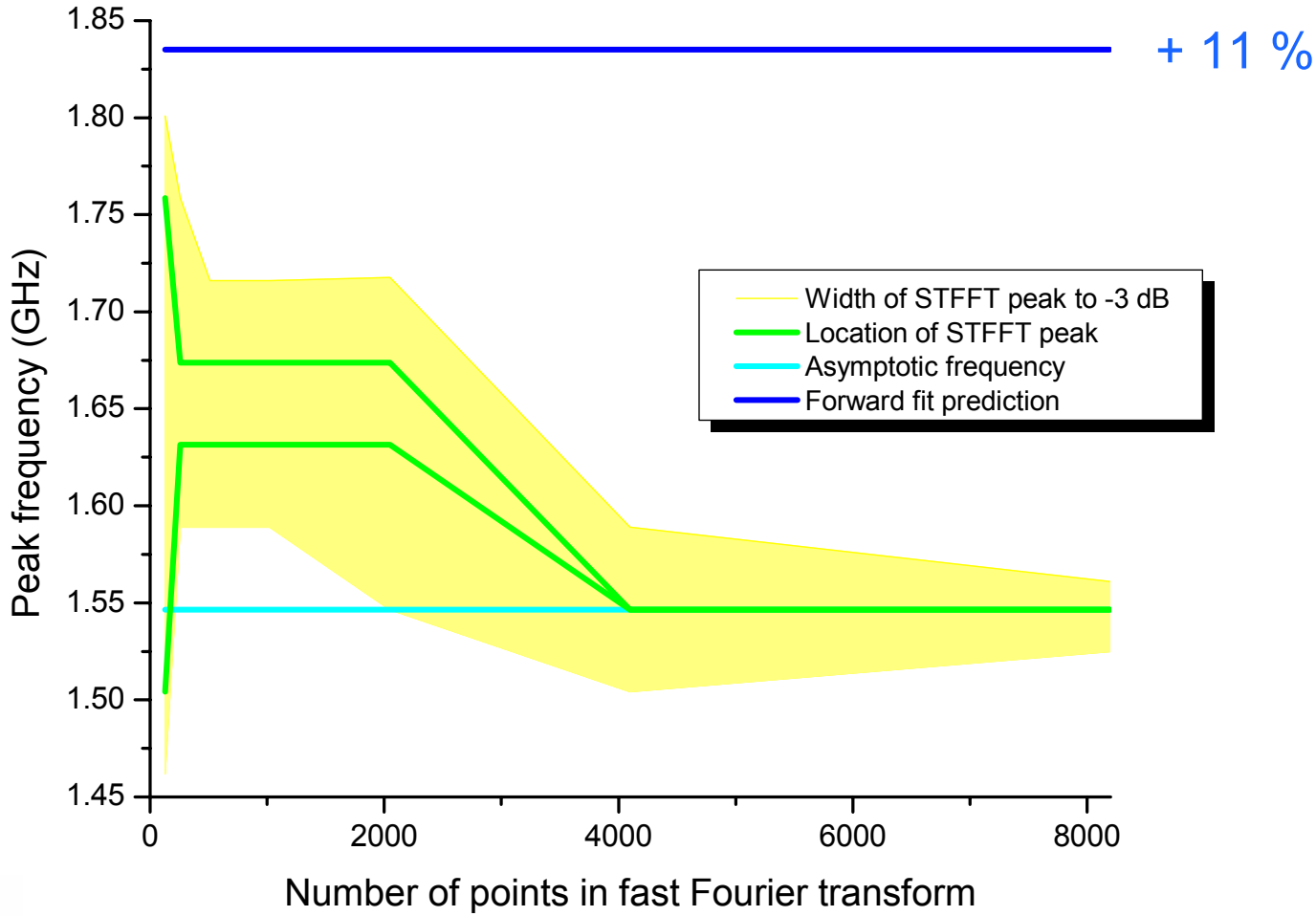
- Implemented on 2 GHz Pentium, Windows XP Professional
- Optimization in MATLAB (MathWorks) with Curve Fitting and Optimization Toolboxes
  - Data were composited from two coverages, trimmed after probe impact, and then centered around the baseline and normalized to $-1 \leq$ data ≤ 1
  - Data were then filtered by 10-pole Chebyshev II IIR filter with 1 MHz to 3 GHz passband and recentered and normalized
  - Nonlinear least squares Levenberg-Marquardt algorithm for fitting
  - Initial guesses generated from FFT or *a priori*

Forward Analysis: Example

Robust Levenberg-Marquardt algorithm



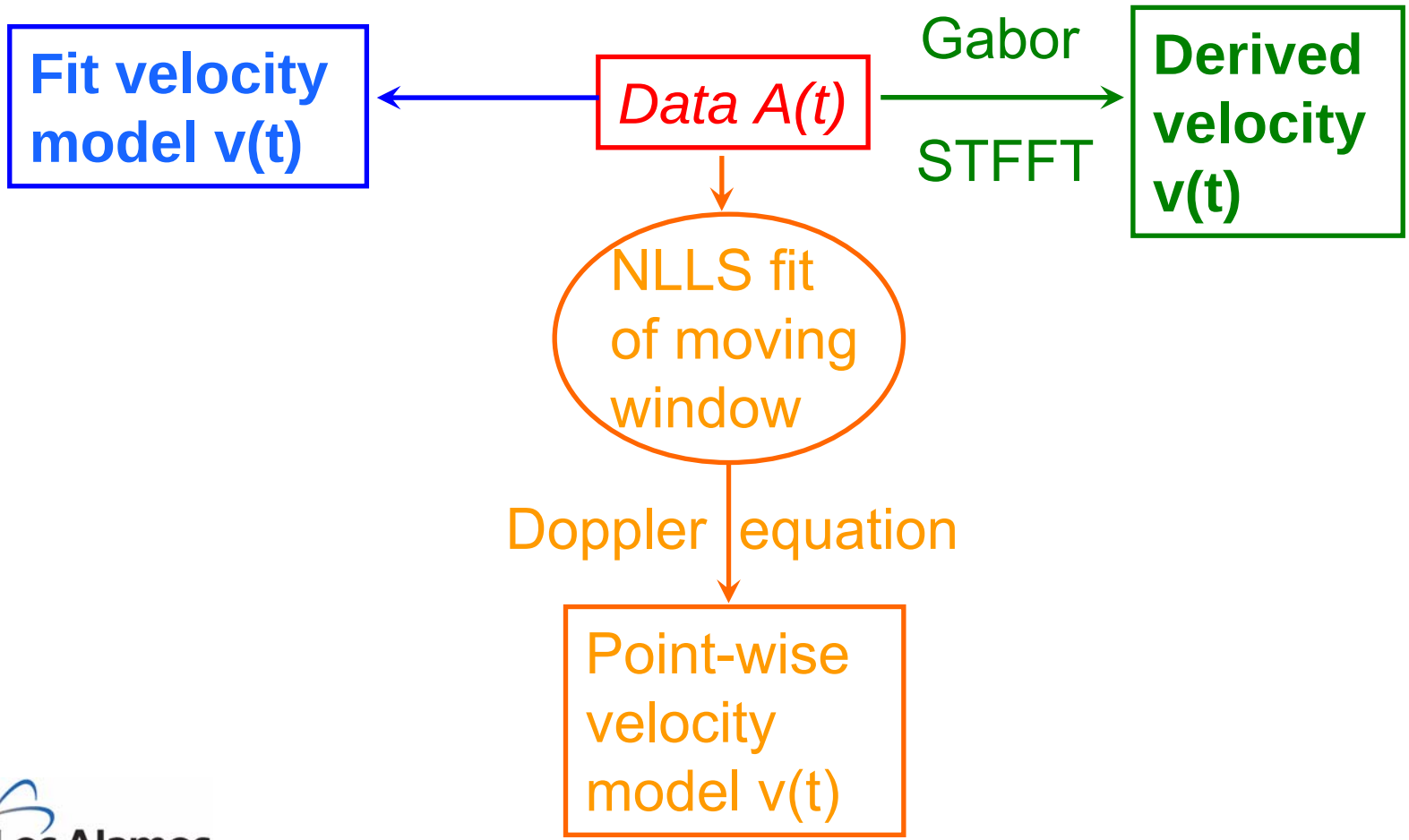
Forward Fit Analysis: Accuracy?



Forward Analysis: Speed

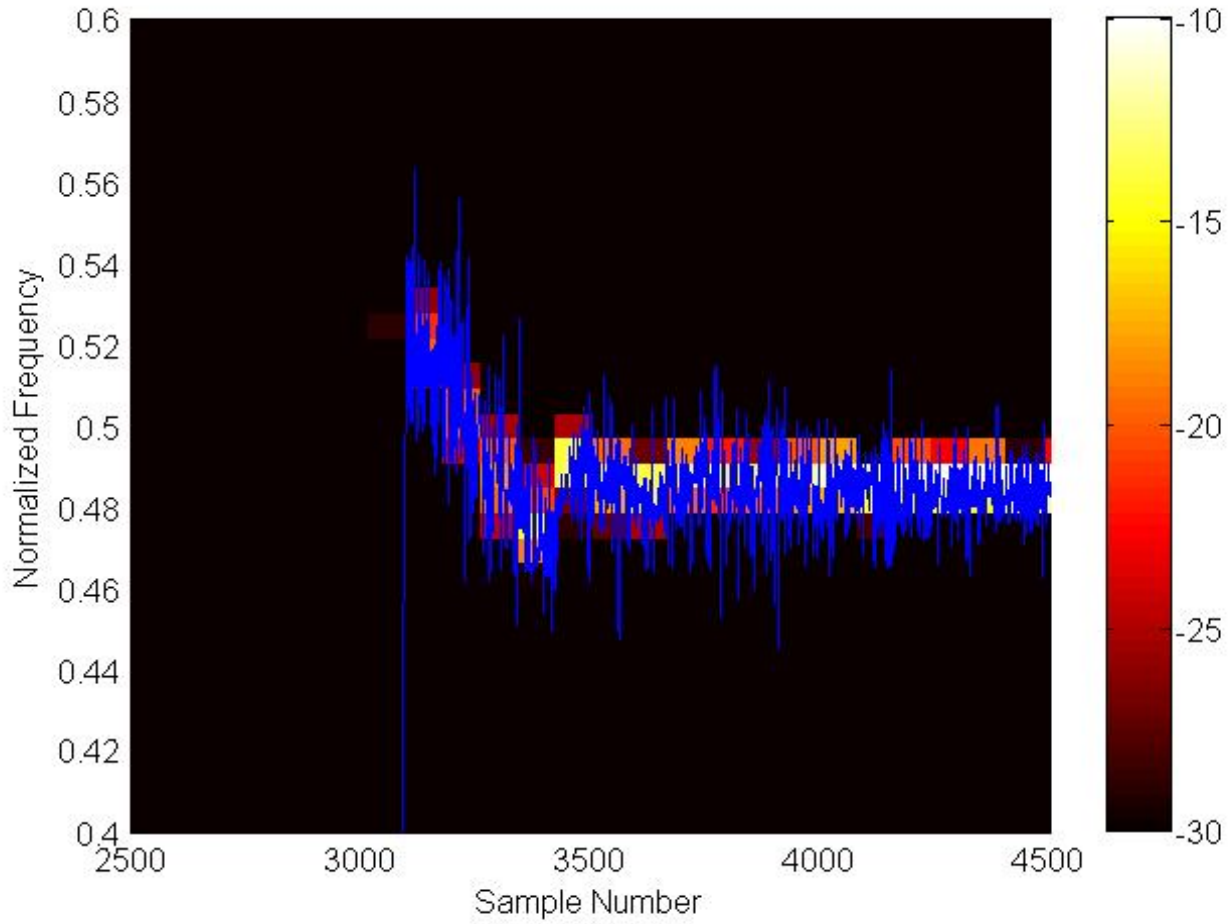
Method	*Time Required*
STFFT spectrogram	5 seconds
Forward fit, FFT results as initial guess, fit constant velocity only	1 hour
Forward fit, as above fitting all components except harmonics	2 hours
Forward fit, as above fitting all components	2.5 hours
Full fit, as above with *a priori* initial guess	4 hours

Moving Fit Analysis: Concept

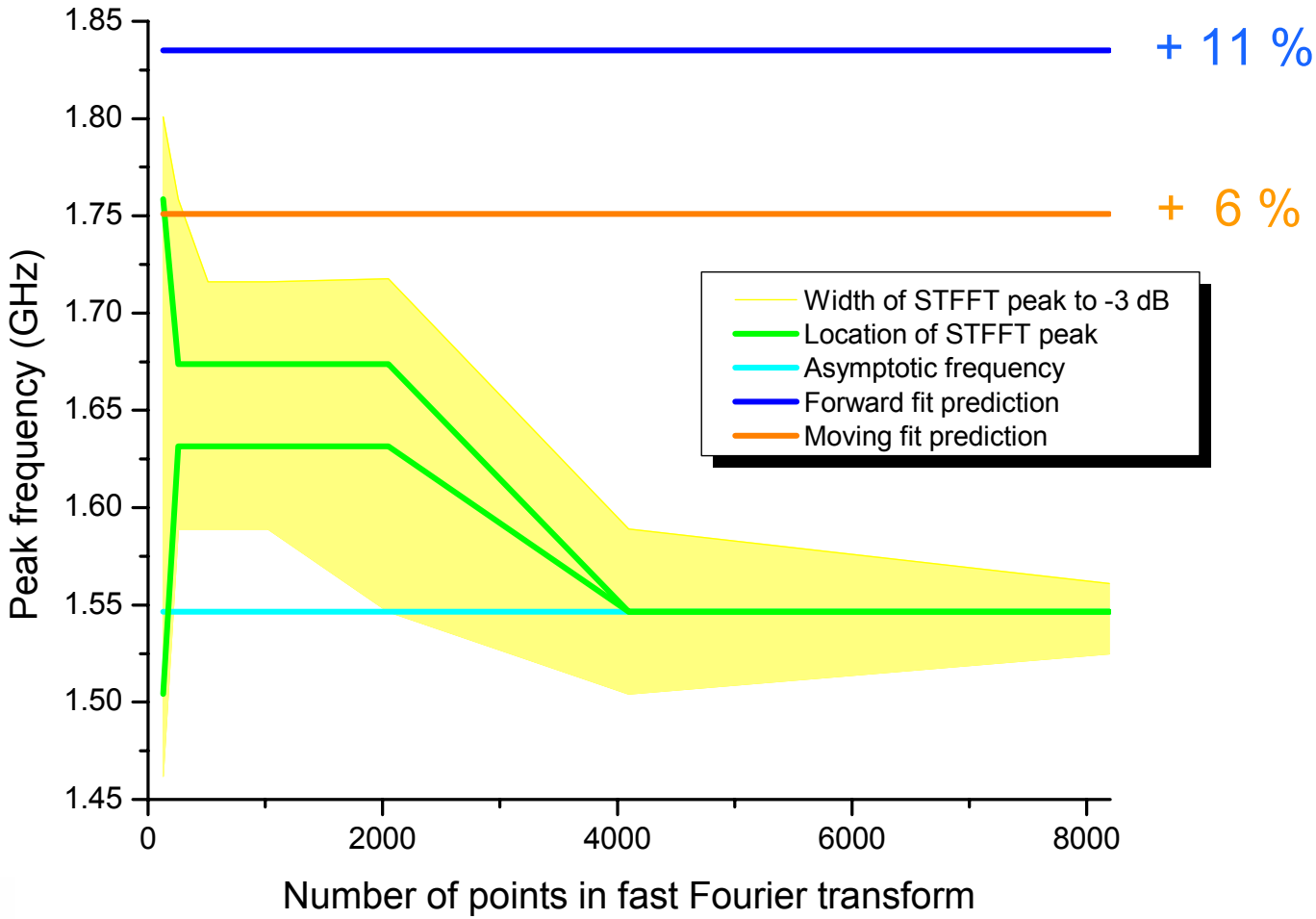


Moving Fit Analysis: Example

30 points fit (1.5 ns)
10 point step (500 ps)
Robust trust-region algorithm



Moving Fit Analysis: Results



Comparison of Analysis Methods

Method:	STFFT	Forward Fit	Moving Fit
Accuracy	??	???	?
Precision	Low	High	Medium
Speed	5 seconds	1-4 hours	45 minutes

Conclusions and Future Directions

- Forward and moving fit methods promising
  - Improved accuracy and precision simultaneously
  - Must investigate robustness
- Must solve accuracy question
  - Comparison with VISAR
  - Synthetic datasets
- Need to improve computational method
  - Speed
  - Robustness
  - Optimize
- FFT and fit-based methods complementary