Resolution Capabilities of the Fourier Transform Method for PDV

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This discussion examines the accuracy and resolution of the FT method for PDV data

Test the Fourier Transform method

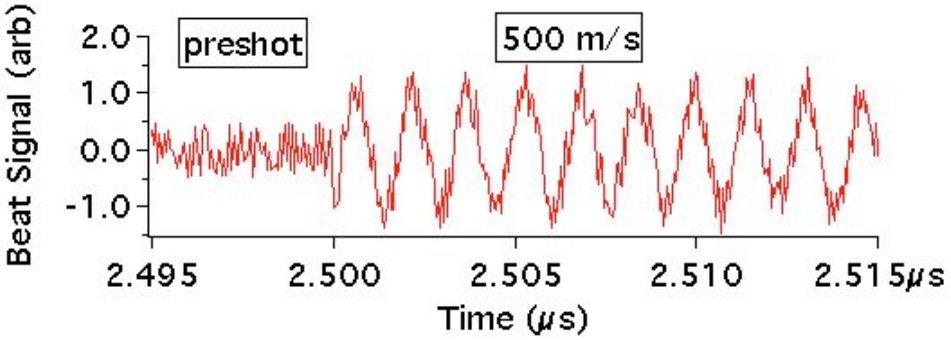
1. Test accuracy and uncertainty of results
2. Examine velocity resolution for single velocity
3. Examine velocity resolution for 2 velocities

Test the accuracy and uncertainty of the FT method

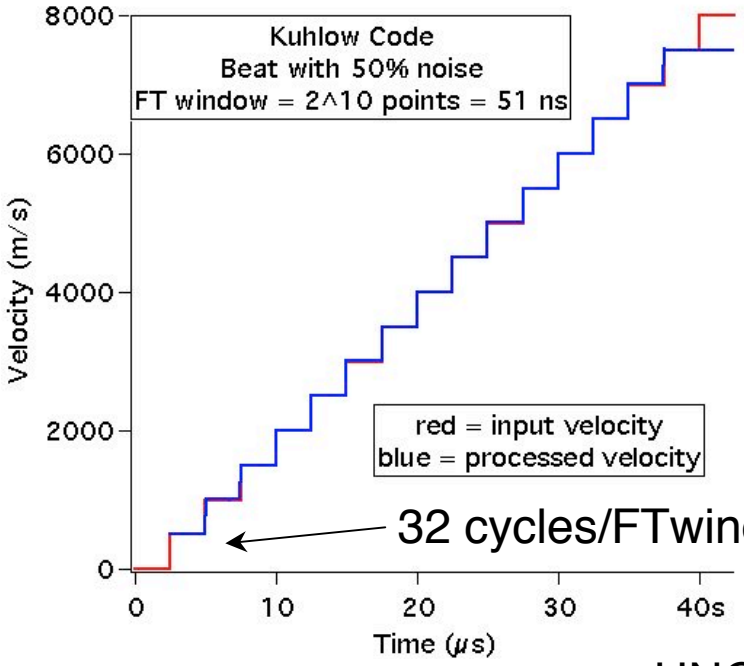
Build a velocity profile consisting of step velocities
Construct the associated beat waveform
Add random noise, say, 50%
Process with FT code using different FT windows

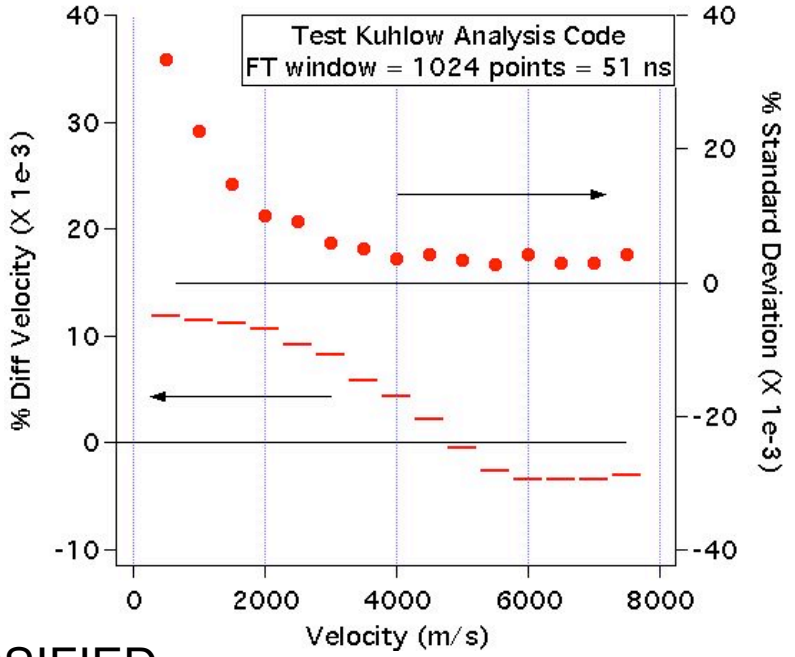
The FT analysis software generates accurate velocity time histories with sufficient windows

Generate a beat signal with:
Stairstep profile
Amplitude = 1
Noise amplitude = 0.5



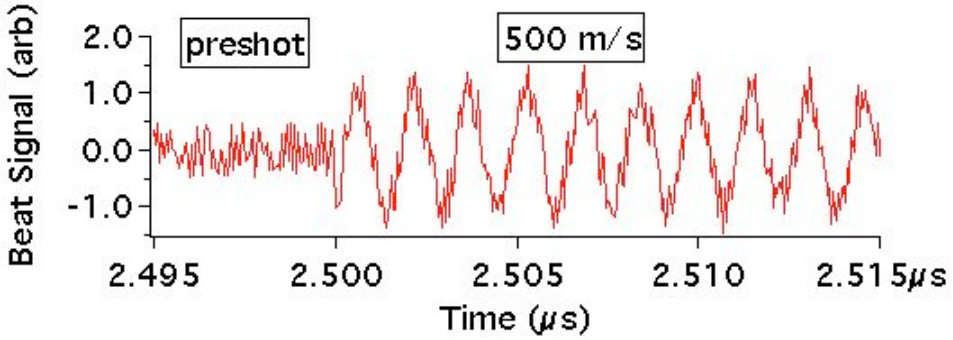
1024 points = 51 ns window



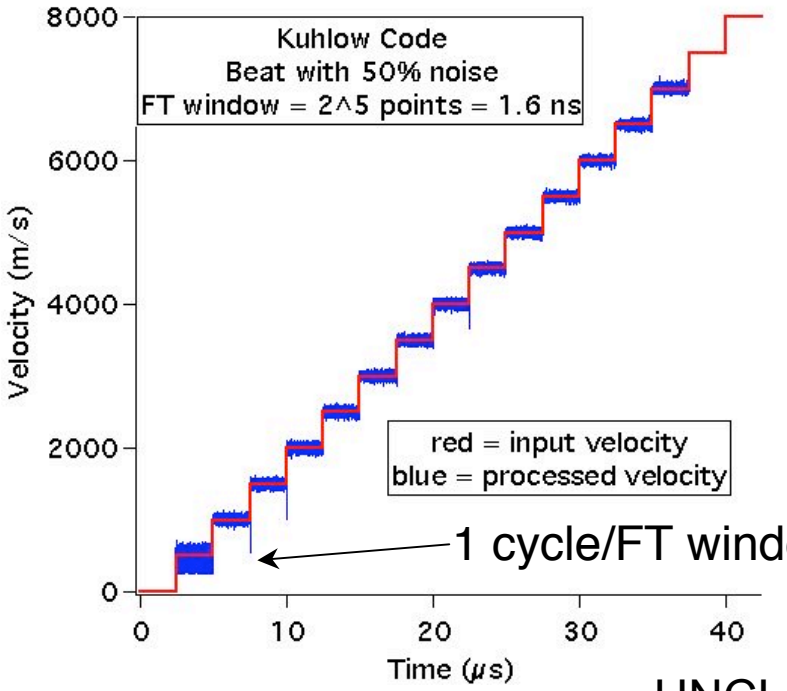


The errors increase with the FT analysis software as the window size approaches one beat cycle

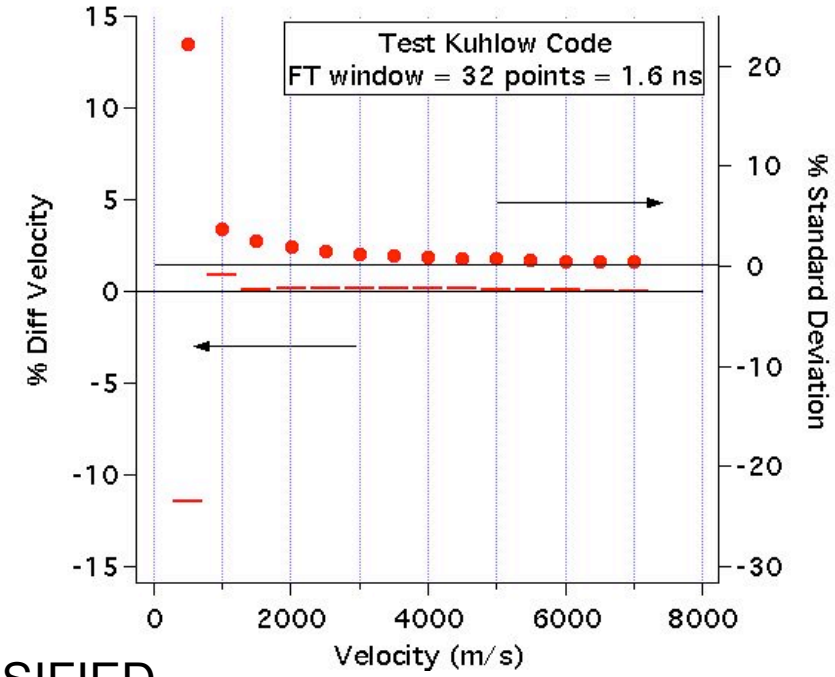
Generate a beat signal with:
Stairstep profile
Amplitude = 1
Noise amplitude = 0.5



32 points = 1.6 ns window



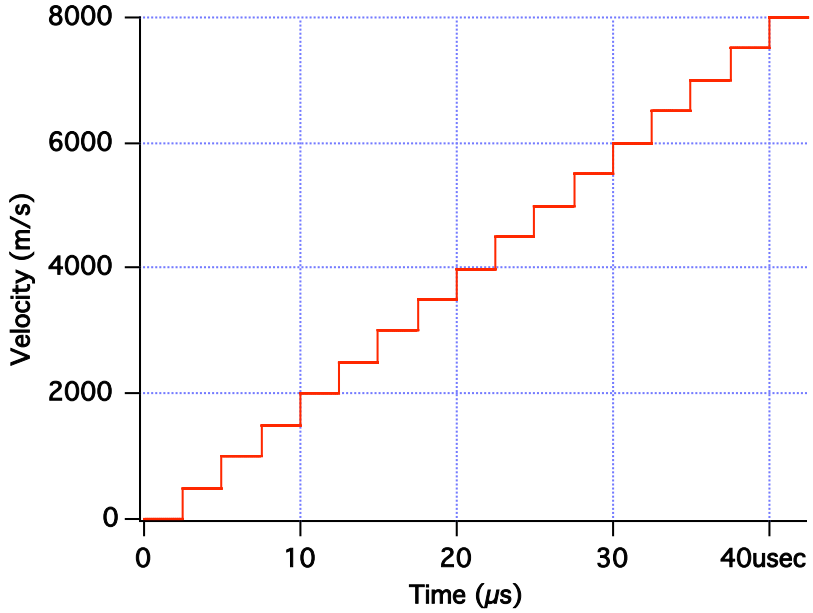
1 cycle/FT window

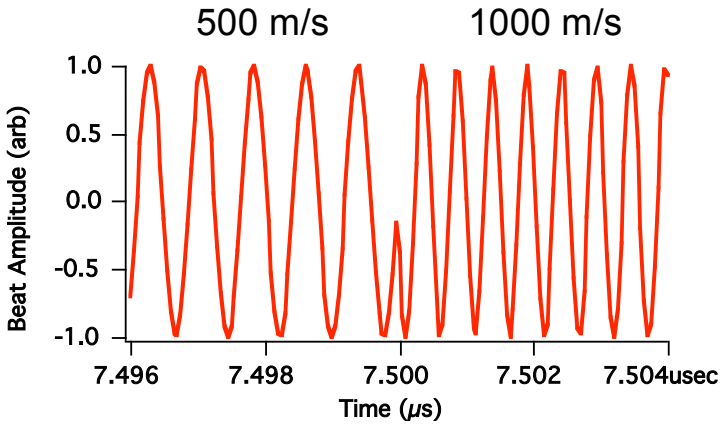


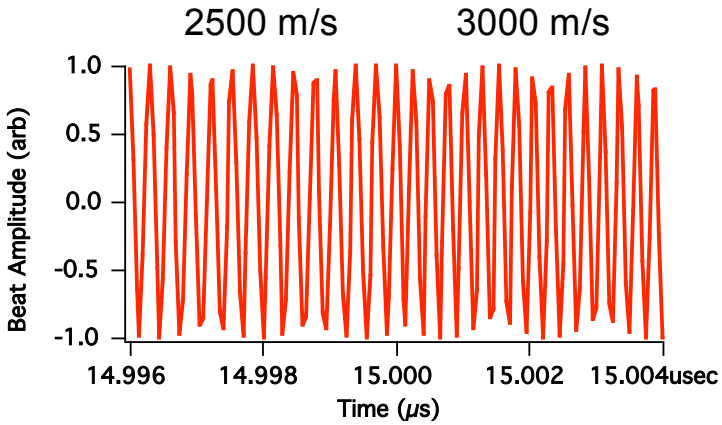
Determine the dVdT product for a single velocity

Build velocity profile with step velocities
Process with FT code using different FT windows
Measure the FWHM of the velocity profiles
Calculate the resulting dVdT products

Generate a beat waveform that corresponds to a stair step velocity profile

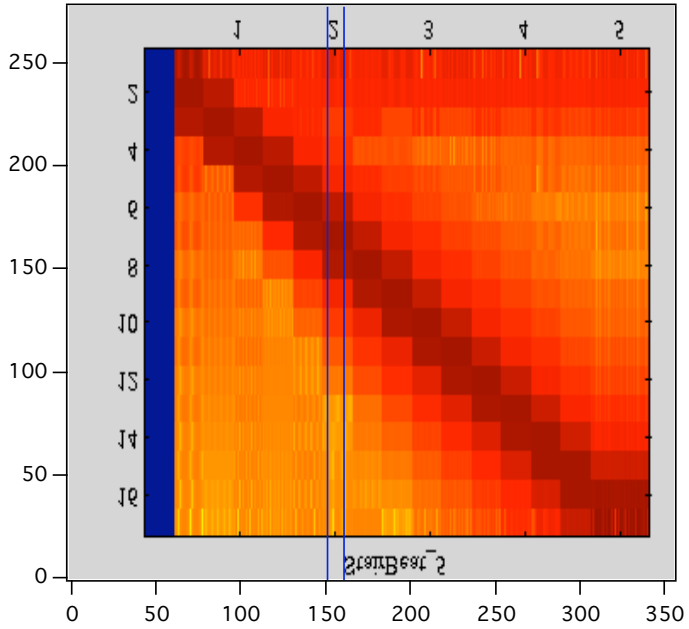






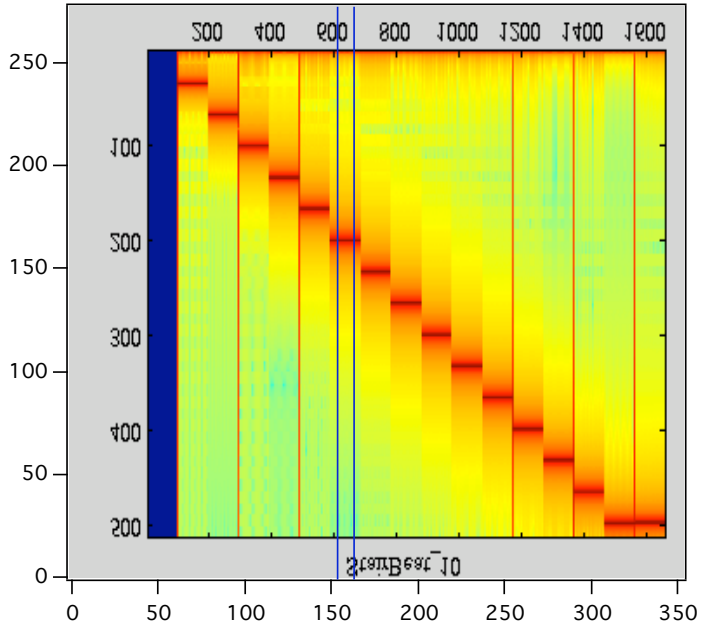
Measure the velocity FWHM in the calculated spectrograms

FT window = 2^6 points = 3.2 ns



V(m/s)	dV(m/s)	dVdT(nm)
500	765.3	2449
1000	742.3	2375
1500	765.3	2449

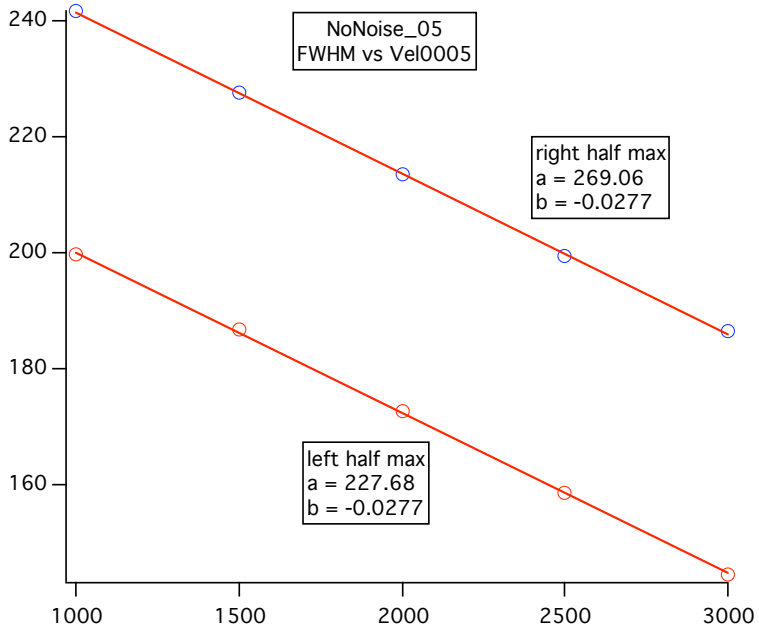
FT window = 2^10 = 51 ns



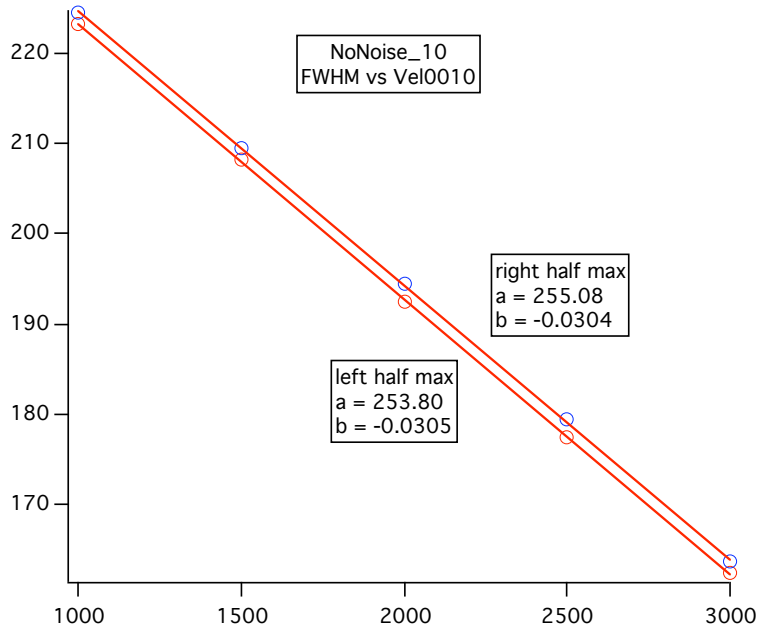
V(m/s)	dV(m/s)	dVdT(nm)
500	36.5	1862
1000	39.9	2035
1500	43.2	2203

The velocity FWHM is independent of velocity for a given FT window

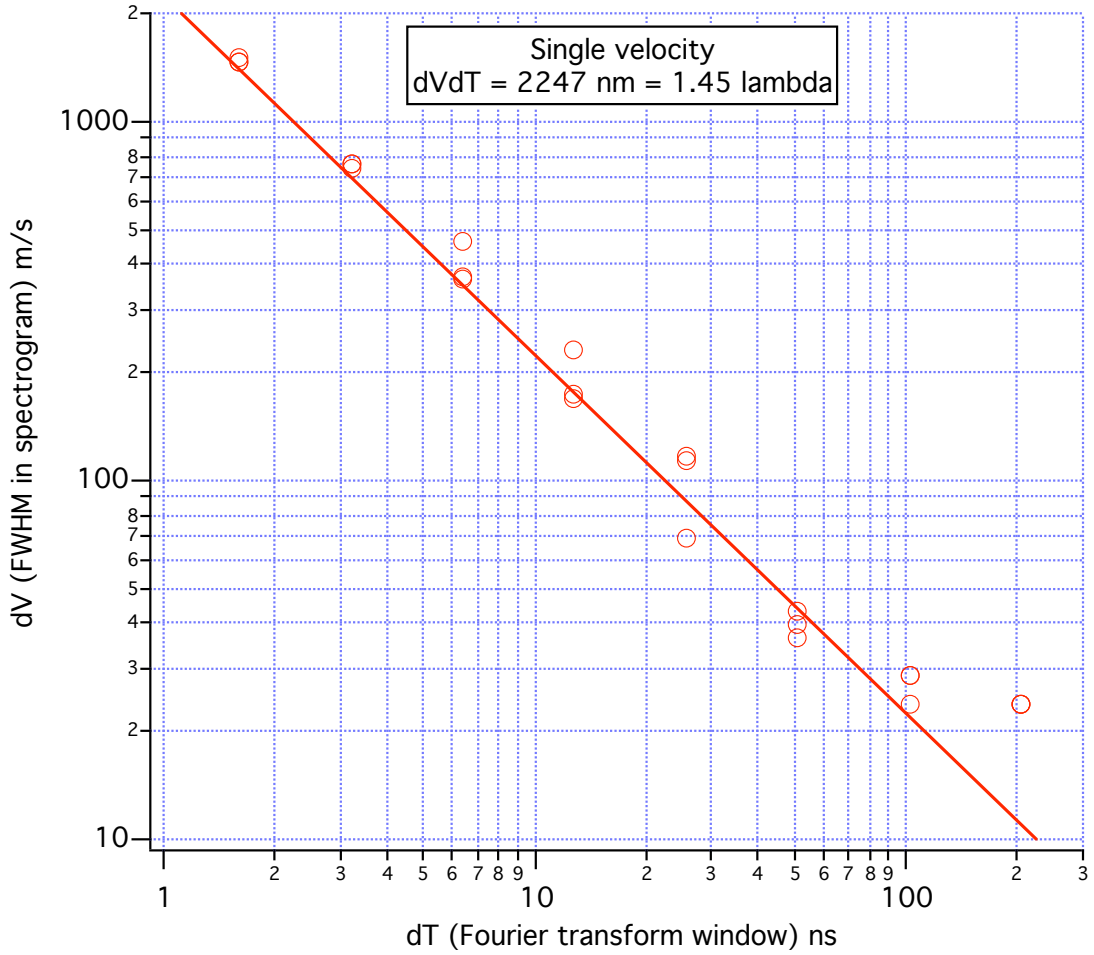
FT window = 2^5 points = 1.6 ns



FT window = 2^10 points = 51 ns



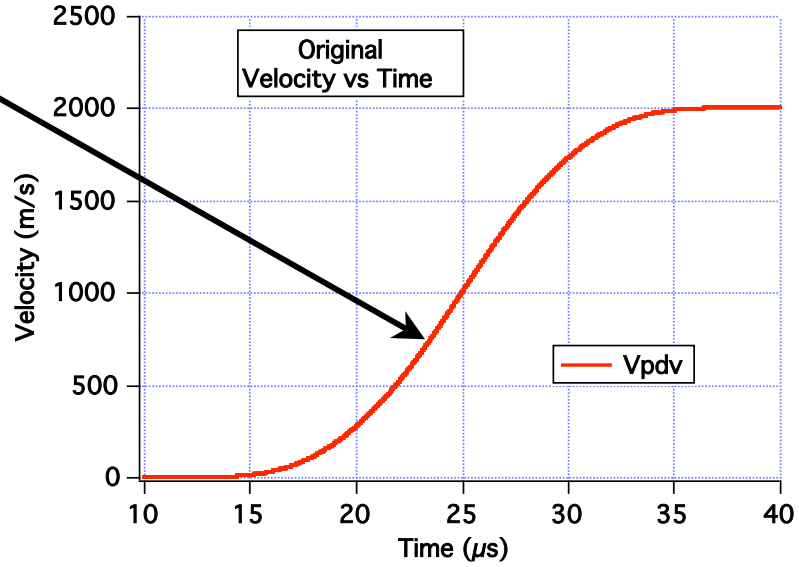
For a single velocity, the dVdT product is approximately 2247 nm = 1.45 lambda



No noise
in the data
for this analysis

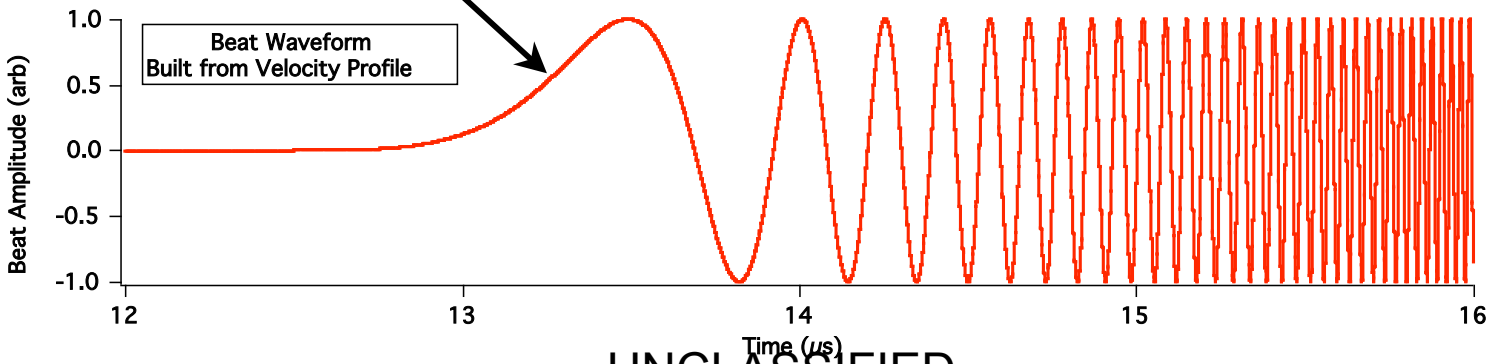
Construct monotonically increasing velocity

This velocity profile



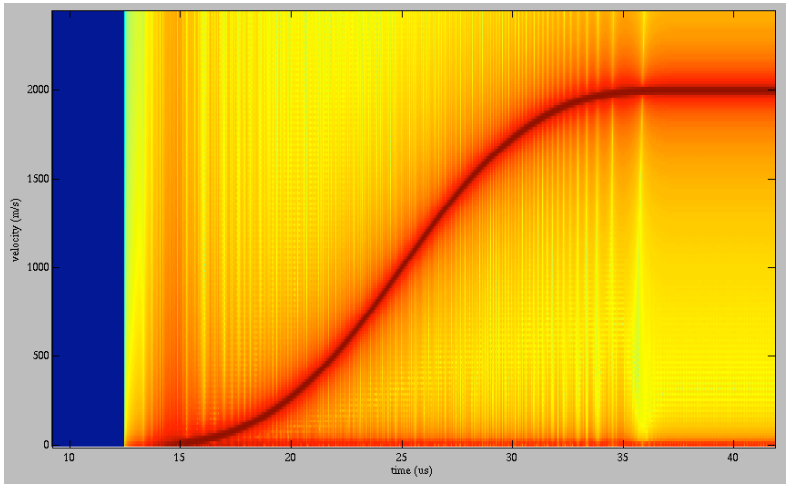
generates this beat waveform

1000 m/s = 1.29 GHz

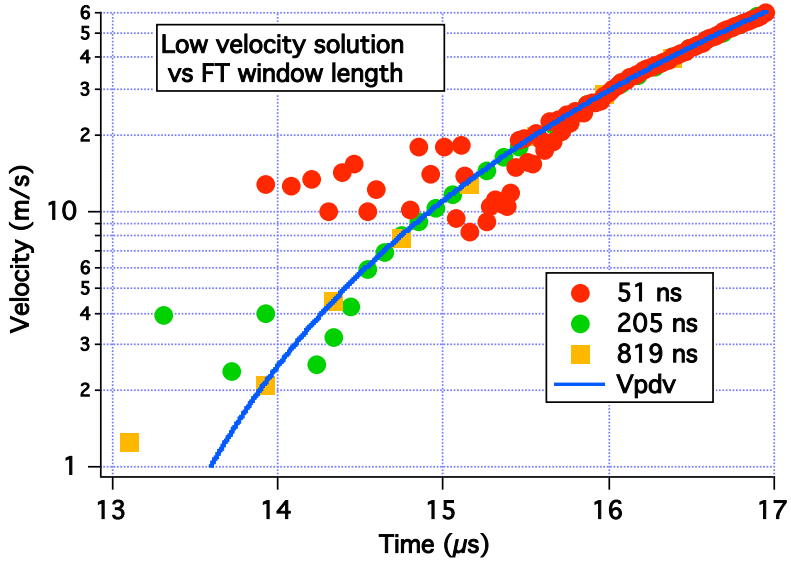


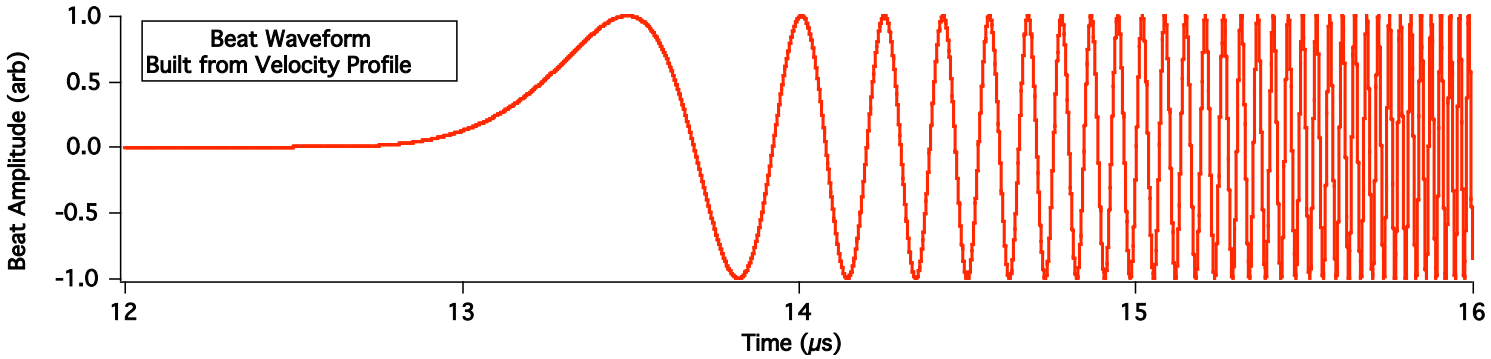
Longer FT windows can process data down to lower velocities

Spectrogram with 51 ns FT window



Low velocity performance

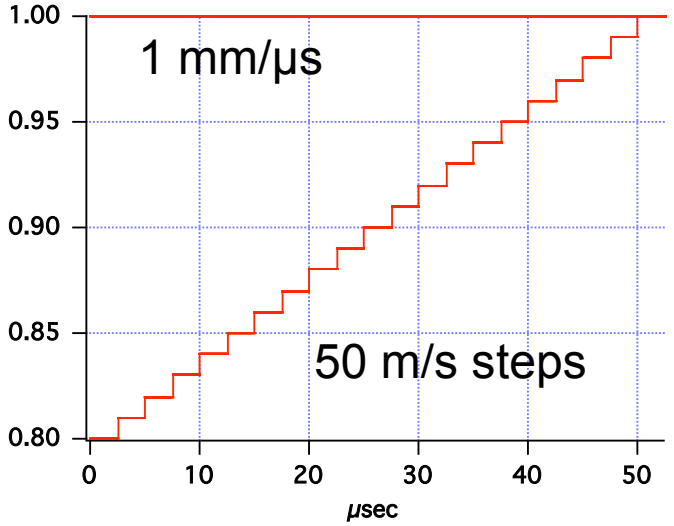


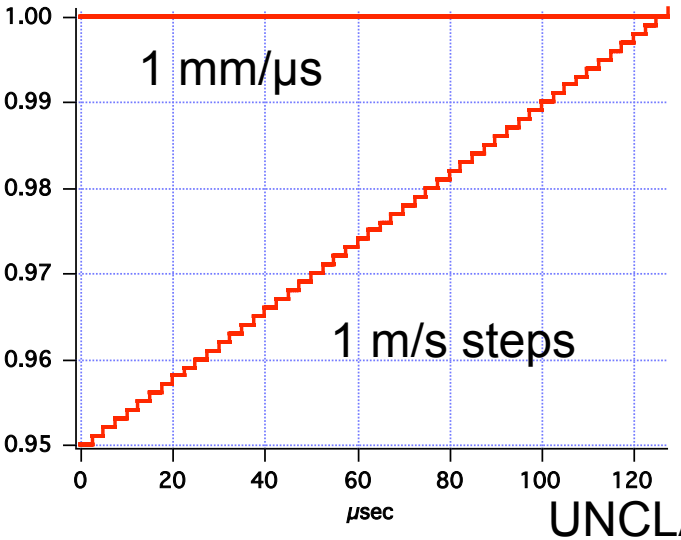


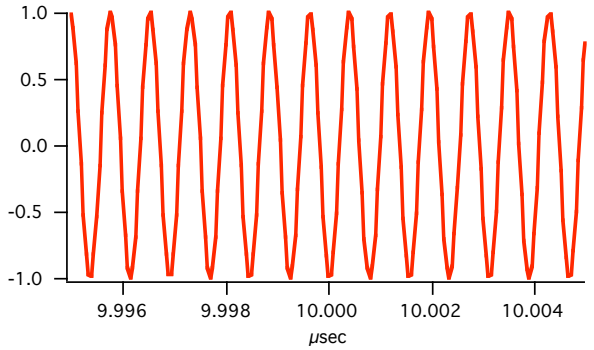
Determine the minimum dV that can be resolved for two velocities

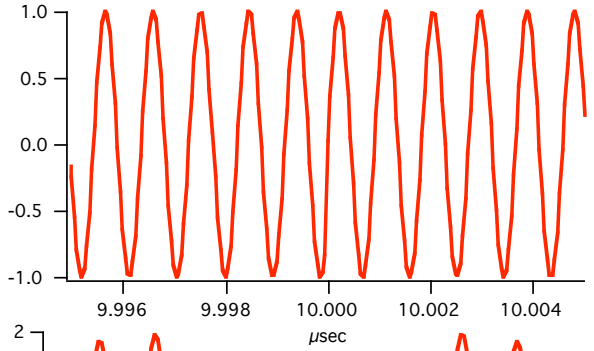
Build velocity profile with step velocities plus a constant velocity
(of equal amplitude)
Process with FT code using different FT windows
Measure the minimum V difference for each FT window
Calculate the resulting dVdT products

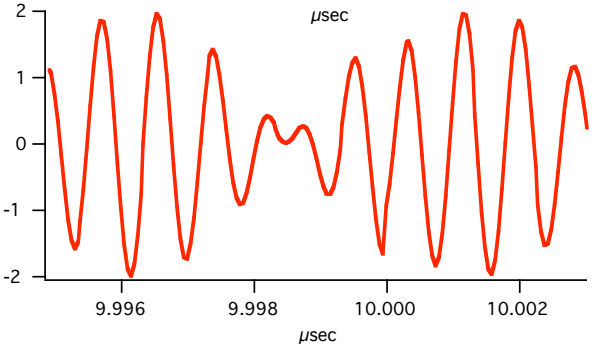
Build the beat waveform for two velocities that get closer together





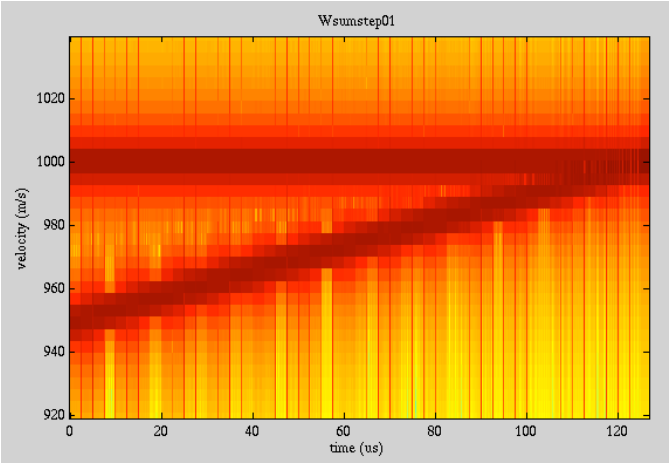


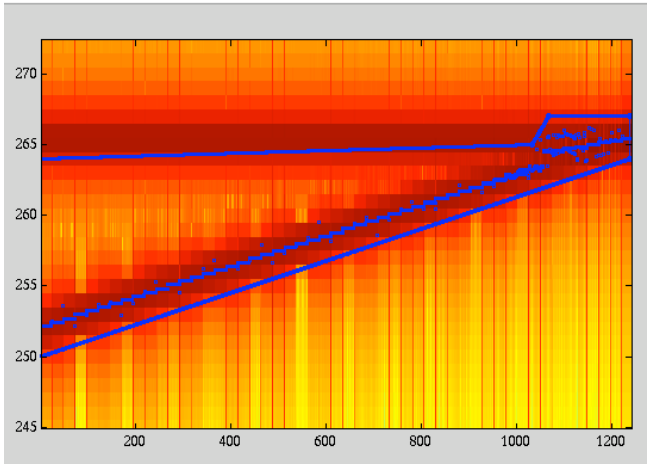


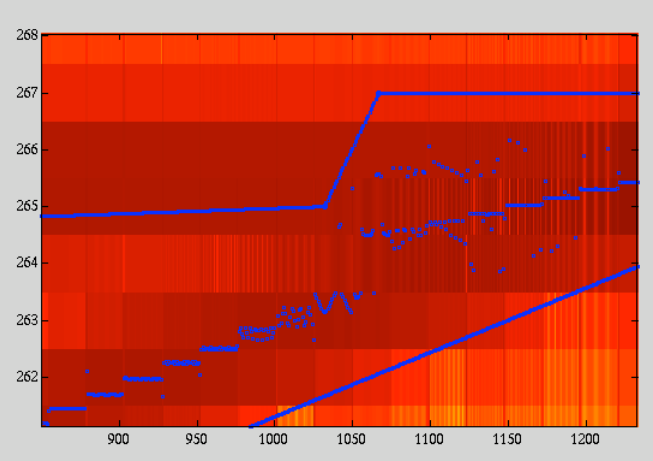


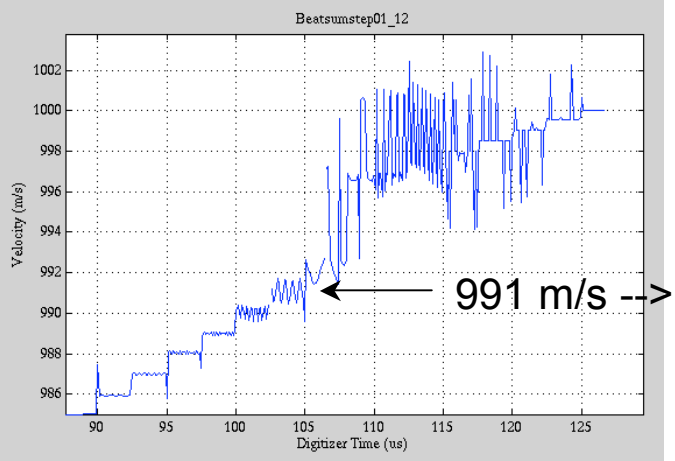
Use the FT code to find the minimum dV for different FT windows

This example is for FT window = 2^12 points = 204 ns

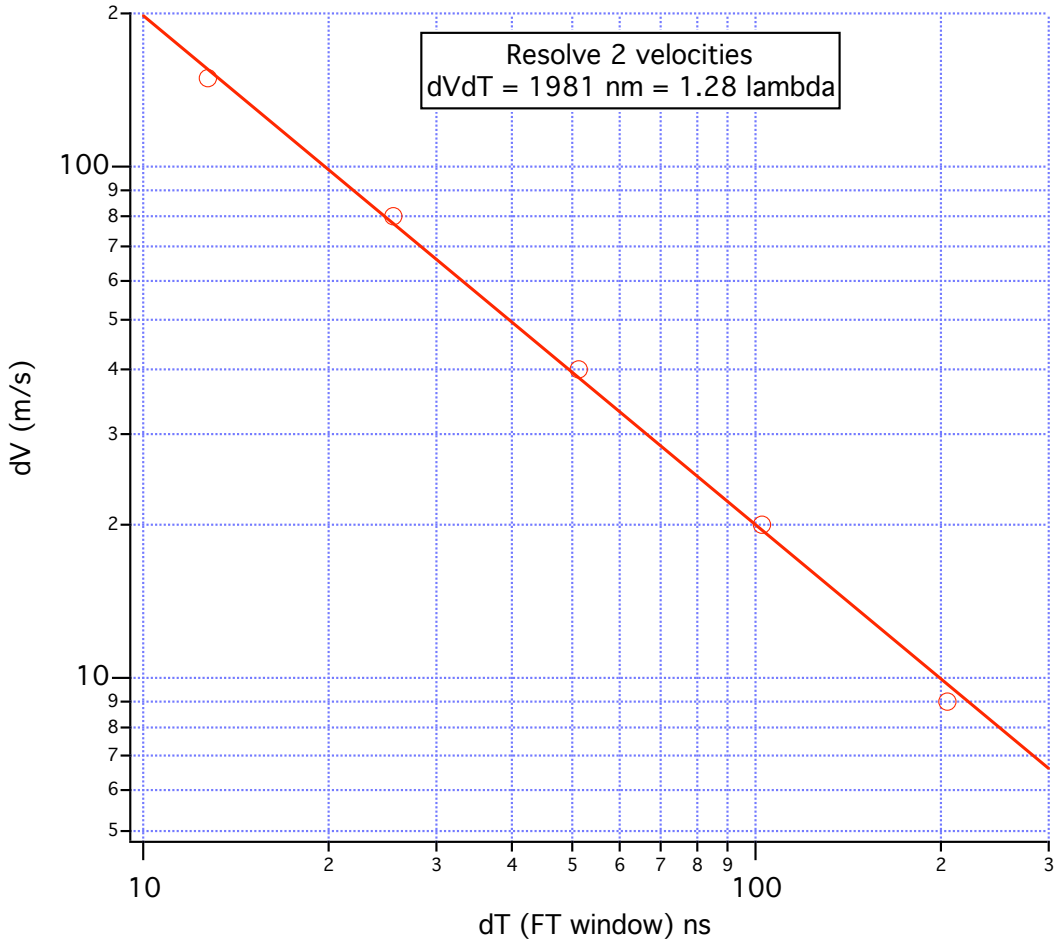








The dVdT product is approximately 1.28 lambda for resolving two velocities



No noise
in the data
for this analysis

Summary

Be sure to have at least 3 beat cycles per FT window.
(50% noise)

The dVdT product is approximately 1.45 lambda for 1 velocity.
(no noise)

The dVdT product is approximately 1.28 lambda
for resolving 2 velocities (no noise).