Simultaneous measurements of wind speed at multiple distances without range ambiguity

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Motivation

• CW lidar
  – Measures continuously
  – Can have range ambiguity due to clouds and other high scatters

• Pulsed lidar
  – Has a low pulse repetition frequency
  – Does not have range ambiguity and can measure at multiple distances simultaneous

• Frequency Stepped Pulse Train (FSPT) modulated lidar
  – Theoretically capable of measuring continuously
  – Does not have range ambiguity and can measure at multiple distances simultaneous

• Proof of concept measurements
Lidar system design

- An all fiber based lidar
  - wavelength: 1545 nm
  - Transmission power: 1 W

- Focused telescope
  - Aperture: 7 cm

- Coherent detection

- Signal processing by FFT and averaging
Lightwave Synthesized Frequency Sweeper

- Fiber based Frequency Stepped Pulse Train generator
- Generates FSPT by recirculation of a pulse in an fiber optical ring.
- Shifts the frequency by a fixed amount for each circulation

Schematic drawing of the LSFS setup.
Light propagation scheme

[Diagram showing light propagation scheme with labels for FSPT Transmitted light, Local Oscillator, Received light, and Reflected light.]
Time-space representation of the received scatter from an FSPT modulated lidar

Range cells are defined from
\[ x_i = \left( (i-2)T_{\text{pulse}} + (i-1)T_{\text{inter}} \right) \frac{c}{2} \]
to
\[ x_i' = \left( iT_{\text{pulse}} + (i-1)T_{\text{inter}} \right) \frac{c}{2} \]

Line of sight velocity in a given range is calculated as:
\[ V_{\text{LOS},i} = \frac{\lambda}{2} f_D (x_i : x_i') \]
Signal processing

Detector

BPF

Digitizer, FFT, average

CNR
Wind speed measurements

- Proof of concept measurements
  - 550ns pulses
  - 30ns inter pulse time
  - 40MHz frequency shift
  - 1 W average power

Focus: 84 m
Focus: 168 m
Focus: 261 m
Wind speed direction

Headwind

Tailwind

CNR

Frequency (MHz)

CNR

Frequency (MHz)
Conclusion

• We have demonstrated the FSPT modulated lidar and achieved proof of concept measurements

• We hope that this method in the future will help lidars overcome some of their problems
  – Range ambiguity for CW lidars
  – Low PRF for pulsed lidars

• The goal is to achieve detection in multiple range cells from 15m to 200m with a spacing of 30m and with a high measuring rate