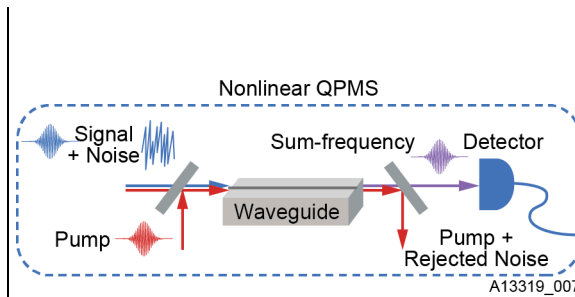


# Quantum Parametric Mode Sorting (QPMS) Lidar for Snowpack Characterization

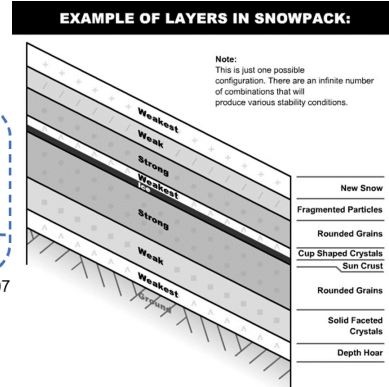
PI: Carl Weimer, Ball Aerospace

## Objective

- Develop a lidar that takes advantage of quantum technologies to profile and characterize 20x deeper snowpack to better understand layering and possible grain characterization
- QPMS methods improve on direct detection lidar in increased SNR, and improved background (sunlight) rejection
- Demonstrate long range precision (mm) ranging from natural scenes, with the promise of improved topographic mapping of snow scenes and coastal bathymetry
- Design and evaluate a multi-spectral multi-polarization lidar that extends CALIPSO-like capabilities to snow and water scenes for both day and night measurement
- Develop and Validate the use of applying diffusion theory to multiple scattered light to estimate snow depth and compare with QPMS results
- Begin working the path to space implementation



Utilizing coherence, QPMS better rejects background light, rejects multiple scattering, allowing for precise ranging through the optically dense snowpack, and turbid waters for bathymetry.



The complexity of snowpacks requires a new approach with higher resolution.

## Approach

- Use QPMS detection with Time-Frequency laser modes to perform ranging measurements
- Translate demonstrated techniques at 1550 nm to the visible 515 nm to allow QPMS work with snow
- Develop a QPMS system to detect visible (515nm) backscatter
- Perform controlled laboratory testing of snow scenes at Ball Aerospace
- Intercompare lidar results with penetrometer instruments to understand the snow depth and possible information on snow water equivalent grain size, density, and layers
- Package and qualify new SPAD detectors for space

**Co-Is/Partners:** Jennifer Lee, Ball; Y. Huang, K. Stamnes, Y. M. Sua, Stevens; Y. Hu, NASA LaRC; HP Marshall, Boise State; X. Zheng, Brandon Marshall Arizona; Jason Stoker, USGS

## Key Milestones

- |   |       |
|---|-------|
| • Complete design of 515 nm QPMS Tx/Rx            | 05/22 |
| • Procure optical subsystems                      | 07/22 |
| • Fabricate upconversion device at CUNY           | 08/22 |
| • Complete Lidar Receiver Architecture/ROM        | 01/23 |
| • Assemble QPMS lidar system                      | 03/23 |
| • Complete functional testing at Stevens          | 04/23 |
| • Kick-off SPAD detector qualification            | 04/23 |
| • Complete system level testing at Ball Aerospace | 08/23 |
| • Complete SPAD Packaging for Space               | 09/23 |
| • Complete Snow Testing                           | 03/24 |
| • Complete Path to Space and Radiometry           | 04/24 |
| • Complete Water Testing at Ball Aerospace        | 06/24 |
| • Complete Theory/Validation of Multiple Scatter  | 09/24 |

TRL<sub>in</sub> = 2    TRL<sub>current</sub> = 3