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New Opportunities for Combined Raman and High Spectral Resolution Lidar Retrievals

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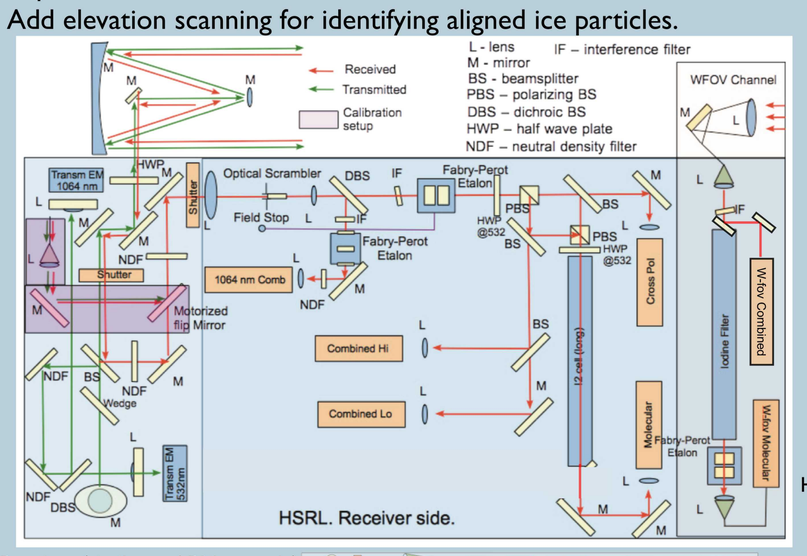
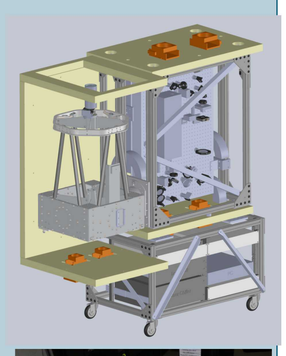
Abstract

The 2015 Combined HSRL and Raman lidar Measurement Study (CHARMS) demonstrated the potential for aerosol microphysical properties to be retrieved from simultaneous measurements from two ground-based lidars, the U.Wisconsin-High Spectral Resolution Lidar (HSRL) and the SGP Raman lidar [Ferarre, et al.]. The U.W.-HSRL transmits laser pulses at both 532 and 1064 nm, and the SGP Raman lidar transmits pulses at 355 nm. Merging data from these instruments afforded the opportunity to retrieve effective radius, number, surface area, volume concentrations, and fine-mode fraction under certain conditions. Upcoming redeployments of an upgraded version of the North Slope HSRL (NSHSRL) and the Oliktok Raman lidar will provide new opportunities for multi-wavelength lidar investigations and data products. Upon completion of the upgrade, the NSHSRL will transmit and receive both 532 nm and 1064 nm signals and will be redeployed for an extended period of time at the Southern Great Plains (SGP) site near the SGP Raman lidar, enabling collection of a second CHARMS dataset at the SGP. Planning is underway for the AMF3 Raman lidar currently in Oliktok to be redeployed at the North Slope site in Utqiaġvik, AK. When redeployments of the Oliktok Raman lidar and NSHSRL are complete, analyses of merged data from the Raman-lidar, HSRL, and other instruments at the NSA site will be possible, enabling collection of a CHARMS dataset at the NSA site. We describe here planned upgrades by the University of Wisconsin to the capabilities of the NSHSRL and initial plans for deployment of the NSHSRL at the SGP site in 2020 and future deployment of the Oliktok Raman Lidar and NSHSRL in Utqiaġvik (Barrow).

Planned upgrades the NSHSRL

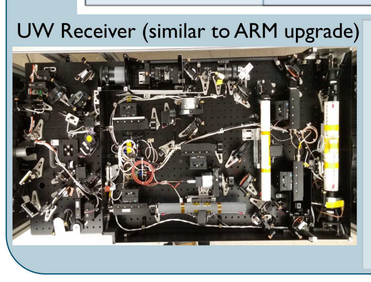
- Improve the HSRL instrument data system with a 16-channel photon counting board.
- Replace the polarization based transmit-receive switch with a beam splitter version.
- Install a fiber spatial mode scrambler in the receiver.
- Provide for direct injection of seed-laser light during calibration.
- Add 532 nm wide field-of-view molecular and combined molecular/aerosol channels
- Add 1064 nm narrow field-of-view channels.
- Improve the 532 nm etalon isolation valve
- Add elevation scanning for identifying aligned ice particles.

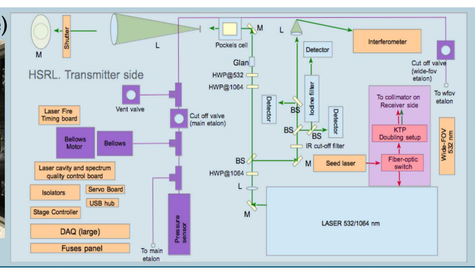




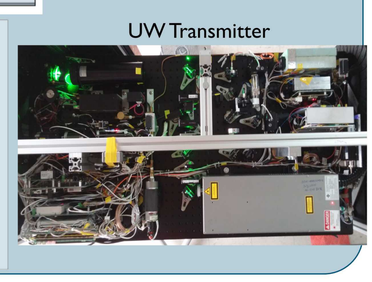
Horizontally-oriented UW system

UW Receiver (similar to ARM upgrade)





UW Transmitter



Background

The total aerosol radiative forcing from a column of atmosphere is a function of the aerosol optical properties as well as the aerosol spatial distribution.
With sufficiently many independent lidar measurements it is possible to retrieve aerosol physical and optical parameters under suitable conditions [1, 2]:

- Requires measurements of backscatter and extinction coefficients, β and α , respectively, at multiple wavelengths
- Achieved by generating and transmitting optical pulses at multiple wavelengths and detecting separately molecular and aerosol backscatter
- Aerosol distribution within each layer needs to be well-described by a monomodal log-normal function, as assumed by the retrieval algorithm
- Roughly five parameters (e.g., 3 β and 2α) are needed to keep parameter retrieval uncertainties below 20% [2]

A small number of individual instruments make sufficient measurements to apply the multiwavelength lidar retrieval algorithms, but combining separate instruments can achieve similar results, as demonstrated by CHARMS.

ARM capabilities and needs:

The ARM instrument network contains instruments that could be synergistic for multiwavelength retrievals, but current instrument locations and capabilities are not yet compatible with CHARMS data analysis.

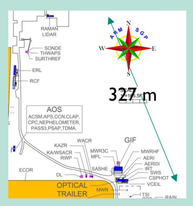
Current situation :

- Long-term ARM Raman Lidar installations in Oklahoma, Azores, and Alaska (Oliktok site)
  - Provide estimates of β and α at 355 nm
- Long-term ARM HSRL installation in Alaska (Utqiaġvik site), mobile HSRL on AMF2
  - Currently provide β and α at 532 nm (only)
- Sun photometers for estimating aerosol Ångstrom exponent at all sites.
- Routine extinction retrieval using Raman Lidar [3] and HSRL.

Need co-location of instruments and more wavelength diversity in the measurements (e.g., β and/or α at 1064 nm) for effective multiwavelength retrievals..
Planned: upgrade and relocate instruments ….

Planned deployments

SGP Raman Lidar



SGP (Winter 2020)

- Field tests of upgraded HSRL beginning Feb 2020
- HSRL installed in the Optical Trailer.
- Raman Lidar running in normal configuration
- Collect data suitable for " $3\beta + 2\alpha$ " algorithm

SGP Optical Trailer

Outlook: In situ aerosol measurements would offer a strong compliment to the existing ground based aerosol suite, if airborne aerosol measurements are available during 2020. Tethered-balloon UAS aerosol measurements may offer a valuable means for detailed validation studies.

NSA (late Summer 2020 / Summer 2021 ,TBD)

- HSRL redeployed, potentially Summer 2020
- Raman Lidar potentially to move to Utqiaġvik following the MOSAiC campaign
- All NSA lidars will be nearly co-located

Outlook: Routine multiwavelength retrievals at NSA would offer a new means for studying the strong vertical gradients that can exist in Arctic aerosols. Options for in situ aerosol measurements aloft need to be explored.

References

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3. Thorsen, Tyler and Fu, Qiang. 2015. "Automated retrieval of cloud and aerosol properties from the ARM Raman lidar. Part II: Extinction." Journal of Atmospheric and Oceanic Technology 32(11): 1999-2023

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NNSA National Nuclear Security Administration

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