SAND2022-14750C

Potential Performance Enhancements to the ARM Raman Lidars

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Background

The ARM Program has two Raman Lidars (RLs) deployed at fixed observation sites, one at the Southern Great Plains (SGP) site in Oklahoma and one at the Eastern North Atlantic (ENA) site in the Azores [Turner et al.]. A third RL is deployed with the ARM Mobile Facility 3 (AMF3). All of the RLs are sheltered in modified sea containers (fig. 1). The AMF3 RL deployed in 2014 is the newest of the RLs, but all share a common overall design. The RL at the SGP site has operated nearly continuously since 1997 with major upgrades in 2006 and 2015. The RL at ENA has been operational since 2015, but it was originally deployed in 2010 in Darwin, Australia. Technological improvements in electronics and optical components since the ARM RLs were built provide opportunities to enhance system performance, and this poster discusses some of the enhancements that can be made to the RLs.

Fig. 1: Photos of two of the ARM Raman Lidars. The systems fill one sea container each with additional utilities in a separate container.

Potential Upgrades

Receiver subsystem

Potential receiver improvements are available through upgrades to the PMTs, filters, and the transient recorders. Replacement of the existing PMTs in the narrow FOV with Hamamatsu ultra-bialkali cathodes would give approximately 50% improvement in quantum efficiency. The smaller active area of the new PMTs would require additional lenses to reformat the beams.

Improvements in available rotational Raman narrowband filters are estimated to provide a factor of two increase in the signals used for temperature measurement for the SGP RL. A smaller, 50%, increase is estimated for ENA and AMF3 because of differences in the filter characteristics at the different sites.

Upgrading the existing Licel transient recorder boards from 12-bit analog digitization to newer 16-bit digitization boards would gain a factor of 16X in the dynamic range prior to averaging. The analog and digital measurements are overlapped and made consistent with each other through a process known as "gluing" [Whiteman et al., Newsom et al.], and the increased analog dynamic range could be exploited to improve this process.

An analysis could also be conducted to determine whether wide FOV rotational Raman measurements are now possible with a suitable combination of filters and FOV.

Transmitter subsystem

Additional system improvements could be achieved by employing a laser with 200 Hz repetition rate and greater pulse-to-pulse energy stability, which is now possible with solid state laser components.

ARM Raman Lidar Design

Present day design

The ARM RLs transmit 355nm wavelength pulses with approximately 300 mJ/pulse at a rate of 30Hz. The returned light is collected with a 24" telescope and relayed to the receiver. A wide field of view (FOV) of approx. 2 mrad is received in addition to a narrow FOV approx. 300 urad to extend the region of spatial overlap between the transmitted and received beams. Dichroic mirrors and interference filters provide narrowband detection of the elastically scattered 355 nm light as well as Raman shifted scattering from water vapor at 408 nm, nitrogen at 387 nm in both FOVs. Additionally, the rotational Raman scattering from O_2 and N_2 around at 353 nm and 354 nm, is collected for temperature measurement in the narrow field of view. The transmitter and receiver optics are laid out on separate optical boards, and the system layout is depicted in fig. 2.

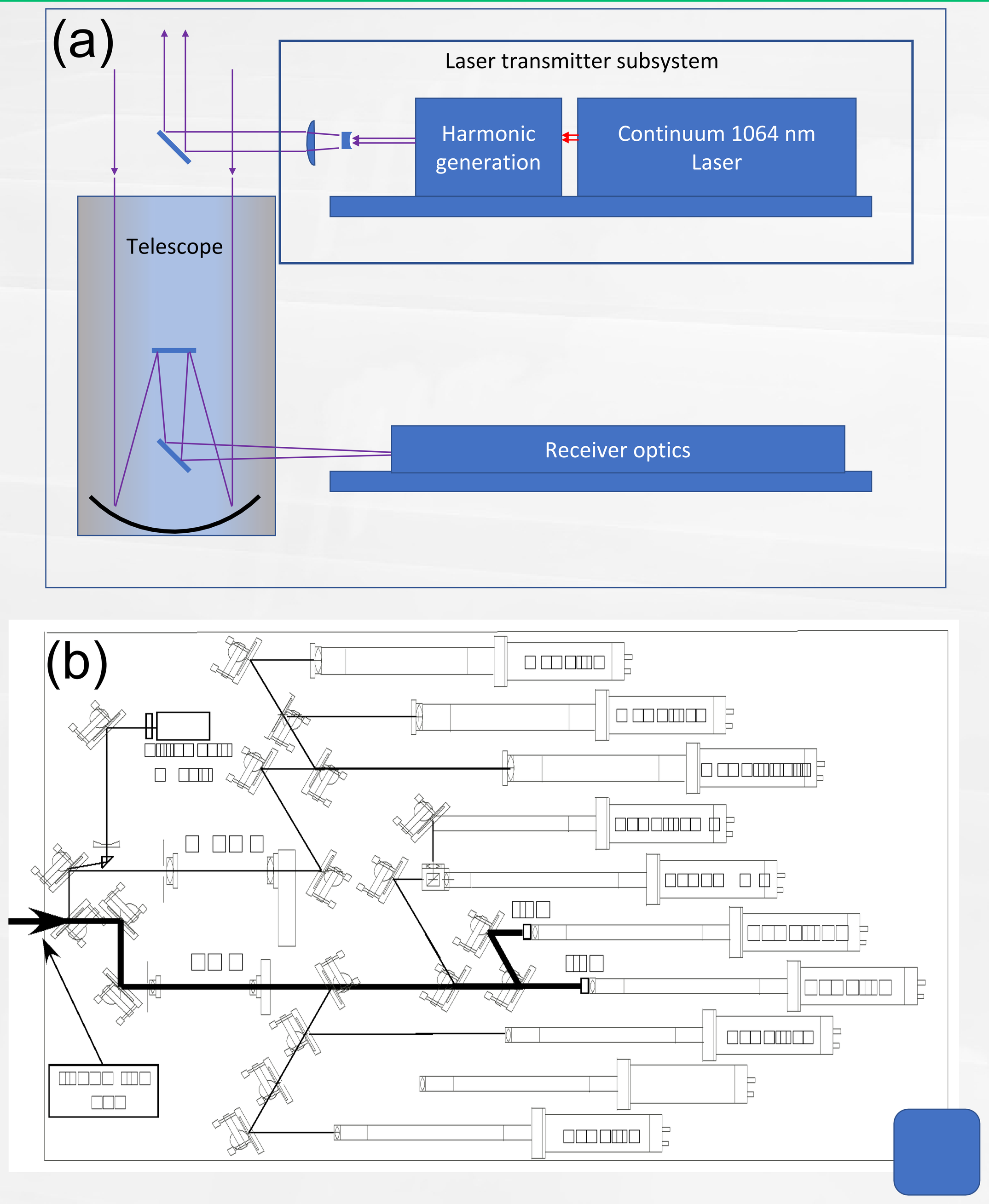

Fig. 2: RL system schematic diagram (a) overall system (b) receiver subsystem.

Discussion

The AMF3 RL is currently planned to be deployed at the SGP site for an extended period of time prior to its relocation to the southeastern U.S.. The colocation of two ARM RLs at the SGP site will afford us a valuable opportunity to intercompare instruments and to quantify the performance of existing components and assess the benefit of upgrading components. The impact of aging of the SGP PMTs is an example of an effect that is difficult to assess [Hum, et al.] but may be addressed though this intercomparison.
Potential benefits available through component upgrades include:

- Increased signal-to-noise ratio in the raw data
- Improved water vapor and temperature retrievals over the full height range
- Additional capabilities such as temperature measurements lower in the atmosphere and faster update rates.

References

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Acknowledgments: *Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND # xxx*

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