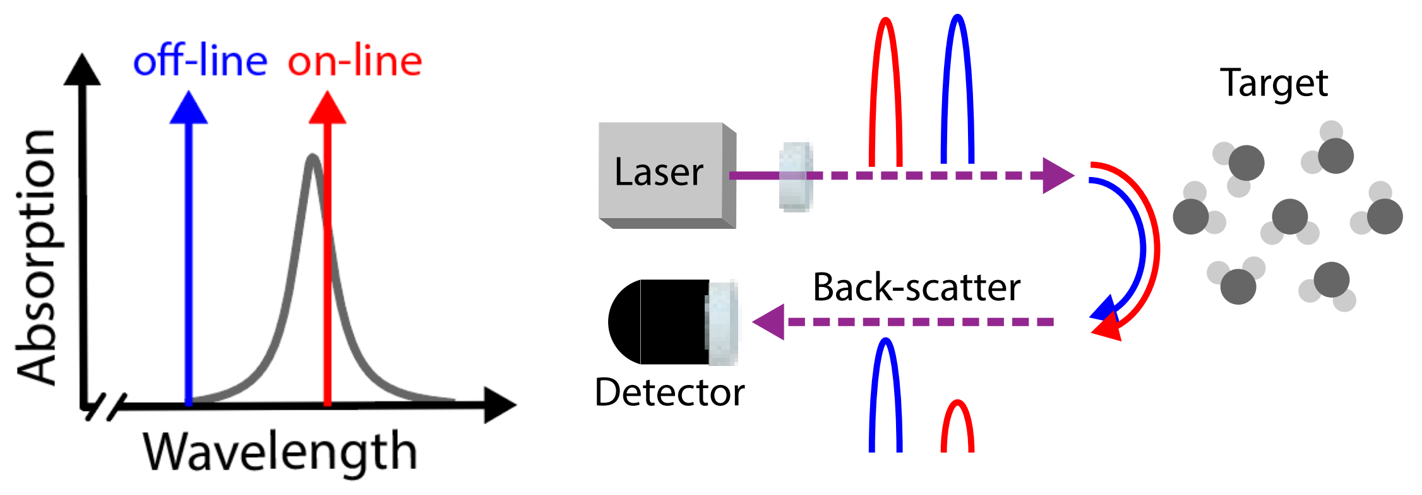
National Aeronautics and Space Administration

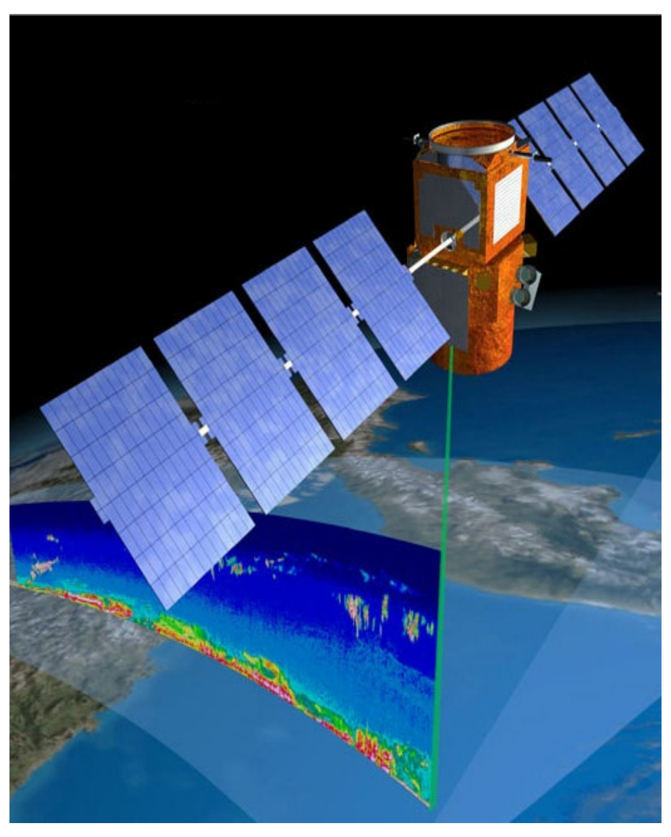
All-semiconductor continuous wave profiling for spaceborne differential absorption lidar (DIAL)

Author: Simone Bianconi, JPL postdoctoral fellow (3890)
John Dykema (Harvard University), Eric Kittlaus (389W),
Mahmood Bagheri (389W), Siamak Forouhar (3890)

Motivation

DIAL measurement concept: comparing the return echo around a spectral absorption line to retrieve range-resolved concentration of atmospheric species





Benefits:

- High-precision measurement of low-concentration species of atmospheric interest (e.g. water vapor, greenhouse gases)
- Possibility for simultaneous temperature and wind retrieval through Doppler broadening
- Instrument tunability across different conditions and latitudes
- Complementary with DAR to offer wide coverage across different conditions (clouds, ocean, etc.)

Challenges:

- Complexity and SWaP-C of instrument limit the number of airborne and spaceborne missions
- Need wavelength agility for wide spectral coverage (flexible operation at different latitudes, altitudes and background)

Spectral coverage

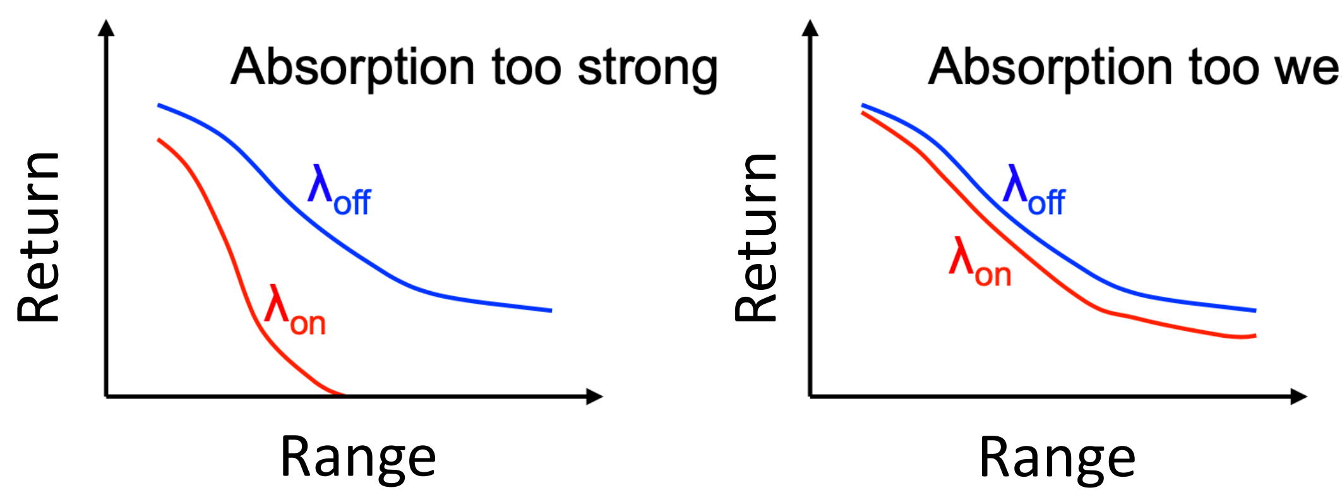
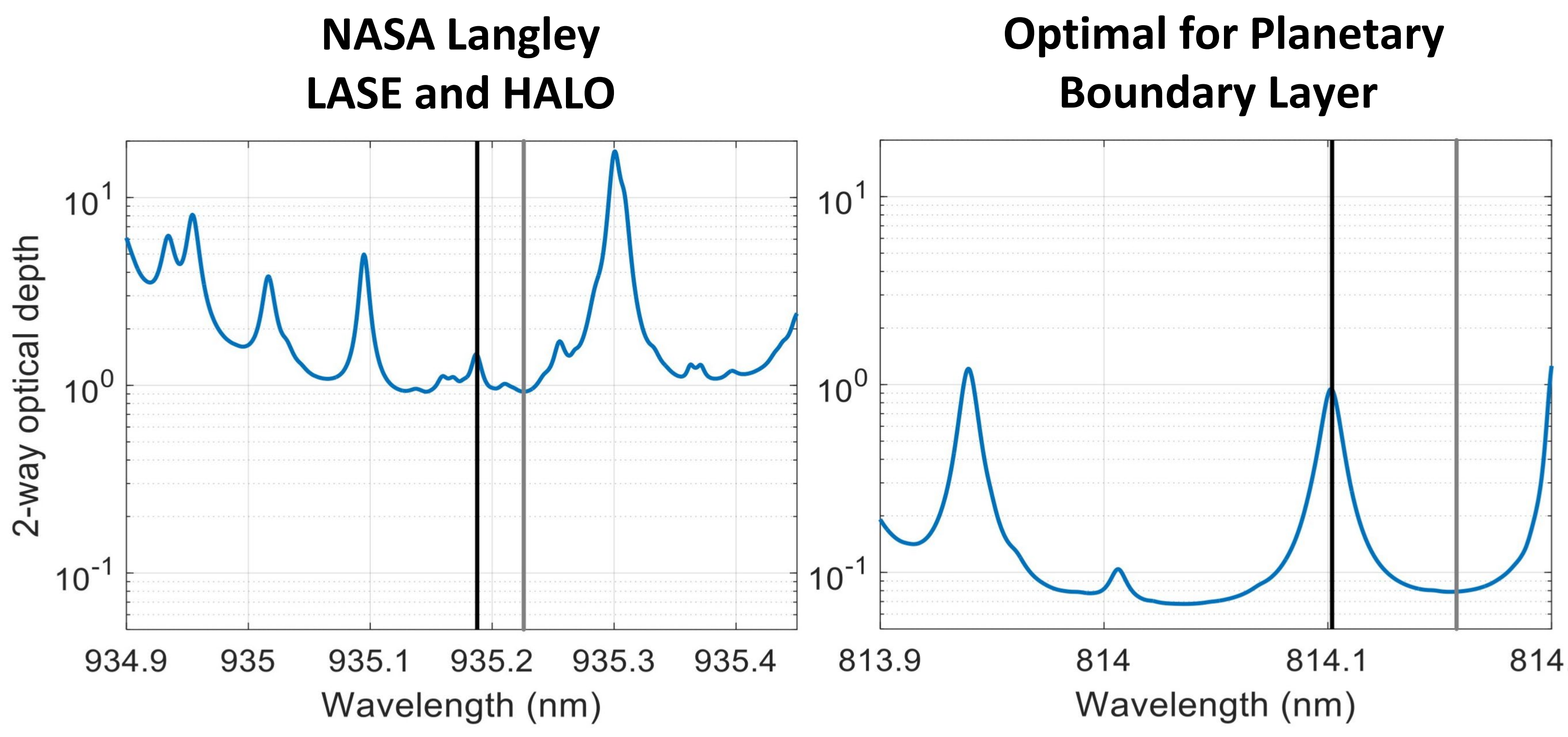


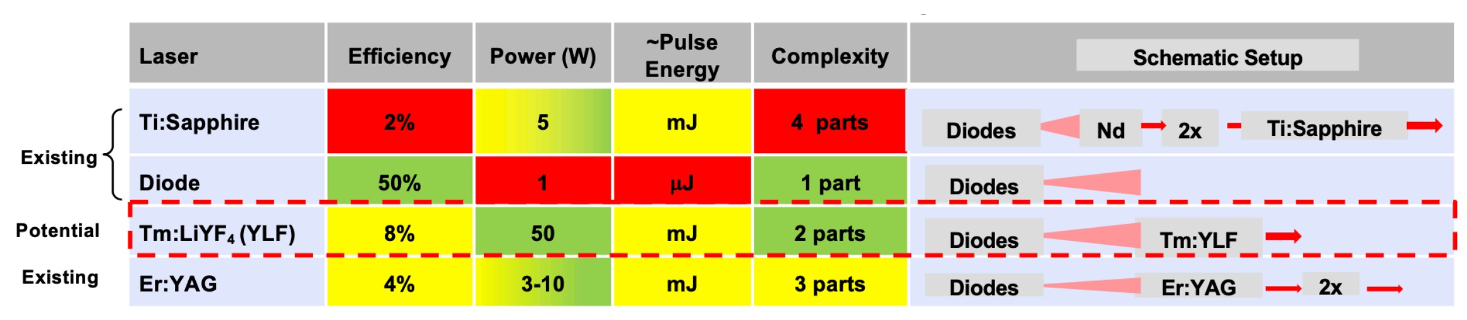
Image credit: C. Senff, NOAA

Two-way optical depth:

$$\tau(\lambda_{on}, R_{max}) = 1.1$$

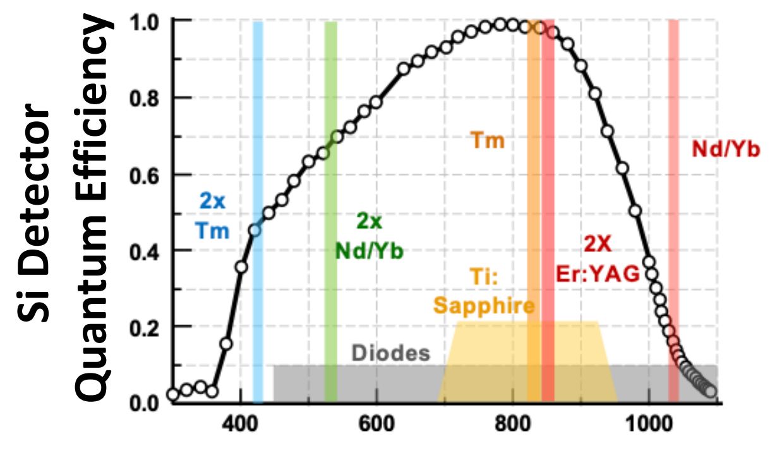
Remsberg and Gordley, 1978





	Laser	Efficiency	Power (W)	~Pulse Energy	Complexity	Schematic Setup
Existing	Ti:Sapphire	2%	5	mJ	4 parts	Diodes → Nd → 2x → Ti:Sapphire →
	Diode	50%	1	μJ	1 part	Diodes
Potential	Tm:LiYF$_4$ (YLF)	8%	50	mJ	2 parts	Diodes → Tm:YLF →
Existing	Er:YAG	4%	3-10	mJ	3 parts	Diodes → Er:YAG → 2x →

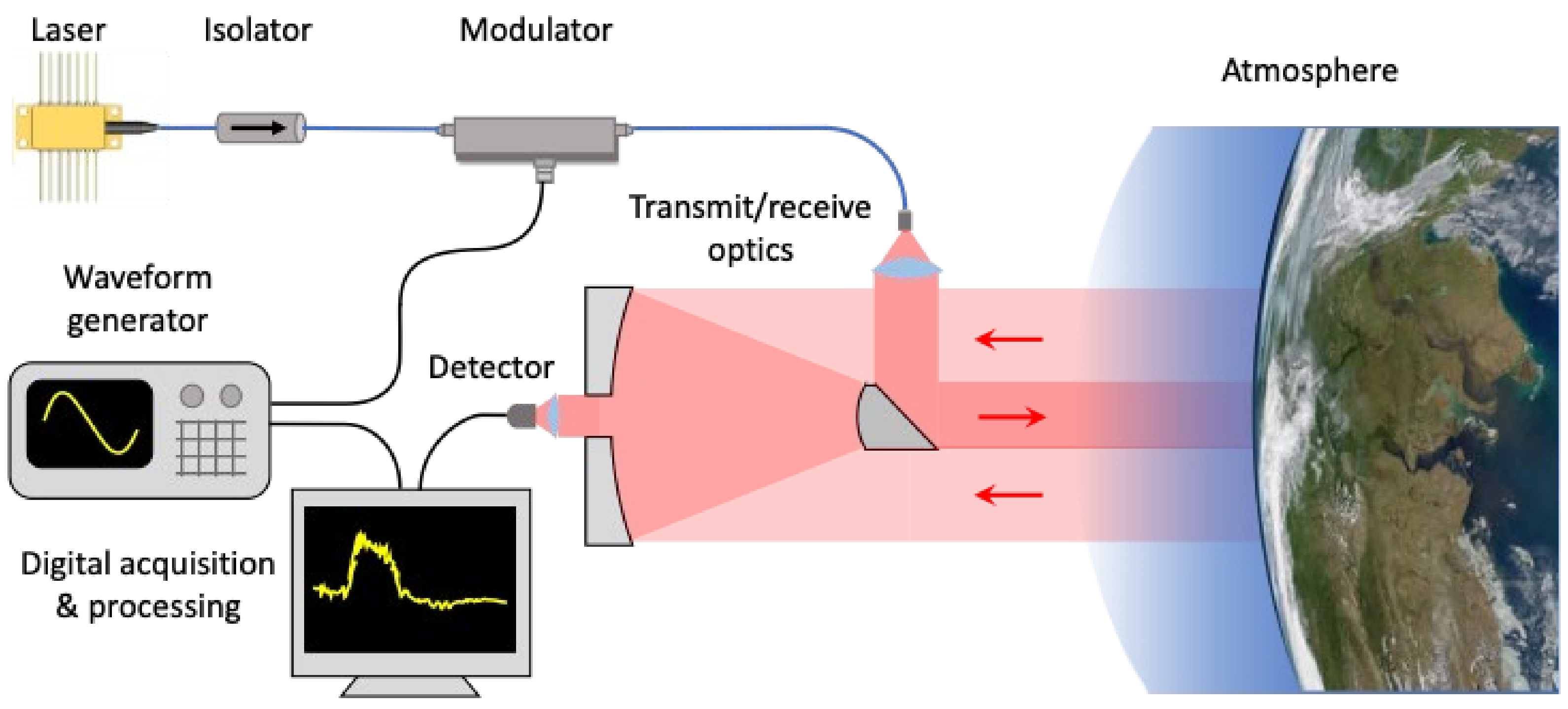
Image credit: T.Y. Fan *et al.*, MIT Lincoln Laboratory



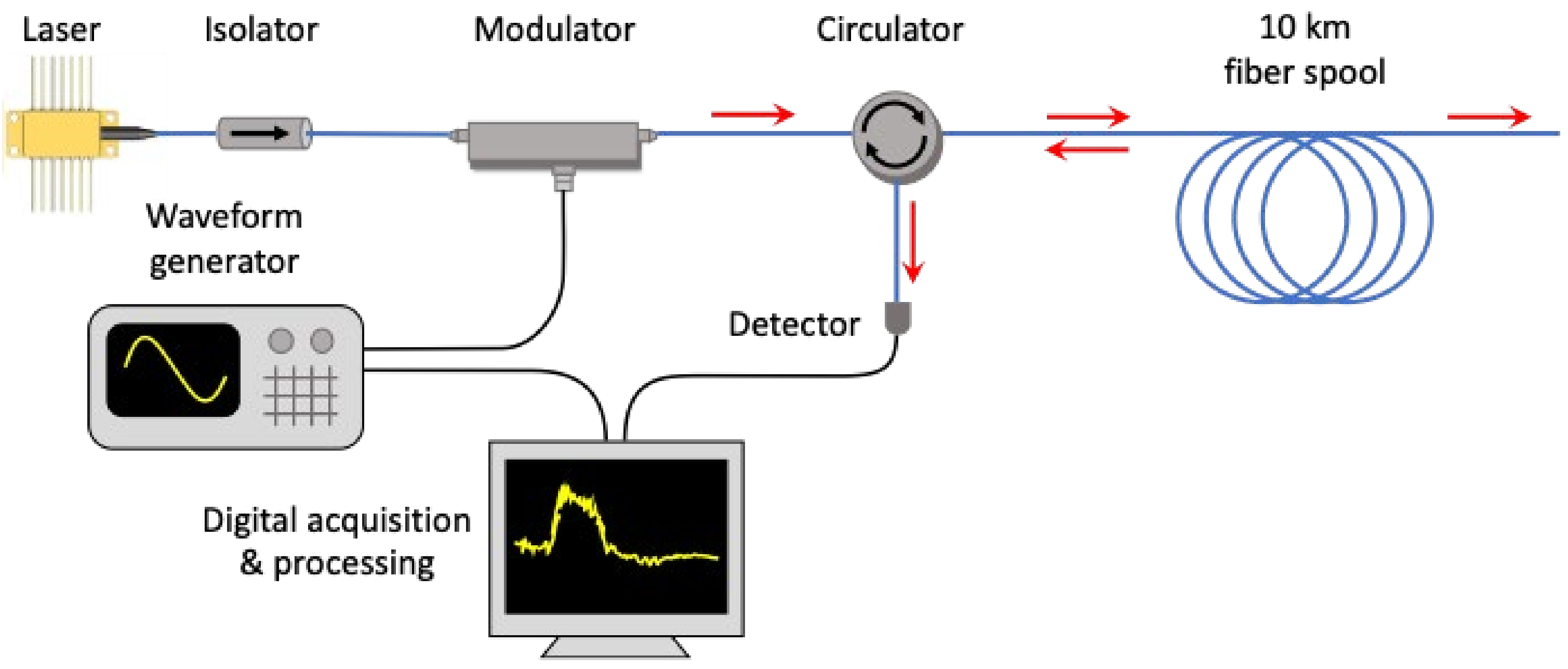
Experimental results

We experimentally demonstrated **CW profiling** using Rayleigh backscattering in several km of fiber to mimic backscattering in the atmosphere.

Lidar instrument



Laboratory



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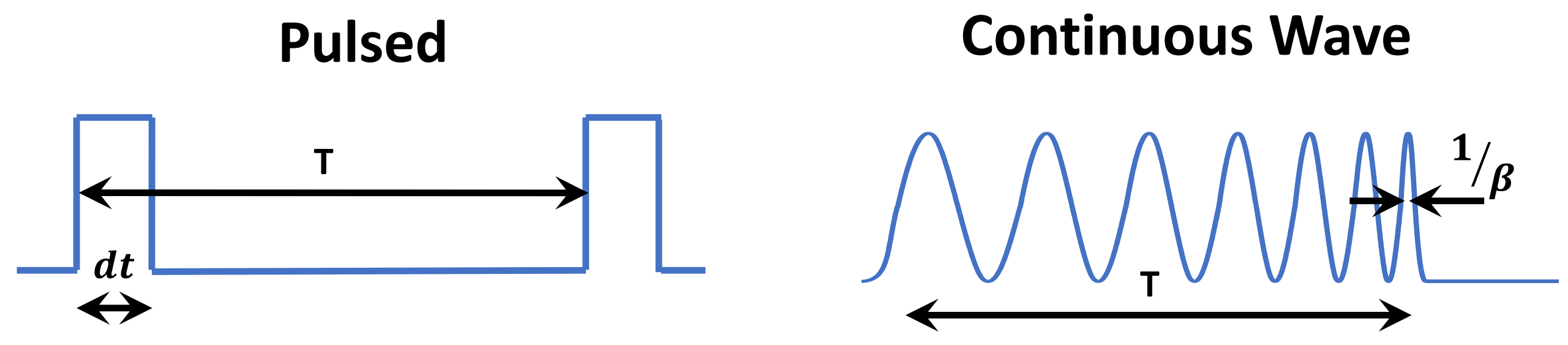
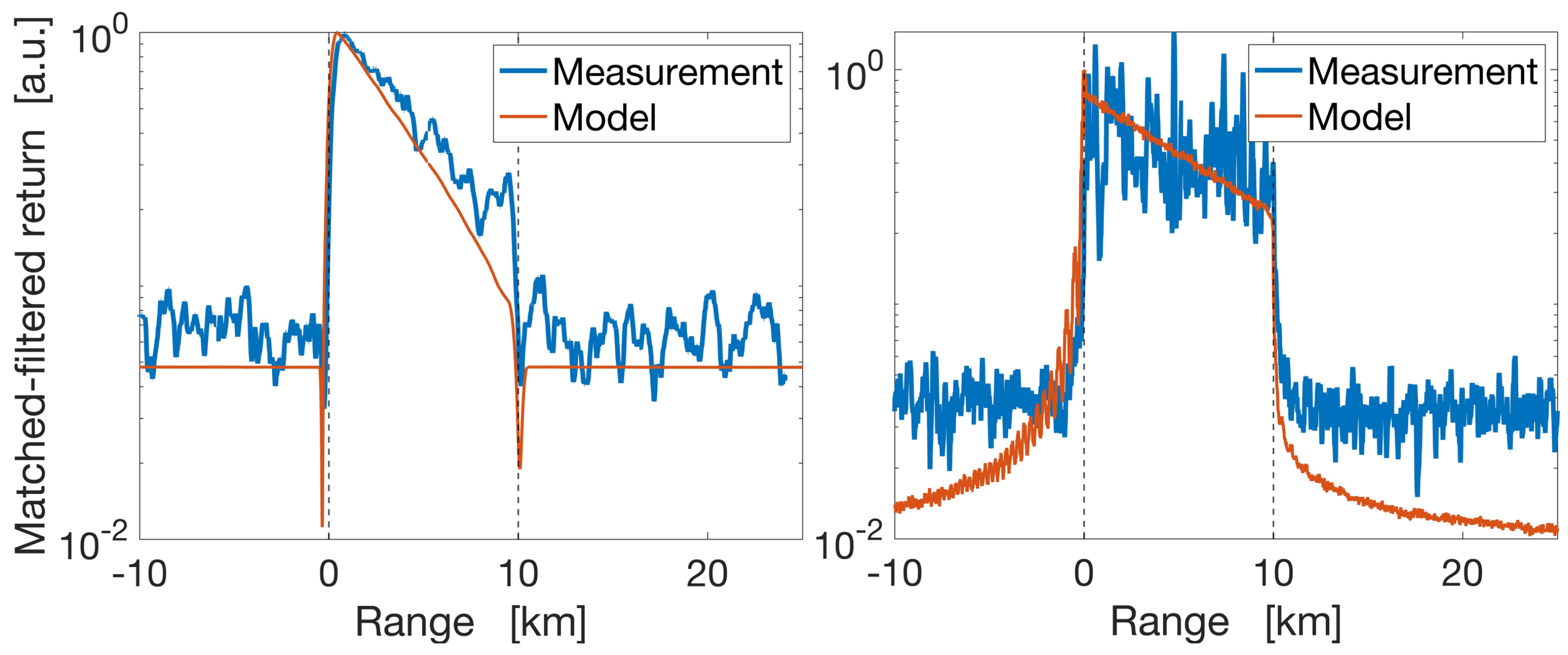


10 km homogeneous Rayleigh backscattering target



Peak power: 50 mW
Pulse width: 5 μs

CW power: 1.25 mW
Chirp bandwidth: 750 kHz

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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Publications:

1. Space Studies Board, National Academies of Sciences, Engineering, and Medicine and others, [Thriving on our changing planet: A decadal strategy for Earth observation from space], National Academies Press (2019).
2. Teixeira, J., Piepmeier, J., and Nehrir, A., “Nasa incubation study on planetary boundary layer,” in [IGARSS 2020-2020 IEEE International Geoscience and Remote Sensing Symposium], 6144–6145, IEEE (2020).
3. Ai, X., P´erez-Serrano, A., Quatrevalet, M., Nock, R. W., Dahnoun, N., Ehret, G., Esquivias, I., and Rarity, J. G., “Analysis of a random modulation single photon counting differential absorption lidar system for space-borne atmospheric co 2 sensing,” Optics express 24(18), 21119–21133 (2016).
4. Nehrir, A. R., Repasky, K. S., and Carlsten, J. L., “Micropulse water vapor differential absorption lidar: transmitter design and performance,” Optics express 20(22), 25137–25151 (2012).

Author Contact Information: *Simone.Bianconi@jpl.nasa.gov*