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Mars Orbiting Lidar

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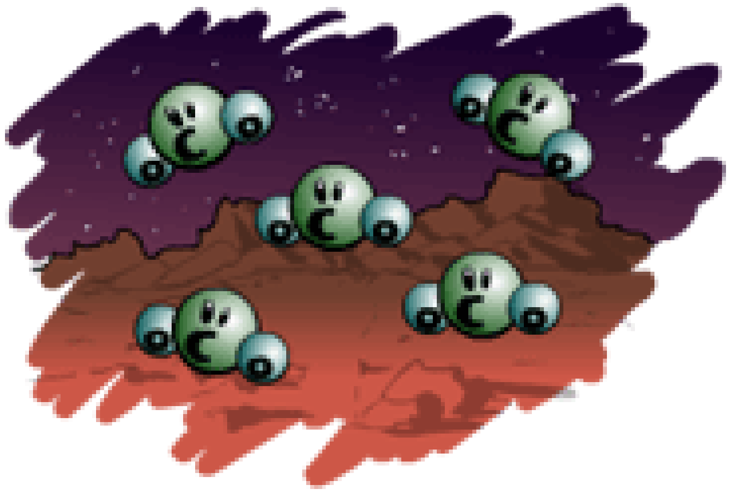

Motivation

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- Provide an instrument to profile Martian atmosphere: wind (by Doppler shift), atmospheric density (by DIAL of CO_2), and aerosol density. (by backscatter intensity).
- Measurement of three parameters can be made with single orbiting 2-μm lidar.
- Unknowns of Martian atmosphere have significant impacts on future exploration:

  "**orbital remote-sensing weather station** is recommended to obtain vertical profiles of V, T, and ρ around the globe with high temporal and spatial resolution, particularly emphasizing heights between 0-20 km and 30-60 km."*

* From NASA draft report "An Analysis of the Precursor Measurements of Mars Needed to Reduce the Risk of the First Human Mission to Mars."

Specific Customer Needs

- Dr. Robert Tolson, National Institute of Aerospace, wishes for aerocapture designs:
  - Global scale wind from surface to 20 km altitude
  - Global scale atmospheric density from 30-60 km altitude
  - Global scale dust density from surface to 50 km altitude
- Dr. John Wilson, NOAA Geophysical Fluid Dynamics Lab, wishes for global climate studies:
  - Primarily, global scale wind measurements.

Technology Heritage

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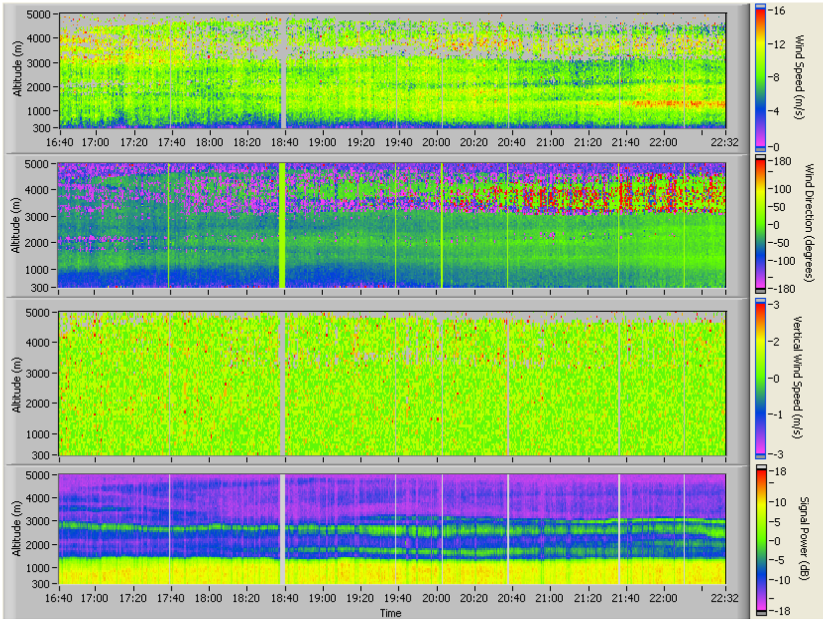
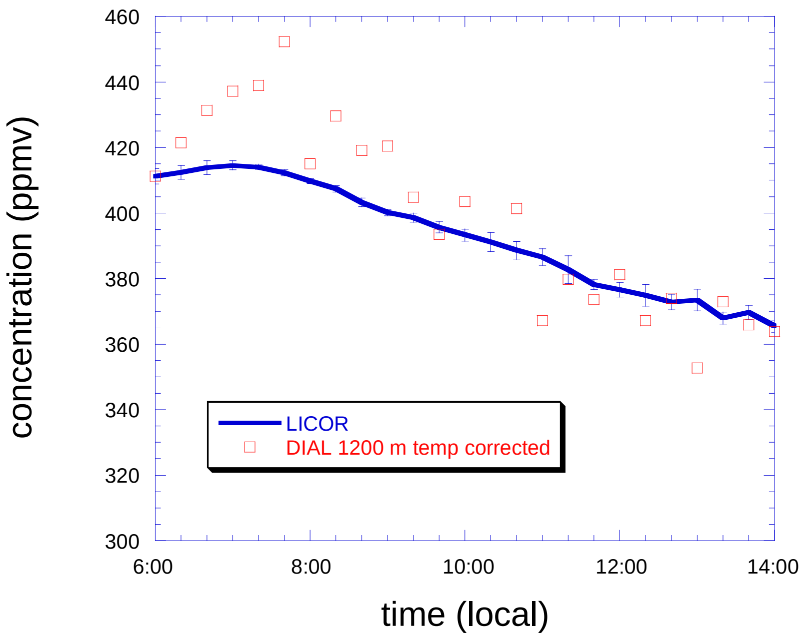
- LaRC, primarily under LRRP, has developed technology to enable lidar measurements from Mars orbit: high-energy lasers, conductive cooling, single-frequency spectrum, precise wavelength control, and optimized heterodyne detectors.
- Proof-of-concept demonstration has been made of coherent DIAL lidar system for simultaneous wind and CO_2 measurement:



3-D wind profile over 6 hours



DIAL compared to in-situ sensor

Approach

- Phase 1: 1-year duration (FY 2005)
  - Create model of lidar performance in Mars atmosphere.
  - System designs and trade studies.
  - Technology assessment.
- Phase 2: 2-year duration
  - Build breadboard prototype lidar.
  - Calibrate CO_2 precision with spectroscopy.
  - Test and validate with atmospheric measurements correlated with other sensors.

Mars Lidar Simulation Model

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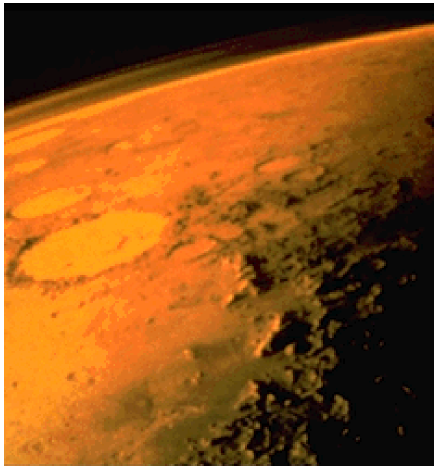
- Adapting an existing computer model of Doppler lidar performance from Earth orbit to Mars orbit.
- Contracted with Simpson Weather Associates, Inc. for model development (work began February 2005).
- Model is being developed in modular steps:
  - Convert Earth atmospheric parameters to Mars parameters.
  - Create analysis of Martian wind measurement performance.
  - Add capability for double laser pulse operation.
  - Develop DIAL simulation.
- Near-term work by SWA is to understand dust characteristics; working with NASA Ames group.

A Rough Calculation

- Extrapolating current understanding of Earth wind measurement capabililty, and
- Extrapolating on detection of dust devils on Mars by Mars Orbiting Laser Altimeter (MOLA)
- Wind measurements are easier on Mars than Earth. A relatively modest lidar would do the job on Mars:
  - Pulse energy = 100 mJ
  - Telescope aperture = ½ m diameter
  - Averaging = 20 pulses



System Design--CO_2 Line Selection

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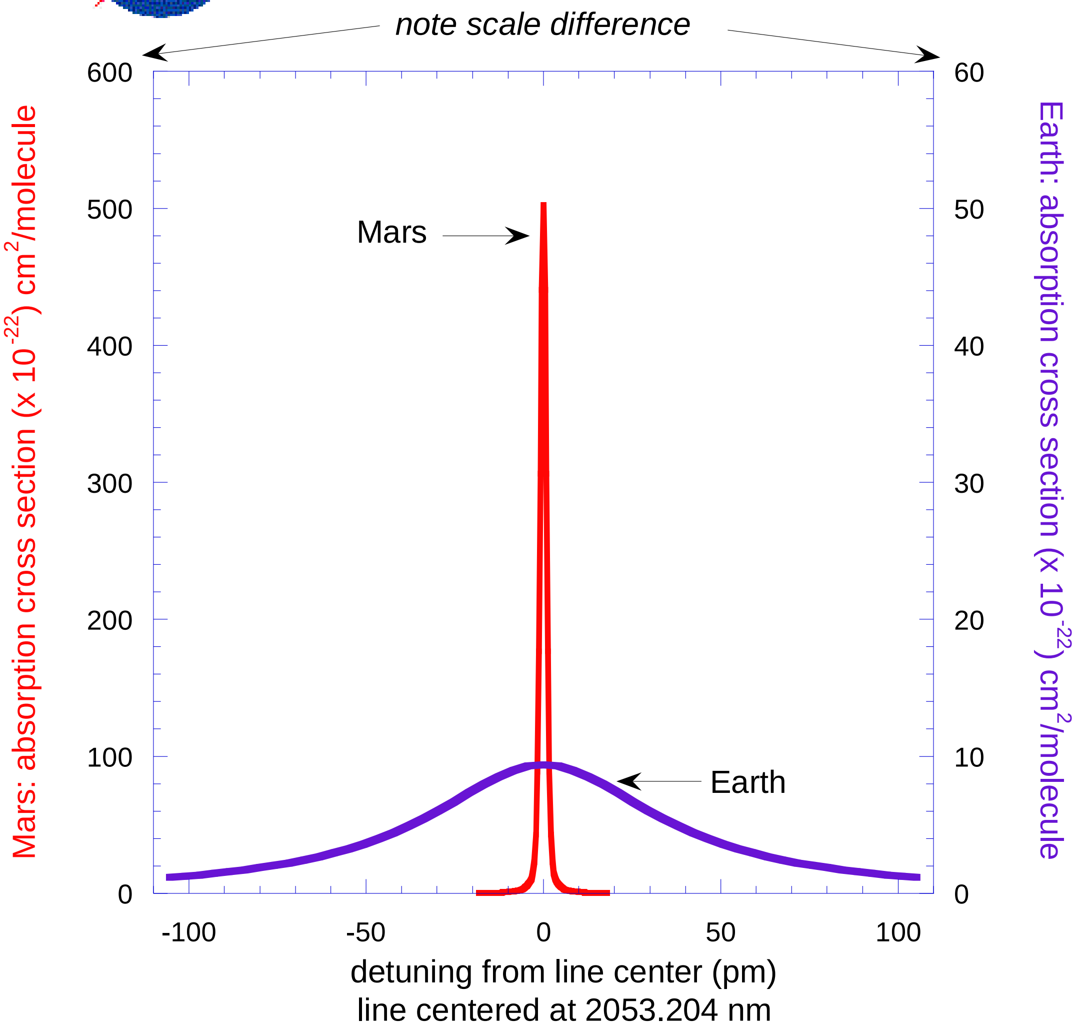

Line centered at 2053.204 nm selected for:

- good laser operation
- insensitivity to temp.
- line strength
- no interference from other gases.

Line is “tall and skinny” compared to Earth because of much lower pressure on Mars.

Transmission on Line Center

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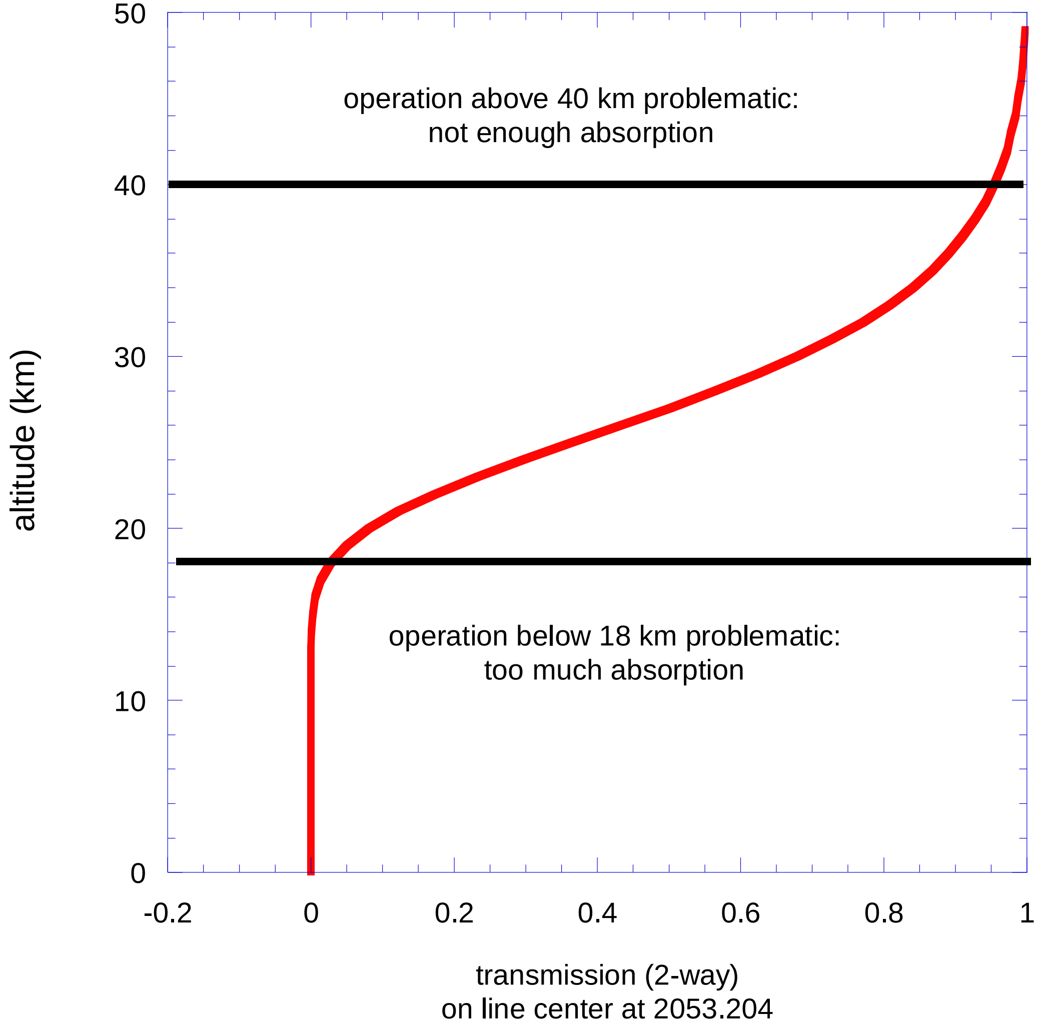

Line strength gives measurements at high altitudes, where density measurements are desired.

Altitude of optimum operation can be tailored:

- •choose neighboring line of different strength (stronger and weaker are available)
- •tune laser off line center
- •exploit Doppler shift

Wavelength Control

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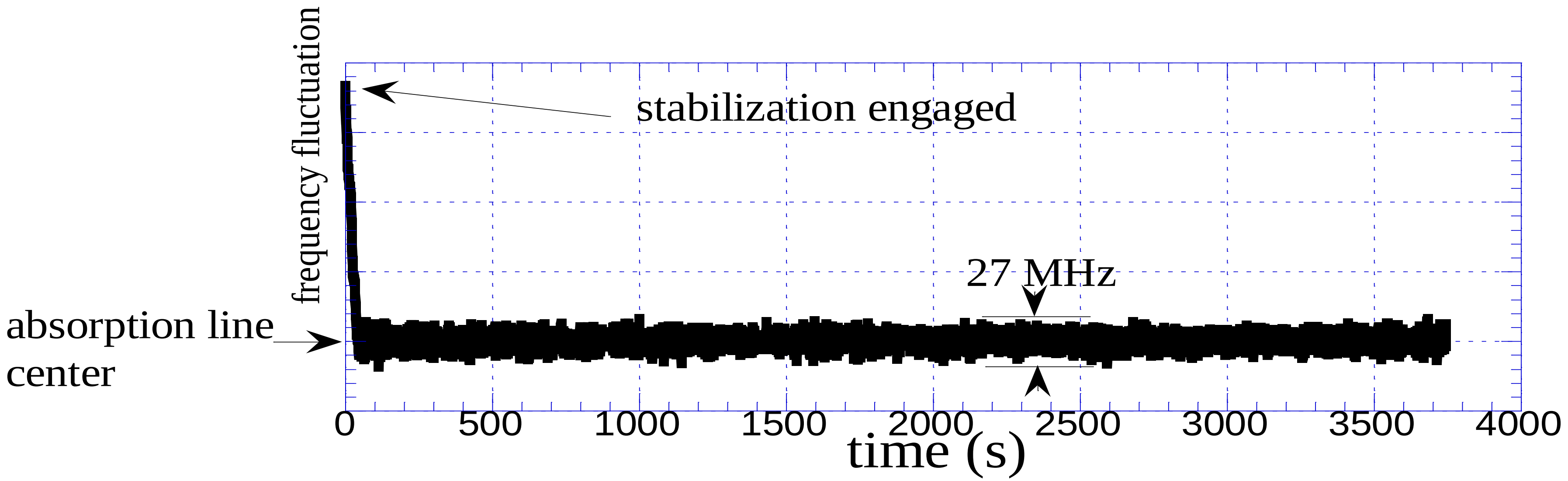
- Critical because of narrow width of martian lines.
- Wavelength locking techniques already developed:



• Since this development in 2000 other researchers (Coherent Technologies, Inc.) have improved technique to +/- 300 kHz, well within requirements for Mars measurements.

Technology Assessment

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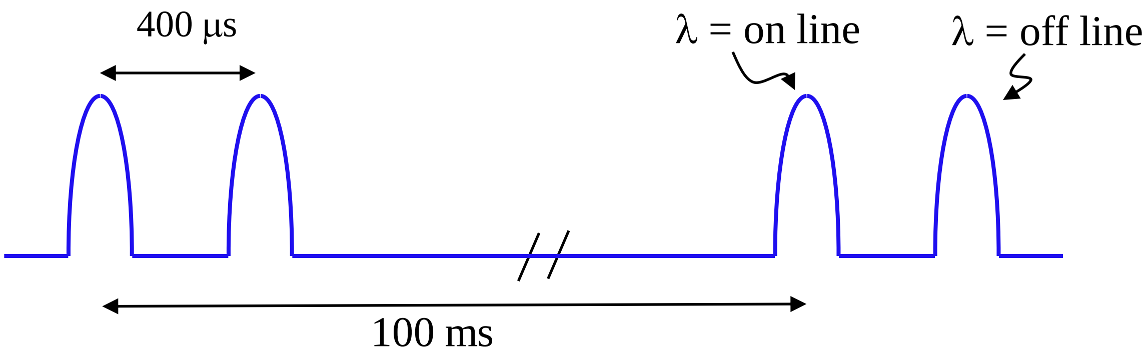
- Rapid wavelength switching in double-pulse operation for DIAL has not been sufficiently demonstrated.
- Must injection seed at two different wavelengths for each pulse of a doublet.
- Switching must occur in less than 100 μs.
- Have identified commercial technology (Civcom, Inc.) with electro-optic switch that can switch in 400 ns. A procurement has been initiated for a custom designed switch for 2 μm.



Conclusions

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- Characterization of atmosphere of Mars shown to be critical for exploration. Wind, density, and dust are needed measurements.
- 2-μm coherent DIAL is promising for wind, CO_2 concentration, and dust profiling with a single instrument.
- Performance model under development.
- Accessible absorption lines are well suited to CO_2 measurements in the upper atmosphere, where measurements are desired.
- Most of lidar technology needed has been demonstrated in lab and system testbed. Remaining technology of rapid wavelength switching is being addressed.