

# Mars Atmospheric Characterization Using Advanced 2- $\mu\text{m}$ Orbiting Lidar

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## Abstract

Mars atmospheric characterization is critical for exploring the planet. Future Mars missions require landing massive payloads to the surface with high accuracy. The accuracy of entry, descent and landing (EDL) of a payload is a major technical challenge for future Mars missions. Mars EDL depends on atmospheric conditions such as density, wind and dust as well as surface topography. A Mars orbiting 2- $\mu\text{m}$  lidar system is presented in this paper. This advanced lidar is capable of measuring atmospheric pressure and temperature profiles using the most abundant atmospheric carbon dioxide ( $\text{CO}_2$ ) on Mars. In addition Martian winds and surface altimetry can be mapped, independent of background radiation or geographical location. This orbiting lidar is a valuable tool for developing EDL models for future Mars missions.

## 1. Introduction

Characterization of Mars atmosphere is an important challenge for future exploration of the planet. The ability to land large payloads on surface depends upon EDL strategy, which relies on atmospheric and surface conditions to reduce uncertainties and risks for future Mars missions. Landing spacecraft on Mars is known to be hazardous. However, EDL operation risk can be reduced by improved knowledge of atmospheric conditions, surface range and approach velocity, while continuously mapping the approaching terrain for potential hazards. Atmospheric and surface investigations from orbit are the highest priority objectives for EDL of large systems. Laser remote sensing techniques are strong candidates to meet such objectives. For example, orbiting lidar instrument capabilities would include surface mapping, planetary atmospheric profiling, and 3-D imaging for hazard avoidance, motion sensing and docking activities [1]. To address these

challenges, a Mars orbiting pulsed 2- $\mu\text{m}$  lidar instrument is presented in this paper. This instrument has the capability to characterize critical parameters of Martian atmosphere. Orbiting 2- $\mu\text{m}$  lidar would target  $\text{CO}_2$ , the most abundant atmospheric gas on Mars, for temperature, pressure and density profiling. Using the backscatter lidar signal, range-resolved profiles of wind, aerosols and dust could be obtained. Ranging, a byproduct of the pulsed operation, is useful for surface studies. Measurements are obtained with resolutions that are difficult to achieve by other means.

## 2. Technical Approach

NASA Langley Research Center (LaRC) has been developing lidar enabling technologies for atmospheric wind and  $\text{CO}_2$  measurements for Earth science [2-4]. This includes state-of-the-art 2- $\mu\text{m}$  single or multi-pulsed laser transmitters for various lidar applications [2, 5]. Single-pulse 2- $\mu\text{m}$  lasers based on LuLiF technology is compatible with the  $\text{CO}_2$  R32 absorption line. Using this technology Doppler lidar and coherent DIAL are used for airborne 3D-wind and  $\text{CO}_2$  measurements, respectively [2-3]. Multi-pulse 2- $\mu\text{m}$  laser based on YLF technology, targeting the  $\text{CO}_2$  R30 line, demonstrated accurate airborne sensing of  $\text{CO}_2$  using the IPDA technique [4-5]. Key advantages of these systems include multi-pulsed operation, using single pump-pulse, and wavelength tuning, switching and locking for each pulse. Other capabilities include high repetition rate, which is preferable for space platform, space qualified packaging, rigid system design with low power consumption and small size.

Adopting this 2- $\mu\text{m}$  lidar technology from a Martian orbiter, figures 1 and 2 compare near-surface  $\text{CO}_2$  absorption cross section spectra for Earth and Mars environments. The profiles are driven from HITRAN.

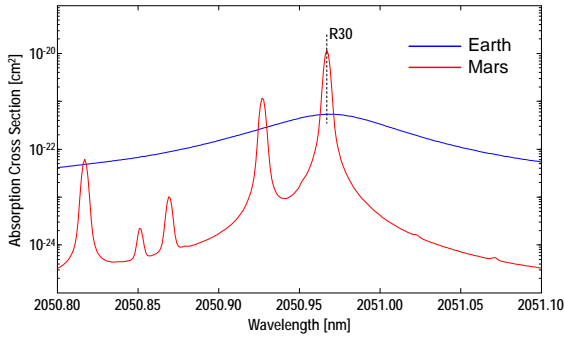


Figure 1: CO<sub>2</sub> absorption spectra around R30 line, achievable by Ho:Tm:YLF laser transmitter, for both Earth and Mars surfaces.

For Earth, standard atmospheric conditions and 400 ppm CO<sub>2</sub> dry-air mixing ratio are considered. For Mars, mean surface pressure and temperature of 600 Pascal and -60°C, respectively and 100% CO<sub>2</sub> abundance are assumed. Operating from a Martian orbiter, while implementing multi-pulsed operation, would generate enough information to solve for pressure, temperature and density profiles. For example, wavelength tuning and locking capabilities could target temperature insensitive lines, to solve for pressure and density. Backscatter return signal would include aerosol and dust profiling. Using coherent-detection, wind velocity could be achieved. Altimetry is directly obtained through time-delay measurement of the pulsed nature of the transmitter. This exhibits the multi-pulsed 2- $\mu$ m orbiting lidar as a valuable tool for developing EDL models for future Mars missions.

### 3. Summary and Conclusions

NASA LaRC has been developing advanced wind and CO<sub>2</sub> airborne enabling 2- $\mu$ m pulsed lidar technologies for Earth science. Continuing efforts are focused to extend such technology to space. Key capabilities of the 2- $\mu$ m lidar include multi-pulse generation, with wavelength tuning, switching and locking. Based on LuLiF and YLF technologies, the transmitter can target the R32 and R30 CO<sub>2</sub> lines, respectively. CO<sub>2</sub> is the most abundant atmospheric gas on Mars. Targeting precise wavelengths, temperature, pressure and number density profiles could be obtained from a Martian orbiter. Winds, aerosol, dust and altimetry are other products of this lidar system. Measurements from this orbiting lidar are valuable for developing EDL models for future Mars missions.

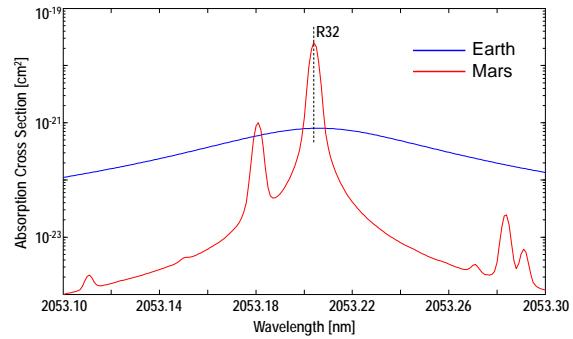


Figure 2: CO<sub>2</sub> absorption spectra around R32 line, achievable by Ho:Tm:LuLiF laser transmitter, for both Earth and Mars surfaces.

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