Development of a water vapor measurement system on the surface of Mars

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Studying water distribution and transport on the surface of Mars is crucial for understanding the planet's atmospheric history, the potential for past or present life, and preparing for manned missions. In particular, the variation of near-surface concentration of water vapor and the isotope ratio of D/H provides insights into the global water circulation dynamics on Mars. One of the essential processes is water exchange between the regolith and the atmosphere.

Regolith-atmosphere water exchange occurs through the process of physical adsorption. The adsorption constant largely depends on temperature, which is known to change by approximately 60 K during the day. Although many simulation studies have been conducted, a comprehensive understanding of the process and its contribution to global water transport is yet to be obtained.
While orbital explorers provided valuable data, a comprehensive understanding of near-surface water transport requires in-situ measurements from landers or rovers, which are currently inadequate. For instance, the Curiosity rover (NASA, 2012-) utilized a relative humidity sensor, which could not measure humidity during daytime periods due to significant drops in relative humidity at high temperatures. Although Curiosity was also equipped with a laser spectroscopy system, this apparatus was not specifically designed for water vapor detection and thus, unable to measure the D/H ratio precisely.

To overcome these challenges, we have developed a Laser Absorption Spectroscopy (LAS) system, tailored for effective measurement of low-concentration water vapor in Martian surface conditions. Our LAS system is not only accurate, straightforward, compact, and lightweight, but it also simultaneously measures the D/H ratio, a feat not previously achieved on Mars.

Our experimental results have validated the efficacy of our system in measuring water vapor concentrations under Martian conditions. While its sensitivity for HDO detection was slightly inadequate, further enhancements, such as incorporating Wavelength Modulation Spectroscopy (WMS), are expected to elevate the system's sensitivity to the required levels.

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