DIAL

Mobile Differential Absorption Lidar

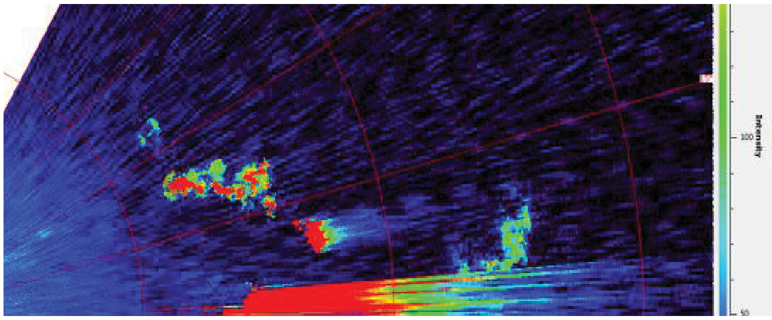
At the forefront of today's environmental monitoring challenges, SDL is developing new technologies and techniques to leverage lidar systems for advanced scientific field work. SDL provides novel solutions to help understand how agriculture, industry, and energy extraction can affect the composition of the atmosphere and quality of life.

SDL designed and fabricated a custom differential absorption lidar (DIAL) laser instrument and mobile laser laboratory. As the only mobile DIAL laboratory operating in North America, SDL's DIAL system provides in-situ monitoring, resulting in more accurate and faster data collection. The system can also quickly scan from scene to scene, and the field of regard is flexible for targeting large volumes. DIAL operates in the short-wavelength infrared (1.4–1.7 μm) and may be configured to operate in the ultraviolet region (300–450 nm). Though the system is currently tuned to detect methane and carbon dioxide, it is designed with forward compatibility for VOCs, NOX, and ozone detection. SDL's DIAL team members are leaders in the field of atmospheric lidar for environmental and remote sensing applications, with a history of field-proven success.

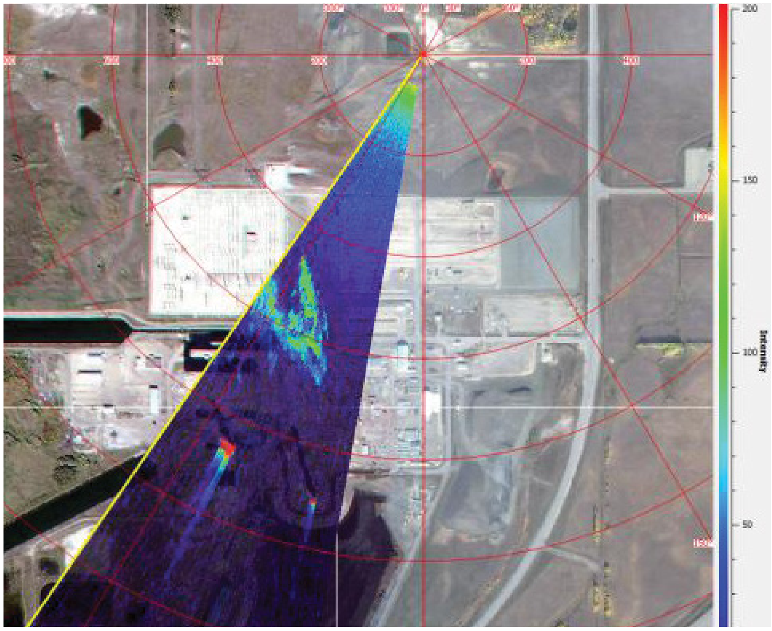
DIAL technology detects emissions by comparing laser pulses of two different wavelengths. One of the laser pulses is absorbed by the desired gas, while the second is not. The difference between the intensity of these two pulses determines the gas concentration at each point along the beam. The laser beam may be scanned across a wide area to collect a 3D concentration picture.

SDL's mobile DIAL laboratory will continue to play a key role in the mission to assess and maintain air quality in the United States and Canada. DIAL is used to detect the concentration of fugitive emissions, specifically carbon dioxide and methane released into the air from energy producers in the region.

Coal-fired power plant



Vertical DIAL scan



Horizontal DIAL scan

Space Dynamics Laboratory
Utah State University

1695 North Research Park Way | North Logan, Utah 84341
info@sdl.usu.edu | www.sdl.usu.edu

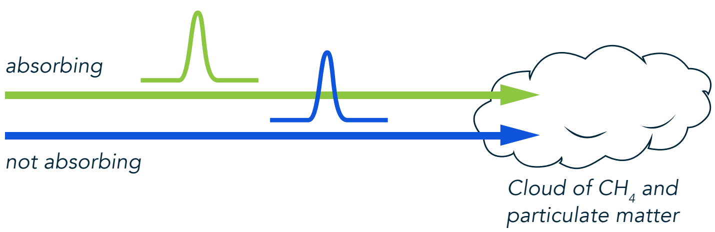
SDL/15-235 Rev. A

DIAL DETECTION

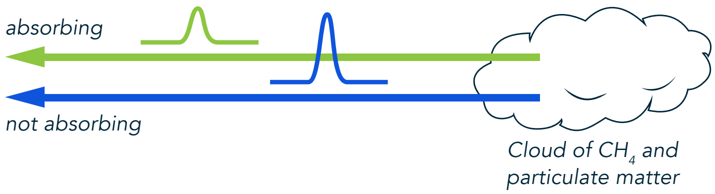
DIAL technology detects emissions by comparing laser pulses of two different wavelengths. One of the laser pulses is absorbed by the desired gas, while the second is not.

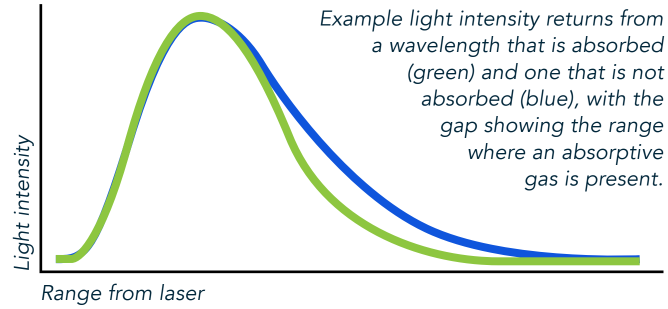
The difference between the intensity of these two pulses determines the gas concentration at each point along the beam.

OUTGOING LASER PULSE



RETURNING LASER PULSE





Example light intensity returns from a wavelength that is absorbed (green) and one that is not absorbed (blue), with the gap showing the range where an absorptive gas is present.

Gas	λ-on	λ-off
CO_2	1.5720 µm	1.5722 µm
CH_4	1.64391 µm	1.64351 µm

Laser wavelengths used for absorbing (λ-on) and not absorbing (λ-off) channels for two common gases.

DIAL SIGNAL ANALYSIS

Received power

$$P_\lambda(r) = C_\lambda \left(\frac{\beta_{\pi\lambda}(r)}{r^2}\right) \exp^{-2\left[\int_{r_1}^{r} (\beta_\lambda(r_p) + \sigma_\lambda n(r_p))\, dr_p\right]}$$

- P_λ *is the signal power received back*
- r *is the range*
- C_λ *is the radiometric constant depending on the geometric factors*
- $\beta_{\pi\lambda}$ *is the angular scattering coefficient in the π direction or the backscatter direction*
- β_λ *is the scattering attenuation coefficient*
- σ_λ *is the absorption cross section*
- n *is the number of absorbing molecules in a unit volume at range* r

Retrieved concentration

$$n(r_p) = \frac{-1}{2\Delta\sigma}\left(\frac{d}{dr}\ln\left(\frac{P_{\lambda on}(r)}{P_{\lambda off}(r)}\right)\right) + \frac{1}{2\Delta\sigma} \cdot \frac{d}{dr}\ln\left(\frac{\beta_{\pi\lambda on}(r)}{\beta_{\pi\lambda off}(r)}\right) - \frac{1}{\Delta\sigma}(\beta_{\lambda on}(r_p) - \beta_{\lambda off}(r_p))$$

Term A: Derivative of the ratio of the received power (on/off)
Term B: Derivative of the ratio of the backscatter terms (on/off)
Term C: Difference of the scattering attenuation terms (on–off)
All terms depend on reciprocal of the absorption cross section (on–off)