Remote Detection of Chemicals Associated with Clandestine Drug Labs

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Brief Project Overview:
Montana State University, the University of Montana, and the National Jewish Health Medical Center along with their partners are developing laser-based remote sensing technologies to detect clandestine drug labs, starting with meth labs. The technology can be adapted to detect the hazards inside labs to aid first responders and clean up personnel. Advances in the areas of laser operation, detection, and knowledge of the detectable chemicals are all being addressed by the Remote Methamphetamine Detection Initiative (REMEDI) partnership, which includes partners from academic institutions, research institutions, for-profit and not-for-profit private sector organizations, state and local law enforcement organizations, state government, tribal councils, and technology transfer organizations. The goal is a hand held unit for remote chemical sensing via mid-IR absorption spectroscopy. This technology can also be extended to remotely detect other airborne chemicals, including other drug manufacturing signature chemicals, chemicals important to home security, and dangerous or other toxic industrial effluents.

Program Activities:

DIAL—Differential Absorption LIDAR

Idea: Two laser pulses are directed at an effluent plume. One pulse’s wavelength matches an absorption feature of the desired effluent, while the other matches a wavelength region with no absorption features. The light pulses passing through the plume scatter back along the beam path and is directed onto a detector.

Outcome: While propagating through the plume, the pulse with a wavelength matching the chemical of interest loses energy depending on the chemical concentration. The non-matching pulse does not lose energy. This difference in amount of return light determines the presence and concentration of the meth effluent. Higher concentrations produce a more significant difference in return light.

Dual-Wavelength DIAL

We are developing an advanced DIAL technique where two wavelengths are produced (on and off resonance) within the same laser pulse, so the on and off resonance measurements are spatially and temporally correlated. This correlation greatly simplifies the system, allowing the differences in the atmosphere, changes in the scattering surface, and shot-to-shot pulse energy fluctuations to be ignored.

OPG Crystal

OPG – Optical Parametric Generation - is a nonlinear process that splits a pump photon into two lower energy photons (signal & idler). These energies are allowed by the following equation:

\[ \omega_{pump} = \omega_{idler} + \omega_{signal} \]

OPG in a bulk crystal produces a broadband output, which is not ideal for chemical detection. Furthermore, efficient conversion requires phase matching throughout the length of the crystal, which can be near impossible in a bulk crystal.

Modification of OPG: To create a narrowband output, which is more ideal for detecting narrow absorption features, a periodically poled OPG crystal can be used. A periodically poled crystal changes the domain of the crystal by 180° when the propagating light begins to exhibit destructive interference. Also this poled period provides a selection tool for the signal and idler wavelength combinations.

Absorption Peaks & Seed Laser

Goal: Measure chemical absorbance peaks down to 10⁻⁴ in plumes 100m away. To avoid atmospheric absorption lines, we’re working in the atmospheric transmission window between 3 and 4 microns. Several meth effluent absorption lines are located in this window.

Problem: Detection of a single absorption peak requires the laser linewidth to be narrow, but the output of the periodically poled nonlinear crystal is broadband in comparison to the absorption peaks without modification.

Solution: A distribute feedback laser (DFB) that is narrow bandwidth and spatially matched with the pump can be seeded to create a “guide” for the signal and idler outputs to follow, causing the outputs to become cleaner spatially as well as stable in the frequency domain. This laser is called a seed laser and enables the narrowband output required to detect a meth effluent. This also allows us to slightly change the output of the nonlinear crystal for a given poling period by changing the wavelength of the DFB.

Top Contributions:

1. Remote detection of clandestine drug labs.
2. Hazardous chemical detection to aid law enforcement and first responders.
3. Novel mid-IR chemical remote sensing applications.

Top Challenges:

1. Compact Mid-IR Laser development
2. Chemical sensitivity and identification
3. Portable, robust, compact system