Standoff Detection of Chemicals Using Rydberg Fingerprint Spectroscopy and Microwave Rayleigh Scattering

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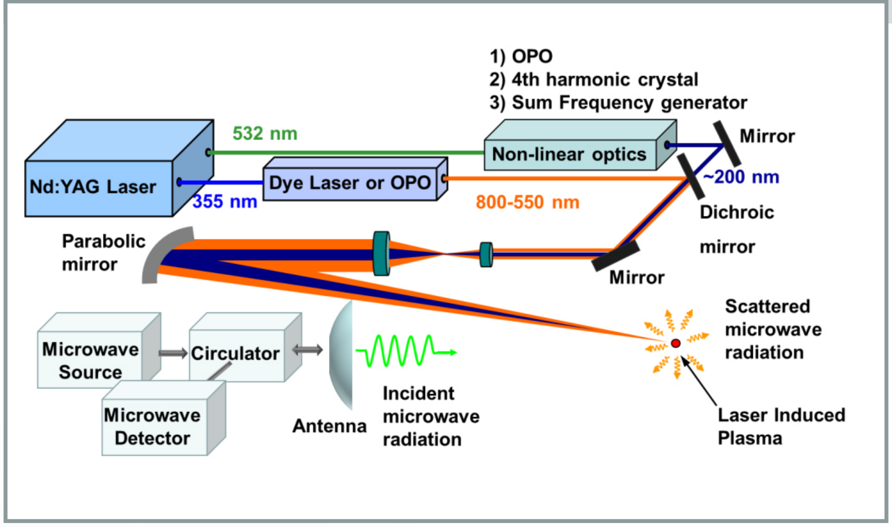

Technology Summary

The invention relates to a method for standoff trace chemical sensing. The basis for the technique is Rydberg Fingerprint Spectroscopy followed by microwave-based detection.

In Rydberg Fingerprint Spectroscopy, target molecules are first excited to a Rydberg state (usually 3s) and then pass through higher lying Rydberg states when probed by two-photon ionization. Transitions between the Rydberg states reveal a highly resolved and purely electronic spectrum that is extremely characteristic of the molecular structure. This spectrum is subsequently recovered by probing the remotely generated photo-induced plasma with microwave radiation. This plasma is transparent to the microwaves, and electrons inside the plasma oscillate in phase with the microwaves thus causing their scattering. The plasma continues to scatter microwaves until the electrons recombine with the molecular ion or become attached to some other molecules. The scattering signal reflects the generation and evolution of the unbounded electrons inside the plasma. As the laser wavelength is tuned through the resonance associated with the multiphoton ionization, the total electron number of the plasma (and thus the intensity of scattered microwaves) changes, strongly peaking at the resonant wavelength, thus recovering Rydberg spectrum.

The complexity of the Rydberg spectrum does not scale with the molecular size, making the technique well suited for detection of large organic molecules such as those of explosives or chemical warfare agents. The remarkable sensitivity of Rydberg electron to the molecular structure allows for distinguishing between chemicals with very close structures, such as new and aged explosives. The technique is largely insensitive to the temperature of the sample and can be applied for non-intrusive detection of combustion intermediates. The technique can be applied to detection of chemical vapors as well as residues on the surfaces.

Advantages

- Can distinguish between molecules of similar structure, such as new and aged explosives
- Can detect highly energetic and short-lived molecules, such as combustion intermediates
- Is well suited for detection of large organic molecules
- The technique is orthogonal to well established techniques and can be used to supplement them thus increasing the reliability of detection
- The technique does not require reflection geometries and can be applied for detection in open air

Potential Applications

- Various standoff detection applications, such as explosives and chemical warfare
- Nonintrusive detection of highly energetic molecules (e.g., combustion intermediates)

Patent

Fedor M. Rudakov and Zhili Zang. *Standoff Detection of Chemicals Based on Structure Sensitive Photoionization through Rydberg States*, U.S. Provisional Patent Application 61/533,364; filed September 12, 2011.

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