Università degli Studi di Padova

Raman spectroscopy for inline analysis of combustion processes

Riccardo Dal Moro - 37th Cycle

Supervisor: To be defined

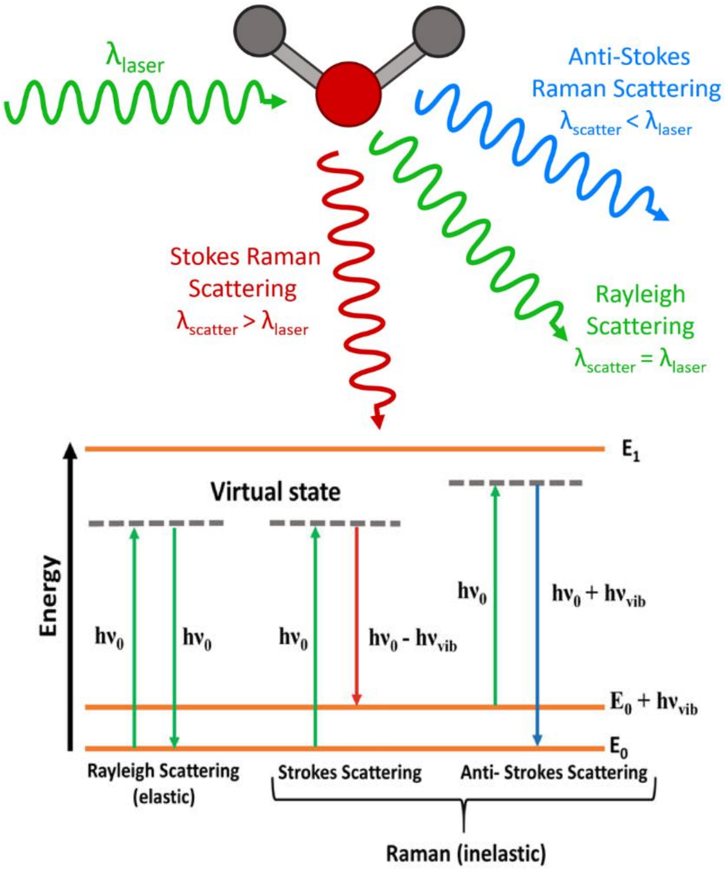
First year admission - 27/10/2021

Raman spectroscopy for inline analysis of combustion processes

Research topic previously assigned by the grant

CNR IFN
Istituto di Fotonica e Nanotecnologie

Introduction to Raman gas spectroscopy

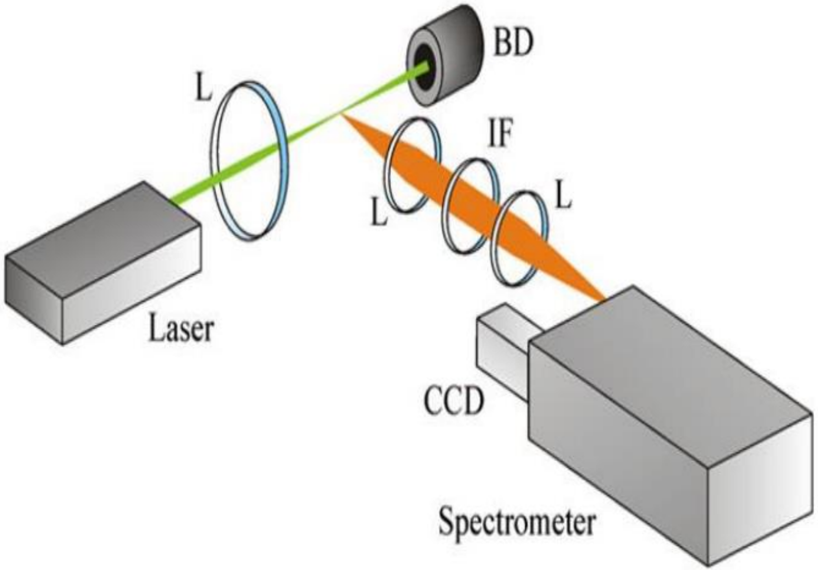


Analytical technique where scattered light is used to analyze a sample:

Rayleigh scattering: elastic scattering
Raman scattering: inelastic scattering
- Stokes and Anti-Stokes components

Substances have their own Raman ‘fingerprint’ that allows them to be identified

Basic Raman gas spectroscopy set up



The laser beam is focused on the sample through a lens (F)

The scattered radiation is collected orthogonally to the laser beam.

The Rayleigh component is filtered by an interpherometric filter (IF).

The spectrum of the filtered signal is disperded by the spectrometer and recorded by an image sensor.

Raman emission dependeces

Raman emission is proportional to:

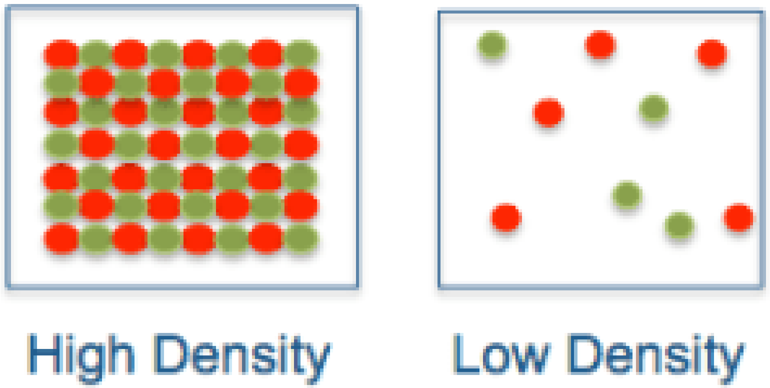
- Intensity of incident radiation (laser pump)
- 1 / λ ^ 4 (wavelength of the laser pump)
- Intrinsic properties of the molecule (cross section)
- Concentration of molecules (density of the material)

Raman spectroscopy for combustion products

In order to perform an accurate analysis of combustion processes (very fast transient phenomena), the requirements are:

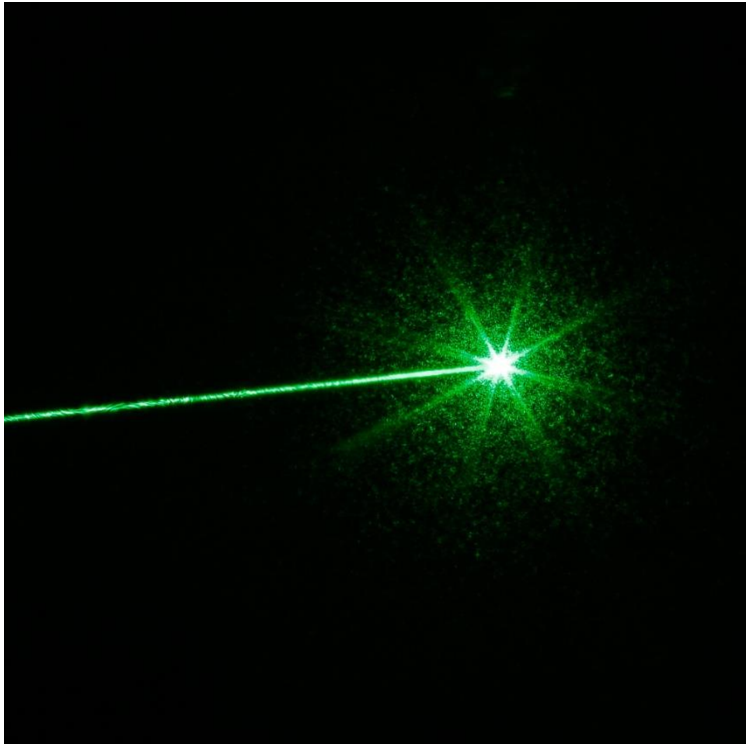
- Fast response
- High sensitivity
- Ability to perform analysis in harsh environment
- Multispecies gas detection

Improving the Raman gas analysis



- Laser source
- Multipass beam path
- Spectrometer
- Detector

Improving the Raman analysis: Laser Source

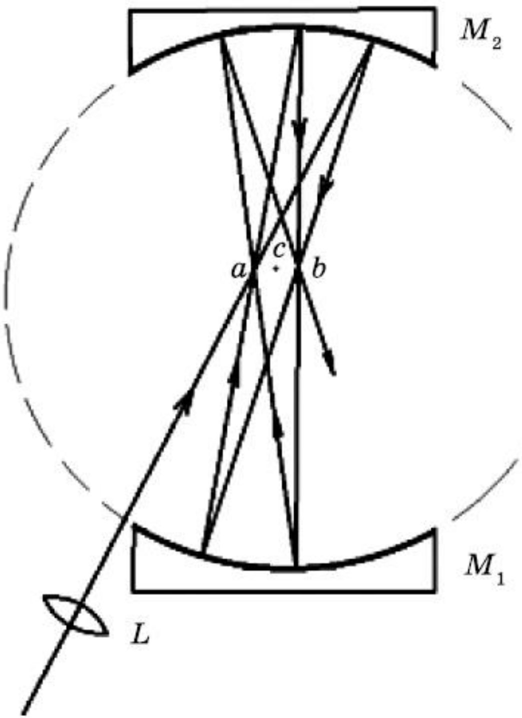


Increasing the Laser power allows us to have a stronger Raman scattering effect.

On the other hand:

- Increases the energy demand
- Increases the stress on the optics
- Safety problems

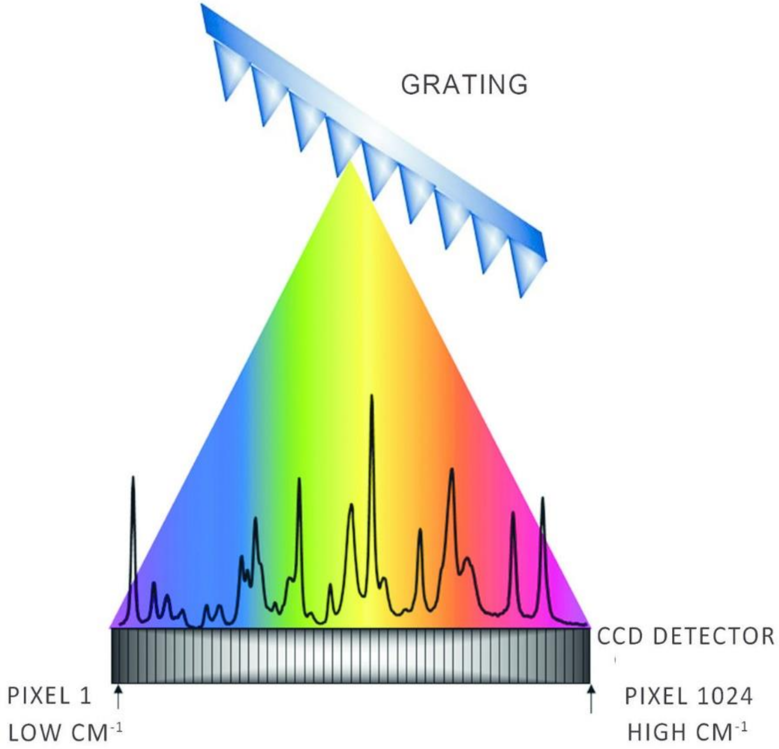
Improving the Raman analysis: Multipass



With a multipass laser path we can improve the Raman performance by reflection of the beam.

This solution acts only on the geometrical path of the beam and does not increase the energetical demand.

Improving the Raman analysis: Spectrometer and detector



Transmission grating

- Use of high performance grating

Cooled CCD detectors:

- Reduced noise

Intensified detectors:

- Signal amplification
- Microchannel plate (MCP) and CMOS detector

800 ANNI 1222·2022

UNIVERSITÀ DEGLI STUDI DI PADOVA

Work Organization

CISAS G. COLOMBO

WBS NUMBER	TASK TITLE	% OF TASK COMPLETE	FIRST YEAR												SECOND YEAR												THIRD YEAR											
			T1			T2			T3			T4			T1			T2			T3			T4			T1			T2			T3			T4		
			O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
1	Study of state of the art																																					
1.1	Bibliographic review	0%	■	■	■	■																																
1.2	Requirements definition	0%		■	■	■																																
1.3	Basic Raman spectroscopy acquisition set up	0%		■	■	■																																
1.4	Optical bench set up & calibration	0%			■	■	■																															
1.5	Atmosferic air analysis	0%			■	■	■																															
1.6	Different gasses analysis	0%				■	■	■																														
2	Multipass laser path design																																					
2,1	Concept design	0%						■	■	■																												
2.2	Mechanical design of the optic surfaces	0%							■	■	■																											
2.3	Multipass Raman spectroscopy acquisition set up	0%								■	■	■																										
2.4	Optical bench set up & calibration	0%									■	■	■	■																								
2.5	Different gasses analysis	0%										■	■	■																								
2.6	Design review	0%												■	■	■	■	■	■	■	■																	
3	Inline combustion gas analysis																																					
3.1	Mechanical and design of the gas analysis chamber	0%														■	■	■	■	■	■	■	■															
3.2	Optical bench set up & calibration	0%																■	■	■	■	■	■	■														
3.3	Inline combustion gas analysis	0%																	■	■	■	■	■	■	■													
3.4	Design review	0%																				■	■	■	■	■	■	■	■									
3.5	Results analysis	0%																				■	■	■	■	■	■	■	■	■	■	■						
4	Thesis and reports																																					
4.1	Reports	0%						■						■						■						■						■						■
4.2	Thesis writing	0%																									■	■	■	■	■	■	■	■	■	■	■	■
4.3	Conferences partecipation	0%									■						■						■						■						■			
5	Educational activities																																					
5.1	Courses	0%	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Thanks for the attention

800 ANNI 1222 • 2022

UNIVERSITÀ DEGLI STUDI DI PADOVA