Bacterial Detection Using Raman Spectroscopy

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Introduction

Bacterial contamination in food is a significant global health issue, affecting 600 million people annually and leading to 420,000 deaths worldwide each year.

Conventional bacterial detection methods are time-consuming and lack specificity, making them often impractical in certain situations.

- Raman scattering is a precise method for identifying molecules and chemical compounds.
- Surface Enhanced Raman Scattering amplifies signal intensity using metallic nanostructures, enabling highly sensitive and specific detection.

By leveraging its unique fingerprint signal, surface enhanced Raman scattering can be a valuable tool for bacterial detection and characterization.

Objectives

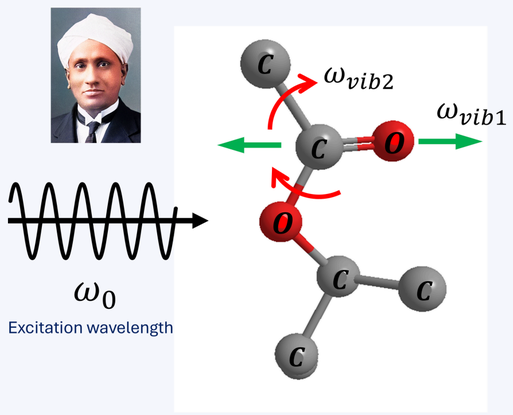
Our project focuses on two primary objectives:

- Rapid detection and identification of bacteria.
- Constructing a prototype able to perform on-site measurements.

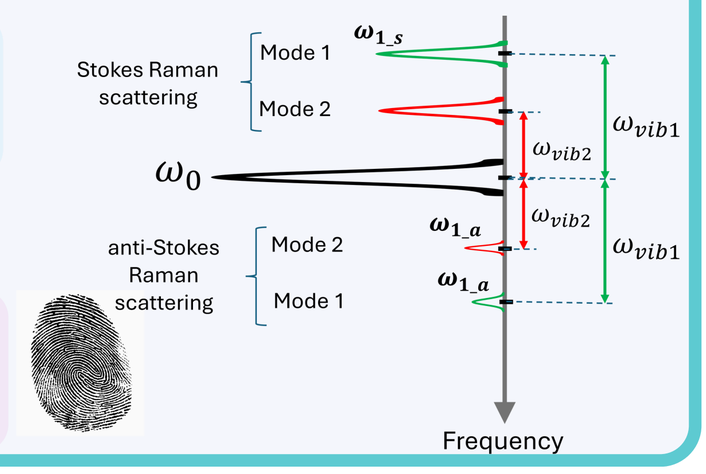
Achieving these goals will enable large-scale testing in food chains, leading to significant real-world impact.

Raman Scattering

Raman scattering is a nonlinear phenomenon



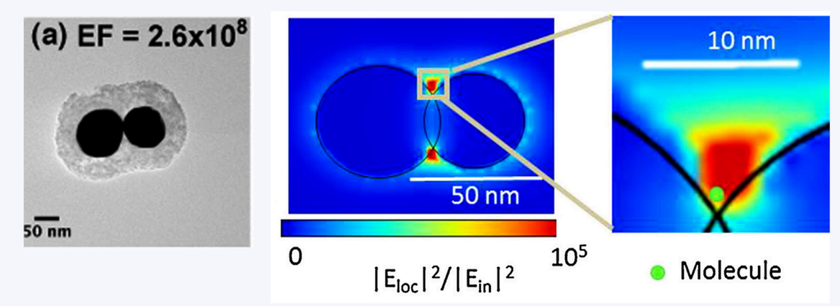
Raman scattering is the fingerprint of chemical bonds



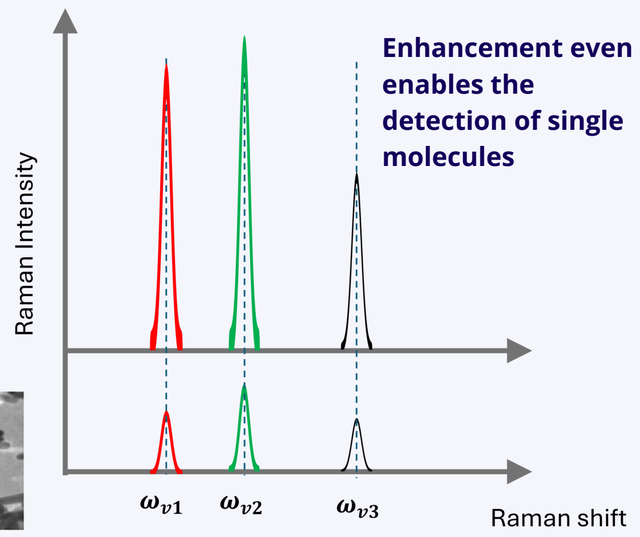
Surface Enhanced Raman Scattering (SERS)

Raman signal strongly depends on the local optical field

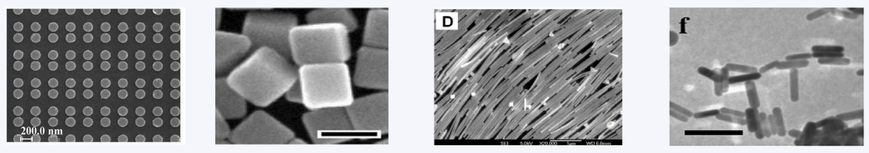
$$Raman\ signal \propto |E|^4$$



SERS significantly boosts the signal's amplitude



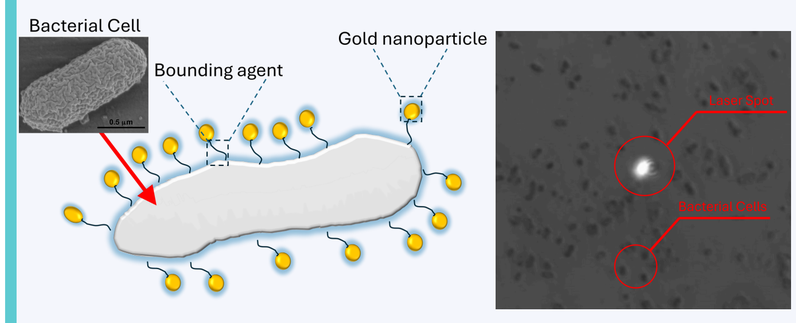
Metallic nanostructures fabrication has become feasible



Our Project

1 Sample Preparation

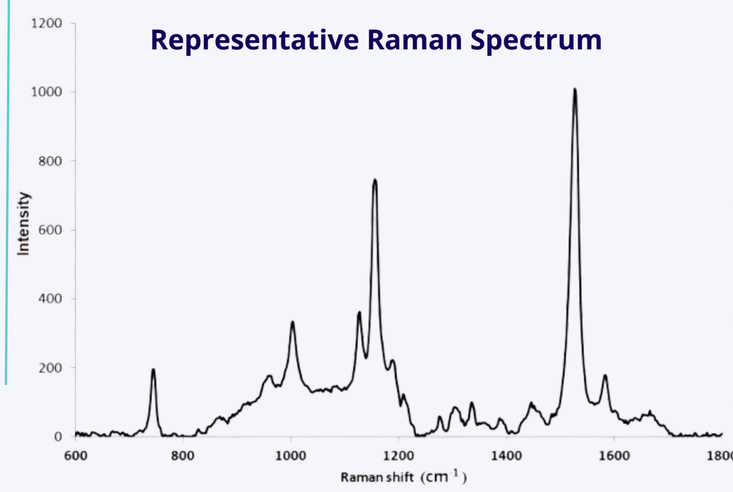
SERS samples were prepared by depositing a few drops of a solution containing both bacteria and functionalized gold nanoparticles onto a glass wafer coated with a reflective metal, followed by drying.



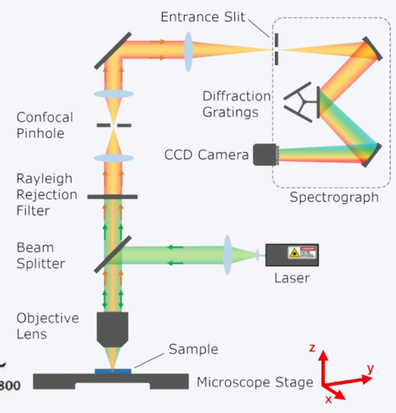
2 Measurments

We obtained spectra using both a custom-built optical setup and a reference Raman microscope for comparison.

Representative Raman Spectrum



Typical optical setup



3 Analysis

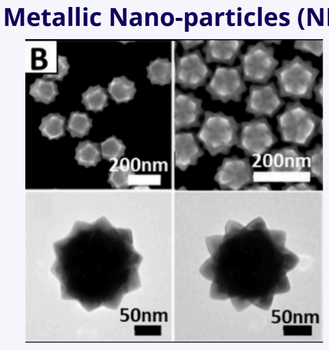
An artificial intelligence model is being developed and trained through which the Data analysis and bacterial identification will be done.

True \ Predicted	*E. coli 1*	*E. coli 2*	*K. pneumoniae 1*	*K. pneumoniae 2*	*K. aerogenes*	*E. cloacae*	*P. mirabilis*	*S. marcescens*
E. coli 1	100							
E. coli 2	8	31	34			1	26	
K. pneumoniae 1		12	72		12			
K. pneumoniae 2	2		5	86	1	3		
K. aerogenes		2	1		59	8		30
E. cloacae		2	4	2	6	72		12
P. mirabilis		1	9	2	12	10	24	28
S. marcescens					3	1		86

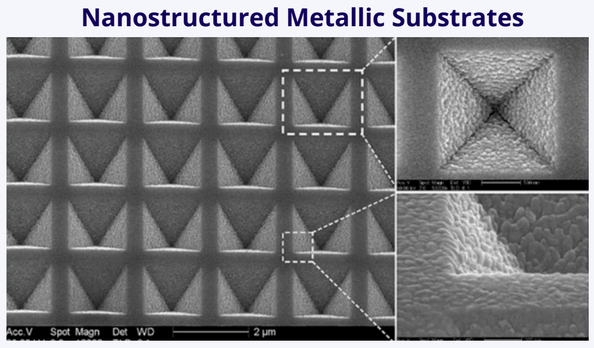
Methodology

Bacterial detection using Surface Enhanced Raman Scattering (SERS) typically involves:

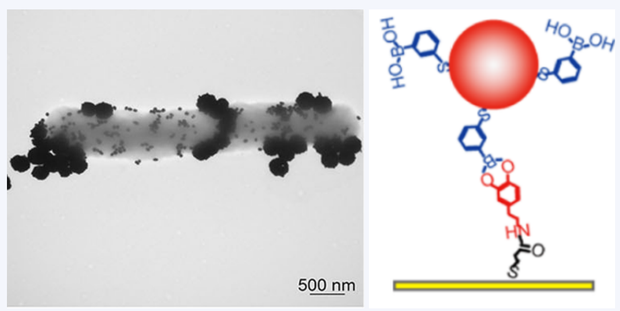
Metallic Nano-particles (NPs)



Nanostructured Metallic Substrates



Gold is preferred for its biocompatibility and stability. The metallic NPs are functionalized with a chemical compound which is used to link it to the bacteria, ensuring proximity and thus clear SERS signals.



Next Steps

Due to project confidentiality, some of the key milestones to be attained which can be shared are:

- Miniaturizing the optical setup for portability.
- Training the AI model on diverse bacteria for more accurate detection.
- Creating a fast, reliable functionalization method for real-world use.
- Developing a technique to better control bacterial samples.

Personal Development

- Gained first hand experience in state-of-the-art research practices.
- Observed the inner workings and dynamics of a research group.
- Closely studied concepts in the field of optics.
- Developed autonomy in work and independent decision-making.
- Improved problem-solving and critical thinking skills in a collaborative environment.

Acknowledgements

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References

Scan for the the bibliography.

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