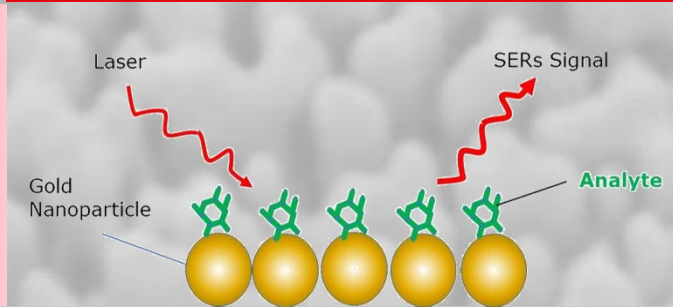
- Introduction
- Project Overview
- Methods
- Results
- Annexes

SERS for continuous quantitative label-free Creatinine detection in PBS

BIOSENSE EPFL

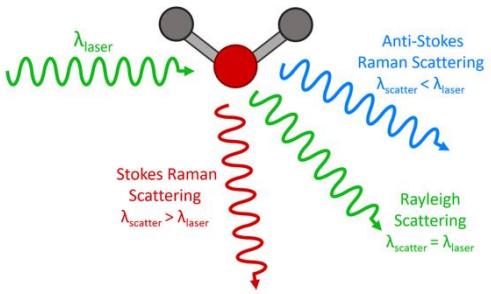
26/08/2025

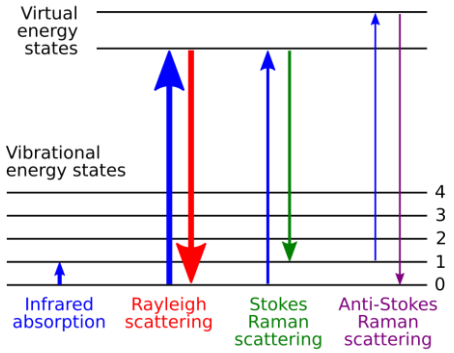


Introduction

Introduction

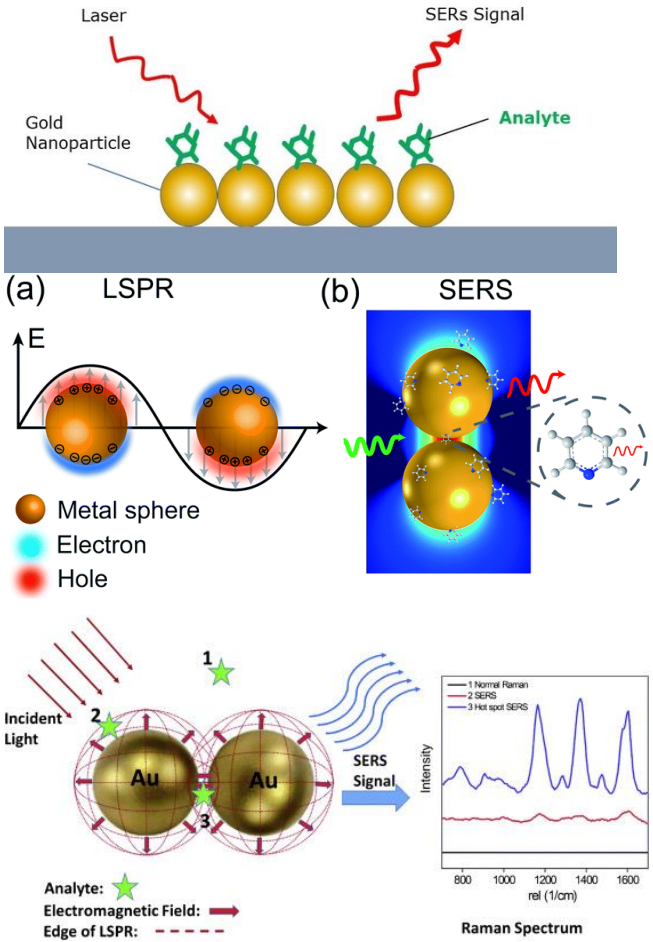
- Raman scattering





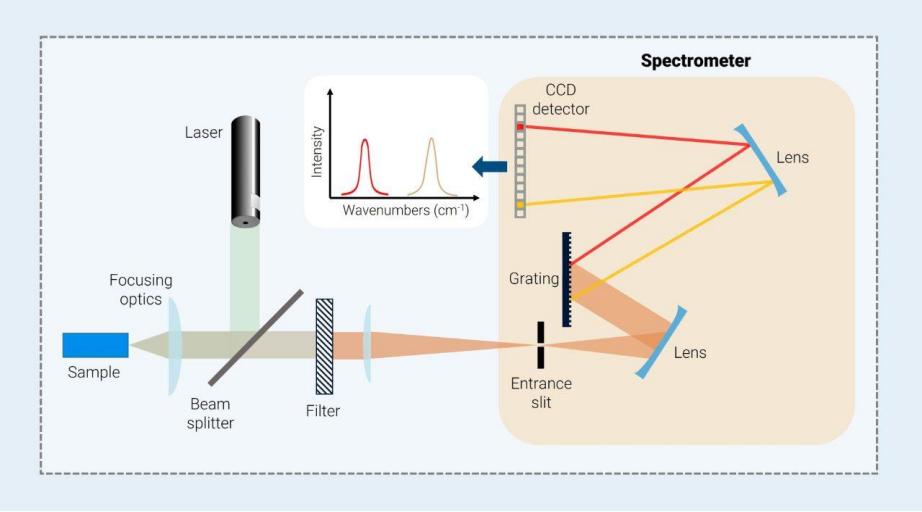
Introduction

- Raman scattering
- Surface Enhanced Raman Spectroscopy



Introduction

- Raman scattering
- Surface Enhanced Raman Spectroscopy
- Setup

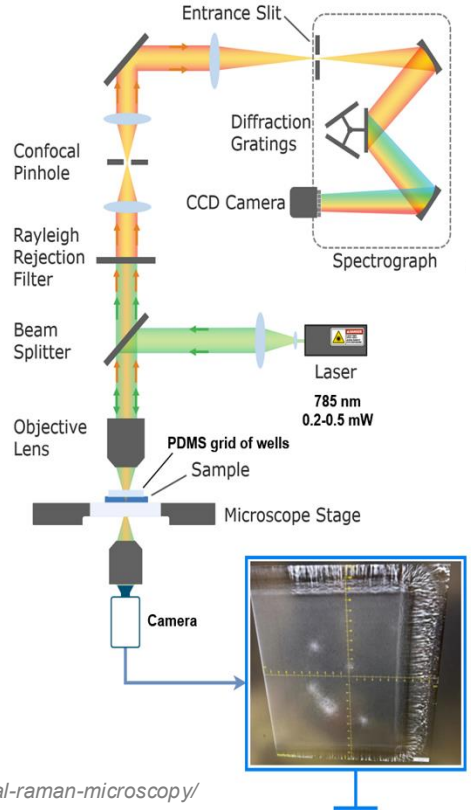


Methods

Methods

Overview

- Measurements



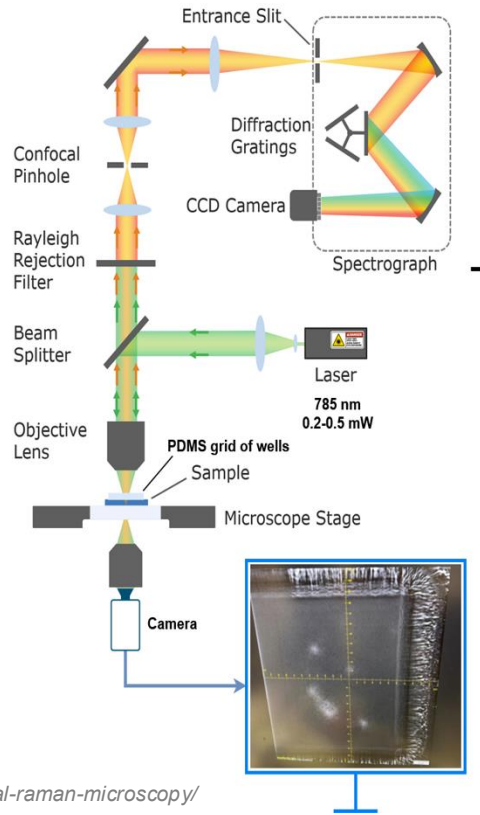
Camera in transmission through the gold chip

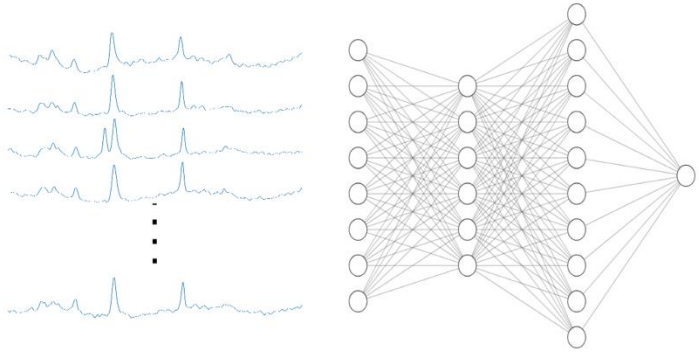
https://www.edinst.com/resource/what-is-confocal-raman-microscopy/

Methods

Overview

- Measurements
- Data proc.
- DNN training
- Prediction





Camera in transmission through the gold chip

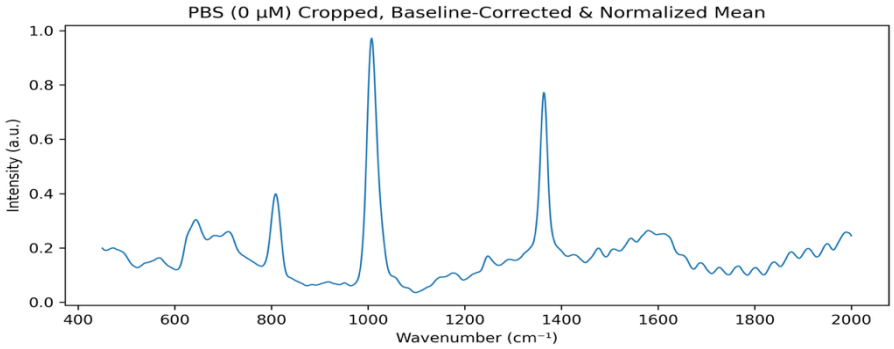
https://www.edinst.com/resource/what-is-confocal-raman-microscopy/

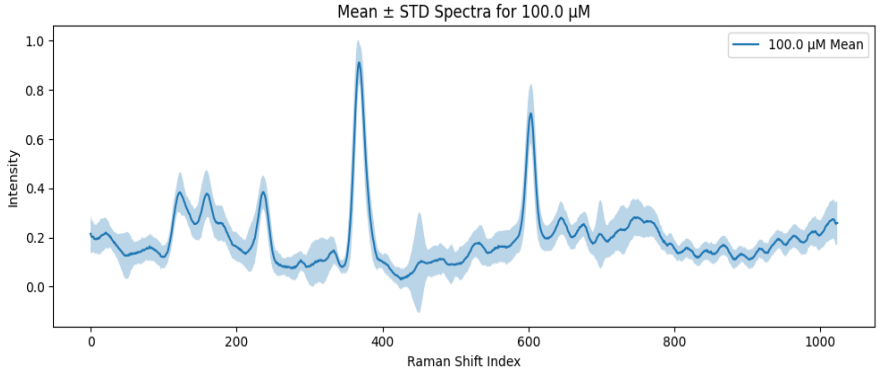
Results

Results

SERS measurements

- PBS mean ($0\mu M$)
- Mean $\pm$ STD (100 μM)

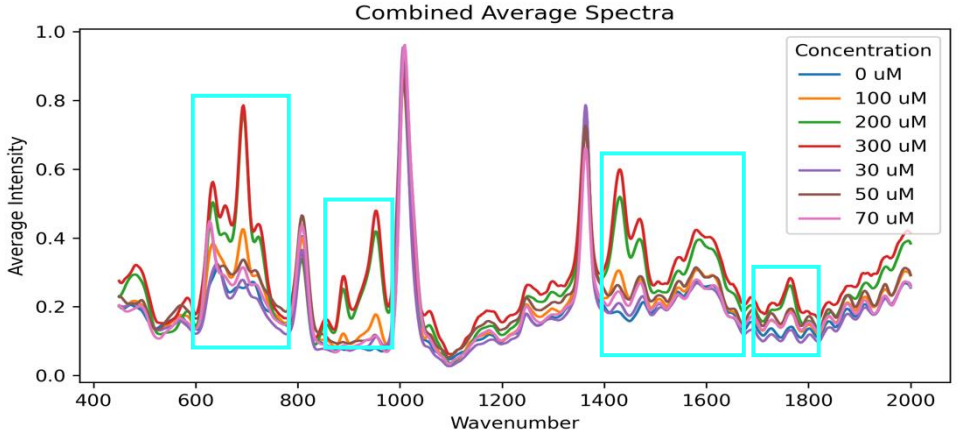




Results

SERS measurements

- PBS mean ($0\mu M$)
- Mean $\pm$ STD (100 μM)
- Average spectra

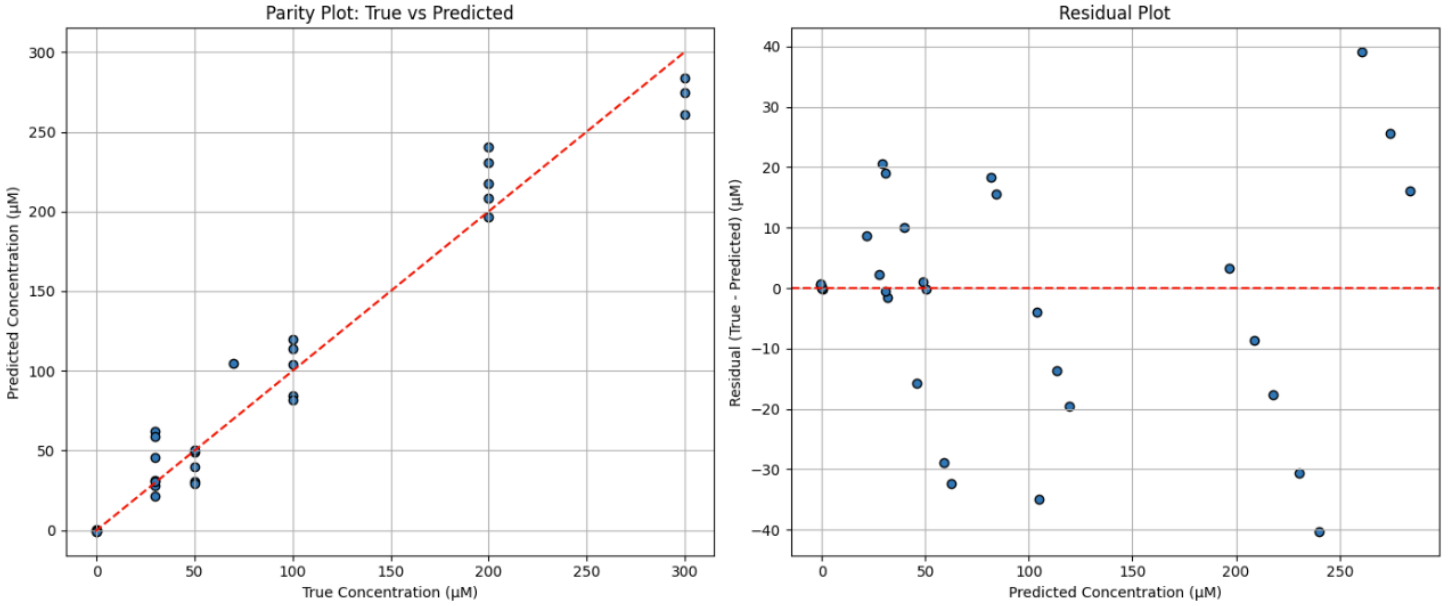


Results

DNN model predictions

$$RMSE = 18.44\ \mu M$$
$$R^2 = 0.96$$

```
Best SVR Params: {'svr__C': 5, 'svr__epsilon': 0.05, 'svr__kernel': 'linear'}
Ensemble SVR Test RMSE: 18.44 µM, R²: 0.960
```




```
y_test_dn[:10] = [  0. 200.   0.  30.  50.   0.  50.  30.  50.  30.]
y_pred_dn[:10] = [-1.8000e-01  1.9666e+02  2.2000e-01  6.2390e+01  4.8900e+01  8.0000e-02
  3.0890e+01  3.1530e+01  2.9350e+01  4.5670e+01]
```

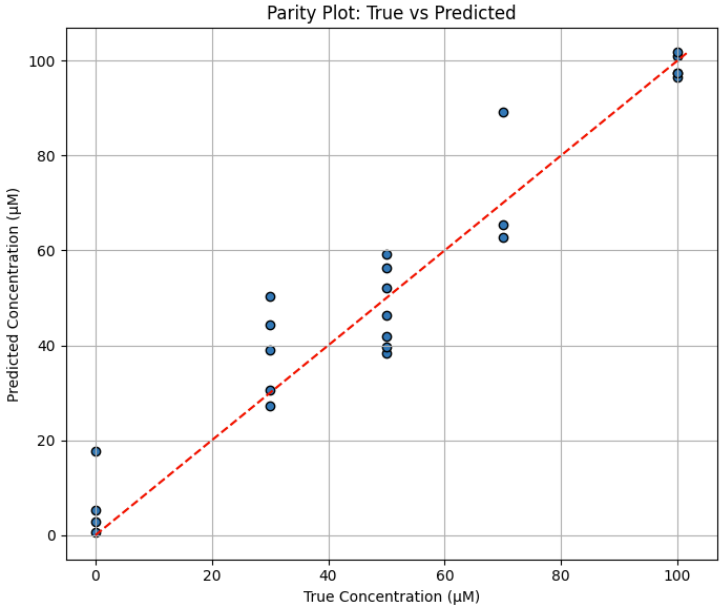
$$\text{RMSE} \leq 20\mu\text{M}\ ,\ R^2 \geq 0.95$$

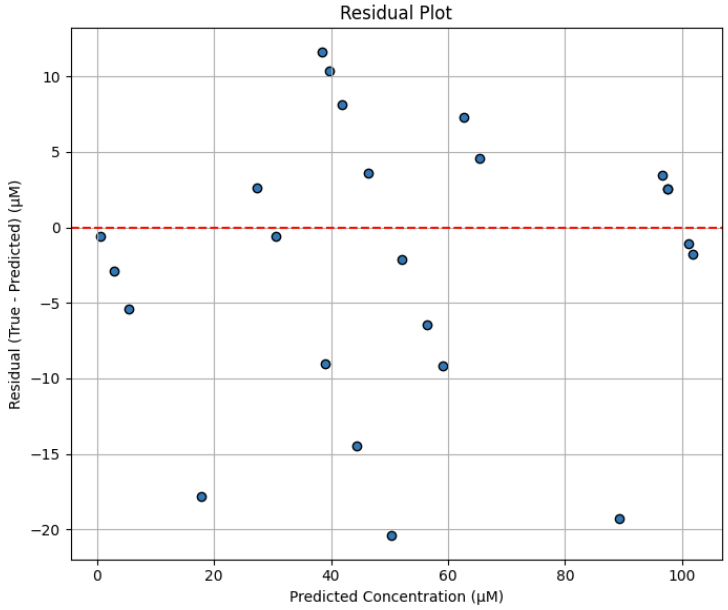
Results

DNN model predictions (0-100uM)

$$RMSE = 9.11\ \mu M$$
$$R^2 = 0.92$$

```
Best SVR Params: {'svr__C': 1, 'svr__epsilon': 0.05, 'svr__kernel': 'rbf'}
Ensemble SVR Test RMSE: 9.11 µM, R²: 0.923
```



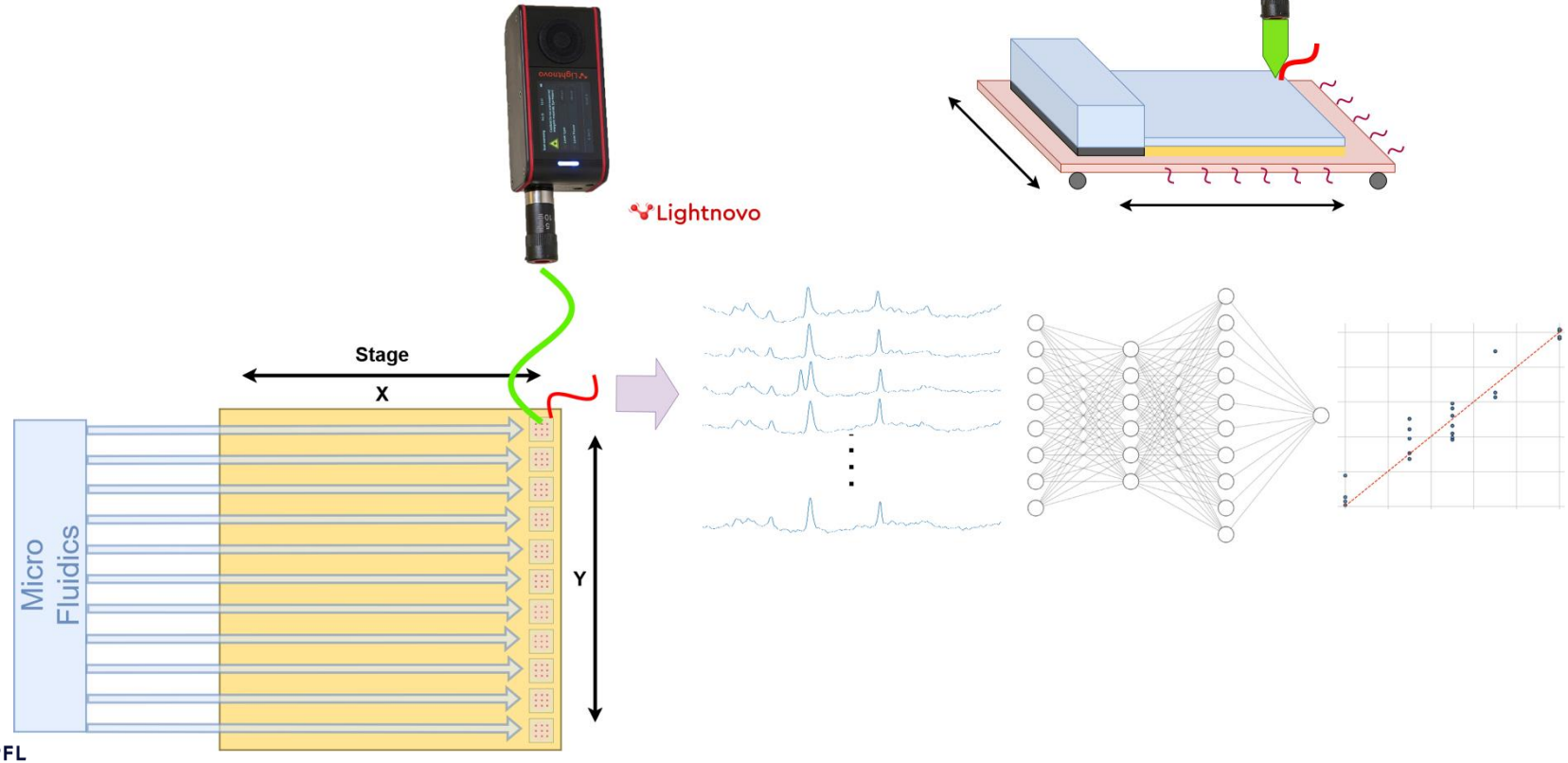



```
y_test_dn[:10] = [100.  30.  50.   0.   0. 100.  70.  50.  50.  70.]
y_pred_dn[:10] = [97.42 30.6  59.18 17.79  5.39 96.57 89.25 38.41 41.87 62.71]
```

$\text{RMSE} \leq 10\mu\text{M}\,,\ R^2 \geq 0.88$

Further

- Device



Acknowledgements

- Prof. Hatice Altug – Supervision & Support (BIOS lab EPFL)
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- Francesca Rodino – Coaching, General support
- Jiayi Tan – Spotting, Raman Measurements, Orders, General support
- Xinyi Huang – Raman Setup & Software, Measurements
- BioSense team

COMSOL

BIOSENSE EPFL

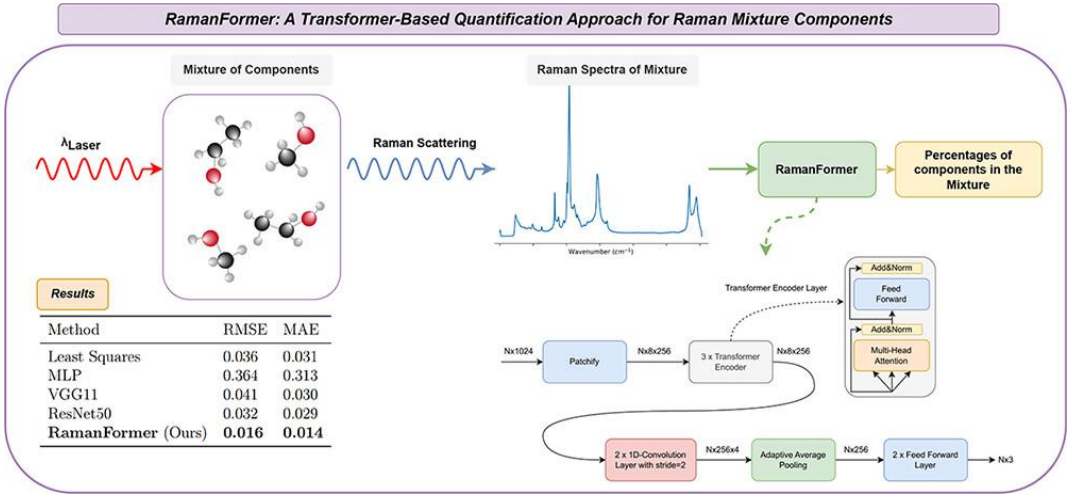
MAKE !
USEFUL. CREATIVE. SUSTAINABLE.

Q&A

Annexes

Literature review

- Classify and quantify 3 compounds simultaneously
- Results: MAE of 1.4% and RMSE of 1.6%

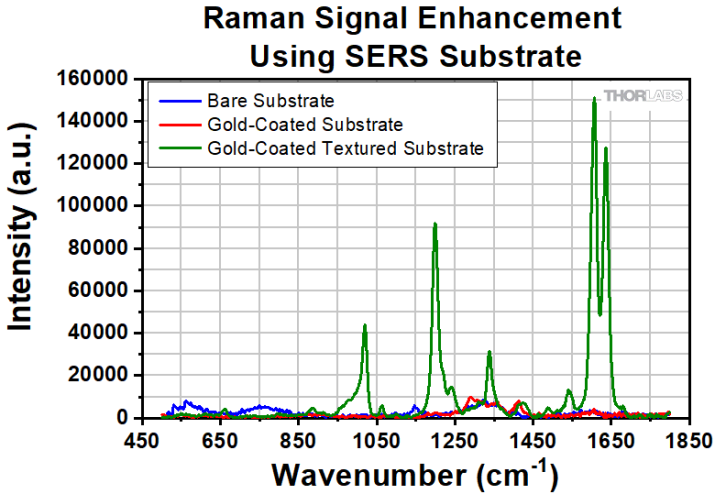


Method	RMSE	MAE
Least Squares	0.036	0.031
MLP	0.364	0.313
VGG11	0.041	0.030
ResNet50	0.032	0.029
RamanFormer (Ours)	**0.016**	**0.014**

[2]
O. C. Koyun et al., "RamanFormer: A Transformer-Based Quantification Approach for Raman Mixture Components," ACS Omega, vol. 9, no. 22, pp. 23241–23251, Jun. 2024, doi: 10.1021/acsomega.3c09247.

Methods

- SERS substrates used
  - Best for 785nm excitation in aqueous environment.



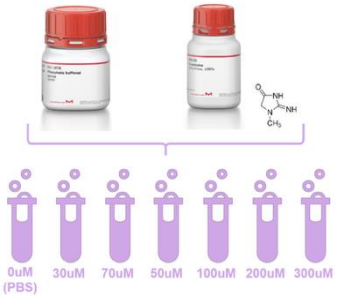
Methods

- Samples

SIGMA-ALDRICH

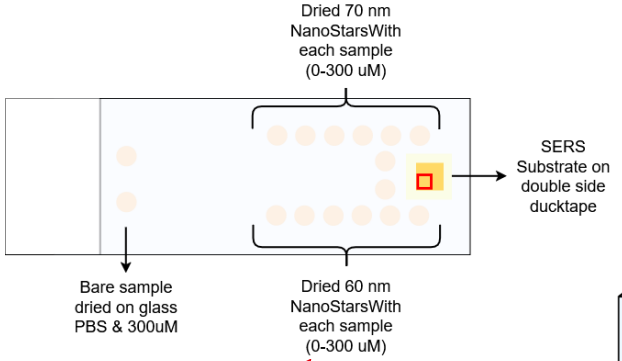
CELLENION
A BICO COMPANY

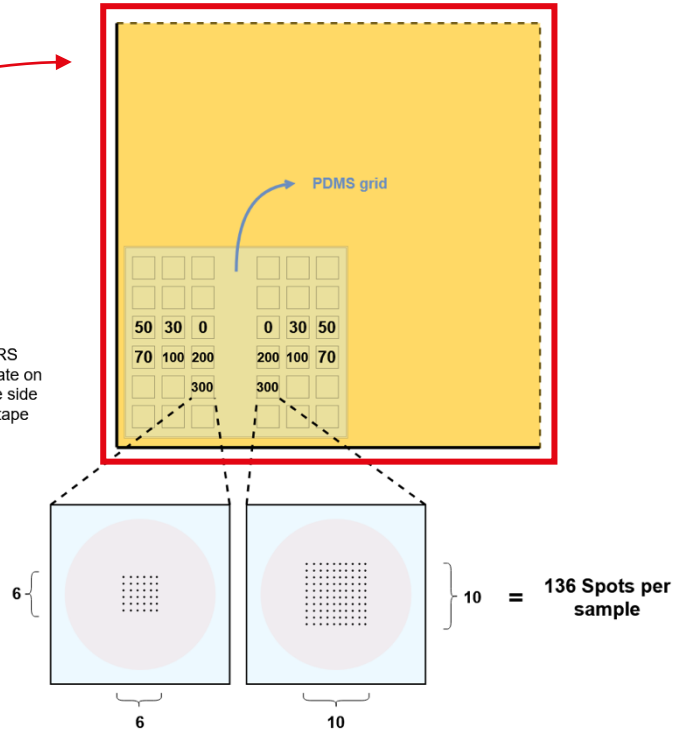
$2\ drops\ of\ 600\ pL$



1 month old solutions of creatinine in PBS + water stored at 5 °C

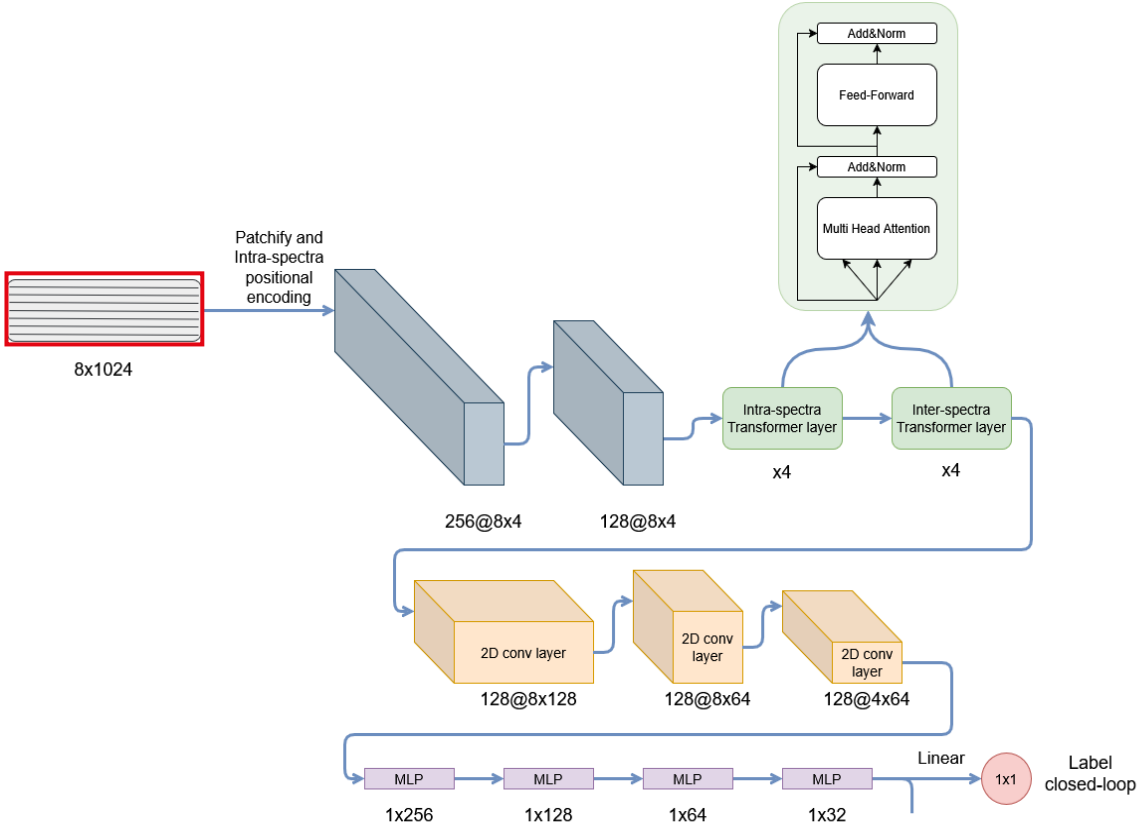
$1\ drop\ of\ 0.1\ mL$





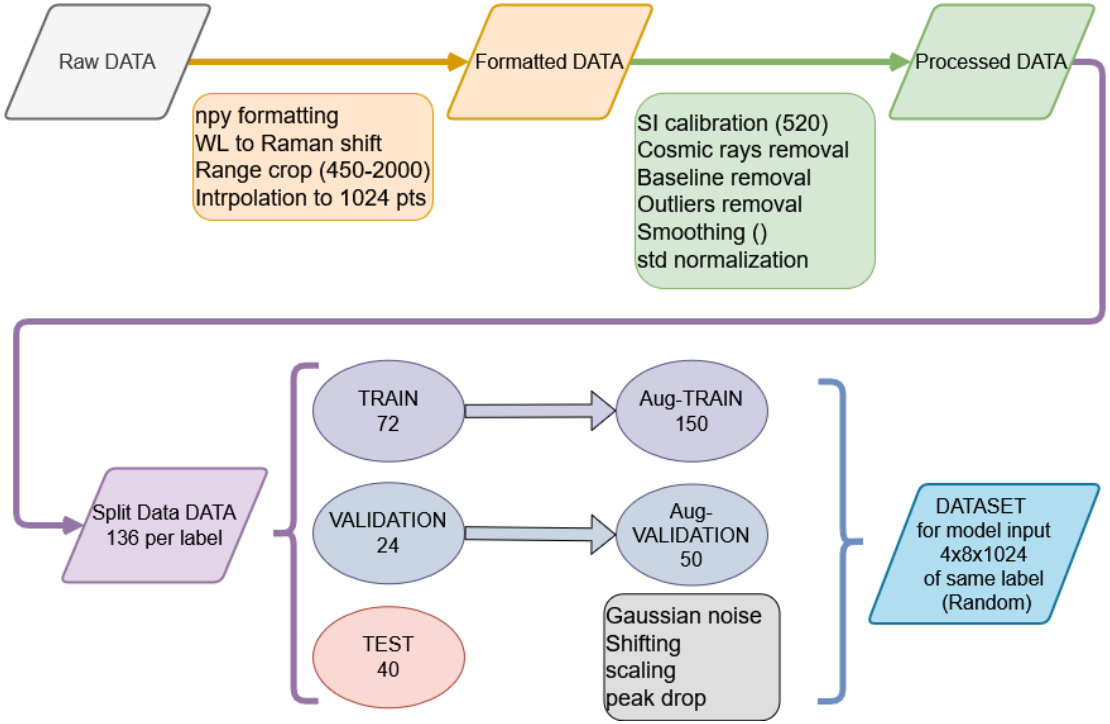
Methods

- DNN Architecture
  - Based on paper



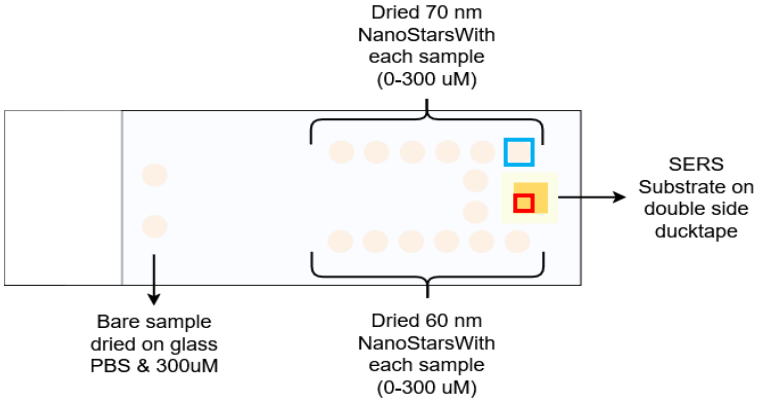
Methods

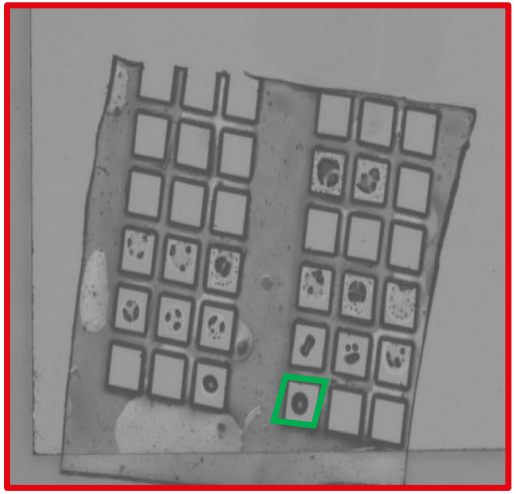
- Data processing and preparation for DNN

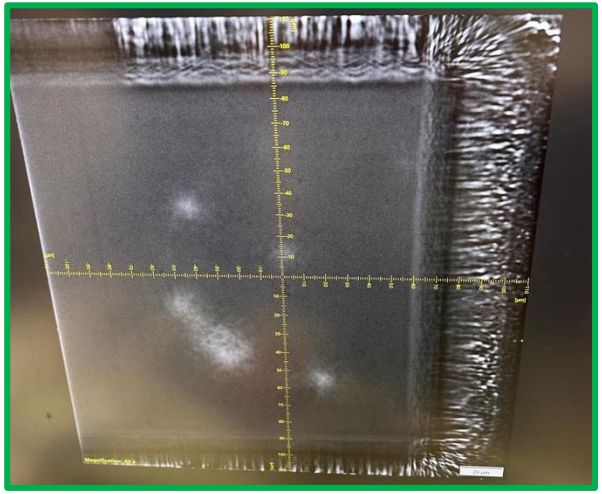


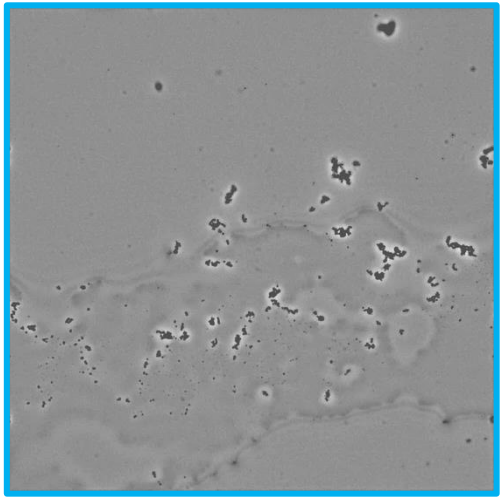
Results

Samples









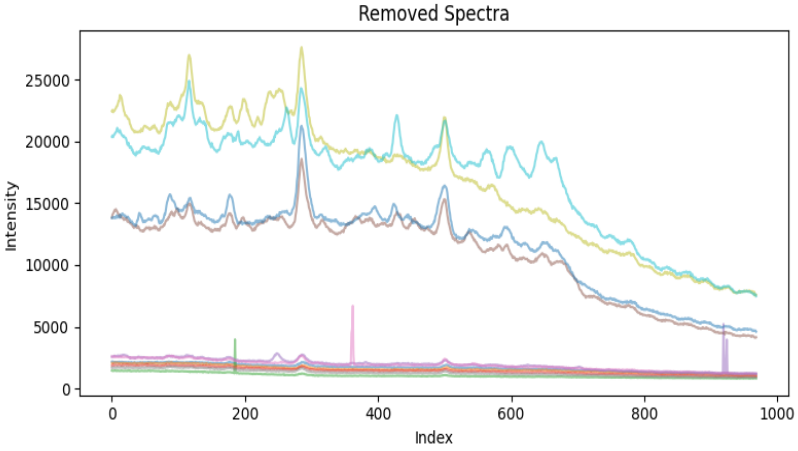
Results

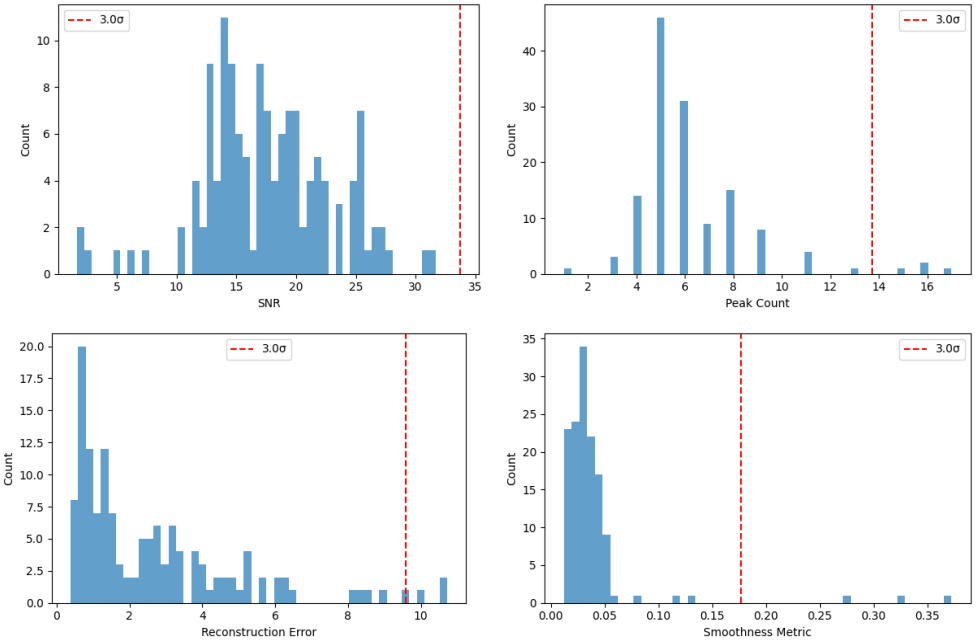
Data outlier removal

Daniel

- SNR
- Peak count
- Reconstruction error
- Smoothness

$$\text{SNR} = \frac{\mu_{\text{signal}}}{\sigma_{\text{noise}}}$$



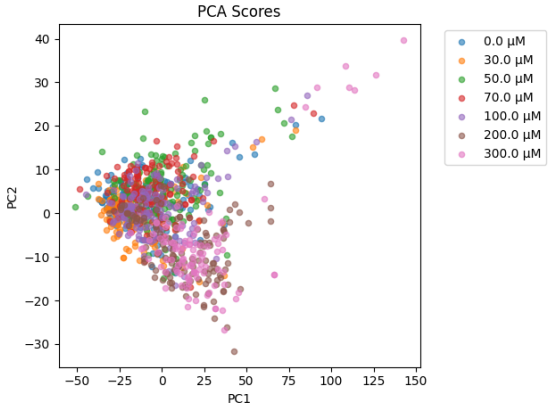


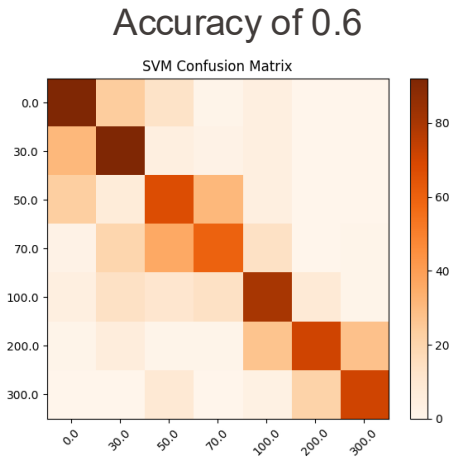
$$\text{Reconstruction Error} = \|X - \hat{X}\|_2^2 = \sum_i (X_i - \hat{X}_i)^2 \qquad \text{Smoothness} = \sum_{i=1}^{n-1} (x_{i+1} - x_i)^2$$

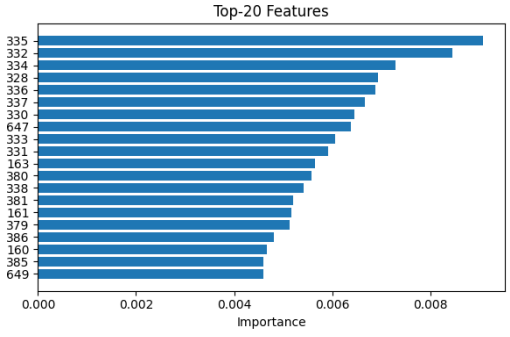
Results

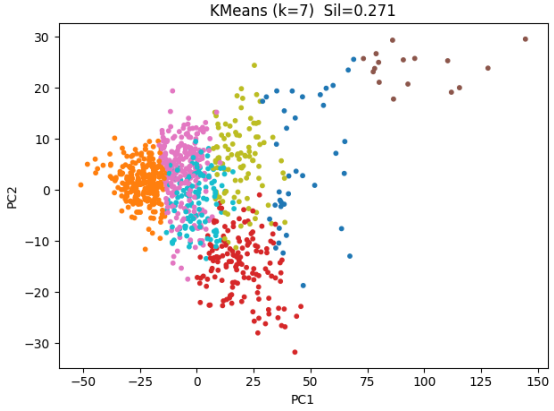
Data metrics

- PCA
- K-means
- Feature importance
- SVM confusion matrix









Critical Assessment

- The number of data points (spots) is low
- The number of samples (labels) is low
- The closed-loop DNN provides bad results, which is abnormal
- The samples making and experimental Raman setup were done only once
- Experiment was done once, no assessment of reproducibility.

References

- [1]O. C. Koyun *et al.*, “RamanFormer: A Transformer-Based Quantification Approach for Raman Mixture Components,” *ACS Omega*, vol. 9, no. 22, pp. 23241–23251, Jun. 2024, doi: 10.1021/acsomega.3c09247.

- Intro figures:
  - https://www.mrmed.in/health-library/nephrology/elevated-kidney-function
  - https://www.bruker.com/en/products-and-solutions/infrared-and-raman/raman-spectrometers/what-is-raman-spectroscopy/raman-spectrometer-optics.html
  - https://en.wikipedia.org/wiki/Raman_spectroscopy
  - https://pubs.rsc.org/en/content/articlehtml/2020/sc/d0sc00809e
  - https://www.mrmed.in/health-library/nephrology/elevated-kidney-function
  - https://www.sciencedirect.com/topics/materials-science/surface-enhanced-raman-spectroscopy