Deep Learning–Driven Signal Optimization in Fusion Spectral Modeling for Rare Earth Element (REE) Prediction in Carbonatites via Combined Laser Induced Breakdown Spectroscopy (LIBS) and Raman Spectroscopy

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Introduction/Background

- Rare Earth Elements (REEs) are critical for energy, defense, and green technologies.
- Carbonatite complexes are key REE sources but are mineralogically complex.
- Conventional methods are expensive and slow for in-field analysis.
- LIBS offers rapid elemental detection while Raman provides molecular and mineral identification.
- Fusion of LIBS and Raman signals can unlock complementary information.

Problem Statement

- LIBS suffers from noise, plasma instability, and matrix effects.
- Raman lacks elemental specificity and is prone to fluorescence.
- Both methods alone have limited reliability for REE analysis.
- Deep learning fusion of LIBS and Raman is largely unexplored.
- No robust framework exists for REE detection in carbonatites

Methodology

- Fuse LIBS and LRS spectra using deep learning.
- Denoise and enhance signals with neural networks.
- Evaluate model performance across mineral types.
- Identify key spectral features for REE prediction.

Possible Results

- Improved REE prediction with fused LIBS–LRS.
- Enhanced signal clarity via deep learning.
- Model works across different minerals.

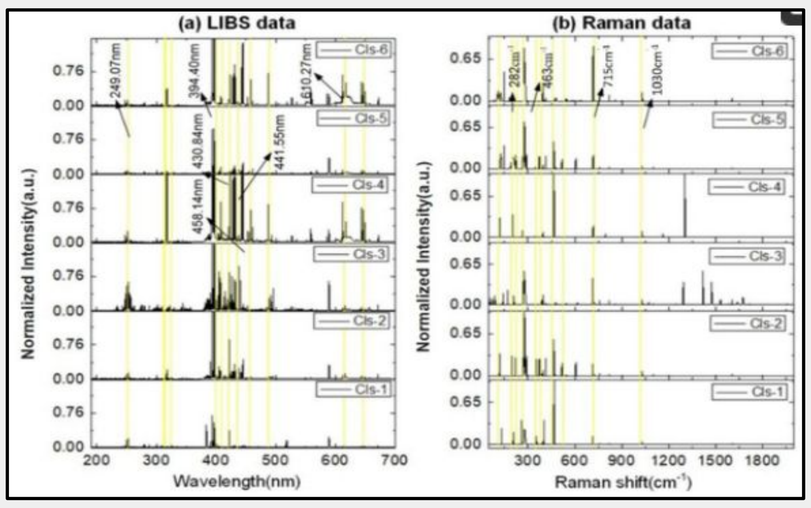

Figure 1:The mineral samples of processed LIBS spectra (a) and Raman spectra (b)t

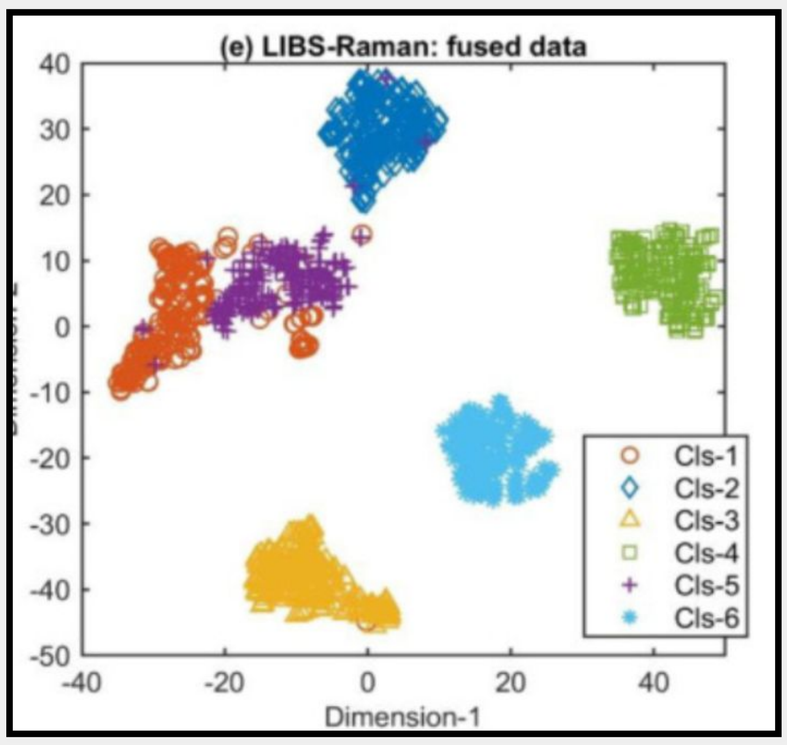

Figure 2:LIBS _Raman Fused Data

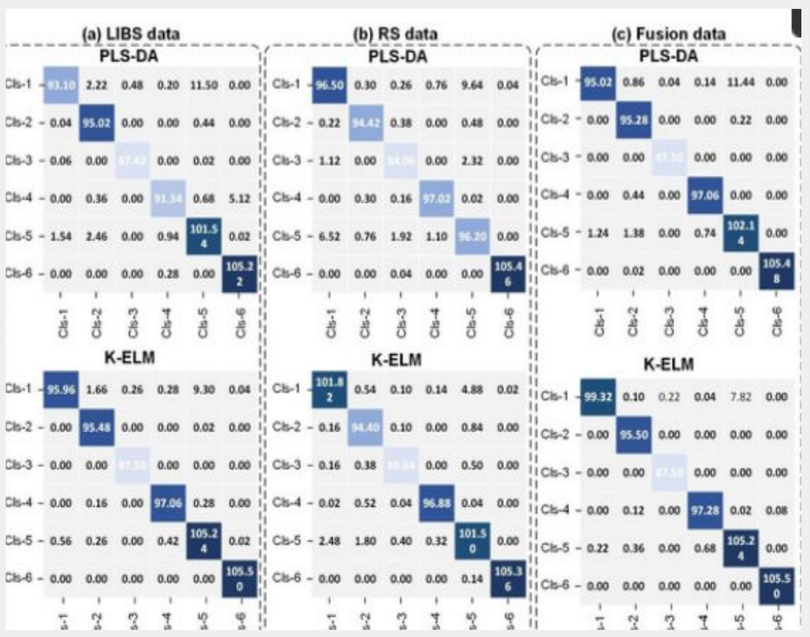

Figure 3:Confusion matrix of mineral classification using PLS-DA and K-ELM for (a) LIBS data, (b) RS data and (c) Fusion data.

Conclusion

- Fused spectral modeling using deep learning shows strong potential for rapid, in-situ REE detection.
- This approach can enhance early-stage mineral exploration and reduce dependence on lab-based assays.
- Further development may support portable AI-powered spectroscopy tools for field geologists.

References

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