



LIBS: a tool for identification of fuel pin failure by monitoring fission gases



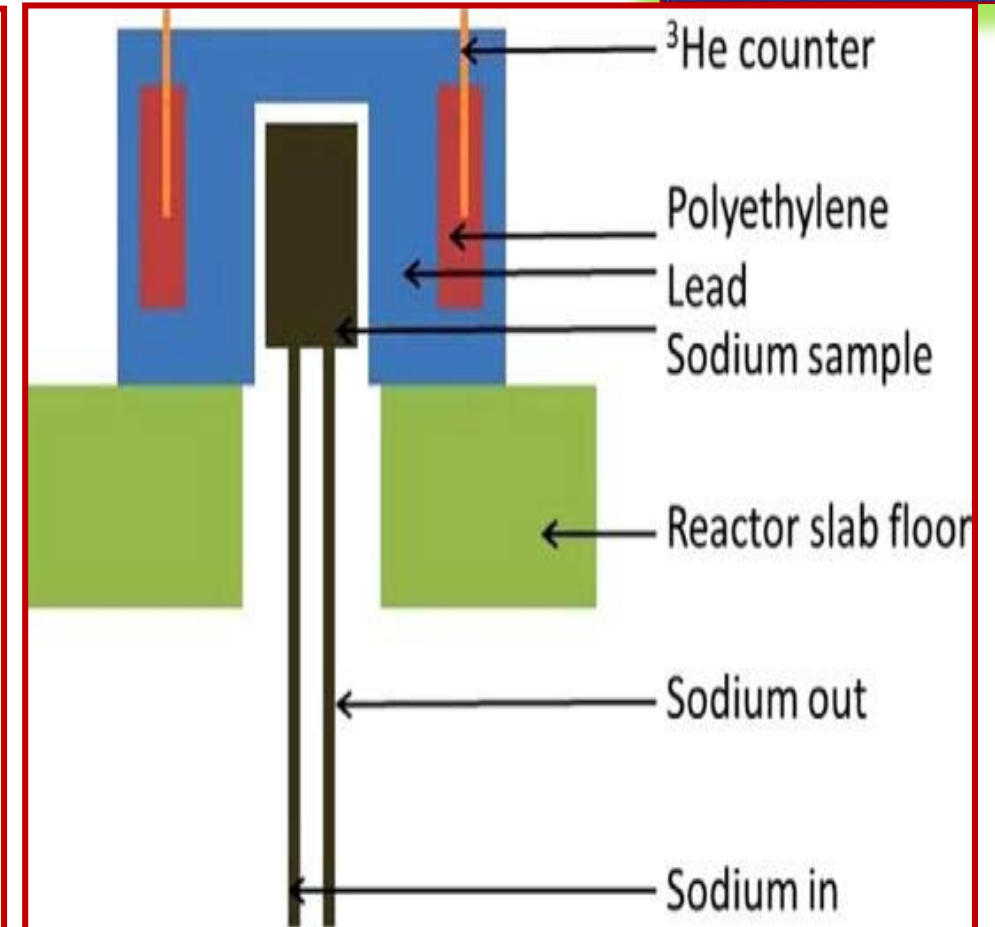
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- **Regular safety practice in FBR**
- ❖ **Failed Fuel Pin (FFP) monitoring.**
- ❖ **Breach in fuel pin: FPs released into coolant**
- ❖ **Conventionally, DND method is used**
- ❖ **For a very small leak: bonding gas (He) & FGs (Kr & Xe) will come out: DND can't be employed**



Schematic of DND detector



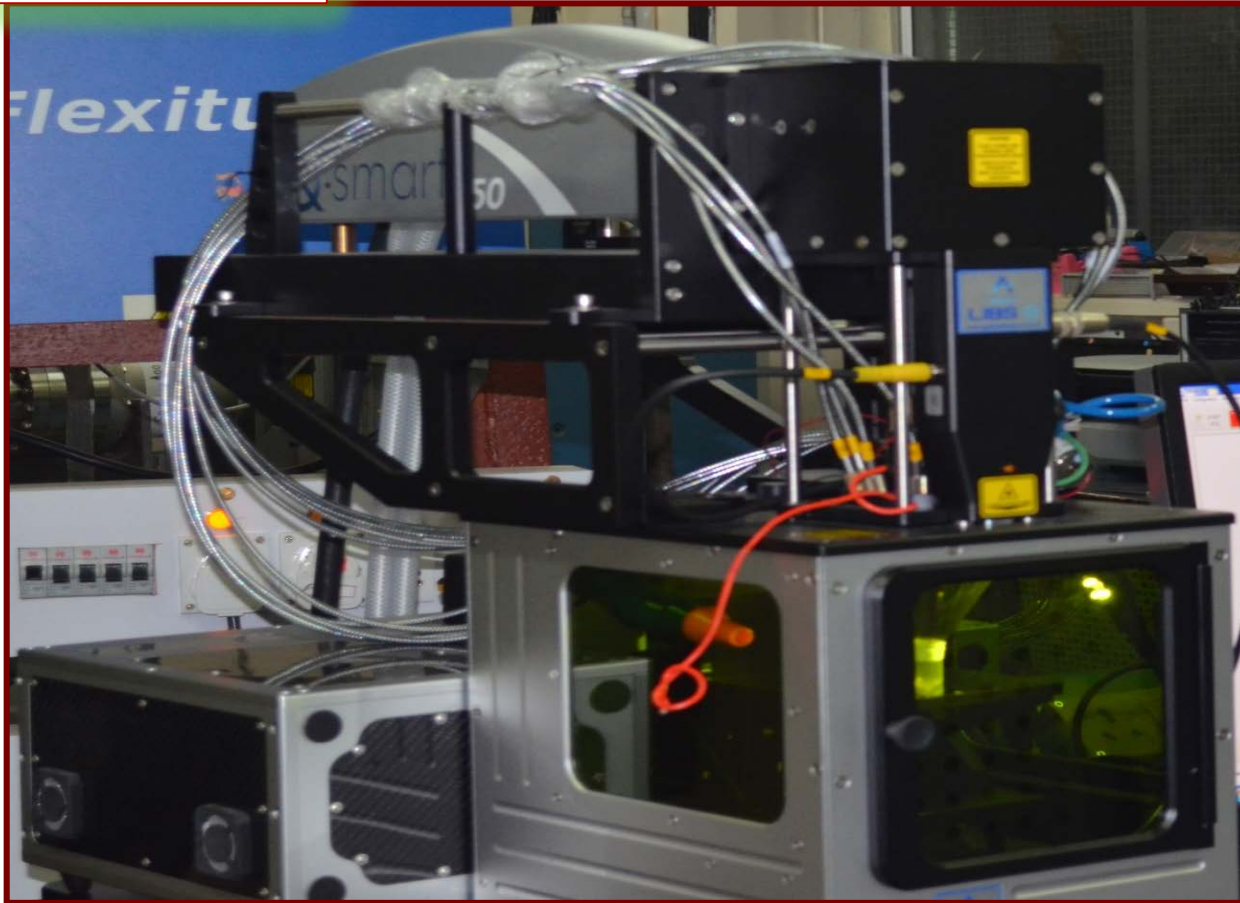
Fission Gas Monitoring



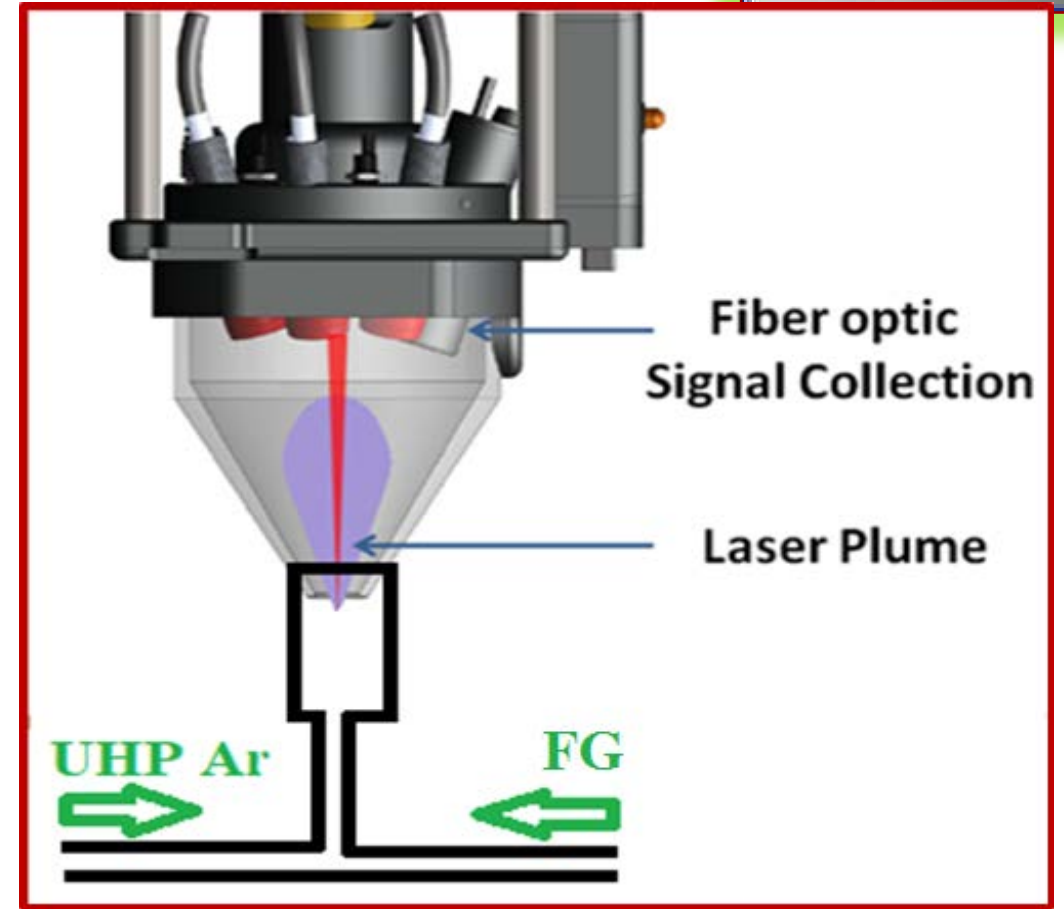
- ❖ **Gamma Spectroscopy for detection of these FGs in nuclear reactor**
- ❖ **γ signal from FGs get submerged with intense γ radiation from ^{24}Na & ^{41}Ar**
- ❖ **All radioactive isotopes of FGs have relatively short half-life (except ^{85}Kr , $t_{1/2} = 10.7$ y).**
- ❖ **Typically isotope analysis of FGs is required at ppt level in Ar.**
- ❖ **Fission yield for ^{85}Kr is ~40 times less than that of total Xe**

➤ **Need for an alternative technique for the on-line detection of FFP**

LIBS Technique



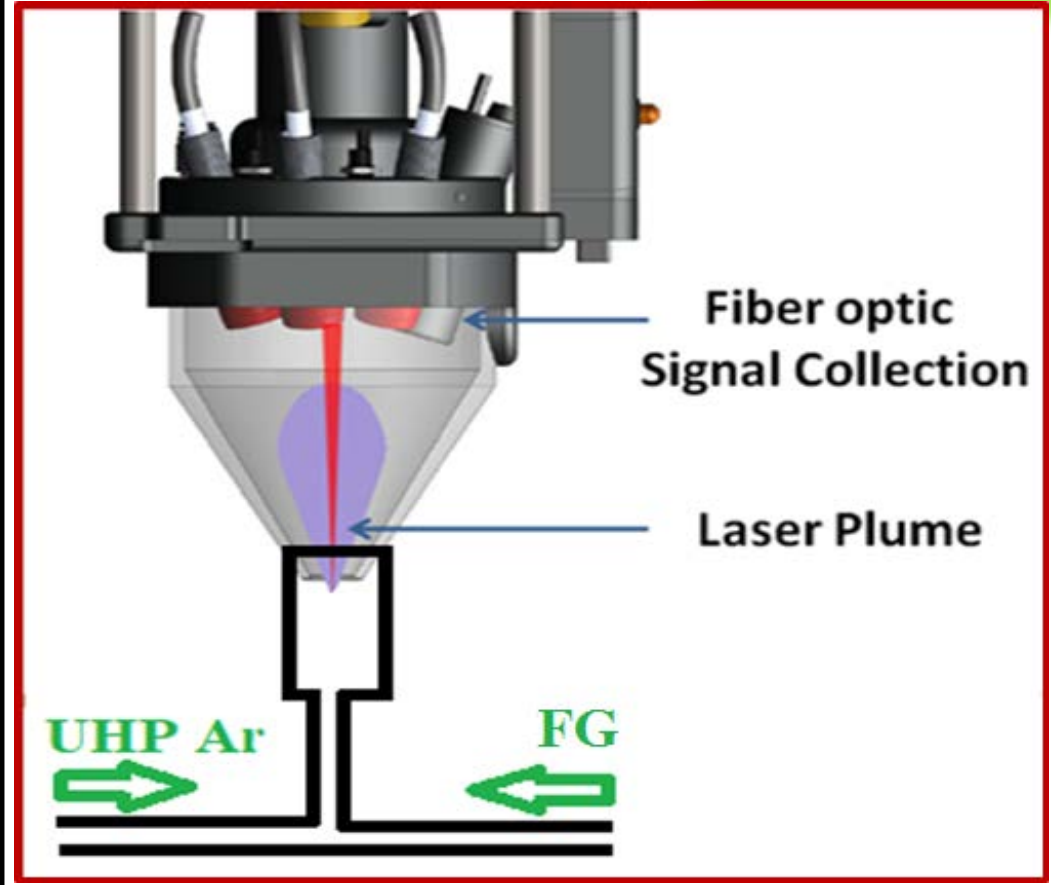
LIBS in Mini-cell



FG gas measurement in LIBS

Advantages of LIBS

- ❖ **Sensors: field portable using fiber optics for analysis at remote location**
- ❖ **Multi-element techniques irrespective of the state of the sample**
- ❖ **Sensitive to μg - ng sample**
- ❖ **Measurement is unaffected by high background radiation.**



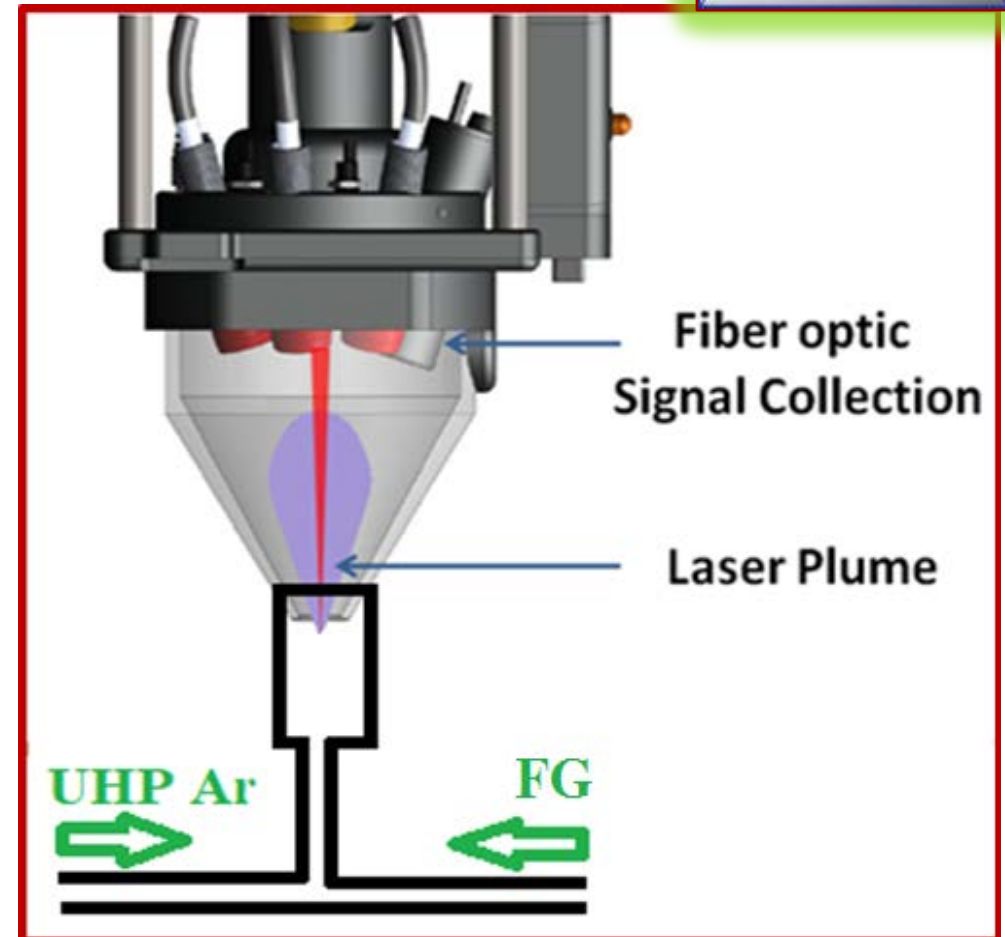
FG gas measurement in LIBS

Experiment



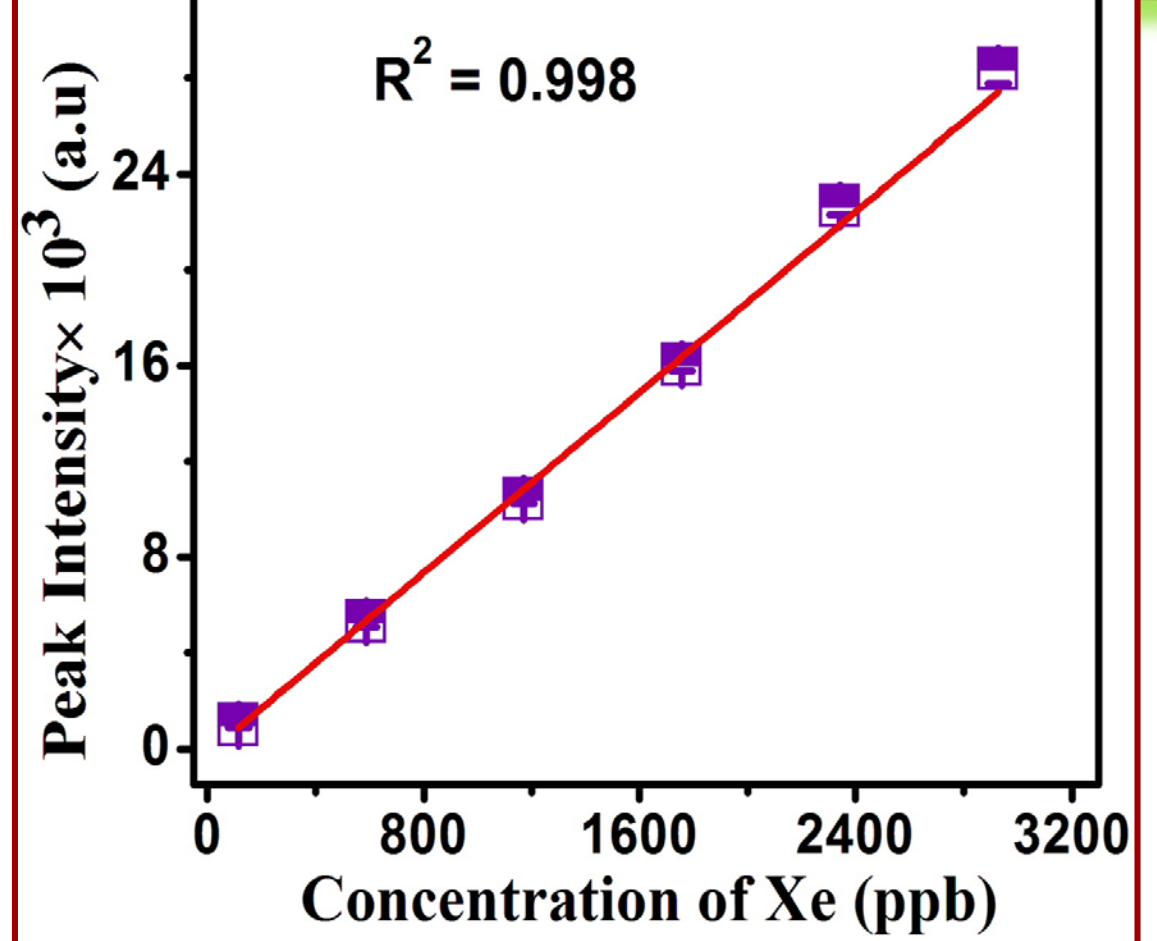
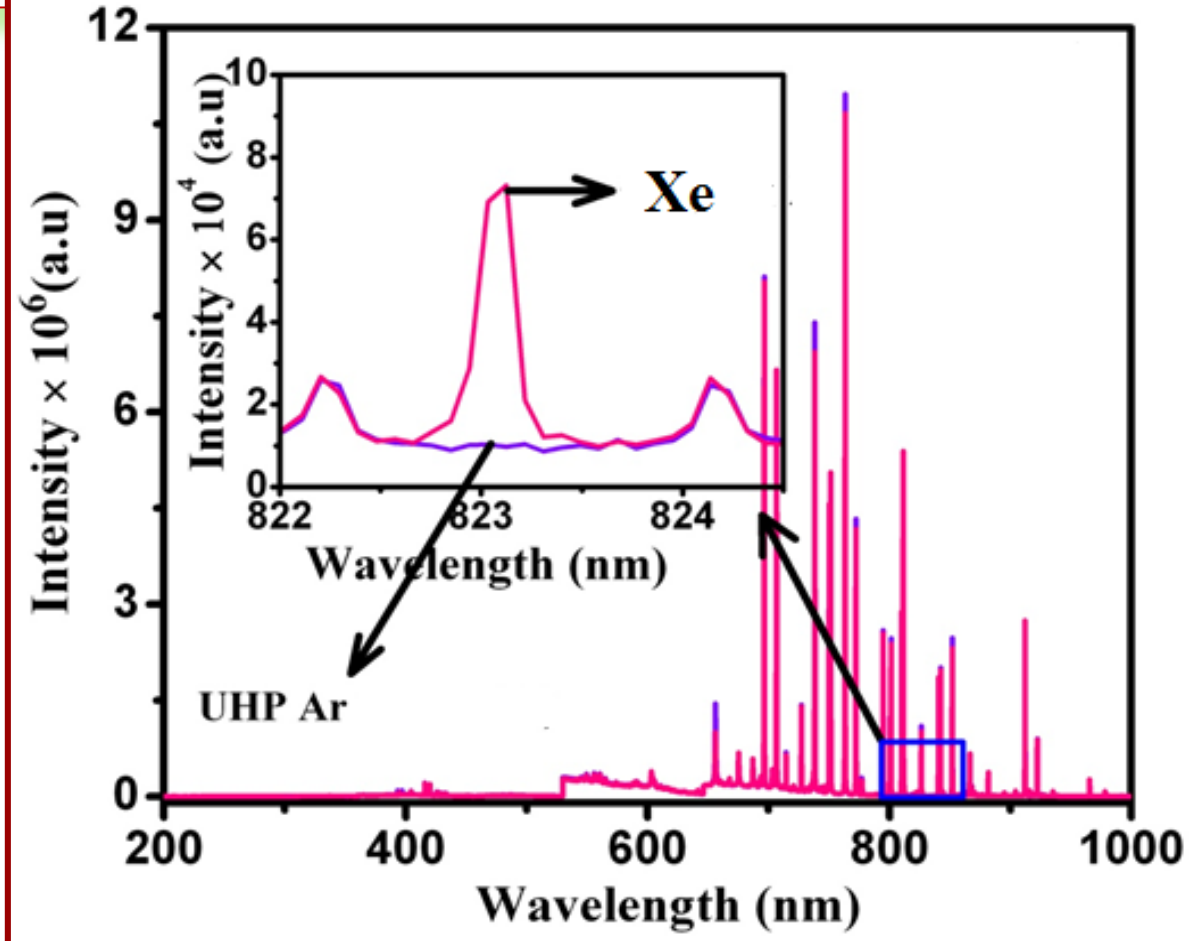
➤ Nd:YAG laser

- ❖ Wavelength: 1064 nm,
- ❖ Energy: 390 mJ for He, 200 mJ for Kr & Xe
- ❖ Pulse width: 10 ns
- ❖ Detector: 180 to 1030 nm
- ❖ Two mass flow controllers: for FG & UHP Ar to LIBS chamber



FG measurement in LIBS

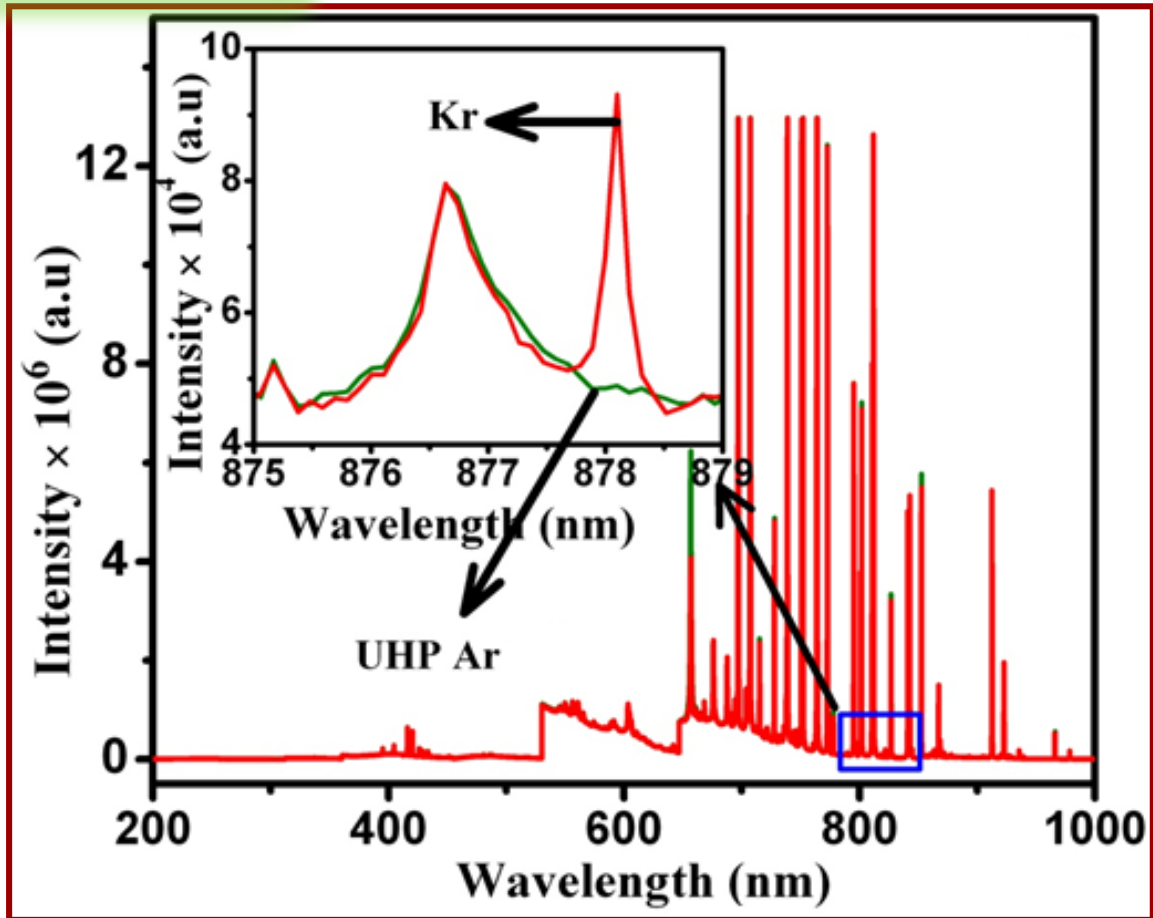
Calibration for Xe



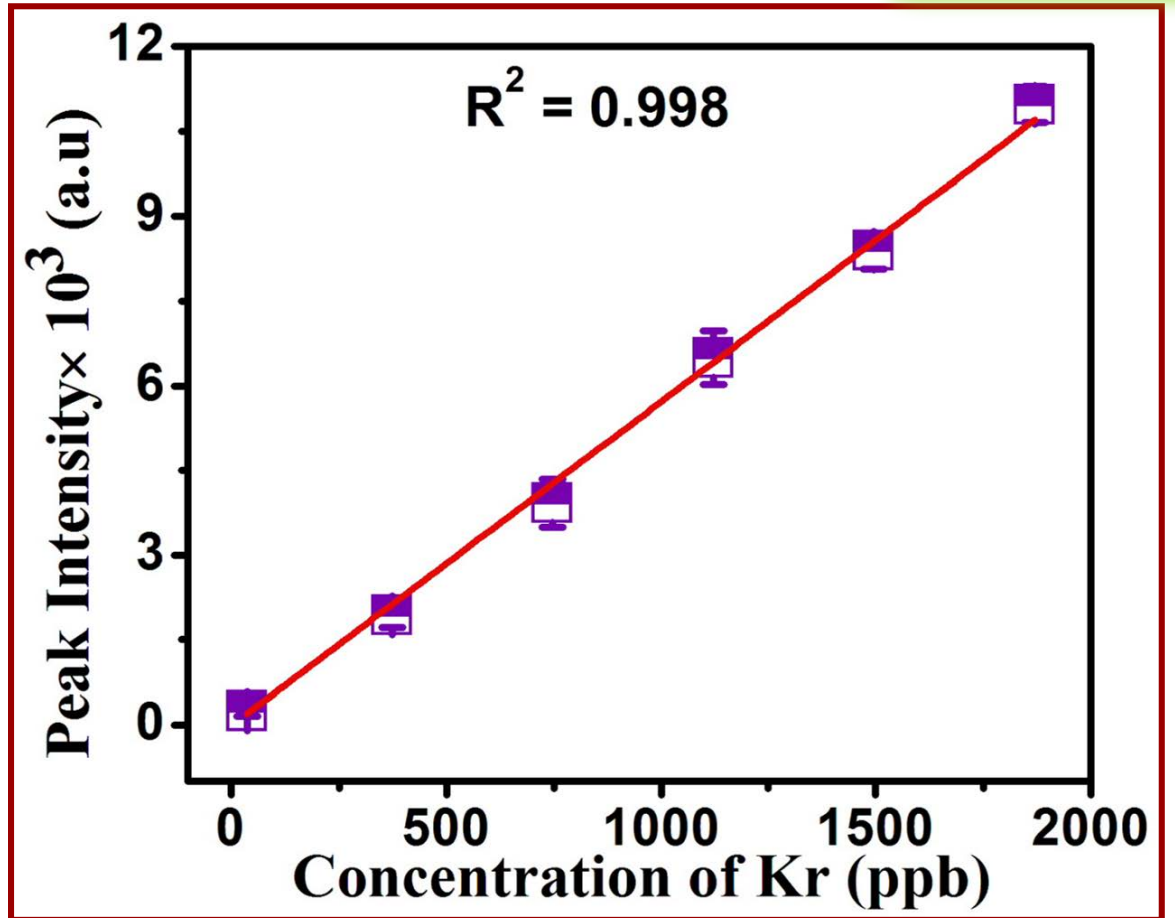
Non-overlapping peak: 823.16 nm

LOD = $3\sigma/S$ = 40 ppb

Calibration for Kr



Non-overlapping peak: 877.67 nm



LOD = $3\sigma/S = 30$ ppb



Calibration for He



- ❖ The non-overlapping peak at 587.4 nm
- ❖ Correlation coefficient (R^2): 0.992
- ❖ LOD = $3\sigma/S = 3$ ppm
- ❖ IP = 24.59 eV



Interpretation



- ❖ For Xe & Kr, ppb level LOD value is achieved
- ❖ LOD value (3 ppm) of LIBS for He is higher
- ❖ He being an inert gas has higher ionization potential, 24.59 eV.
- ❖ He intensity increases ~ 10 times by doubling the laser energy from 200 to 390 mJ.
- ❖ Hence, LIBS with high power laser may possibly decrease the LOD value for He
- ❖ Moreover, high resolution spectrometer will also contribute in this direction to lower the LOD value



Conclusions



- ❖ This method is suitable for analysis at remote location, laser can be guided through portable fibre optics & the emission lines can also be collected & delivered to spectrometer through fiber optics
- ❖ **LIBS is successfully employed for identification of Kr, Xe & He.**
- ❖ The calibration for Kr, Xe & He fits linearly with a good R^2 value.
- ❖ **LOD value for Kr, Xe & He : 30, 40 ppb & 3 ppm respectively**
- ❖ Further work is being explored to reduce the LOD value.

*Thank
you*

