Optical Emission Spectroscopy

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Aim of OES

The objective of OES experiment is to study the optical emission spectrum of a given sample and identify its elemental composition by analyzing the characteristic emission wavelengths.

Additionally, the relative intensities of the emission lines are analyzed to estimate elemental concentration.

Principle

- Optical Emission Spectroscopy (OES) is an analytical technique used to determine the elemental composition of a material by analyzing the light emitted by excited atoms or ions.
- When a sample is subjected to a high-energy source such as plasma, spark, or arc, its atoms absorb energy and are excited to higher electronic energy levels. These excited states are unstable, and as electrons return to lower energy levels, the excess energy is released in the form of electromagnetic radiation.
- The emitted radiation occurs at discrete wavelengths corresponding to the energy difference between quantized electronic levels, given by: $\Delta E = h\nu = hc/\text{lambda}$
- Since each element has a unique set of energy levels, the emitted wavelengths act as a fingerprint for elemental identification.
- The intensity of the emitted spectral lines is proportional to the number of emitting atoms and hence to the concentration of the element in the sample.

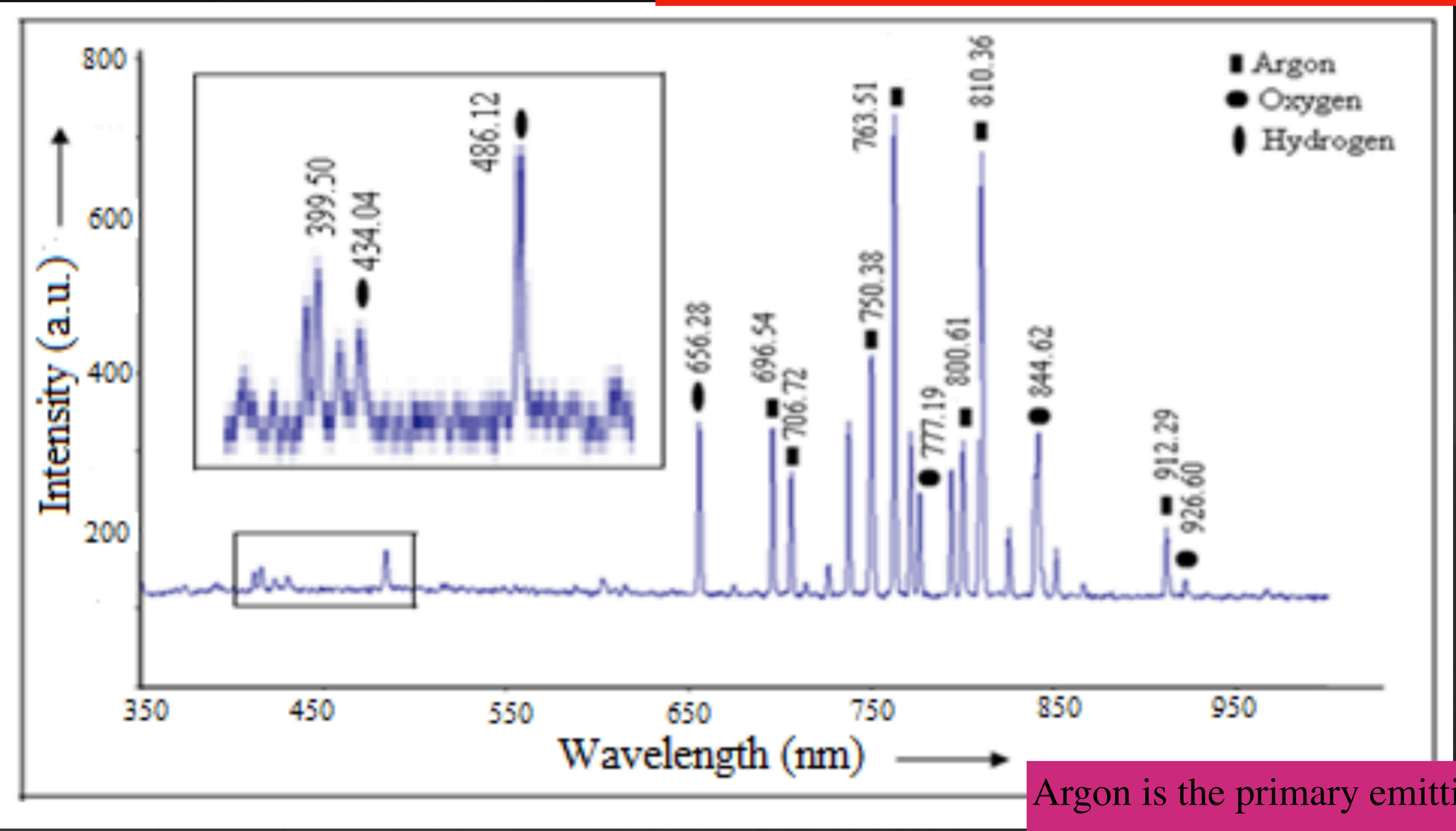
Why Argon? Experimental Setup?

Argon is a noble (inert) gas
Does not chemically react with chamber or electrodes
Has strong, well-defined emission lines
Easily ionized and excited in plasma
Widely used as a standard calibration gas

Plasma source (HF / RF discharge)
Argon gas supply
Vacuum chamber
Optical fiber for light collection
Spectrometer
Data acquisition system

Argon

Emission lines observed from argon, oxygen, and hydrogen
Argon lines dominate the spectrum
Minor oxygen and hydrogen peaks indicate impurities
Strong emission mainly in red and near-IR region
Weak emission in blue/UV region



Mixed gas :
The mixed gas spectrum shows dominant argon emission lines with
additional weak oxygen and hydrogen lines, confirming the presence of trace impurities while maintaining argon as the primary emitting species.

Visible and near-IR dominance

Argon emits most strongly in the visible-red and near-IR

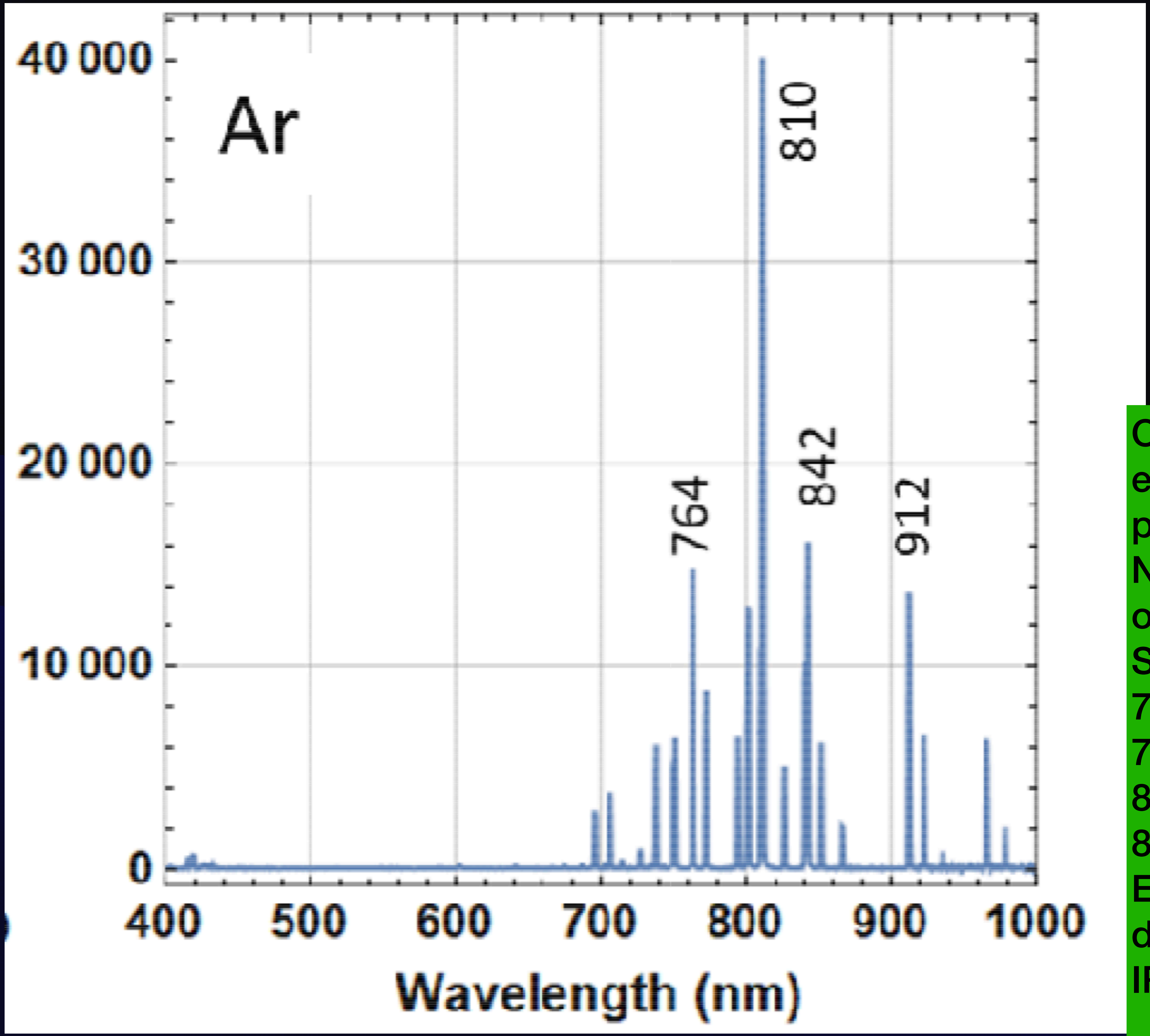
UV and blue lines are present but weaker (shown in inset)

Argon is the primary emitting species

Oxygen and hydrogen originate from residual air or moisture

Fixed peak positions confirm atomic transitions

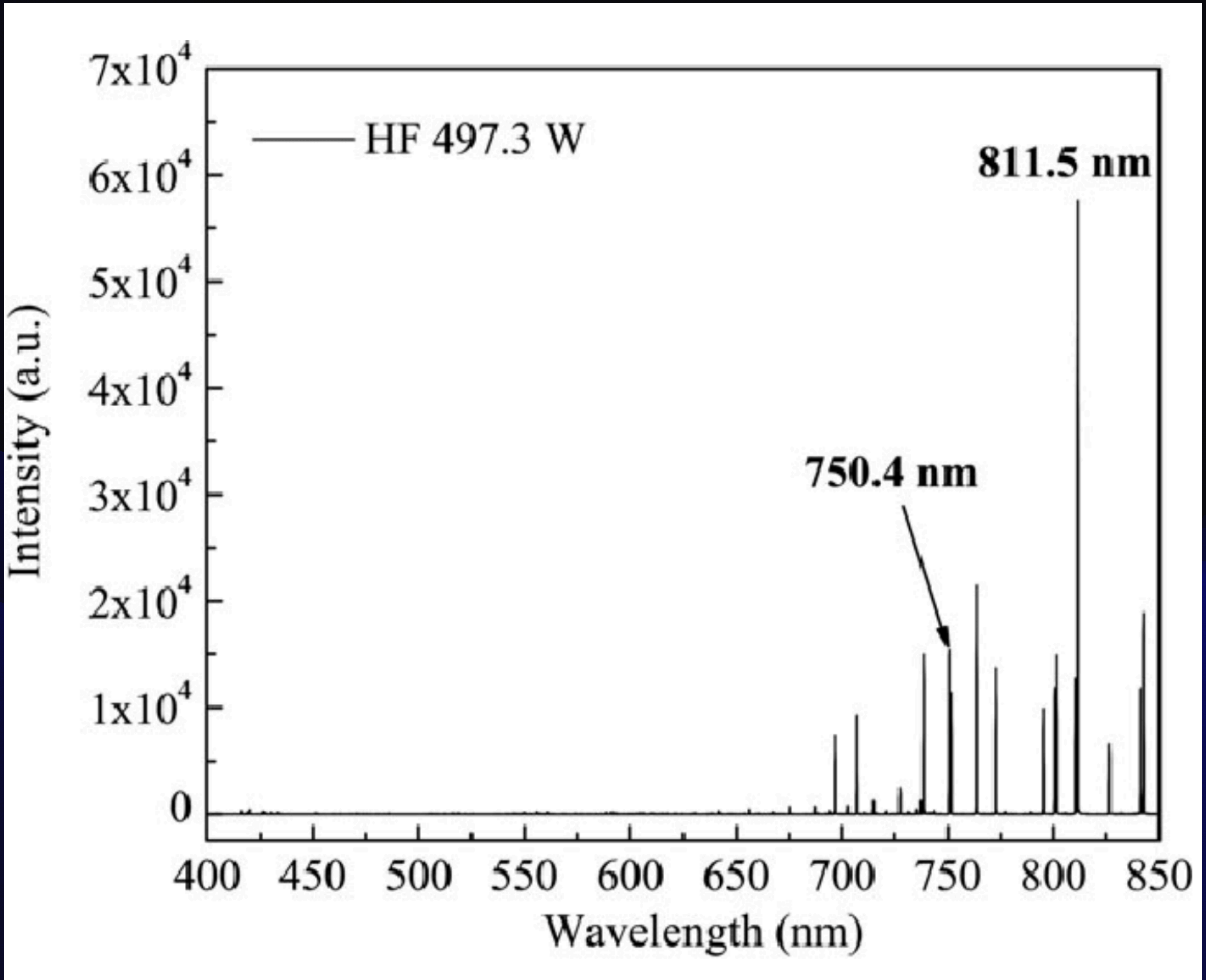
Relative intensity variation reflects excitation conditions



Only argon emission lines are present
No impurity peaks observed
Strong peaks at:
706.7 nm
750.4 nm
810.3 nm
842.4 nm
Emission dominated by near-IR region

The pure argon spectrum consists solely of sharp, intense argon emission lines, with the strongest emission occurring in the near-infrared region, confirming discrete atomic transitions and high gas purity.

Confirms high purity argon plasma
Observed wavelengths are characteristic fingerprints of argon
Strong near-IR emission due to dominant allowed transitions
Sharp peaks indicate stable plasma conditions



The absence of significant emission in the lower visible region and the sharp nature of the peaks confirm that argon emission is dominated by specific atomic transitions with minimal spectral broadening under the given plasma conditions.

Increasing power increases:

Electron density

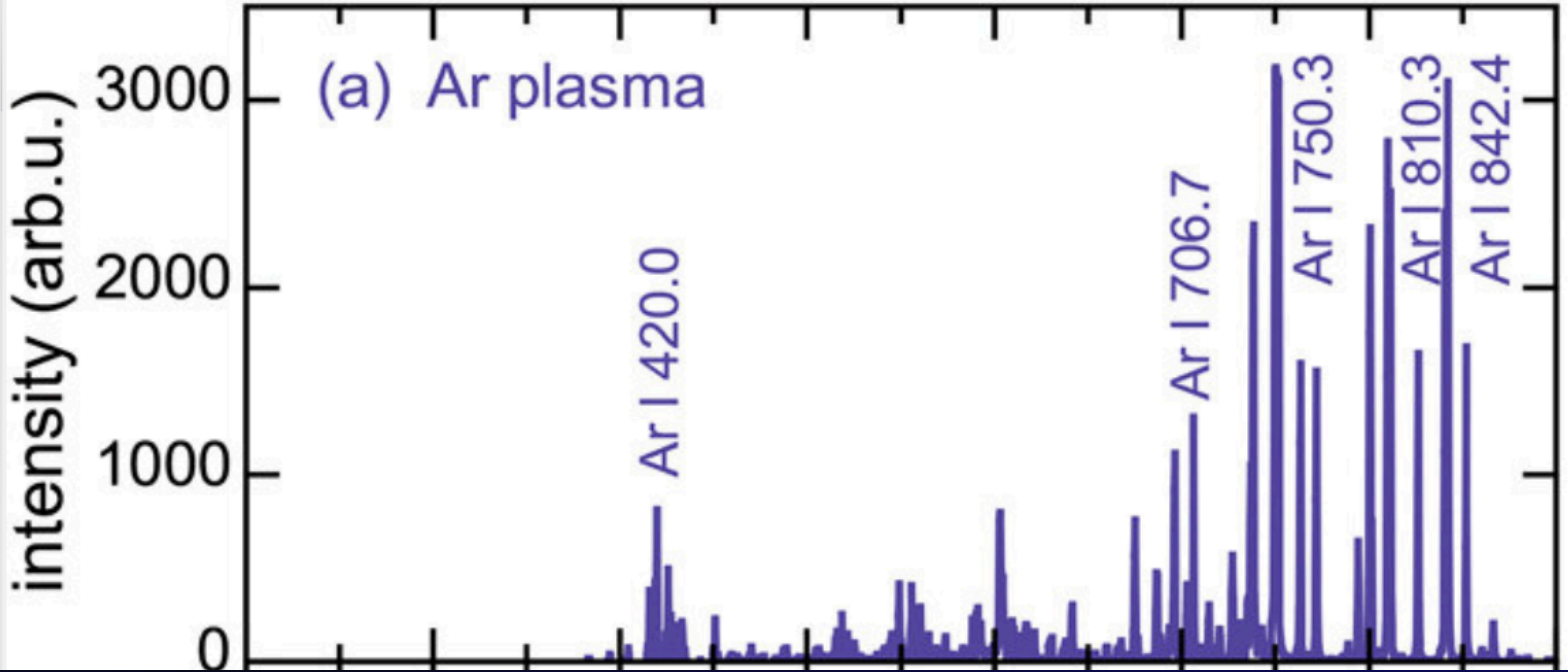
Excitation and ionization probability

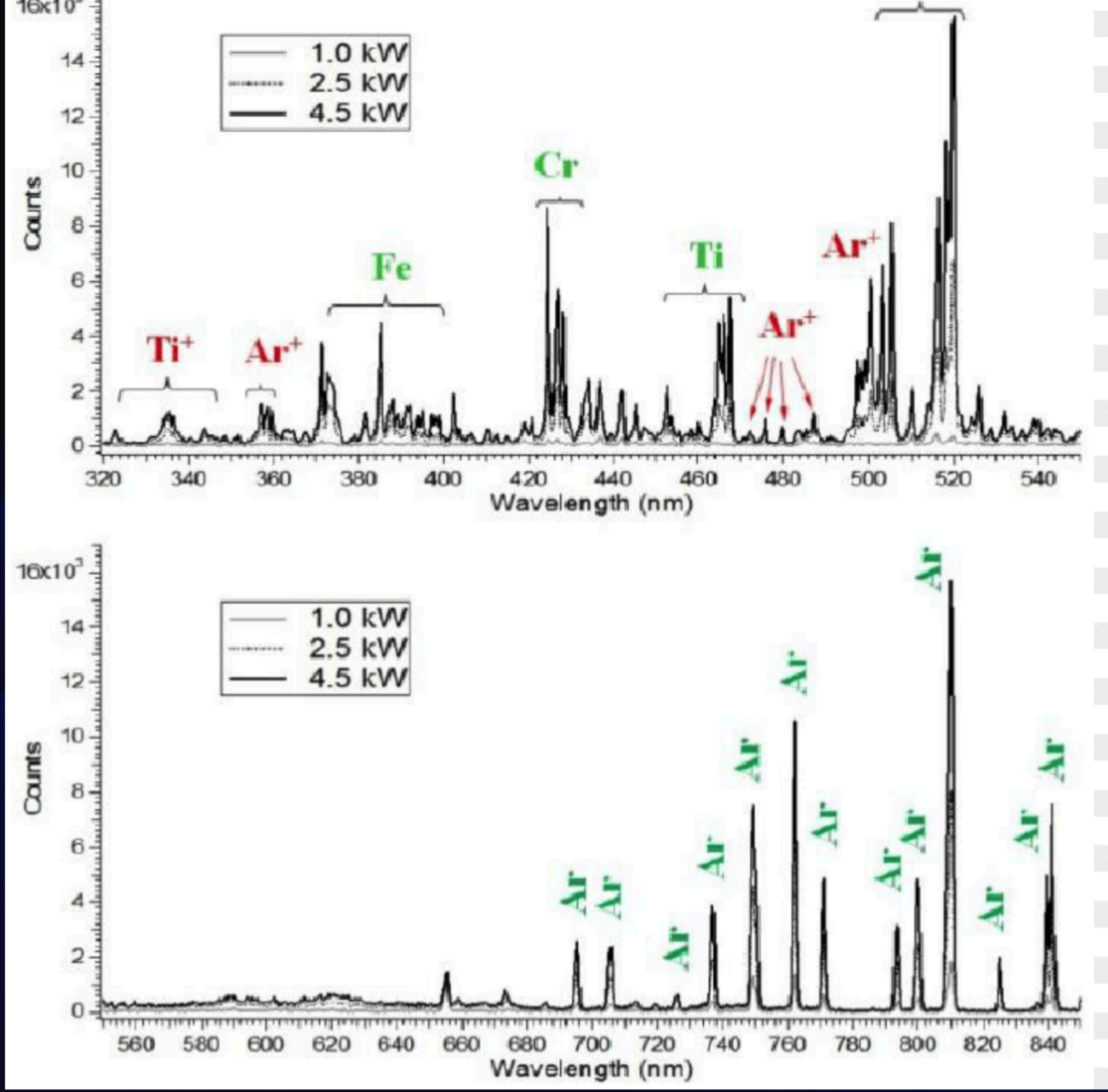
Peak intensity increases with power

Peak positions remain unchanged

Indicates higher population of excited states

ResearchGate





The emission spectra show that increasing plasma power (from 1.0 kW to 4.5 kW) leads to a significant increase in the intensity of spectral lines without changing their wavelength positions. Strong emission lines corresponding to Ar^+, along with metallic species such as Ti, Fe, and Cr, are observed in the UV–visible region, indicating effective excitation and ionization at higher power. In the longer wavelength region, the spectrum is dominated by intense argon atomic lines, confirming argon as the primary plasma gas.

Sources of Error & Applications of OES

Instrumental noise
Plasma instability
Spectral line overlap
Self-absorption at high concentrations
Improper calibration

Elemental analysis of metals and alloys
Semiconductor and thin-film analysis
Environmental monitoring
Plasma diagnostics
Quality control in industries