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# Experimental characterization of double pulse laser-induced plasmas

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## CONTEXT & OBJECTIVES

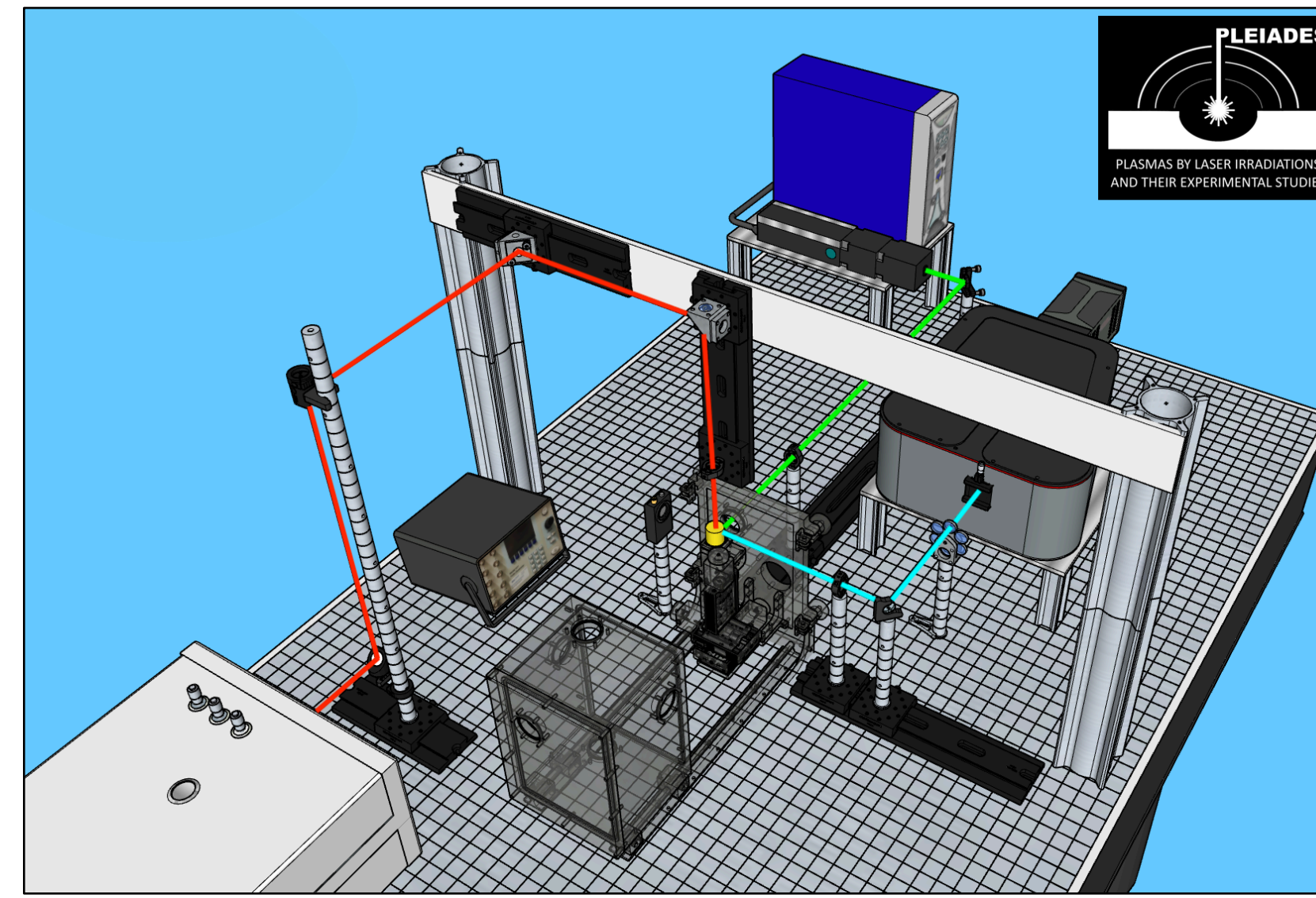
### Diagnostic technique LIBS (Laser-Induced Breakdown Spectroscopy)

For a target composed of elements in very low concentration or whose upper levels of common transitions are high (10 eV or more) the maximization of the output signal is mandatory. One efficient technique is to heat up the plasma with a second pulse shifted in time. This experimental process is called double pulse (DP).

### Objectives

- Obtaining an experimental setup accurately controlled in time and space.
- Quantifying the improvements in terms of output spectral radiance.
- Observing absorption lines by LIAS.
- Quantifying roughly electron and low level number densities.

## EXPERIMENTAL SETUP

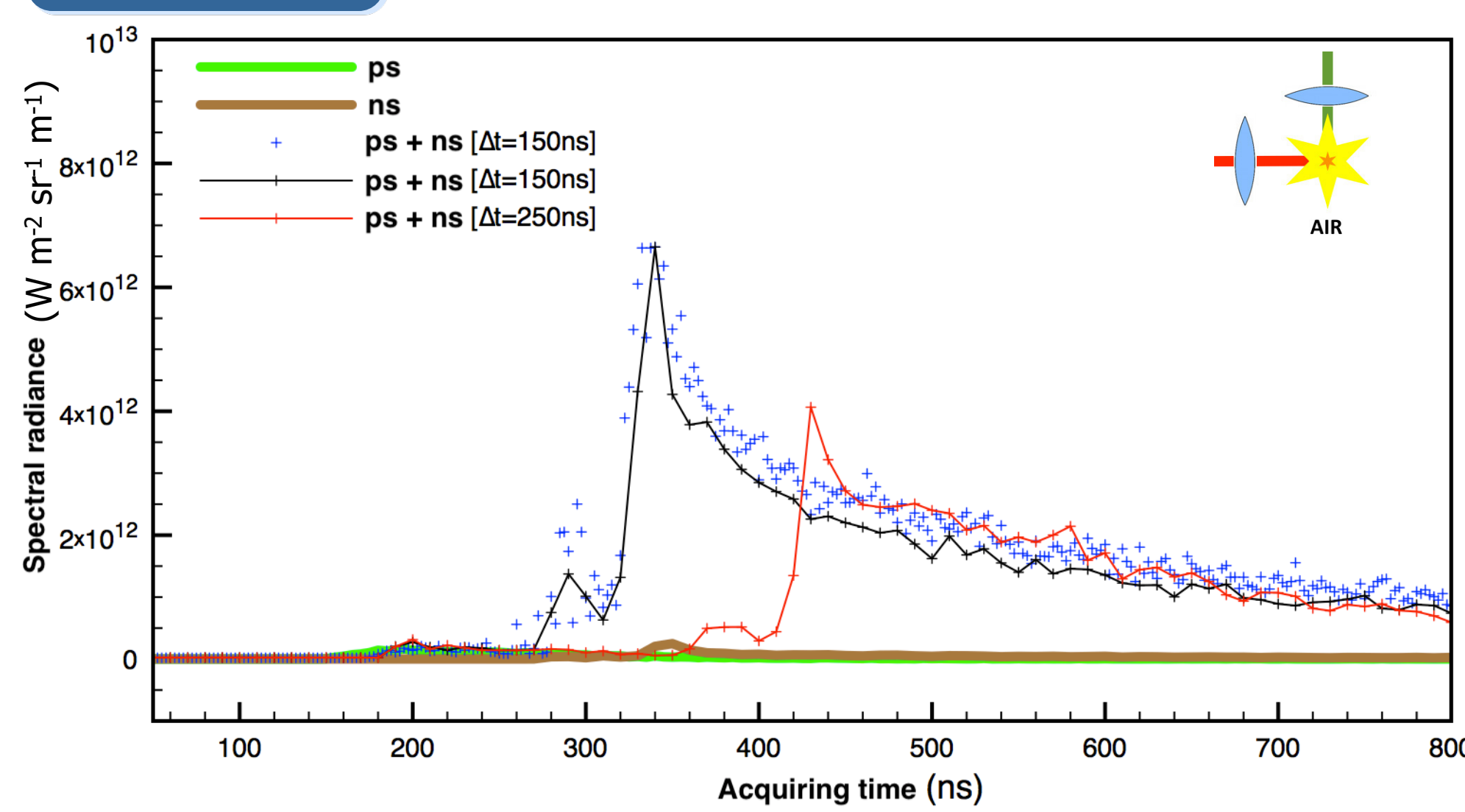


The **first pulse** (1064 nm, 30 ps, 14 mJ) is focused to produce a plasma. The **second pulse** (512 nm, 6 ns, 65 mJ) is focused in this plasma with a temporal shift of  $\Delta t$ . **Heated plasma's** radiation is collected on a **third optical axis** to be analysed by our SCT-320 spectrometer.

### LASERS:

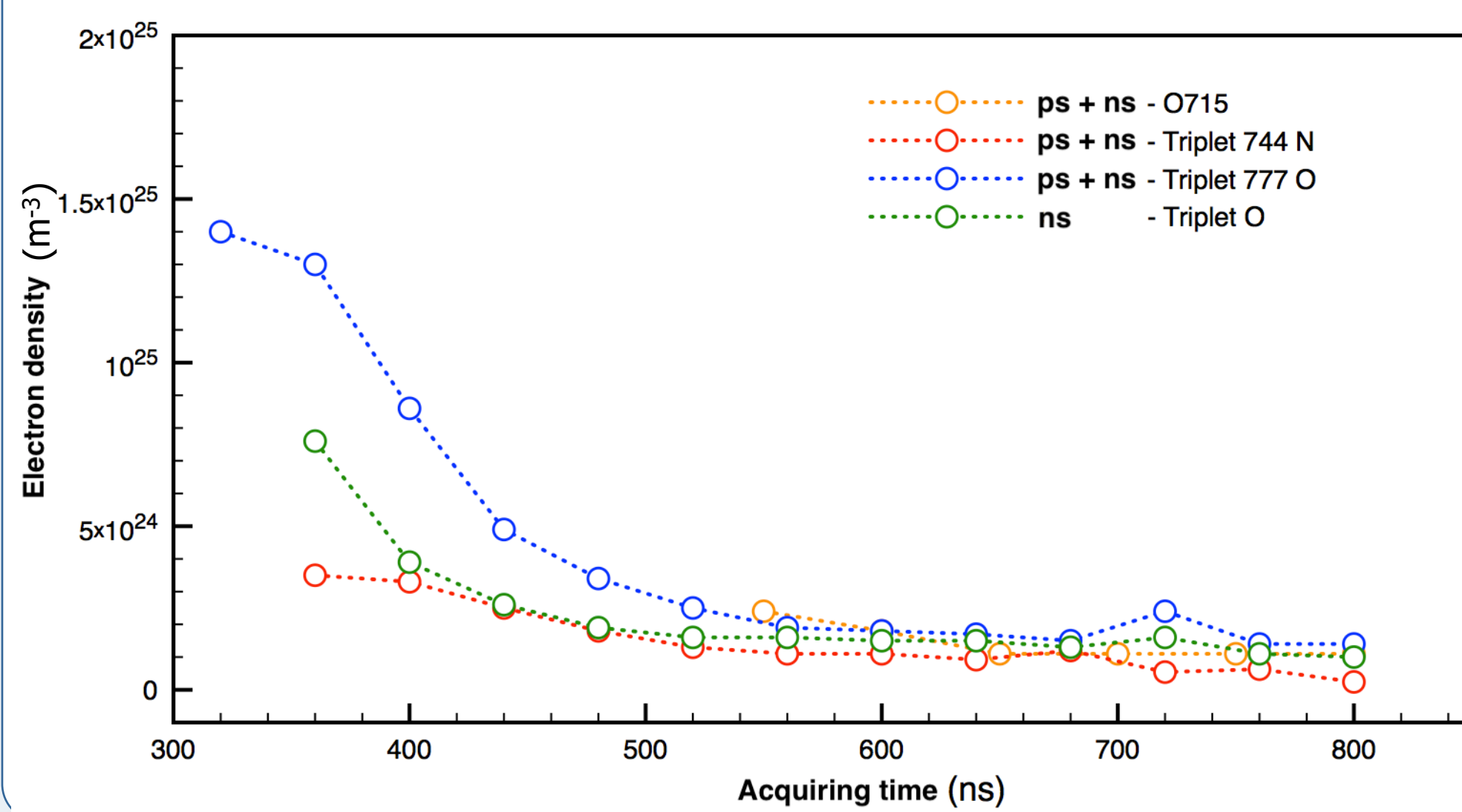
- EKSPLA PL-2251: **ps**
- QUANTEL U100: **ns**

## DP in AIR

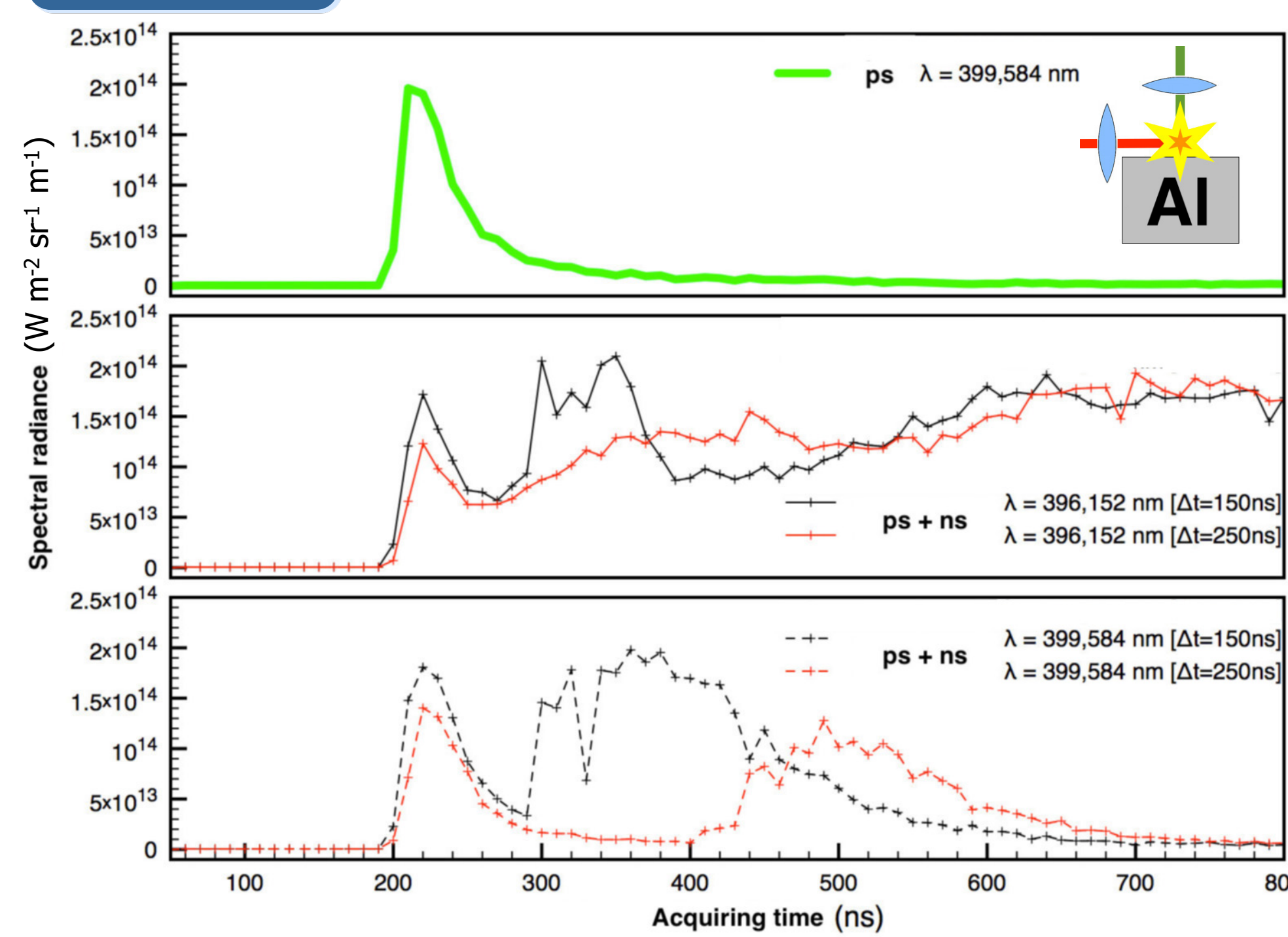


### Comments

- Double pulse setup effective.
- Optimal time shifting to improve the output signal:  $\Delta t = 150$  ns
- First determination of electron density:  $10^{24} \text{ m}^{-3} < n_e < 10^{25} \text{ m}^{-3}$

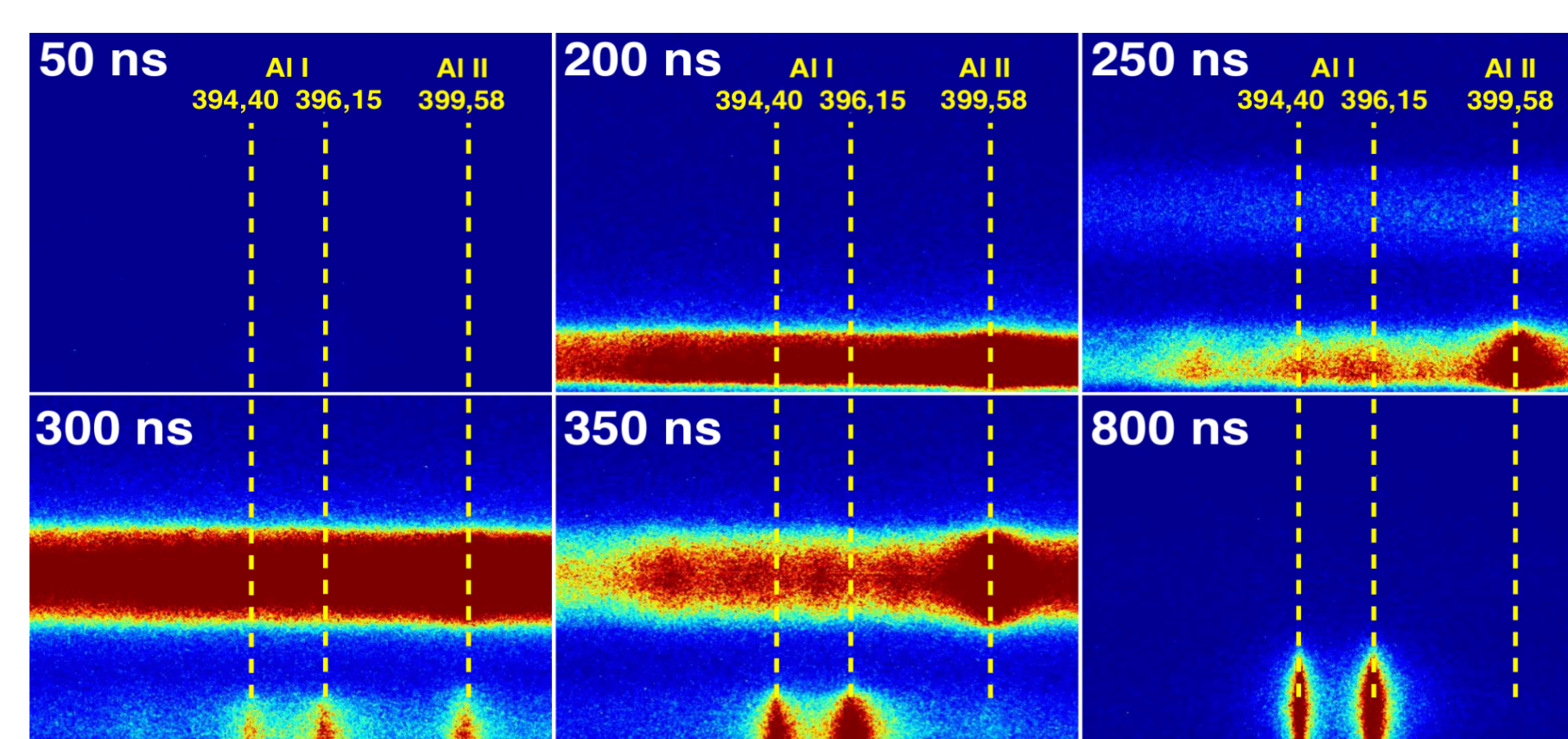


## DP on AL

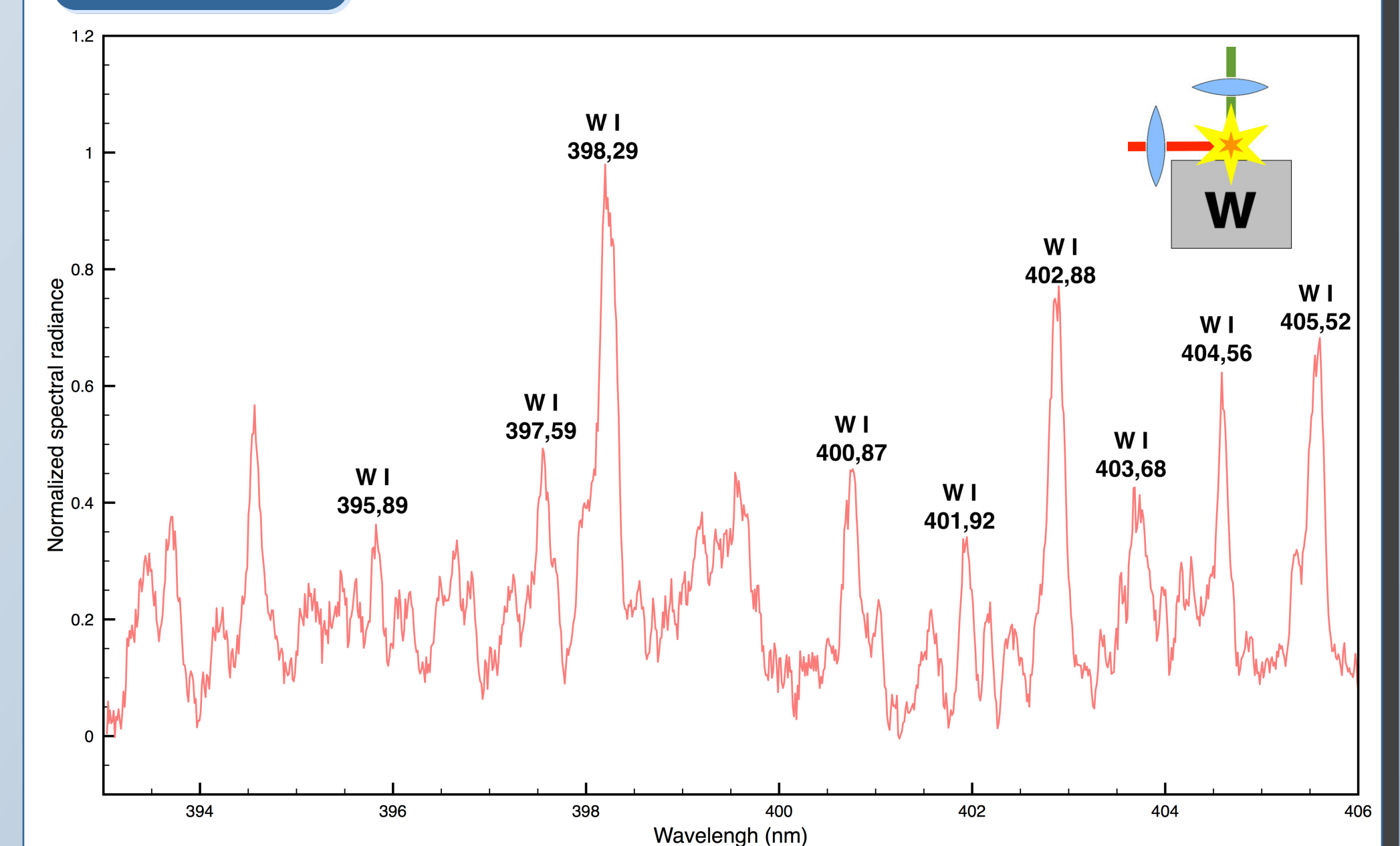


### Comments

- Al II lines only observed in double pulse.
- Recombination significant (ionic emission decreasing for the benefit of atomic one's).

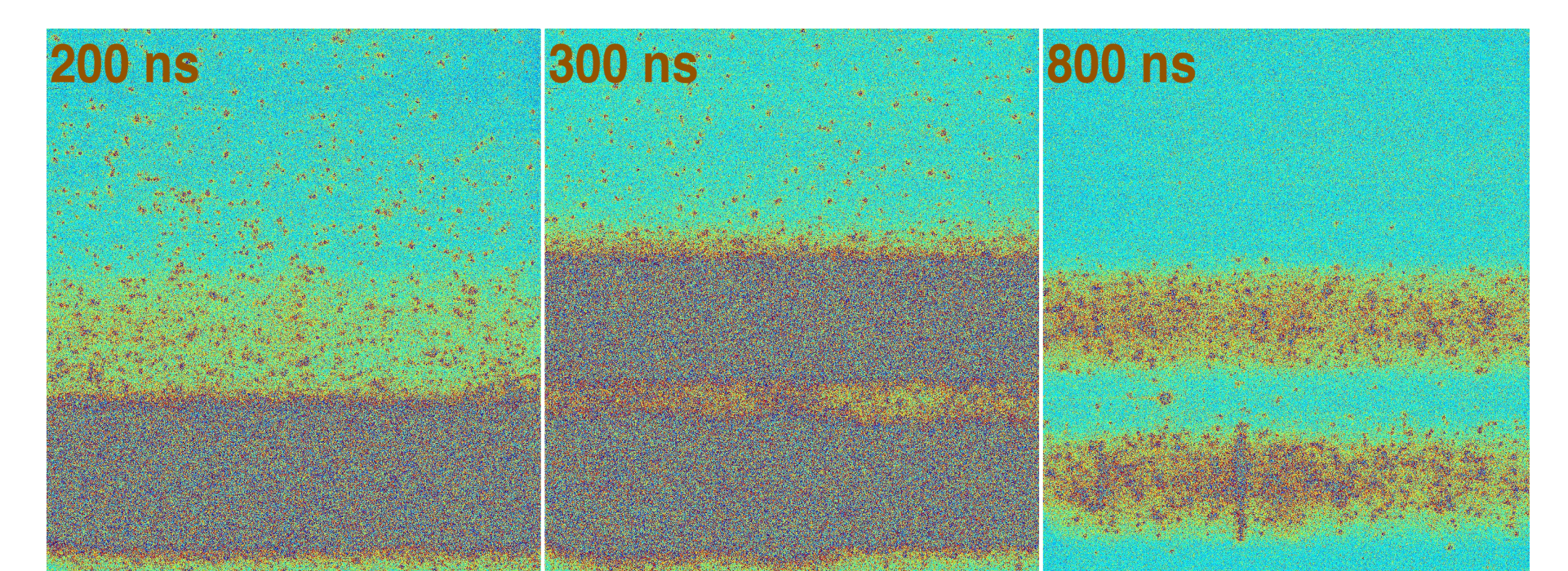


## DP on W

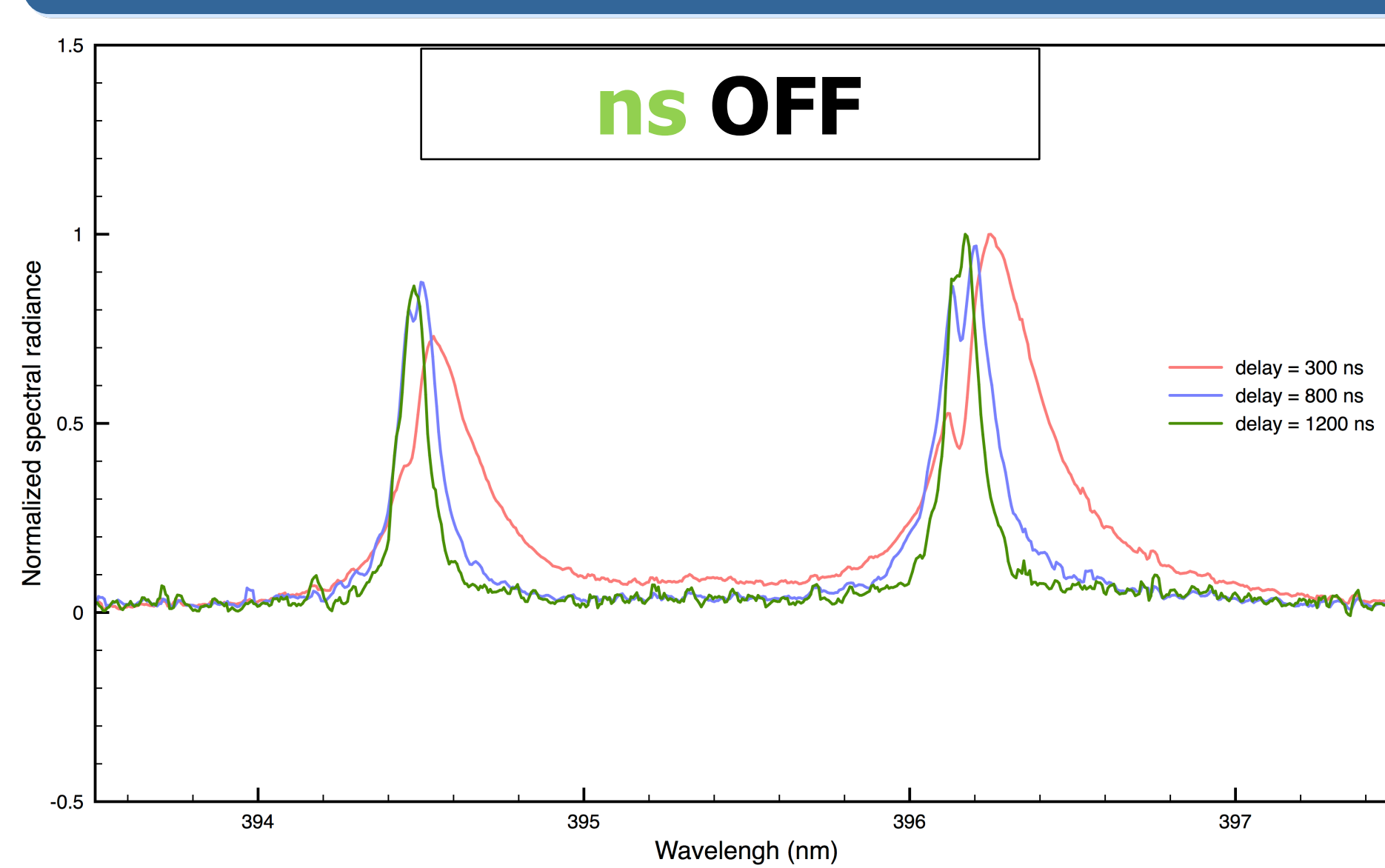


### Comments

- Tungsten significantly radiates, transitions identification is tricky.
- Emission spectra obtained from spectroscopic imagery.
- Computed spectra will be performed to accurately identify the emission lines observed.



## Laser-Induced Ablation Spectroscopy (LIAS)

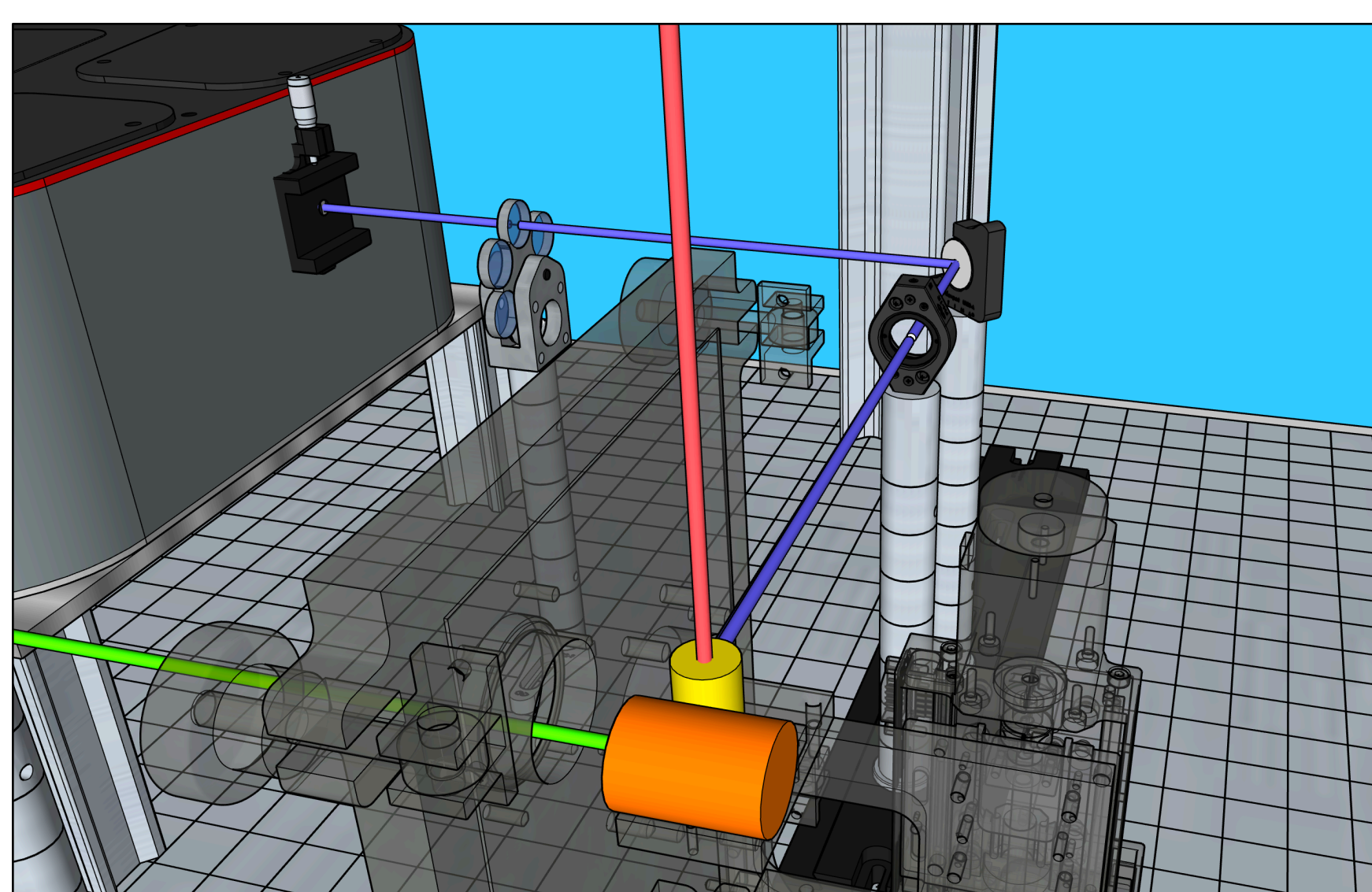


### Comments

- In [ns OFF] configuration, we observe *emission spectra*. As Al I 394.40 nm and Al I 396.15 nm are the resonance doublet, auto-absorption is noticed.

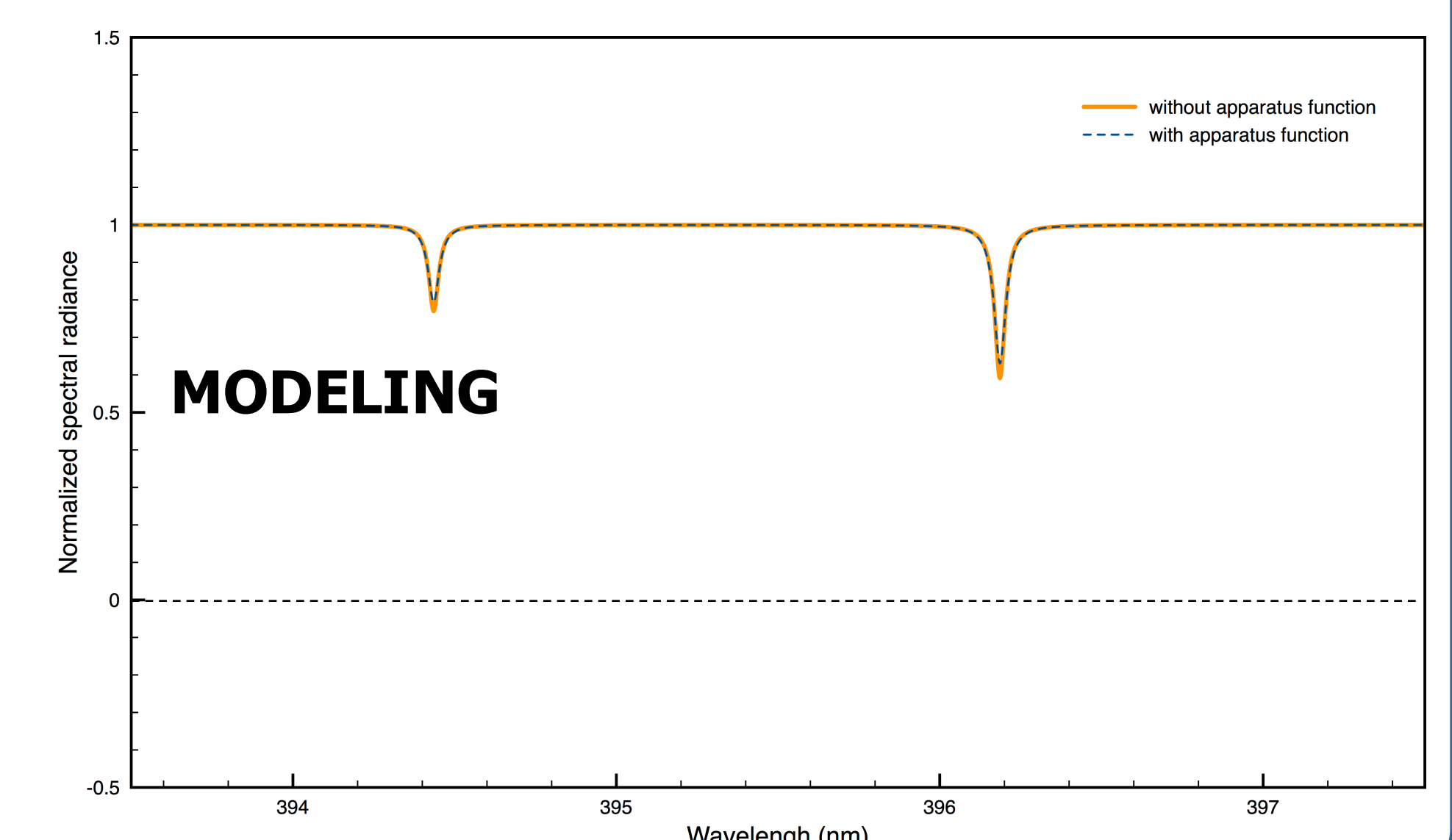
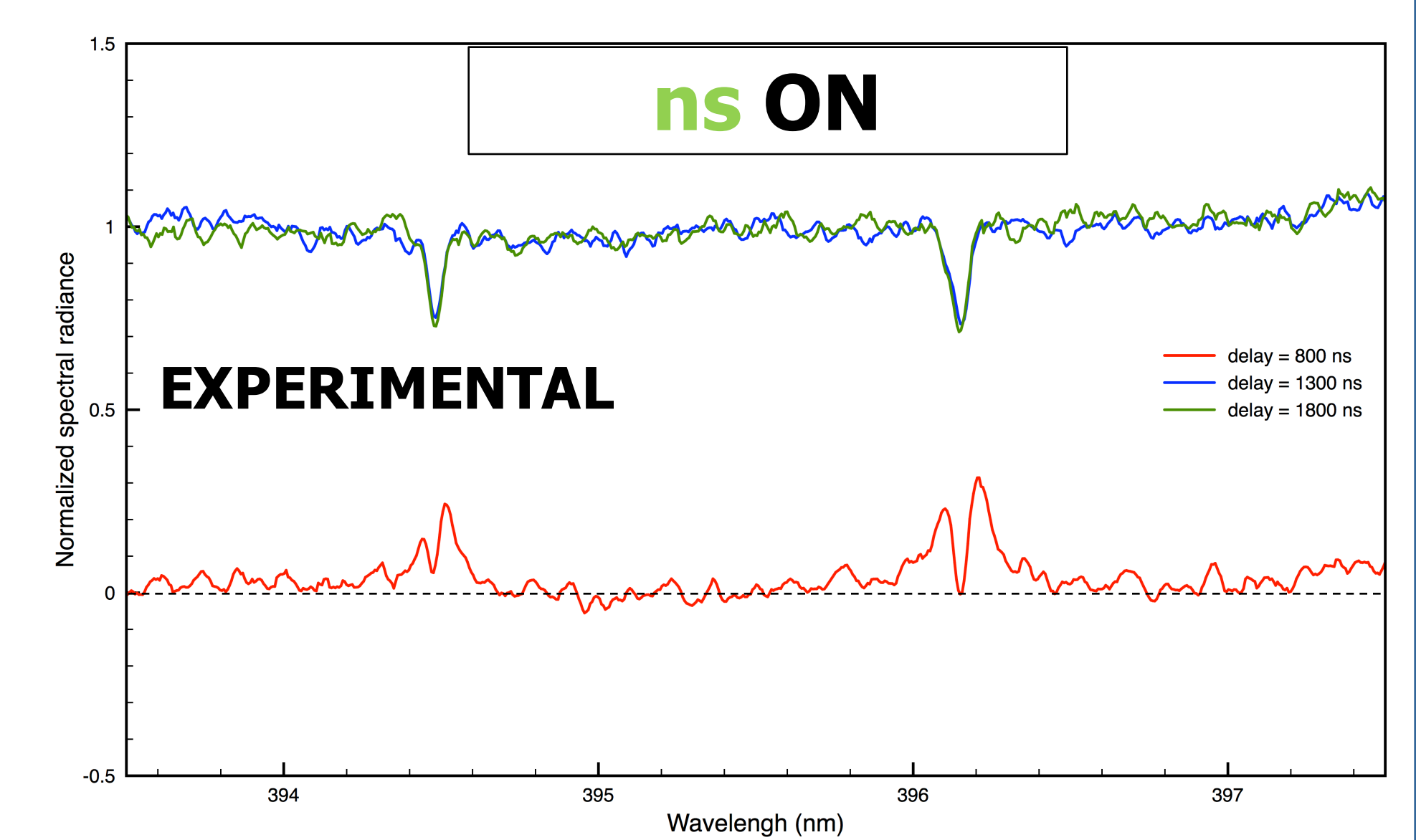
- In [ns ON] configuration, we can observe *absorption spectra*. Absorption is only significant for delay  $\geq 1.2 \mu\text{s}$ .

- Those absorption lines can be fitted with:  
 Electron density  $n_e = 2 \times 10^{23} \text{ m}^{-3}$   
 Electron temperature  $T_e = 10\,000 \text{ K}$   
 Ground state number density  $[N_i] = 3.5 \times 10^{20} \text{ m}^{-3}$   
 External spectral radiance  $L_{\text{ext},\lambda} = 10^{13} \text{ W m}^{-2} \text{ sr}^{-1} \text{ m}^{-1}$



The experimental setup used for LIAS is rigorously the same as described above except that the second pulse is spatially translated.

We obtain two plasmas temporally shifted by a delay: **ps plasma** and **ns plasma**.



## CONCLUSIONS & PERSPECTIVES

- Effective temporally and spatially controlled double pulse setup.
- Detection limits are sorely enhanced, output signal is at least 5x multiplied.
- Possible determination of electron density and electron temperature.
- Possible characterization of lower states by absorption spectra.
- Accuracy can be strongly improved by working with a higher spectral resolution and signals with accumulations.
- Detection of light elements such as H isotopes in heavy matrices like W remains our long-term objective.