First measurements of Tritium by ns-LIBS – Perspectives for ps-LIBS

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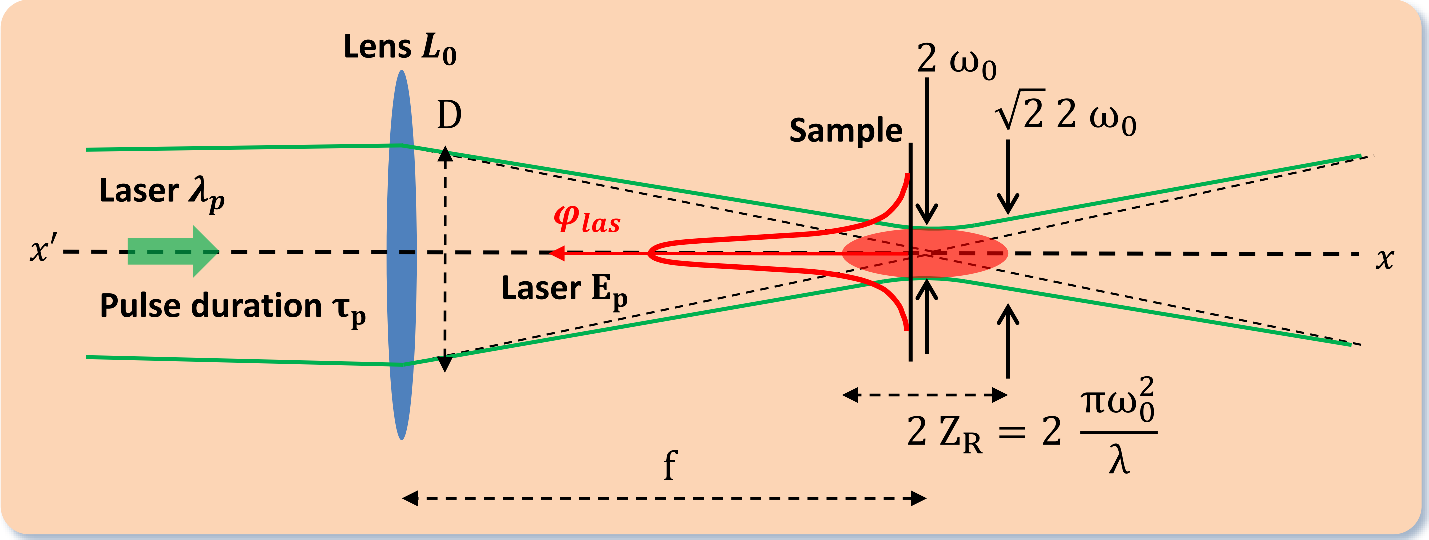
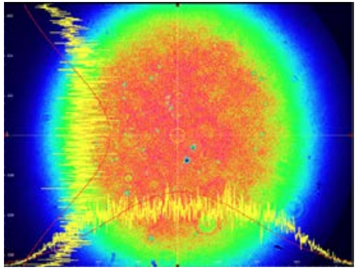
LIBS^{3}H platform for T measurements…

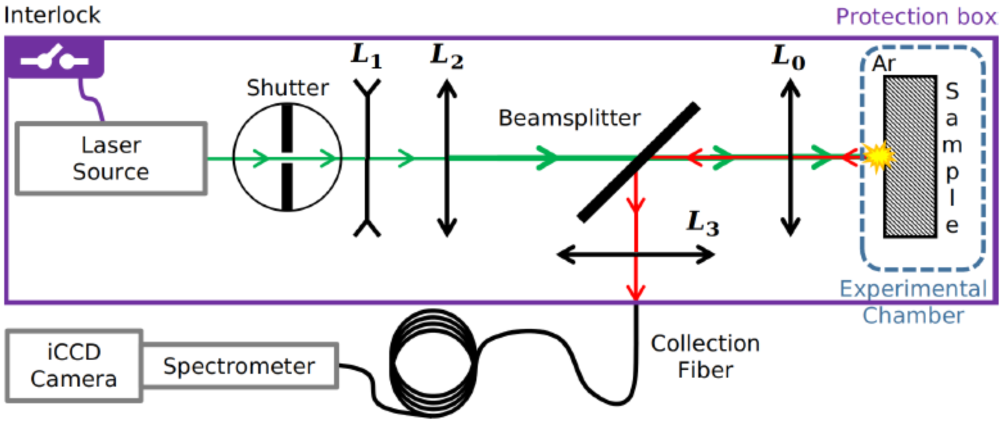


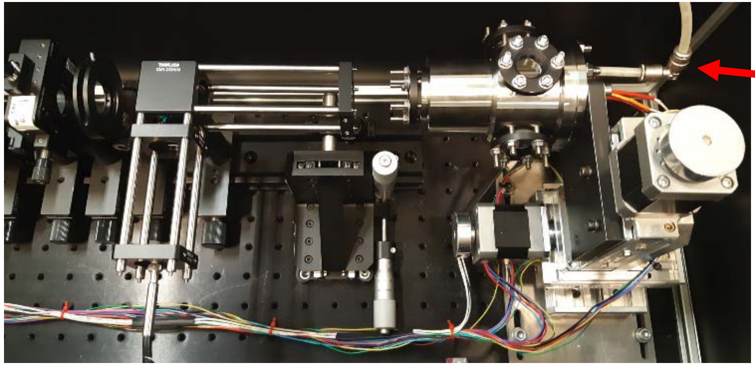
Variable	Values
$E_p(mJ)$	25 (after L_0)
$\tau_p(ns)$	6.9
$\lambda_p(nm)$	532
$D(mm)$	10
$f(cm)$	10
$\omega_0(\mu m)$	55
$\mathcal{M}^2$	16.4
$\varphi_L(W\ m^{-2})$	3.7×10^{14}
$F_L(J\ cm^{-2})$	260

« Top-hat » laser beam

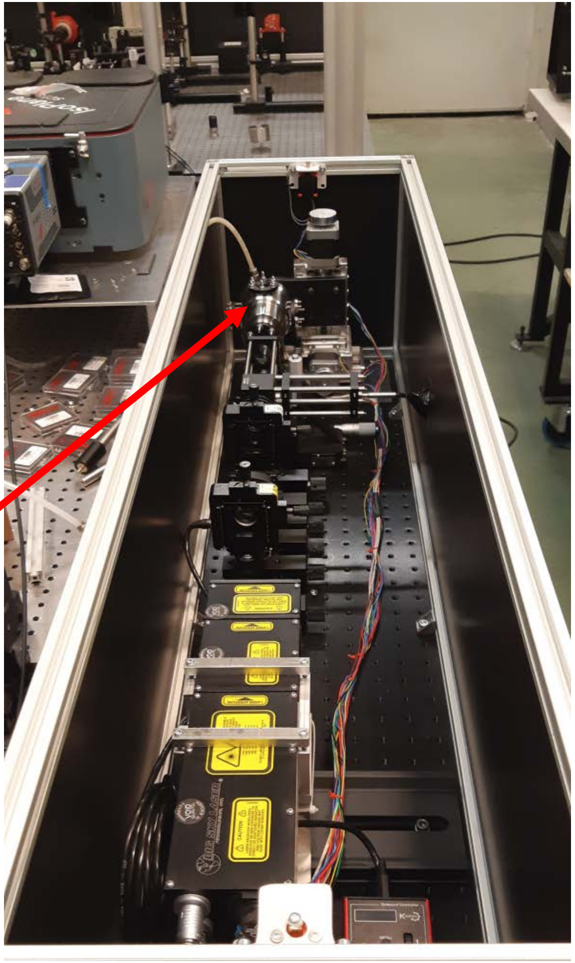


LIBS^{3}H platform for T measurements…

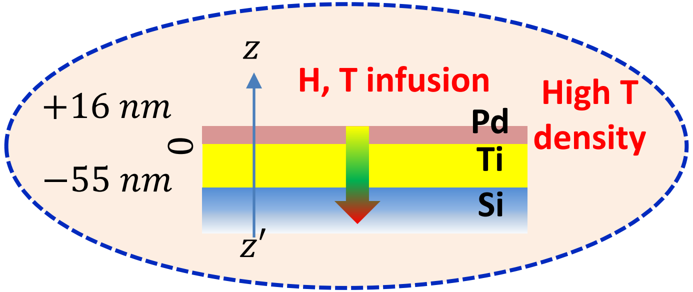




Under Ar at p_{atm}



The tritiated sample...

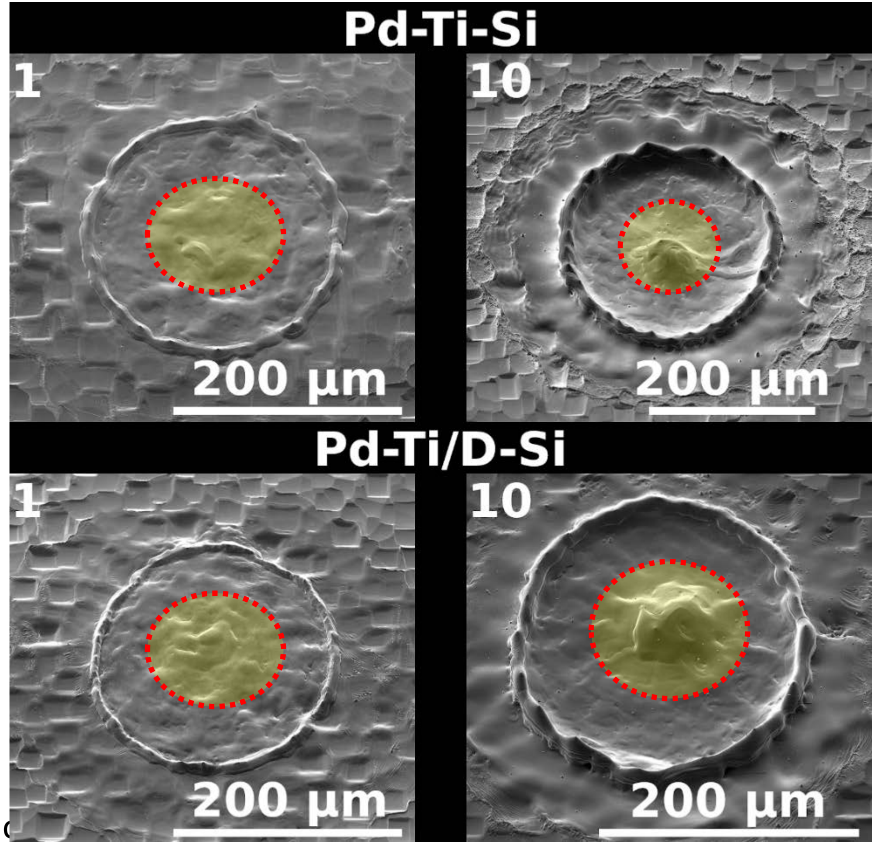


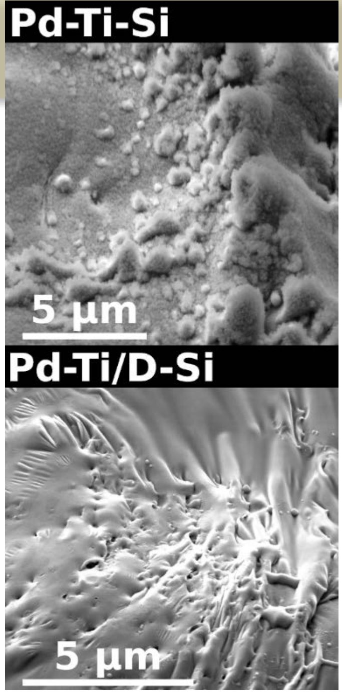
- Avoid the formation of an oxide layer limiting the diffusion
- Favor a high T concentration at $z = 0$
- Diffusion favored in Si by high temperature level $T \cong 300°C$

	Diffusion of H at 20 degrees C		Diffusion of T at 20 degrees C	
Material X	$D_{H,X}$ ($m^2\ s^{-1}$) [Ref.]	$\delta_{H,X}$ (m)	$D_{T,X}$ ($m^2\ s^{-1}$) [Ref.]	$\delta_{T,X}$ (m)
Pd	2×10^{-15} (thin layer [45])	2.7×10^{-6}	1.9×10^{-11} [48]	2.6×10^{-4}
Ti	1.6×10^{-15} [46]	2.4×10^{-6}	2.0×10^{-15} [46]	2.7×10^{-6}
Si	8.0×10^{-19} [34, 47]	5.4×10^{-8}	8.0×10^{-19} [34, 47]	5.4×10^{-8}

	Diffusion of H at 300 degrees C		Diffusion of T at 300 degrees C	
Material X	$D_{H,X}$ ($m^2\ s^{-1}$) [Ref.]	$\delta_{H,D}$ (m)	$D_{T,X}$ ($m^2\ s^{-1}$) [Ref.]	$\delta_{T,D}$ (m)
Pd	2.9×10^{-9} [43, 44]	3.2×10^{-3}	2.9×10^{-9} [43, 44]	3.2×10^{-3}
Ti	4.3×10^{-11} [46]	4.0×10^{-4}	3.4×10^{-11} [46]	3.5×10^{-4}
Si	5.1×10^{-14} [34, 47]	1.4×10^{-5}	5.1×10^{-14} [34, 47]	1.4×10^{-5}

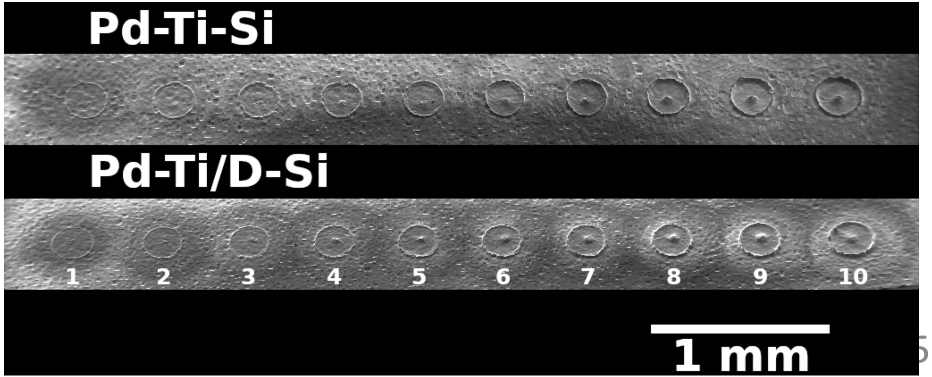
The tritiated sample modified by the laser flux…



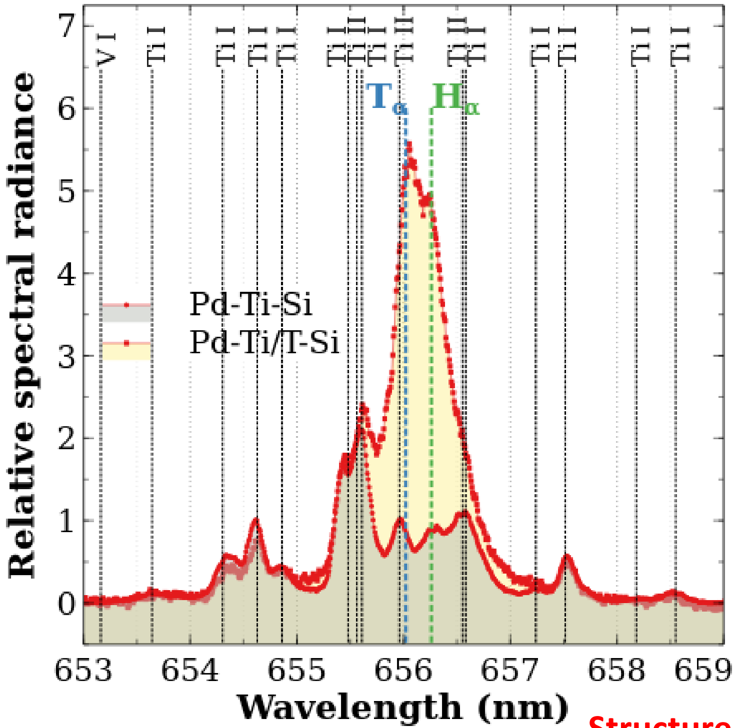


Structure of sample modified by diffusion of T (and H)…

Ablation rate $\approx 400\ nm/pulse$

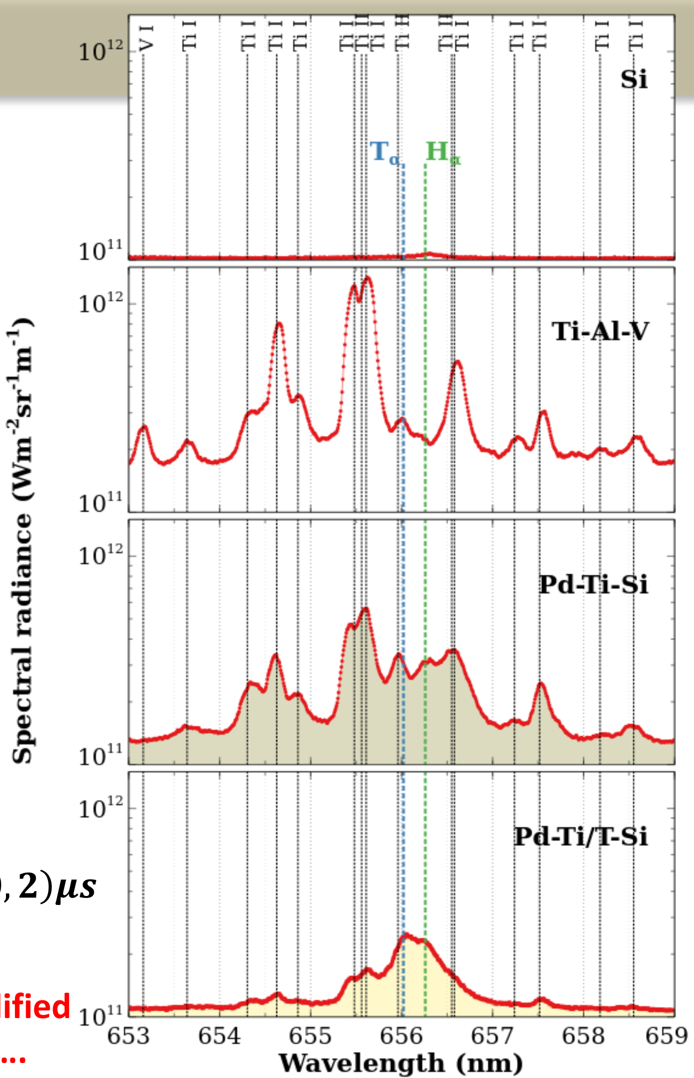


Emission of the laser-induced plasma on the tritiated sample…



$$(t, \Delta t) = (10, 2)\mu s$$

First shot…

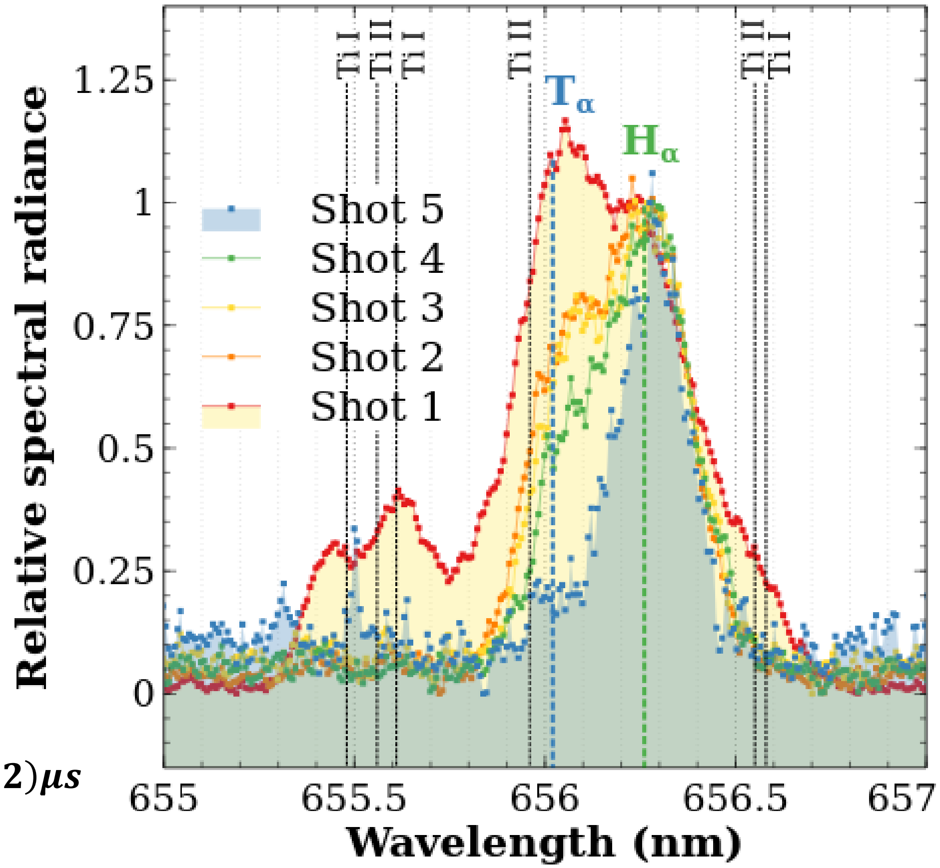


Structure of sample modified by diffusion of T (and H)….

Focus on the emission of T…

- No influence of the wings of the laser pulse (shot2: no longer Ti lines)
- Tritium has diffused in depth
- H has further diffused (higher diffusion coefficient)

$(t, \Delta t) = (10, 2) \mu s$



Rebuilding of the emission of the Tritiated plasma…

$n_e \approx 10^{22}\ m^{-3}$
$T_e \approx 8000\ K$

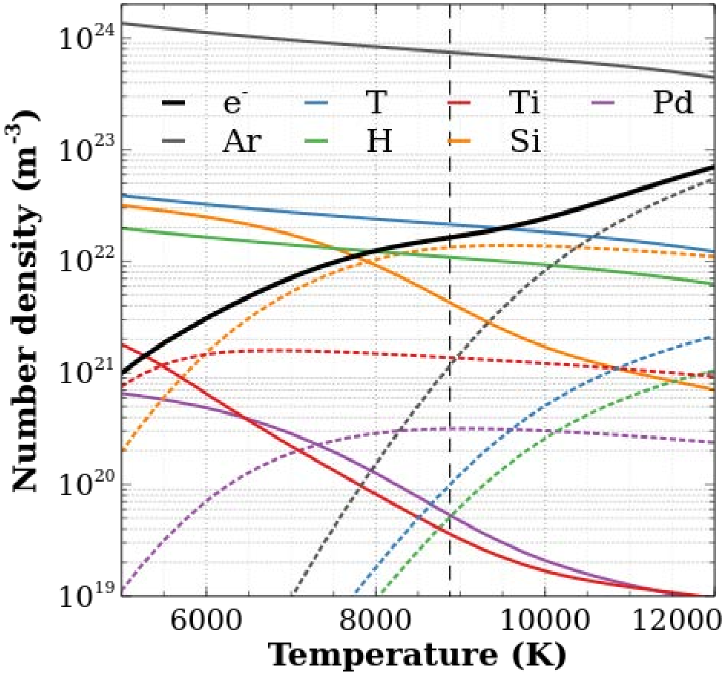
Criterion	Year - Ref.	$n_{e,min}$(Si)	$n_{e,min}$(Ti)	$n_{e,min}$(H-T)	$n_{e,min}$(Ar)
Wilson	1962 - [71]	2.9×10^{24}	1.7×10^{24}	1.4×10^{25}	2.1×10^{25}
Griem	1963 - [72]	1.1×10^{21}	1.1×10^{20}	9.5×10^{21}	1.4×10^{22}
McWhirter	1965 - [73]	1.6×10^{21}	6.4×10^{19}	1.5×10^{23}	2.3×10^{23}
Drawin	1969 - [74]	1.2×10^{20}	1.3×10^{17}	9.9×10^{21}	8.1×10^{22}
Hey	1976 - [75]	9.1×10^{22}	6.9×10^{21}	1.2×10^{24}	1.8×10^{24}
Fujimoto and McWhirter	1990 - [76]	5.5×10^{23}			

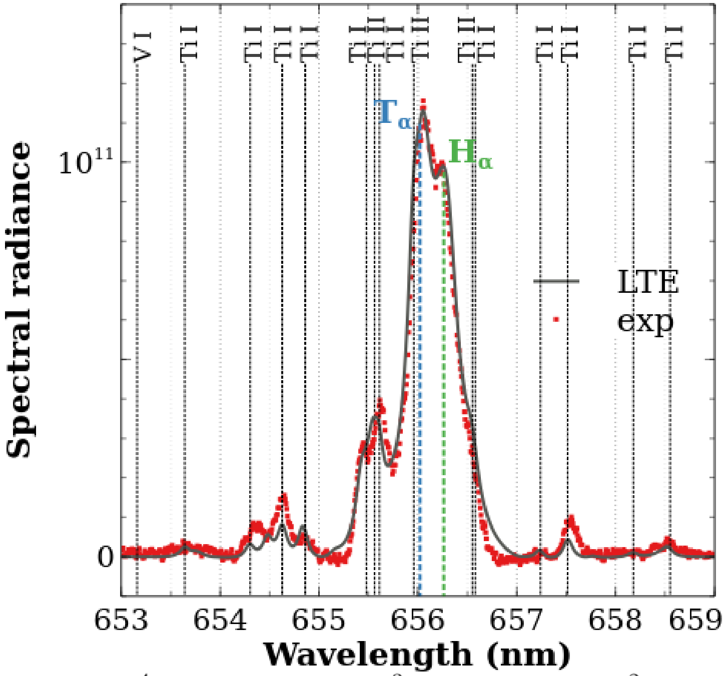
Element	Si	Ti	H, T	Ar
E_1 - E_2 (eV)	0 - 4.930	0 - 2.396	0 - 10.199	0 - 11.624
f_{12}	2.10×10^{-1}	1.70×10^{-2}	4.16×10^{-1}	6.75×10^{-2}
Ψ_1	1.33×10^{-4}	9.34×10^{-3}	1.93×10^{-8}	1.77×10^{-9}
α^{CR} ($m^3\ s^{-1}$)	4.10×10^{-17}			
τ_i (s)	2.60×10^{-6}	2.22×10^{-7}	1.87×10^{-2}	1.43×10^{0}
τ_r (s)	2.44×10^{-6}			
τ_p (s)	1.26×10^{-6}	2.04×10^{-7}	2.44×10^{-6}	2.44×10^{-6}
λ_g (m)	2.38×10^{-7}	4.67×10^{-8}	1.46×10^{-4}	1.36×10^{-4}

- **Criteria globally fullfilled**
- **Elapsed time enough to reach LTE**

Rebuilding of the emission of the Tritiated plasma…

MERLIN – *MultiElemental Radiative equiLibrIum emissioN…*





$x_{Ar} = 0.935$, $x_{Pd} = 4.62 \times 10^{-4}$, $x_{Ti} = 1.76 \times 10^{-3}$, $x_{Si} = 2.2 \times 10^{-2}$, $x_H = 1.37 \times 10^{-2}$,

$x_T = 2.68 \times 10^{-2}$, $T_e = 8900$ K, $p = 10^5$ Pa and $z_p = 1300$ μm.

Sample close to H, T saturation

$x_T \approx 41$ at.% $x_H \approx 21$ at.%

Perspectives…

- **Perform the T density estimation by autoradiography**
- **Compare the composition by the present CF-LIBS methodology implementation with autoradiography**
- **Redo the tritiation on other types of samples (W and Be)**
- **Perform the T measurement using the ps-LIBS**
  - **To reduce the ablation rate**
  - **To decrease n_e and increase the isotopic discrimination capacity**

- **Tests on samples containing D and T to test the isotopic separation**

Many thanks!!!