

DE LA RECHERCHE À L'INDUSTRIE



# LIBS APPLICATION IN JOINT EUROPEAN TORUS

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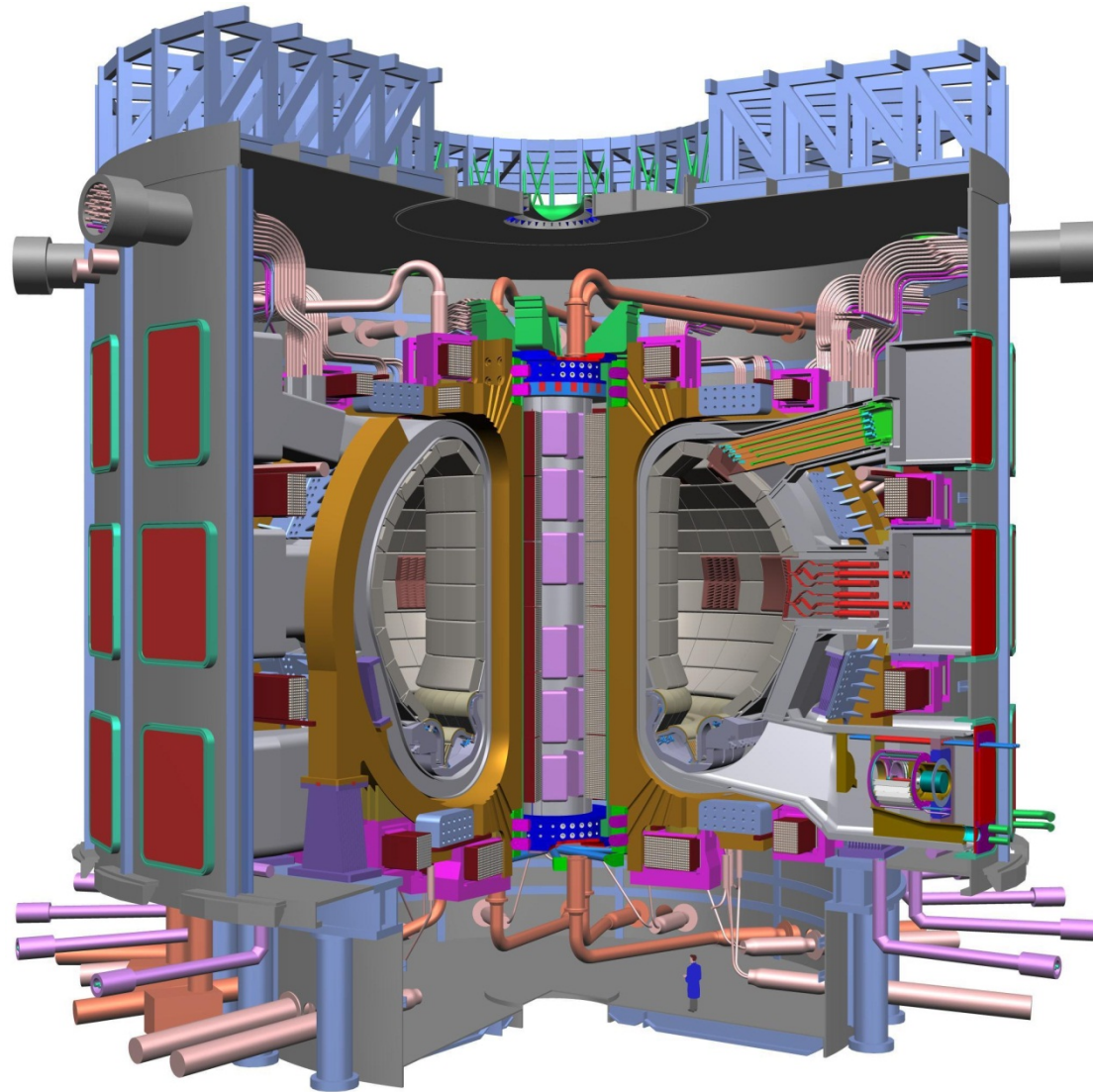
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# Problem: Tritium retention on the walls

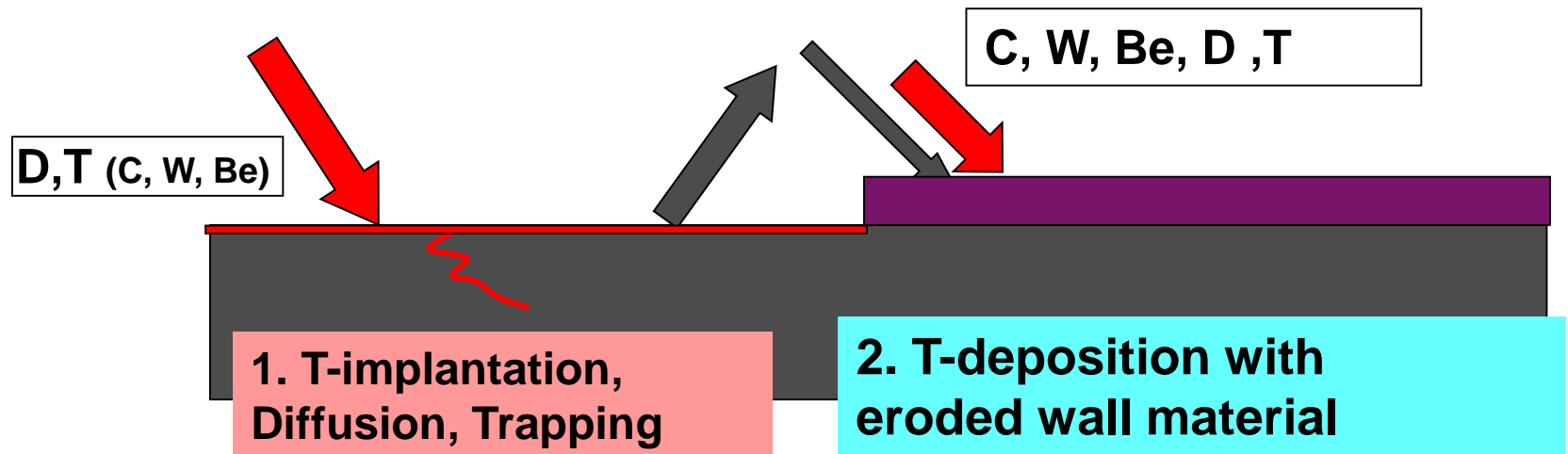
*ITER < 700 g*

## Laser methods to solve the problem:

- LIBS for deposited layer in-depth characterisation (depth & composition)
- **Detritiation by:**
  - laser heating
  - laser ablation



# Tritium trapping on the PFC



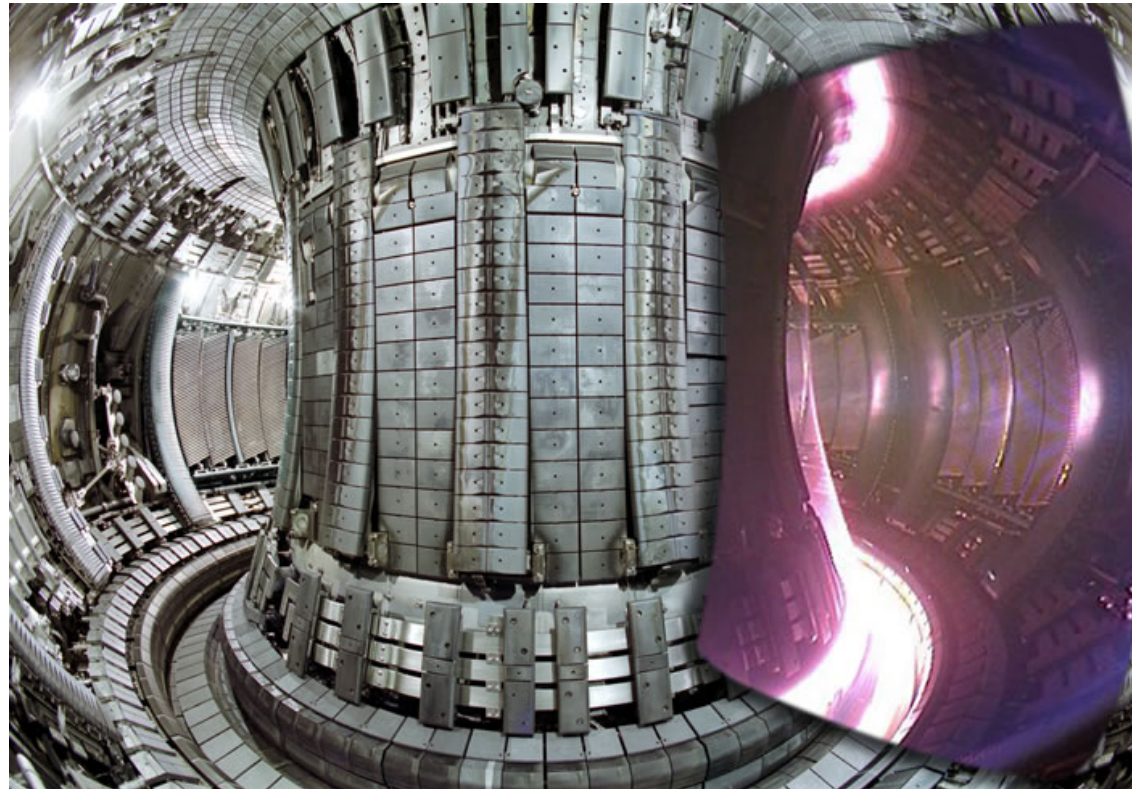
## Deposited layer formation

- 10 nm (Be wall) – 100  $\mu\text{m}$  (divertor)
- up to 50% of D/T
- solid - friable (porous)

# JET (Joint European Torus), Culham, UK

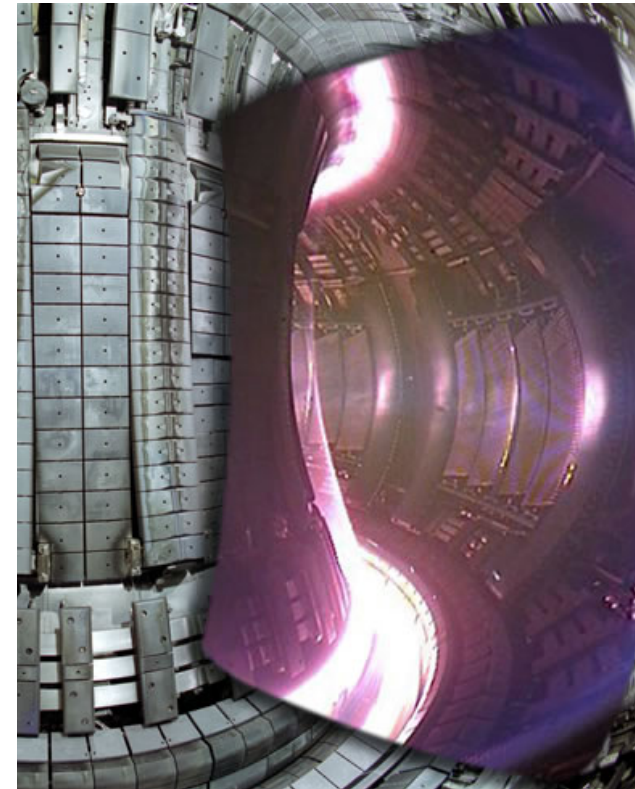
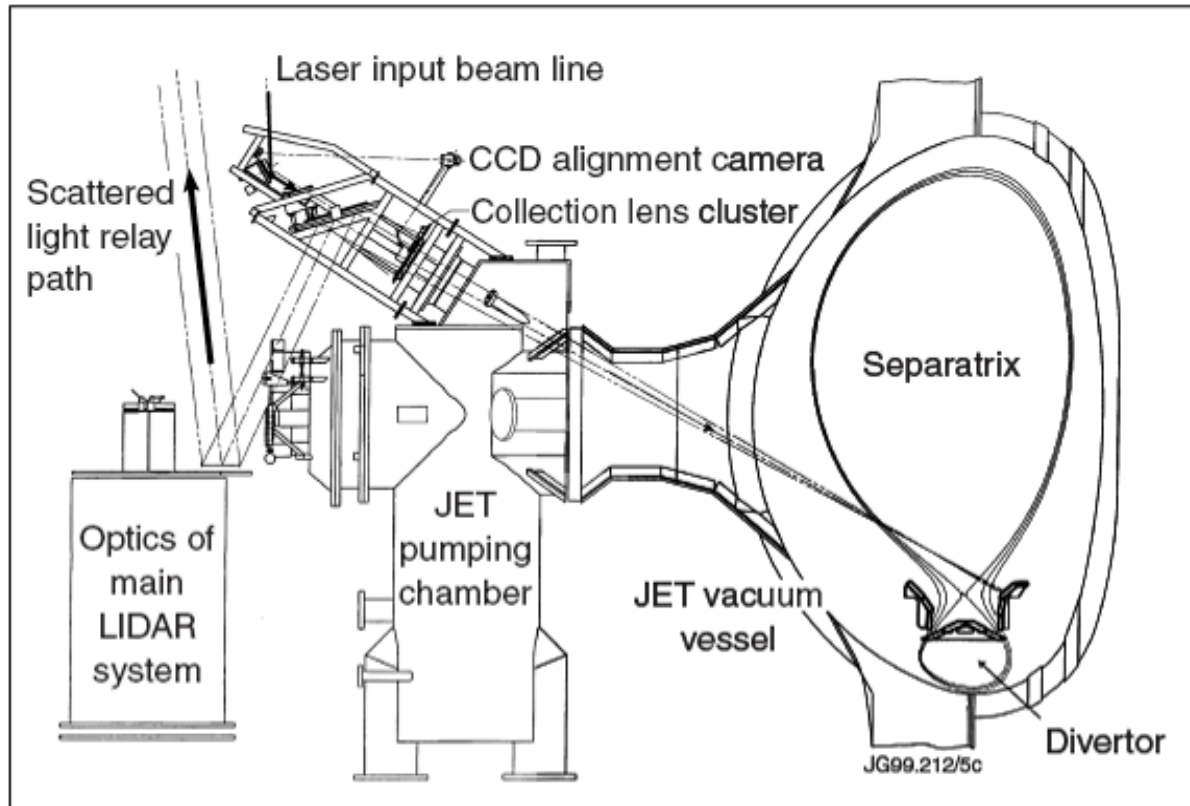
JET – the biggest European thermonuclear installation.

Type	Tokamak
Major radius	2.96 m
Minor radius	1.25–2.10 m
Plasma volume	100 m <sup>3</sup>
Magnetic field	3.45 T (toroidal)
Vacuum	10 <sup>-8</sup> Bar
Plasma	D/T
Operation date	1984–
Diagnostics: EDGE LIDAR	Thomson scattering

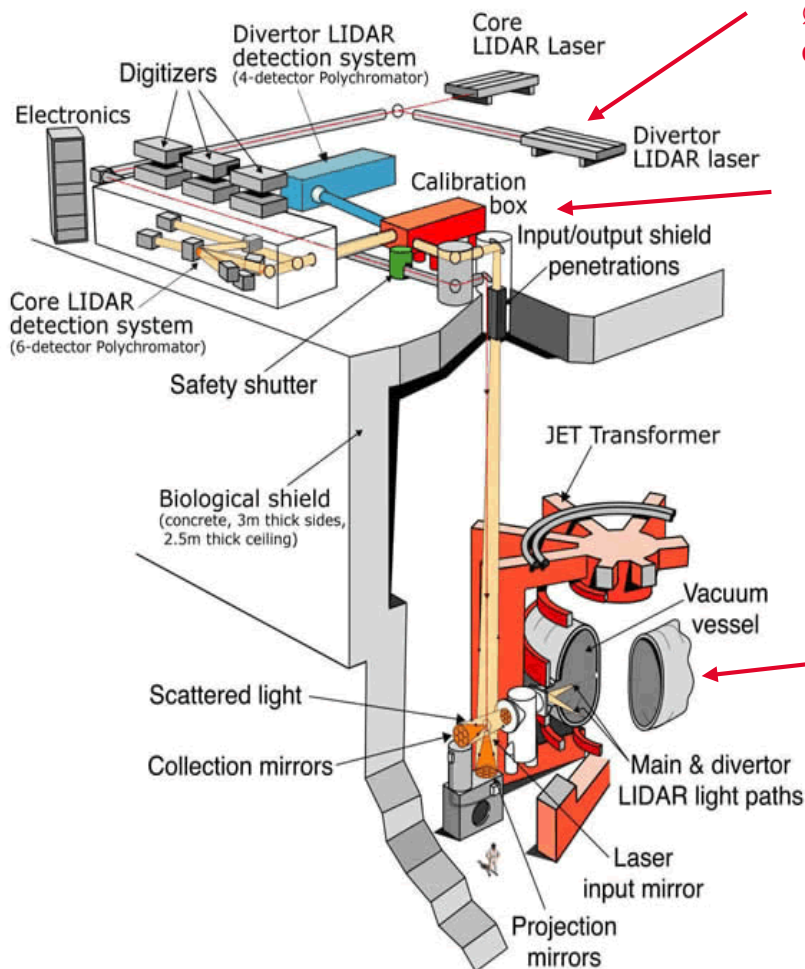




# General layout of EDGE LIDAR Thomson scattering system



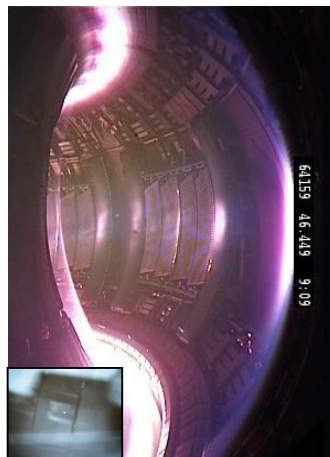
# LIBS in situ application on JET



**Ruby laser:** 690 nm, 3 J; 300 ps,  
 $\varnothing \approx 4$  mm, 80 GW/cm<sup>2</sup>,  
 one shot / 5 min.



**LIBS system:** plasma plume  $\varnothing \approx 20$  mm;  
 NA of the collection system  $\approx 1/40$ ;  $M \approx 1/12$ ;  
 ANDOR Shamrok SR-303i spectrometer,  
 f=300mm, 1200mm<sup>-1</sup>, NA = f/4; slit 200  $\mu$ m.  
 ICCD camera



**Target:** W-stripe with D/Be  
 and impurities deposit  
 (~10-100  $\mu$ m thickness)

- vacuum ( $10^{-8}$  Bar)
- distance - 5 m, with transportation - 7 m
- limited NA for light collection (125 mm on 5 m)
- target (vacuum chamber, non accessible)
- H/D/T (12 eV, thermal diffusion)
- Ruby laser (one shot / 5 min )
- limited experimental time (one week)

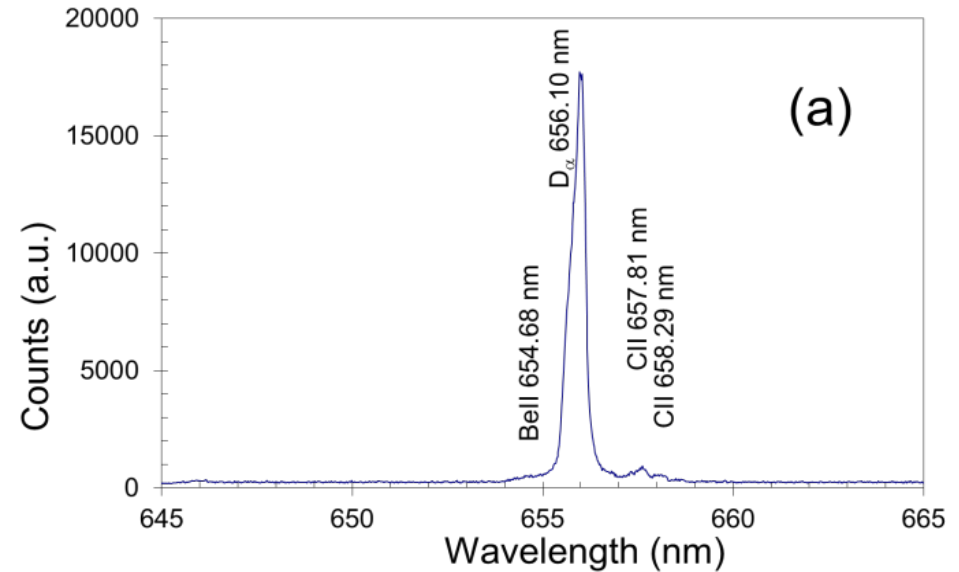
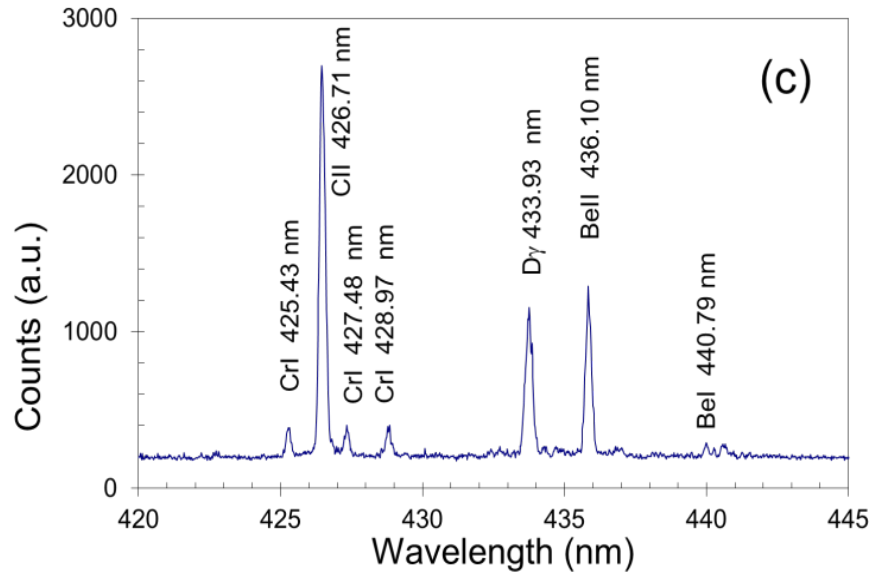
$$LIBS\ Signal(detected\ photons) \cong N_a \times \frac{g_i e^{-E_i/kT}}{u(T)} \times A_{ij} \times$$



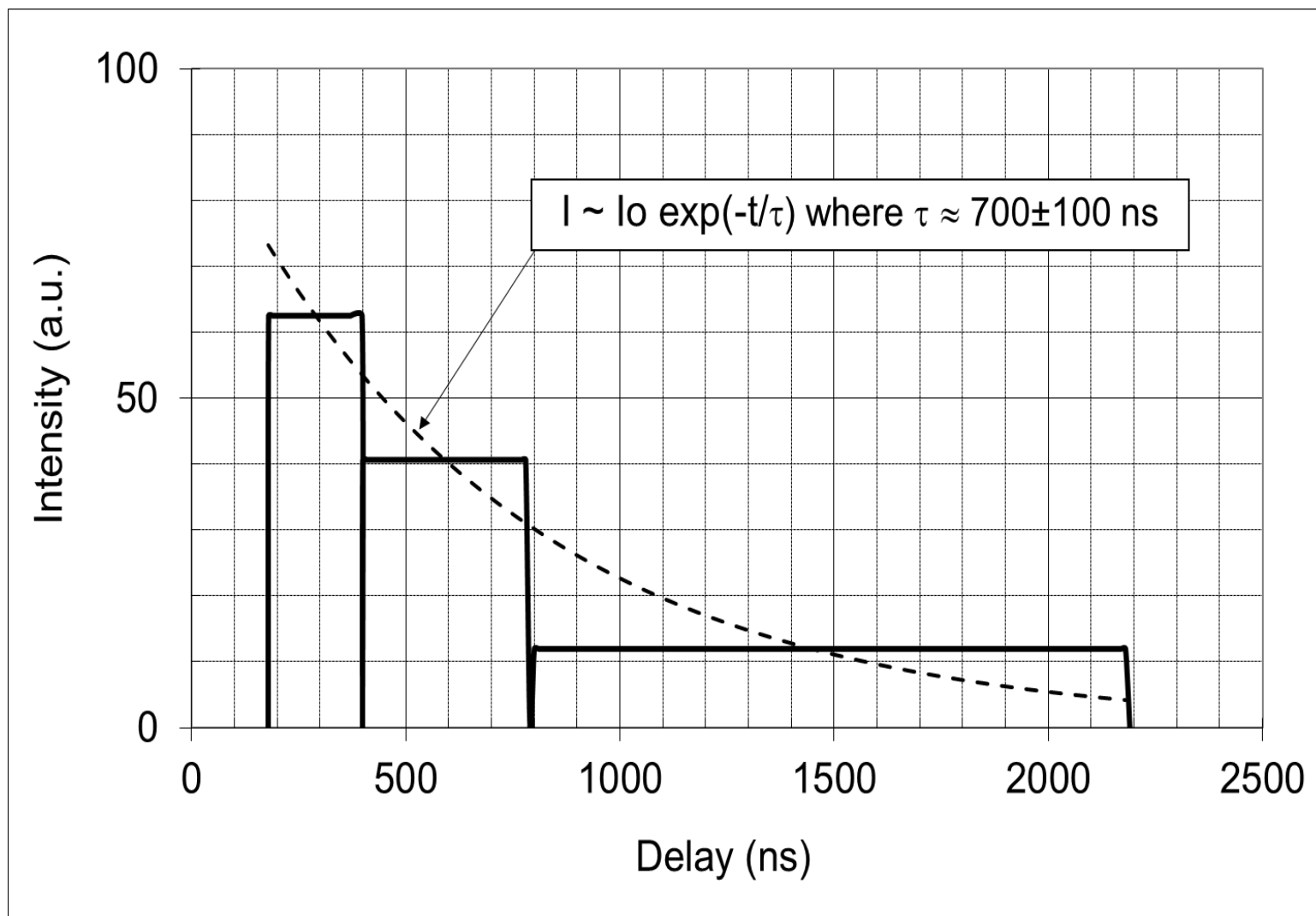


# LIBS spectra with analytical Deuterium lines.

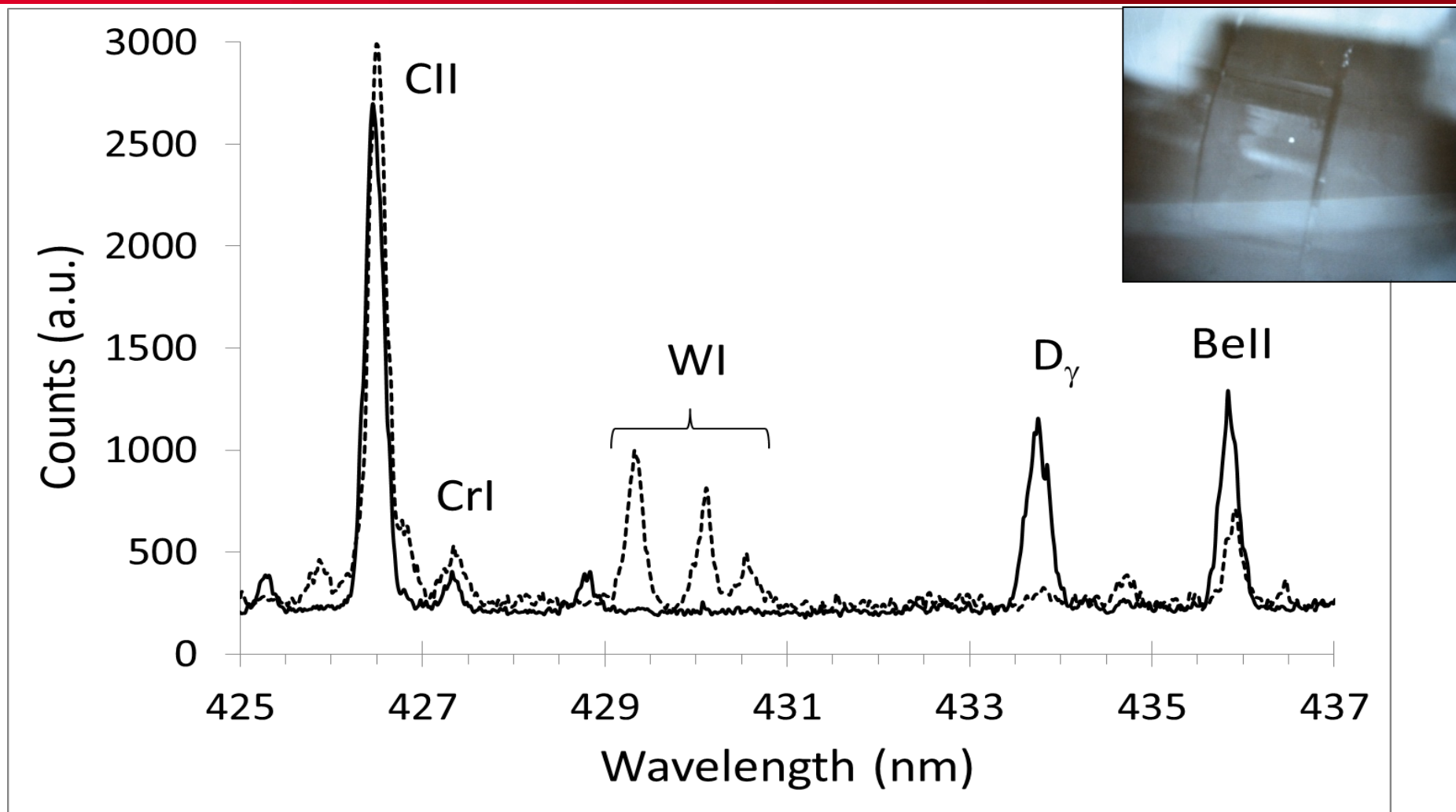
W-stripe zone with the deposited layer, vacuum, laser pulse energy  $\approx 3.0$  J, spectrometer slit width = 200  $\mu\text{m}$ , grating -1800  $\text{mm}^{-1}$ , ICCD camera delay = 180 ns, gate width = 2  $\mu\text{s}$ .



**Cr, C<sup>+</sup>, D $\gamma$ , Be<sup>+</sup>, D $\alpha$  spectral lines are observed**

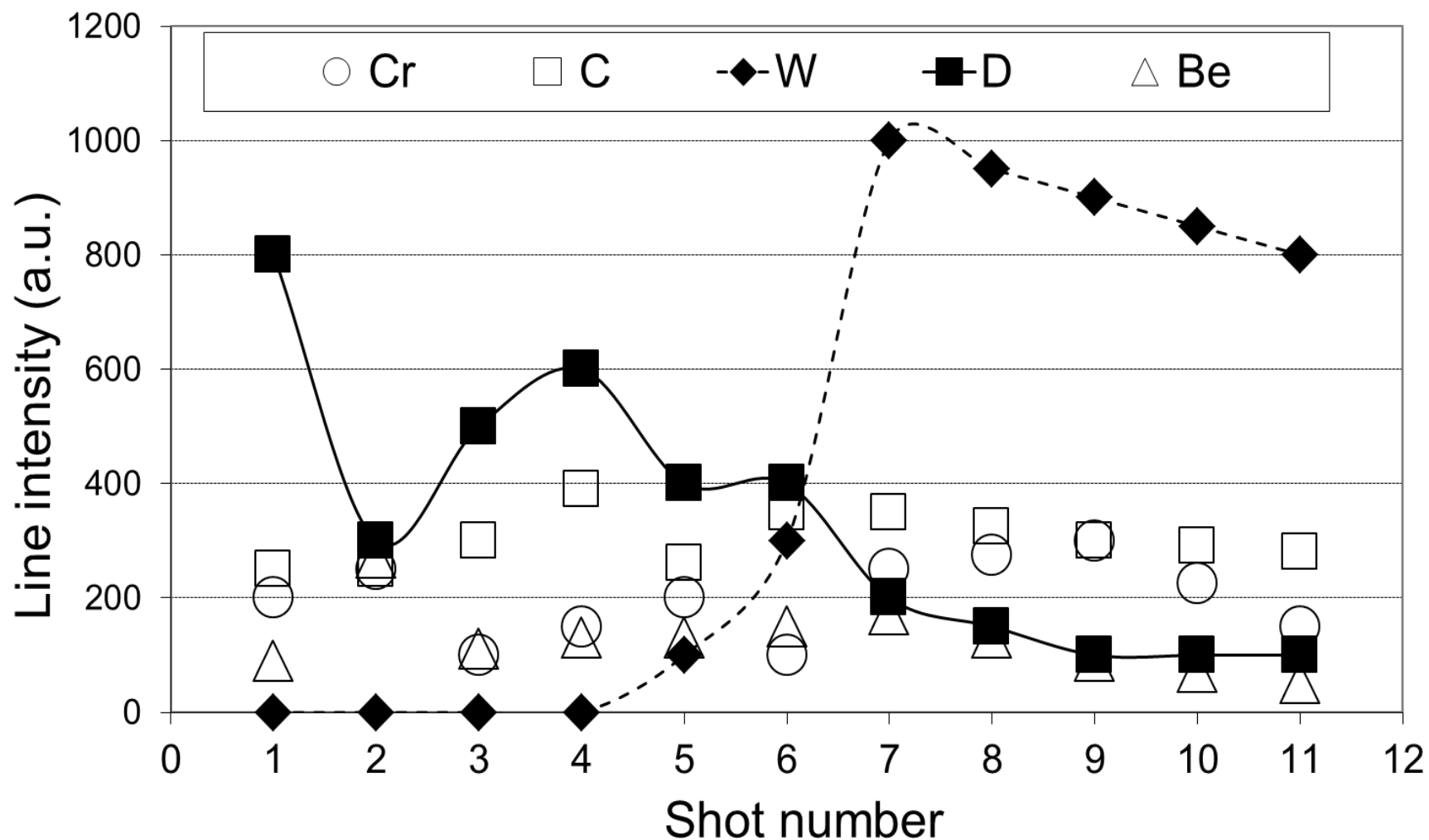


# LIBS spectra after the 1st and 11th laser shots on W-stripe zone with the deposited layer

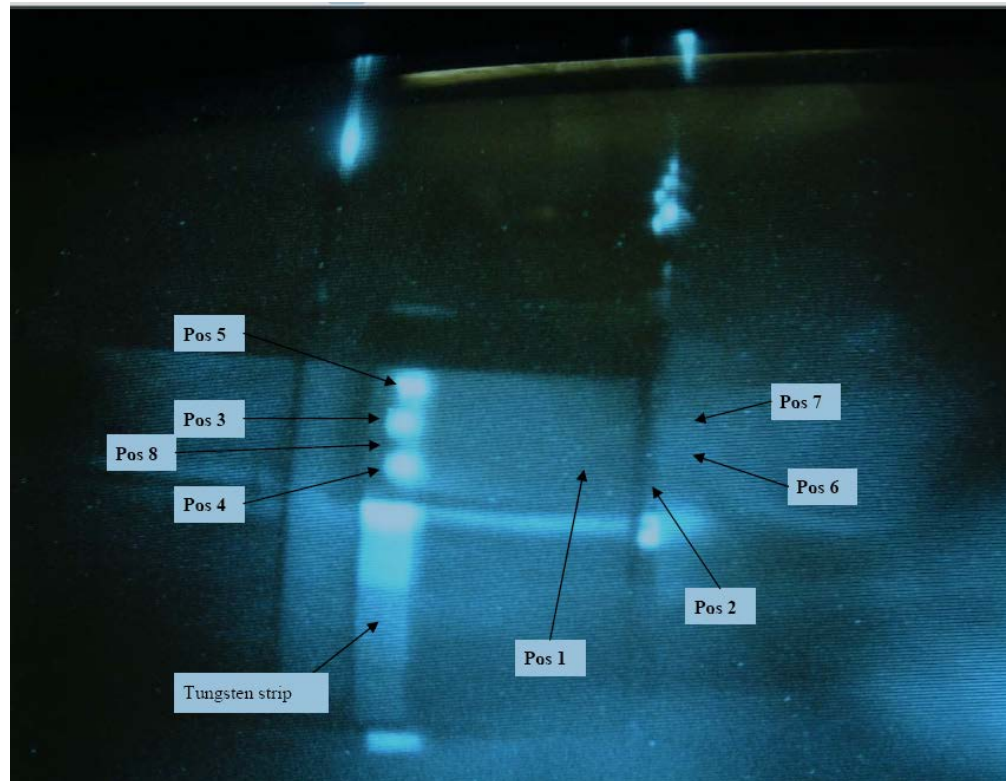


LIBS spectrum after the first (shot nb 46) and 10<sup>th</sup> laser shot (shot nb 56) on the W-stripe zone with the deposited layer. Laser pulse energy –  $\approx 3.0$  J, spectrometer slit width = 200  $\mu\text{m}$ , 1200  $\text{mm}^{-1}$ , ICCD camera delay = 180 ns, gate width = 2  $\mu\text{s}$ , vacuum.

# Shot to shot spectral lines intensity evolution (layer on W-stripe)



# The tiles observed after our experiments





Successful qualitative in situ LIBS application in JET (vacuum  $10^{-8}$  Bar,  $\approx 10$  m,  $D_{\alpha}$  /  $D_{\beta}$  /  $D_{\gamma}$  /  $Be^{+}$  /  $C^{+}$  /  $Cr$ );

Adequate understanding of the processes, problems and difficulties;

Possible improvements (fs/ps laser, collinear double pulse);

H/D/T isotope measurements (spectral resolution  $\geq 10000$ );

Further steps – quantitative LIBS with ITER-like samples, Tokamak integration, and in situ validation.