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Metallic surfaces decontamination by using LASER light

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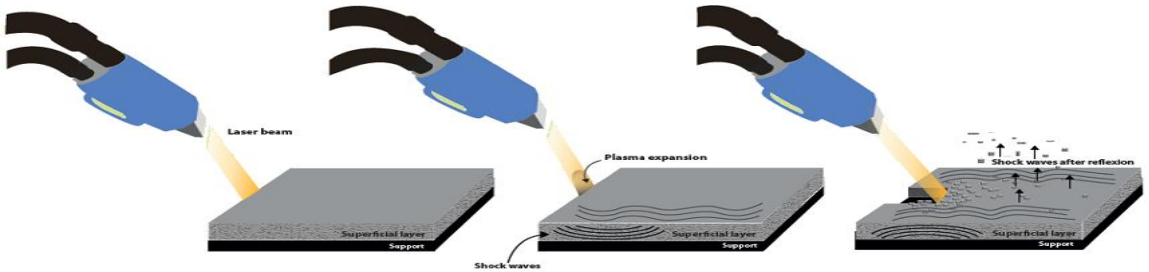
State of the art

- **First studies in 80s-90s**
- **Two different technologies:**
  - **Excimer type LASER (Gas-UV).**
  - **Solid-state type LASER (YAG or Fiber).**
- **Today: Predominance of solid-state technology:**
  - **Higher repetition rate (a few tens of kHz *vs* a few tens of Hz).**
  - **Higher optical fiber length (→ without power loss).**
- **The LASER decontamination in the literature:**
  - **A few papers and thesis.**
  - **Most of the time, 2.5 to 3.0 $J.cm^{-2}$ are required to achieve the decontamination.**

Overview of the LASER technology

- **The technology is based on the interaction between a LASER beam and the surface of the sample (oxide layer, paint…)**

- **Conjugation of 2 concomitant mechanisms:**
  - **Thermal effect**: the rapid increase of the surface temperature, due to the interaction between the LASER beam and the metallic surface, will result in the formation of plasma.
  - **Mechanical effect:** the plasma expansion will generate some mechanical waves which will propagate into the surface to crack and cause the ejection of contaminated particles.



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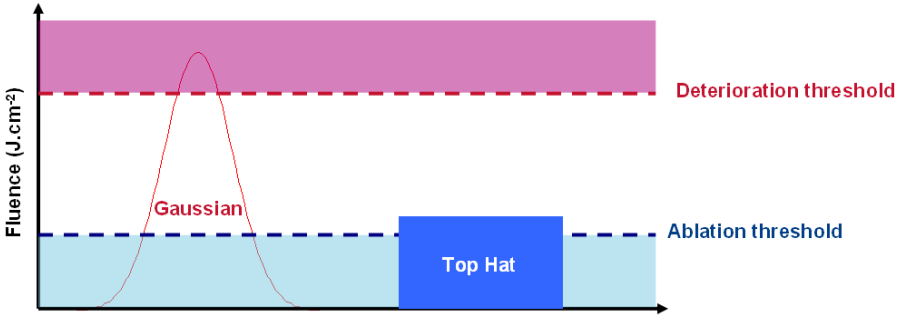
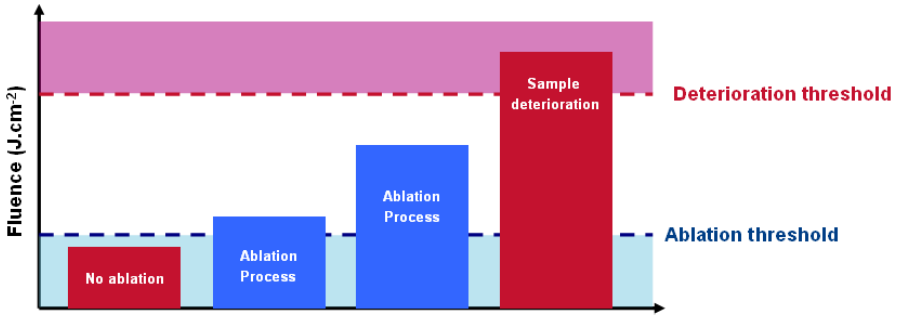
Overview of the LASER technology

Main parameters we have to focus on:

1. **LASER beam profile:** 2 possibilities
   - **Gausian → non homogenous distribution**
   - **Top Hat → homogeneous distribution**



2. **Fluence:** Energy per surface unit
   - **3 possibilities**
     - ❖ No ablation
     - ❖ Ablation
     - ❖ Deterioration



3. **Pulse duration:** Impact the depth of heating and thus, the efficiency of the process (→ from a ten to a hundred of nanoseconds)

4. **Power:** If the ablation threshold is reached → increase of power induced an increase of speed rate

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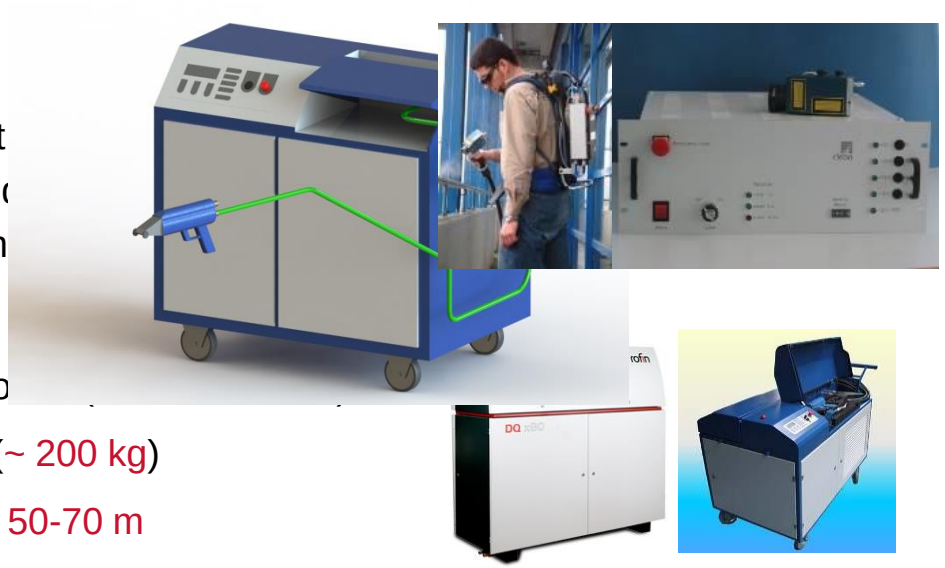
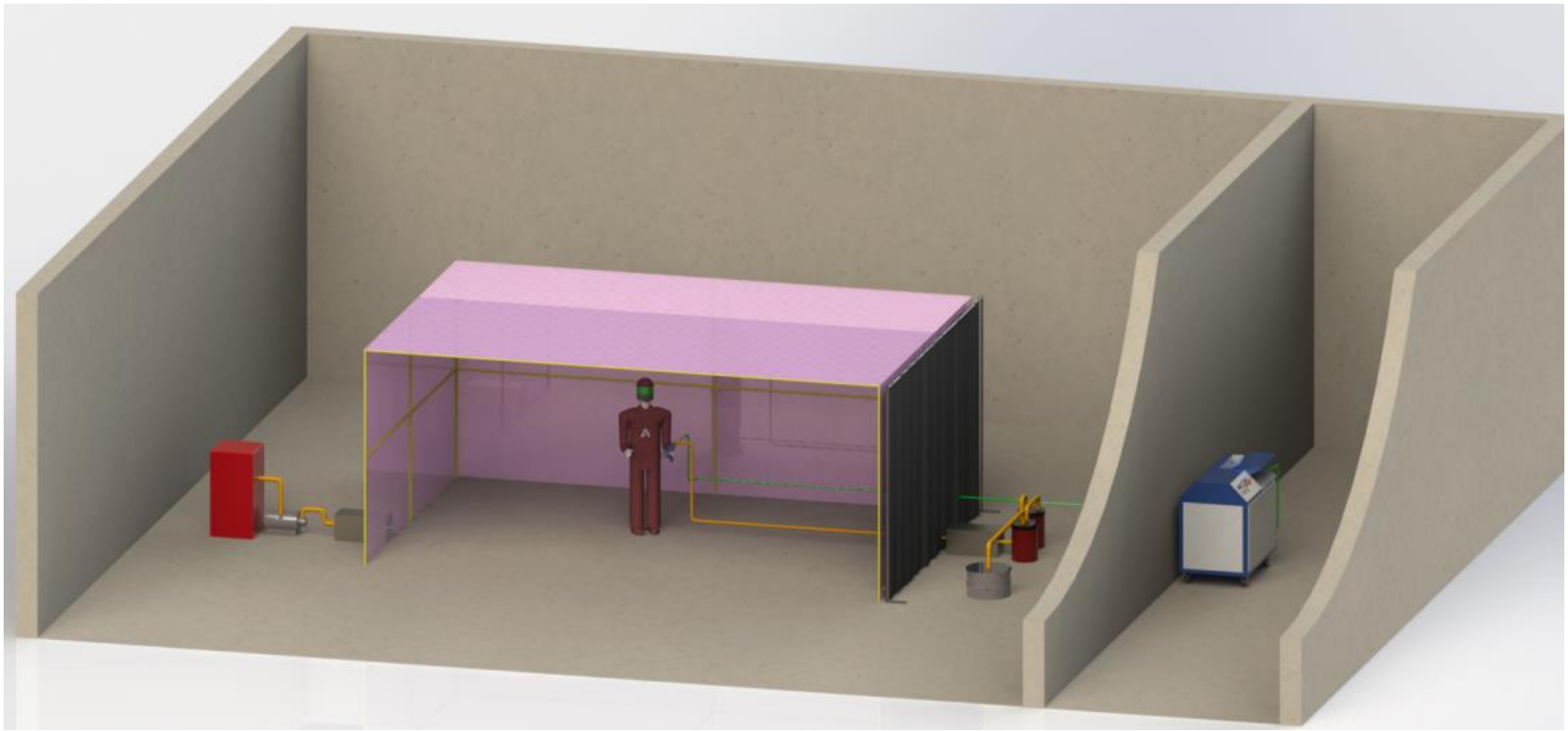
Implementation of the technology

- **The LASER**
  - **3 different units:**
    - The LASER skid
    - The optical fiber
    - The gun
  - **Fiber LASER type**
    - Low to mid power
    - Compact and light
    - Optical fiber limite
    - Air cooling system
  - **YAG LASER**
    - Medium to high po
    - Bulky equipment (~ 200 kg)
    - Optical fiber up to 50-70 m
    - Air-water cooling system



Implementation of the technology

- **"Standard " implementation in hot cell**

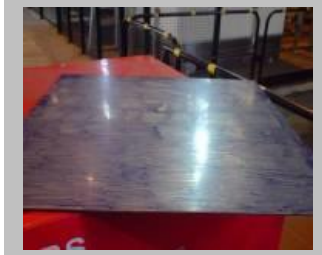


Validation of the technology

In non nuclear conditions

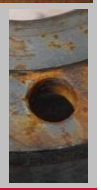
Whiteboard ink

- Simulant for the non fixed contamination
- Speed rate > 11 $m^2.h^{-1}$




- Highly efficient

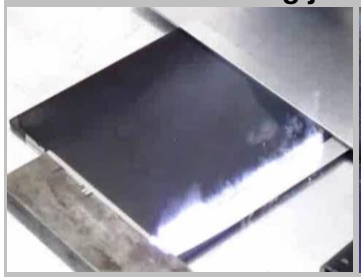
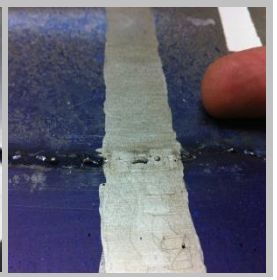


Ferric oxide (Rust)

Coppersmith ink

- Simulant for the fixed contamination
- Speed rate > 8 $m^2.h^{-1}$
- Works on welding joints

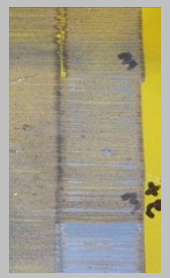
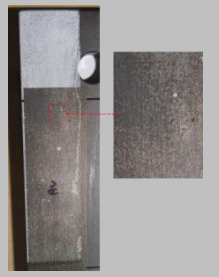
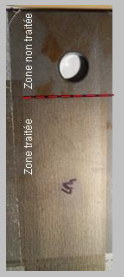



- Works with a thin layer of grease
- Speed rate ~ 4 $m^2.h^{-1}$

Grease

Coatings (paints, resins)

- Speed rate and efficiency are strongly dependent on the chemical composition of the coating

Paint (with lead) ***Aquavigor*** ***LP_4***

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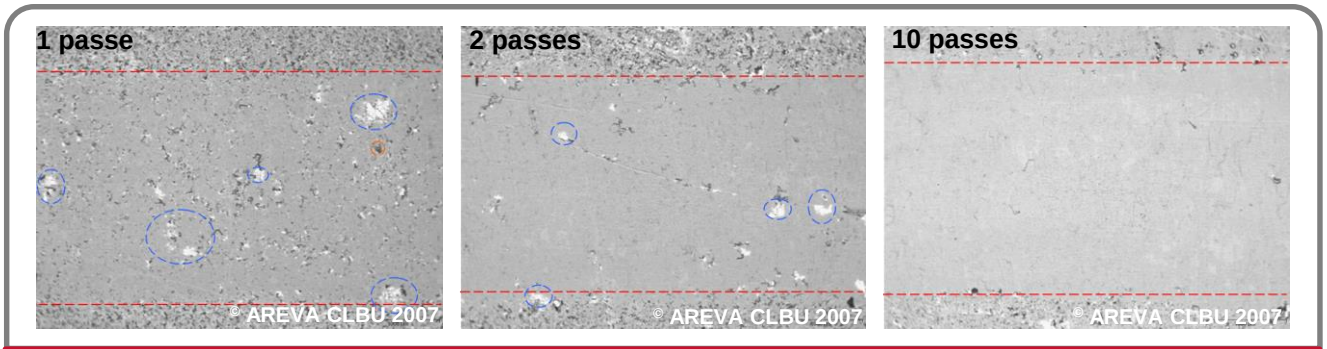
Validation of the technology

In non nuclear conditions

Surface analysis

Scanning Electron Microscopy

- Stable radionuclides have been used (Cs_2CO_3, $SrCO_3$, RuO_2…)



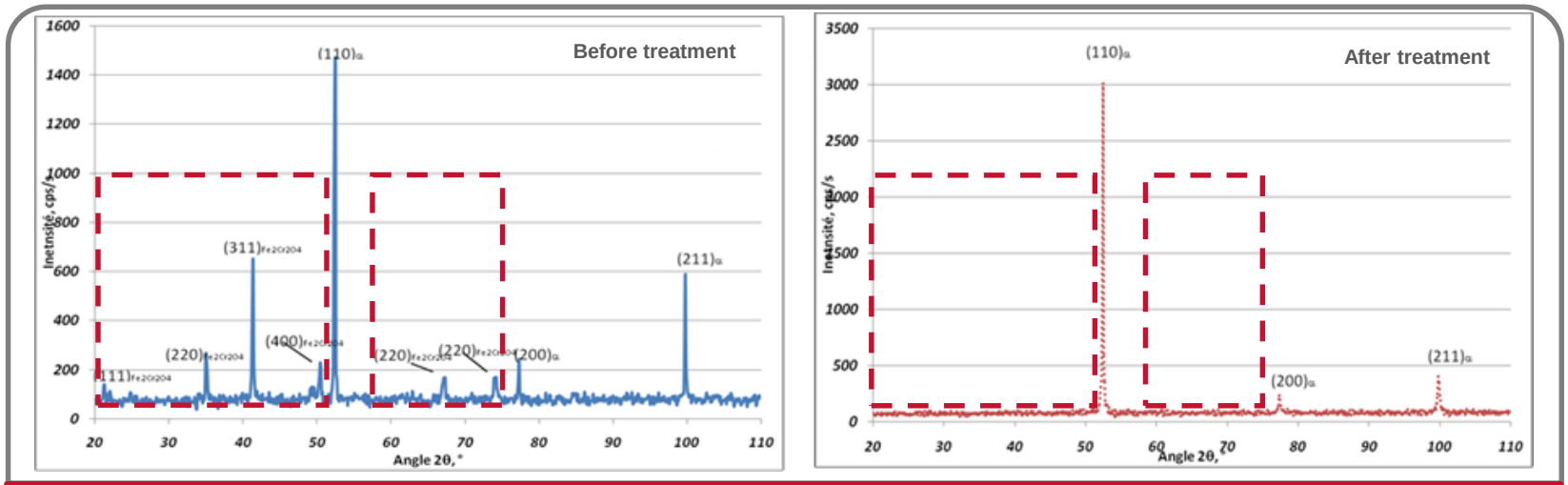
Proven effectiveness on radionuclides removal

Validation of the technology

In non nuclear conditions

Surface analysis

X-Ray scattering analysis



Ferric oxide

Disappearance of the signals related to chromite ($FeCr_2O_4$)

Proven effectiveness on rust removal

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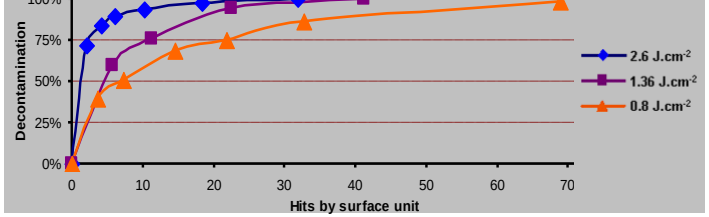
Validation of the technology

In nuclear conditions

- **1st trials on storage tank samples**
  - Thick oxide layer
  - Initial contamination ~ 1000 cps

Before



After

- **2nd trials on metallic samples stored inside a pool**
  - Greasy contamination
  - Initial radiological data
    - 400 cps (α)
    - 7000 cps (βγ)
  - Final radiological data
    - 4 cps (α) → DF100
    - 140 cps (βγ) → DF 50

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Validation of the technology

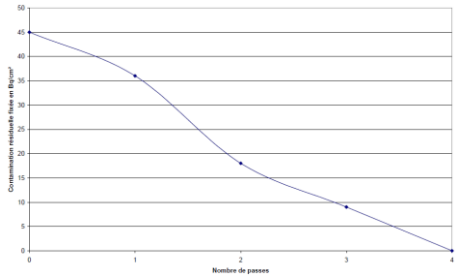
In nuclear conditions

3rd trials on lead ingots

- The ingots came from the CEA Marcoule
- Fixed contamination less than 100 bq.cm^{-2}

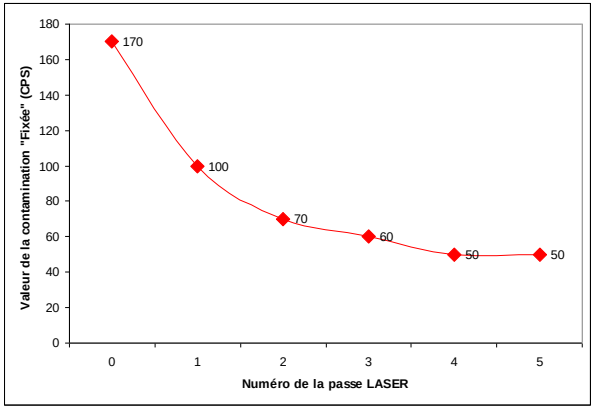
Before

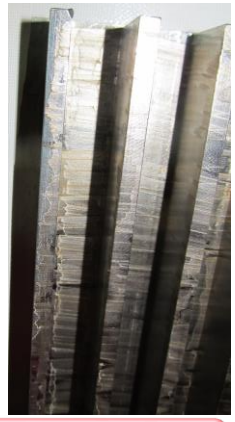
After



4th trials on cask mockup

- Initial radiological data
  - 170 cps (βγ)
- Final radiological data
  - 50 cps (βγ) → 1.5 Bq.cm^{-2}





The French transportation standards can be reached by using the LASER technology

Conclusion

- **The LASER technology appears to be one of the best tool**
  - **Dry process, no use of chemicals, no secondary liquid waste**
  - **Works on samples with different geometries and orientations**
  - **Interesting speed rates especially on rust**
  - **Fully remote controlled**
  - **No direct contact between worker and surface**

- **Complete radiological protection of the equipment**
  - **Patented protection of the gun (FR2980384, JP 2012-031480, EP121852925)**

Thank you for your attention