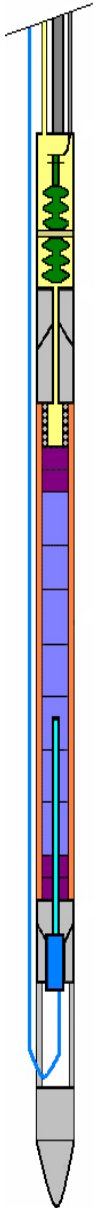
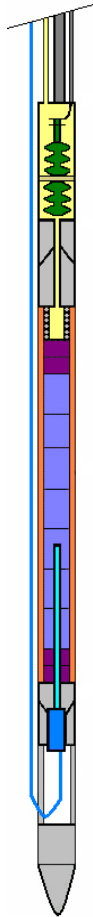


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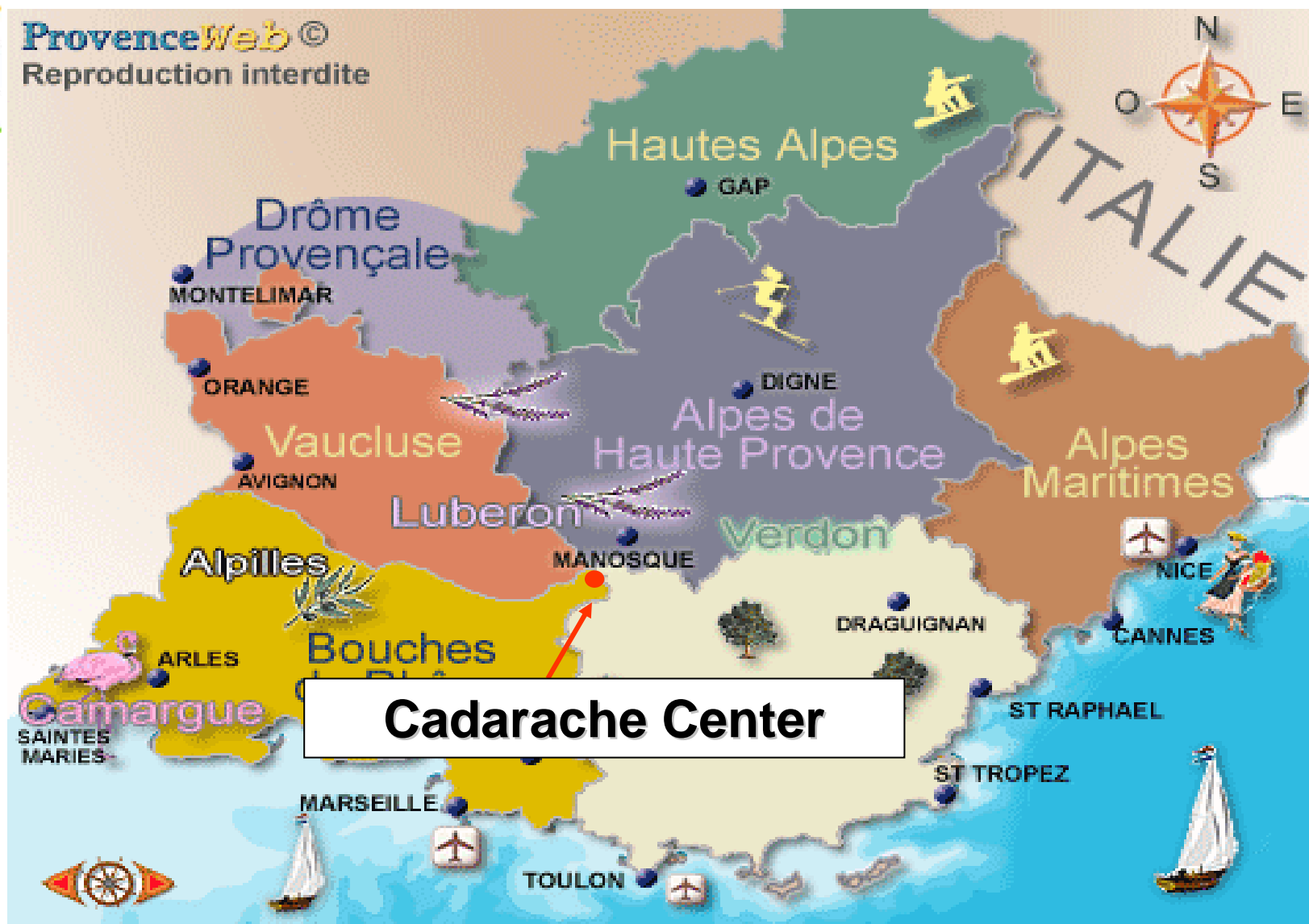
Fuel Rod Instrumentation Techniques Implemented in LECA facility – Cadarache Center Development of Advanced Instrumentation Techniques

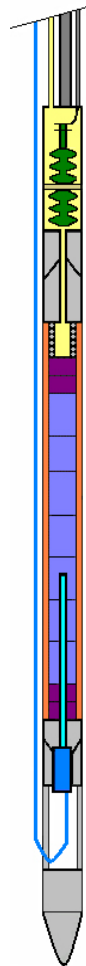
Francis BERDOULA



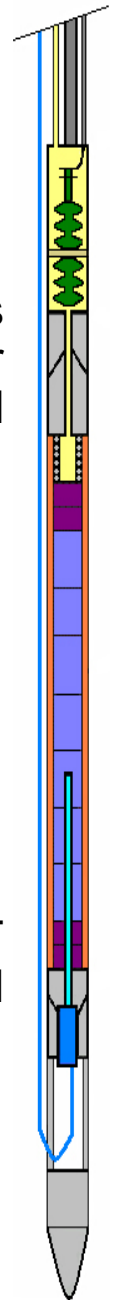


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- ❖ **Introduction** : LECA Facility in Cadarache center
- ❖ **Objectives** : Nuclear Fuel for power reactors capabilities evaluation is strongly based on the intimate knowledge of its behaviour under irradiation. This knowledge can be acquired from refabricated and instrumented fuel rods irradiated at different levels in commercial reactors.
- ❖ An instrumentation bench named “CORALIE”:
 - ◆ *Cutting,*
 - ◆ *Laser welding,*
 - ◆ *Tig welding,*
 - ◆ *Make a center hole,*
 - ◆ *All remote handling operations on fuel rod and cladding.*
- ❖ Fabrication steps for a standard fuel rod “Fabrice rod”,
- ❖ One base-irradiated fuel segment for several cycles in a French EDF commercial reactor was re-fabricated and instrumented with both a fuel centre-line thermocouple and an advanced pressure transducer.
- ❖ **Further projects**:
 - ❖ *Two innovative technologies like fuel stack outer temperature sensor and deep hard drilling technique are in progress in LECA Facility.*
- ❖ Conclusion

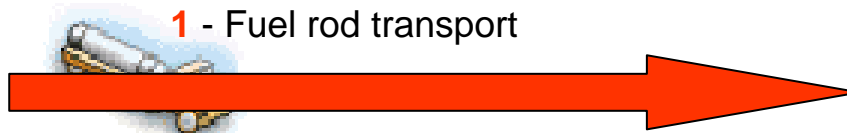
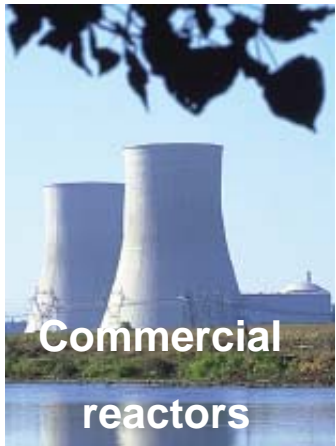


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Fuel Rod Re-Fabrication Cycle

LECA Facility – CEA Cadarache
 Instrumented Fuel rod Re-Fabrication



Fuel rod transport



2 - Re-fabrication
 in Cadarache center

Dual-
 Fuel rod
 Re-fabrication
 Messengers



3 - Irradiation in Osiris reactor



Irradiation of Instrumented fuel rod
 in OSIRIS Reactor

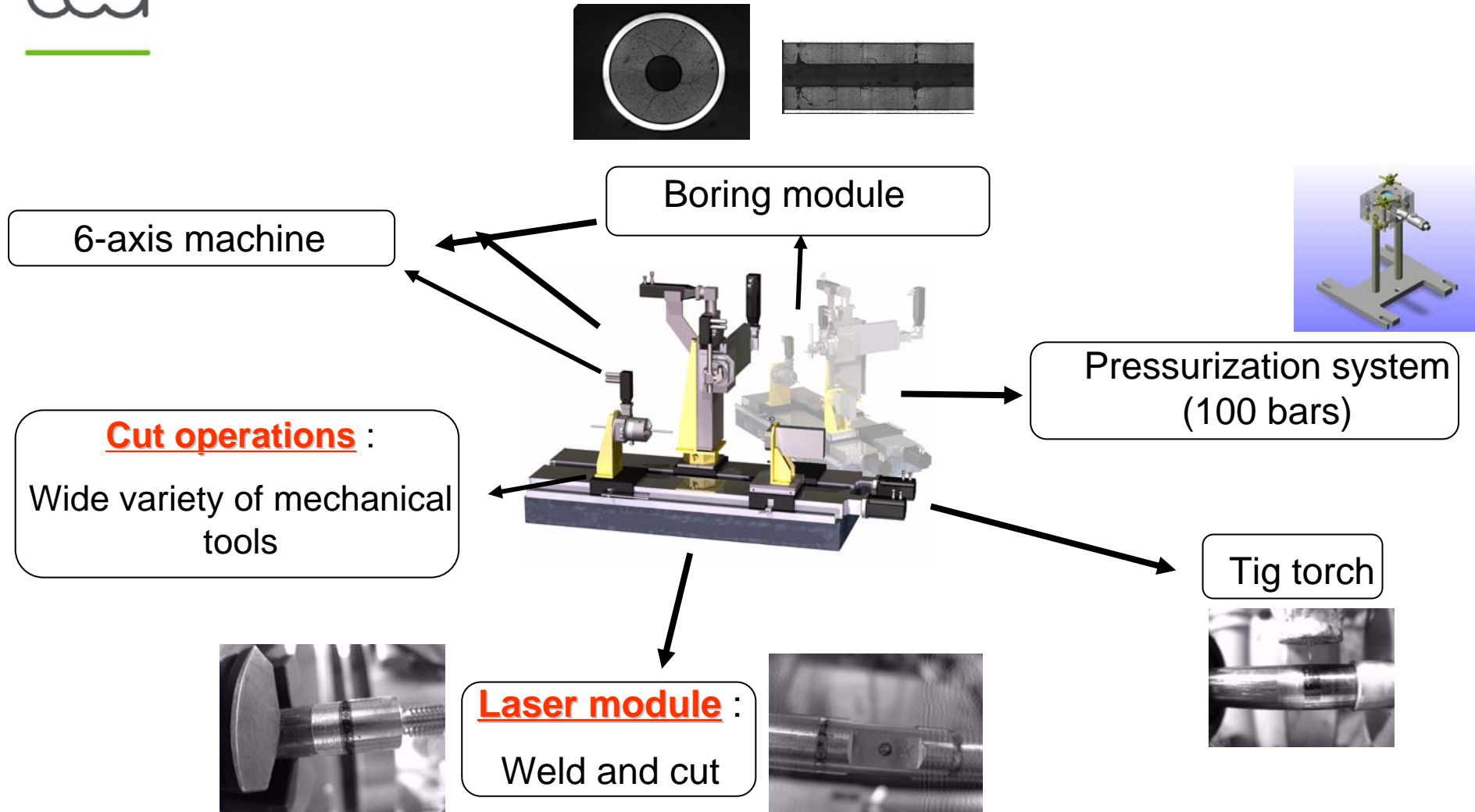


Fuel rod transport





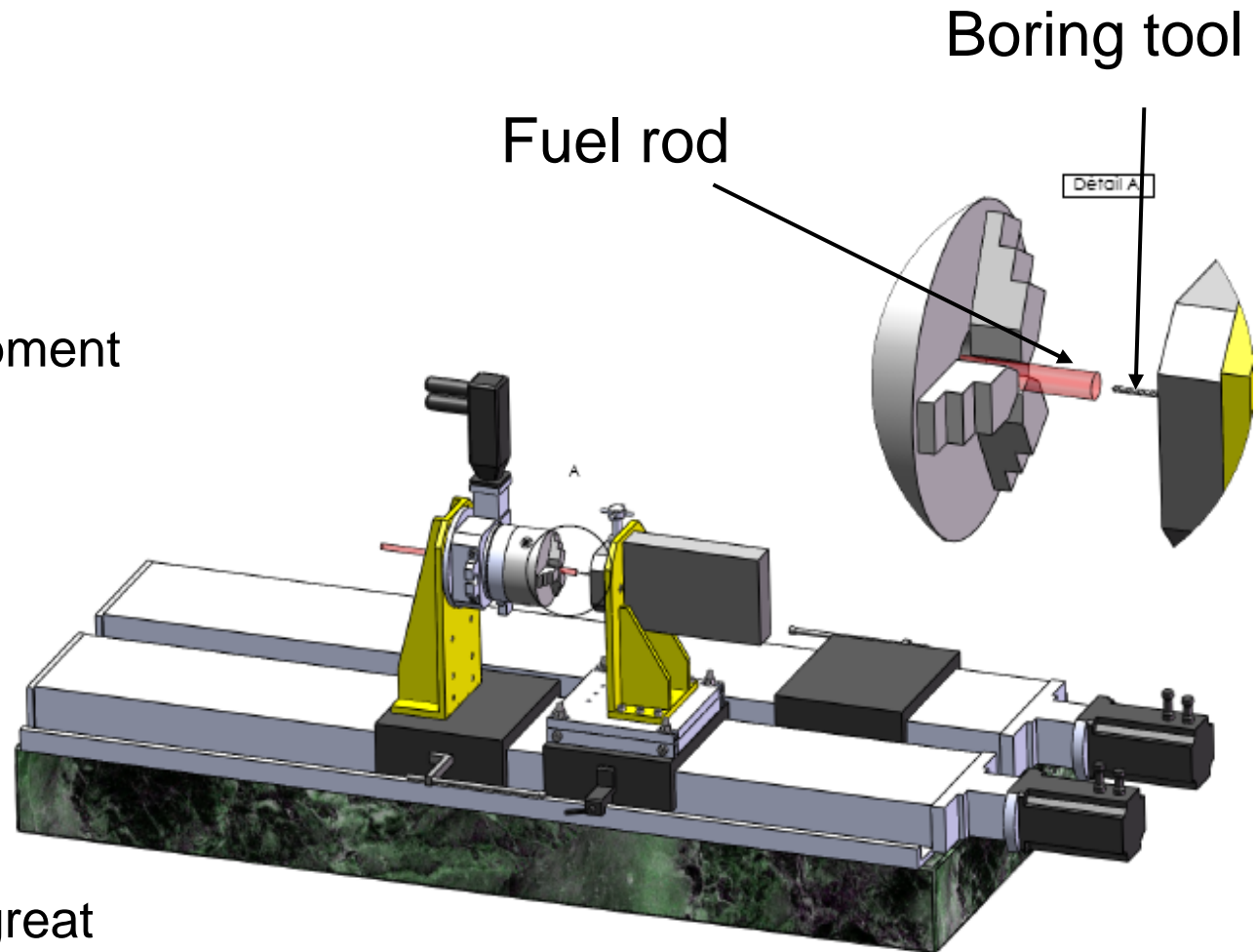
Multi-tasks Instrumentation bench named « CORALIE »





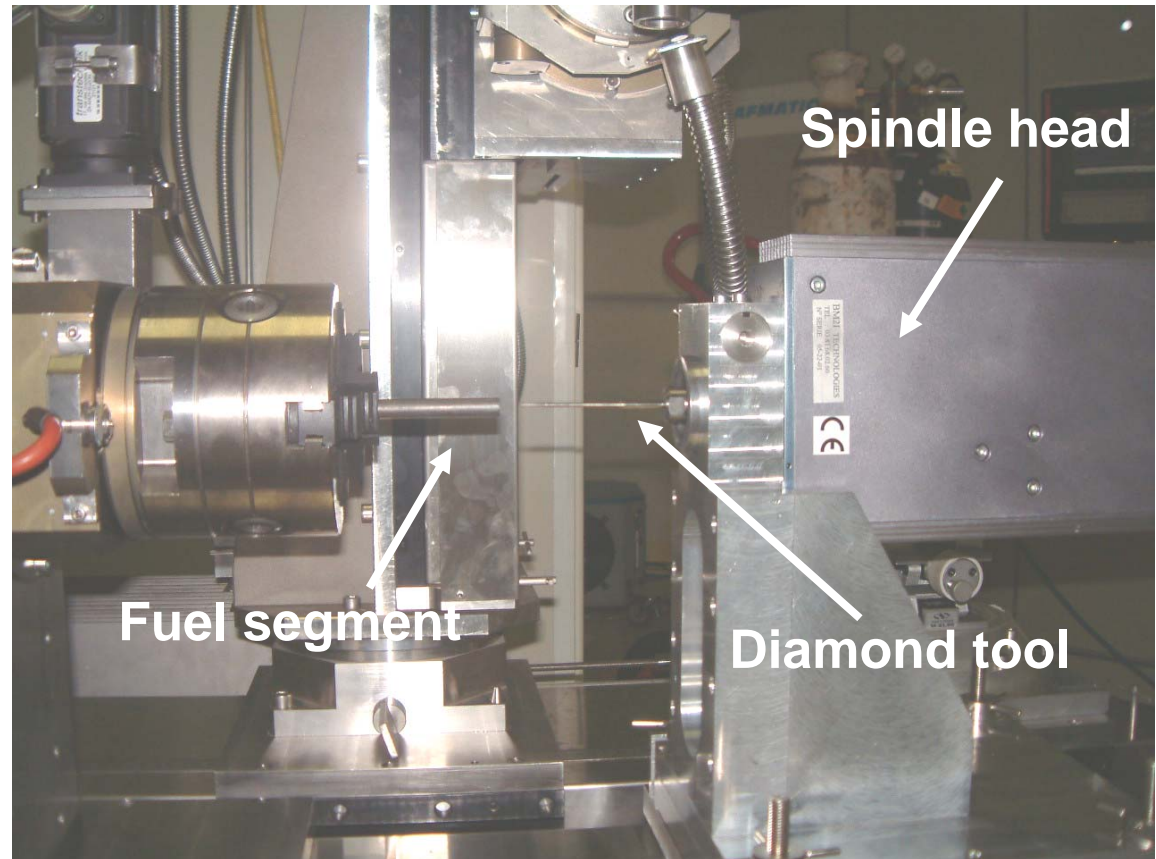
Hard drilling technique :

- specially adapted equipment
- Innovative tool,
- Intricate operations
- Adapted mechanical process,
- The knowledge and great skill of the operators





- Boring module on Coralie Bench,
- Diamond drills are used to make the center hole,
- Below 2 irradiation cycles fuel, this technique can't be applied,
- Drill sets,
- Cooling with a flow of argon gas,
- Vacuum fuel chips.

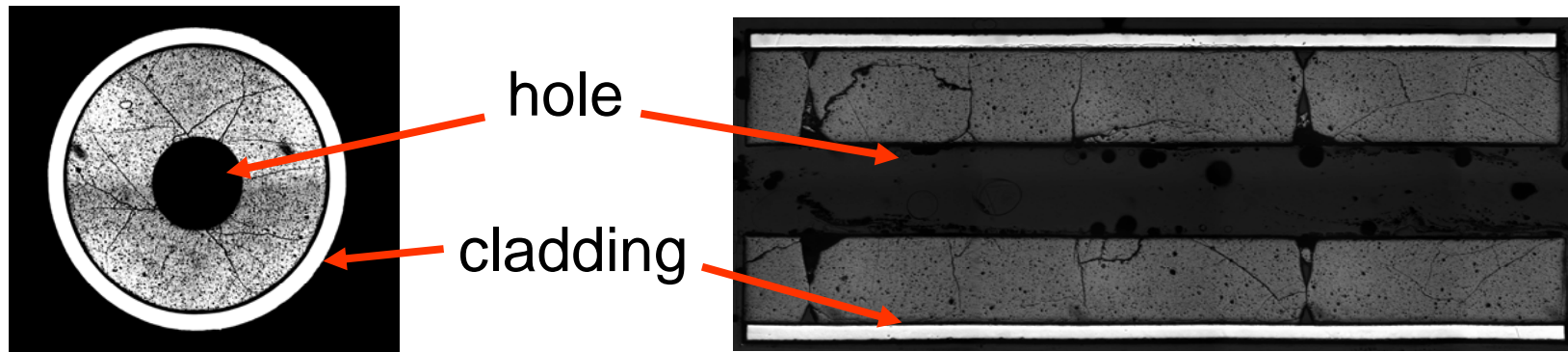


Boring module



❖ Thus, dry drilling process is a convenient technique :

Absence of significant microstructure damage



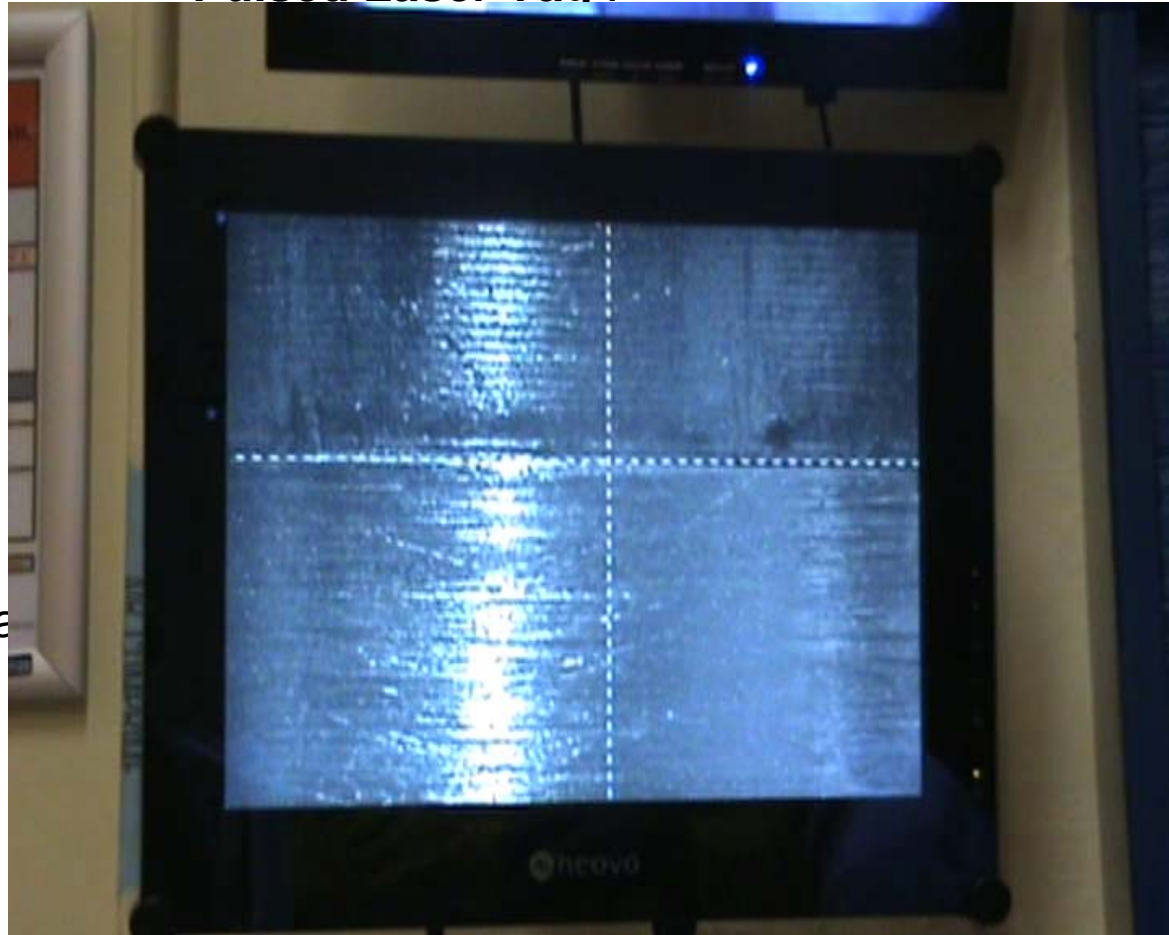
- ❖ Possibility to make a center hole on fuel rods over 2 cycles (50 mm in depth, 2,5 mm in diameter)
- ❖ Concentricity of the hole better than 0.1 mm with the pellets' axis
- ❖ No cooling liquid inside hot cells, only cooling argon gas,
- ❖ Easier implementation in hot cells



Pulsed Laser Yag :

The fuel rod turns
during the laser
beam weld the 2
pieces : end caps
and cladding

-Sea



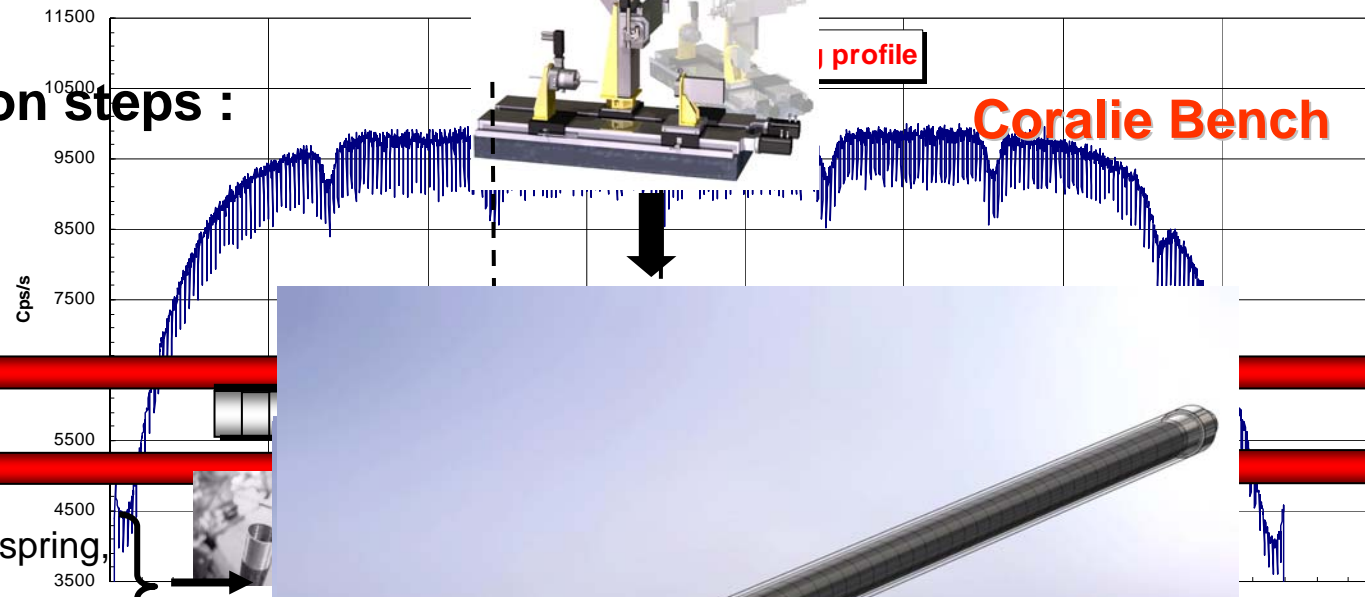
-Small Heat Affected zone 0,6 mm



1 - Fuel rod reception : γ - scanning profile
 Objectives : locate flat section

Re-fabrication steps :

- Mill fuel pellets,
- Prepare joint face,
- Introduce spacers, spring,
- Welding end caps,
- The rod is sealed by welding a hole closed,
- The soundness of welded rods was checked by He leak test and radiography examination



Coralie Bench

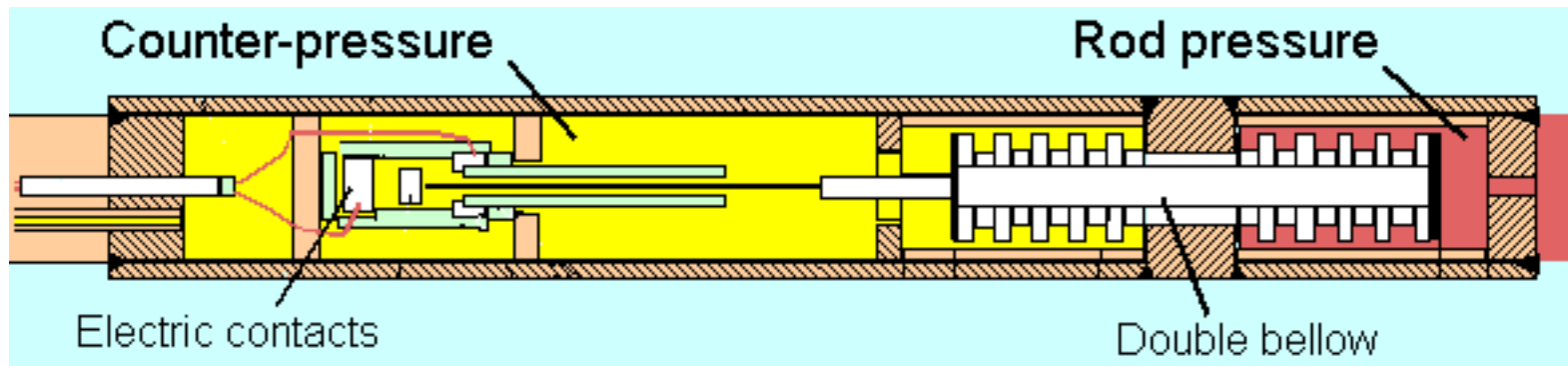
Laser Yag

glass

Welded and sealed hole



- For the introduction of the thermocouple, the irradiated fuel segment was centre drilled using a drilling process without cryogenic cooling.
- The end of the thermocouple was positioned in the middle of the third pellet.
- Tungsten / Rhenium alloys thermocouples are used to measure fuel centre-line temperature.



- Designed to be set up on a pre-irradiated fuel rod
- 2 gas cavities, separated by a double bellow.
- A large pressure range from 0 to 150 bars with accuracy of ± 0.5 bars



100 mm length hole

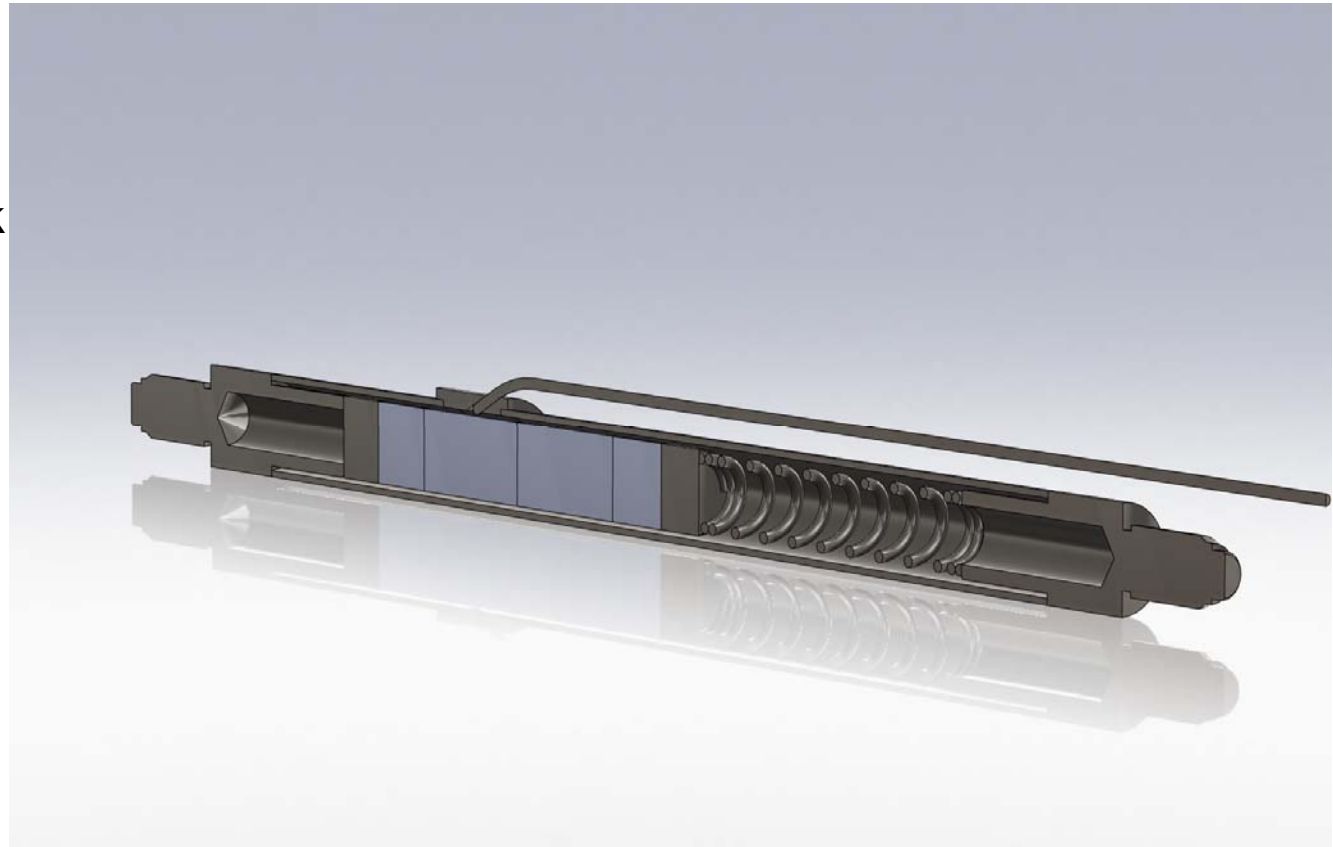
- Designing optimal drill geometry and for improving the drilling process,
- The tool material and geometry and drilling process parameters, including cutting speed, feed, and gas flow,
- A deep-hole drilling process to bore holes to 100 mm depth,
- According to the different requests, integrate the technique in hot cells.



- Integrate a thermocouple to measure the temperature outer fuel stick

Operations :

- Cut out a piece of cladding
- Weld below the piece a thermocouple
- Seal and weld a zircaloy cover





- The latest fuel rod instrumentation techniques implemented in CEA Hot Laboratory have been illustrated by the REMORA project experiments:
- Fuel rod thermocouple for temperature measurement without cryogenic cooling drawbacks for 2 cycles irradiated fuel rods and higher Burn-up
- Fuel internal pressure sensor using the technology of the counter pressure principle for accurate online pressure measurements
- The CORALIE integrated equipment allows :
 - drilling of the fuel pellet stack with a maximum geometric accuracy,
 - welding and sealing of fuel rod end cap using laser technique,
 - reduction of fuel rod cladding heat affected zone,
- The improvements introduced in the processing of refabricated and instrumented irradiated fuel rod samples are expected to achieve better understanding of fuel behavior,
- Innovative instrumentation techniques are conducting in a mock-up.

