

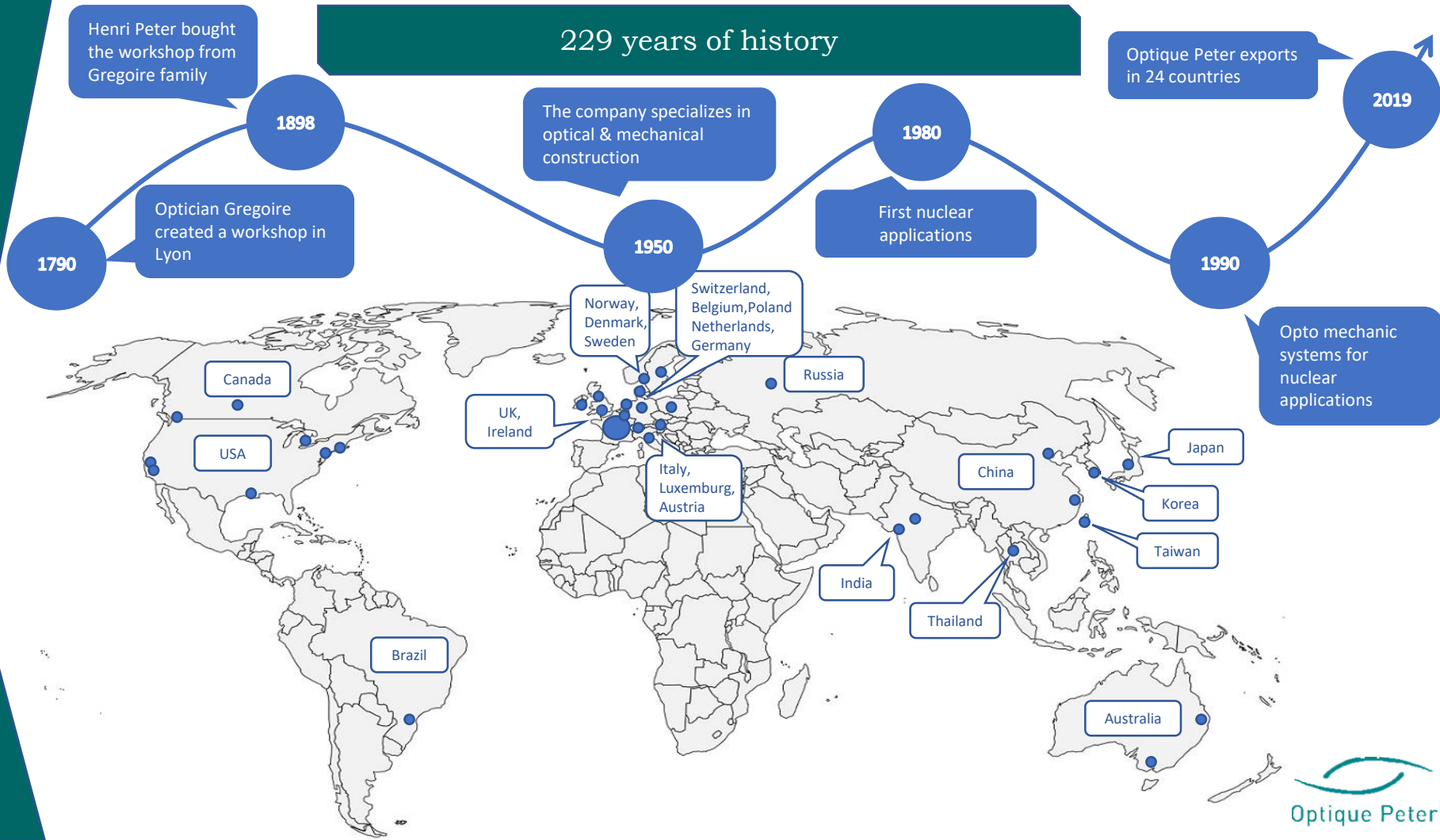
# Design an operation of optical equipment dedicated to Post Irradiation Examination (PIE) in Hot Laboratories



Xavier Rochet

HOTLAB 2019 - September 8th – 12th

## 229 years of history



## 39 Years of experience in Hot labs Equipment



**First radiation resistant camera  
In 1980**



**First hot cell microscope  
In 1993**



**First hot cell Raman  
microscope  
in 2003**

## REFERENCES FOR HOT LAB INSTRUMENTS

**70 Hot lab instruments delivered to 14 research institutes**  
**80 instruments delivered to 18 nuclear power plants**



# Design an operation of optical equipment dedicated to Post Irradiation Examination (PIE) in Hot Laboratories

## GLOVE BOX combined Microscope - Microhardness tester



Configuration with camera inside the glove box



Integrated microhardness tester  
0,1 N to 1 N load  
Vickers or Knoop indenter

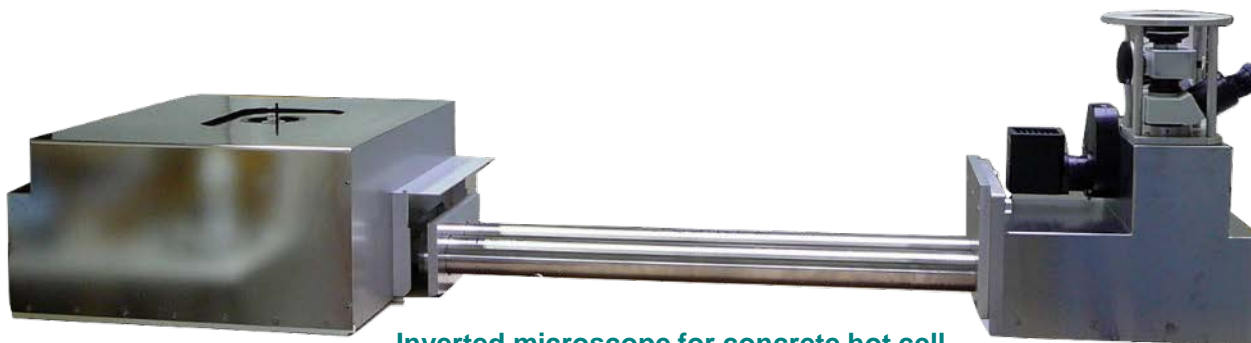


Airtight  
Optical  
path

Configuration with  
Trinocular head and camera located  
outside of the glove box

# Design an operation of optical equipment dedicated to Post Irradiation Examination (PIE) in Hot Laboratories

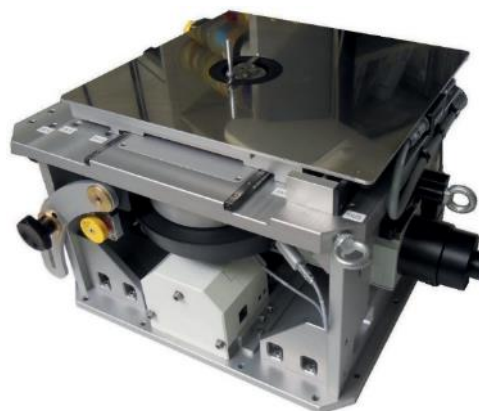
## HOT CELL combined Microscope - Microhardness tester



Inverted microscope for concrete hot cell



Inverted microscope  
For steel hot cell with Alpha box



Inverted video microscope  
(with shielded camera)  
For Lead hot cell



Control cabinet



# HOT CELL INVERTED MICROSCOPES



## Inverted Hot cell material microscope for concrete hot cell

- Light and image paths adapted to the cell dimensions
- Specific design for each cell type & wall thickness : Concrete, Lead, Steel
- Trinocular head, video ports
- All functions Motorized
- Observation: Bright Field, Dark Field, Polarization, DIC...
- Motorized Field and aperture iris
- Motorized 8 positions nosepiece:
- Micro hardness system, control unit outside the cell
- 3 axis X Y Theta stage
- Up to 100 mm diameter specimens
- Up to 100 x 200 mm travel with parking position for protection against radiations
- 360° rotatable motorized specimen support
- Halogen or Led lamp outside the hot cell
- PC control with image analysis / manual control



# HOT CELL INVERTED MICROSCOPES



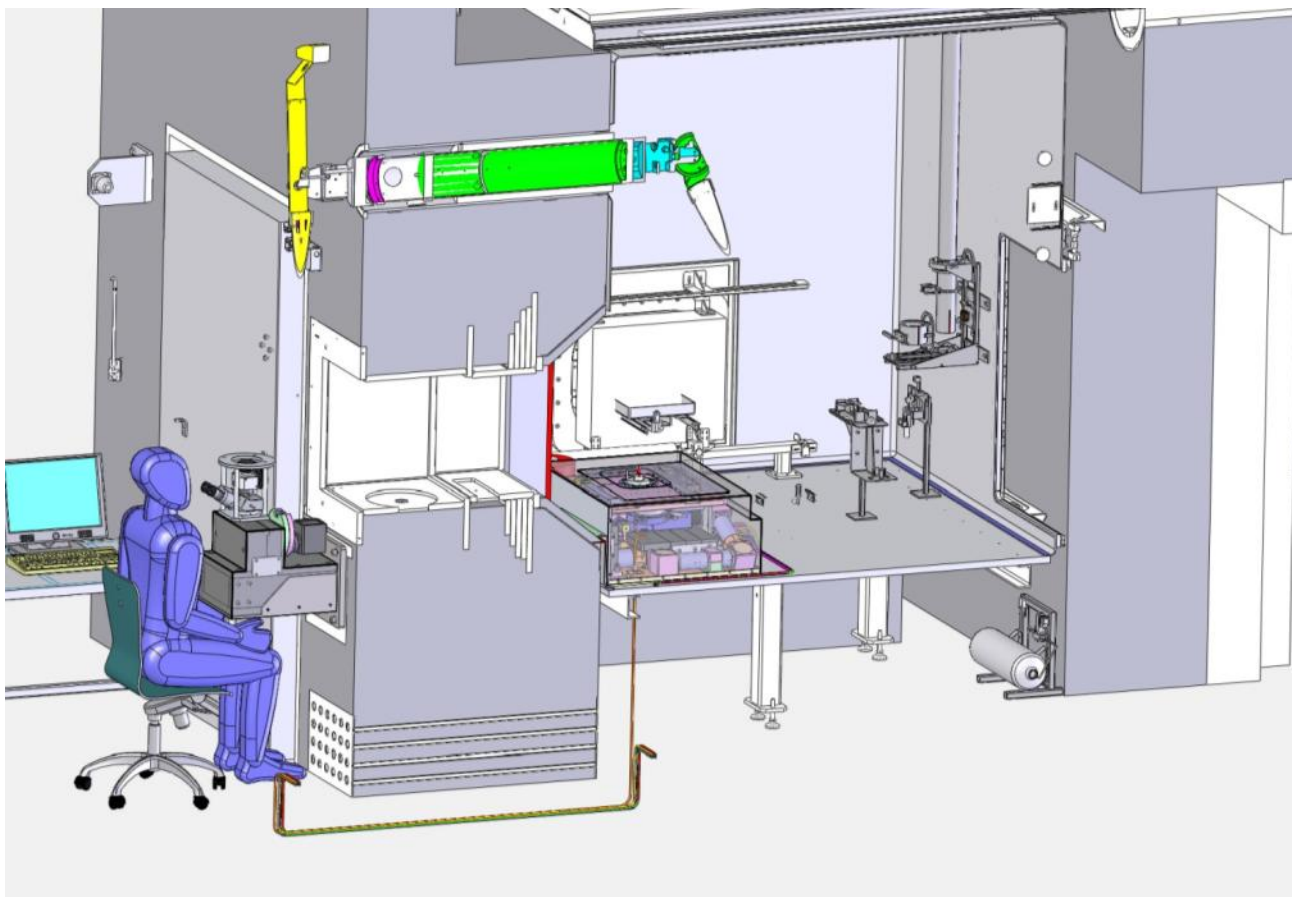
## **Motorized 8 positions nosepiece:**

- **Radiation hardened (no electronic components)**
- **6 objectives / 2 micro hardness sensors (Vickers & Knoop)**
- **7 objectives / 1 micro hardness sensor**
- **8 objectives**



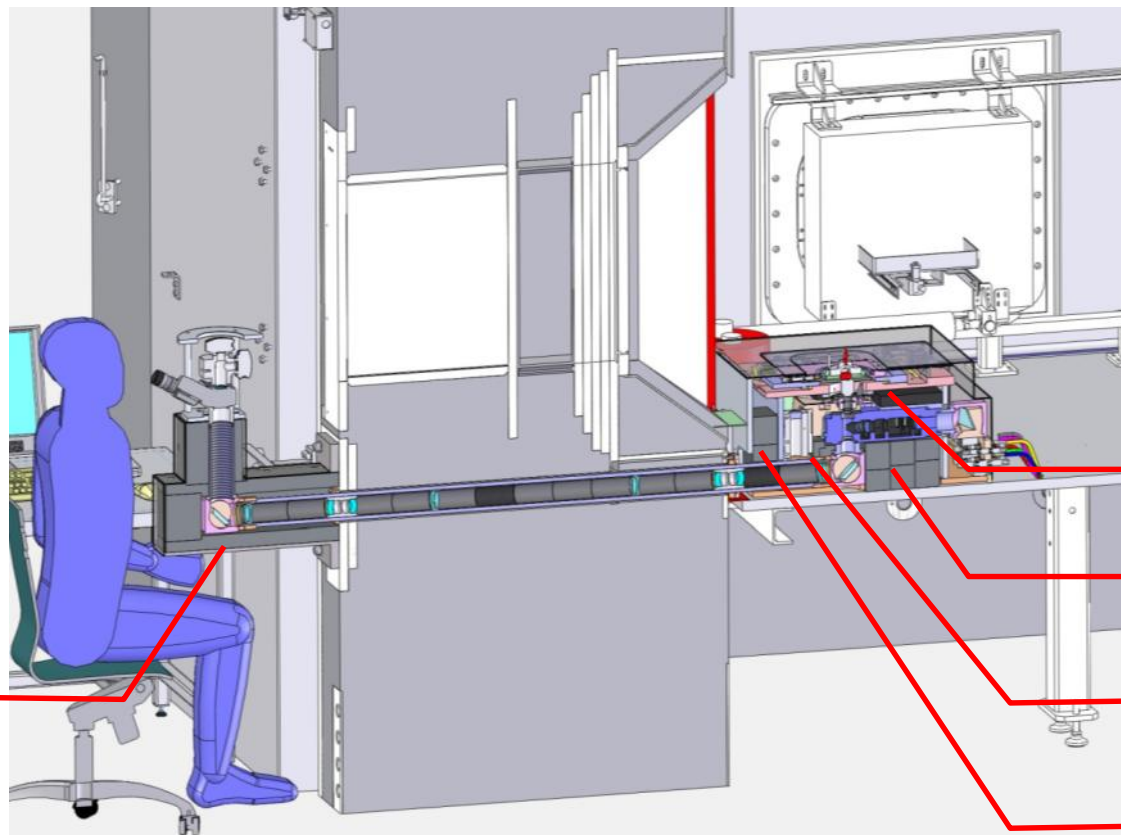
# HOT CELL INVERTED MICROSCOPES

Microscope in concrete hot cell



# HOT CELL INVERTED MICROSCOPES

## Concrete hot cell microscope shielding



External lead  
Shield

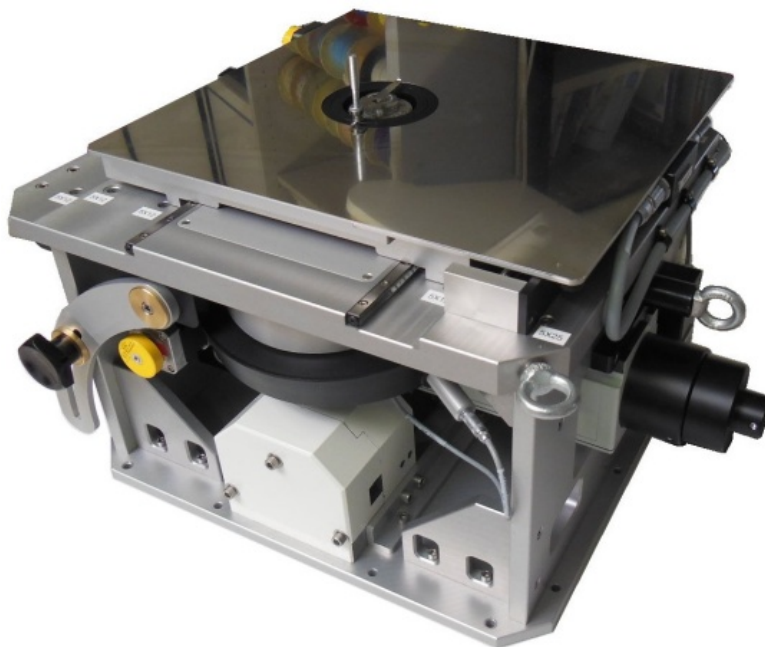
Illuminator lead Shield

Internal main lead Shield

Tube lens lead Shield

Internal front lead Shield

# HOT CELL INVERTED MICROSCOPES

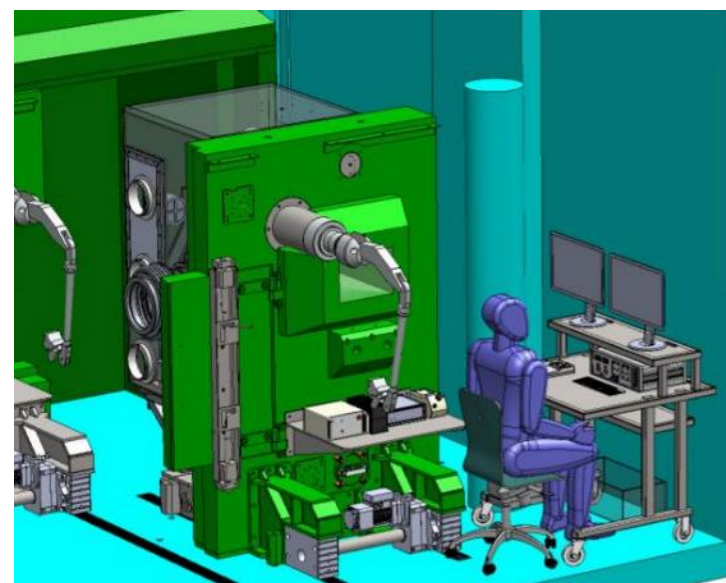
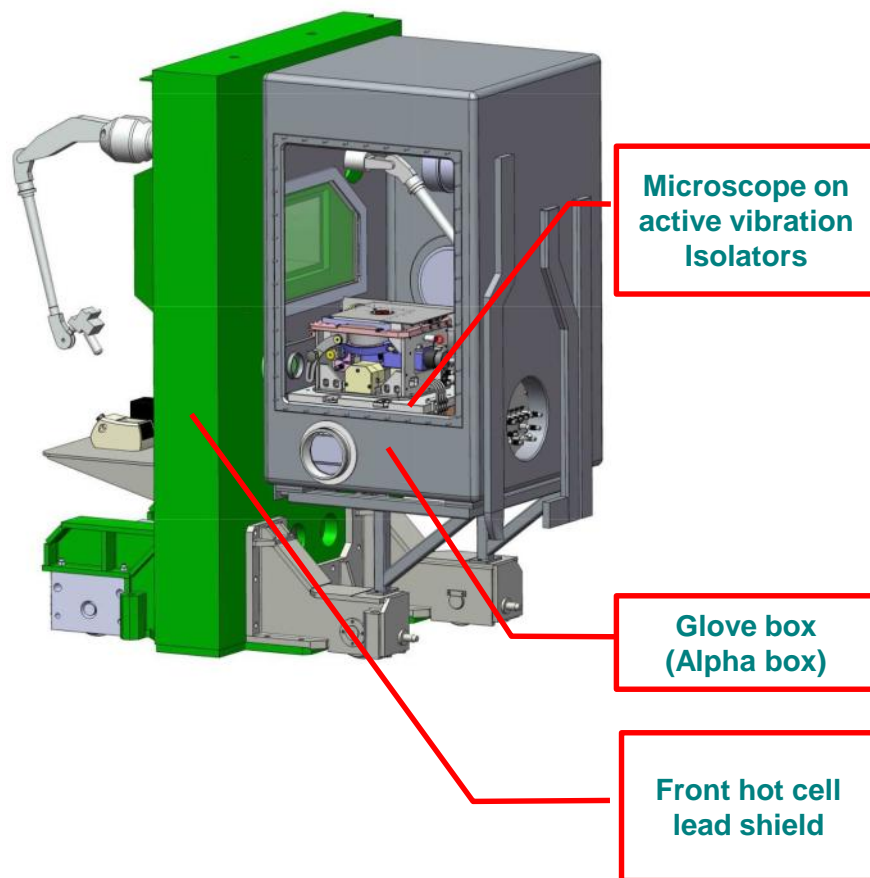


Hot cell microscope  
with integrated shielded digital camera



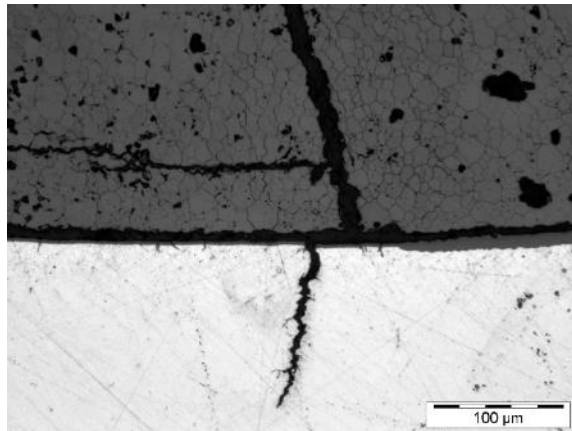
Microscope Control Unit

# HOT CELL INVERTED MICROSCOPES

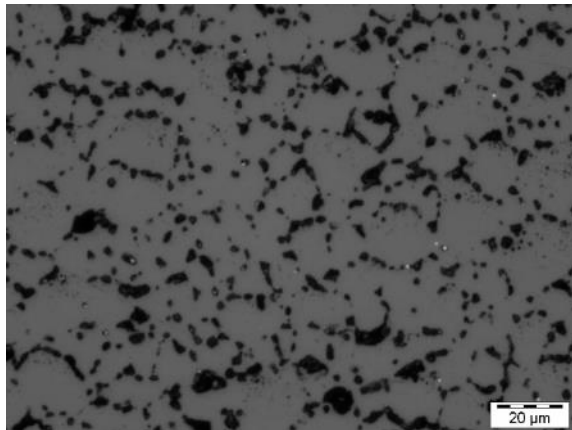


Hot cell microscope with integrated shielded digital camera

# HOT CELL INVERTED MICROSCOPES

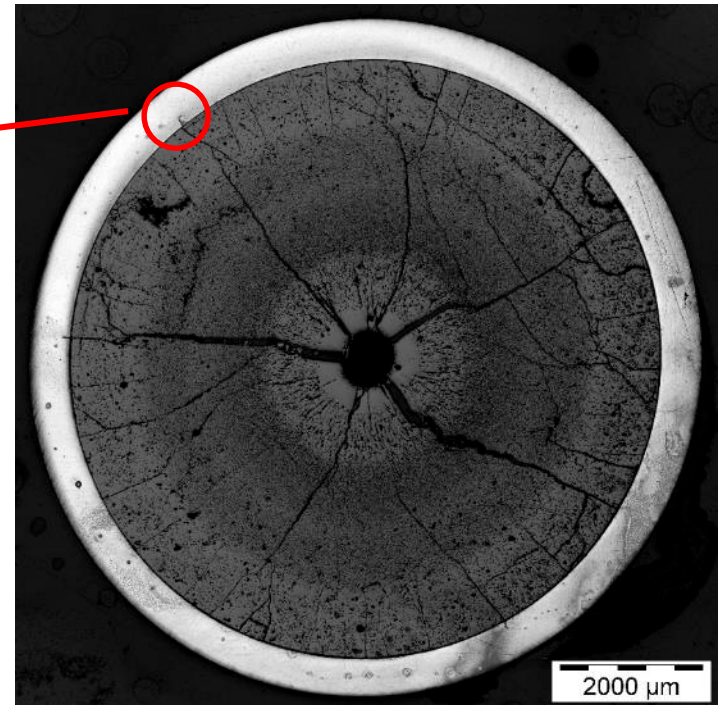


Detail  
20 X



Detail  
50 X

CONCERTO

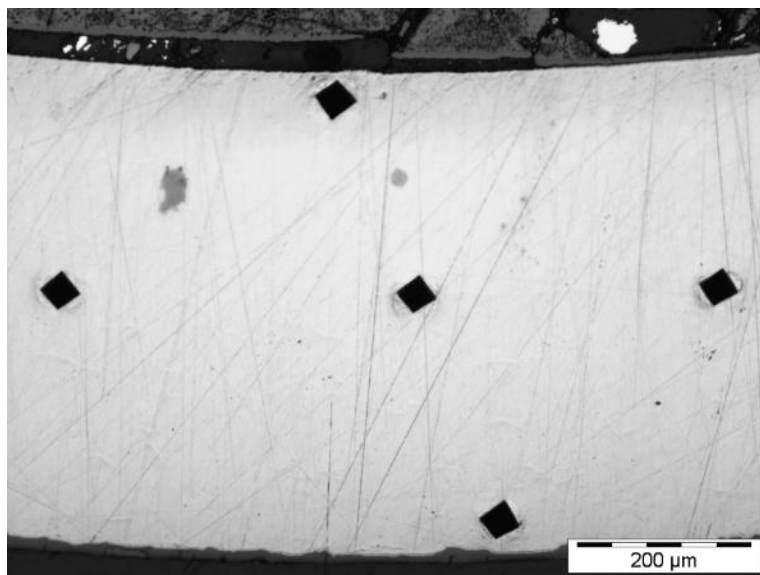


Assembled 2,5 X image  
3 596 x 3 606 pixels – 13 Mpixels

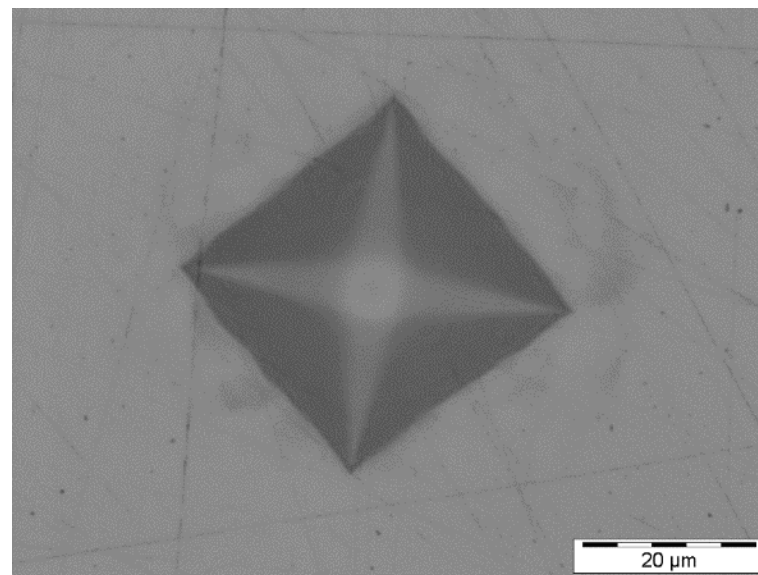


# HOT CELL INVERTED MICROSCOPES

## Vickers Micro Hardness testing



10X – Cladding



100X – Cladding center



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Examination (PIE) in Hot Laboratories

# Multi function Raman Microscopes



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# GLOVE BOX RAMAN MICROSCOPES



**Raman microscope with 2 or 3 lasers**  
**Combined with :**

- Image analysis
- Microhardness testing
- High temperature furnace

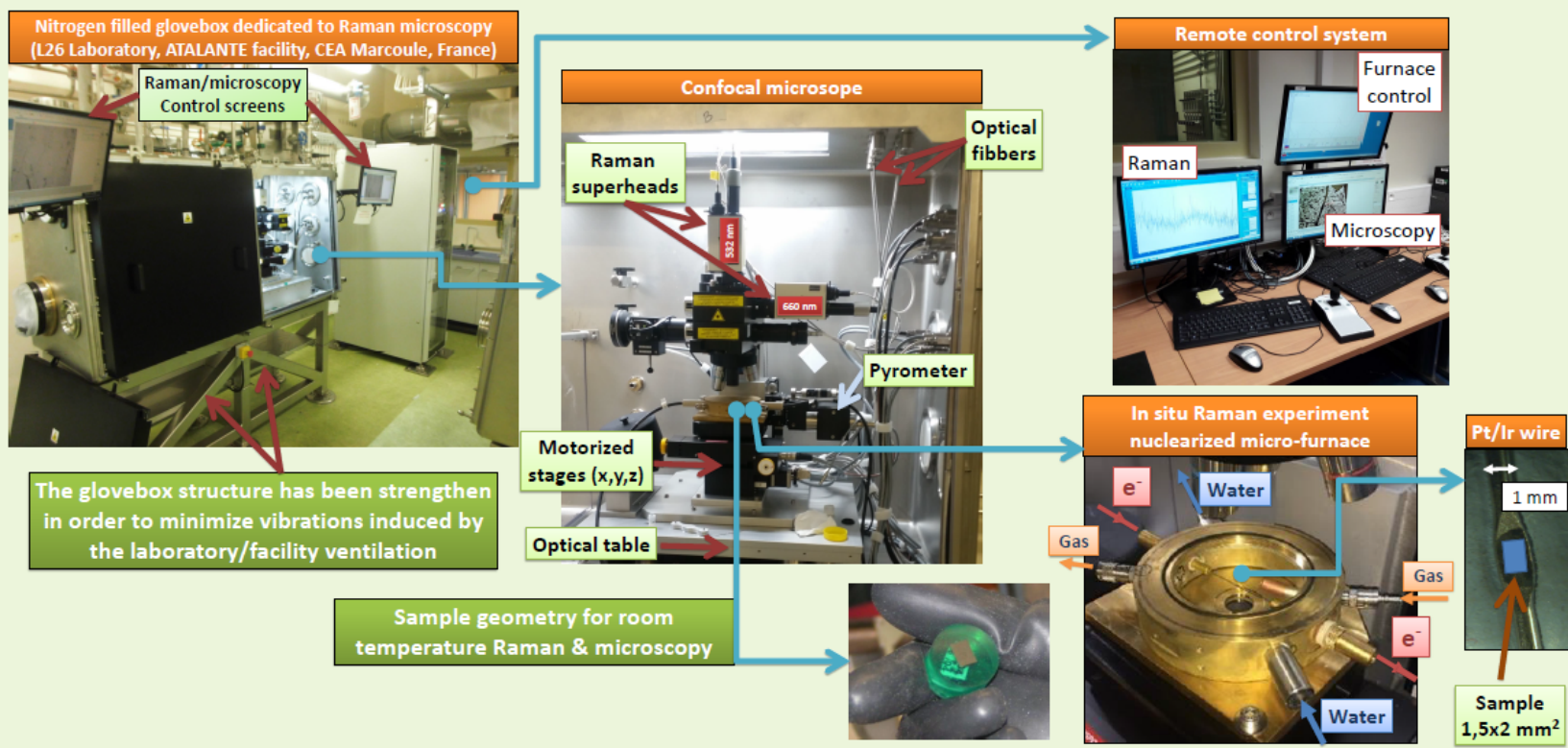


**Raman microscope with single laser**  
**Motorized stage and focus**

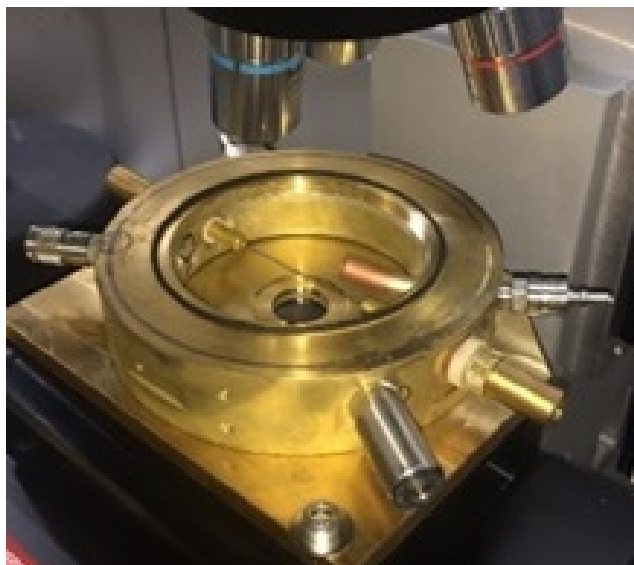
# GLOVE BOX RAMAN MICROSCOPE – MULTIPLE LASERS

## Experimental set-up

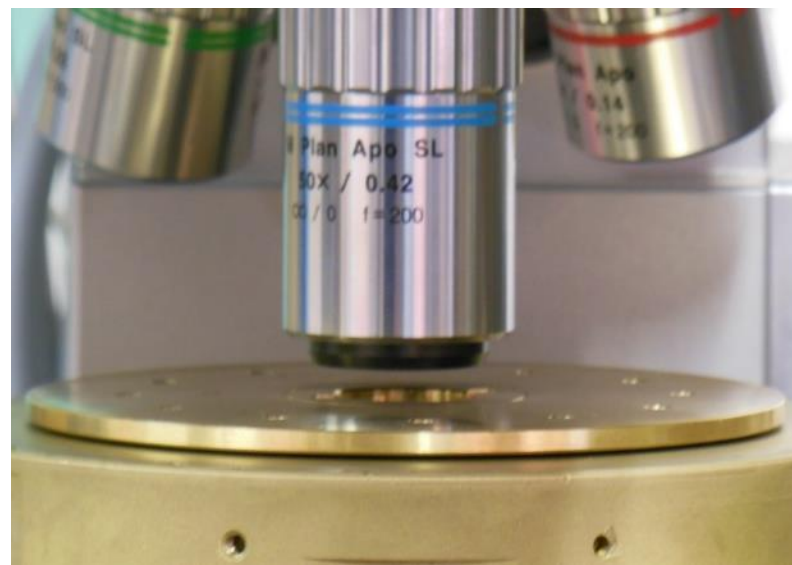
- Horiba® IHR-320 Raman spectrometer with 2 lasers: 532 nm & 660 nm
- Motorized stages : x, y, z and sample rotation
- Micro-hardness device ⇔ micro-indenter => Vickers test
- Confocal microscope equipped with 2 exchangeable turrets dedicated to:
  - Microstructural observations (optical & Raman): equipped with 4 Olympus® objectives (x5 to x100), the micro-indenter device and a Raman calibration objective.
  - *In situ* high temperature Raman experiment: equipped with 3 Mitutoyo® long working distance objectives (x5 to x50) and a Raman calibration objective.



# GLOVE BOX RAMAN MICROSCOPE – MULTIPLE LASERS



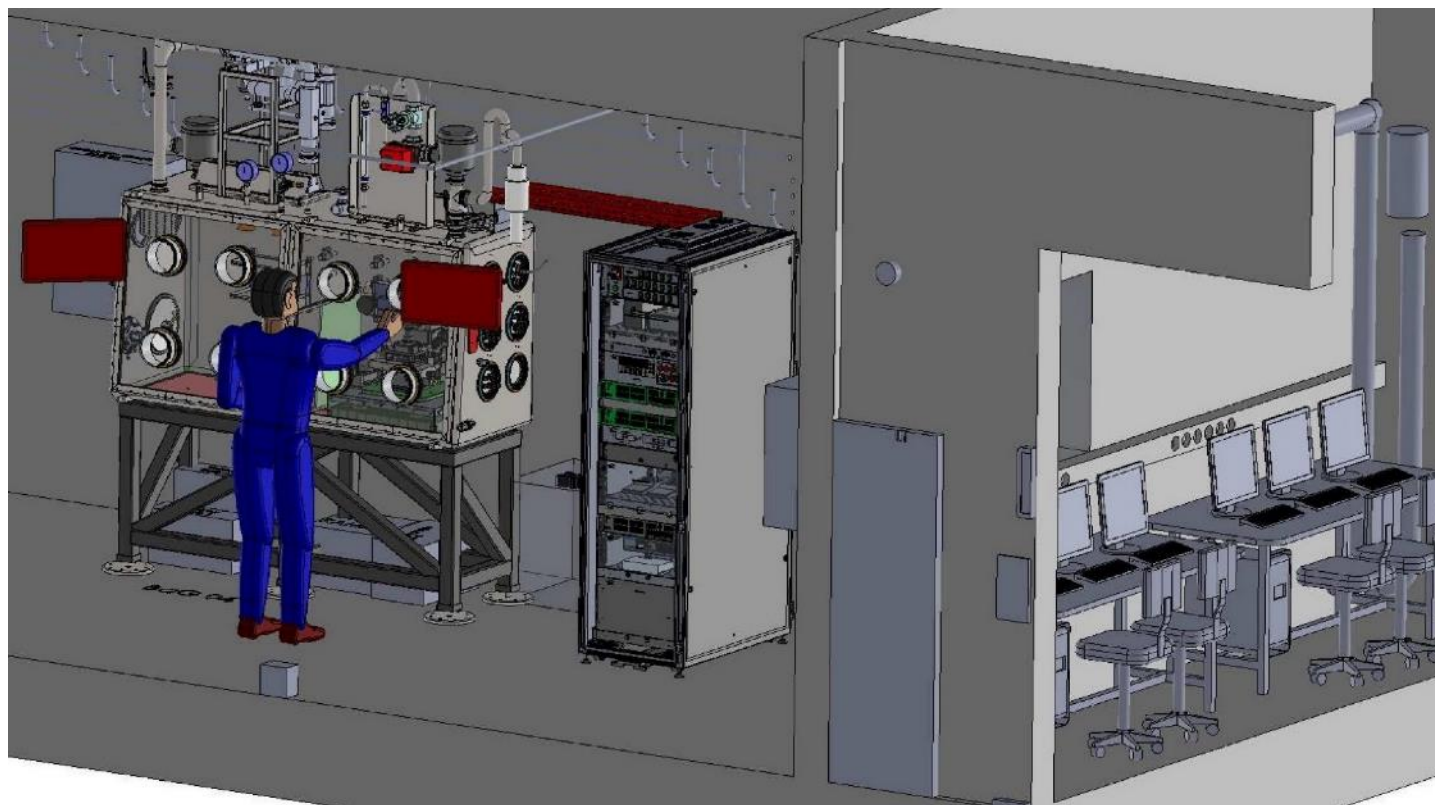
**Sample heating furnace  
(up to 1 700 °C)**



**Special long working  
distance objectives for  
Raman spectroscopy in  
heating furnace**



# GLOVE BOX RAMAN MICROSCOPE – MULTIPLE LASERS



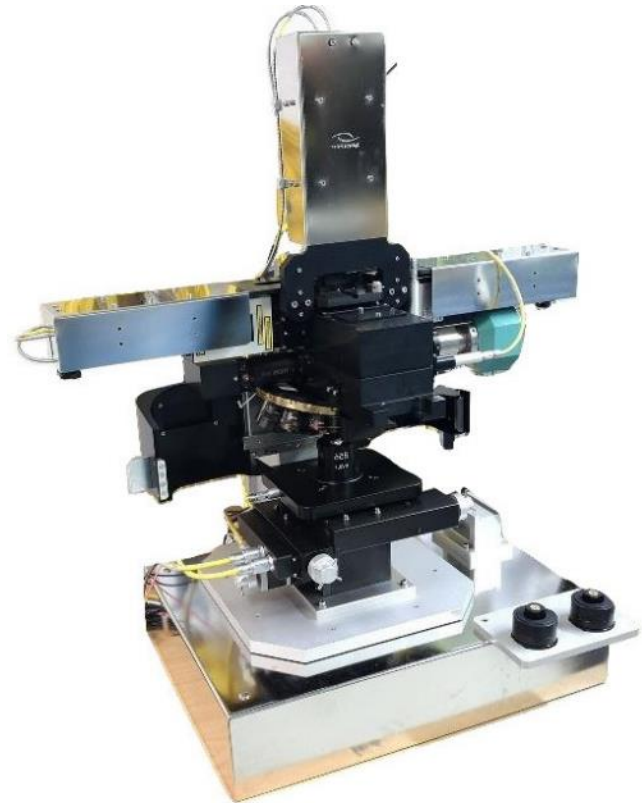
**Raman microscope  
and control cabinet  
located in hot lab**

**Remote Raman microscope  
control room**

# HOT CELL RAMAN MICROSCOPES



**Raman microscope**  
**Single laser**  
**Fully handled and assembled with**  
**tele manipulators**

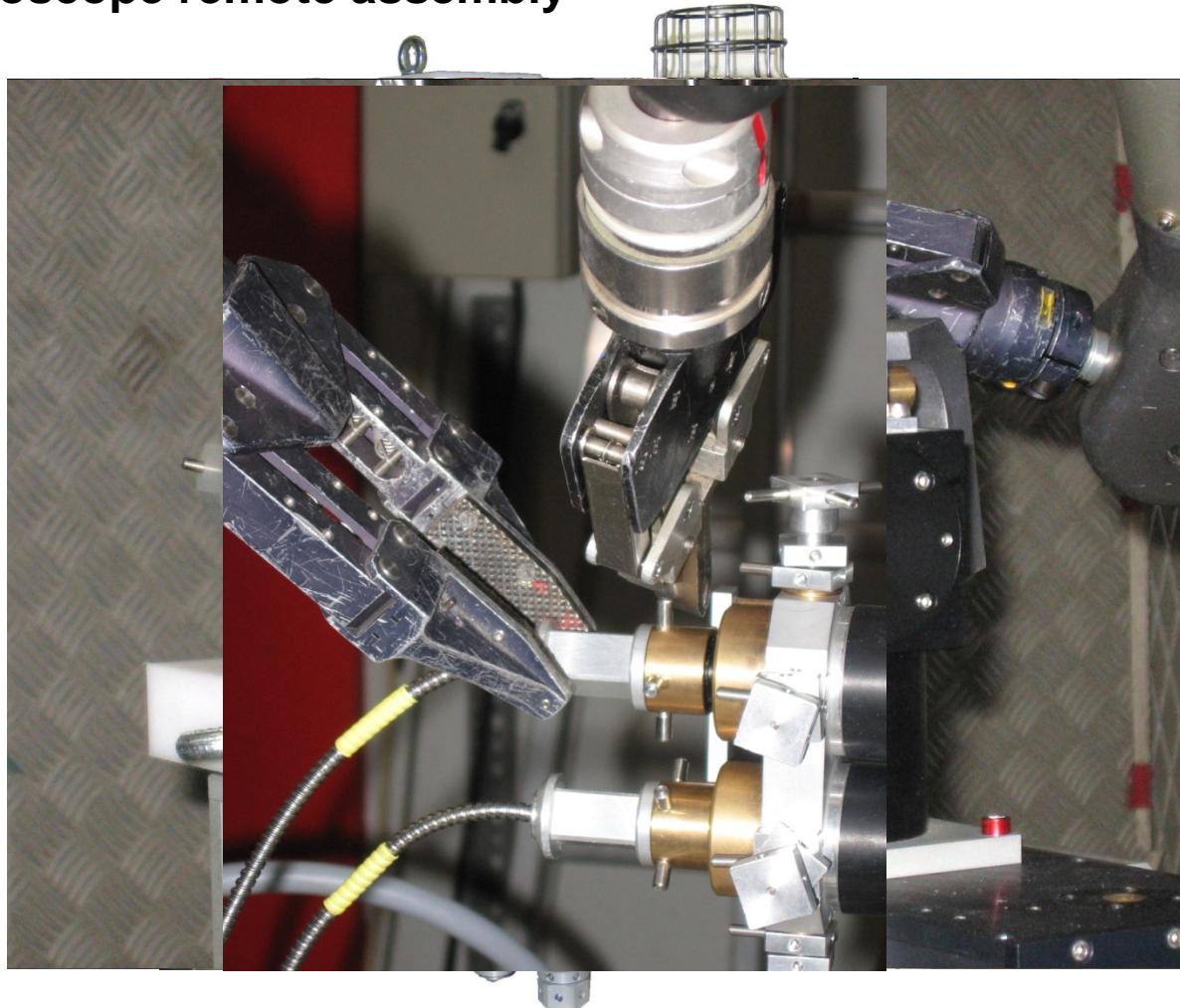


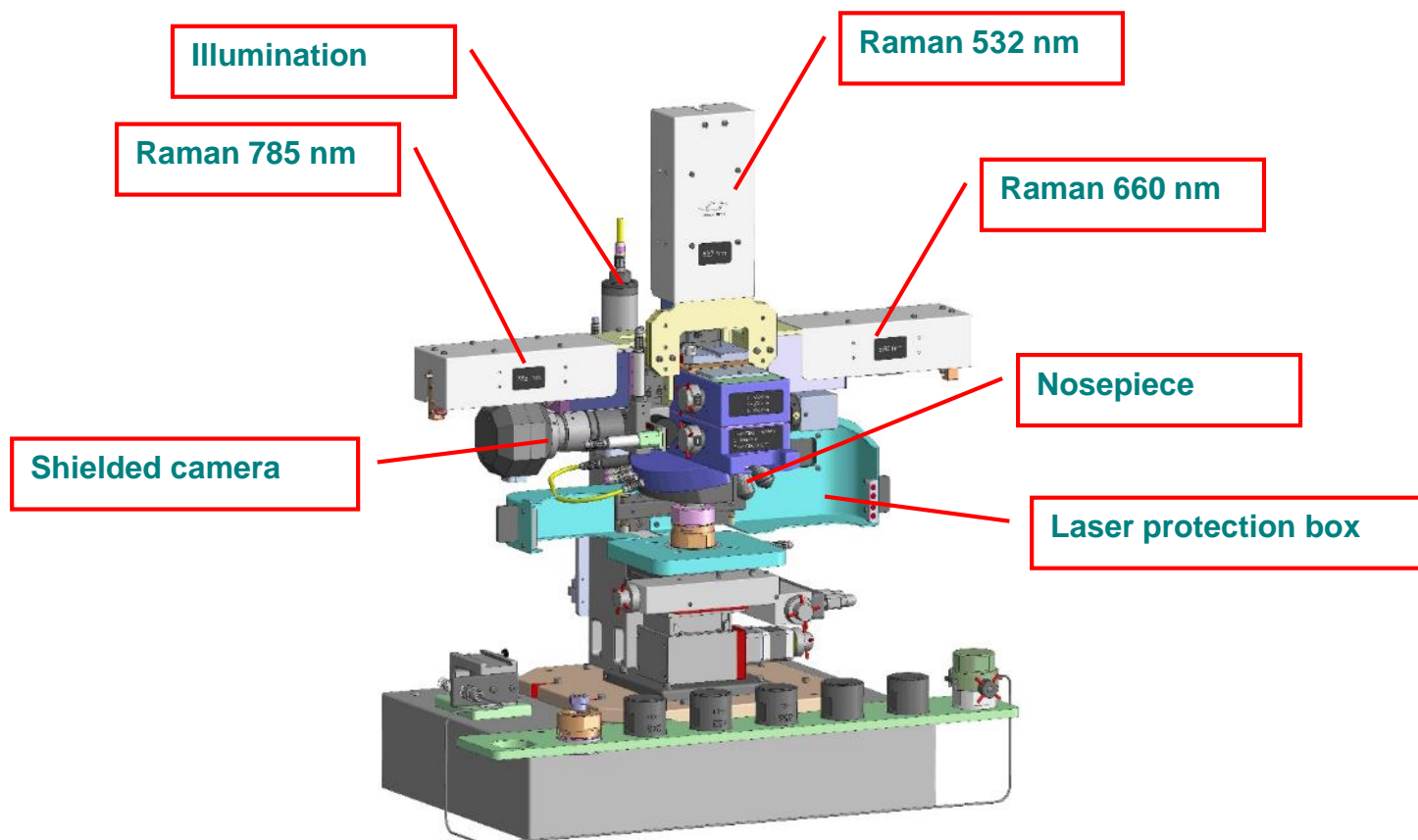
**Raman microscope**  
**3 lasers**  
**Image analysis**  
**Microhardness tester**



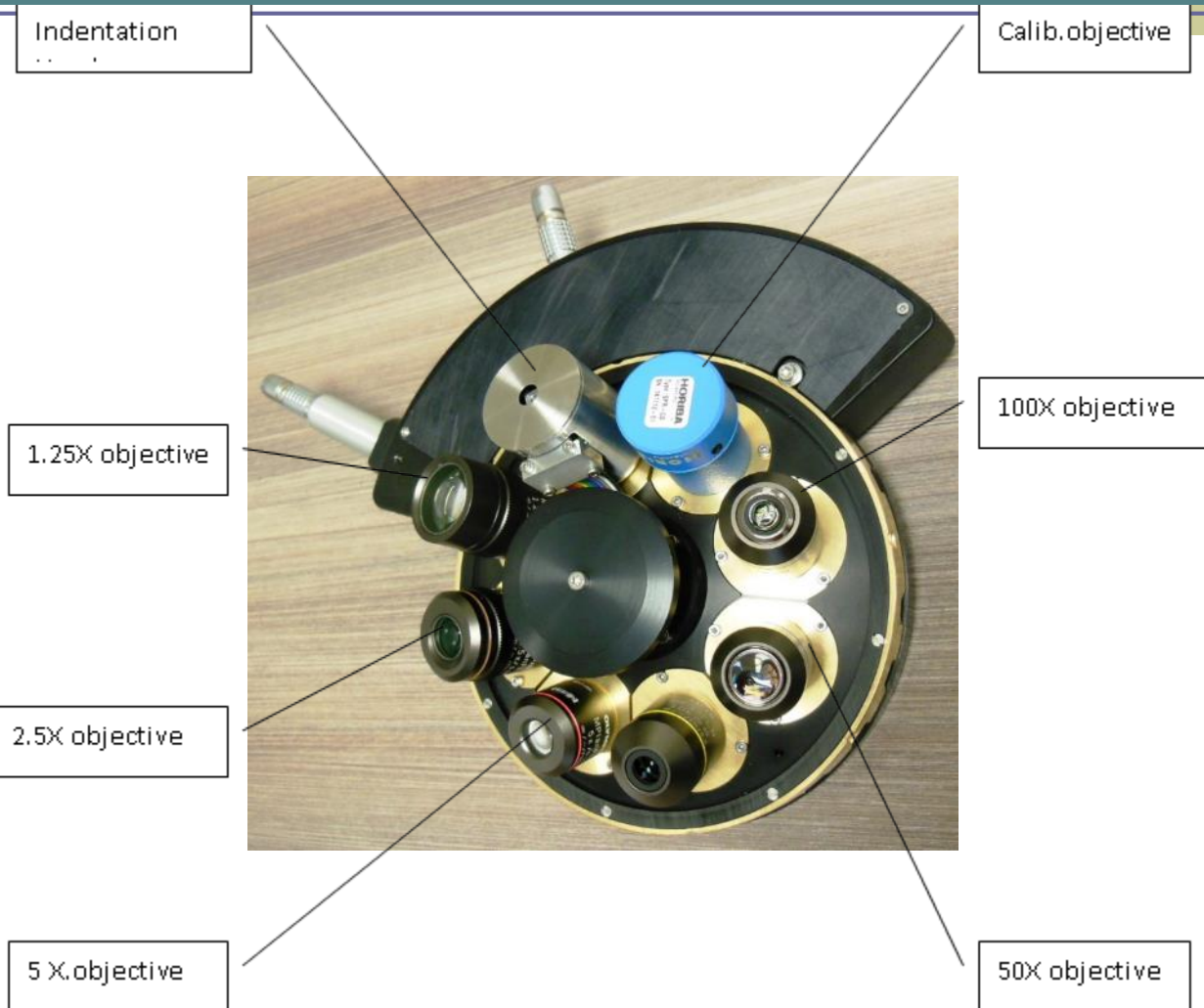
# Hot Lab optical instruments operation and maintenance

## Raman Microscope remote assembly

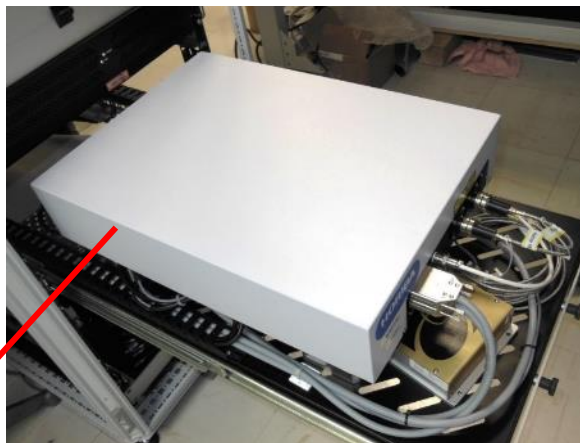




# HOT CELL RAMAN MICROSCOPE



# HOT CELL RAMAN MICROSCOPE



Laser rack (3 lasers)



Spectrometer

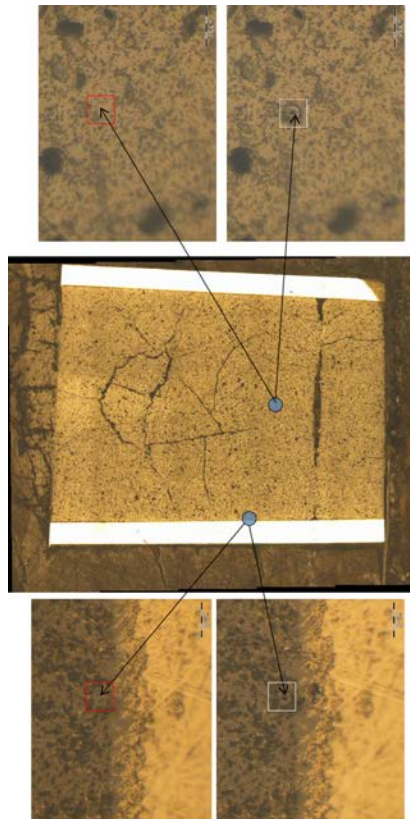
Raman microscope control cabinet

# HOT CELL RAMAN MICROSCOPE

- **Raman spectroscopy with up to 3 different laser wavelengths :**
  - Available : 532 nm – 660 nm – 785 nm
  - Other wavelength upon request
  - Laser excitation and Raman signal transmitted by optical fibers
  - Laser autofocus for accurate Raman cartography
  - Confocal Raman heads for enhanced spatial resolution
  - X Y Z spatial resolution < 4  $\mu\text{m}$  for visible lasers (532 nm, 660 nm)
  - X Y Z spatial resolution < 10  $\mu\text{m}$  for NIR laser (785 nm)
  - Spectral resolution with IHR320 spectrometer :
    - Better than 8 $\text{cm}^{-1}$ (1200 gr/mm grating)
    - Better than 6  $\text{cm}^{-1}$  (2400 gr/mm grating)
- **Image analysis :**
  - Reflected light illuminator for bright field observation
  - Bright field, Polarization with rotatable analyzer
  - Powerful LED illumination
- **Microhardness tester :**
  - One or 2 microhardness testers (Vickers and/or Knoop)
  - 10 g to 400 g load
- **Fully motorized microscope**
  - Motorized nosepiece with 6/8 objectives
  - Motorized focusing and XY stage
  - Motorized Laser selection and optical mode selection
  - Motorized illuminator

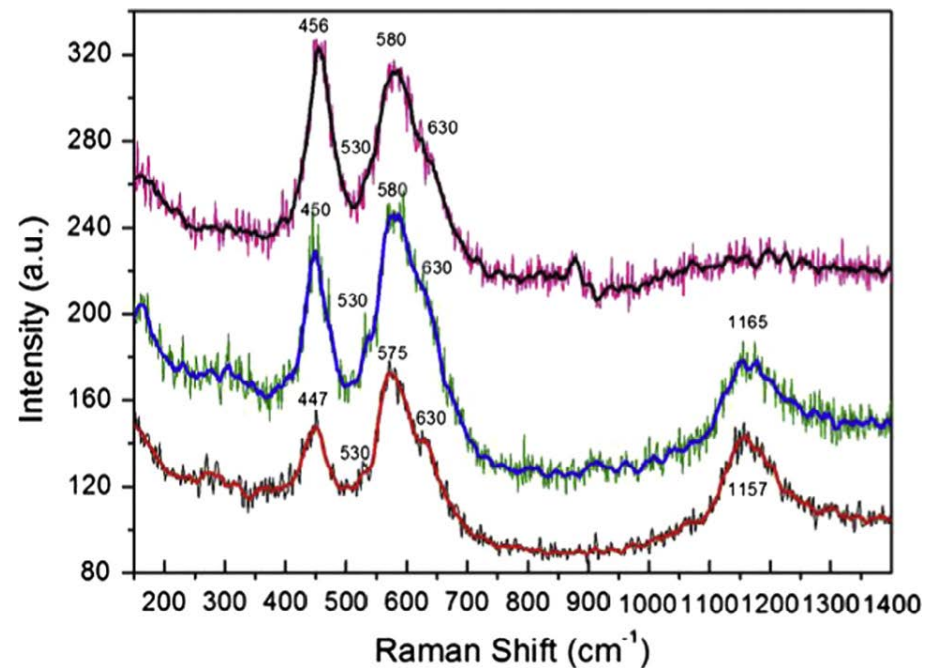


# HOT CELL RAMAN MICROSCOPE



Optical microscope image of the UOX60 sample

## Raman micro-spectroscopy of UOX60 spent fuel



Raman spectra of UOX60 sample in central zone  
(black – raw data; red – smoothed data)



# MICRO HARNESS TESTER – Glove Box / Hot Cell



**Micro Harness tester on  
vibration isolation unit**

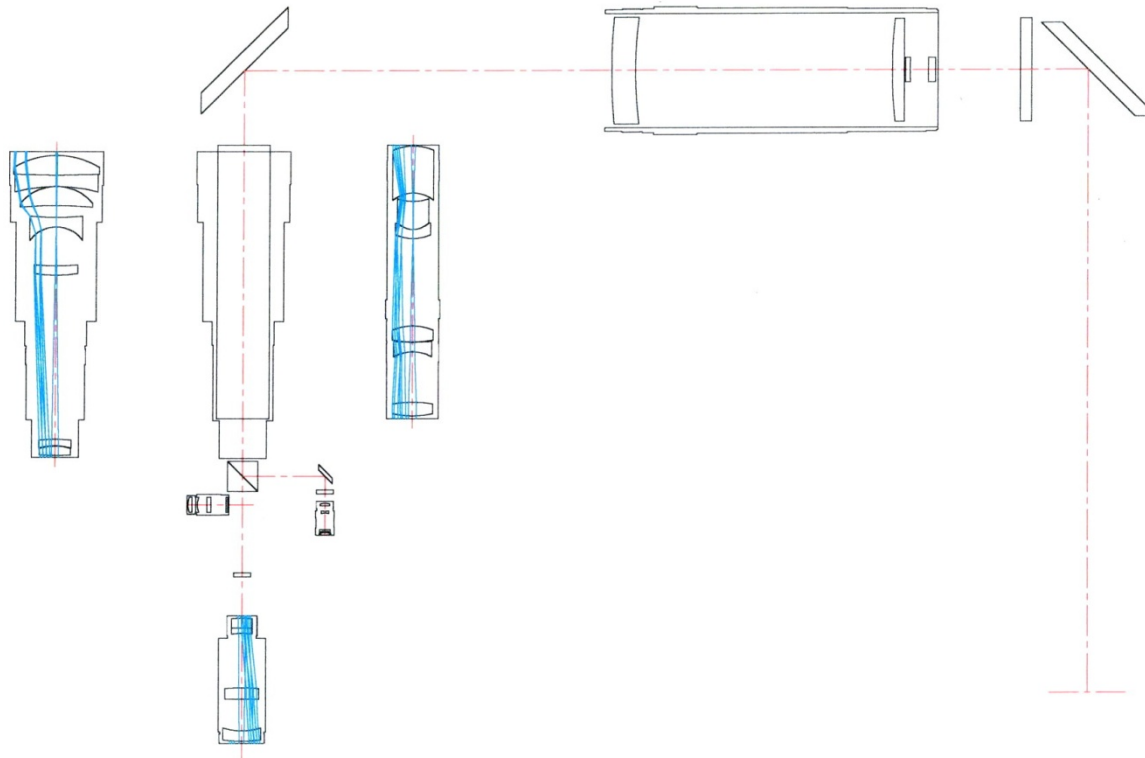


**Remote control unit  
Located out of the glove box  
(No electronic components  
inside the glove box)**

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# Hot Cell Periscope

## Mirror optic apochromatic hot cell periscope



# HOT CELL MACROSCOPES



High precision measuring  
macroscope/microscope



Heavy duty macroscope  
Up to 25 Kg sample  
Telecentric zoom optic  
Annular, coaxial and transmitted light illumination

# HOT CELL BINOCULARS

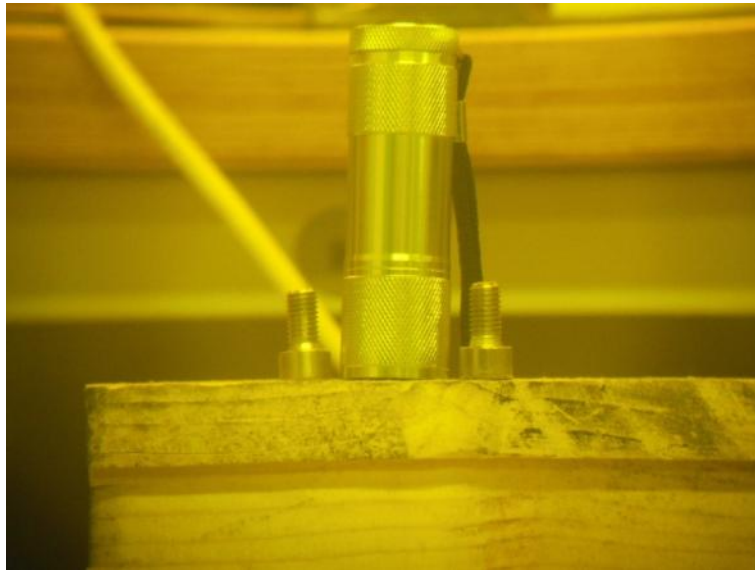


## Hot cell binoculars

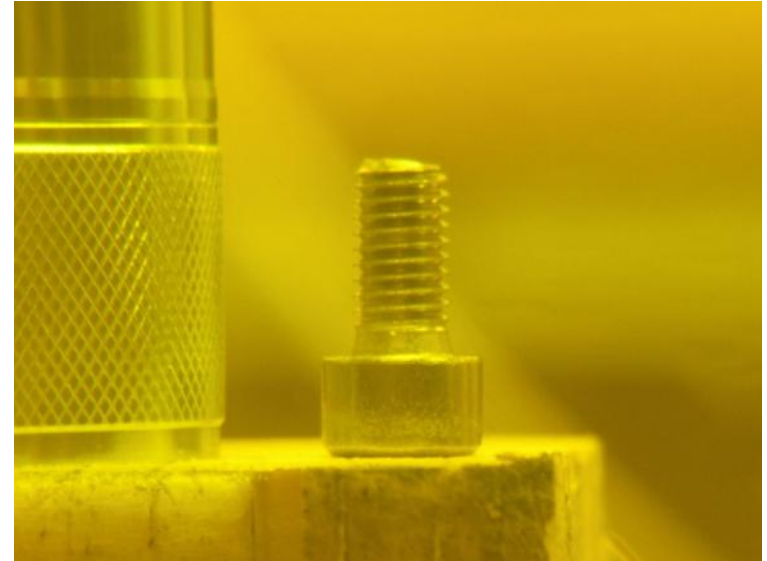
- Compensation of the optical aberrations of thick hot cell radiation resistant glasses
- Adjustable stereoscopic observation angle according to focusing distance, allows fine stereoscopic observation from 1,5 m to infinite
- 10x, 14x, 20x and 28x magnification with different oculars
- Heavy duty tripod on dolly



# HOT CELL BINOCULARS



**Binocular / object distance : 1,6 m**



**Binocular / object distance: 2,8 m**

**Images taken with a digital camera placed in front of the ocular**

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**THANK YOU FOR YOUR ATTENTION**