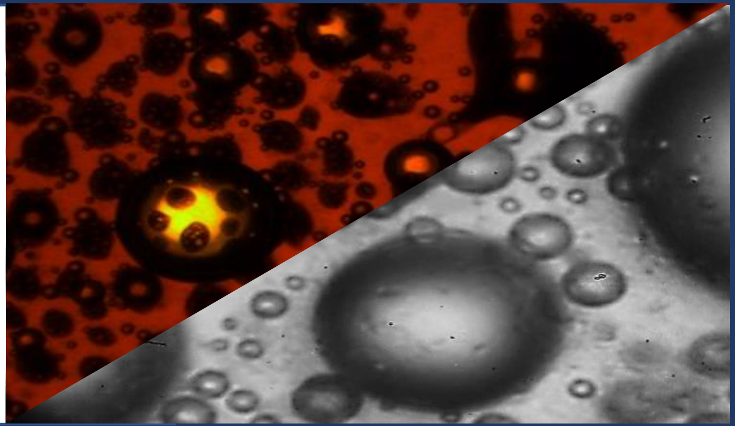
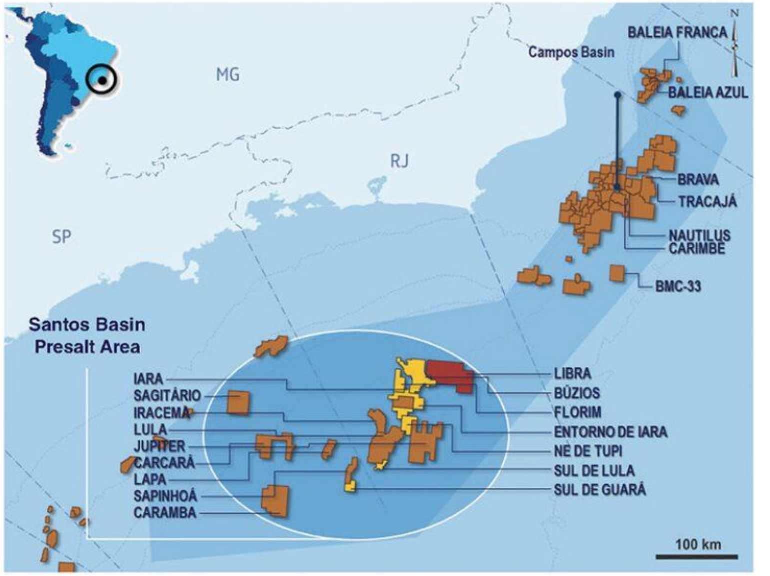
JIP Alliance

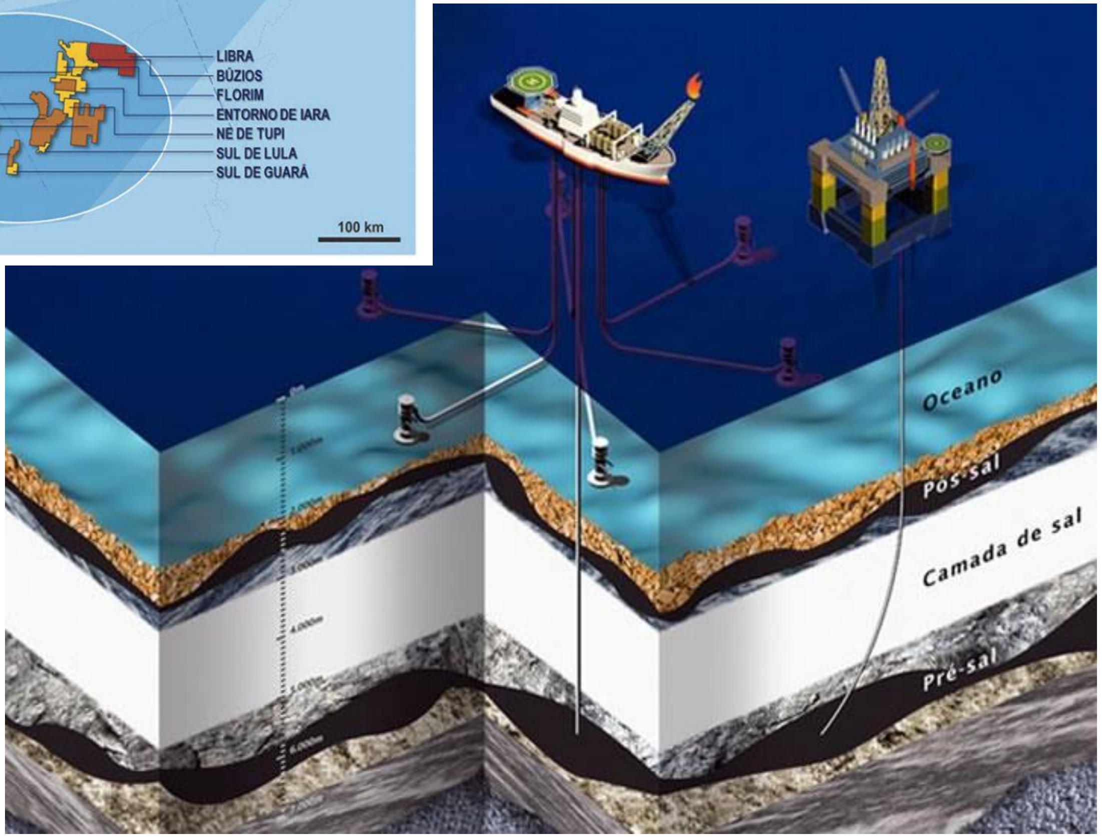
PVT pour les fluides non-conventionnels de type pre-salt



José Francisco Romero Yanes, Chih-Wei Lin, Hosiberto Batista de Sant'Ana, Jérome Pauly, Magali Pujol, Julien Collell, Felipe Fleming, Jean-Patrick Bazile, Djamel Nasri, François Montel, Hervé Carrier, Jean-Luc Daridon

BRAZILIAN PRE-SALT FLUIDS





0
2000
3000
5000
{5000
 7000

Pr : 600-700 bar

Tr : 80 - 100°C

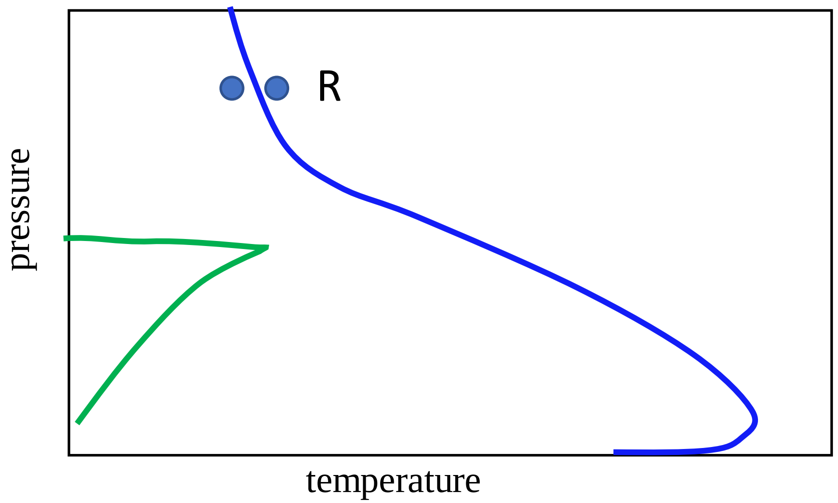
GOR 200 - 600 m^3/m^3

CO_2 up to 55 mol% LO

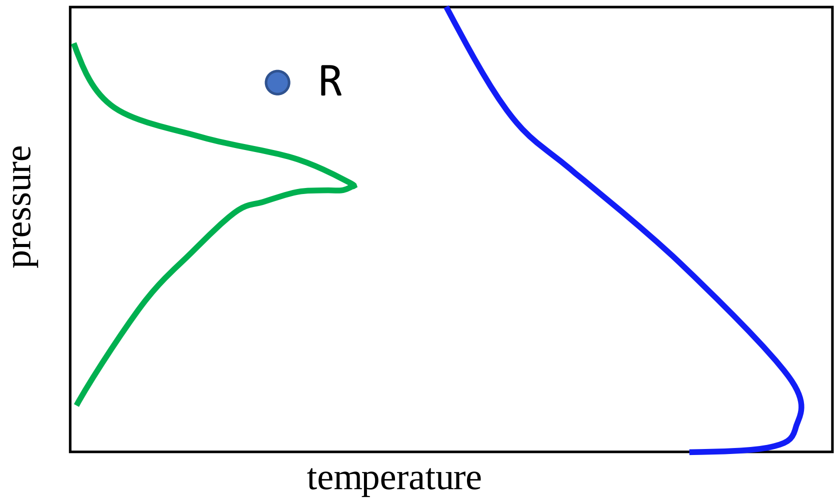
Asphaltene 0.1-0.3 mass% DO

Wax 5-7 mass% DO

PHASE BEHAVIOR OF RESERVOIR FLUIDS

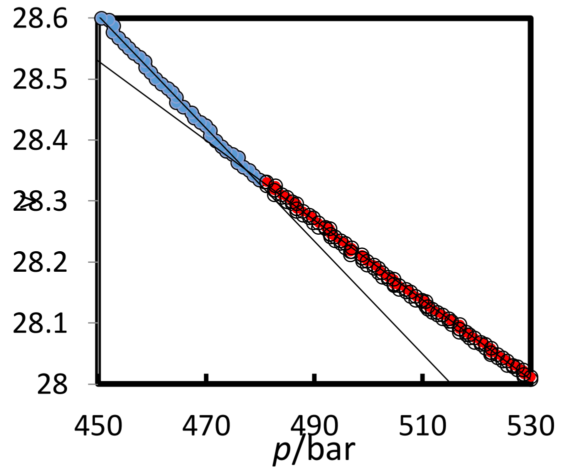


P.S. oil



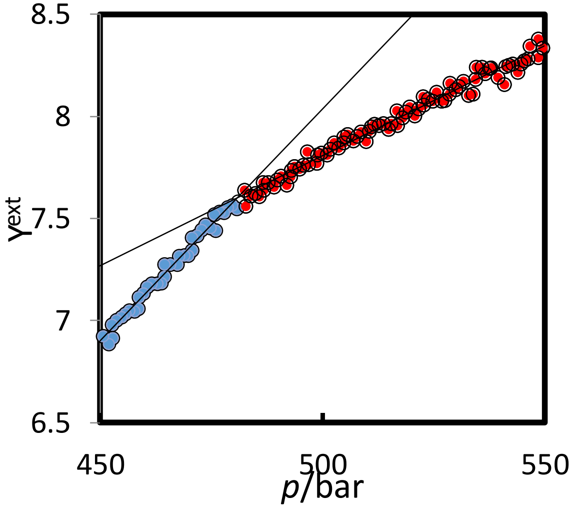
P.S. oil
With
CO^2

Conventional PVT techniques : Synthetic method



$$Y_{ext} = -\frac{V_{ext}}{P}\left(\frac{P - P_{ext}}{V - V_{ext}}\right)$$

✓ *Yext method : CME at Tr*



Challenges

✓ **Multi-scale observation for both fluid and solid phases**

- $L \rightarrow L + V$: mm
- $L \rightarrow L + L$: mm to µm
- $L \rightarrow L + Wax$: 0.5 µm
- $L \rightarrow L + Asphaltenes$: 50 nm

✓ **High opacity**

- Indirect detection of phase transitions : → Sensor in full immersion

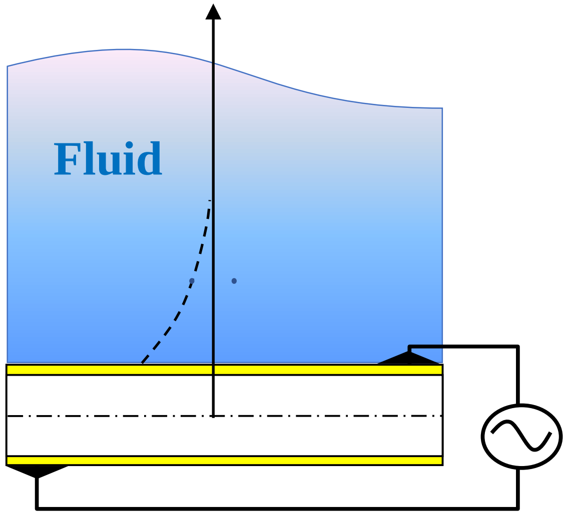
✓ **Complex phase behavior**

- Direct observation : Fluids : full sample (stirring) → HP full visibility cell

  Solids : focalization on a small sample (static) → HP microscopy

Combined Investigation

Indirect detection method : QCR sensor (QCM)



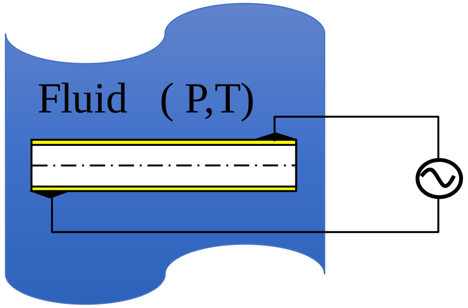
- Measurements of the resonance properties
- Calculation of the physical properties of the surrounding media

$$\begin{cases} \Delta f_{n,oil} = -\sqrt{n}\dfrac{C_m}{\sqrt{\pi f_0}}\sqrt{\rho_{oil}\eta_{oil}} - n2C_m\rho h_D \\ \Delta\Gamma_{n,oil} = \sqrt{n}\dfrac{C_m}{\sqrt{\pi f_0}}\sqrt{\rho_{oil}\eta_{oil}}(1+R) \end{cases}$$

mass

viscous

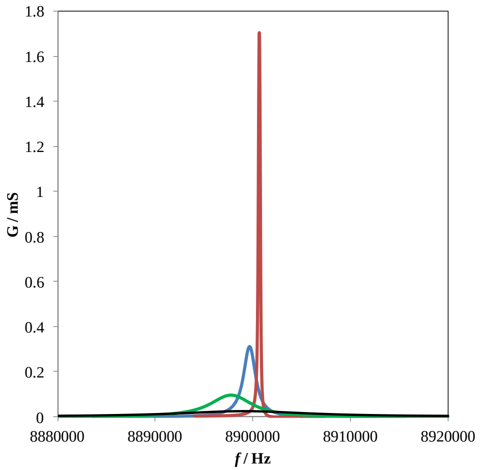
QCR sensor in full oil immersion



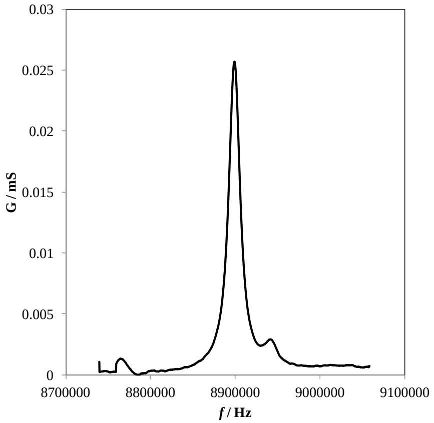
Viscous friction leads to a huge attenuation

Steady state method

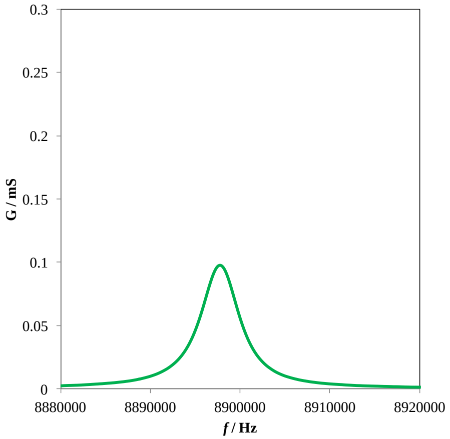
3^{rd}



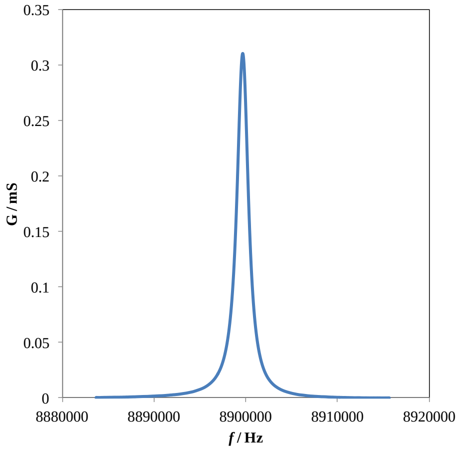
Oil with unstable Asphatenes



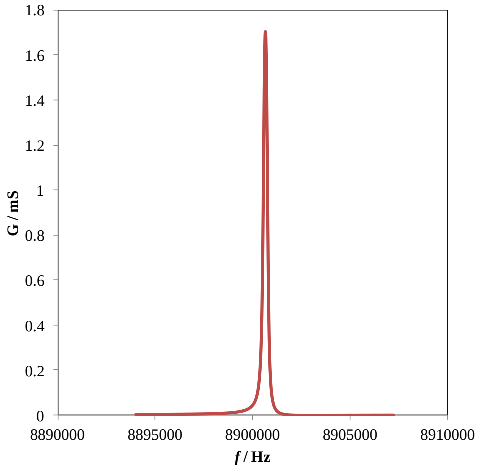
Dead oil



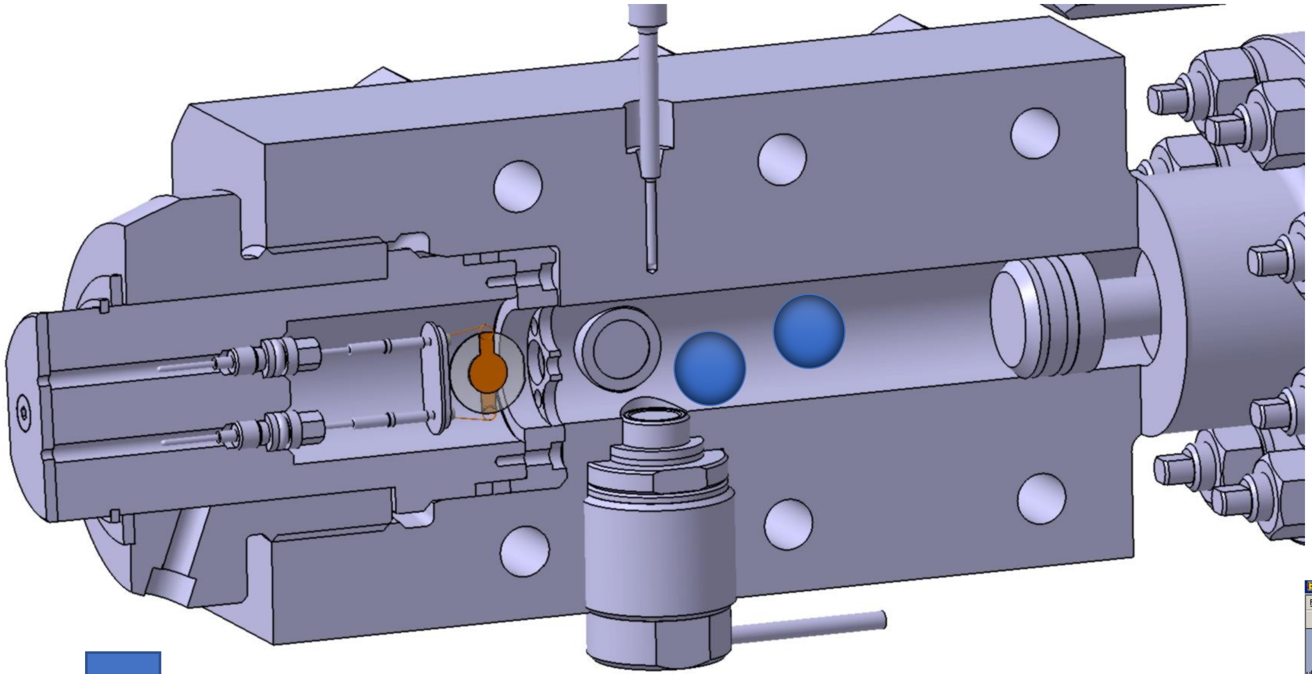
Toluene



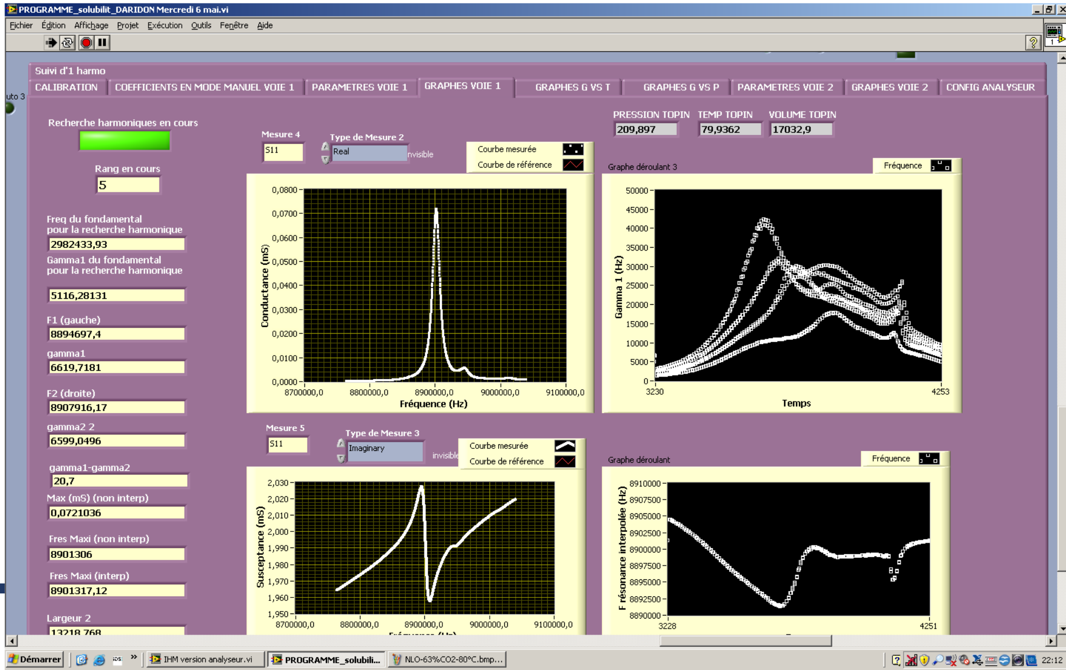
Vacuum



High pressure cell



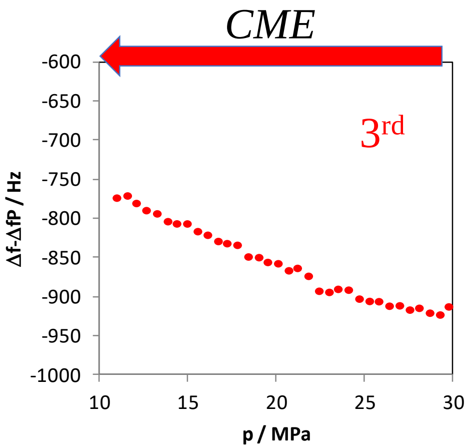
- **P : 0.1 – 100 Mpa**
- **T : 0 – 100 C**
- **V : 20 – 50 cm^3**

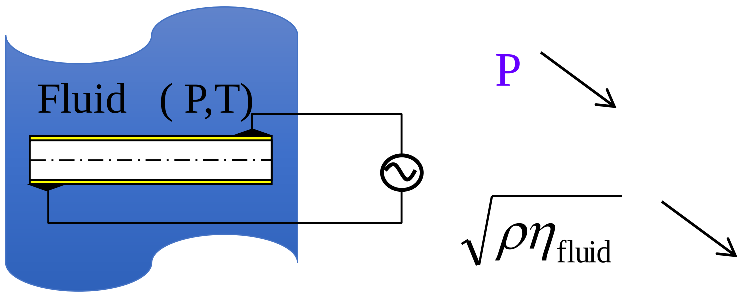


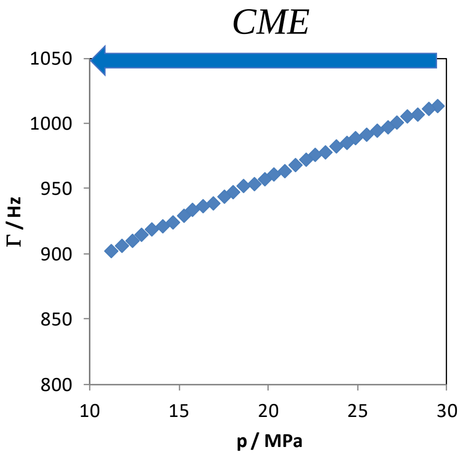
Fluid phase transitions using QCR

Constant Mass Expansion ($CO_2 + nC_{17}$)

L



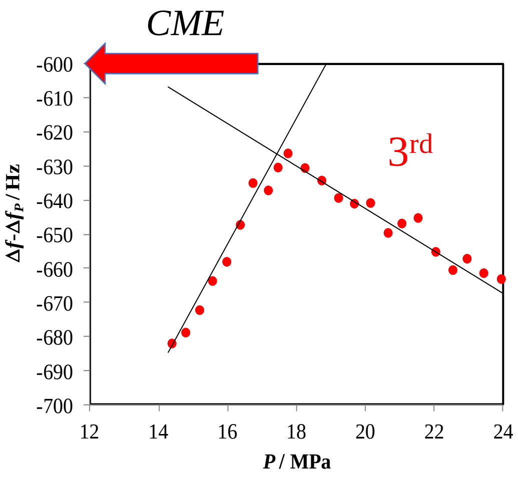


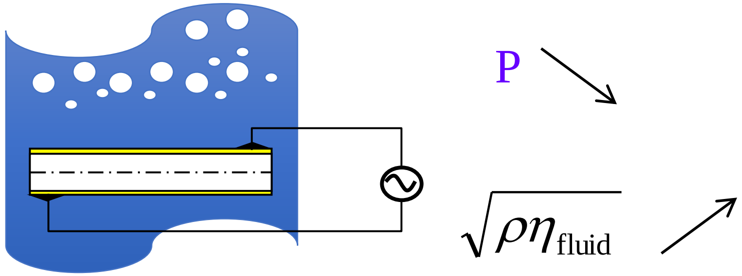


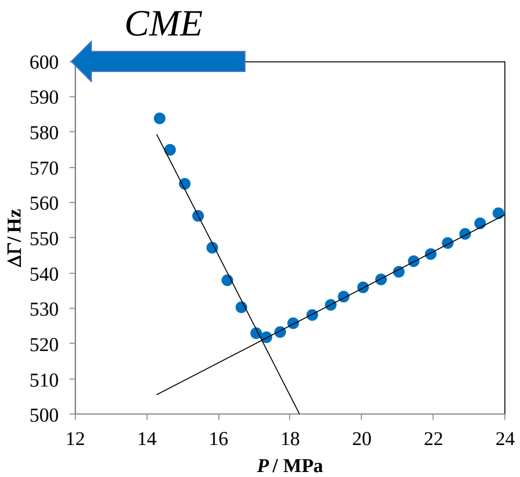
$$\Delta f_{n,oil} = -\sqrt{n}\frac{C_m}{\sqrt{\pi f_0}}\sqrt{\rho_{oil}\eta_{oil}} - n2C_m\rho h_D$$

$$\Delta\Gamma_{n,oil} = \sqrt{n}\frac{C_m}{\sqrt{\pi f_0}}\sqrt{\rho_{oil}\eta_{oil}}(1+R)$$

L+V

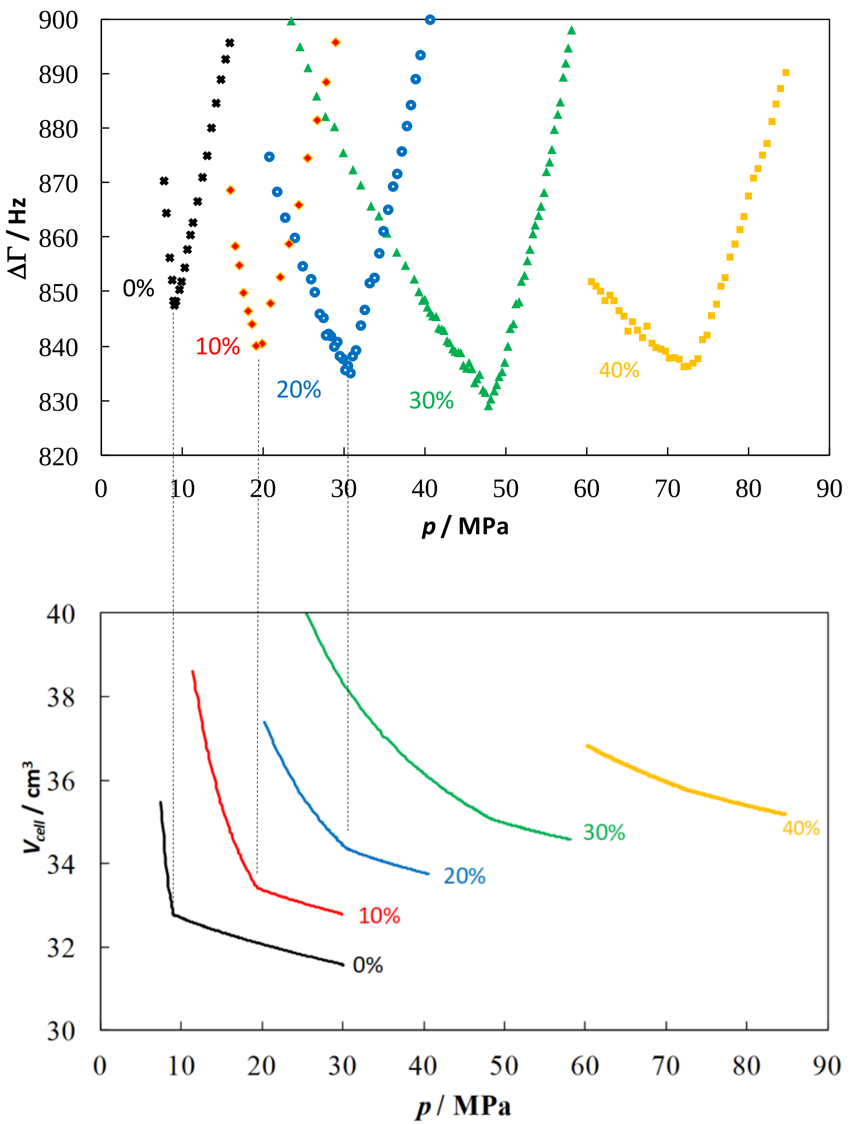






Fluid phase transitions using QCR

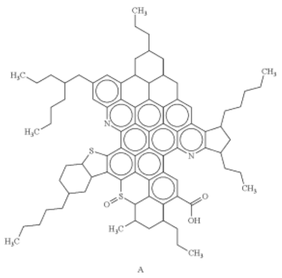
Constant Mass Expansion (gas + oil)

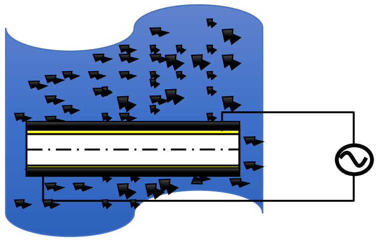


- **The minimum is in good agreement with the observed break in the PV curve.**
- **QCR is more sensitive than PV method.**
- **QCR cannot detect LL phase separation**

Asphaltene instability threshold measurement using QCR

Unstable Asphatenes lead to :





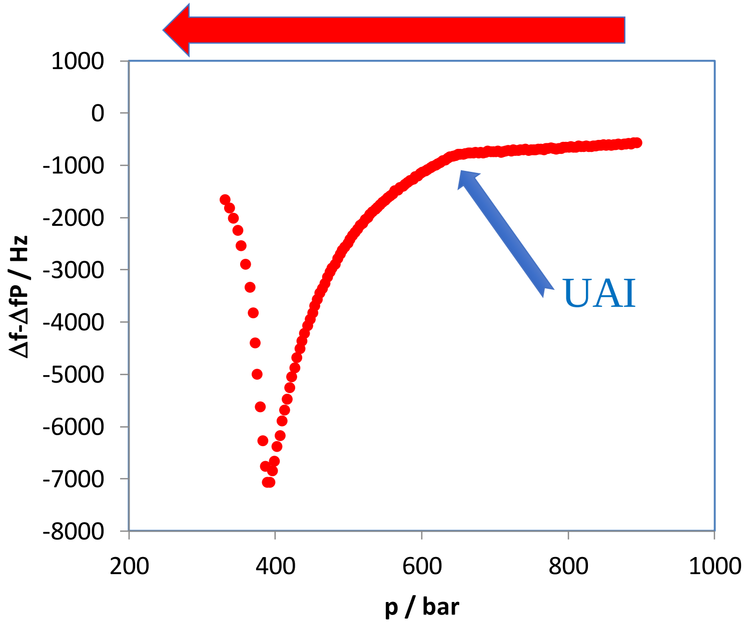
- **an increase of viscosity**

$$\sqrt{\rho\eta_{\text{fluid}}} \nearrow \quad \Delta f_{\text{fluid}} \searrow \quad \Delta\Gamma_{\text{fluid}} \nearrow$$

- **mass deposition**

$$h_D \nearrow \quad \Delta f_{\text{fluid}} \searrow$$

CME of a Live oil

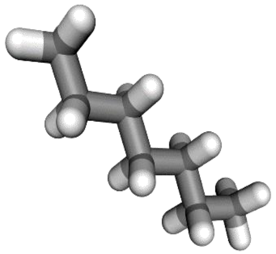


- **Electrical response to AI is Huge. It allows to sense the UAI Threshold**

$$\Delta f_{n,oil} = -\sqrt{n}\frac{C_m}{\sqrt{\pi f_0}}\sqrt{\rho_{oil}\eta_{oil}} - n2C_m\rho h_D$$

$$\Delta\Gamma_{n,oil} = \sqrt{n}\frac{C_m}{\sqrt{\pi f_0}}\sqrt{\rho_{oil}\eta_{oil}}(1+R)$$

Wax Appearance Temperature measurement using QCR



- **Wax precipitation leads to an increase of viscosity**
- **No mass deposition on quartz surface**

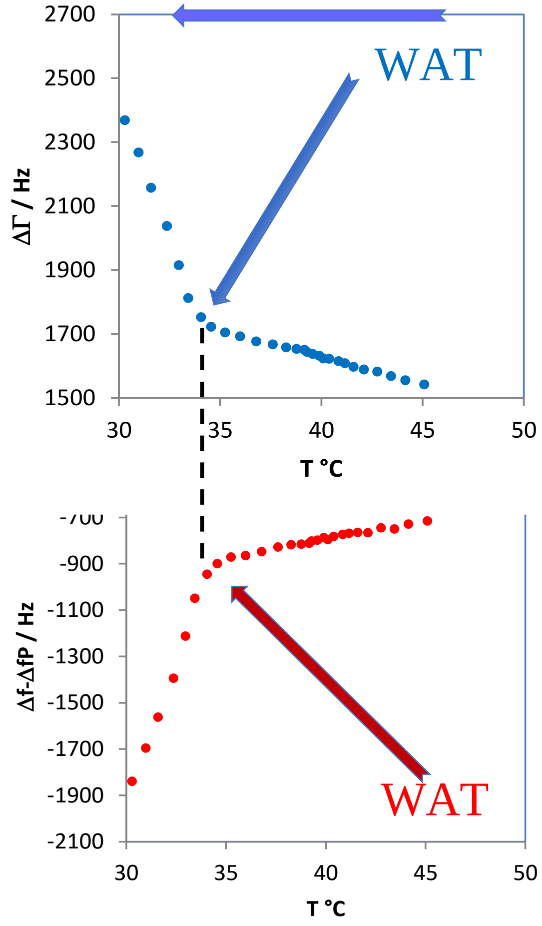
$\sqrt{\rho\eta_{\text{fluid}}} \nearrow \quad \Delta f_{\text{fluid}} \searrow \quad \Delta\Gamma_{\text{fluid}} \nearrow$

$$\Delta f_{n,oil} = -\sqrt{n}\frac{C_m}{\sqrt{\pi f_0}}\sqrt{\rho_{oil}\eta_{oil}} - n2C_m\rho h_D$$

$$\Delta\Gamma_{n,oil} = \sqrt{n}\frac{C_m}{\sqrt{\pi f_0}}\sqrt{\rho_{oil}\eta_{oil}}(1+R)$$

Constant Mass Cooling

Live oil : 400 bar

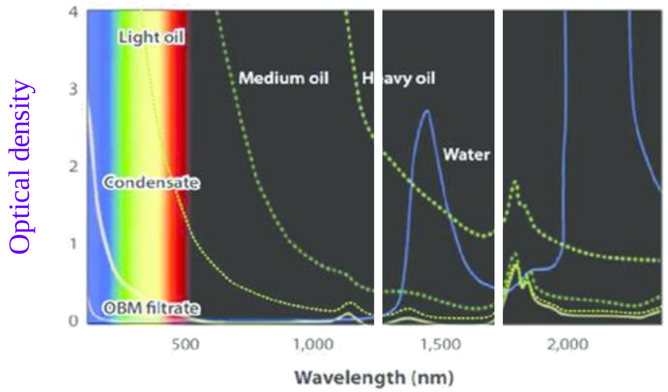


Direct observation

Under visible light, crude oils absorb most of the radiation and appear as dark fluids ➔ **in situ observation of phase transitions is limited.**

Transmittance of a material is a function of the:

- ➢ thickness of the sample ➔ **Fluid sample thickness ↘ 1 to 1/10 mm**
- ➢ wavelength of the incident light ➔ **Visual** ⟶ **Infra Red :** 1 - 2 μm,



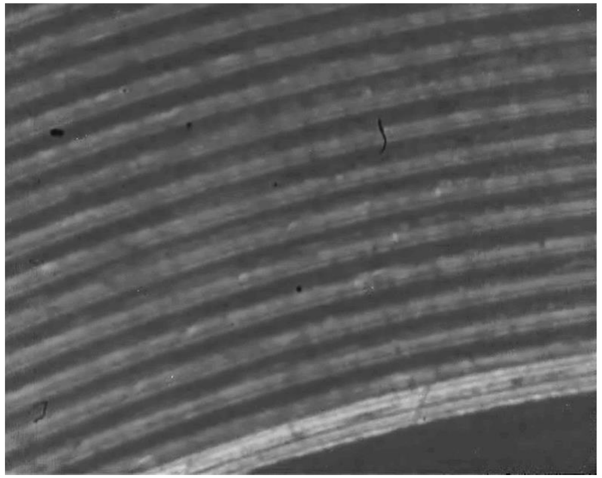
Spectra of different fluids

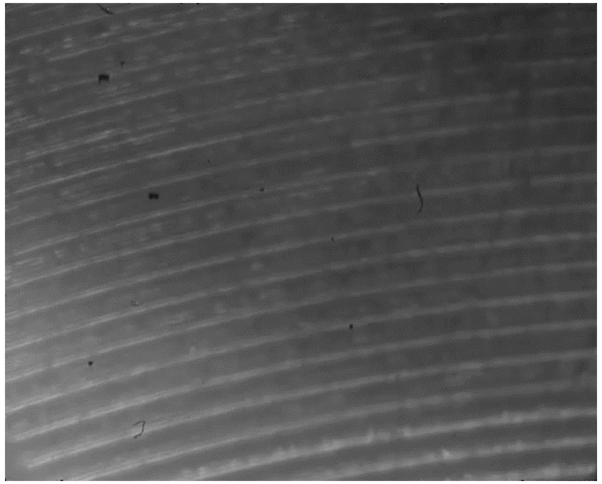
SWIR

PVT CELL with SWIR CAMERA

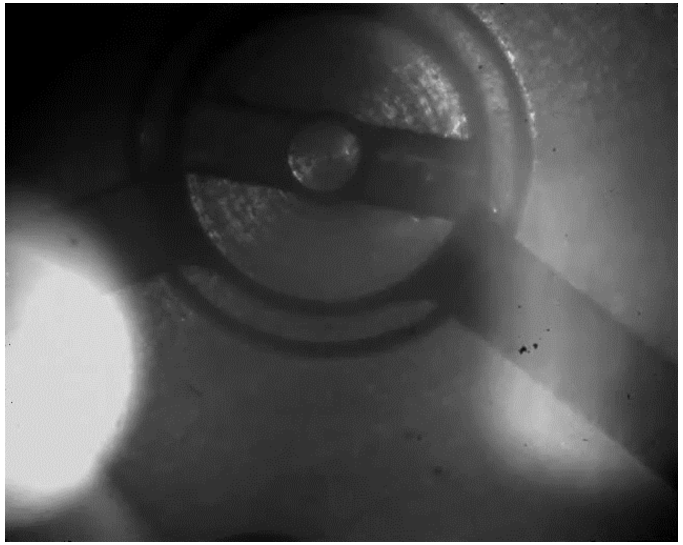
Device

Empty PVT

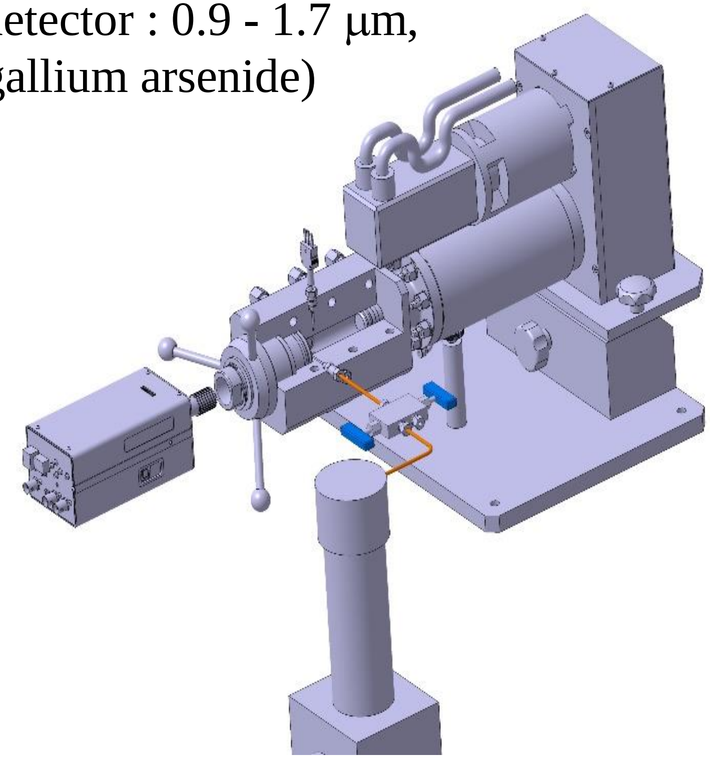




PVT charged with oil



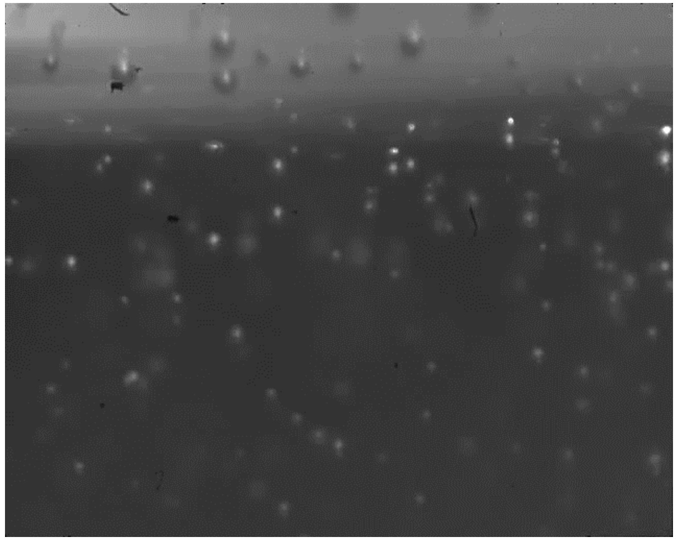
InGaAs detector : 0.9 - 1.7 µm,
(indium gallium arsenide)

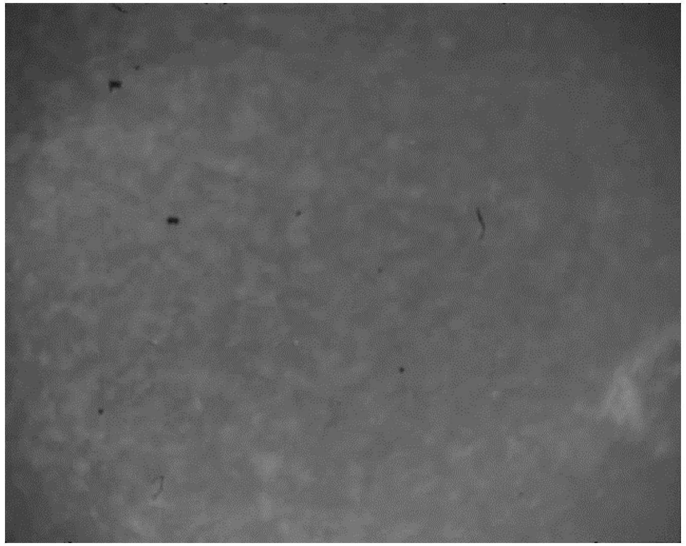


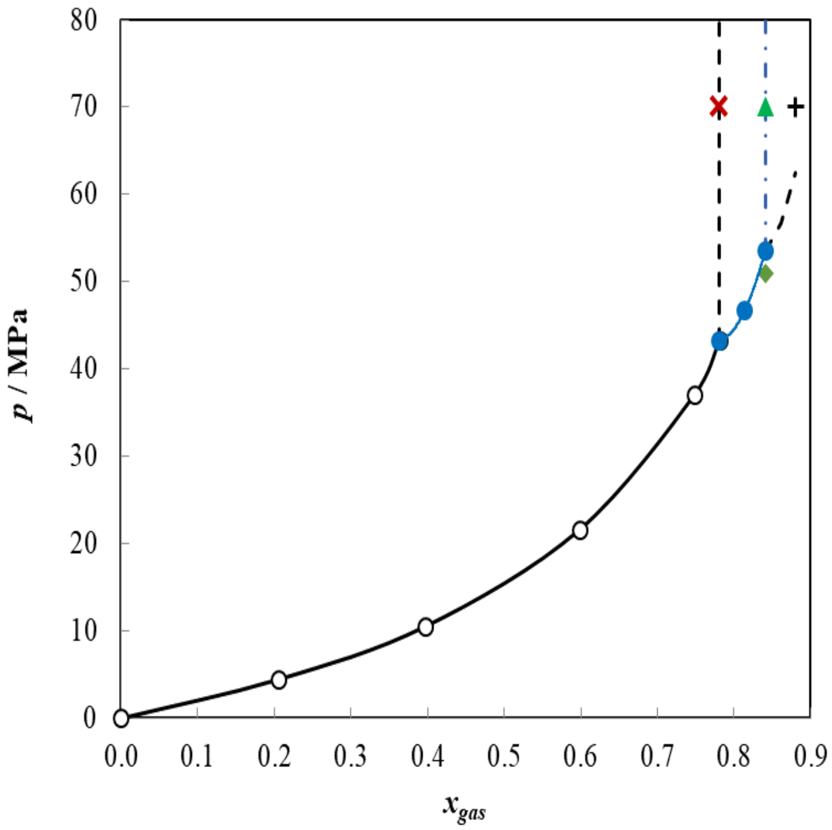
- Fixed focal 12.5 mm length lens
- long working distance objective lens
  - x4
  - x8

PVT CELL with SWIR CAMERA

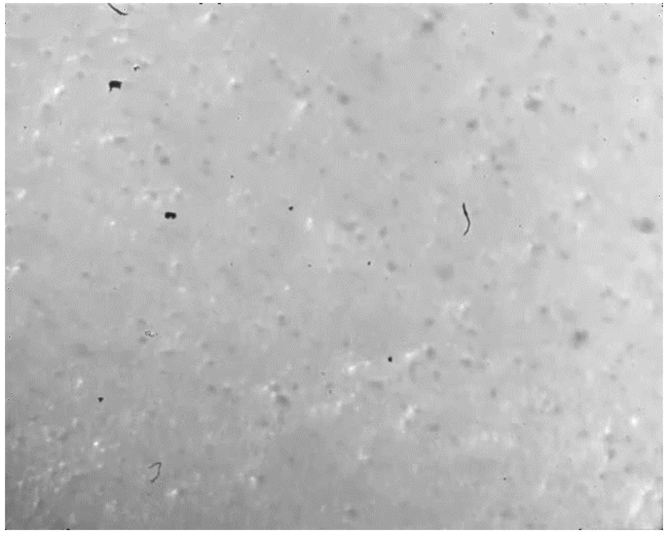
LV / LL / LLV

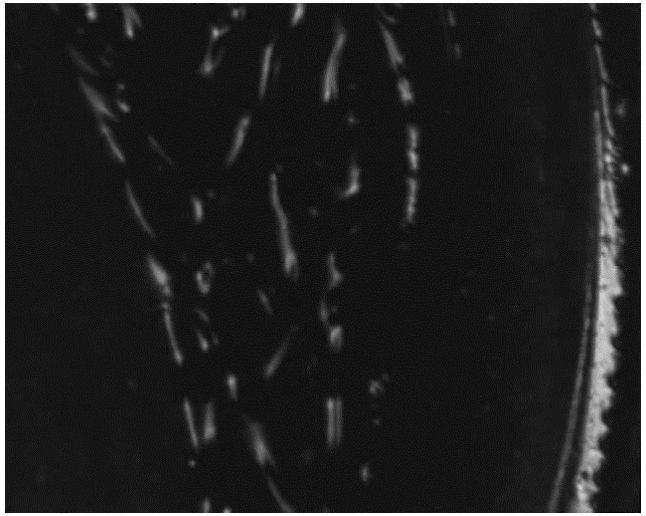


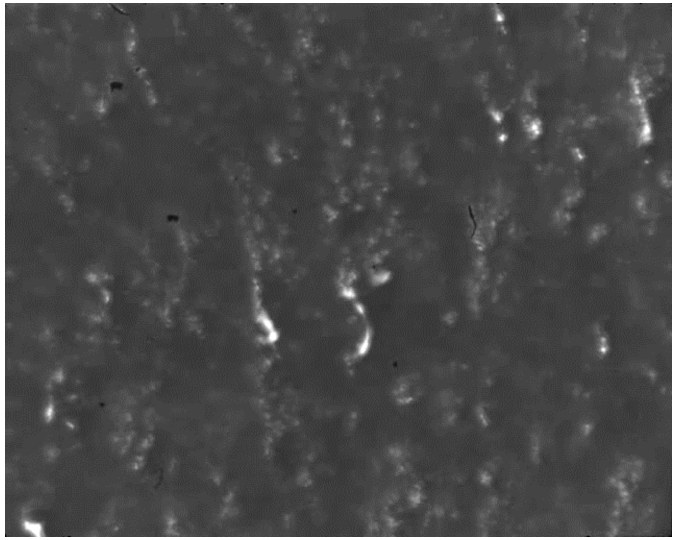


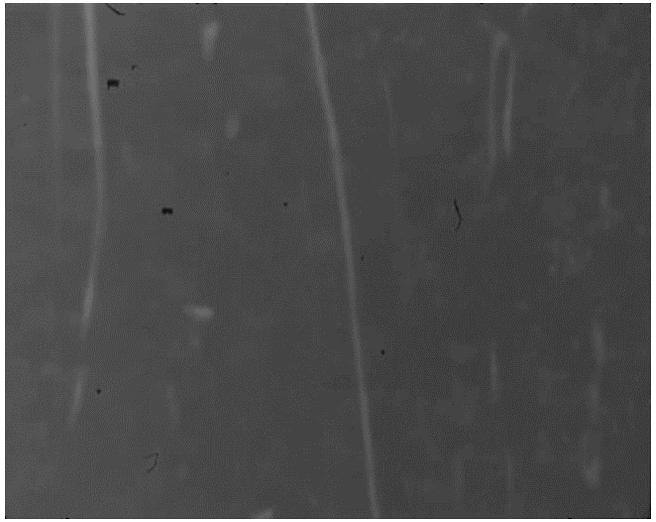


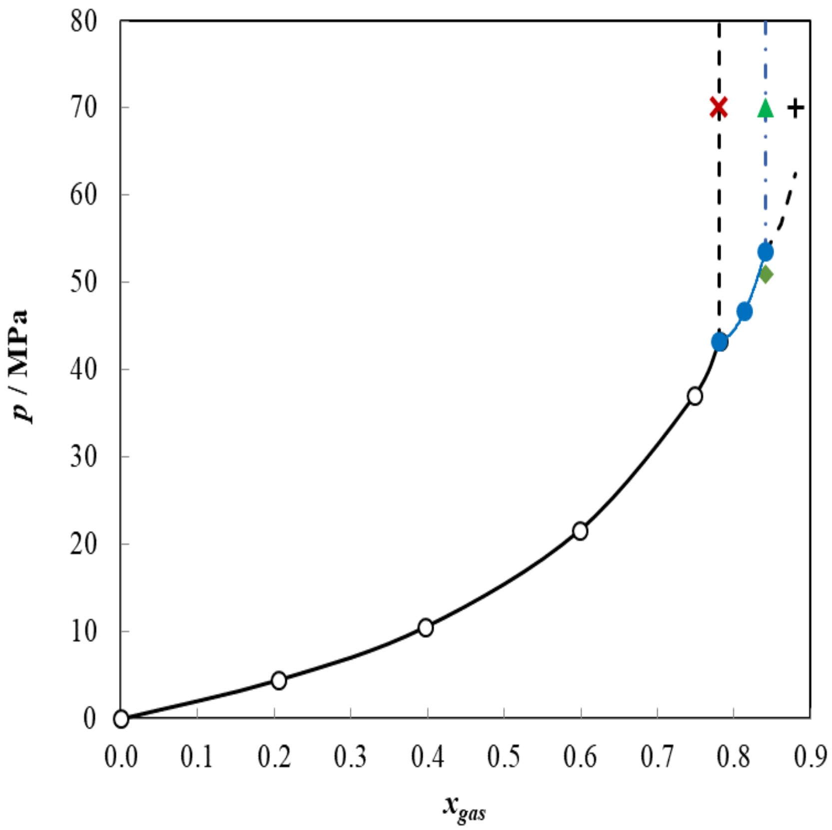
P,x phase diagram of
Recombined gas + PS oil



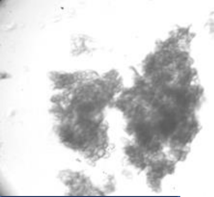




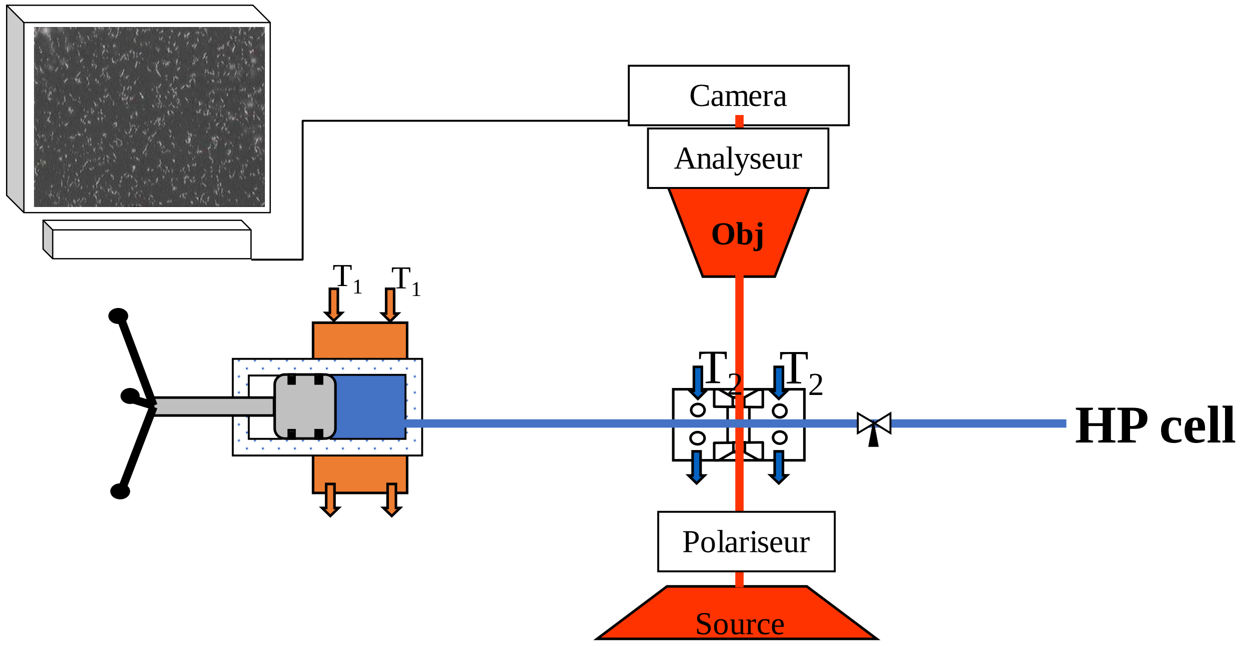


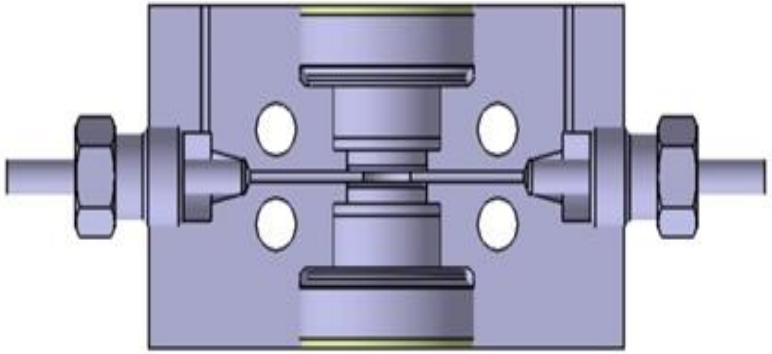


P,*x* phase diagram of
Recombined gas + PS oil



HP Microscopy



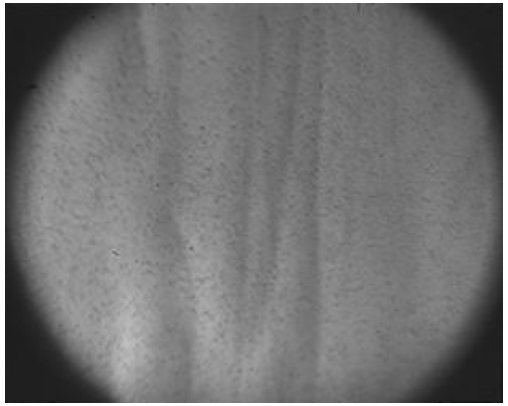


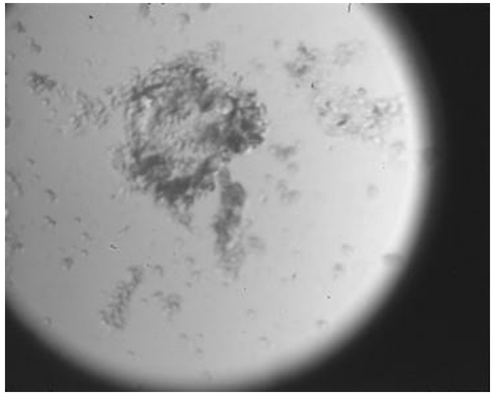
Gap: 1 mm

Magnification: 5 ;20; 50

Visual camera

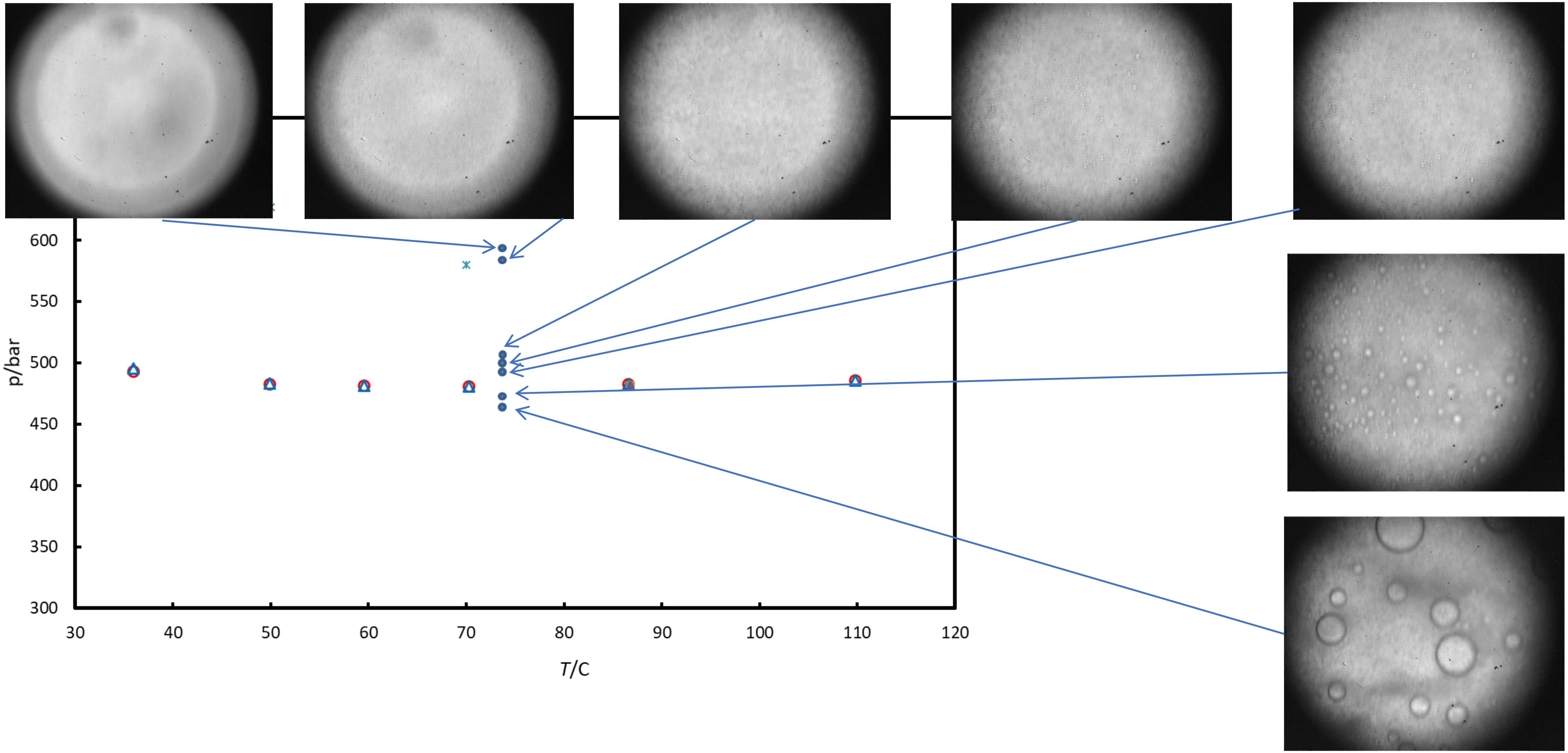
SWIR camera





HP Microscopy + SWIR camera

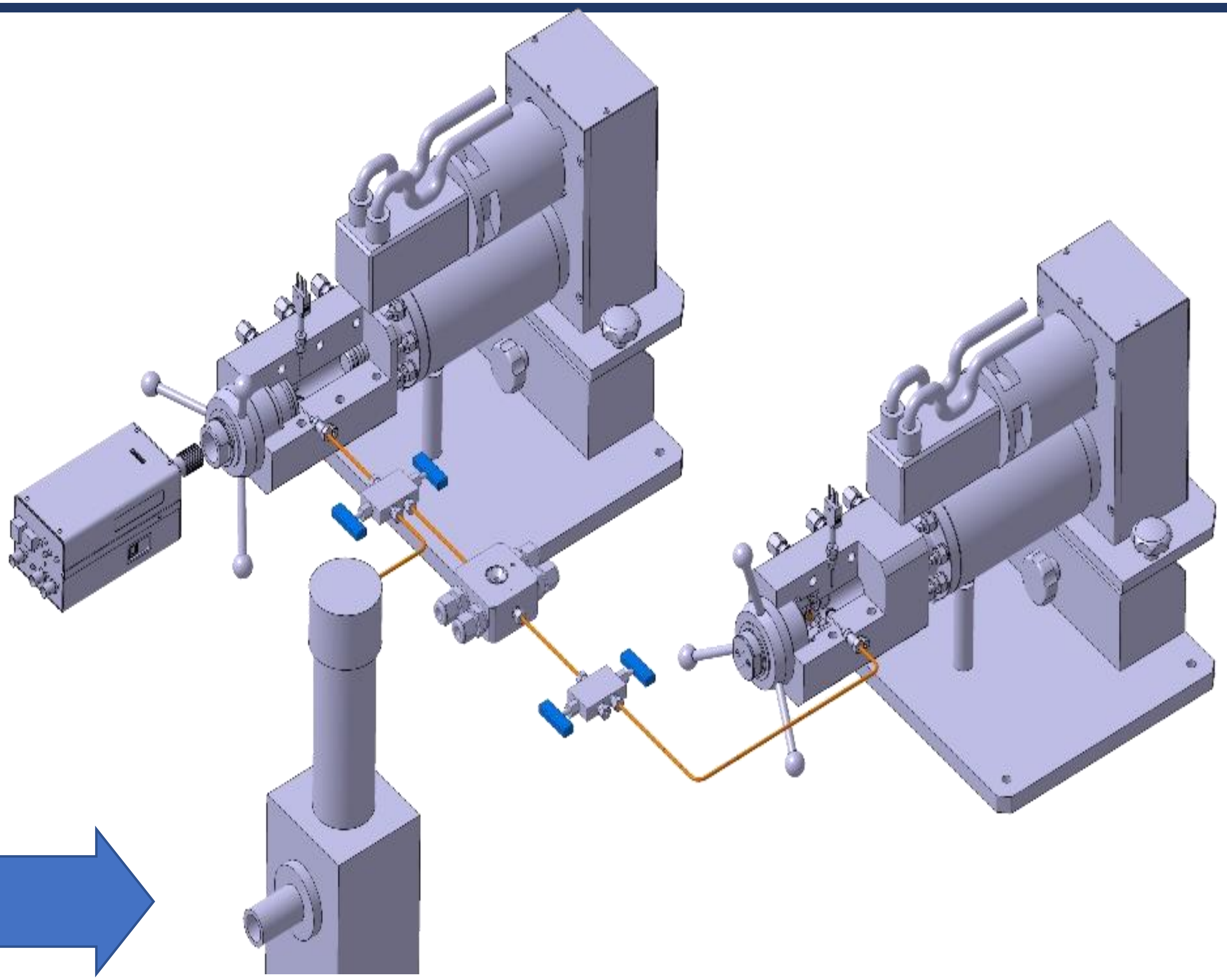
LL / LLV



Conclusion

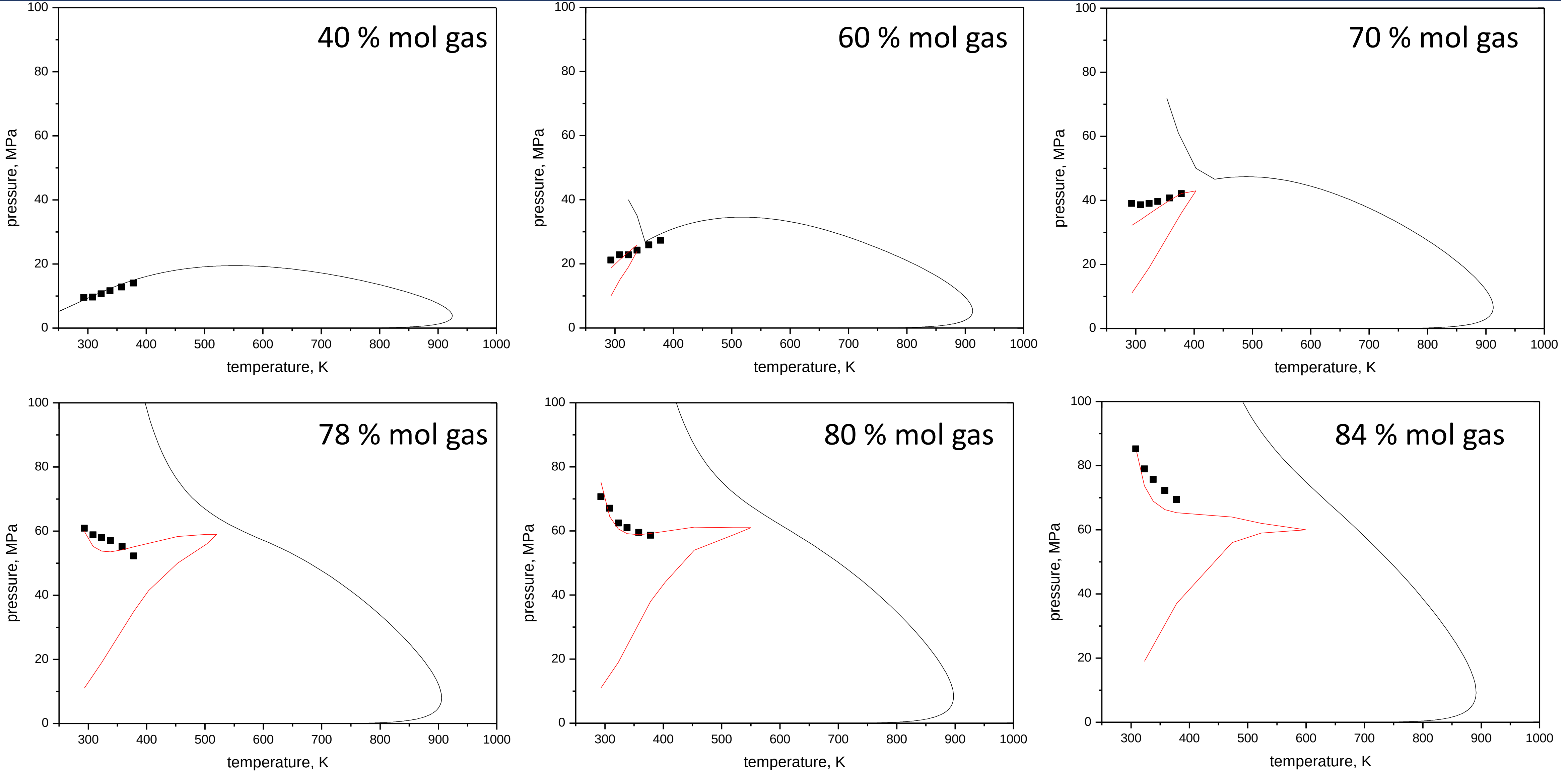
Combined Investigation using 3 devices

Full characterization of PS oil in reservoir conditions

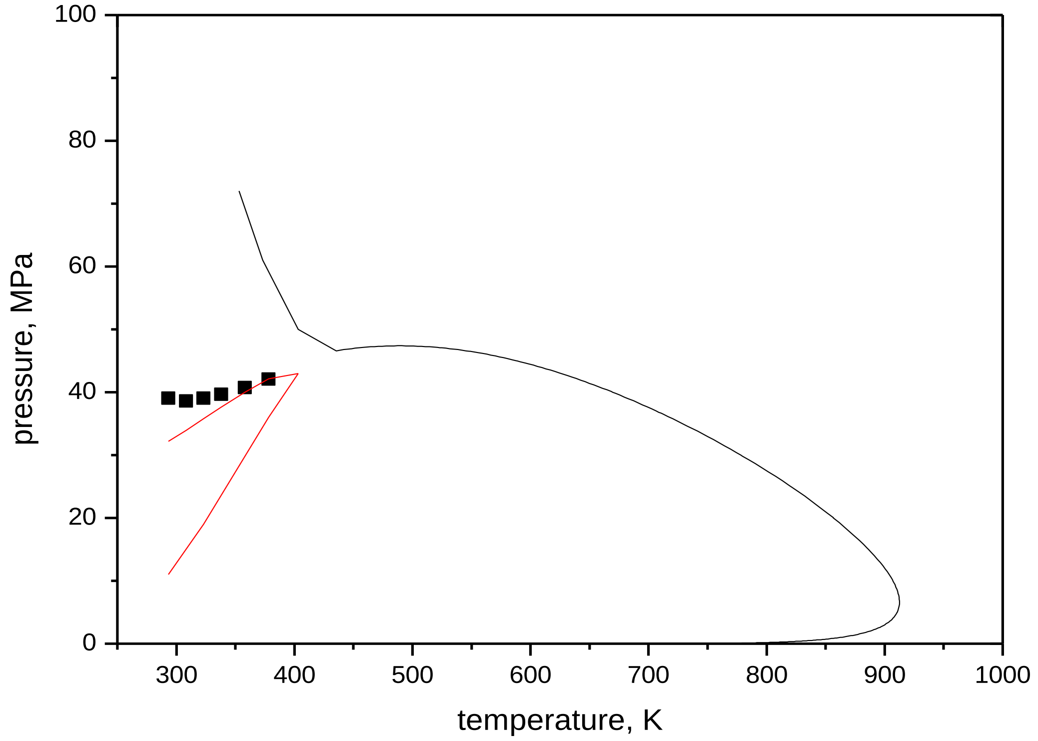


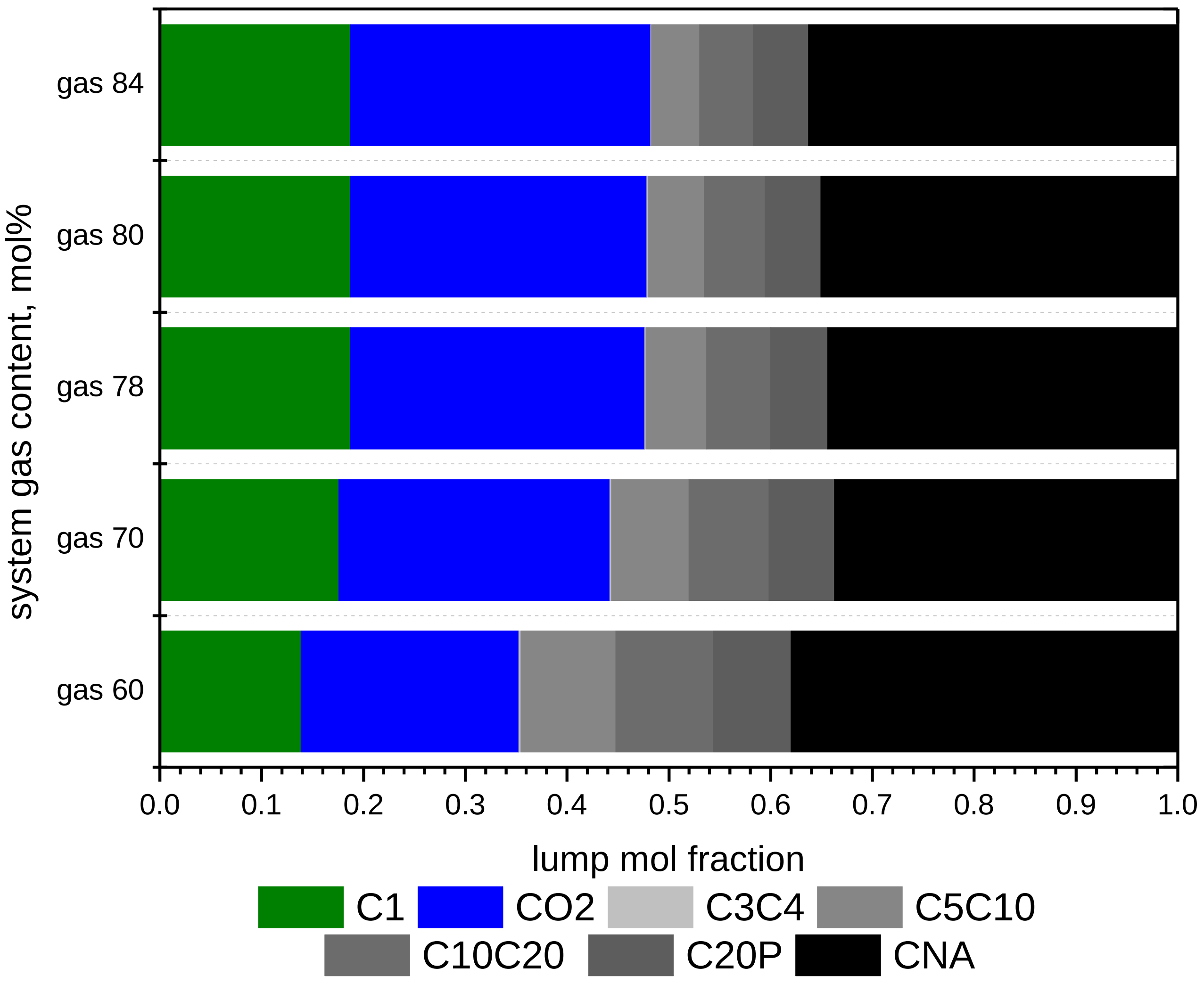
Conclusion

Characterization of gas injection



Conclusion


100
80
60
40
20
0
300
400
500
600
700
800
900
1000
pressure, MPa
temperature, K


gas 84
gas 80
gas 78
gas 70
gas 60
system gas content, mol%
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
lump mol fraction
C1
CO2
C3C4
C5C10
C10C20
C20P
CNA

Merci de votre attention

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