

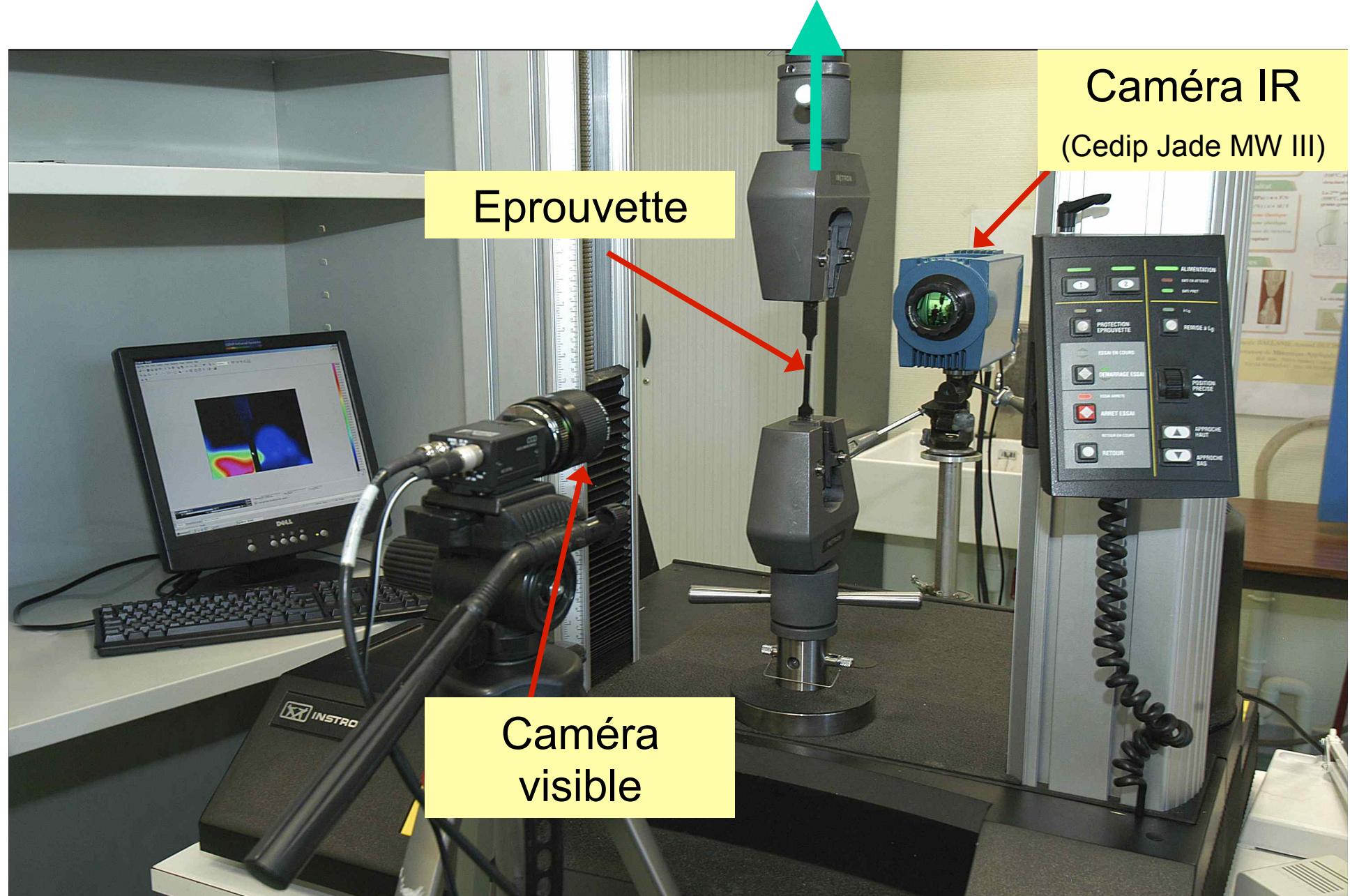
Observations cinématiques et thermiques accompagnant l'effet PLC sur un alliage AlMg

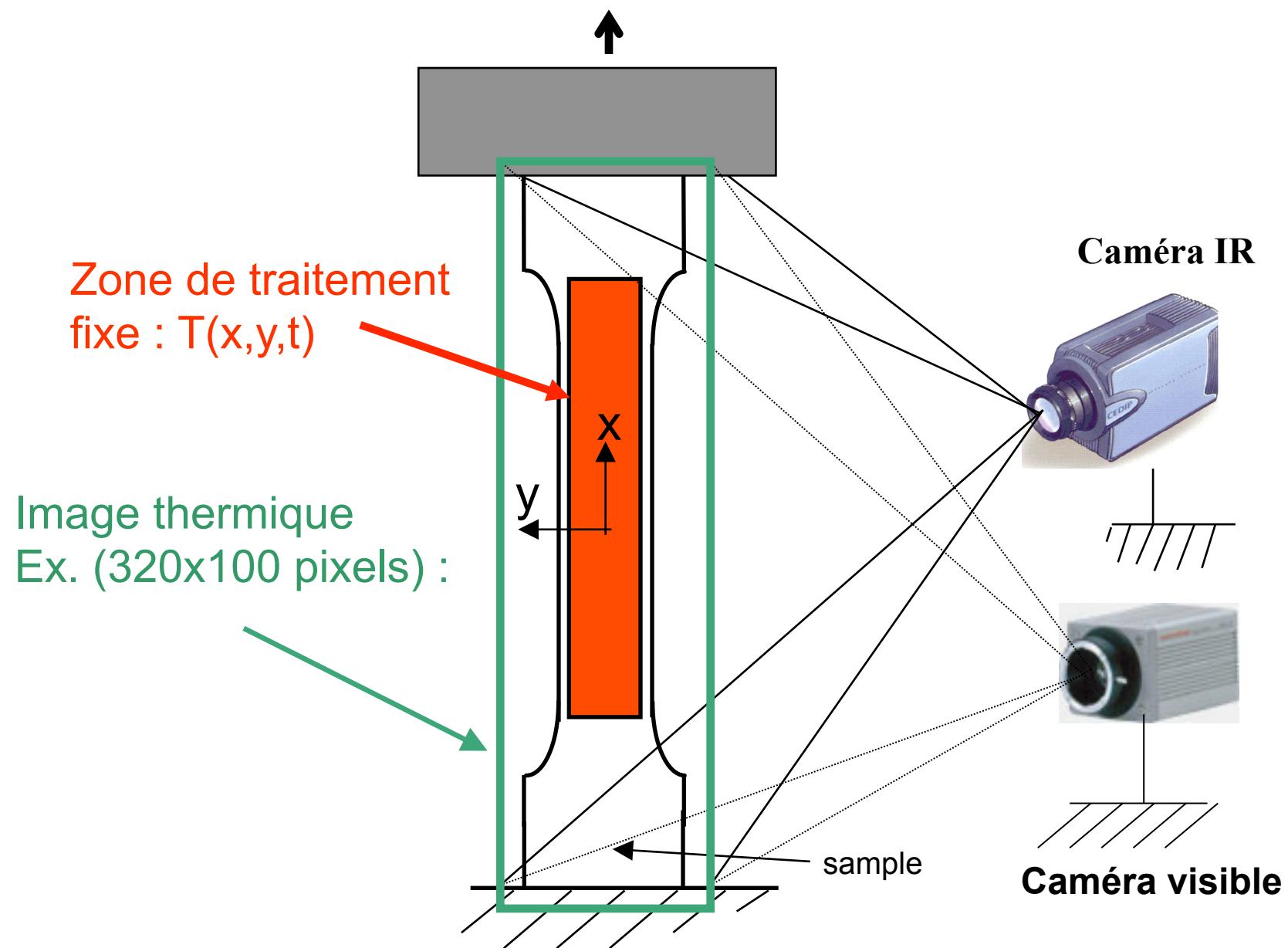
Hervé Louche^(1,2), Pierre Vacher⁽²⁾ et Robert Arrieux⁽²⁾

⁽¹⁾ LMGC, CNRS/Université Montpellier 2, Montpellier

⁽²⁾ SYMME, Université de Savoie, Annecy



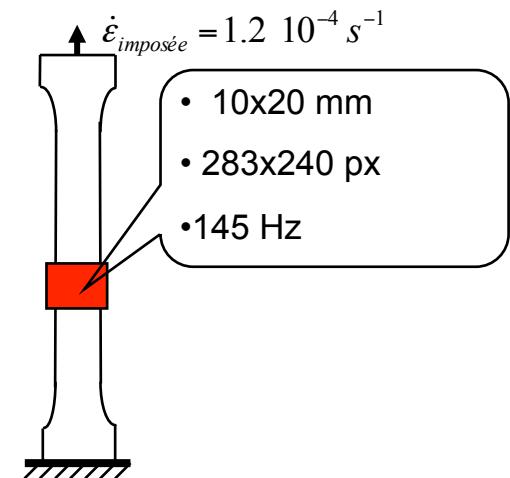
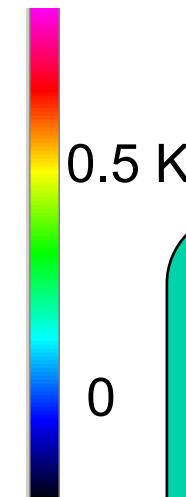
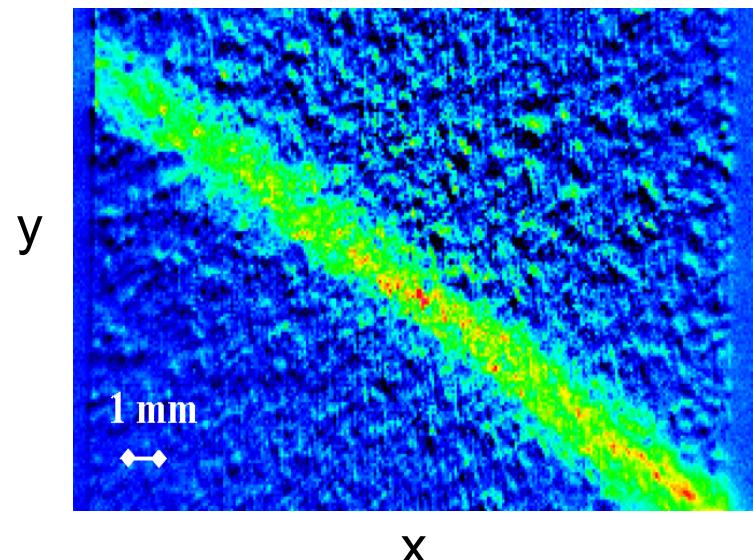




Exemple de champ thermique associé à une localisation (PLC)

Essai de traction quasi-statique sur un Alliage AlMg (A5086)

Bande PLC (types A,B,C)



- Chargement mécanique → Variations de température
- CL thermiques → Champs thermiques (le plus souvent...) hétérogènes...
- Intensité des variations de température → intensité des phénomènes physiques associés?
- Comment relier ces variations de température aux comportements (modèles) du matériau?

**Estimation et analyse des sources de chaleur
(causes) associées**



Application (ici) à deux types de localisation (Lüders, **PLC**)

1) Estimations des champs de sources de chaleur à partir de champs thermiques

2) Etude de phénomènes de localisation

- Bandes de Lüders et striction
- Bandes PLC

3) Conclusions

Equation diffusion de la chaleur 3D

$$\rho C \frac{dT}{dt} + \operatorname{div}(\vec{q}) = d_1 + \rho T \frac{\partial^2 \psi}{\partial T \partial \varepsilon^e} \dot{\varepsilon}^e + \rho T \frac{\partial^2 \psi}{\partial T \partial \alpha_j} \dot{\alpha}_j + r, \quad j = 2, \dots, n$$

Dissipation intrinsèque Thermoelasticité Couplages Thermomechaniques Sources de chaleur externes
 Inertie thermique Diffusion

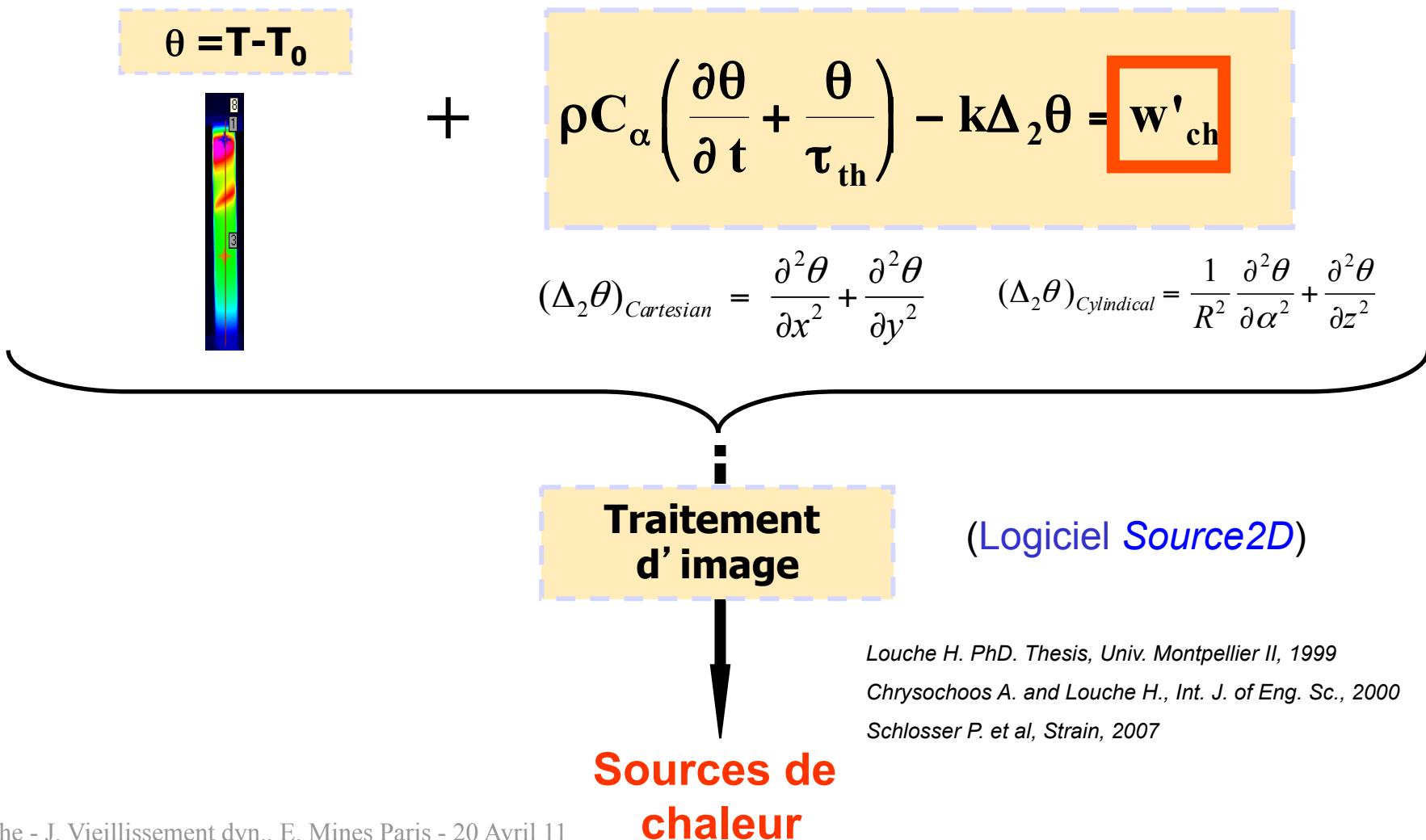
Sources de chaleur w'_{ch}

$$\boxed{\rho C \frac{dT}{dt} - k \Delta T = w'_{ch} + r}$$

$w'_{Dissipée} + w'_{Couplages Thermo Méca}$

Equation diffusion de la chaleur 2D

(Hyp. Coques minces (plaque ou tube) : température et sources homogènes dans l' épaisseur



1) Estimations des champs de sources de chaleur à partir de champs thermiques

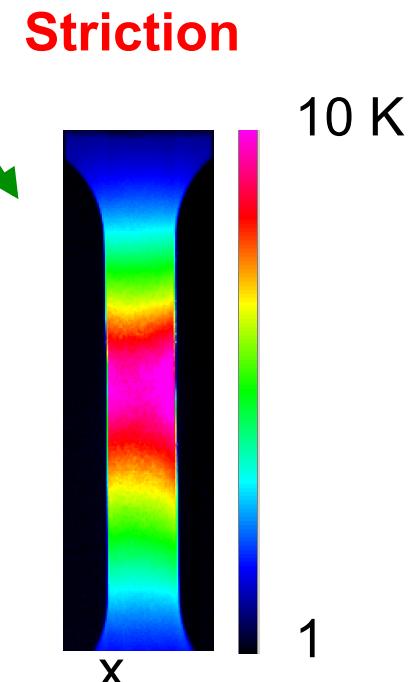
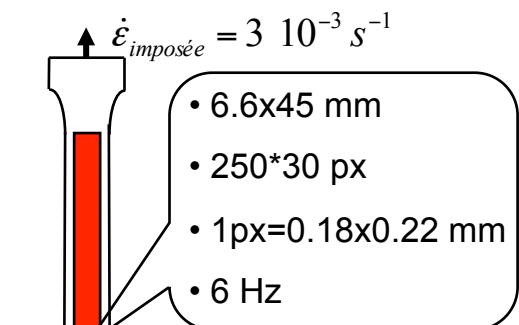
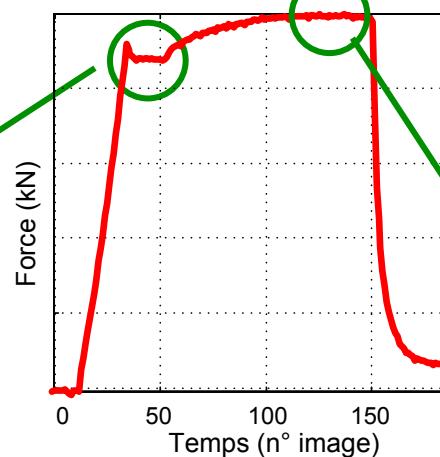
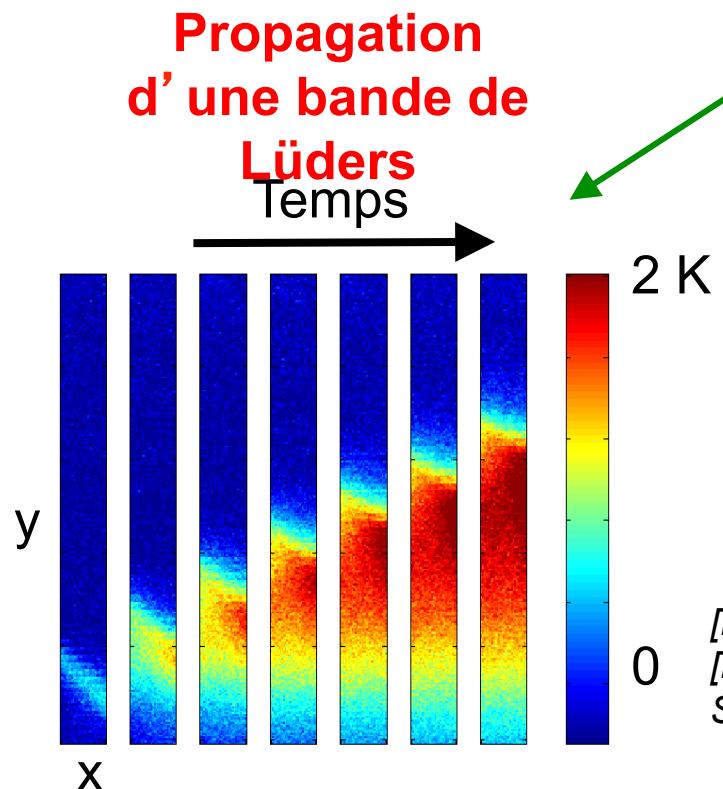
2) Etude de phénomènes de localisation

- Bandes de Lüders et striction
- Bandes PLC

3) Conclusions

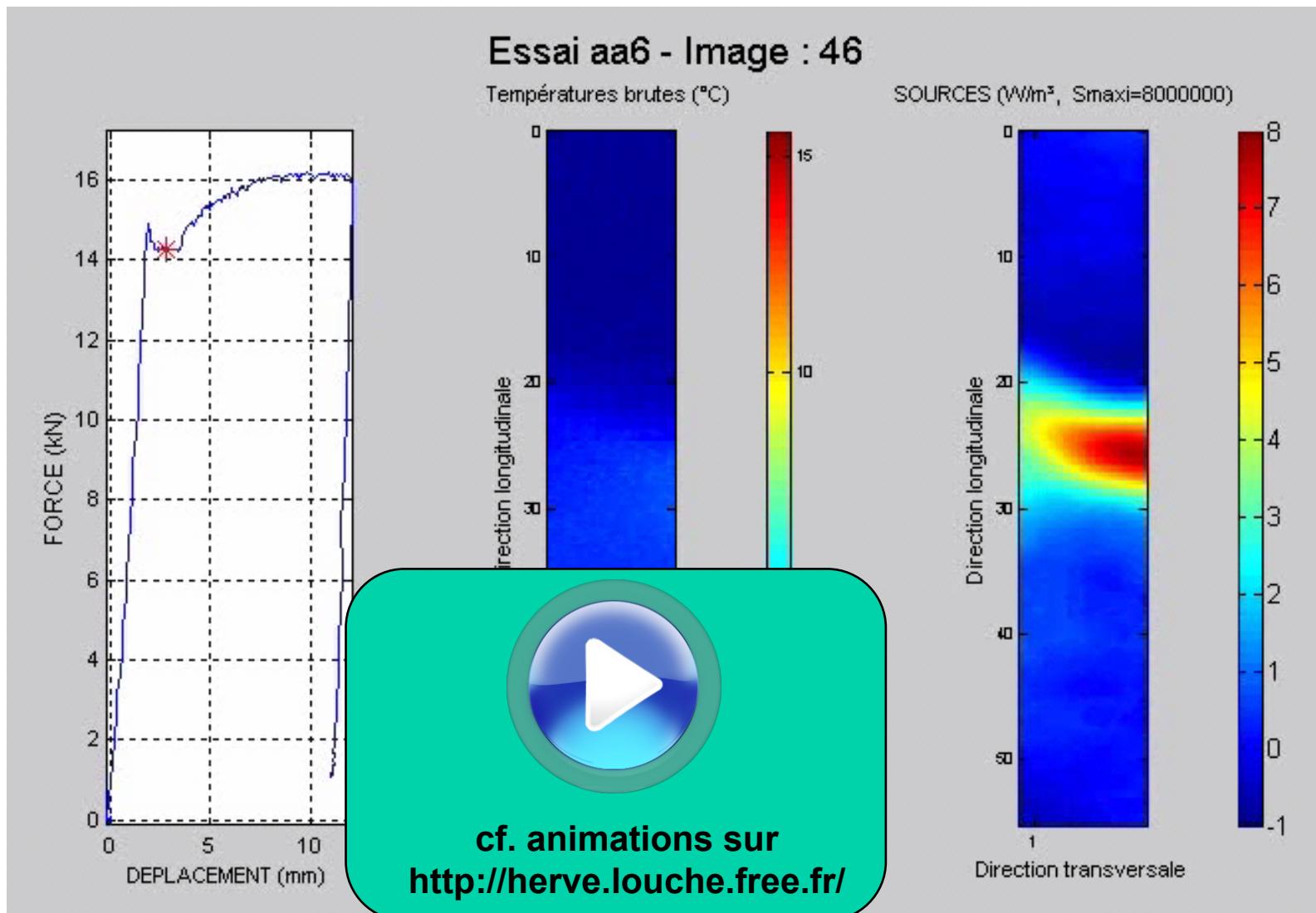
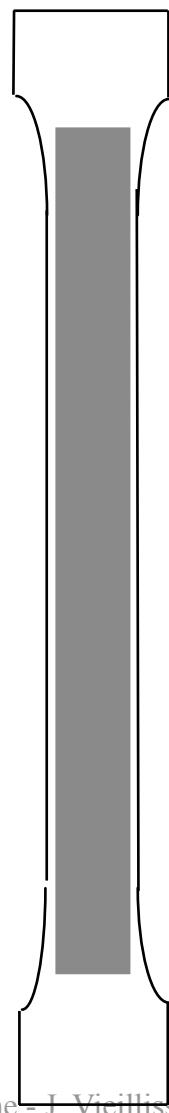
Champs thermiques et cinématiques associés à différents phénomènes de localisation

1) Essai de traction quasi-statique sur un acier doux

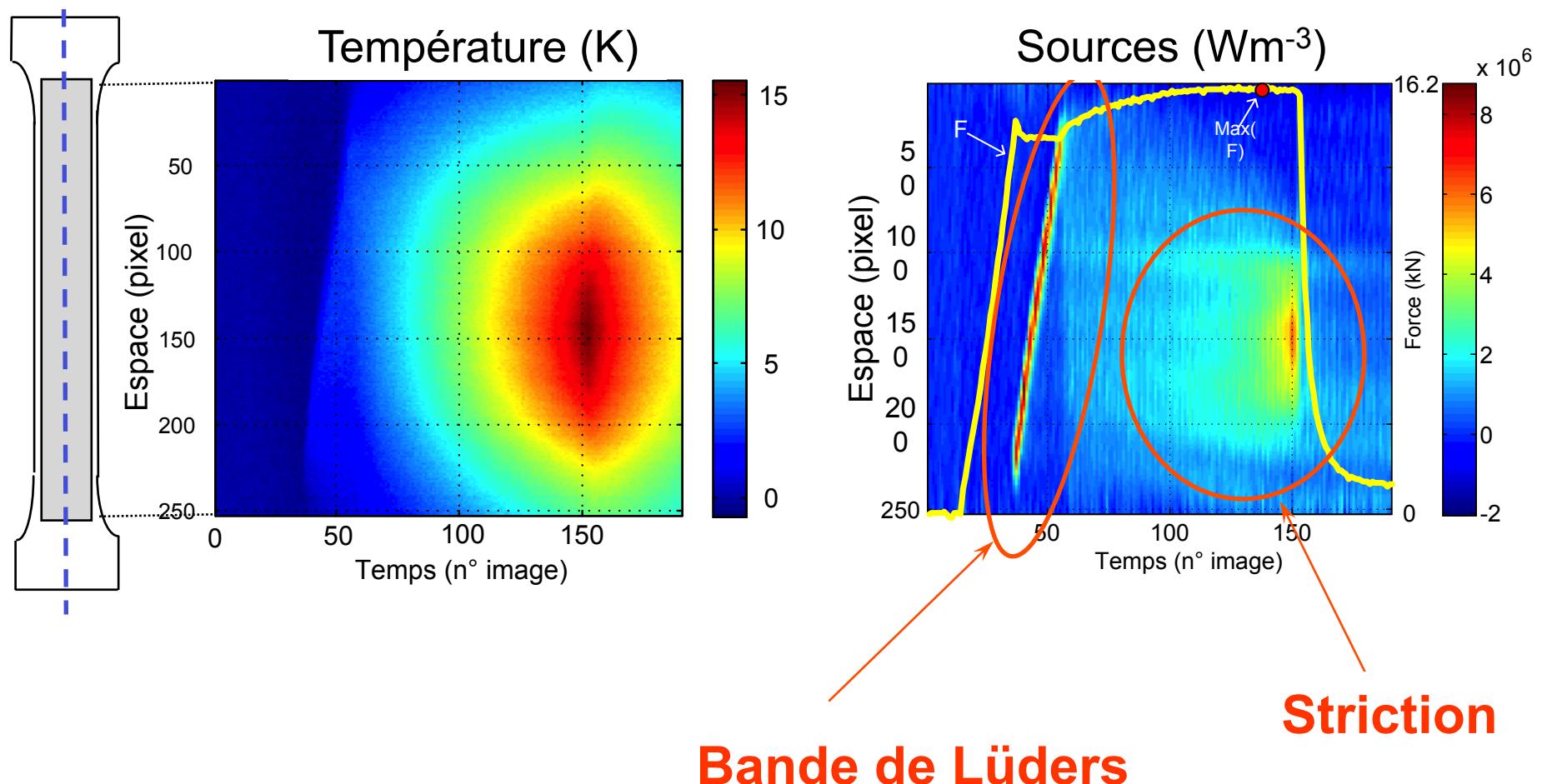


[Louche, PhD, 1999]
[Louche H., Chrysochoos A., Mater.
Sci. Eng. A., 2001]

S355MC mild Steel - Imposed velocity : 0.15 mm/s



Representation spatio-temporelle



Temperature and Heat sources associated to a Lüders band

«Angle» :

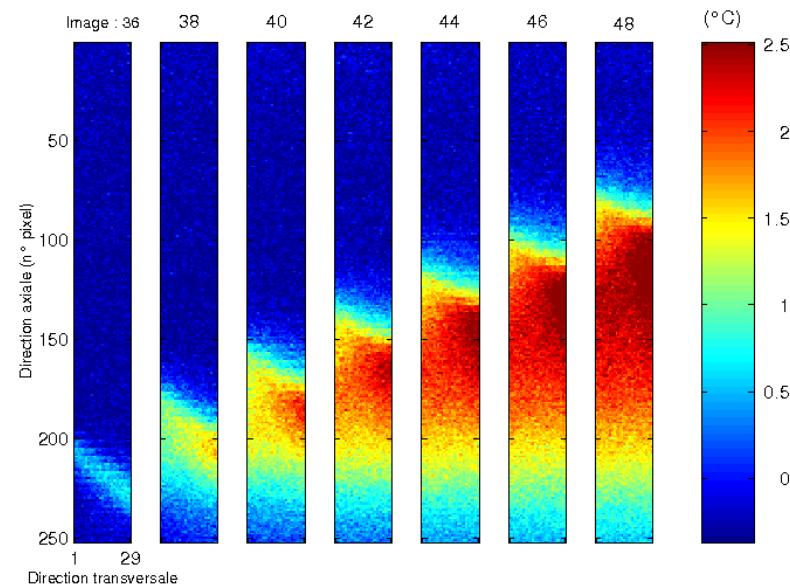
- $\sim 70^\circ$

Velocity :

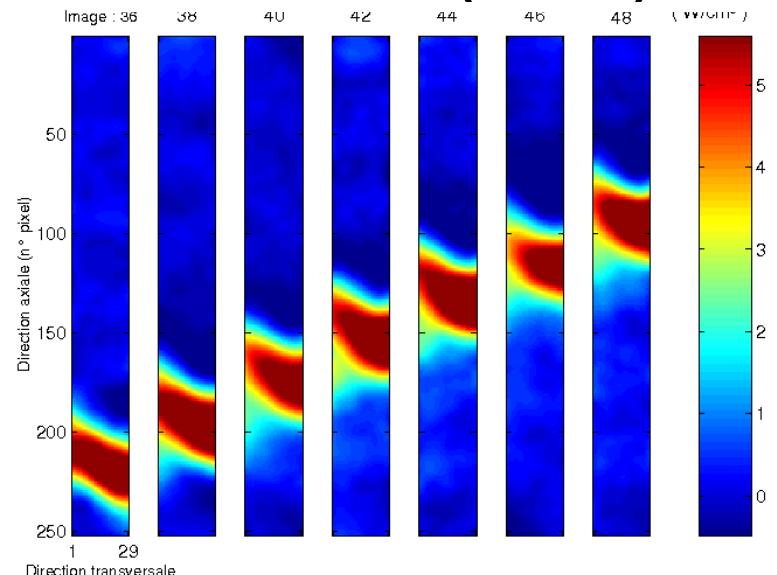
- 4 mm/s

[Louche H., Chrysochoos A.,
Mater. Sci. Eng. A., 2001]

Temperature (K)

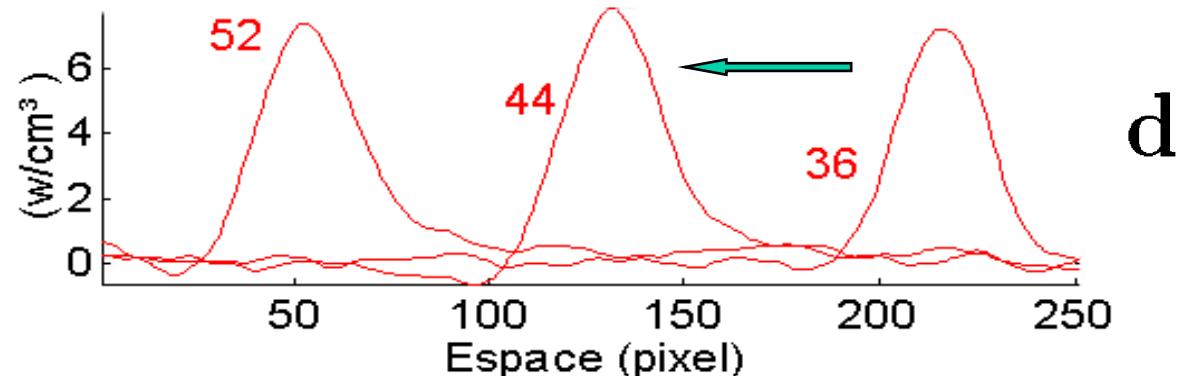


Sources (W/m^3)



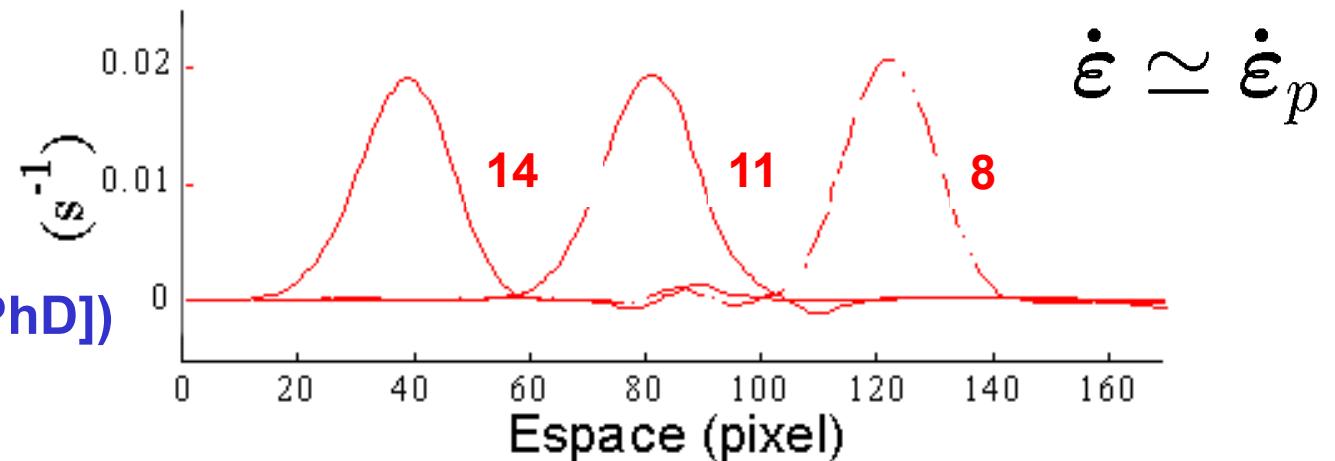
1D Comparison to kinematical fields...

Propagation of a
“Dissipative
wave”



Propagation
“Strain rate
wave”

([Wattrisse 99, PhD])



Proportionality between Dissipation and
Strain rate as... in plasticity models :

$$d_1 = \sigma_o |\dot{\epsilon}_p|$$

1) Estimations des champs de sources de chaleur à partir de champs thermiques

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- Bandes de Lüders et striction
- Bandes PLC

3) Conclusions

PLC1 : champs thermiques
bandes type A
A 5086

PLC2 : champs thermiques
bandes type B
A 5086

PLC3 : champs cin. +EA
bandes type A
A 5854

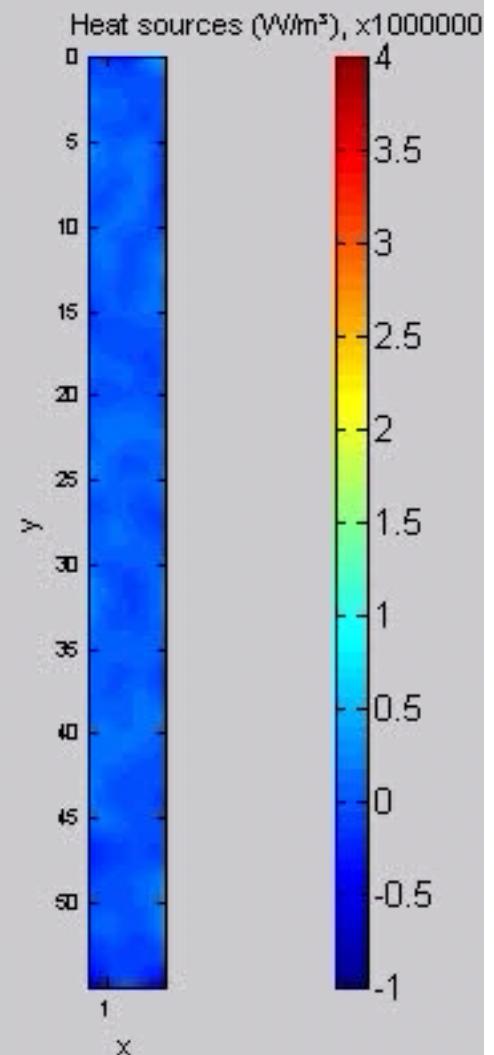
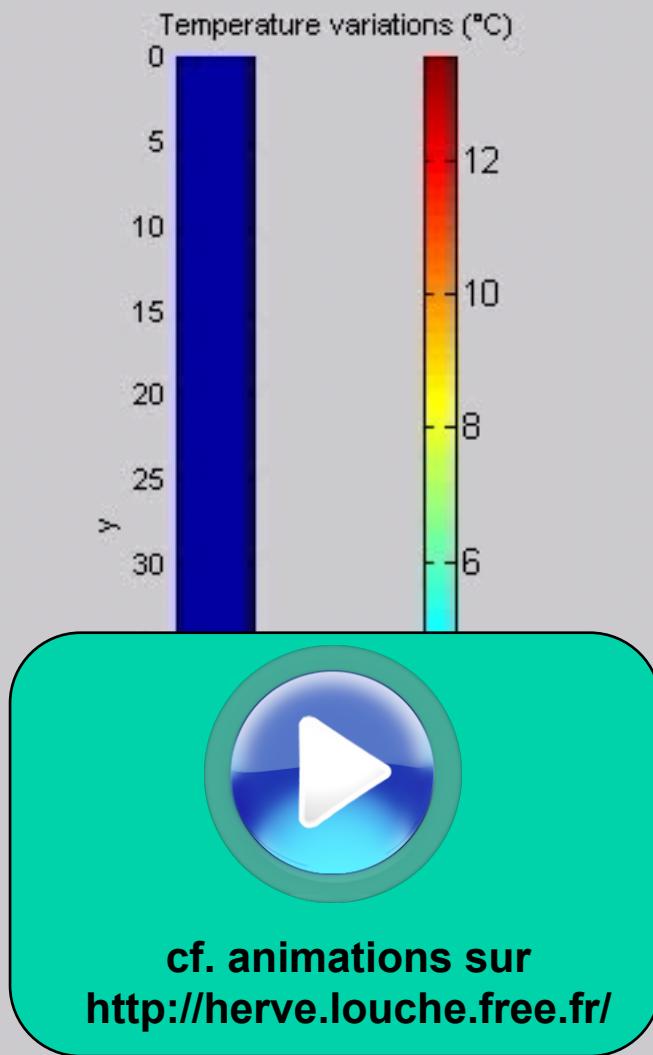
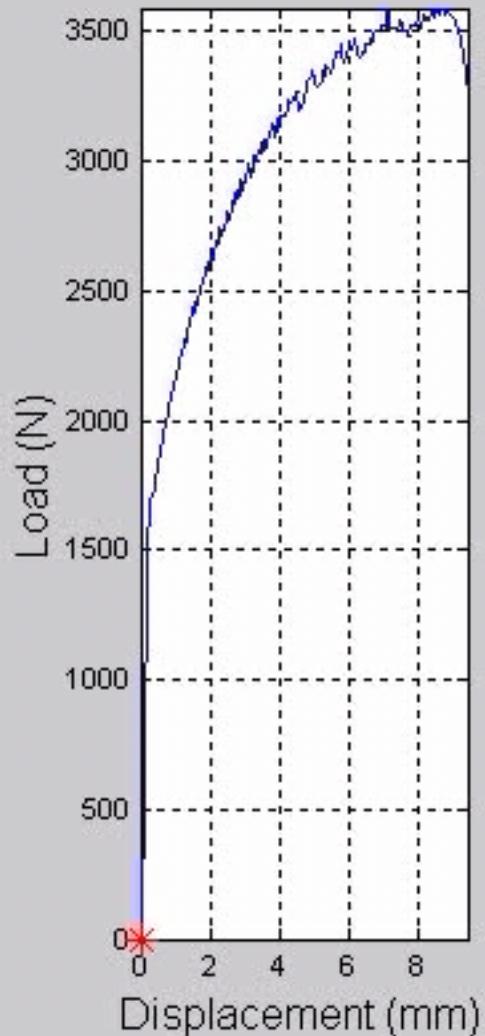
PLC4 : champs cin.+EA
bandes type C
A 5854

PLC 1 : Champs Thermiques

- A5086
- Vitesse de déformation élevée ($2 \cdot 10^{-2} \text{ s}^{-1}$)
→ **bandes type A**
- Images IR : 145 Hz
- 1px : 0.26 mm

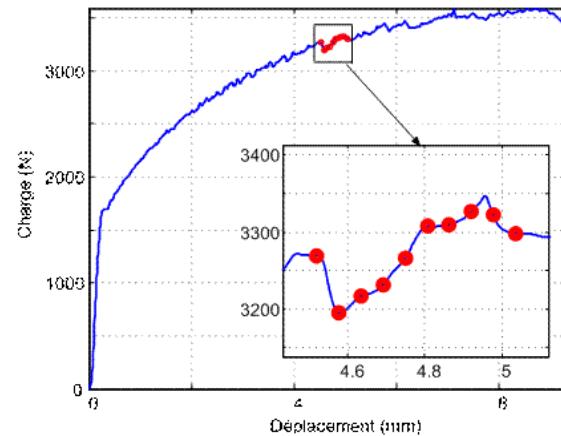
Louche et al , Mater. Sc. Eng. A, 2005

Test plc38 (AlMg alloy 5086) - Image : 1

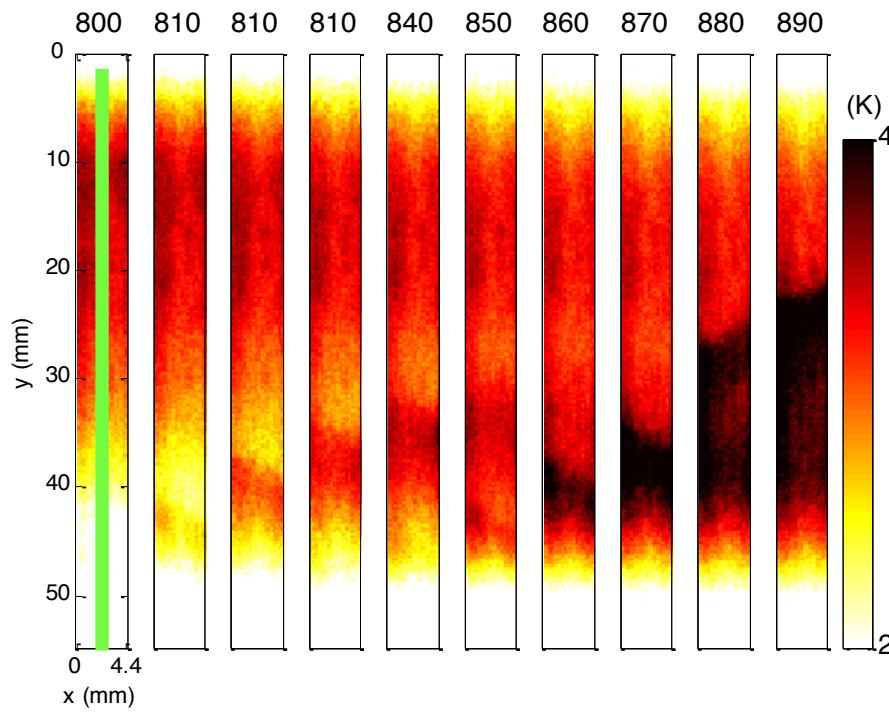


(Hervé Louche - Lmeca - University of Savoie - France - May 04)

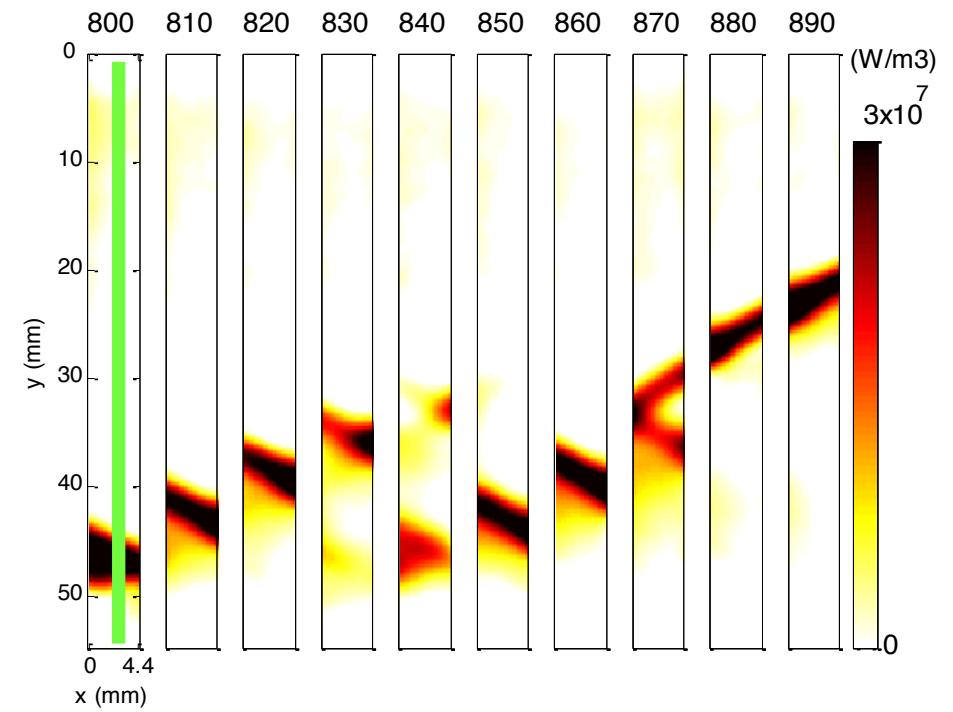
Cf. animation



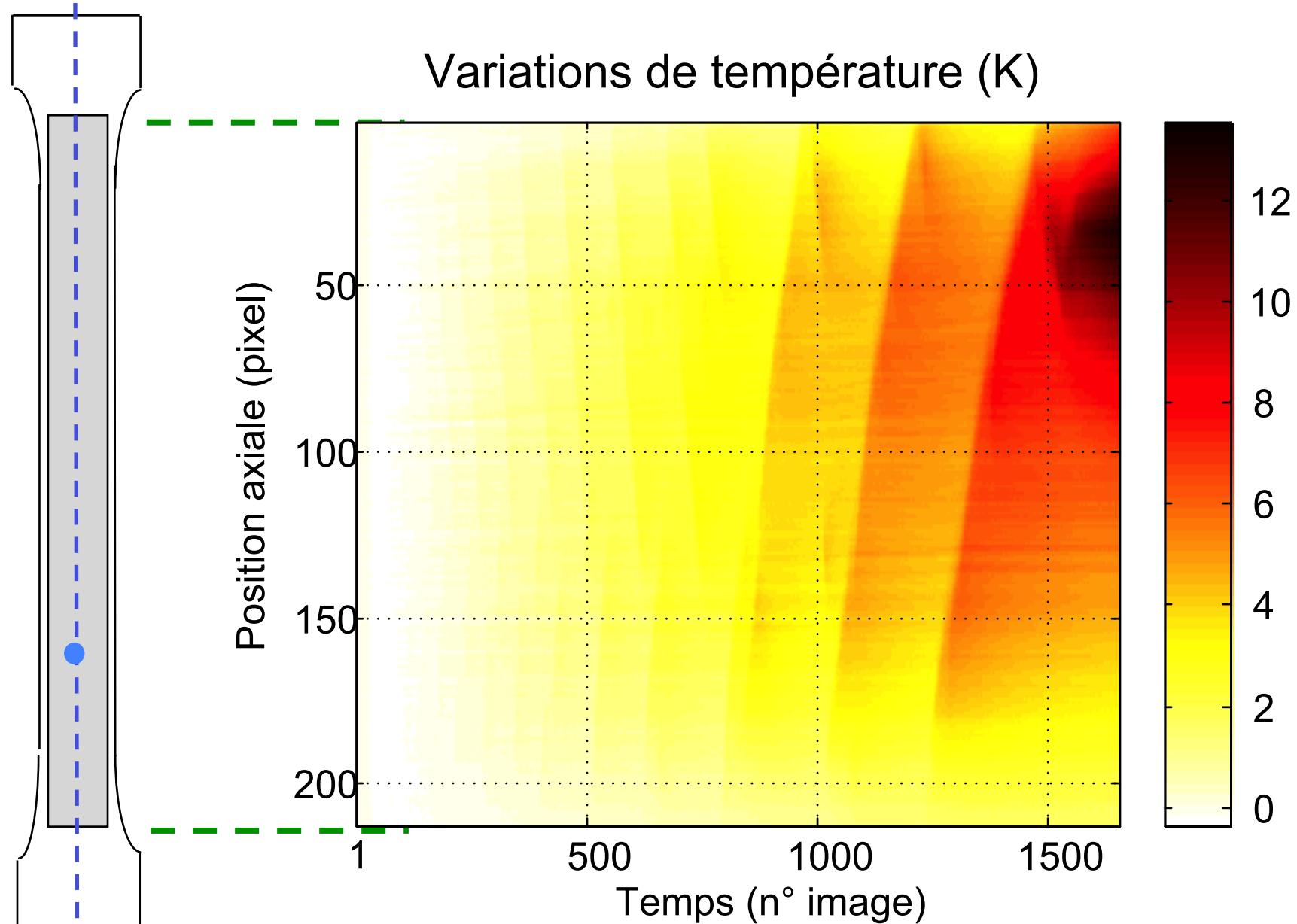
Variations de température



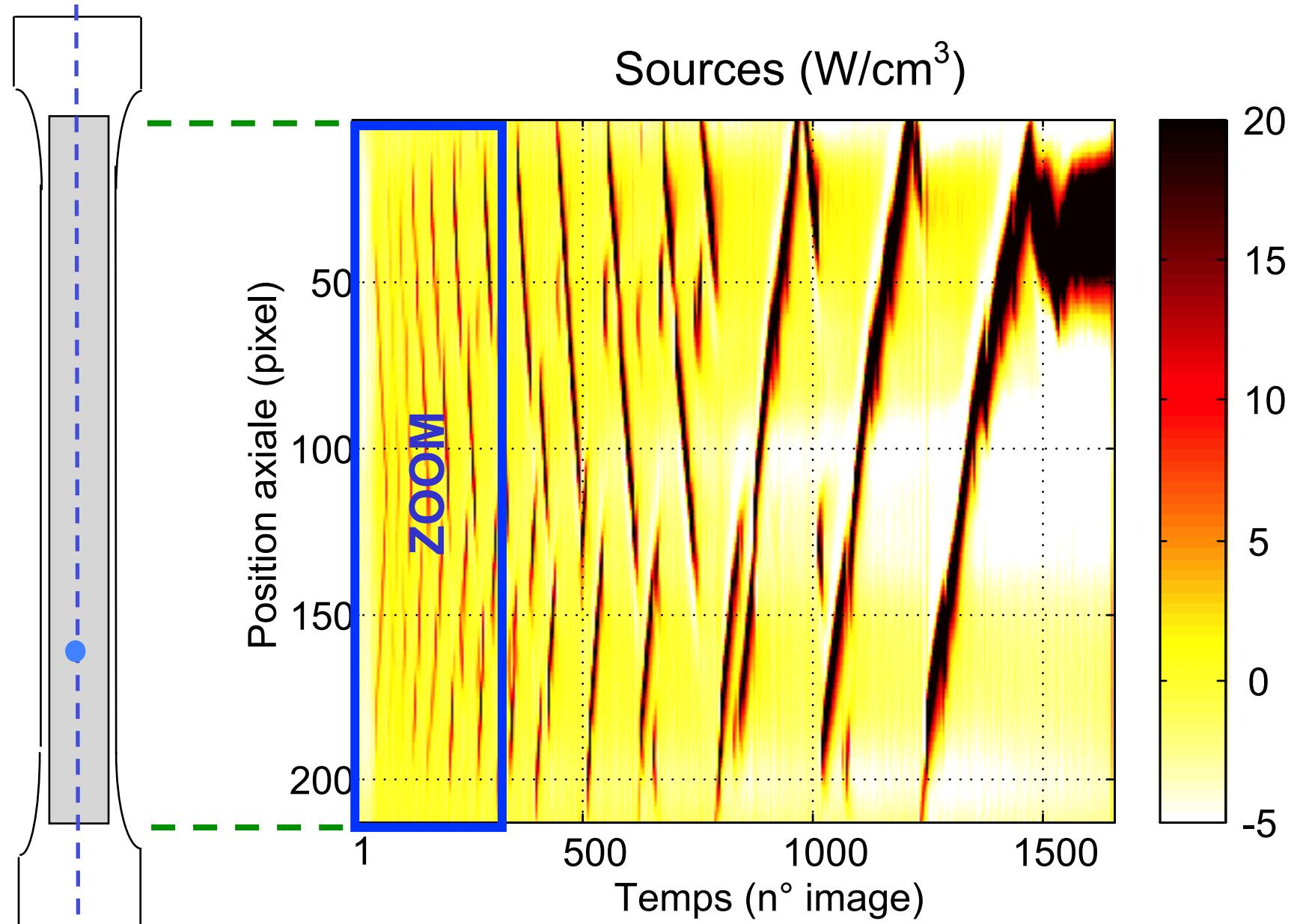
Sources de chaleur

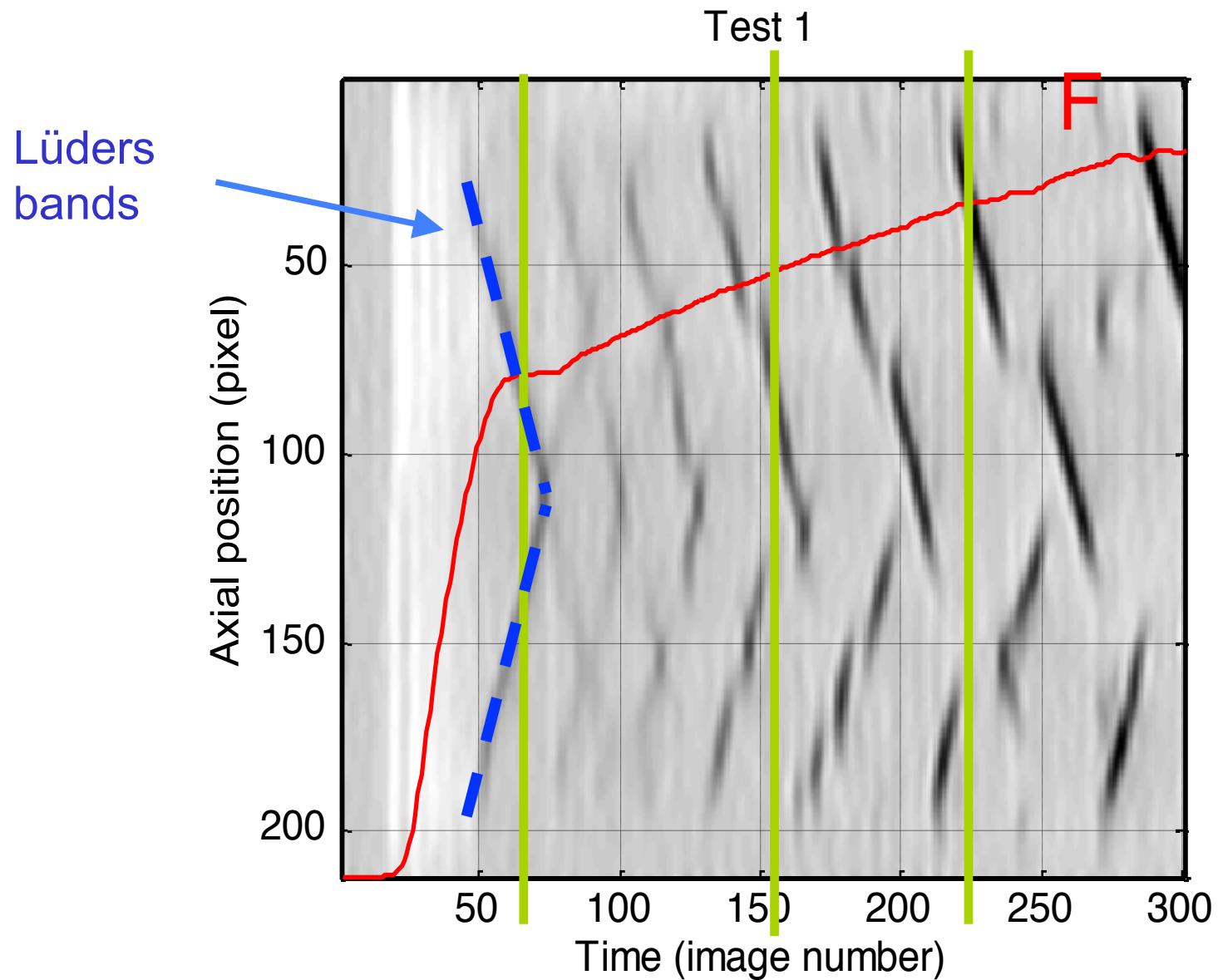


Représentation spatio-temporelle

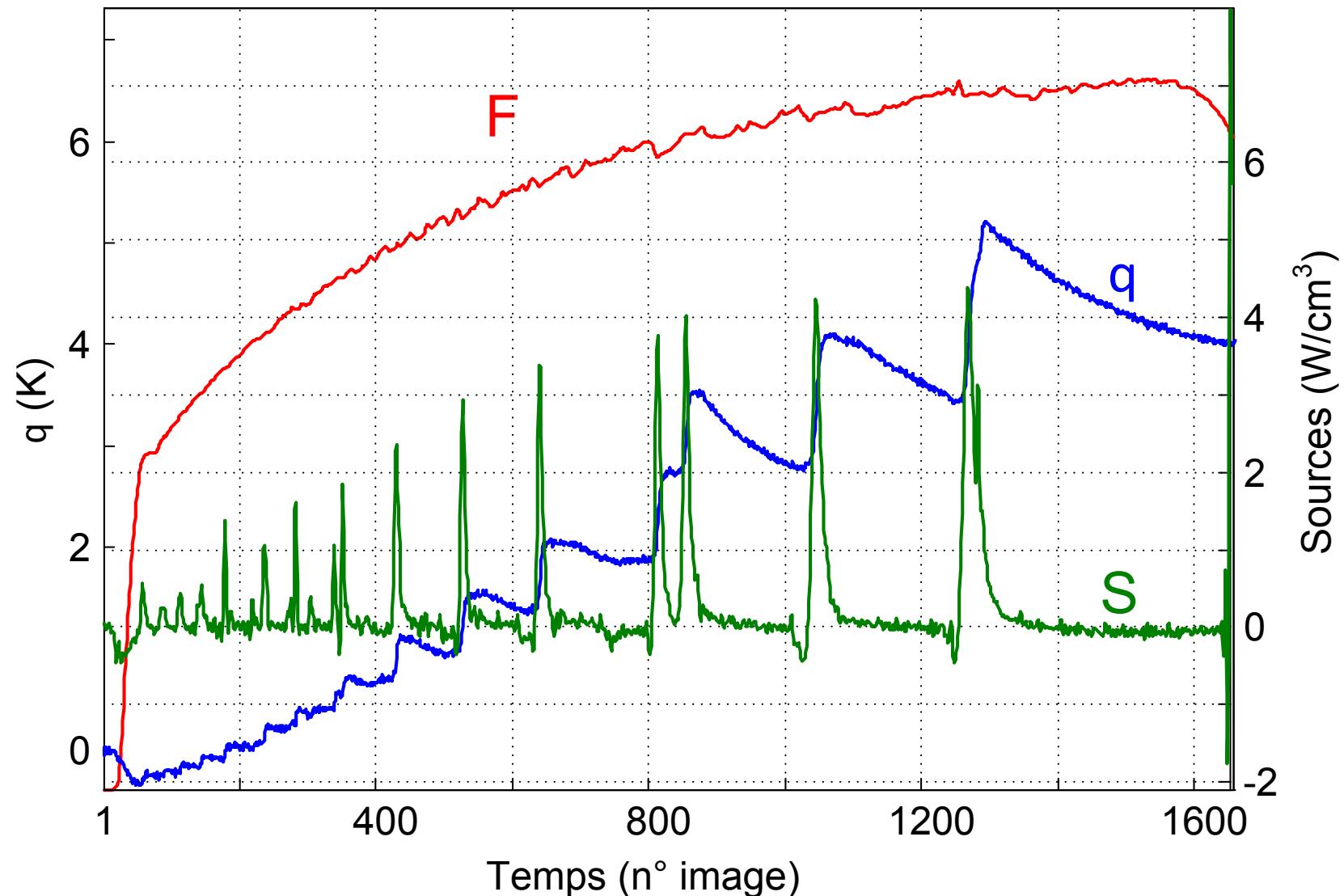


Représentation spatio-temporelle





Confrontations global (F) local (θ , S)



Bilan :

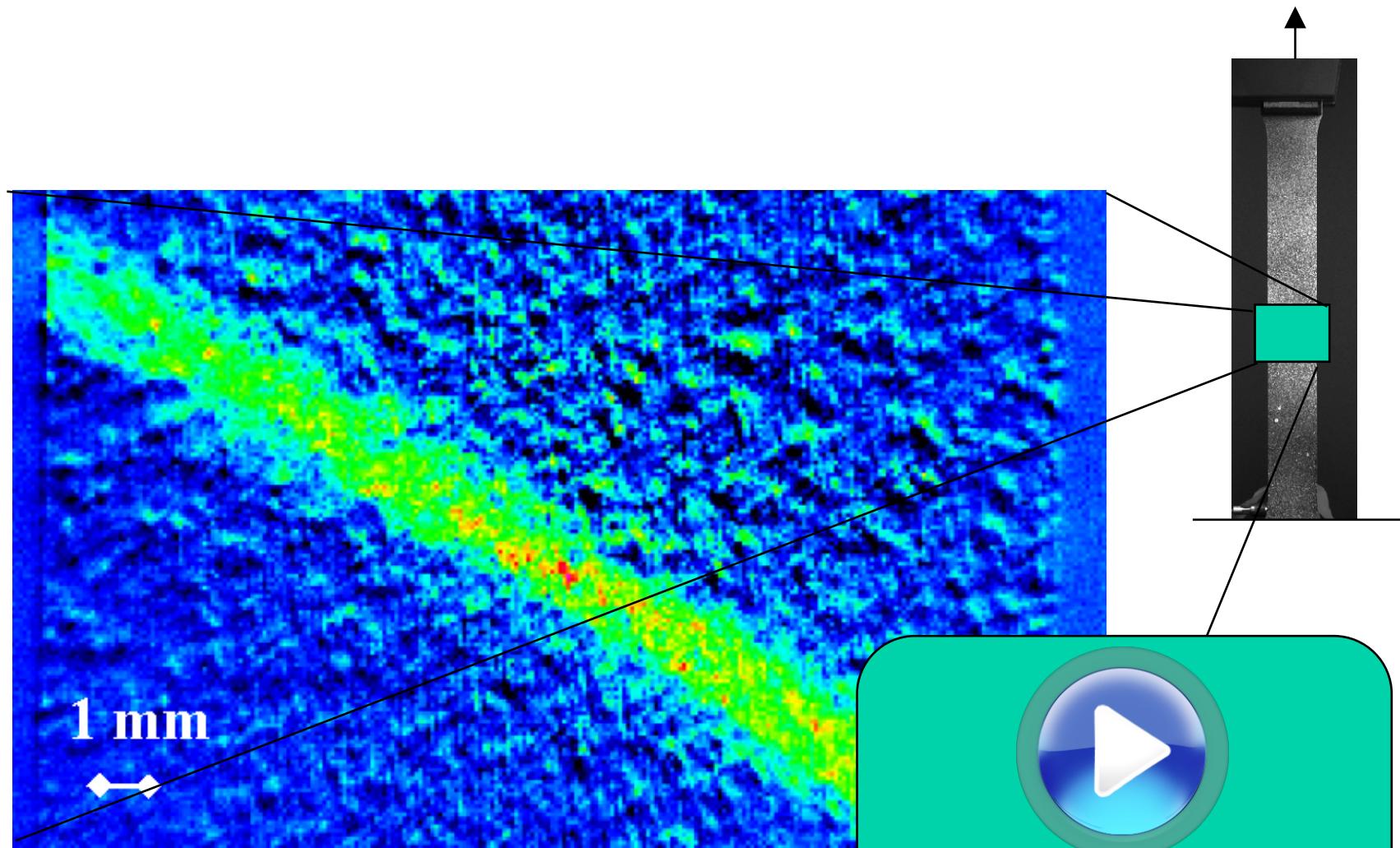
- Sources (dissipation) localisées, propagatives : bandes de type A
- Caractéristiques des bandes
 - largeur
 - orientation ($58^\circ \pm 1^\circ$)
 - Intensité des puissances dissipées
 - période
 - vitesse, ...

PLC 2 : Champs Thermiques

- A5086
- Vitesse de déformation faible ($1.2 \cdot 10^{-4} \text{ s}^{-1}$)
 **bandes type B**

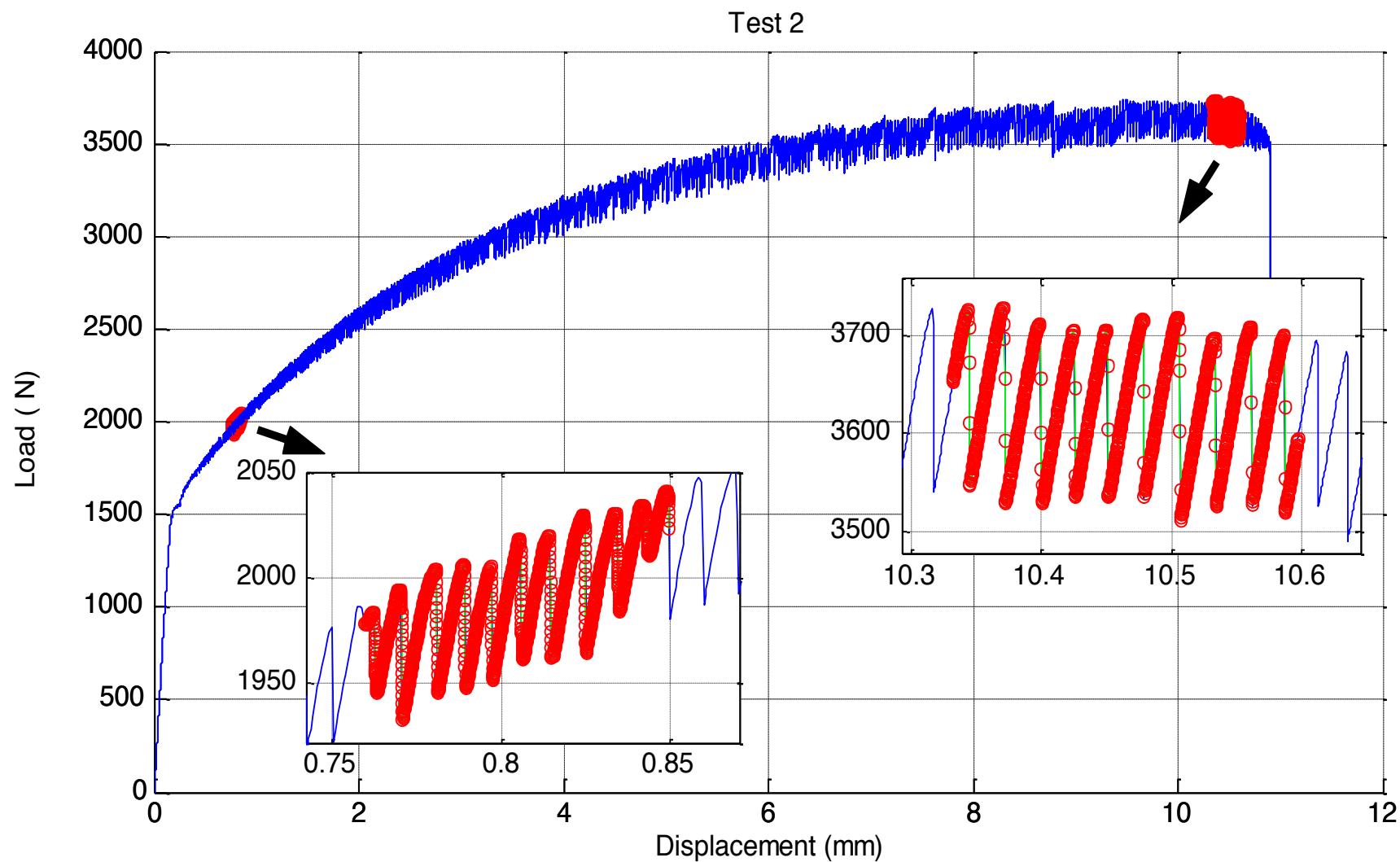
Louche et al , Mater. Sc. Eng. A, 2005

Example of thermal effects associated to band type B



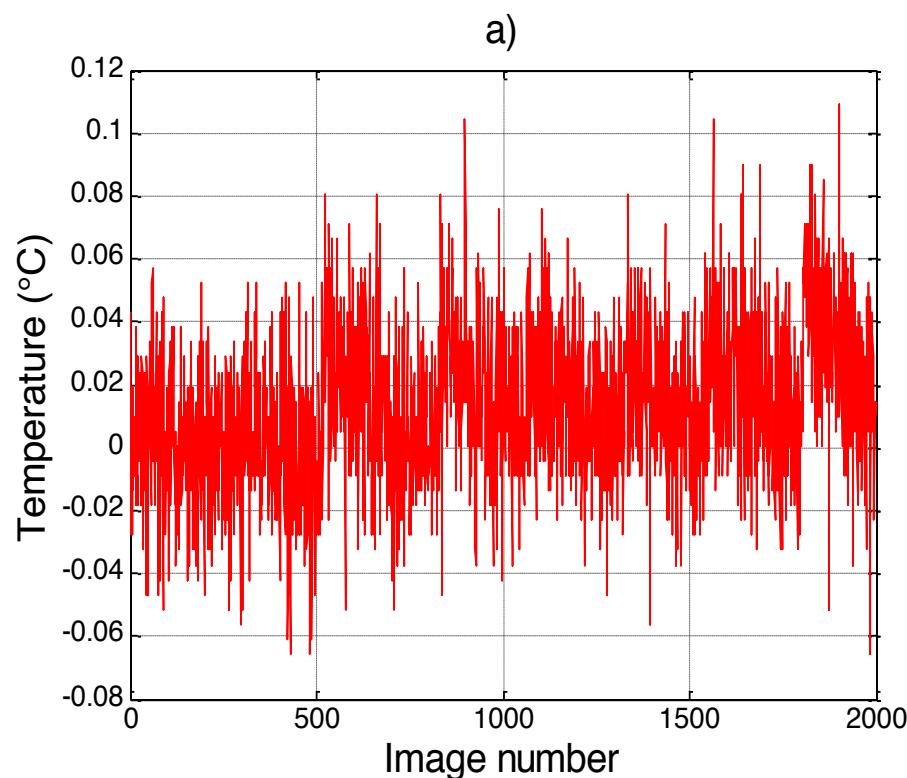
cf. animations sur
<http://herve.louche.free.fr/>

Low strain rates ($1.2 \cdot 10^{-4} \text{ s}^{-1}$) : band type B

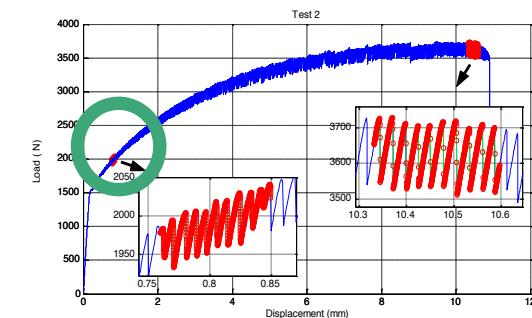
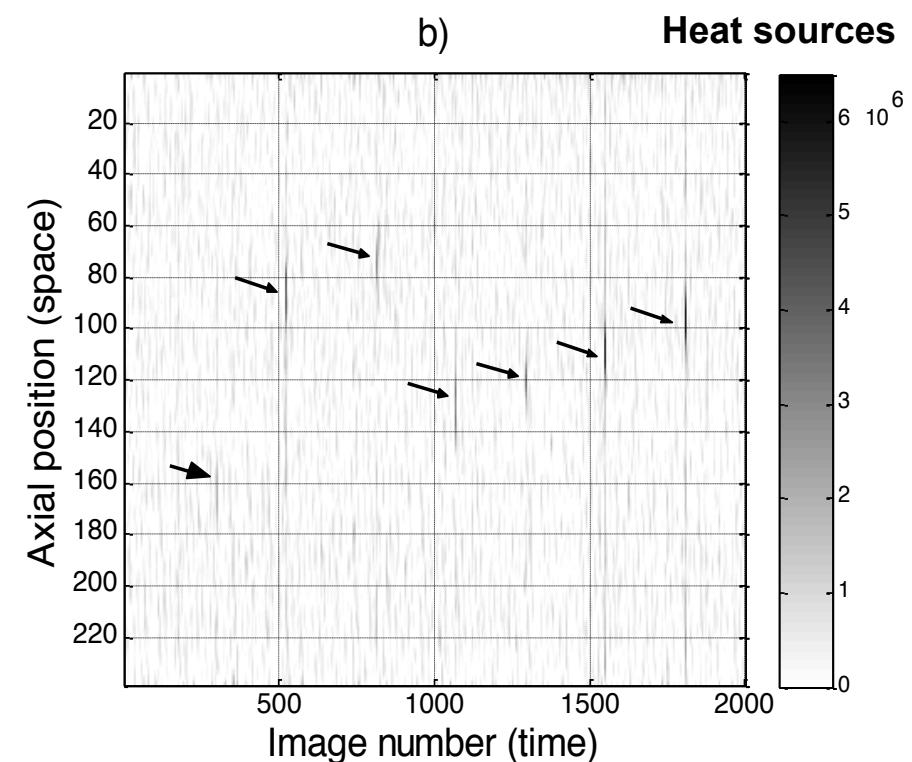


PLC band detection

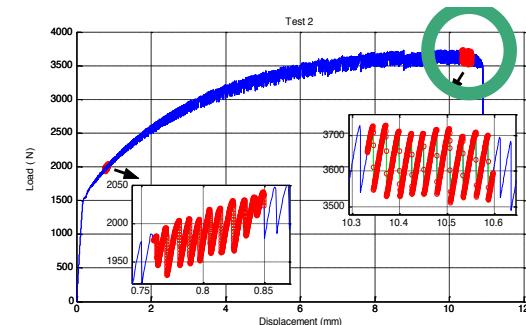
Very low thermal variations



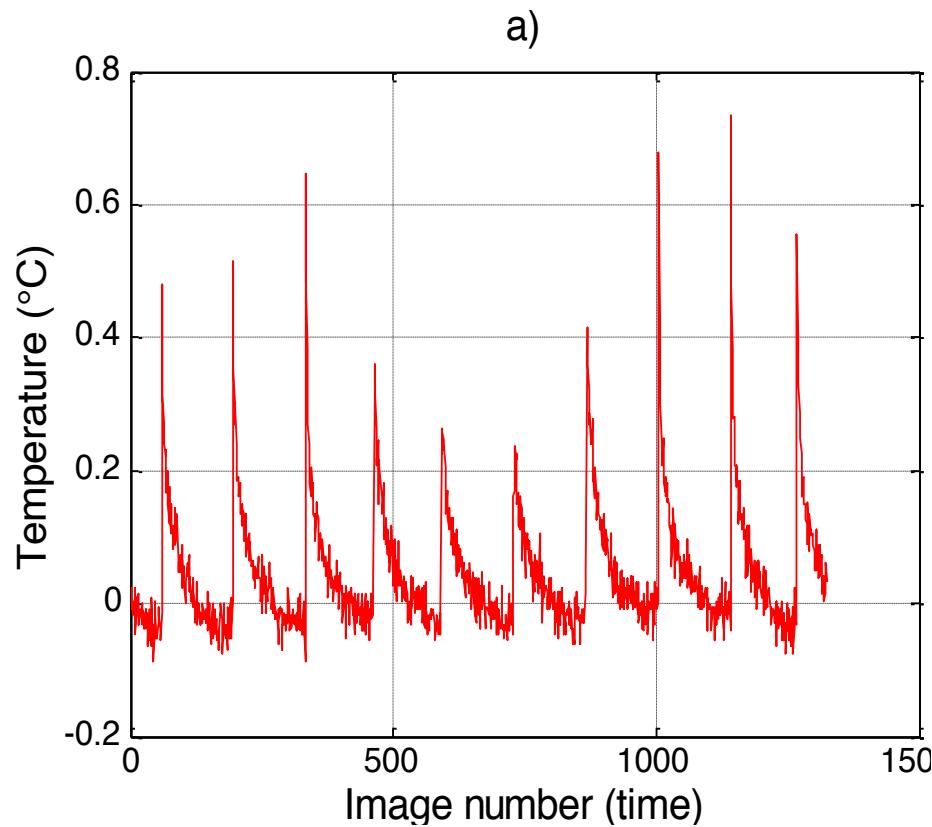
The heat sources allow detection of 7 PLC band type B



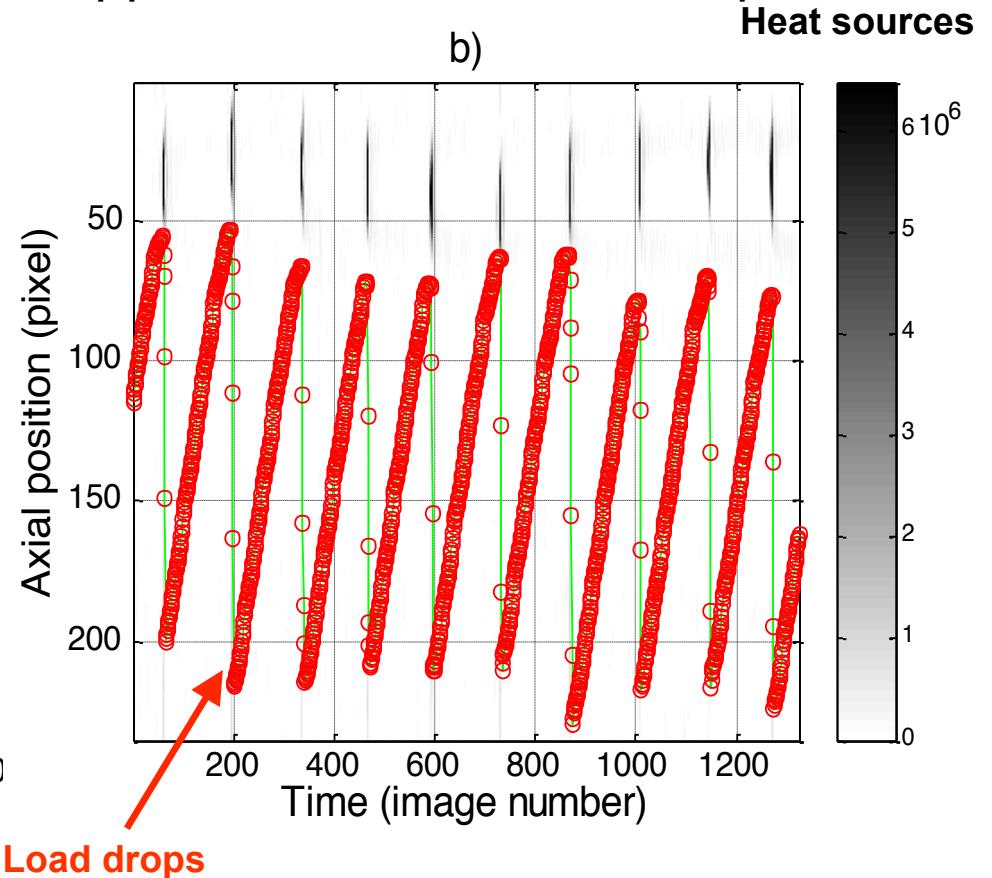
PLC band detection



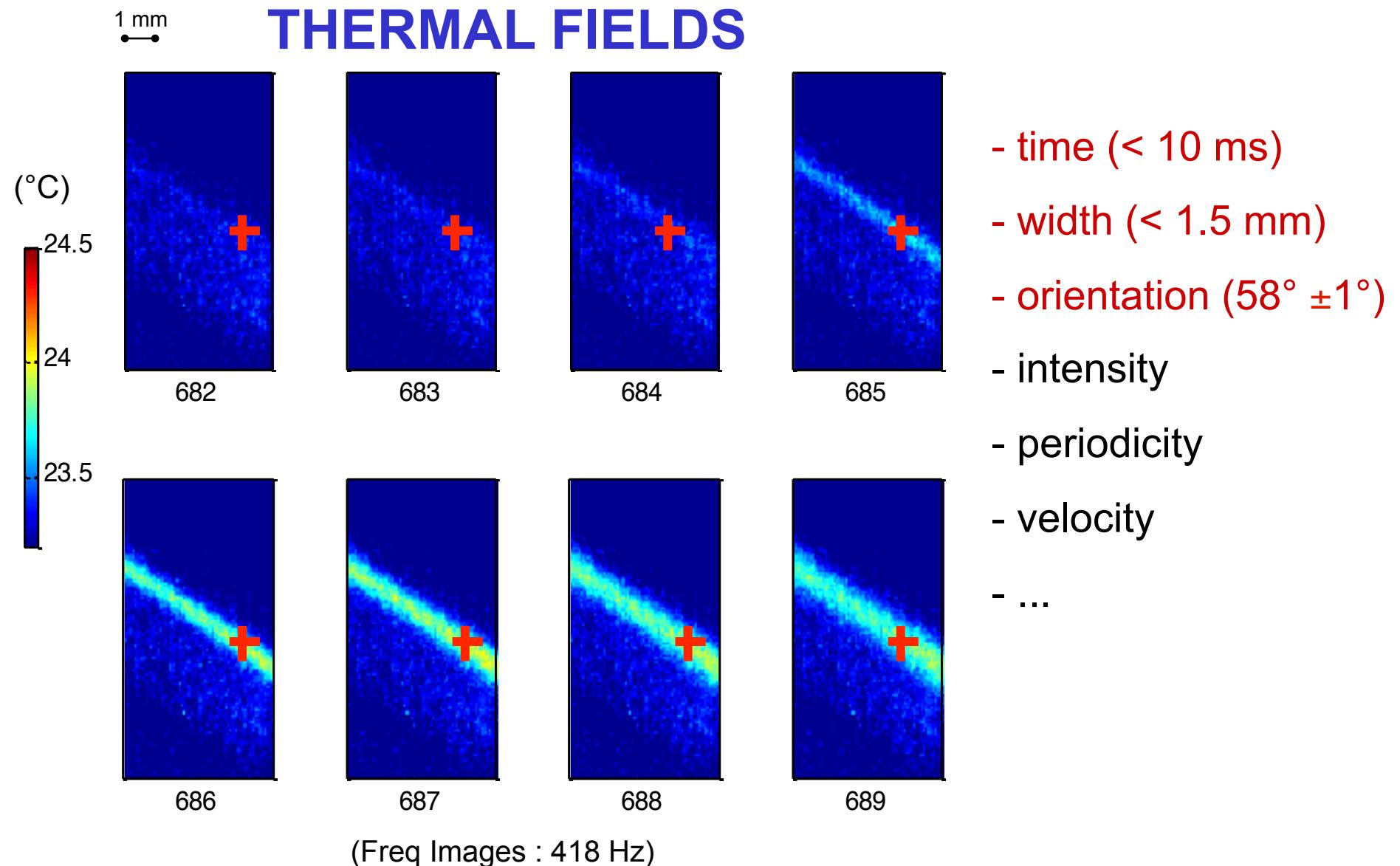
Low thermal variations



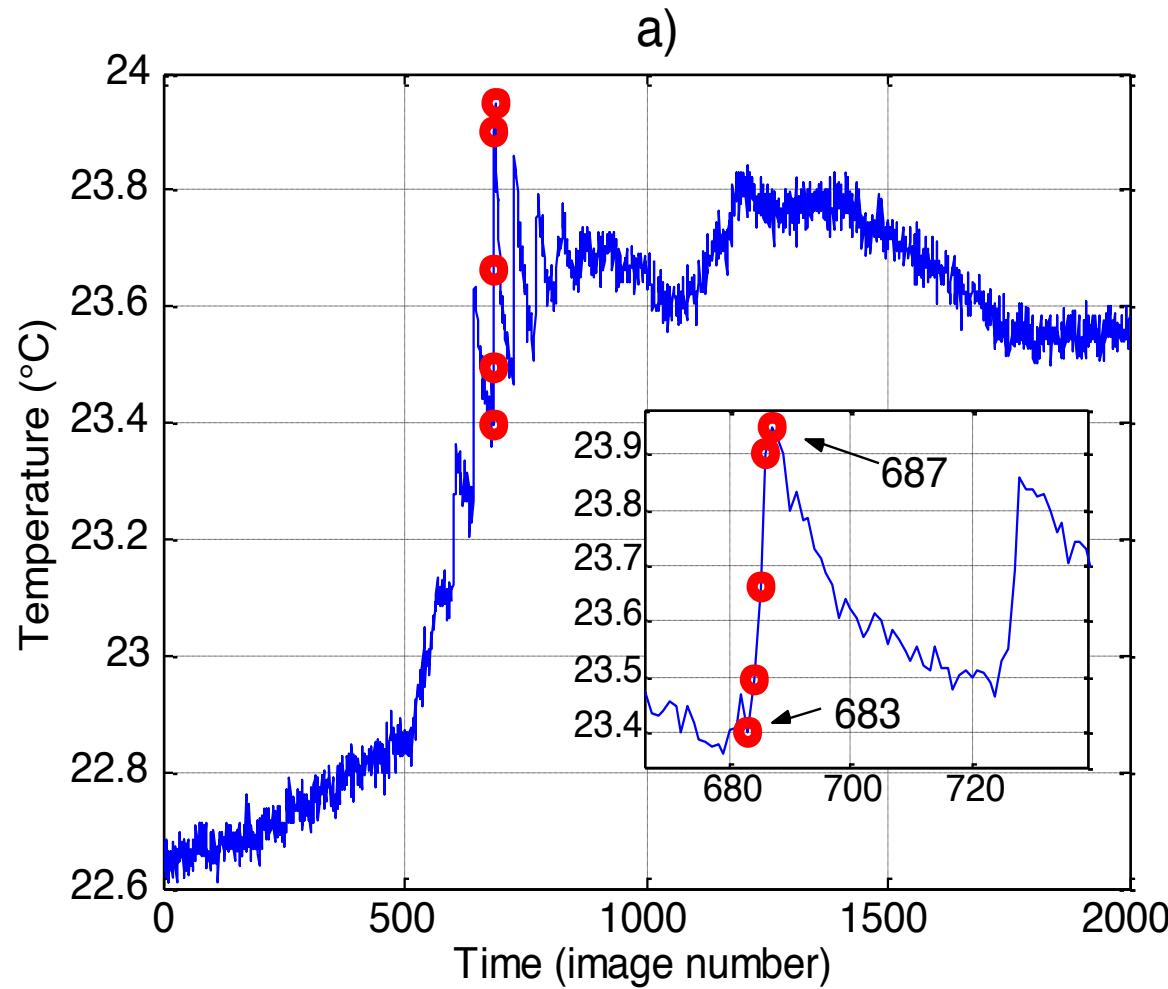
Correlation of heat sources
apparition with the load drops



Band characteristics



characteristic time : T



T : 4 images < 10 ms

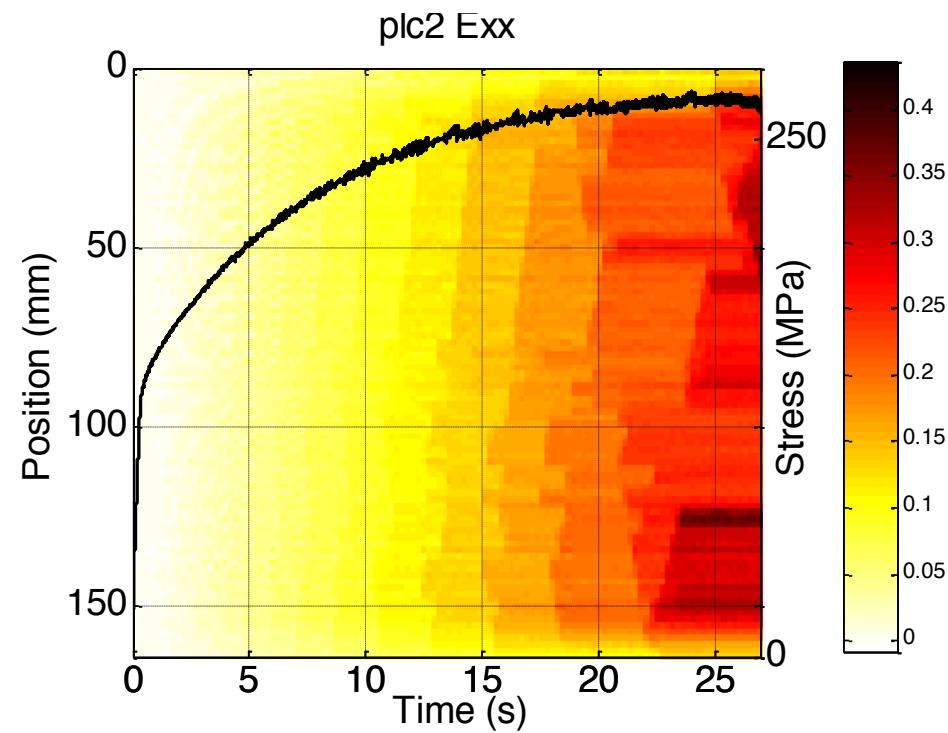
Louche et al , Mater. Sc. Eng. A, 2005

PLC 3 : Champs cinématiques et Emission Acoustique

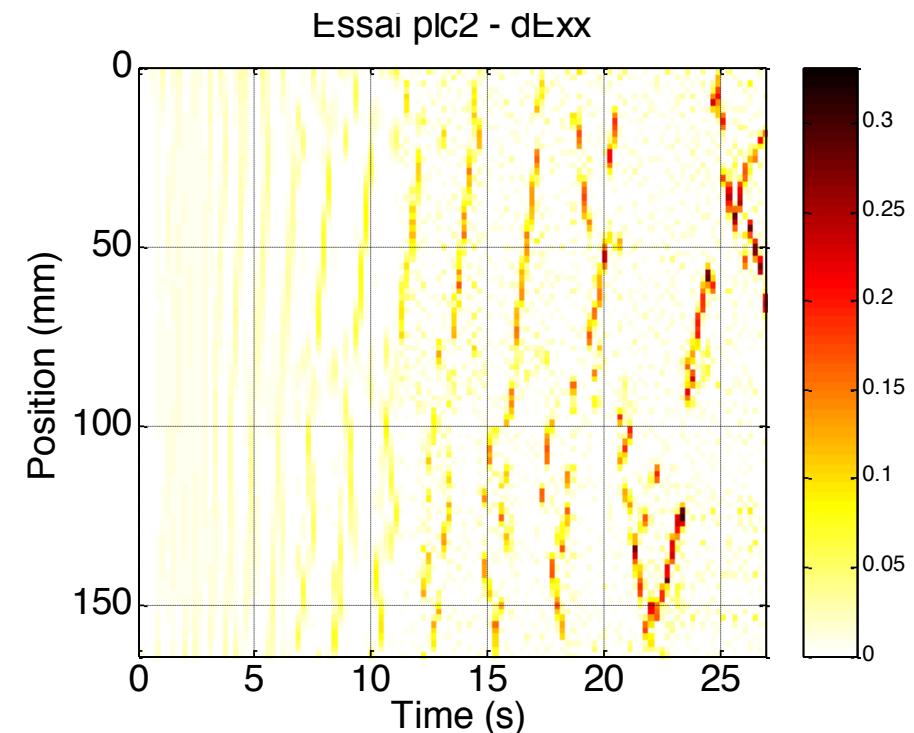
- A5854
- Vitesse déformation élevée: 10^{-2} s^{-1}
→ **bandes type A**
- Images visibles : 4.5 Hz
- Charge et Emission Acoustique : 2560 et 5120 Hz

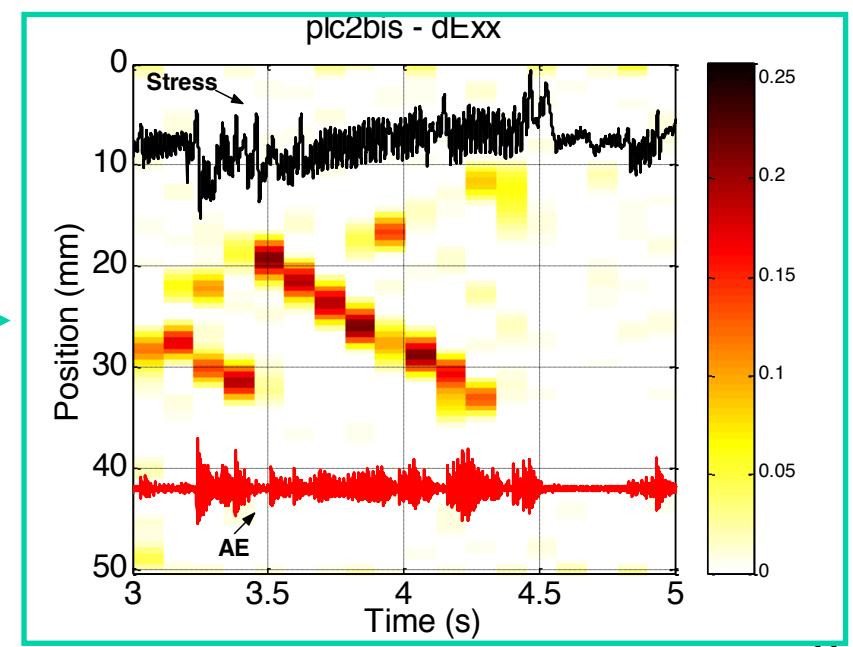
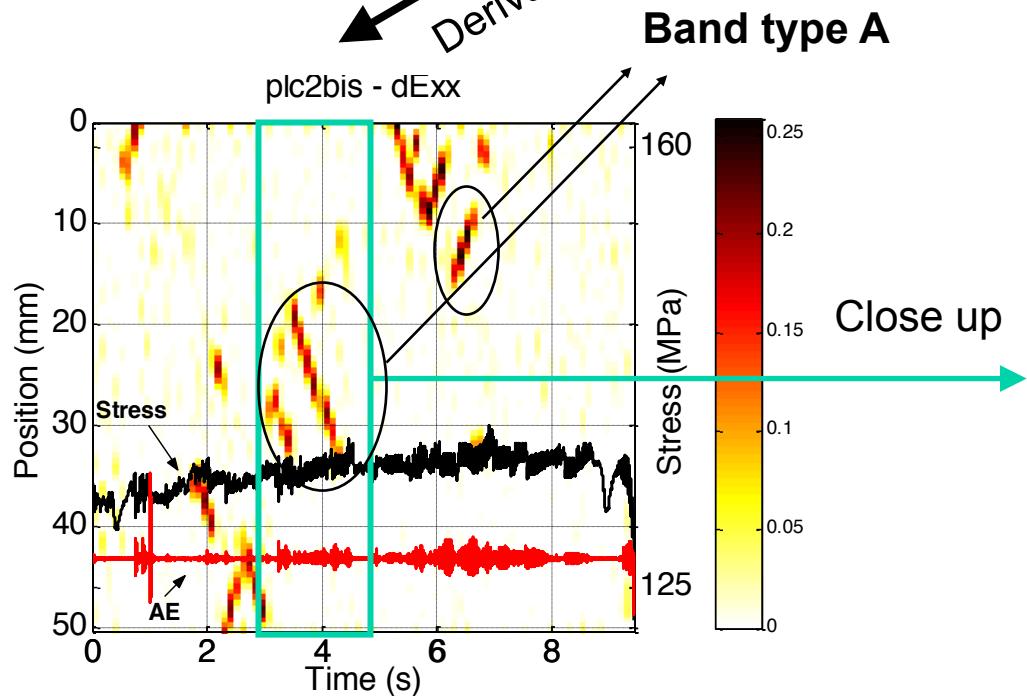
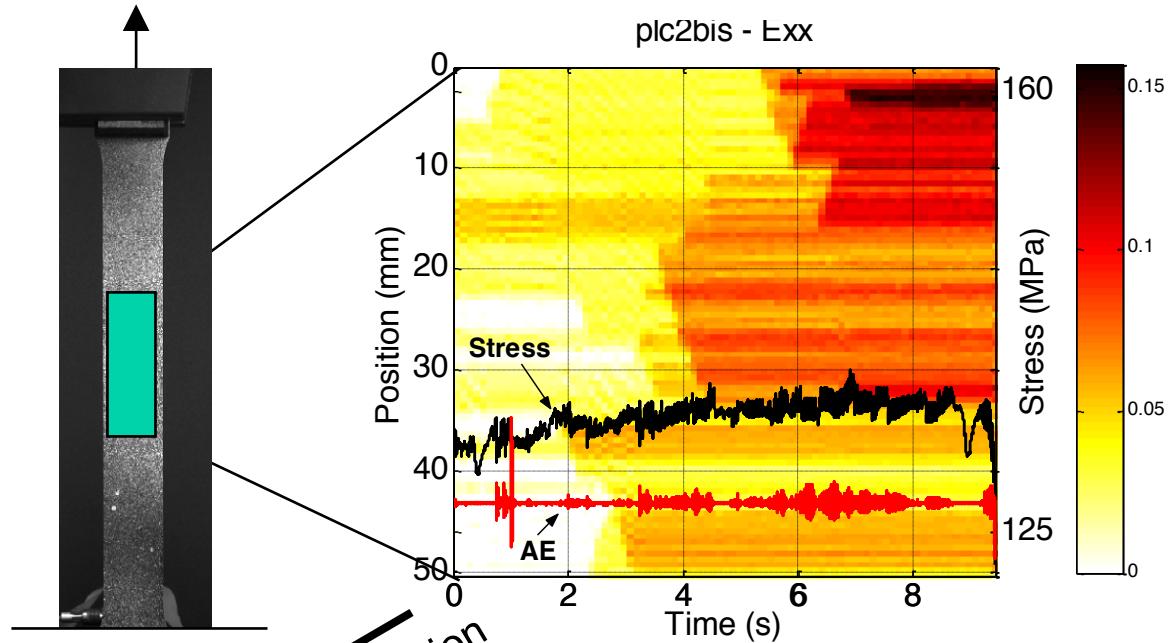
Louche et al, Exp. Mech., 2009

Strain profiles



Strain rates profiles

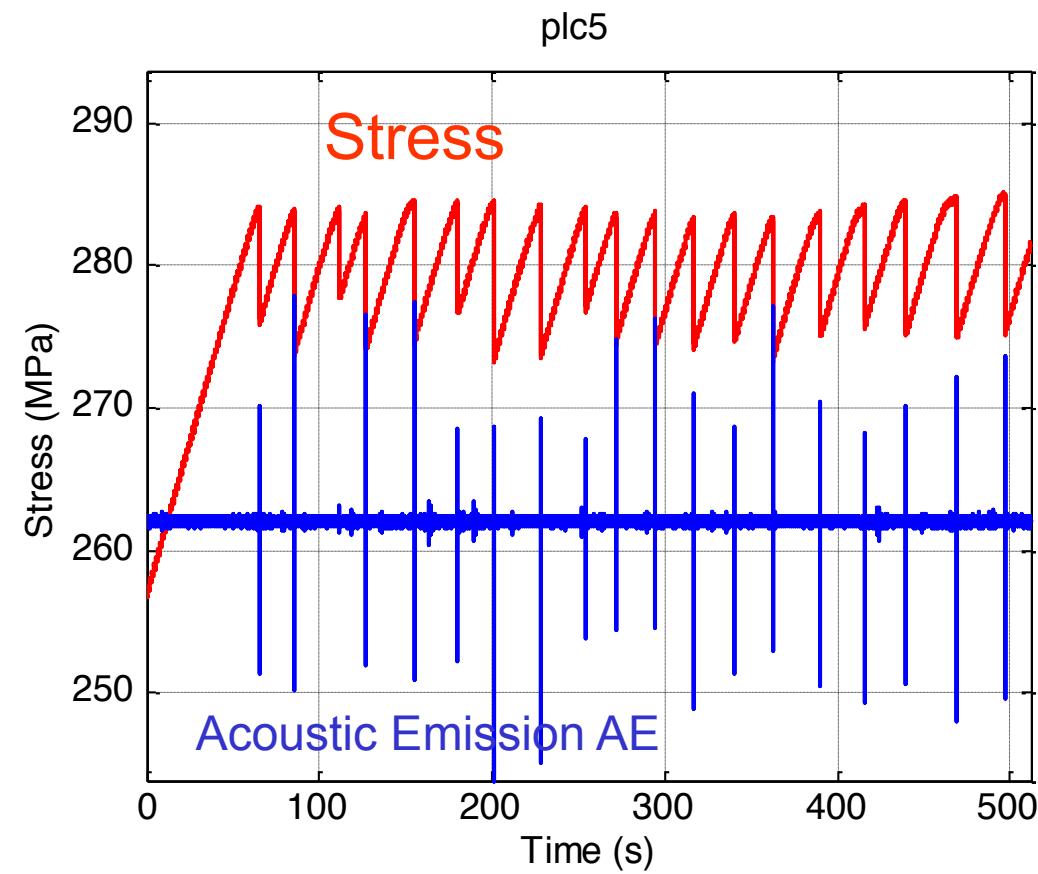
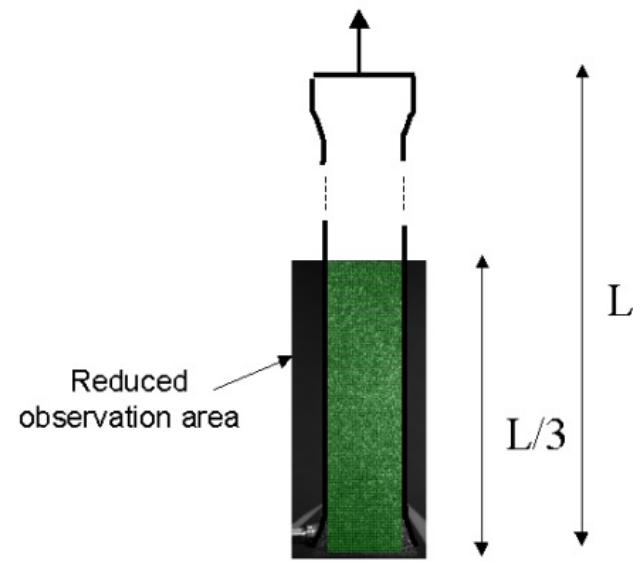




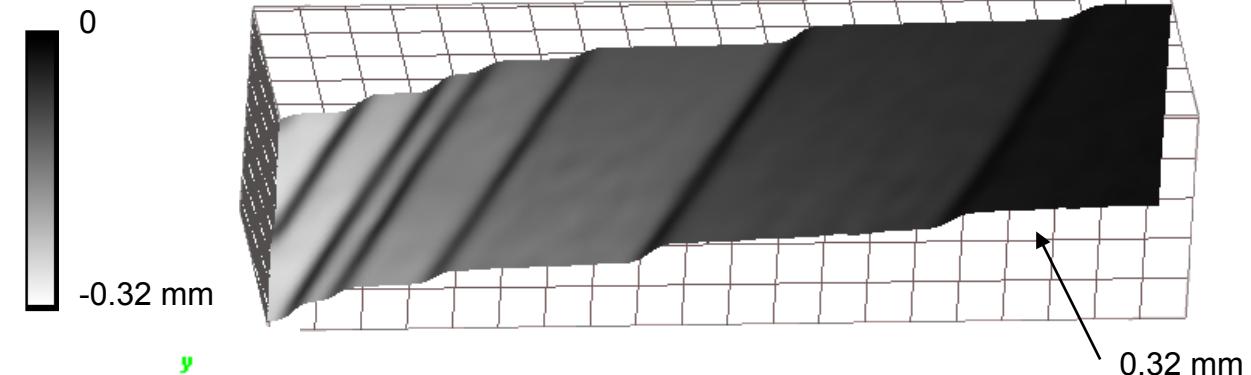
PLC 4 : Champs cinématiques et Emission Acoustique

- A5854
- Vitesse déformation faible : 10^{-5} s^{-1}
→ **bandes type C**
- Images visibles : 4.5 Hz
- Charge et Emission Acoustique : 2560 à 5120 Hz

Louche et al, Exp. Mech., 2009

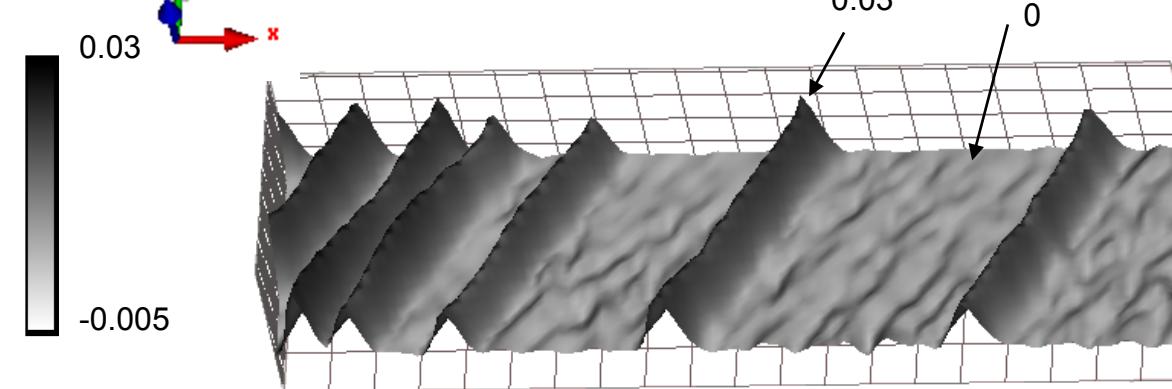


Displacement field



Axial Strain field

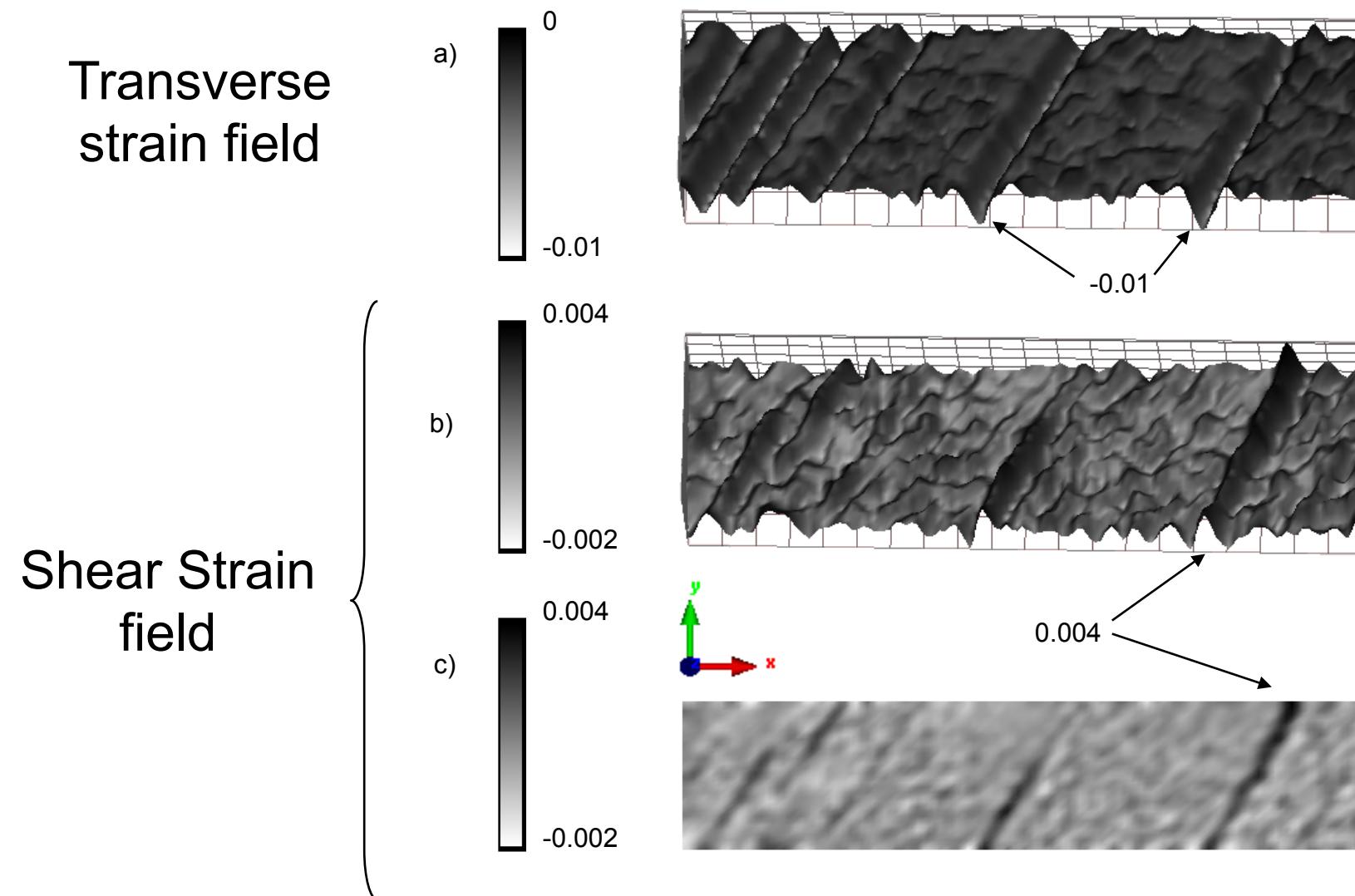
{



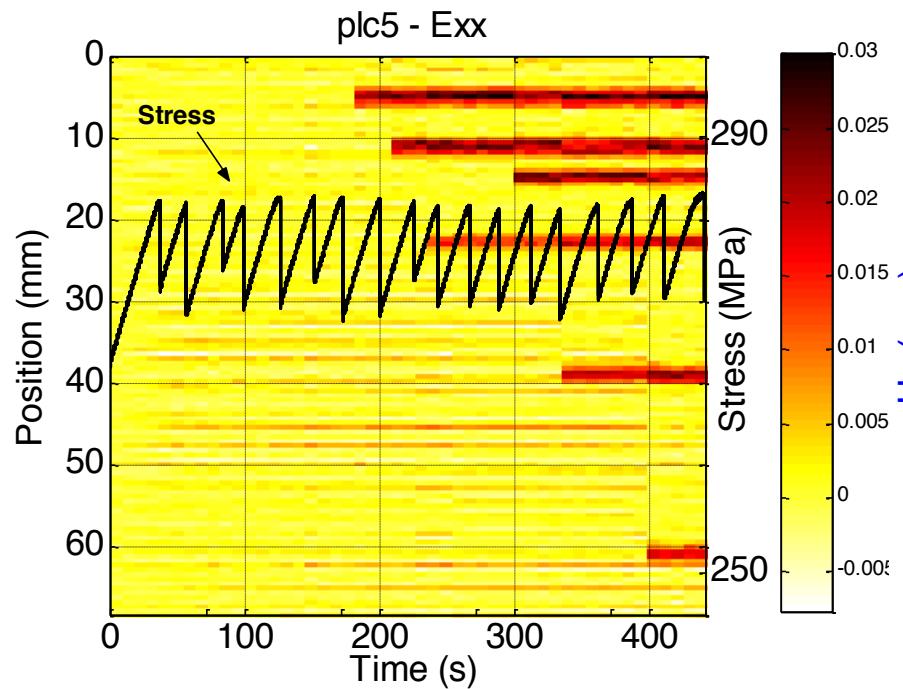
c)



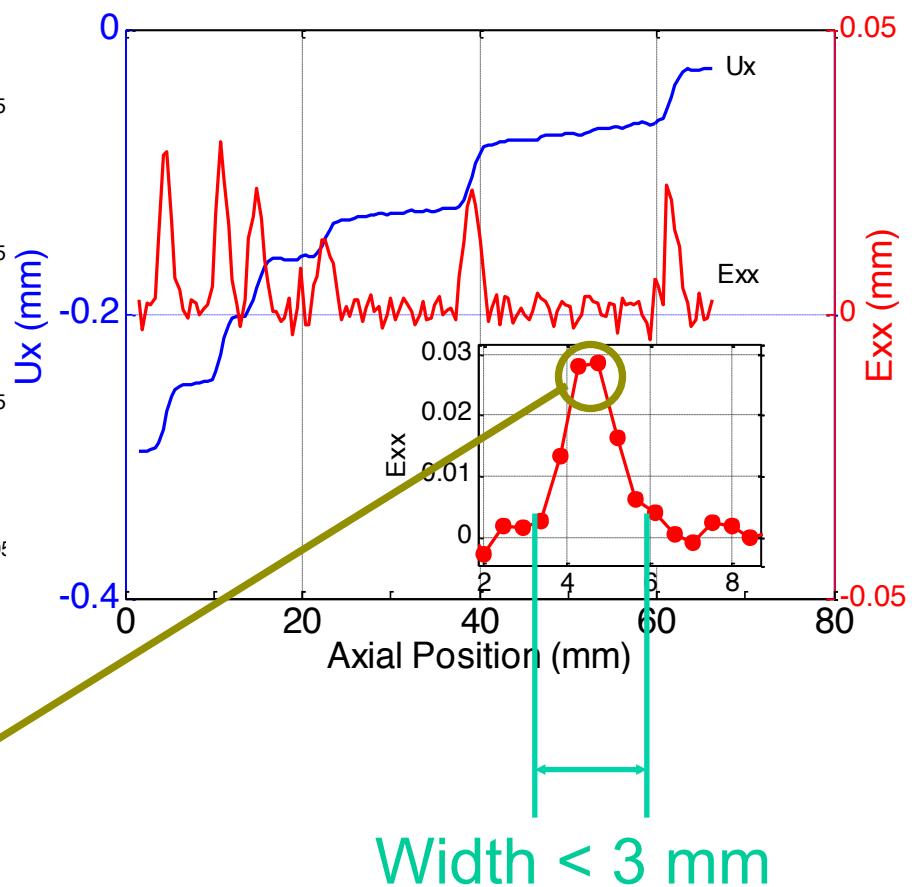
(frame rate : 4.5 Hz)



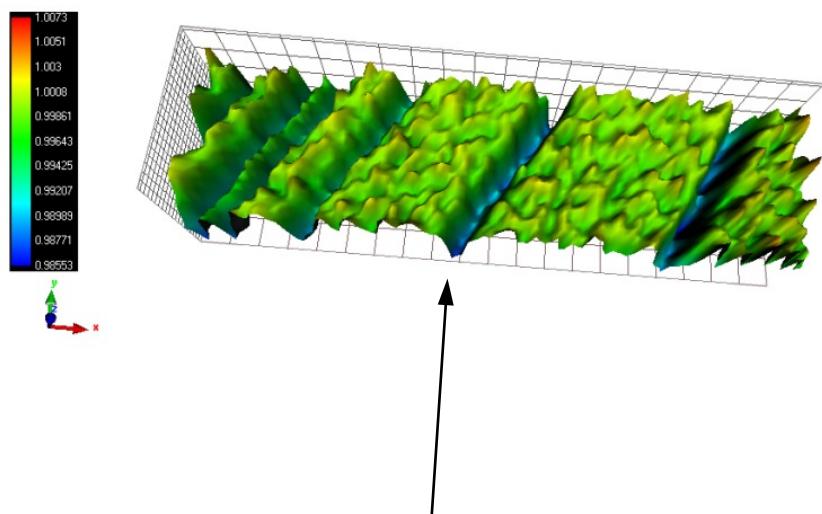
Evolution of an axial strain profile



Axial displacement and strain profiles

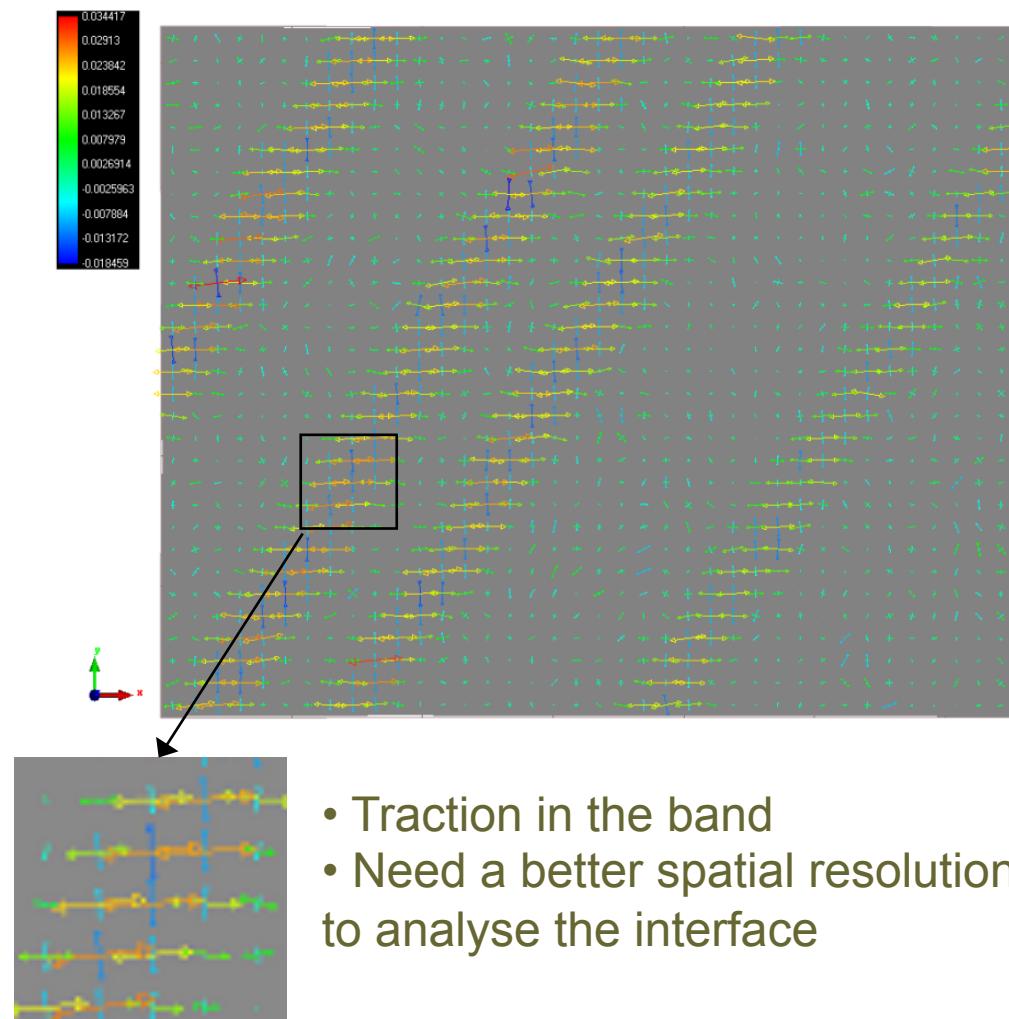


Thickness variation field



Thickness variation in the
band : 2 mm

Principal strain field



- Traction in the band
- Need a better spatial resolution to analyse the interface

Conclusions

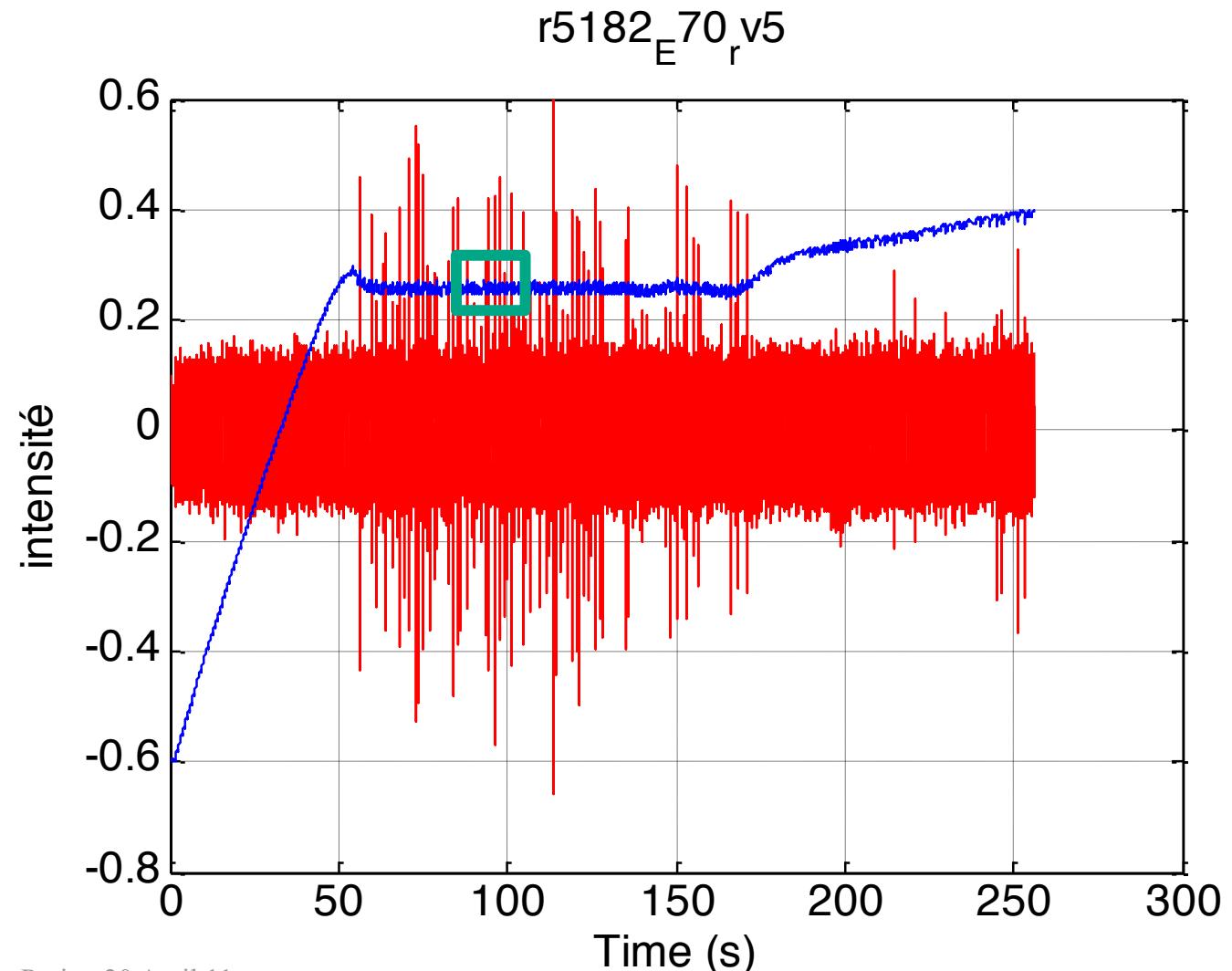
- **Mise en évidence d' effets thermiques associés à des phénomènes de localisation.**
- **Intérêt d' exploiter les champs de sources de chaleur pour étudier les phénomènes de localisation.**
- **Influence des couplages thermomécaniques (intensité de l'échauffement local micro?) sur le vieillissement dynamique?**
- **Distinctions entre bandes de Type A et B?**

Suite...

- **Synchronisation champs thermiques et cinématiques.**
- **Améliorations des résolutions spatio-temporelles.**
- **Etudier d'autres chargements et/ou géométries.**

Collaboration avec A. Benallal (LMT Cachan) et O.S. Hopperstad (Univ. Trondheim Norvège), Avril 2010

Observation simultanée de bandes de Lüders et de PLC!



Collaboration avec A. Benallal (LMT Cachan) et O.S. Hopperstad (Univ. Trondheim Norvège), Avril 2010

Observation simultanée de bandes de Lüders et de PLC!

