IMAGERIE THERMIQUE A HAUTE RESOLUTION SPATIALE PAR NANOCRISTAUX FLUORESCENTS

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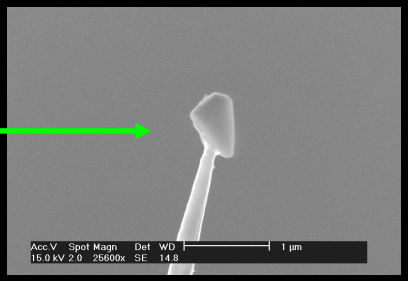
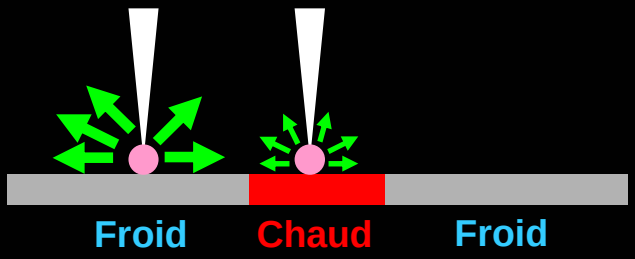
Jessica Labeguerie-Egea, Michel Mortier (ENSCP, Paris, France)	Synthèse de particules fluorescentes
P. Löw, C Bergaud (LAAS, Toulouse, France)	Fabrication de nanofils
R. Latempa, H. Diaf, J. Lesueur, D. Fournier (LPEM, ESPCI, Paris, France)	Fabrication de nanofils
S. Volz (EM2C, ECP, Châtenay-Malabry, France)	Simulations

17 décembre 2009

PLAN

Particule fluorescente





Capteur thermique

1) Matériau fluorescent

2) Procédure de fabrication des sondes

3) Imagerie thermique : mode DC

4) Imagerie thermique : mode AC

5) Imagerie thermique dans des liquides

LE MATERIAU FLUORESCENT

Particules fluorées codopées Erbium/ytterbium : extrêmement robuste

Synthèse : M. Mortier team (ENSCP, Paris)

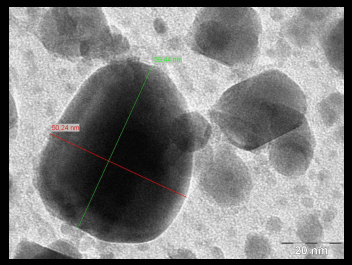
Verre

$(ZrF_4)_{45.5},(BaF_2)_{23},(YbF_3)_{11},(ErF_3)_3,(AlF_3)_3,(InF_3)_{0.5},(NaF)_{14}$

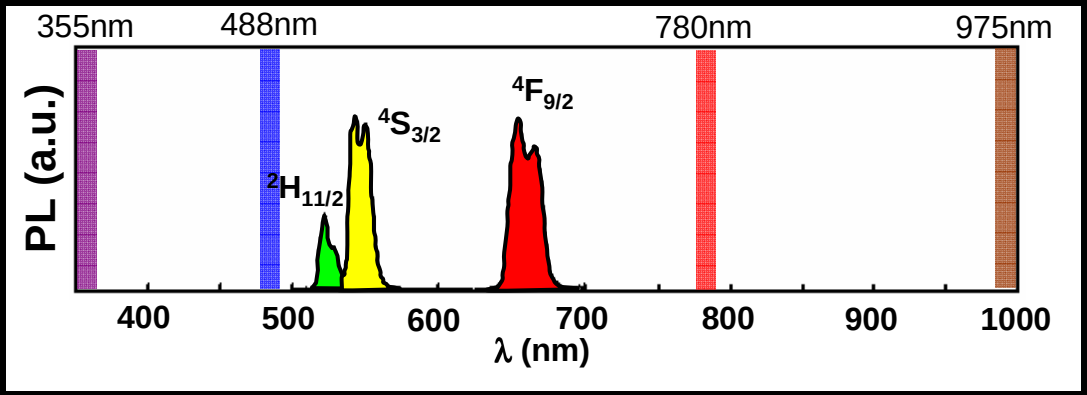
Grosse pièce : qui doit être réduite en poudre

Nanocristal

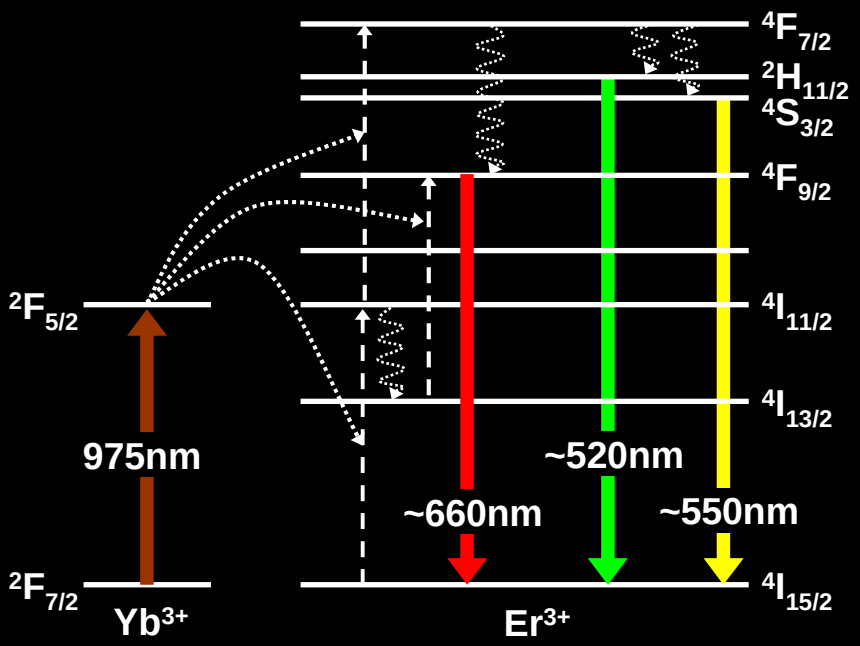
$PbF_2 : Er^{3+}/Yb^{3+}$

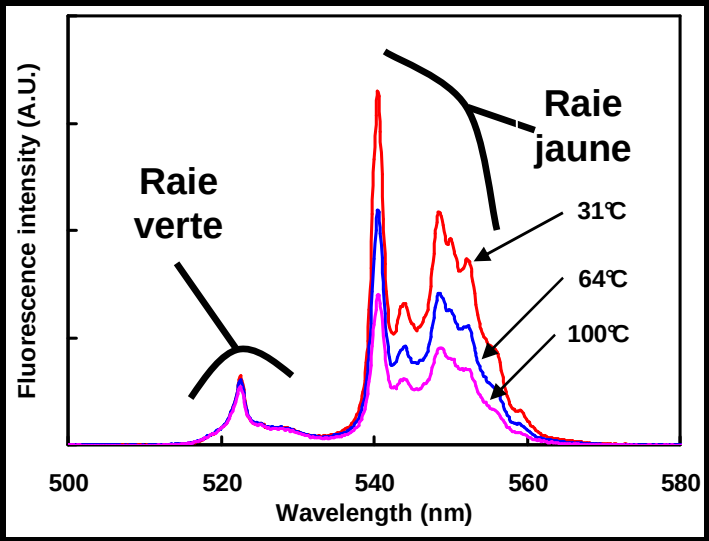


TEM : G. Patriarche (LPN, Marcoussis)

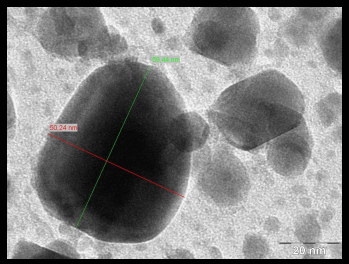


TEMPERATURE DEPENDANCE DE LA FLUO

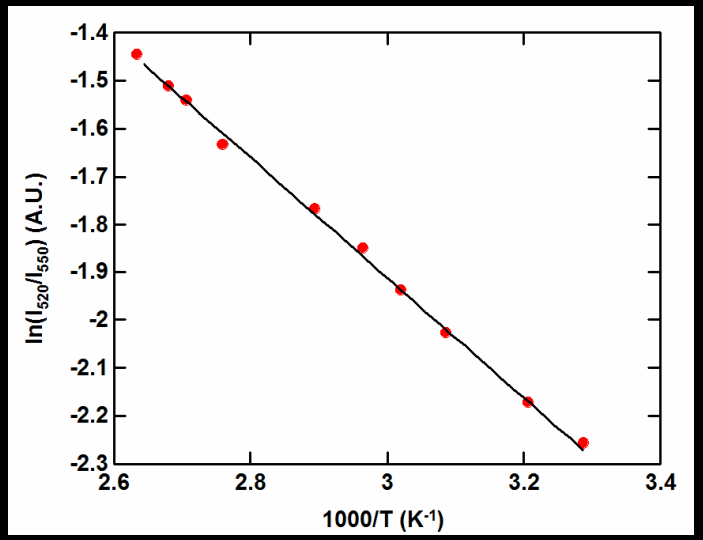




Nanocristal $PbF_2 : Er^{3+}/Yb^{3+}$



$$\ln\left(\frac{I_{520}}{I_{550}}\right) = C' - \frac{\Delta E}{kT}$$



PROCEDURE DE FABRICATION DES SONDES

Collage de la particule fluorescente

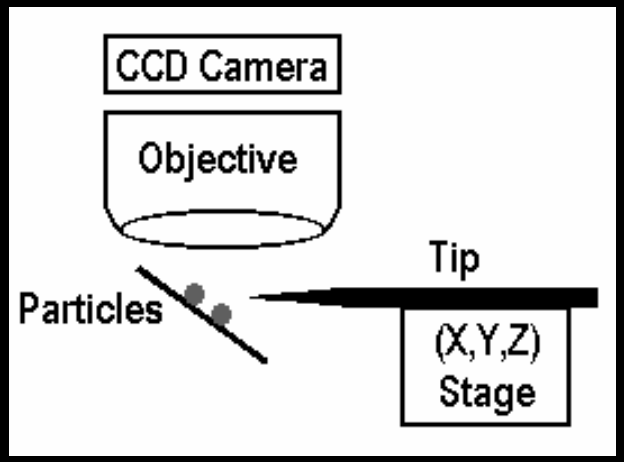
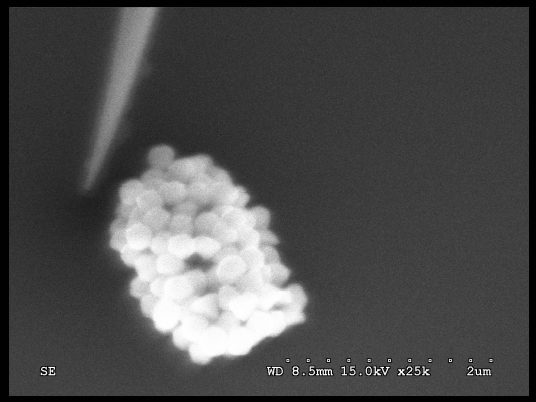
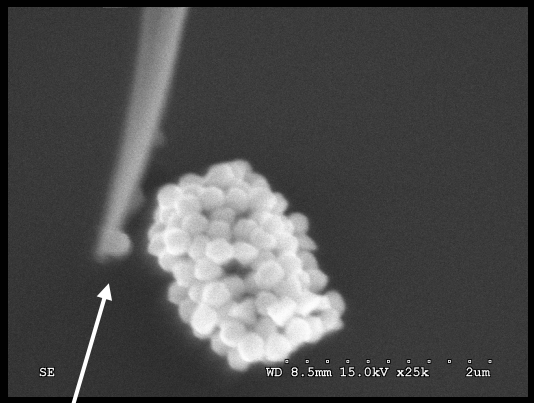


Image optique: 16.5 x 11.7 μm^2

Particule de taille 250nm

Collage in-situ dans un SEM



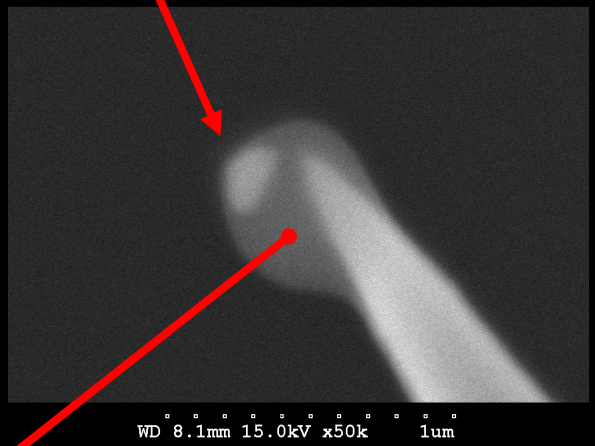


Particule de taille 250nm

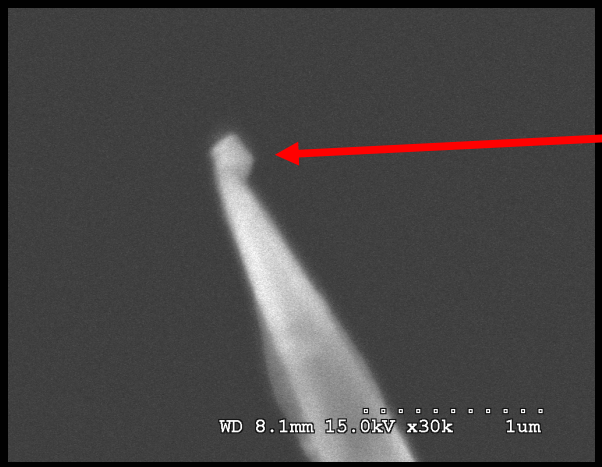
EXEMPLES DE POINTES OBTENUES

Taille ~ 200 nm

Nanoparticule: taille 100-150nm

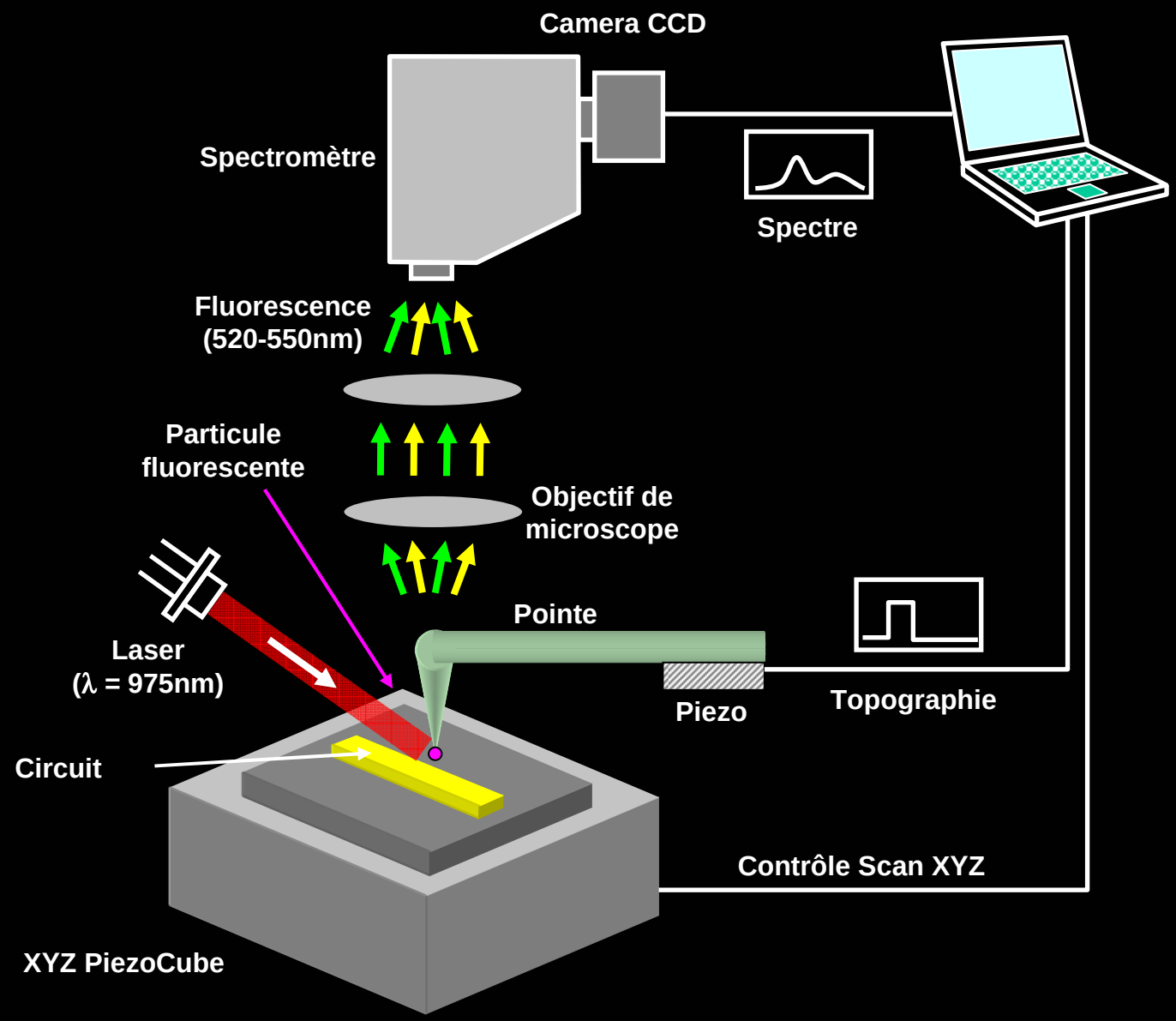


Polymère



Nanoparticule: taille 100-150nm

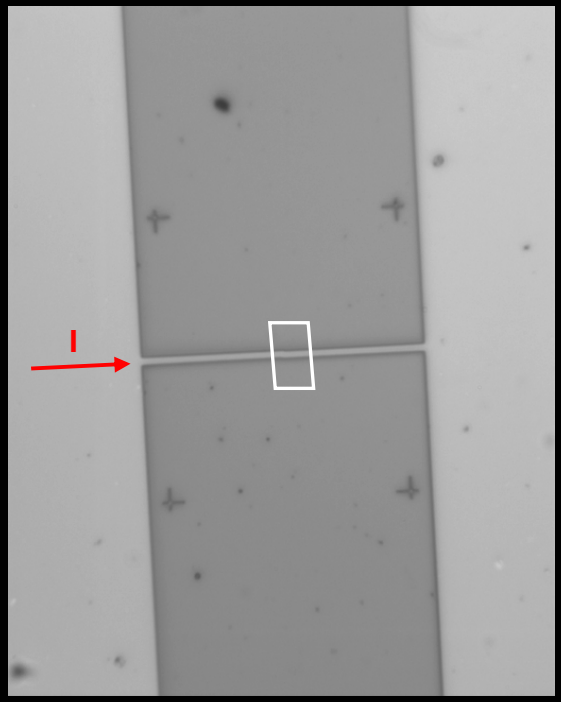
DISPOSITIF EXPERIMENTAL : IMAGERIE MODE DC



EXEMPLE : PISTE DE NICKEL

Échantillon:
P. Löw, C. Bergaud
(LAAS, Toulouse)

SiO_2 / Ni / SiO_2 / Si
Largeur : 1µm
Longueur : 40µm



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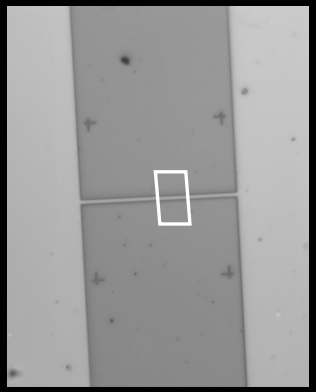
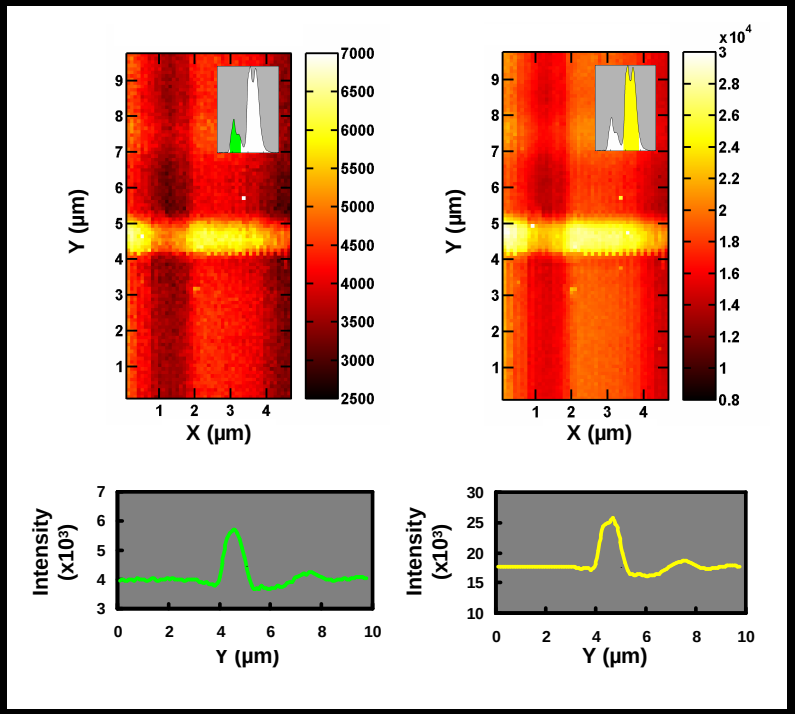


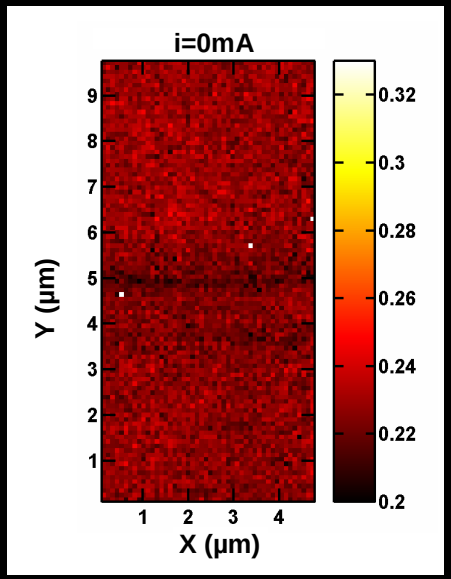
i=0mA

Fluorescence verte

Fluorescence jaune



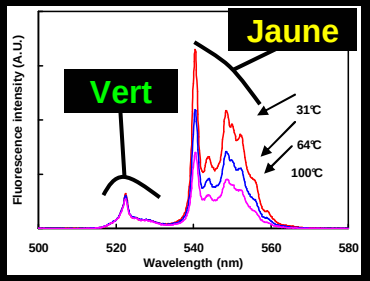
Rapport d'intensité de fluorescence



Pas de variations de température

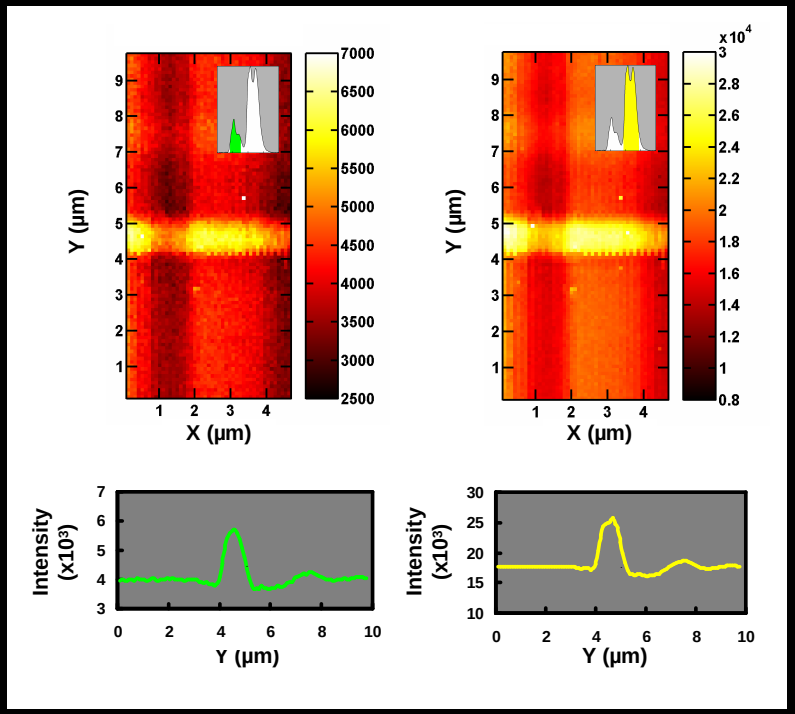
EXEMPLE : PISTE DE NICKEL

Échantillon:
P. Löw, C. Bergaud
(LAAS, Toulouse)



i=0mA

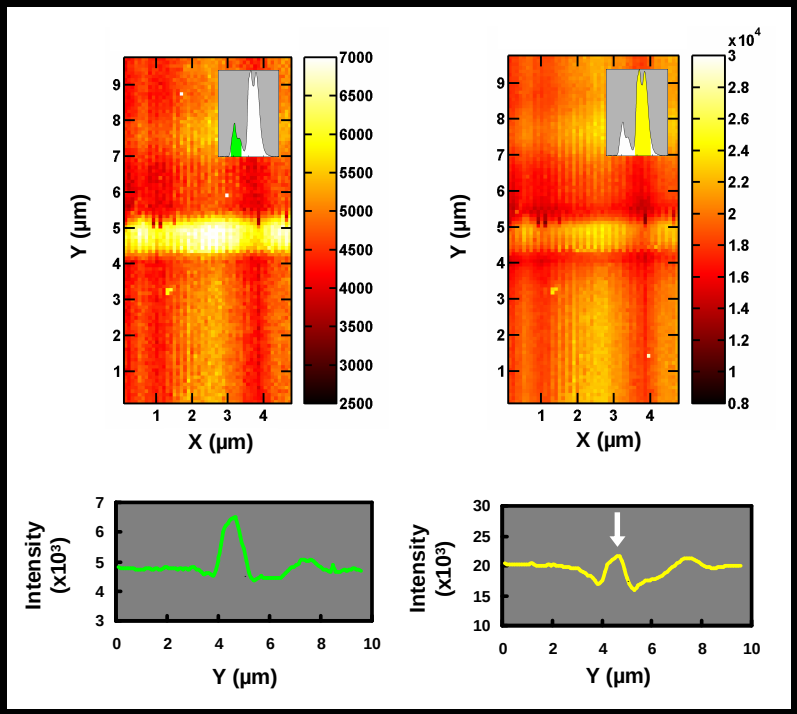
Fluorescence verte



Fluorescence jaune

i=6mA

Fluorescence verte



Fluorescence jaune

EXEMPLE : PISTE DE NICKEL

Échantillon:
P. Löw, C. Bergaud
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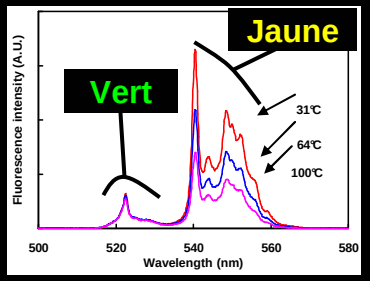
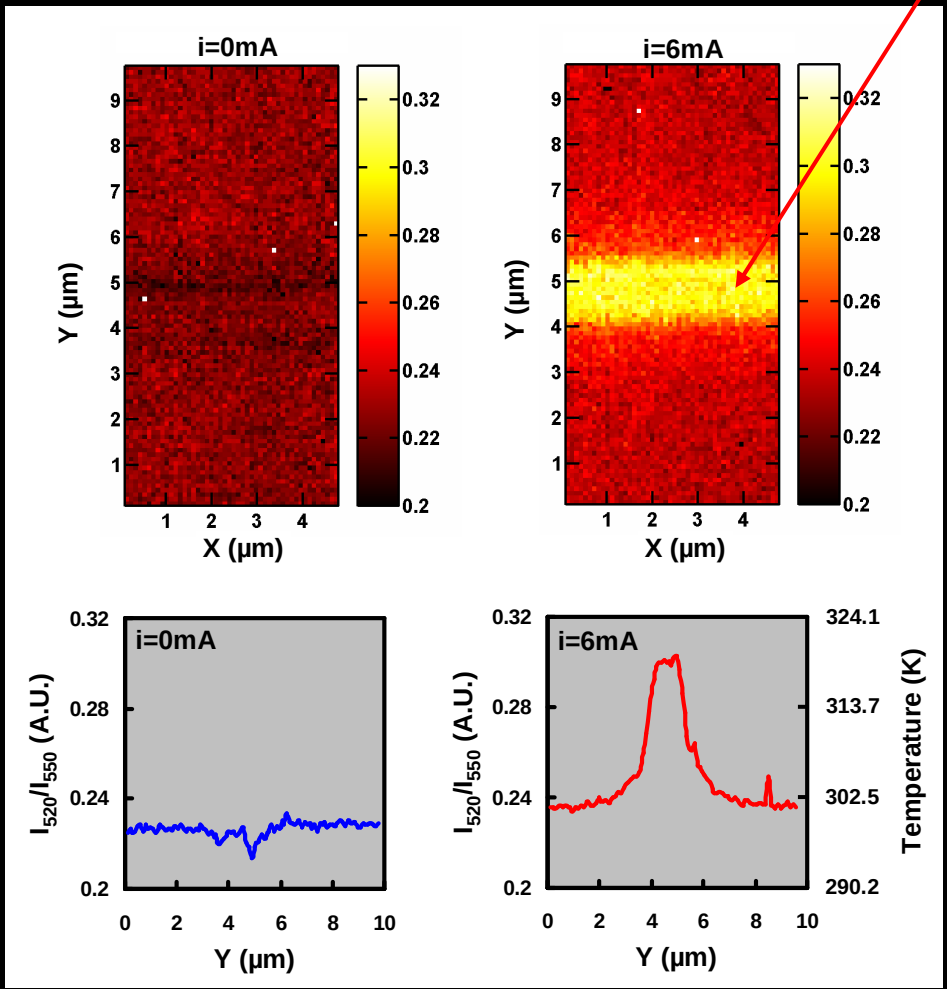


Rapports d'intensité de fluorescence

Augmentation de température



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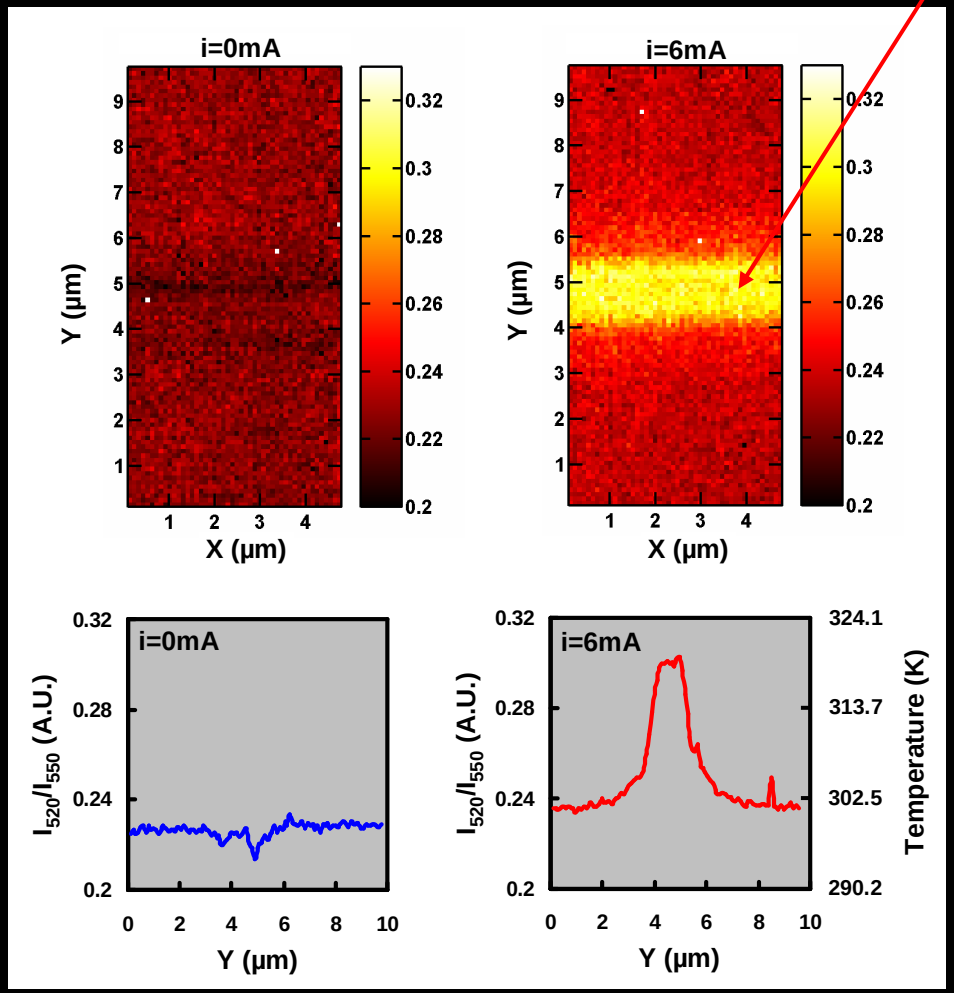
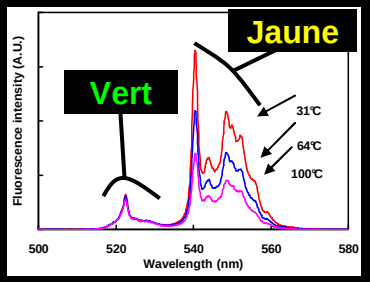
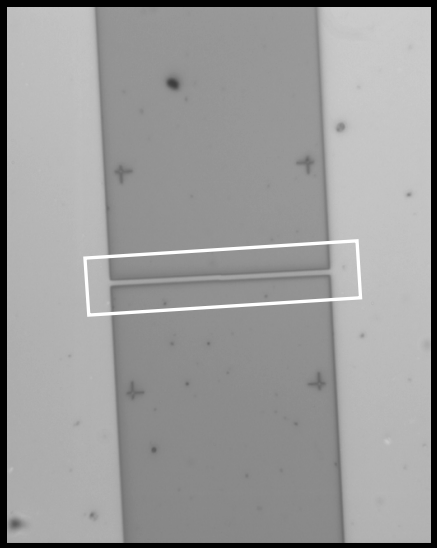
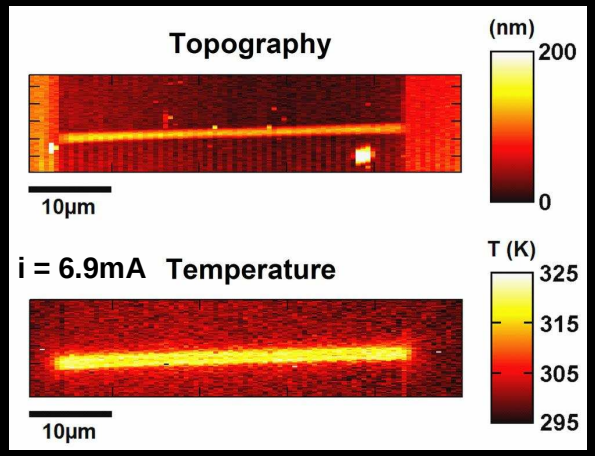




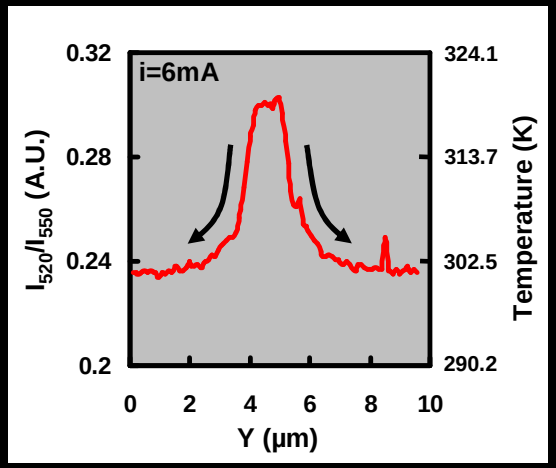




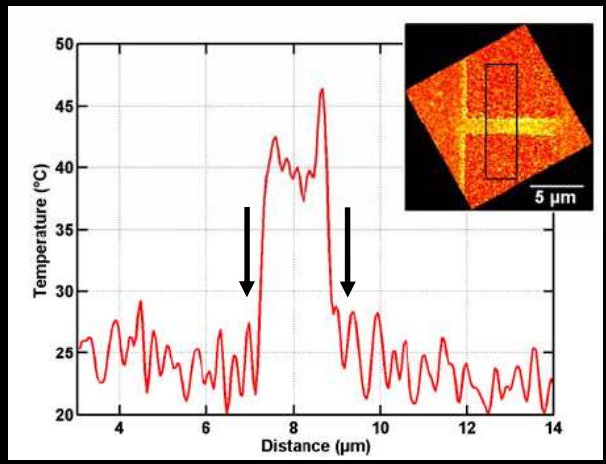
Nanotechnology **20**, 115703 (2009).

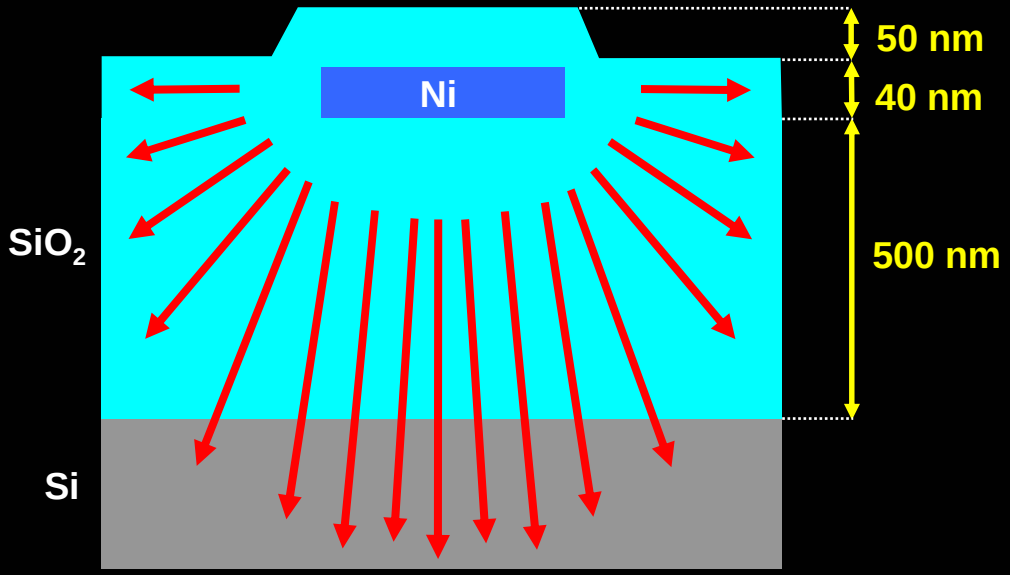
INFLUENCE DE L'EPAISSEUR D'OXYDE

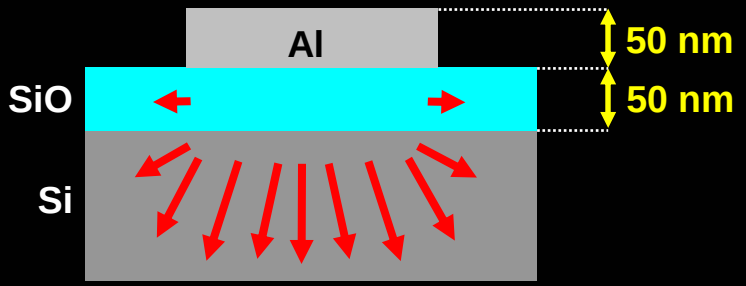
Nickel



Aluminum

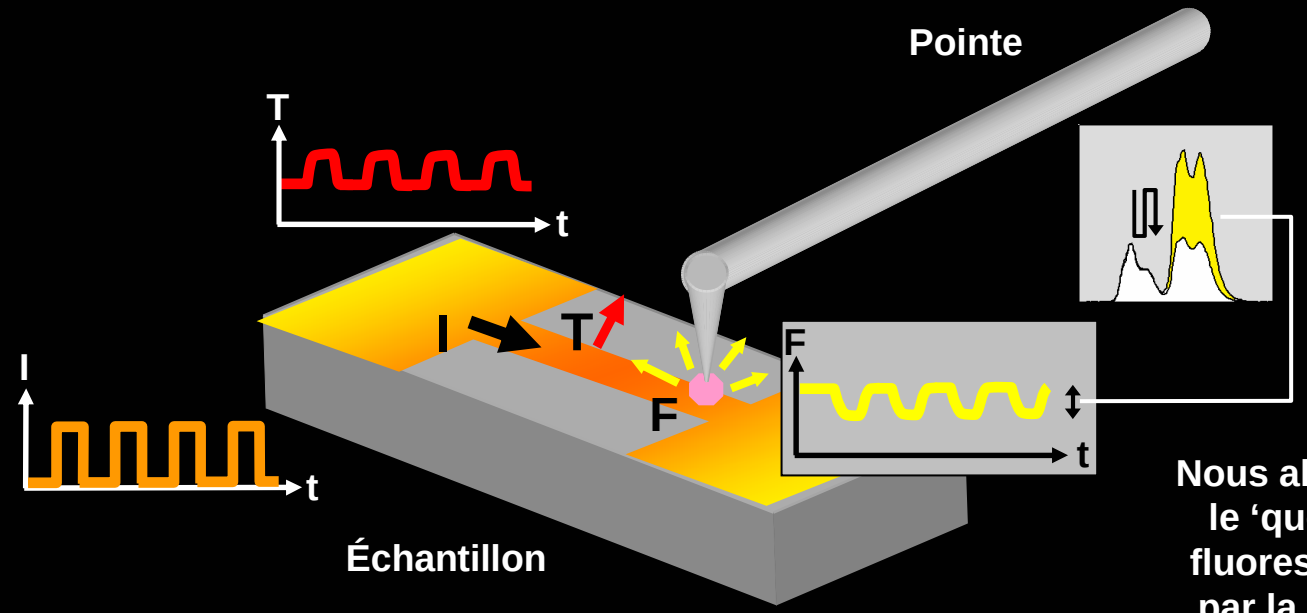




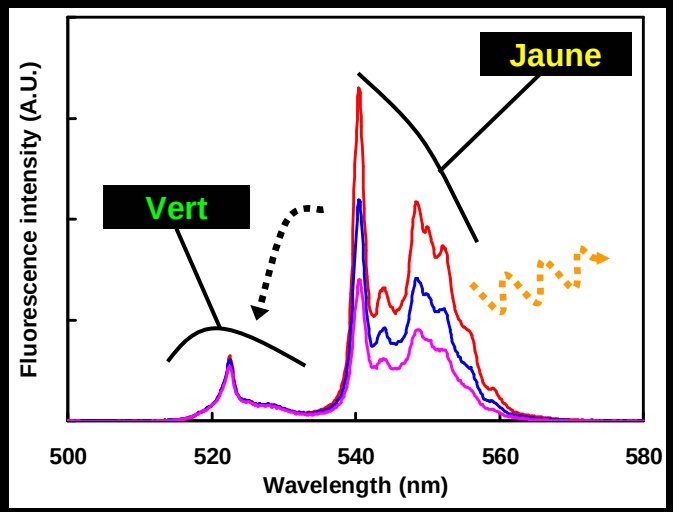


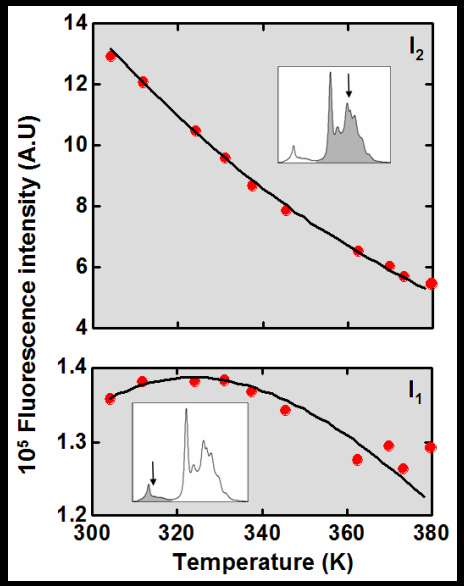
JAP **102**, 024305 (2007).

IMAGERIE THERMIQUE EN MODE AC



Nous allons mesurer le 'quenching' de fluorescence induit par la température





Rate equations

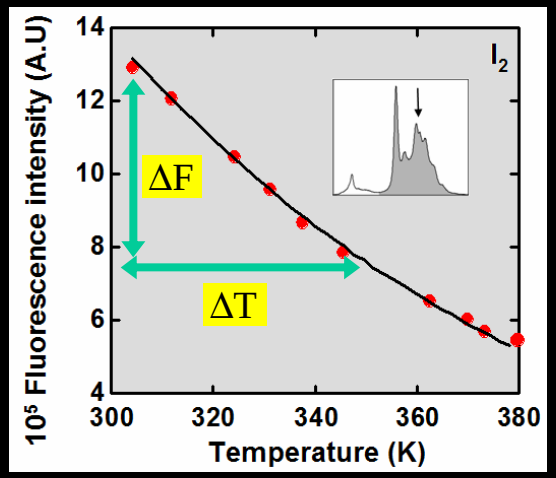
$$I_1(T) = \frac{QAe^{-\Delta E_{12}/k_bT}}{(1+Ae^{-\Delta E_{12}/k_bT})(1+k_{nr}/k_r)}$$

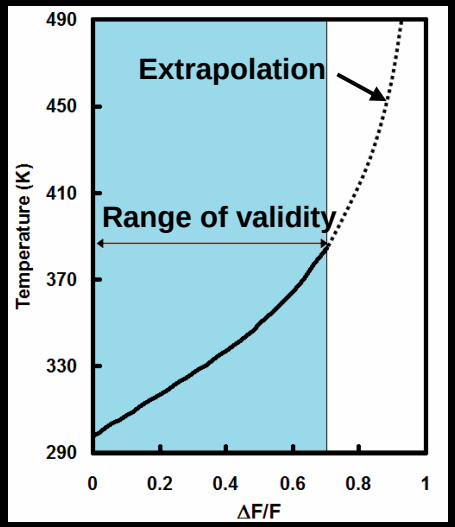
$$I_2(T) = \frac{Q}{(1+Ae^{-\Delta E_{12}/k_bT})(1+k_{nr}/k_r)}$$

IMAGERIE THERMIQUE EN MODE AC

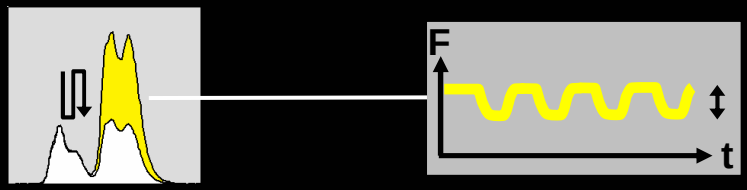
Rate equations gives

$$I_2(T) = \frac{Q}{(1 + Ae^{-\Delta E_{12}/k_b T})(1 + k_{nr}/k_r)}$$



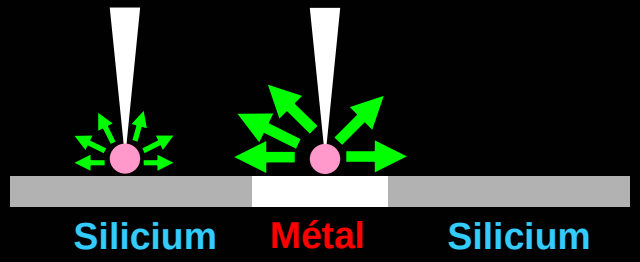


During a scan we measure



$$\Delta F = I_2(T_{amb}) - I_2(T_{max})$$

Cependant



Pour s'affranchir des inhomogénéités, nous devons normaliser nos images

Fluorescence modulée thermiquement

Fluorescence à la température ambiante

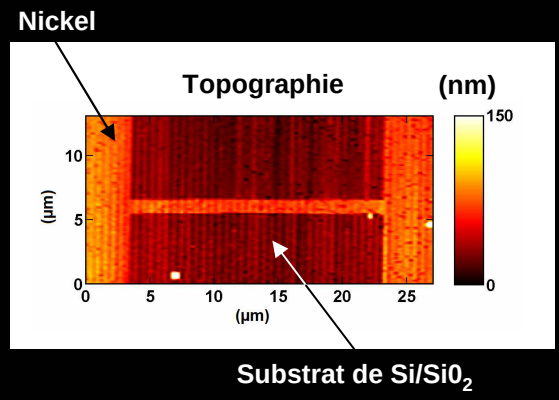
$$\frac{\Delta F}{F} = \frac{I_2(T_{amb}) - I_2(T_{max})}{I_2(T_{amb})}$$

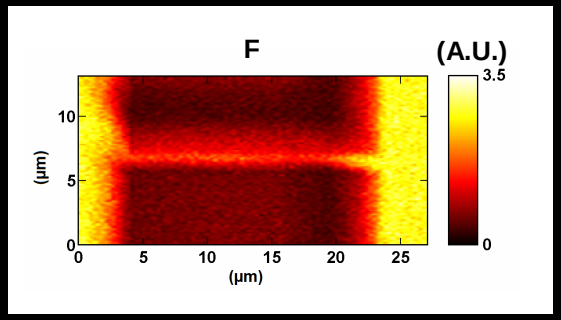
$$T_{max} = f\left(\frac{\Delta F}{F}\right)$$

EXEMPLE D'IMAGERIE AC

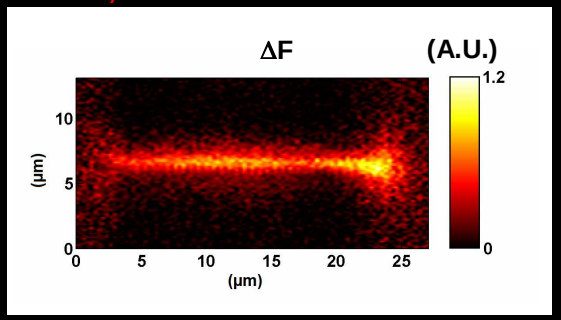
Échantillon: P. Löw, C. Bergaud (LAAS, Toulouse)

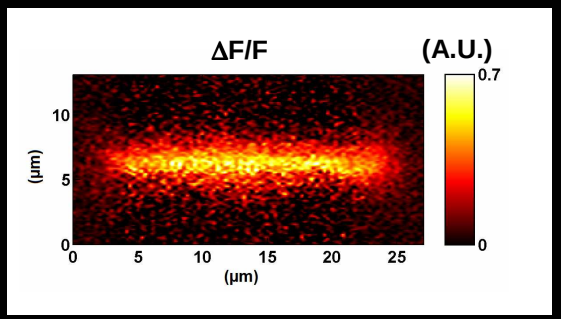
SiO_2 / Ni / SiO_2 / Si
Largeur : 1µm
Longueur : 20µm

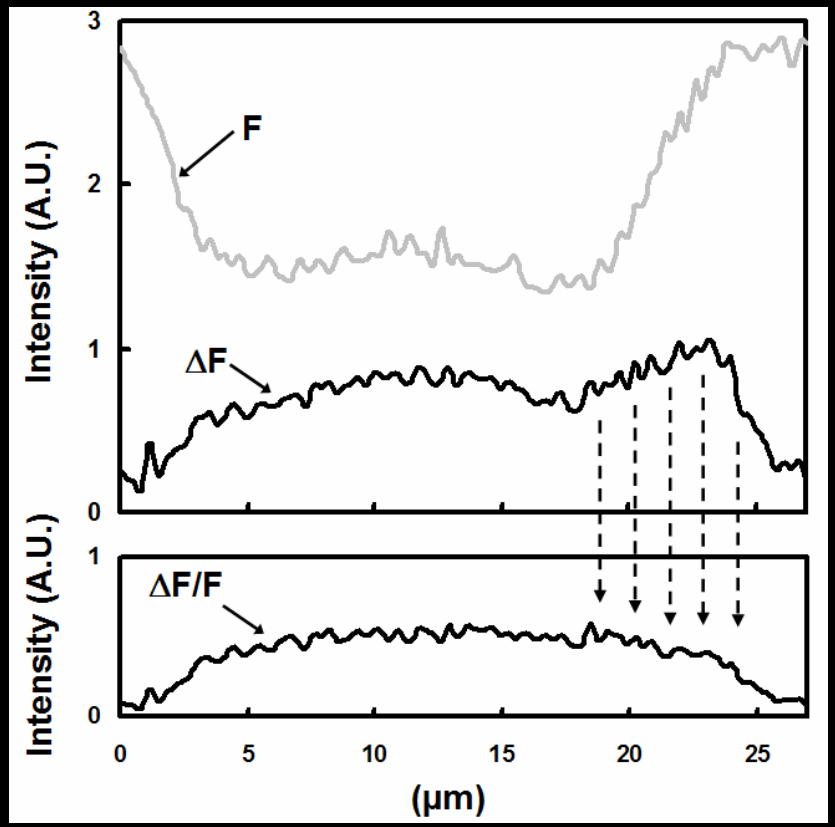




i=8mA, f=530Hz



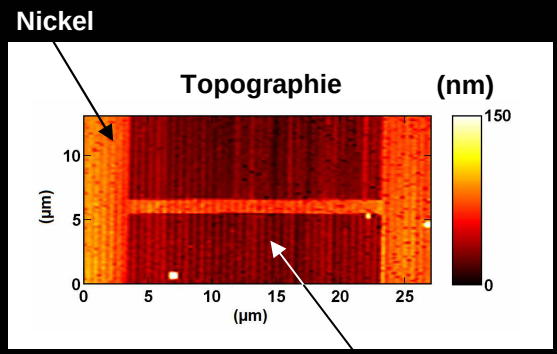


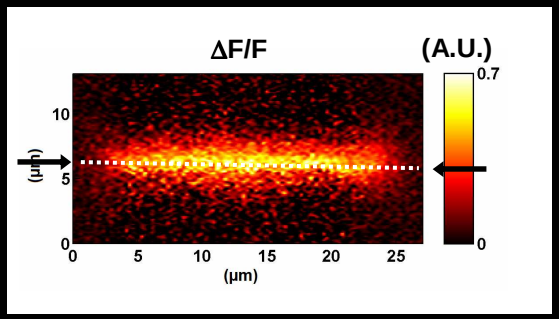


EXEMPLE D'IMAGERIE AC

Échantillon: P. Löw, C. Bergaud (LAAS, Toulouse)

SiO_2 / Ni / SiO_2 / Si
Largeur : 1µm
Longueur : 20µm





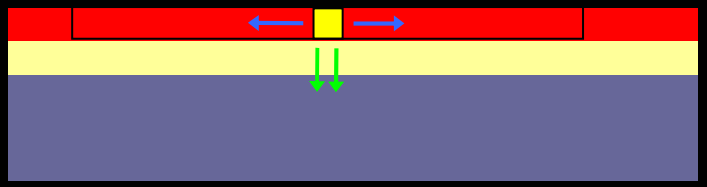
Simulation de l'échauffement :

$$k_{Ni}\frac{d^2\theta(x)}{dx^2} + J^2\rho_0\left[1+\alpha_{Ni}\theta(x)\right] - \frac{h_{eff}}{t_{Ni}}\theta(x) = 0$$

Diffusion de la chaleur le long du métal

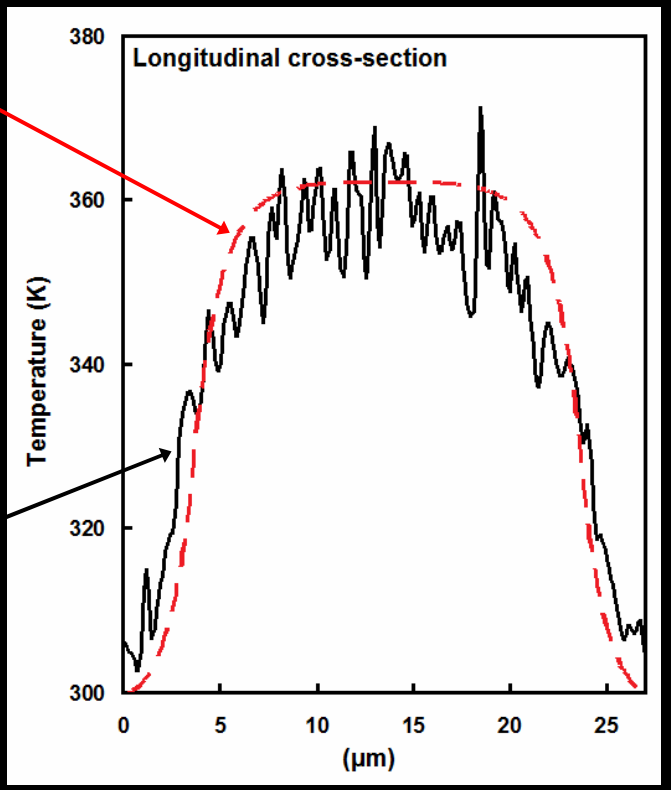
Terme source

Diffusion de la chaleur vers le substrat



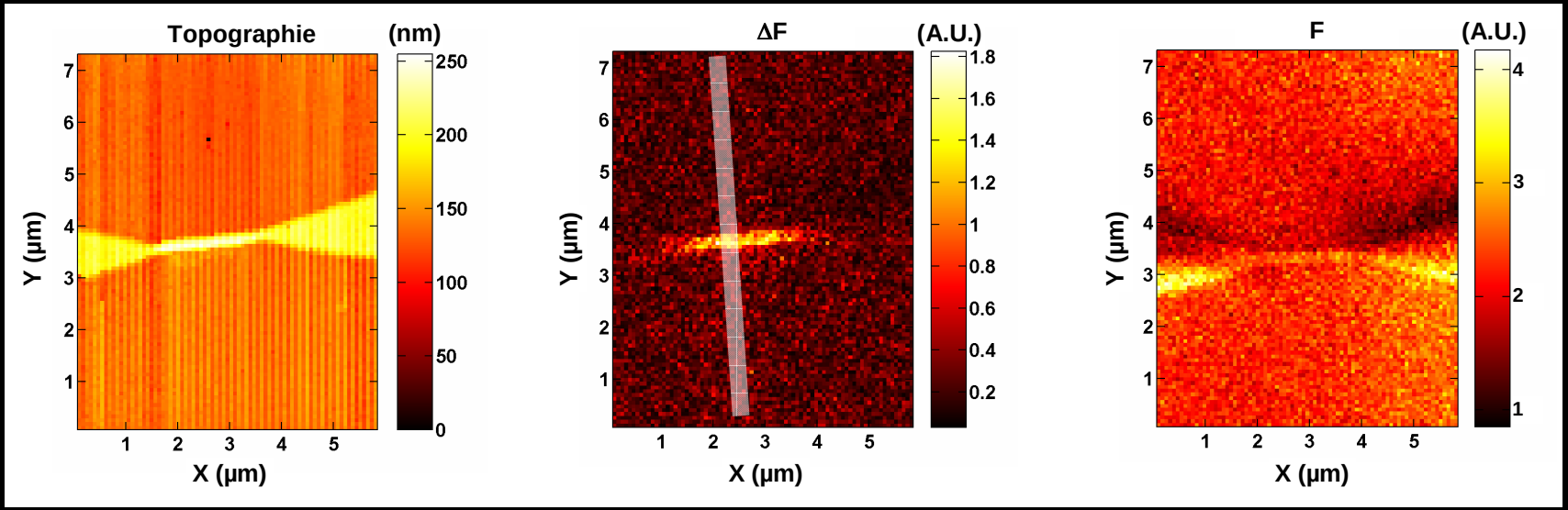
Simulation

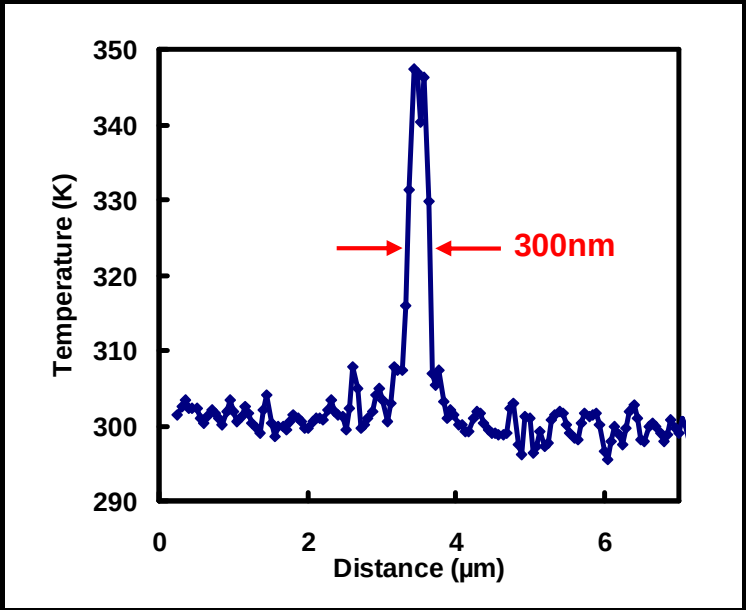
Expérience



NANOFIL DE TITANE DE LARGEUR 100nm

Échantillon: E. Saïdi, J. Lesueur (LPEM/ESPCI)



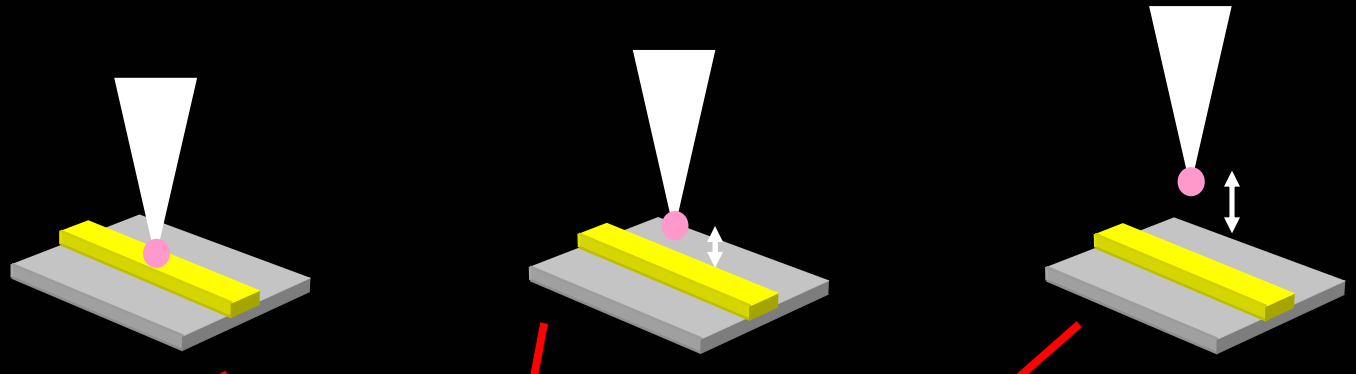


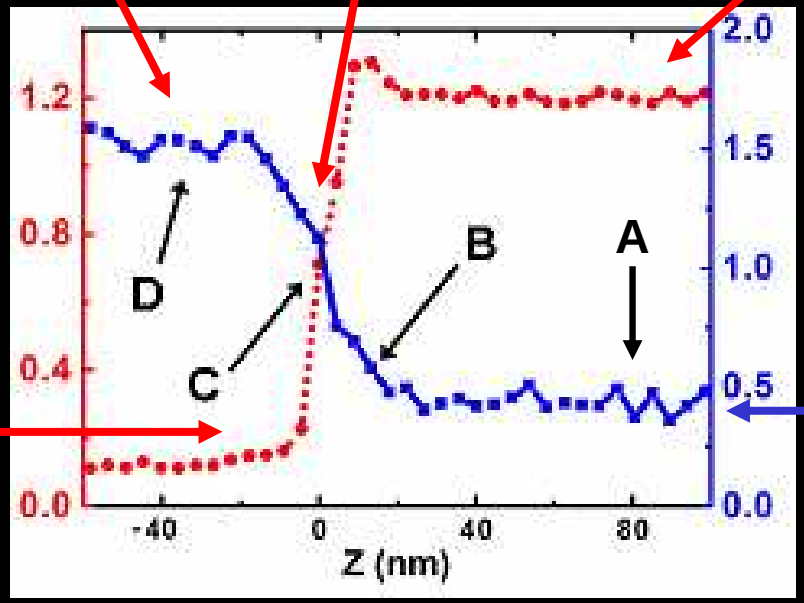
Expérience : Elika Saïdi

TRANSFERT THERMIQUE POINTE/SURFACE

Échantillon : P. Löw, C. Bergaud (LAAS)

Fil de Nickel : largeur = 500nm





Amplitude d'oscillation

Signal thermique (A.U)

ZONE A: Transfert de chaleur par conduction dans l'air

ZONES B and C: Transfert de chaleur lors du contact intermittent

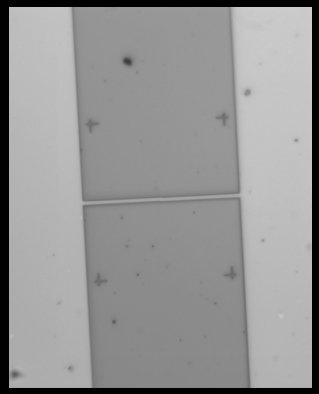
ZONE D: Transfert de chaleur par contact direct

APL **92**, 023101 (2008).

Expérience : Benjamin Samson

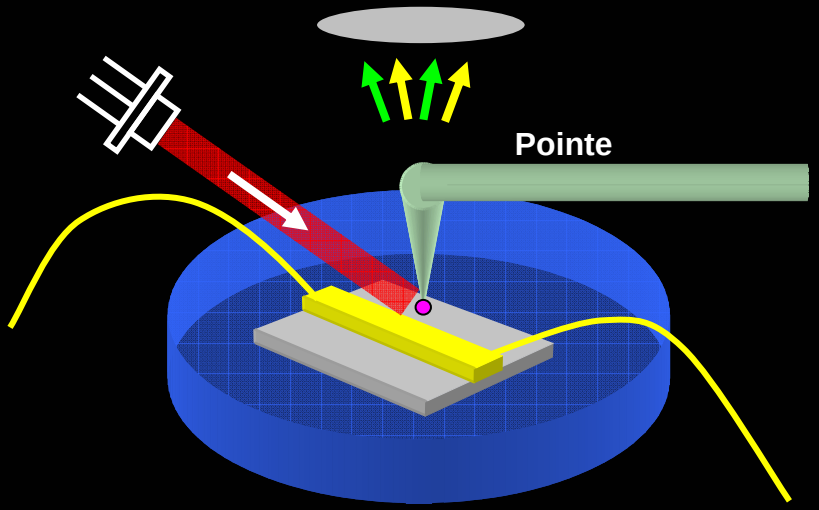
IMAGERIE THERMIQUE DANS DES LIQUIDES

Échantillon : P. Löw, C. Bergaud (LAAS)



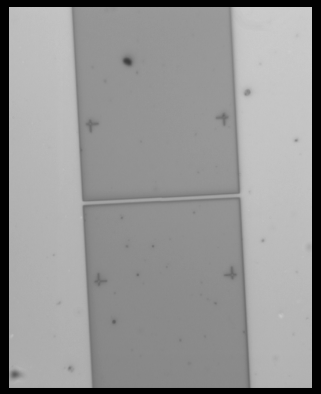
Nanodispositifs chauffants

Utilisés pour induire le mouvement de molécules (rotation, translation)



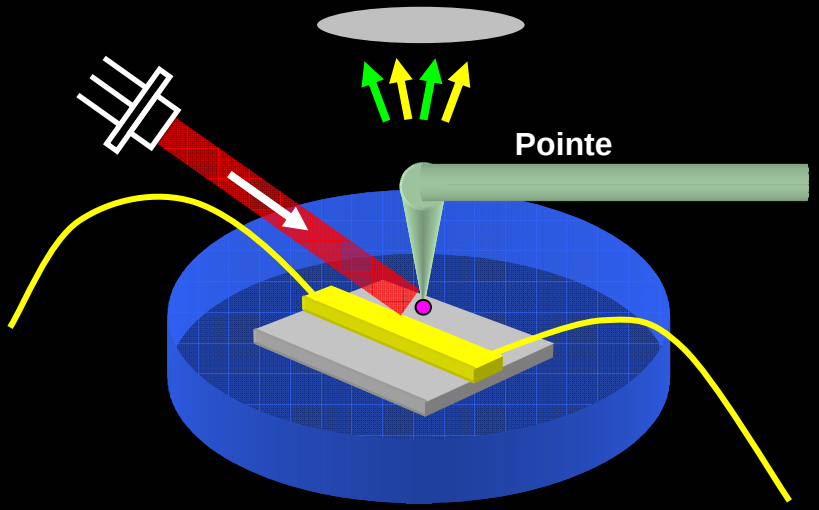
IMAGERIE THERMIQUE DANS DES LIQUIDES

Échantillon : P. Löw, C. Bergaud (LAAS)

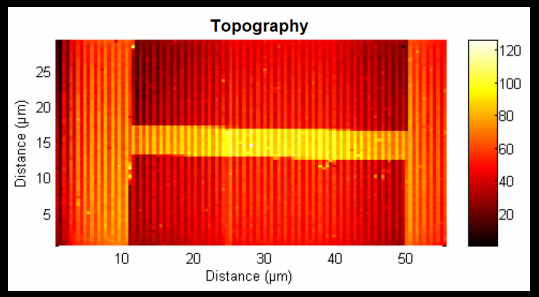


Nanodispositifs chauffants

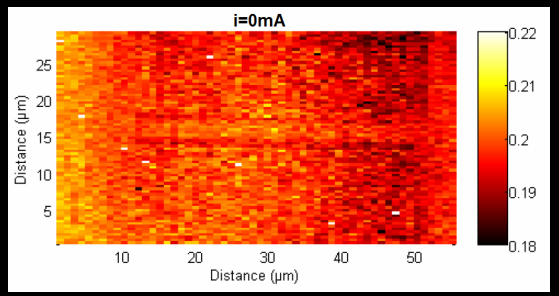
Utilisés pour induire le mouvement de molécules (rotation, translation)



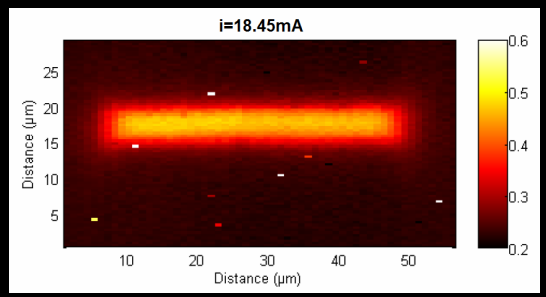
Piste de Nickel :
largeur = 4µm
longueur = 40µm



Pas de courant



Courant DC

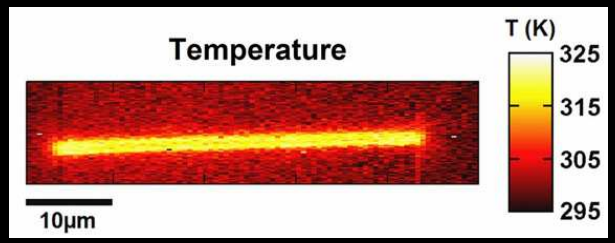


Expérience : Loïc Lalouat

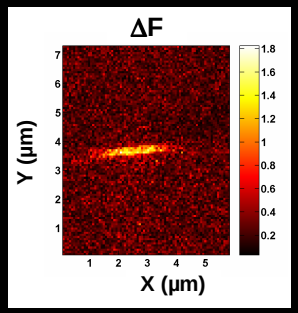
CONCLUSION

Particule fluorescente : capteur de température miniature efficace

Imagerie thermique : mode DC



Imagerie thermique : mode AC



Imagerie thermique : dans des liquides