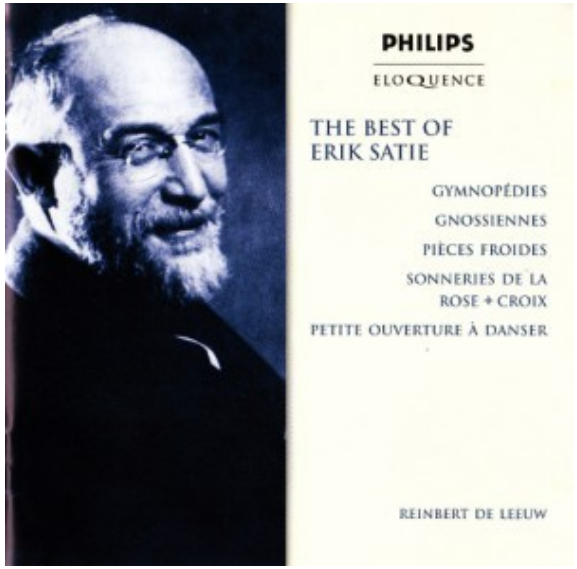
Manipulation d'objets submicrométriques en système microfluidique par utilisation du champ électrique

Martinus WERTS

Lab. SATIE (CNRS UMR 8029)
Ecole normale supérieure de Rennes, département mécatronique
Campus de Ker Lann, 35170 Bruz, France
martinus (*point*) werts (*arobase*) ens (*tiret*) rennes (*point*) fr

Financial support: ANR JCJC COMONSENS



Erik SATIE: compositeur à succès

(* 1866 Honfleur, † 1925 Arcueil-Cachan)

SATIE: laboratoire de "*electrical engineering*"

SATIE: laboratoire multi-partenaire

CNRS - ENS Cachan - CNAM - Univ. Cergy-Pontoise - IFSTTAR - Univ. Paris-Sud - ENS Rennes

SATIE: 2 pôles de recherche

- Composants et Systèmes pour l'Energie Electrique (CSEE)
- Systèmes d'Information et d'Analyse Multi-Echelles (SIAME)

SATIE: laboratoire multi-site, équipes multi-site

SATIE au département mécatronique de l'ENS Rennes

- énérgie électrique renouvelable
- biomicrosystèmes et capteurs

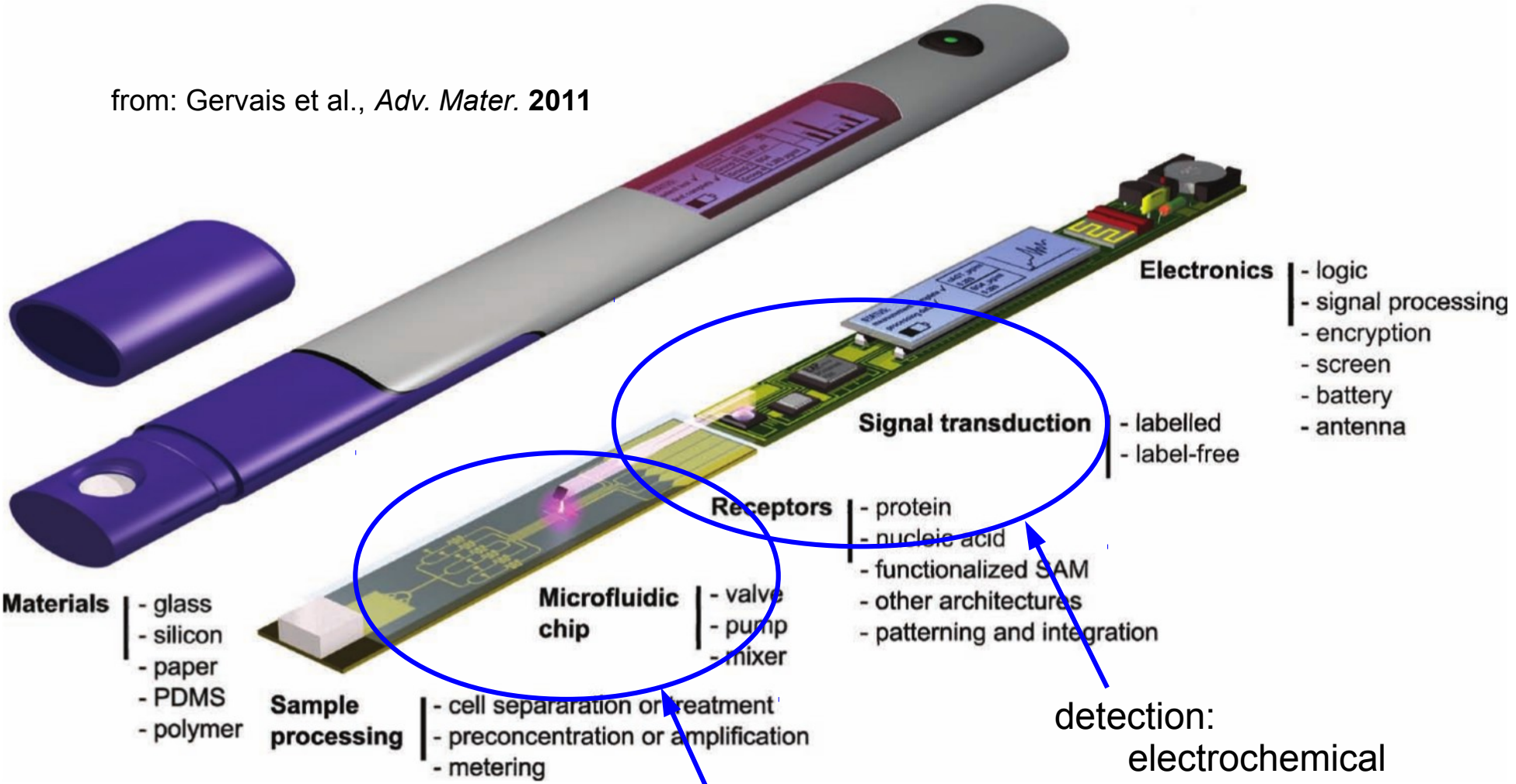
biomicrosystèmes (bioMEMS)

- outils pour la biologie et la biotechnologie
  - “puces à cellules”
    - étude de la biologie cellulaire, de la génétique
    - thérapie génique
  - “puces à ADN”
    - séquençage du génome

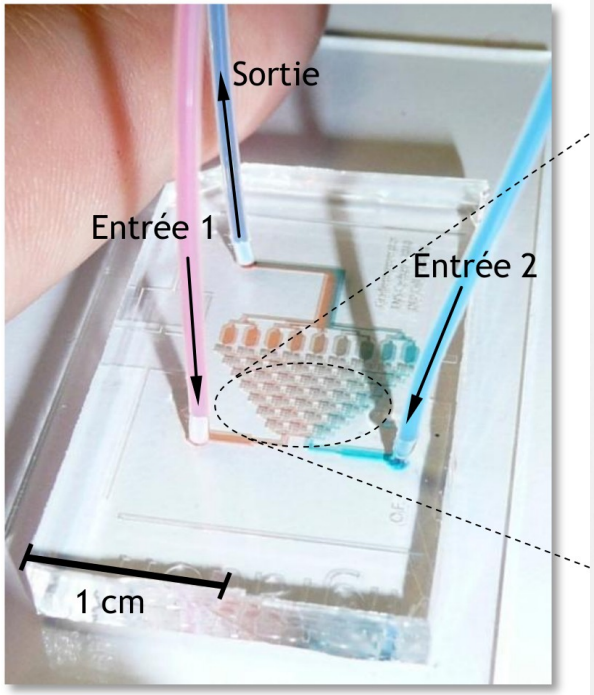
- détection et quantification de biomarqueurs
  - “point of care diagnostics”

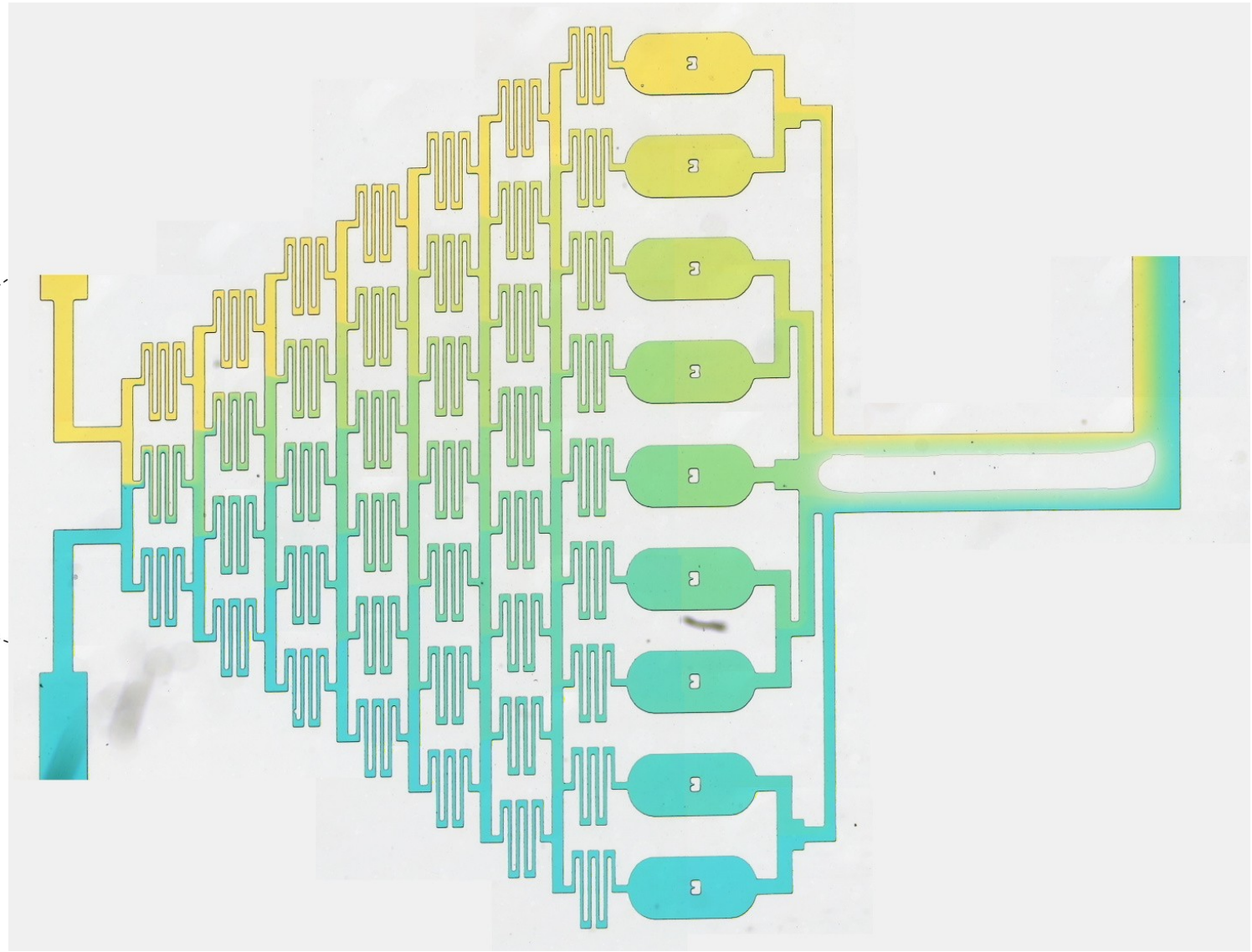
    analyses médicales sans passage par laboratoire centralisé
    - rapidité
    - autonomie: suivi thérapeutique à domicile
    - zones géographiques loin d'infrastructures médicales

idealized “point of care” diagnostic system



the joy of microfluidics

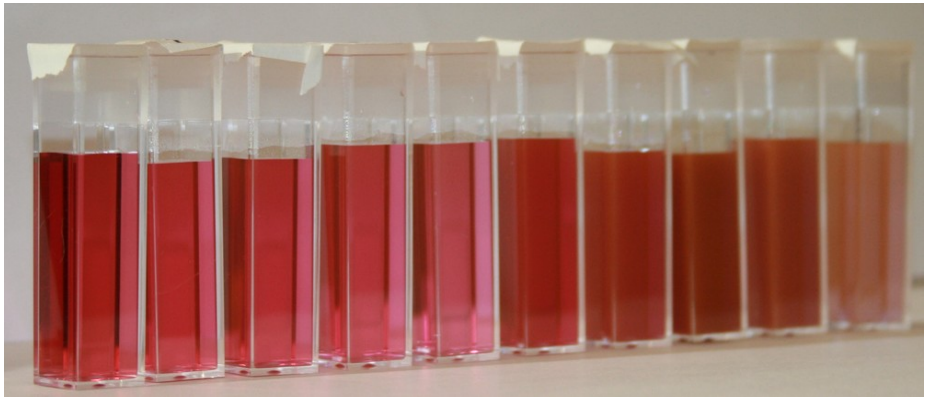




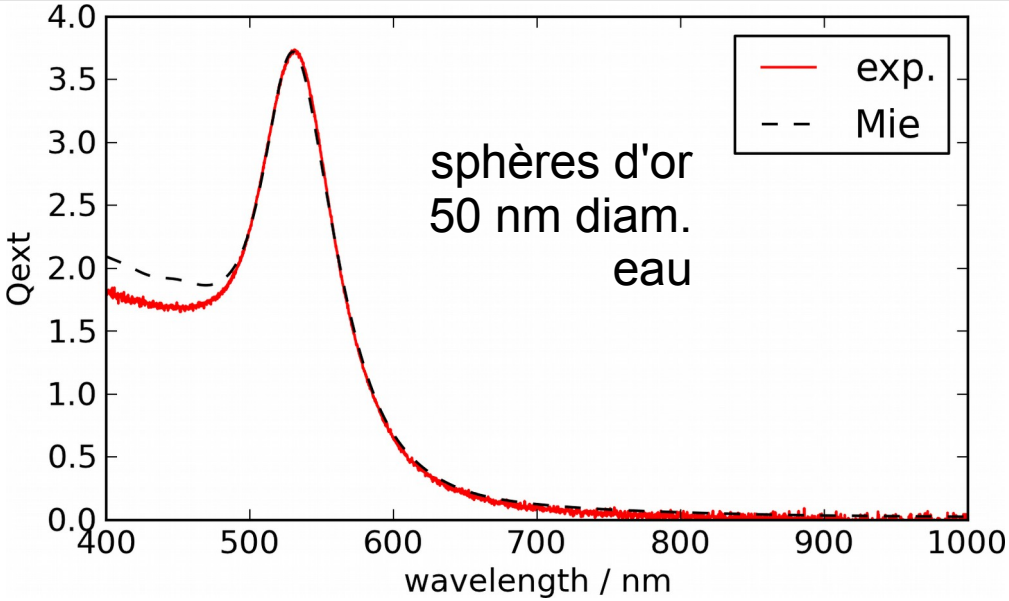
- precision engineering of fluid flow and mass transport
- quantitative RGB optical read-out of molecular concentrations

Werts et al., *Lab on a Chip* **2012**

nanoparticules d'or: antennes aux fréquences optiques

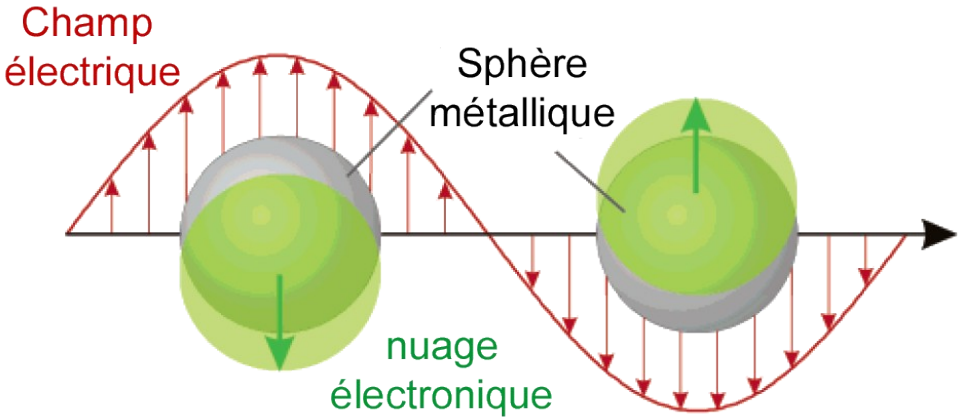


nanoparticules d'or dans de l'eau
diamètre 15...80 nm



Navarro&Werts, *Analyst* **2013**

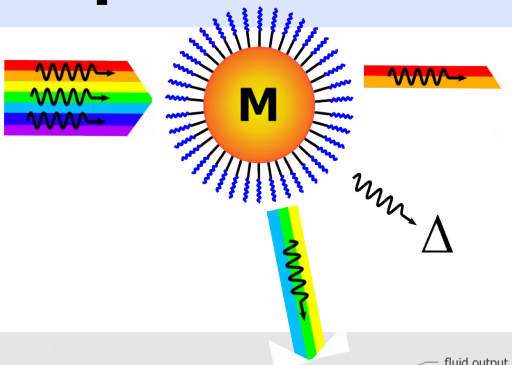
modèle interaction particule d'or - lumière: *résonance plasmonique*

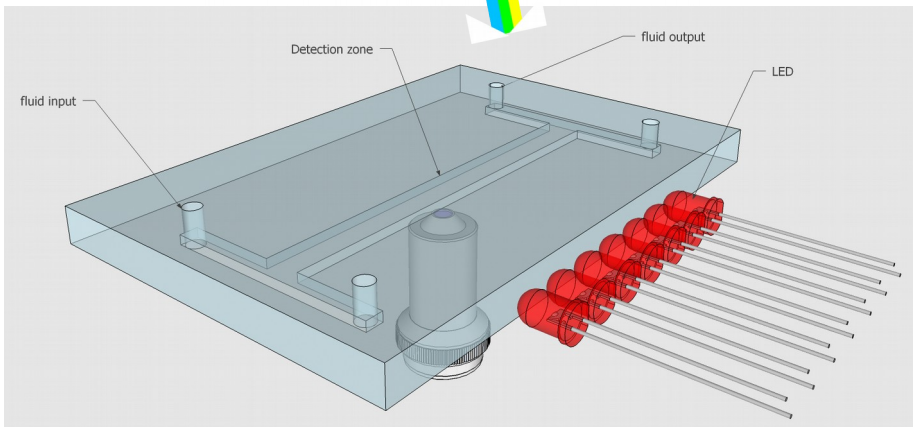


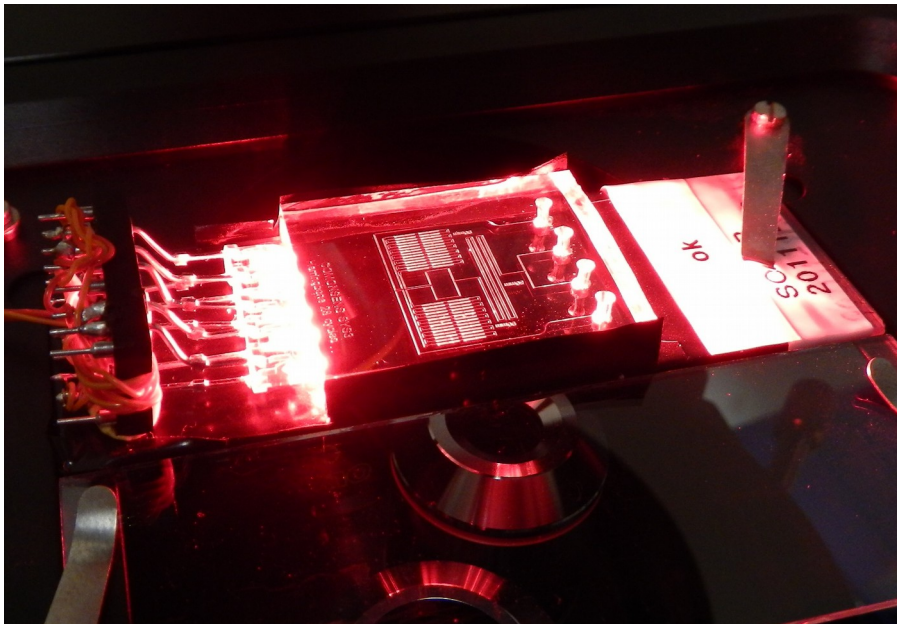
- cf. oscillateur harmonique amorti
  => résonance (fréquences optiques)
- fréquence de résonance
  sensible à l'environnement de la particule

=> => (bio)capteur optique

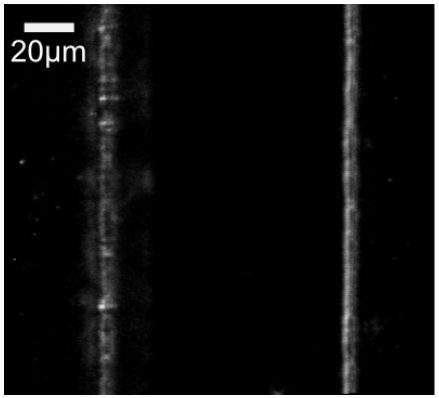
détection en microscopie champ sombre par diffusion résonante de la lumière



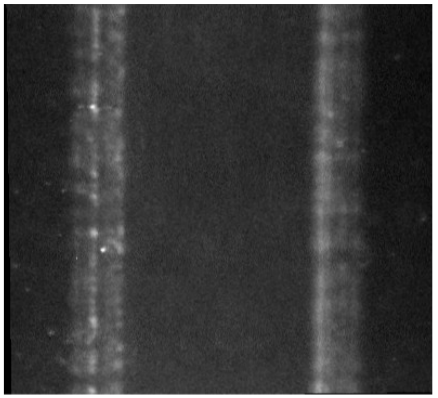




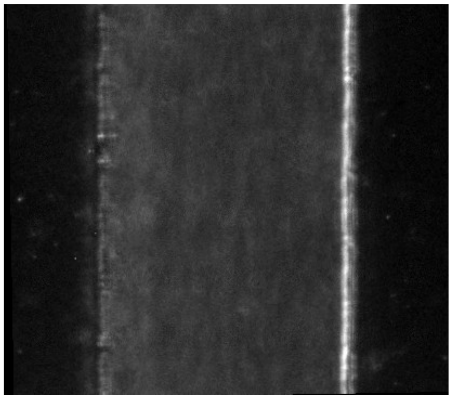
water



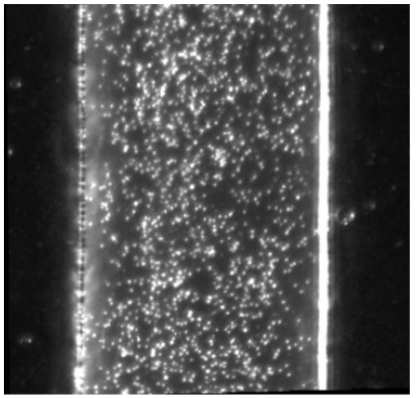
50 nm AuNP



80 nm AuNP

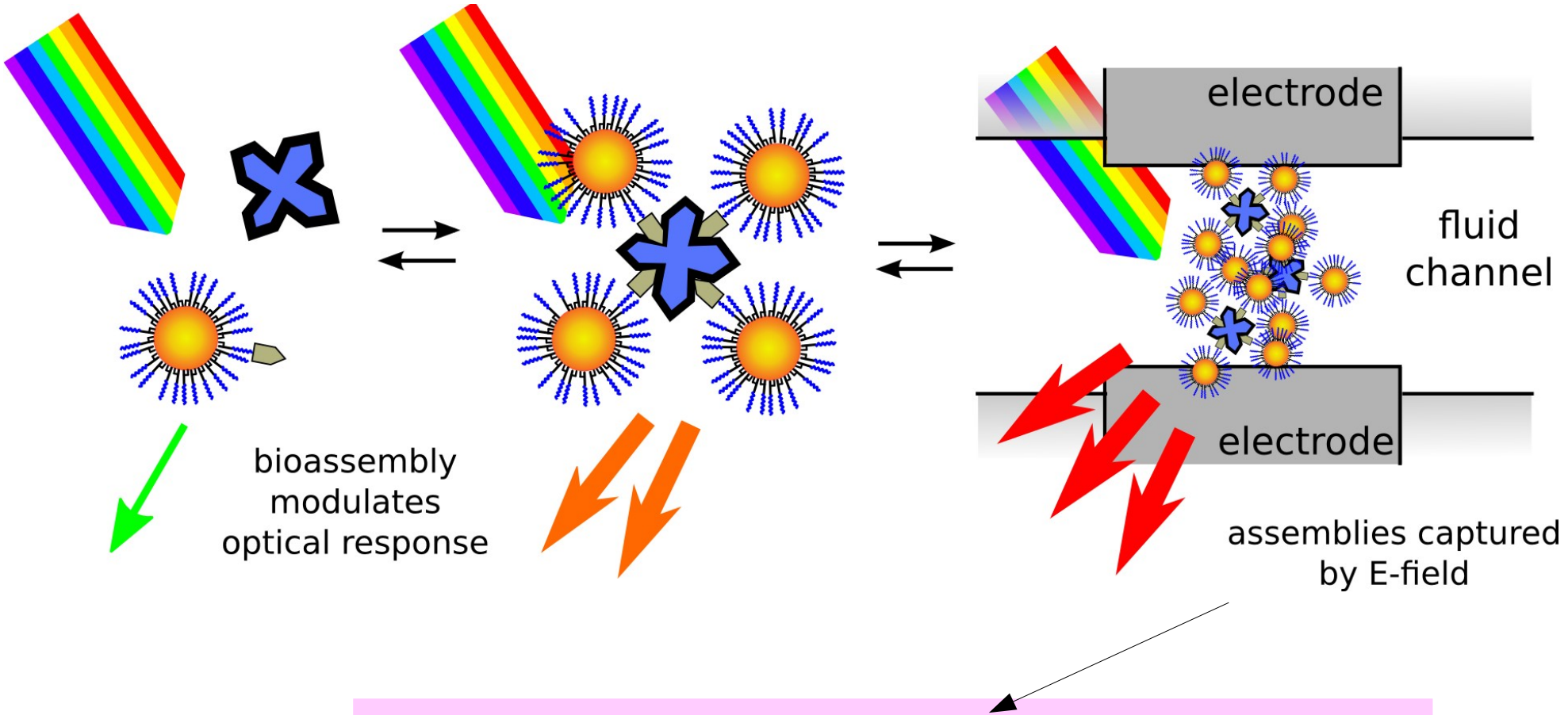


150 nm AuNP



Werts et al., *Proc. SPIE* **2013**, *8595, 85950W*

biosensing particles & electric fields



electric fields and aqueous solutions

<u>“traditionally”:</u> DC electrokinetic phenomena
<u>microsystems:</u> AC electrokinetic phenomena

AC electrokinetic phenomena

AC electric fields in microfluidic systems ("electromicrofluidics")

- alternating current at higher frequencies (1 kHz ... 10 MHz):
  greatly reduced electrochemistry at electrodes
  higher fields possible

- strong E-fields => small interelectrode distance (microsystems!)

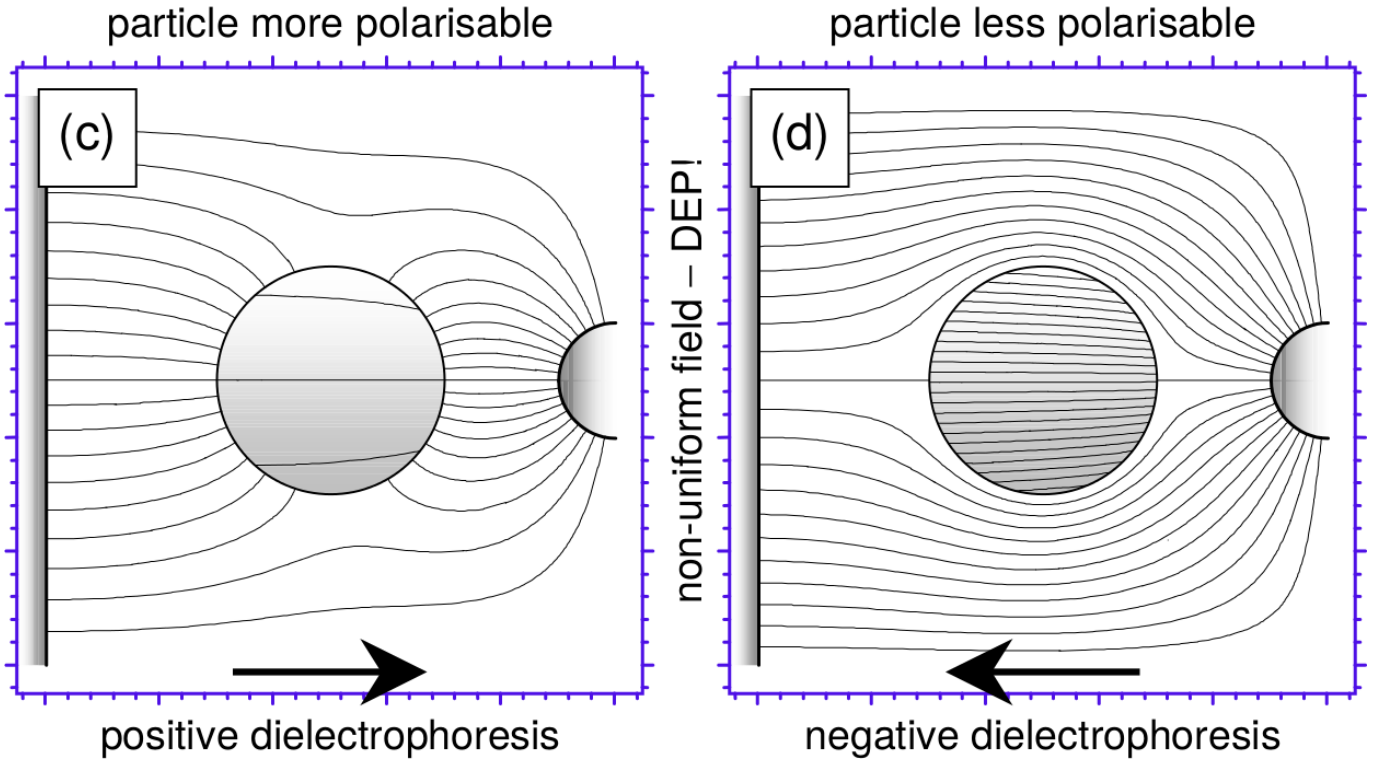
three main electrokinetic phenomena

1. AC electro-osmosis
2. electrothermal effect

→ "electrohydrodynamics"

3. dielectrophoresis

dielectrophoretic force on a polarizable particle



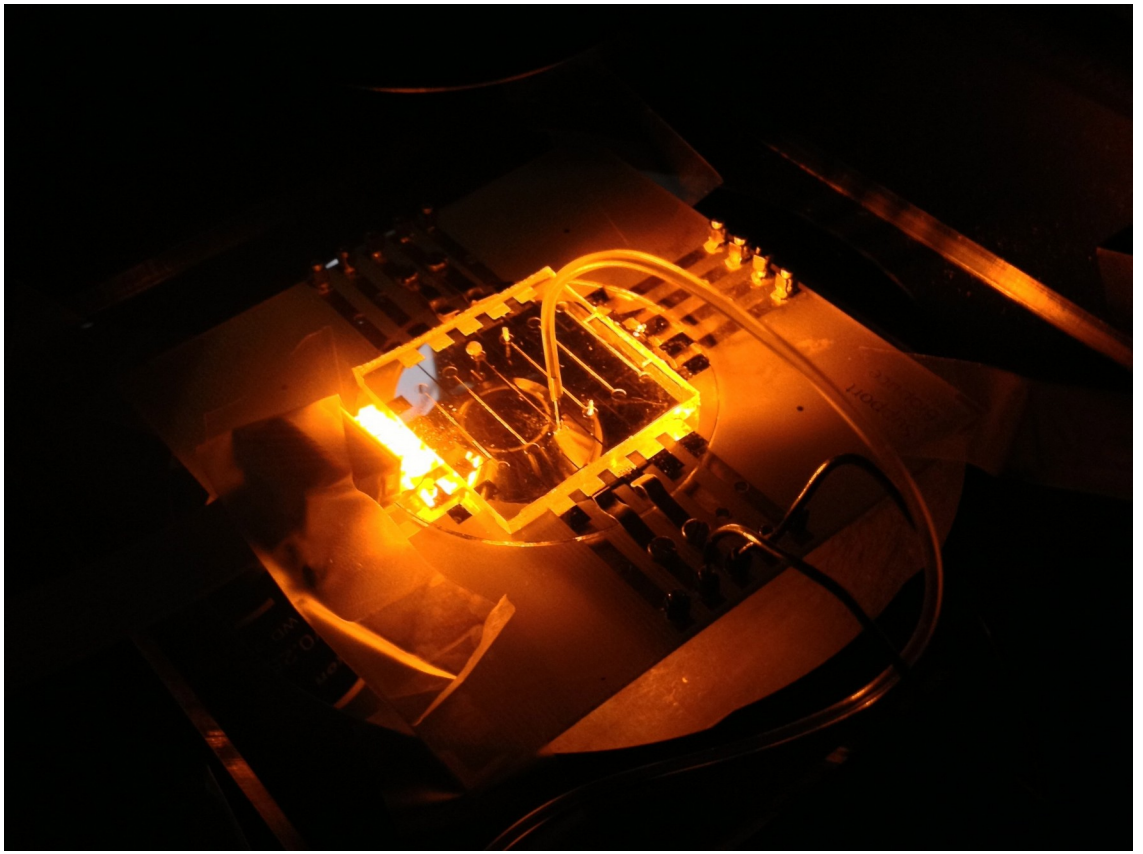
$$F_{\mathrm{DEP}} \propto R^3_{\mathrm{particle}}$$

- permittivité particule ≠ permittivité du liquide
- force sur la particule dans un champ électrique non-uniforme
- particule en milieu visceux: force => vitesse limite (loi de Stokes)

  => diélectrophorèse (DEP)

Morgan & Green. “AC Electrokinetics: colloids and nanoparticles” (2003)

light, particles, water, electricity

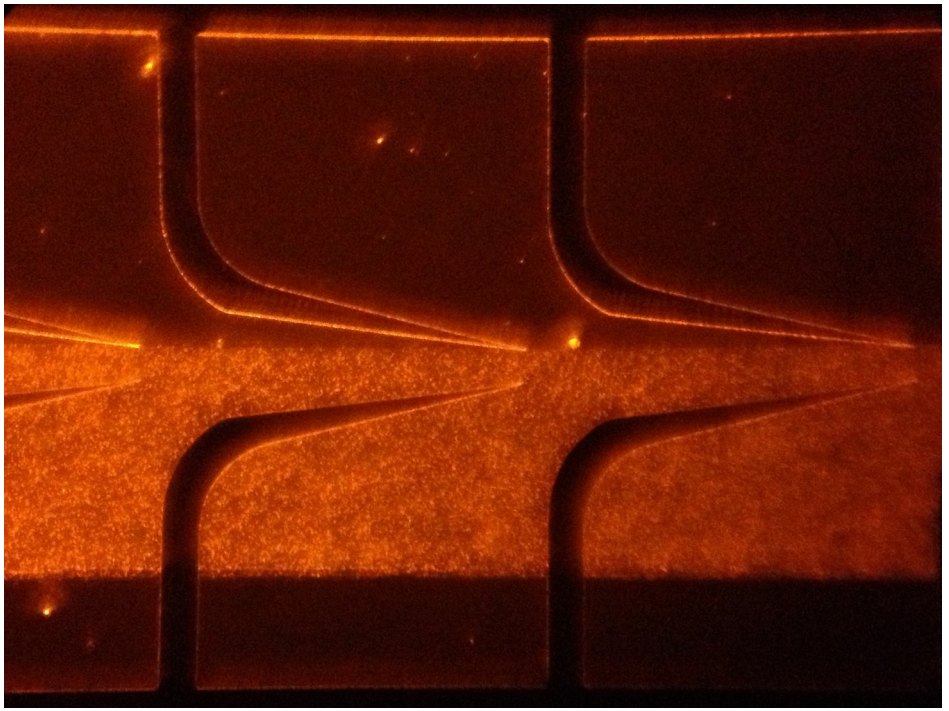


- fabrication microélectrodes in ITO (lithographie salle blanche)
- fabrication structure microfluidique, intégration LEDs
- source AC: générateur de fonction
- microscope optique

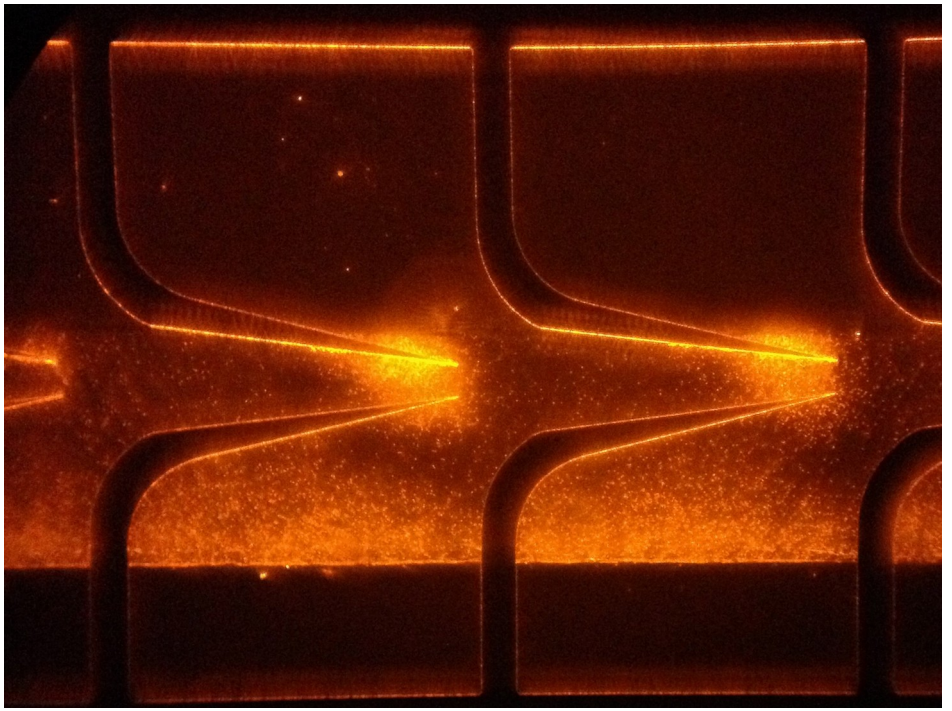
- chimie nanoparticules
- spectroscopie optique

AC electrokinetics of plasmonic particles

AC off



AC on, U_0 10V



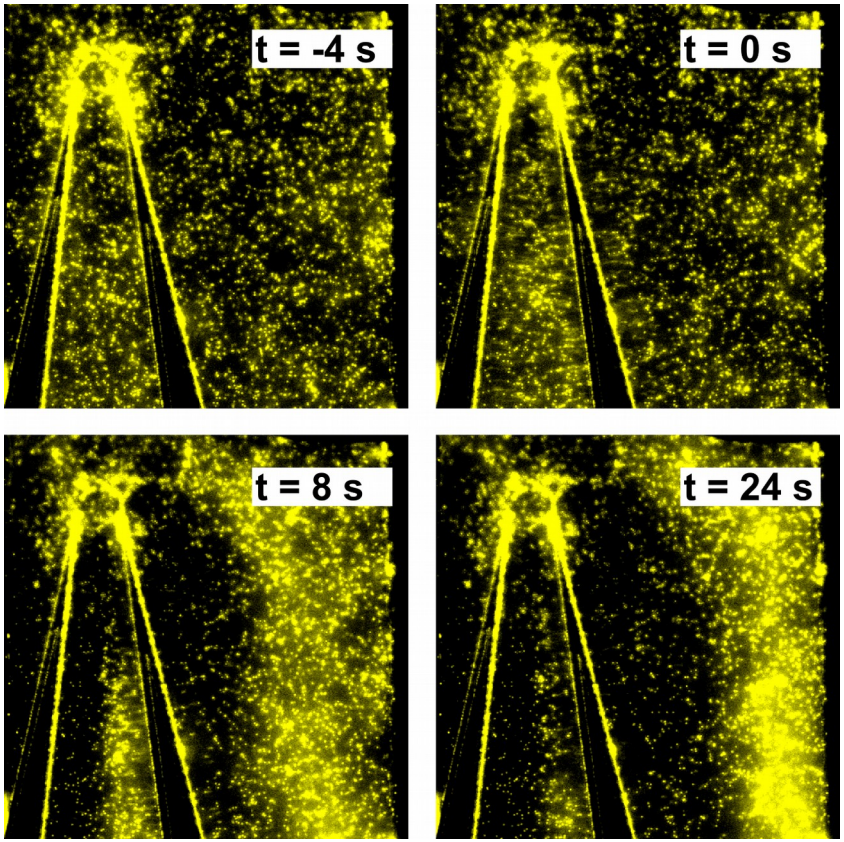
sample: 150 nm gold colloids, water 0.04 S m^{-1}
LED dark field, 580 nm

electrokinetic manipulation of nanoparticle suspensions

150 nm TEG-coated gold nanoparticles in water
medium conductivity: 1 mS m^{-1}

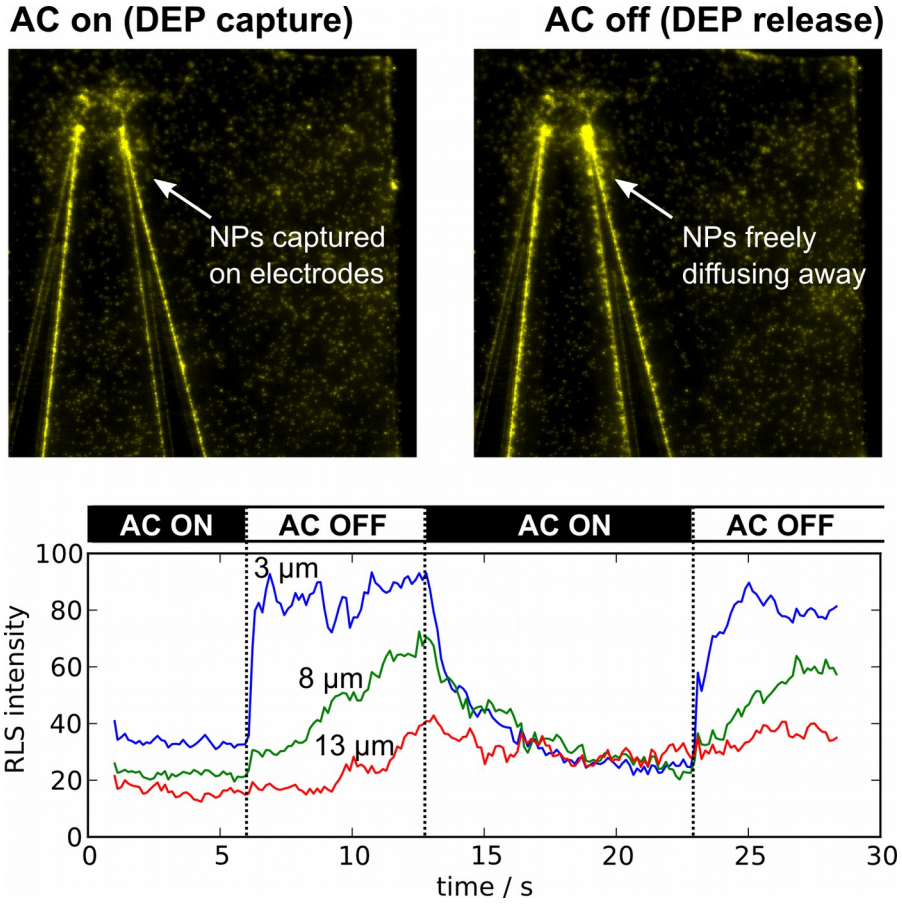
electrothermal flows

100 kHz, 20 V_{pp}



dielectrophoresis

1 MHz, 20 V_{pp}

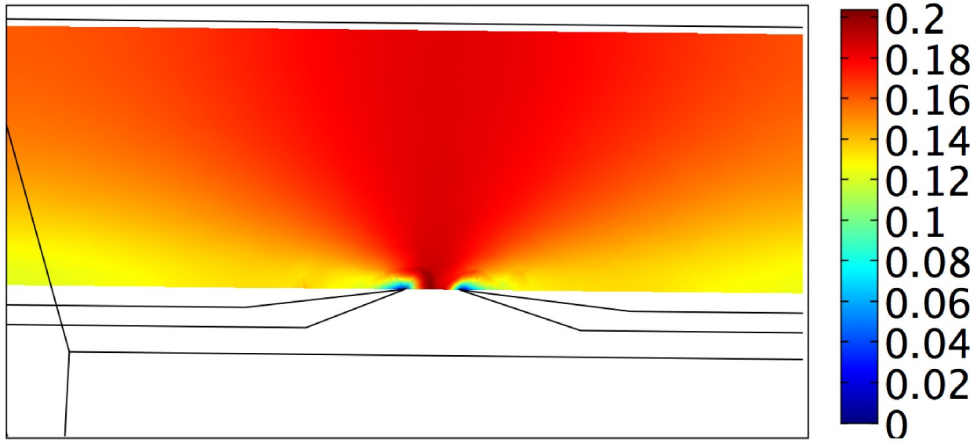


IEEE J. Sel. Top. Quant. Electron. **2014**, *20*, 6900613

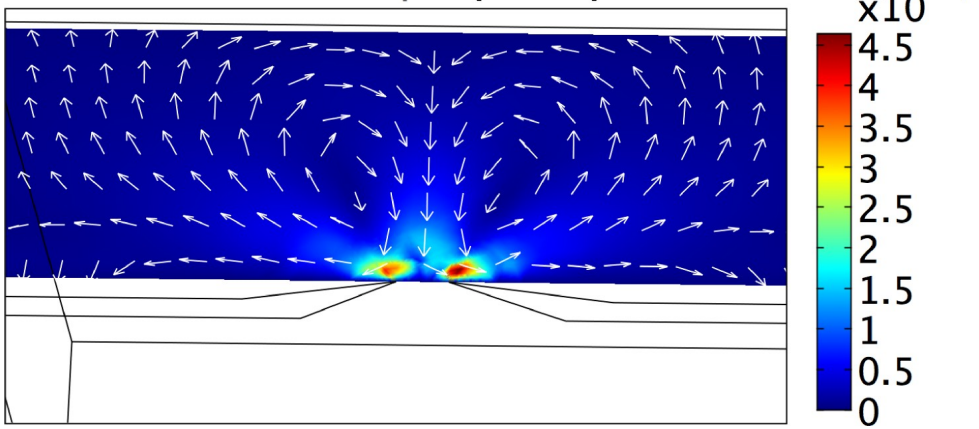
numerical results

electrothermal flows

Temperature rise (K)

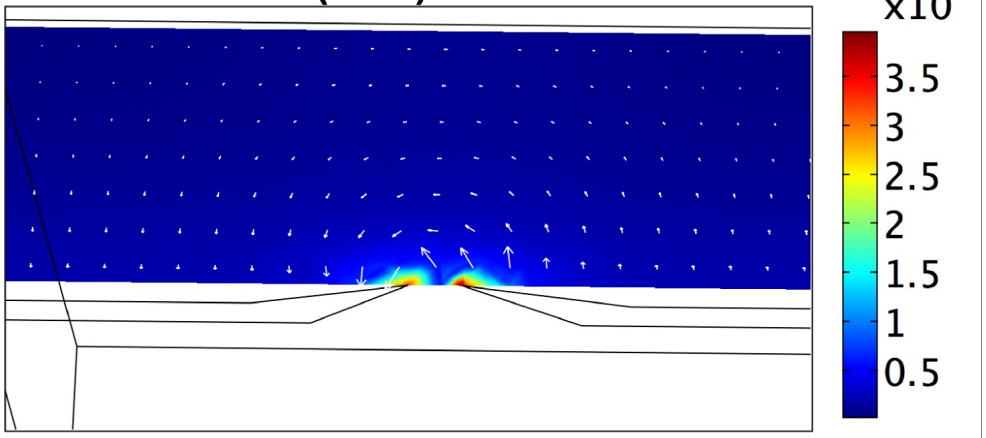


Electrothermal flow (m s^{-1})

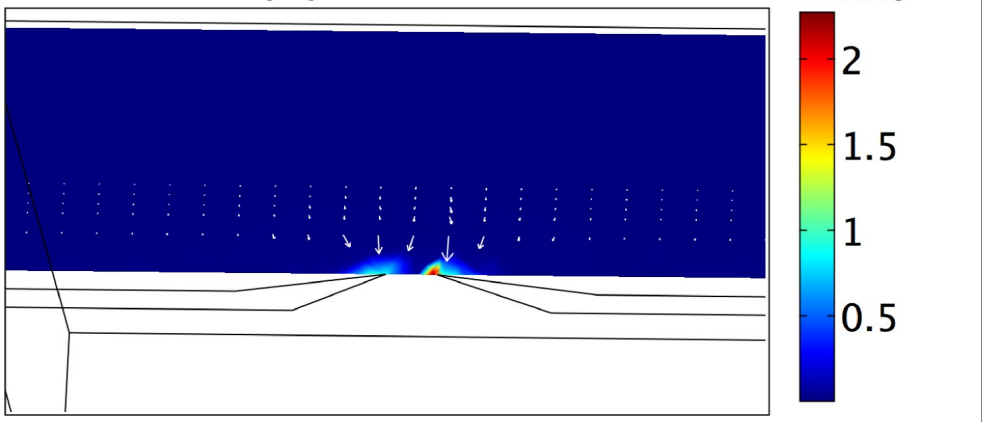


dielectrophoresis

Electric field (V/m)



DEP force (N)



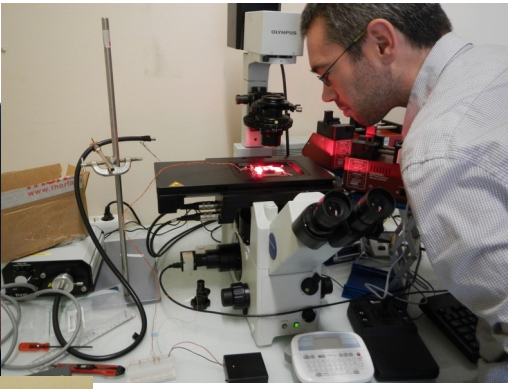
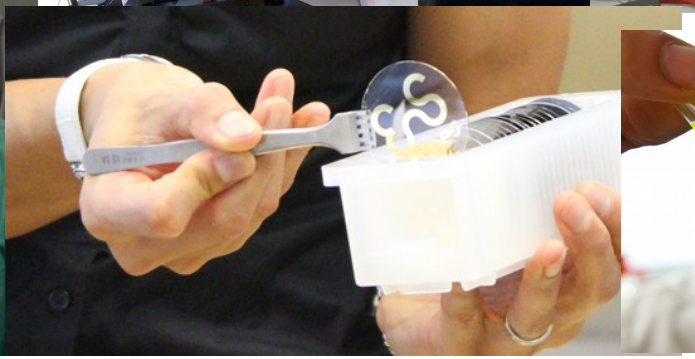
IEEE J. Sel. Top. Quant. Electron. **2014**, *20*, 6900613

Brownian motion, Poiseuille flow, dielectrophoresis

See the movie at:
http://perso.ens-rennes.fr/~mwerts/DEP-video.html

...and you for your attention




Biomicrosystems & sensors group - SATIE - ENS Rennes

http://www.ens-rennes.fr
http://www.satie.ens-cachan.fr