The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
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IAEA
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2328-8

Preparatory School to the Winter College on Optics and the Winter College on Optics: Advances in Nano-Optics and Plasmonics

6 - 17 February, 2012

Introduction to optical fabrication II

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Introduction to optical fabrication. II

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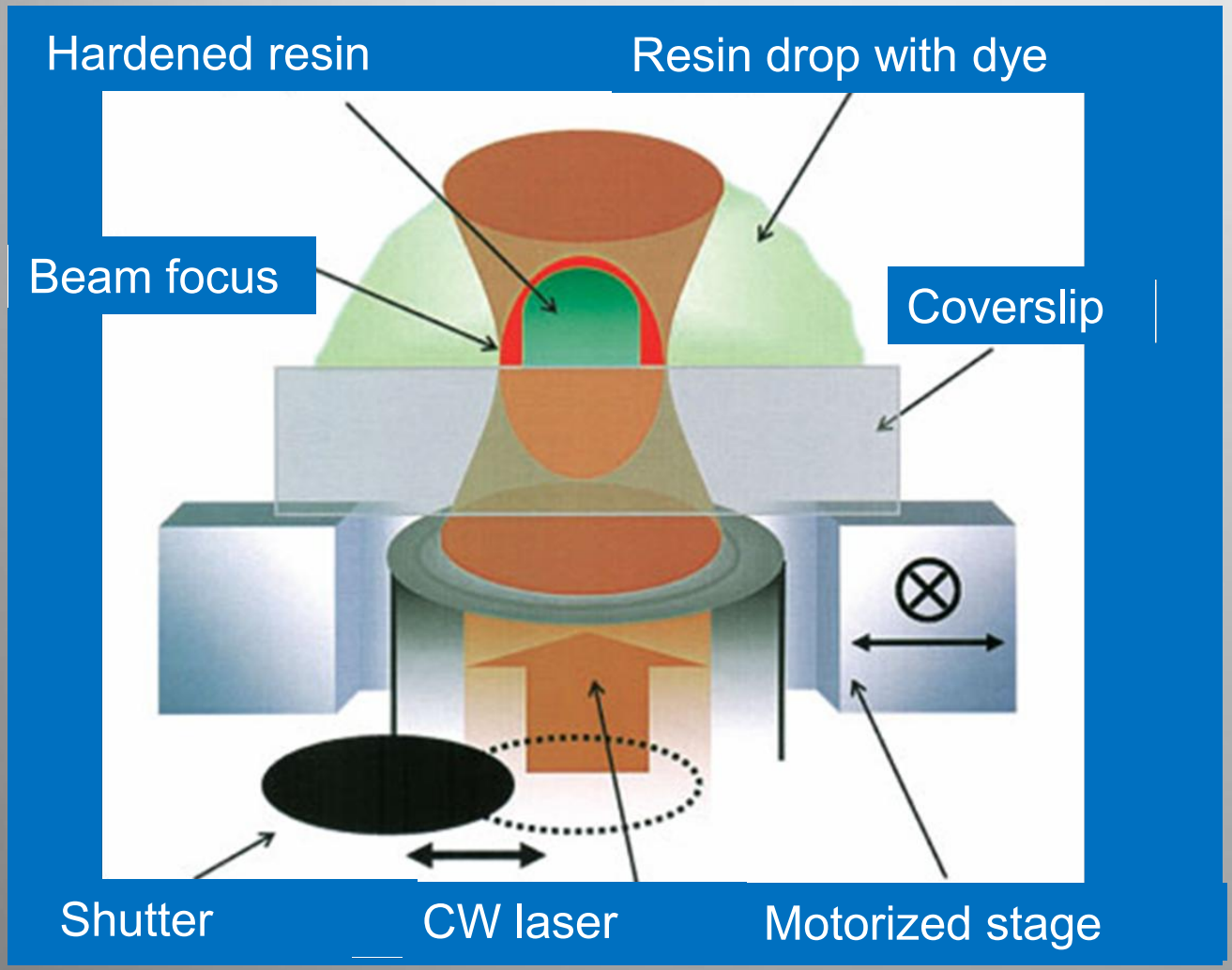
Introduction

- Optical lithography: Ways to break the diffraction barrier
  - ↓ λ (projection, interferencial, ablation)
  - Non linear (multiphoton, near field)
- SPAG – Surface Percolation and Growth
- Protein patterning
- Nano Printing Nano Particles

OUR SCHEME

- SURFACE PERCOLATION AND GROWTH
  - ONLY ONE LASER
  - ONLY ONE PHOTON

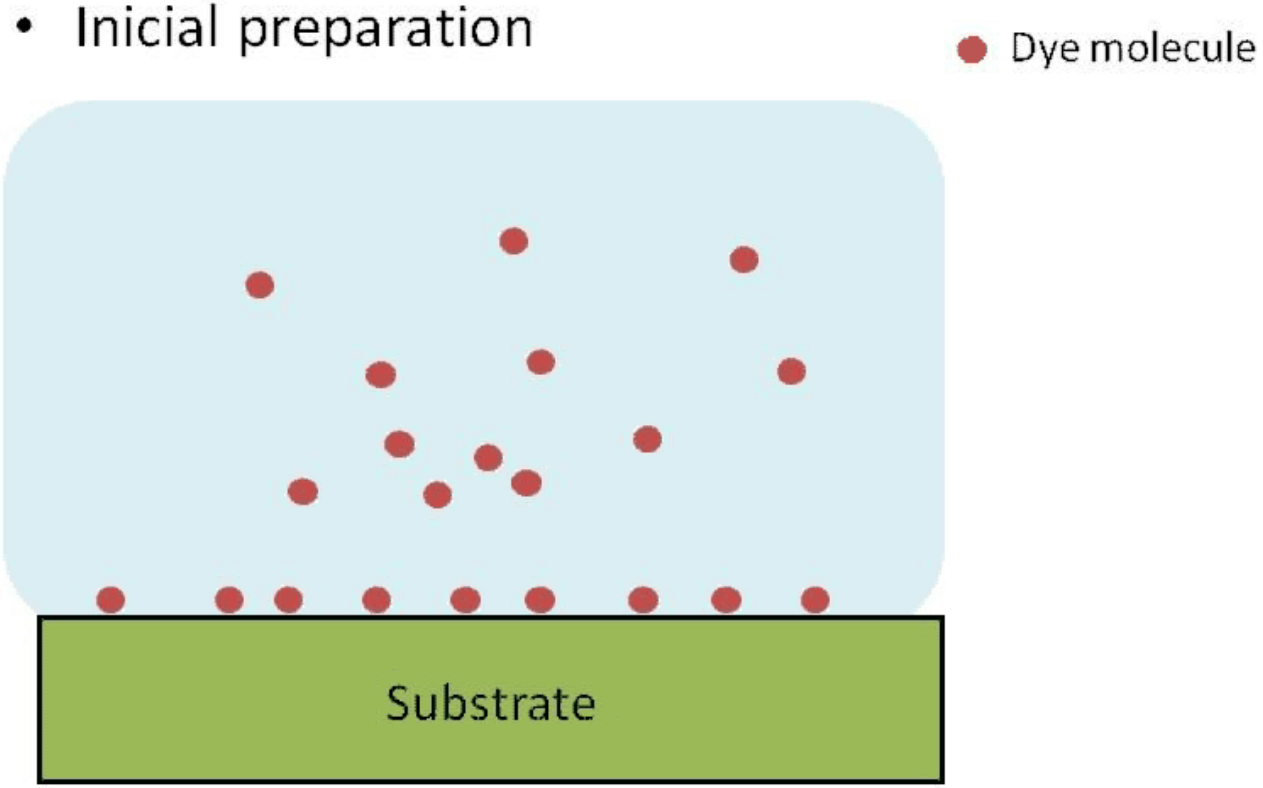
Experimental setup



- Parameters
  - dye
  - wavelength
  - Dye concentration
  - Laser power
  - Exposure time

Polimerization

- Inicial preparation



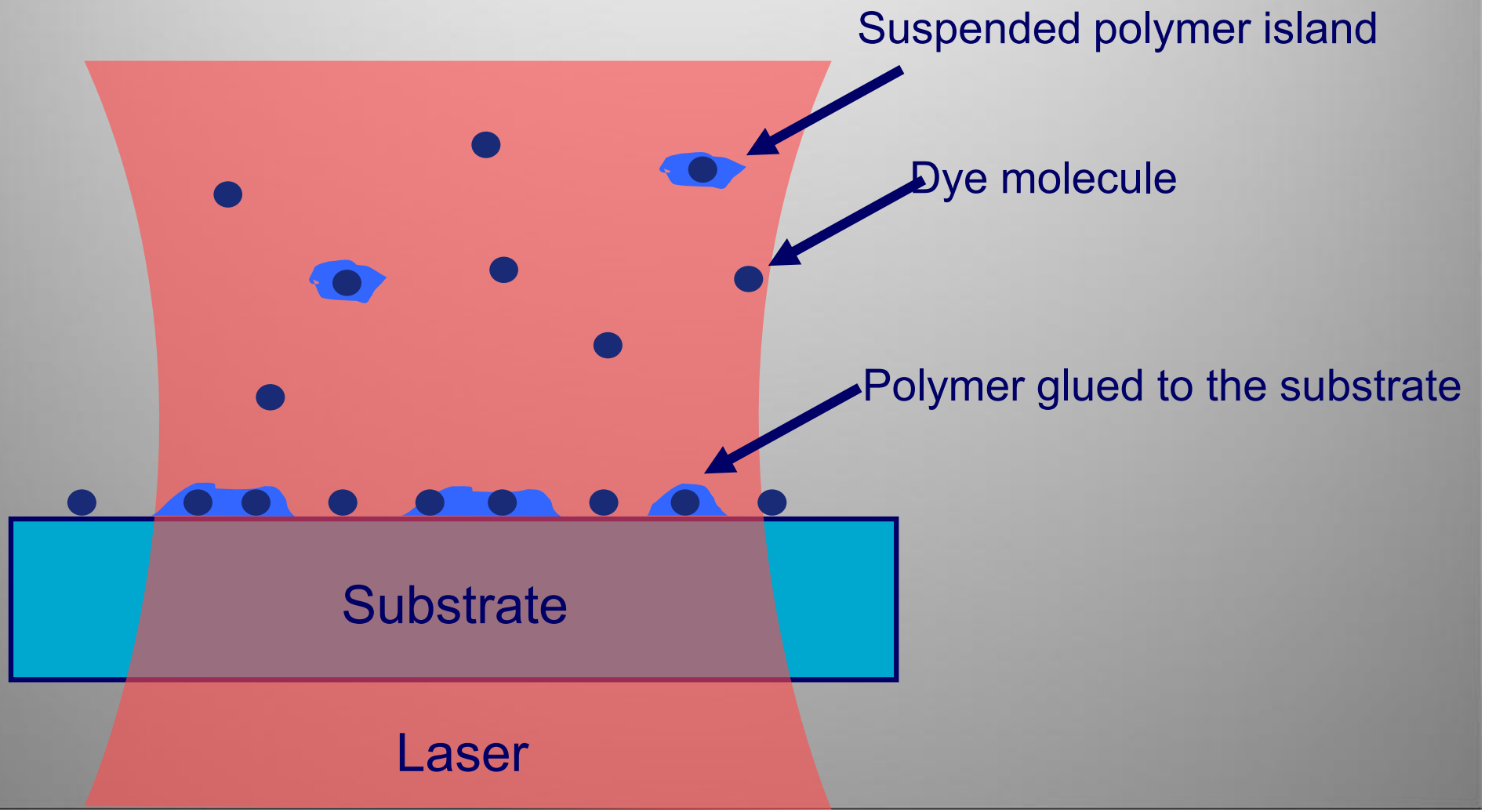
Adhesive + Dye

- Adhesive
  - Photocurable with UV
  - Refractive index n=1.54
  - Non toxic
  - Solvent resistent
  - Loz cost $24/oz

- Dye
  - Interacts with the adhesive to start polymerization
  - Tested dyes
    - **ADS675MT**
    - ADS740MP
    - ADS760MP
    - ADS775PI
    - **NileBlue perchlorate**
    - LDS821
    - HITC

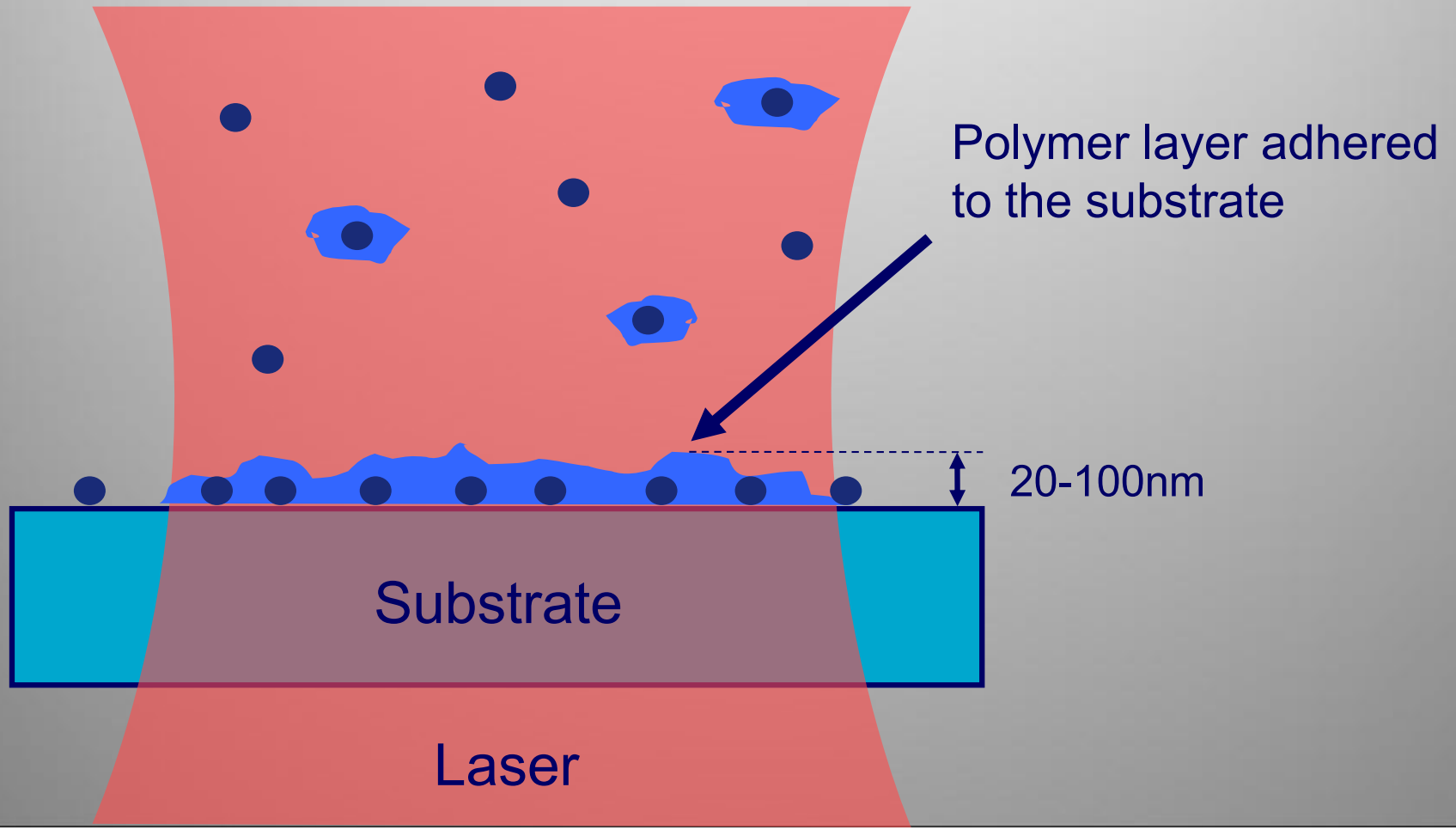
Polimerization

- Inicial stage



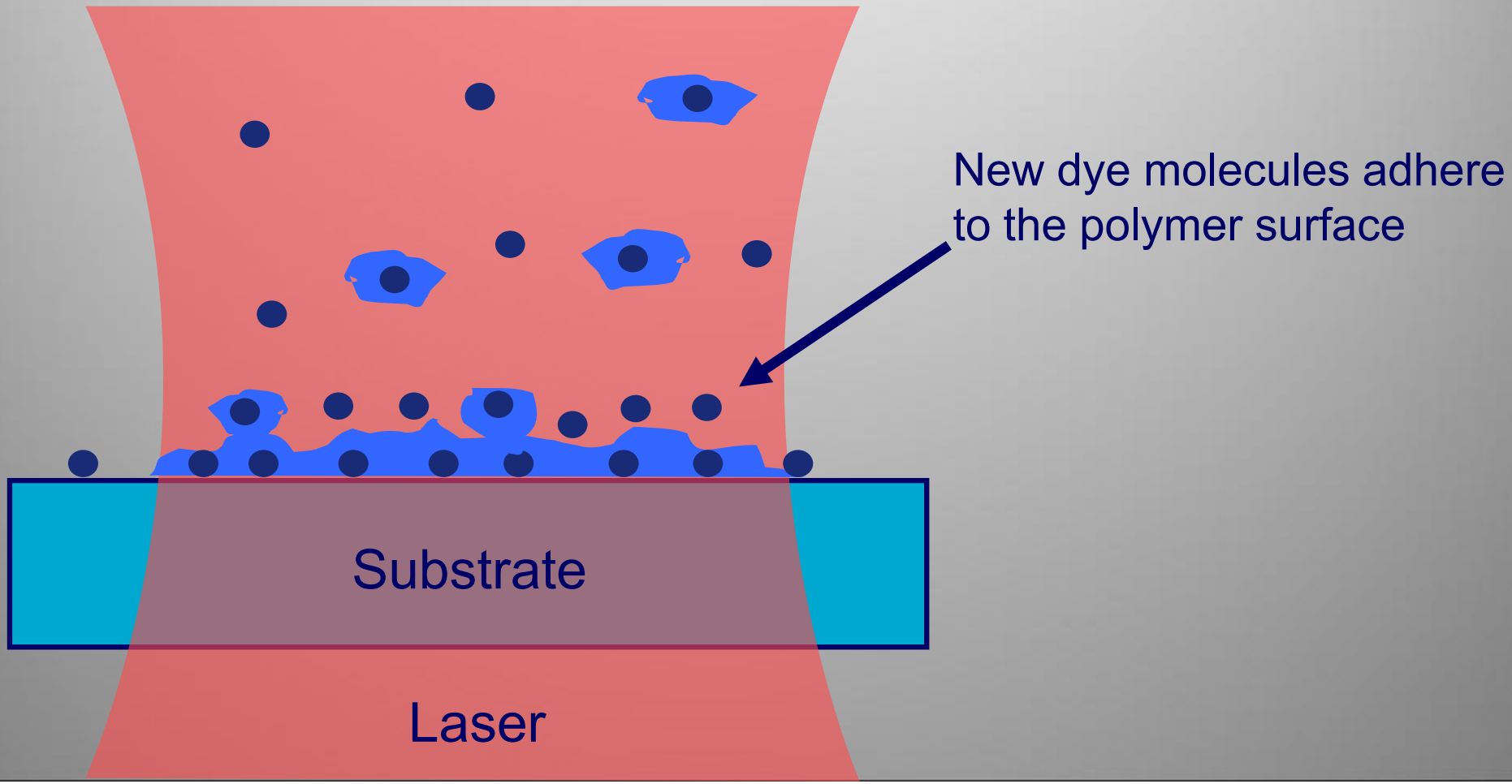
Polimerización

- Surface percolation



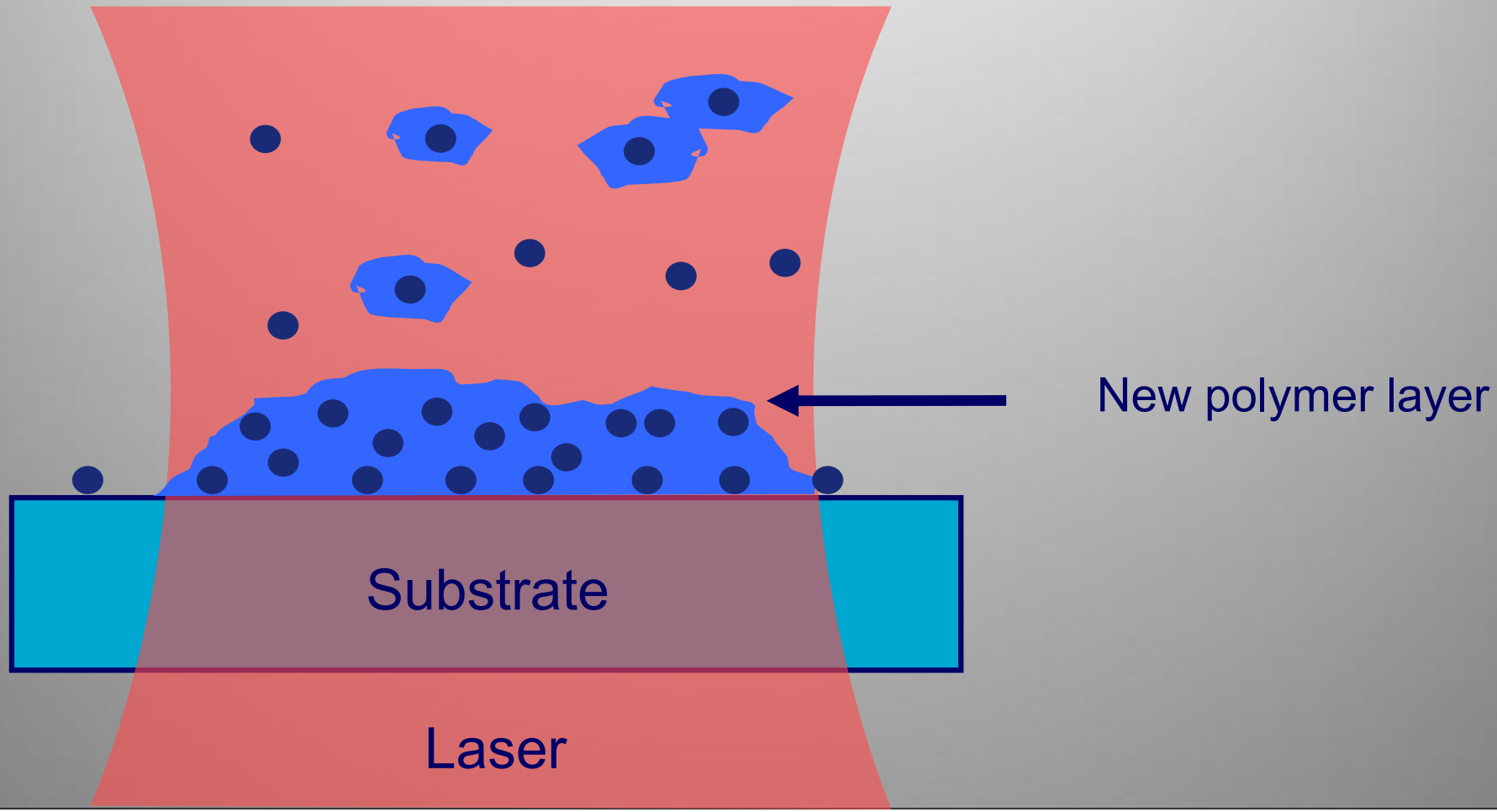
Polimerización

- Adsorption of new molecules



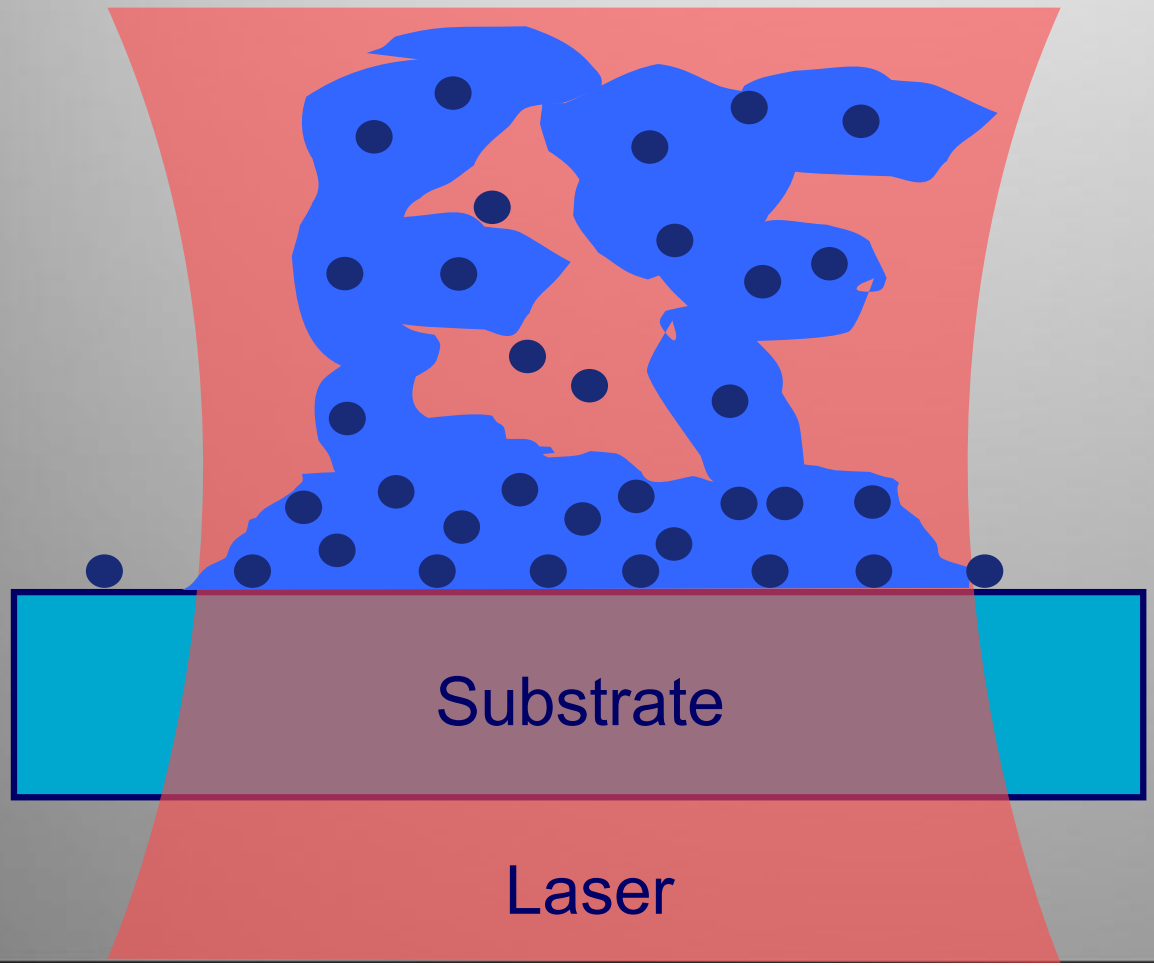
Polimerización

- Growth



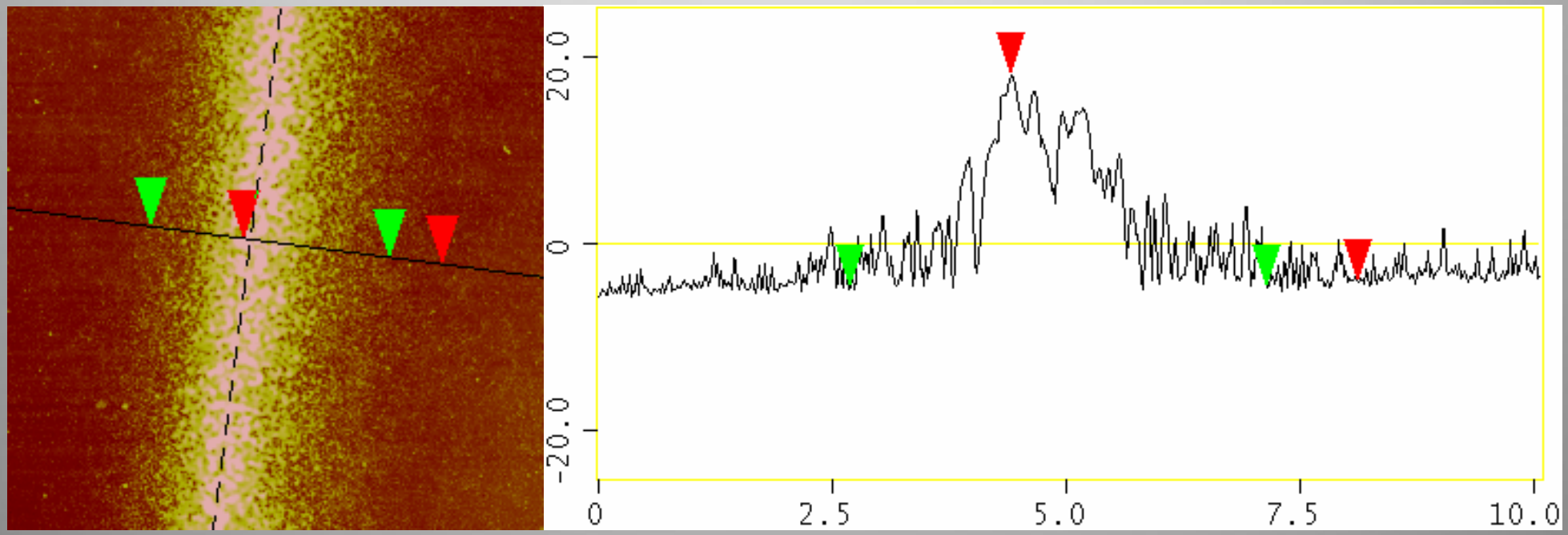
Polimerización

- Volume percolation

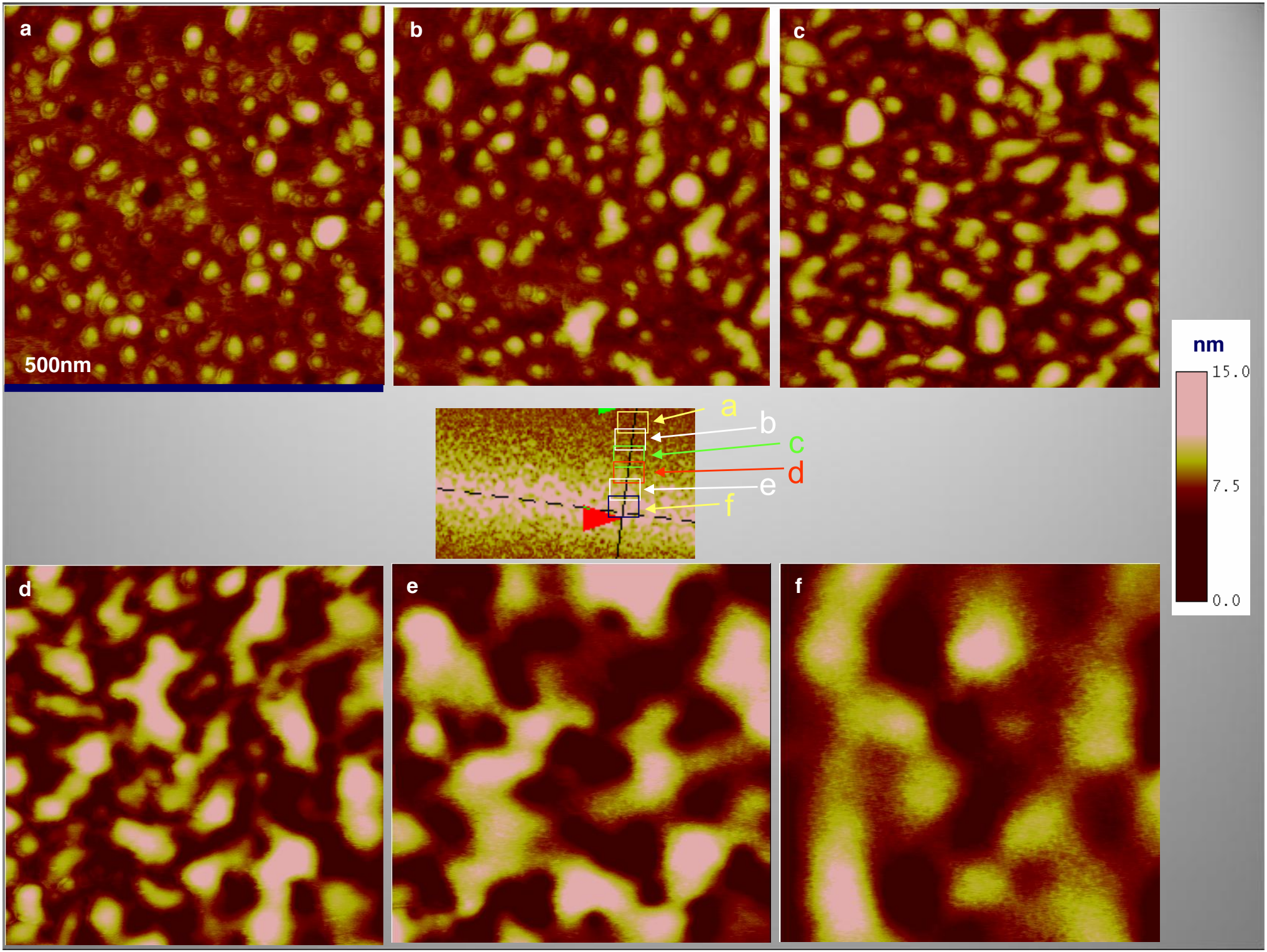


Results

- Surface Percolation



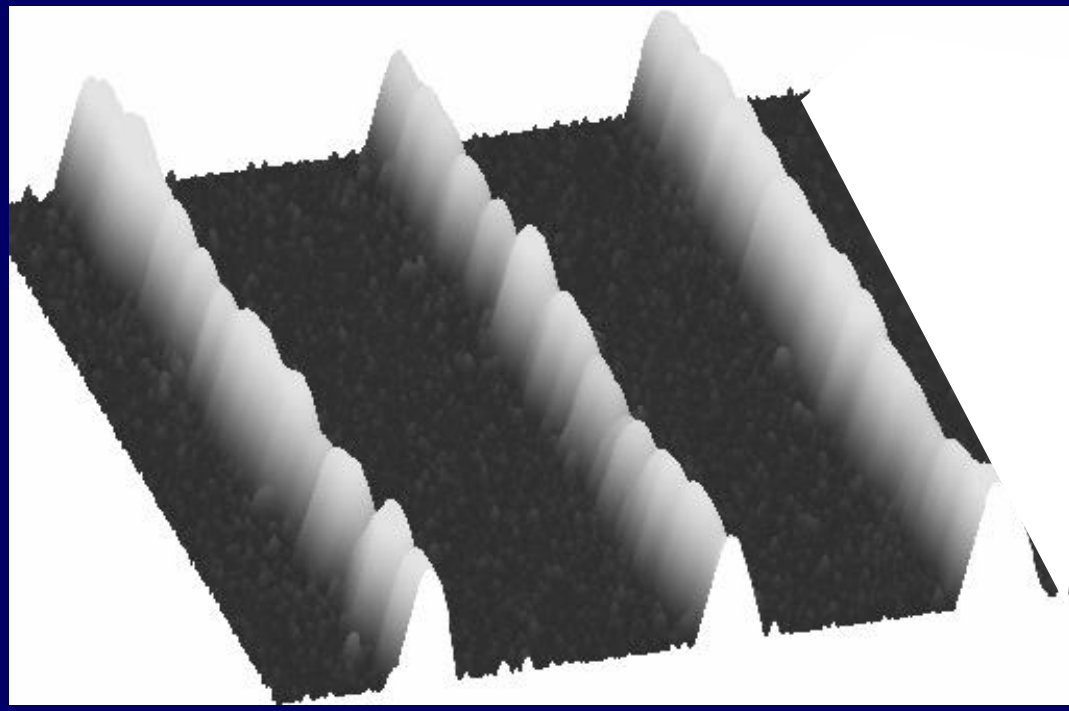
$$dh/dt = v\,\Phi_P\,\sigma I(t)\,\rho$$

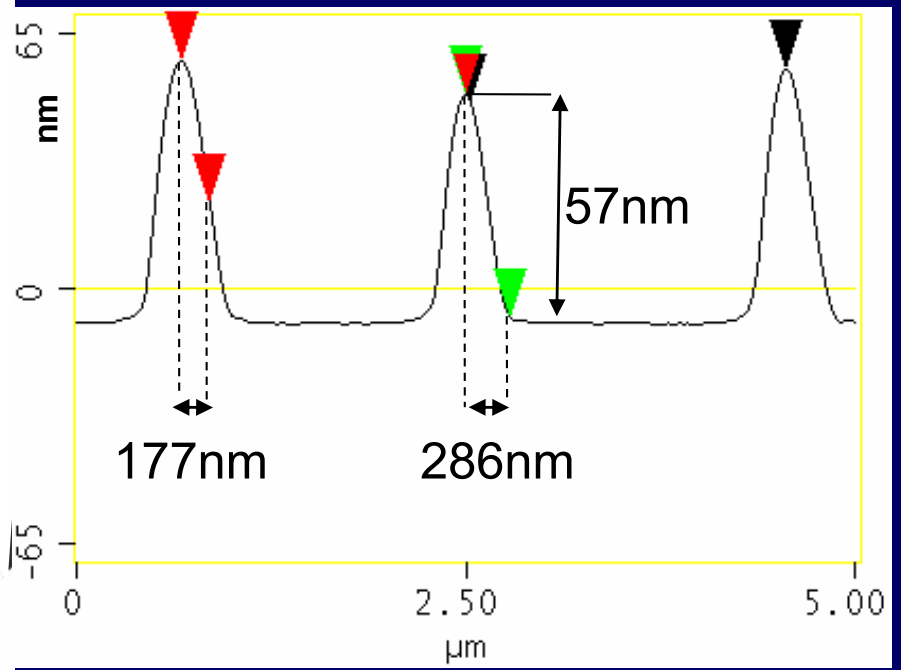

a
b
c
500nm
a
b
c
d
e
f
nm
15.0
7.5
0.0
d
e
f

Results

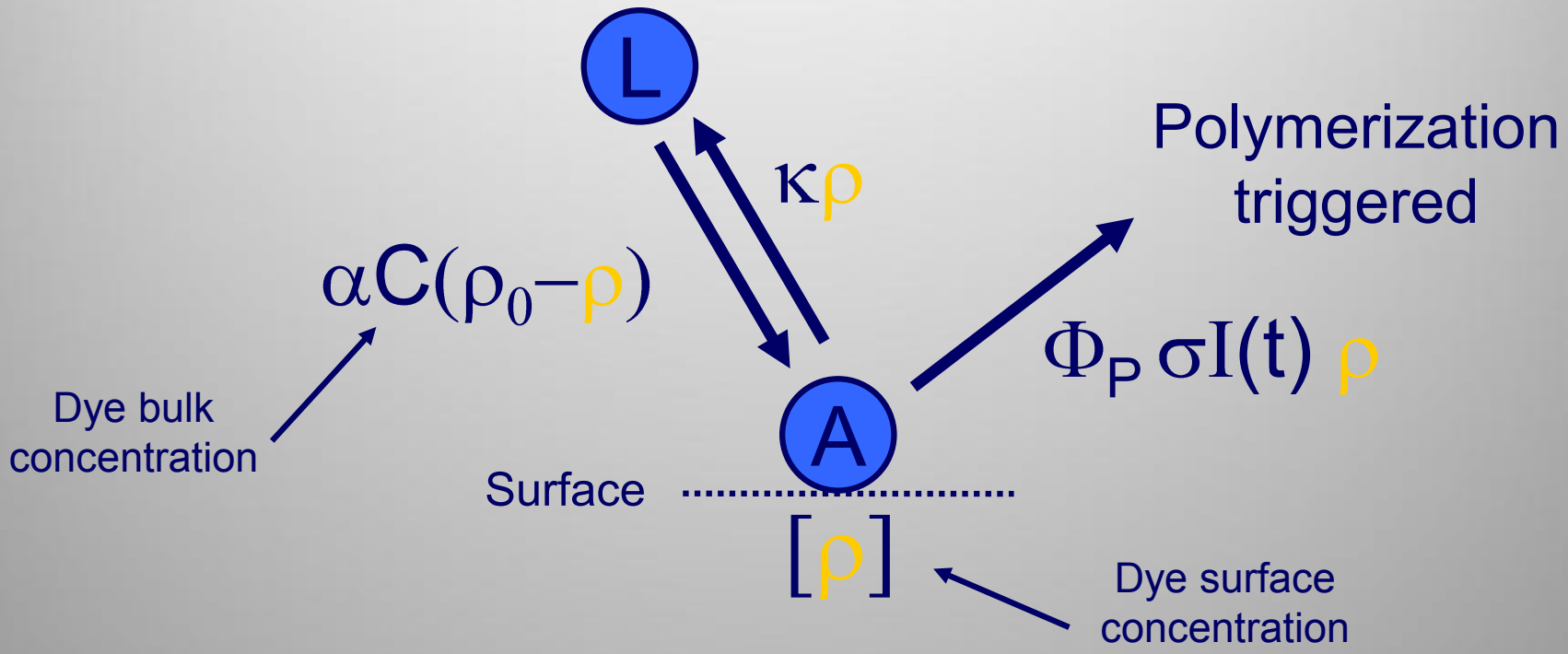
- Lines with NileBlue-NOA63 1mM

NA=0.9
t=0.05s
P=550μW
F~7,7 10^{22} phot cm^{-2}





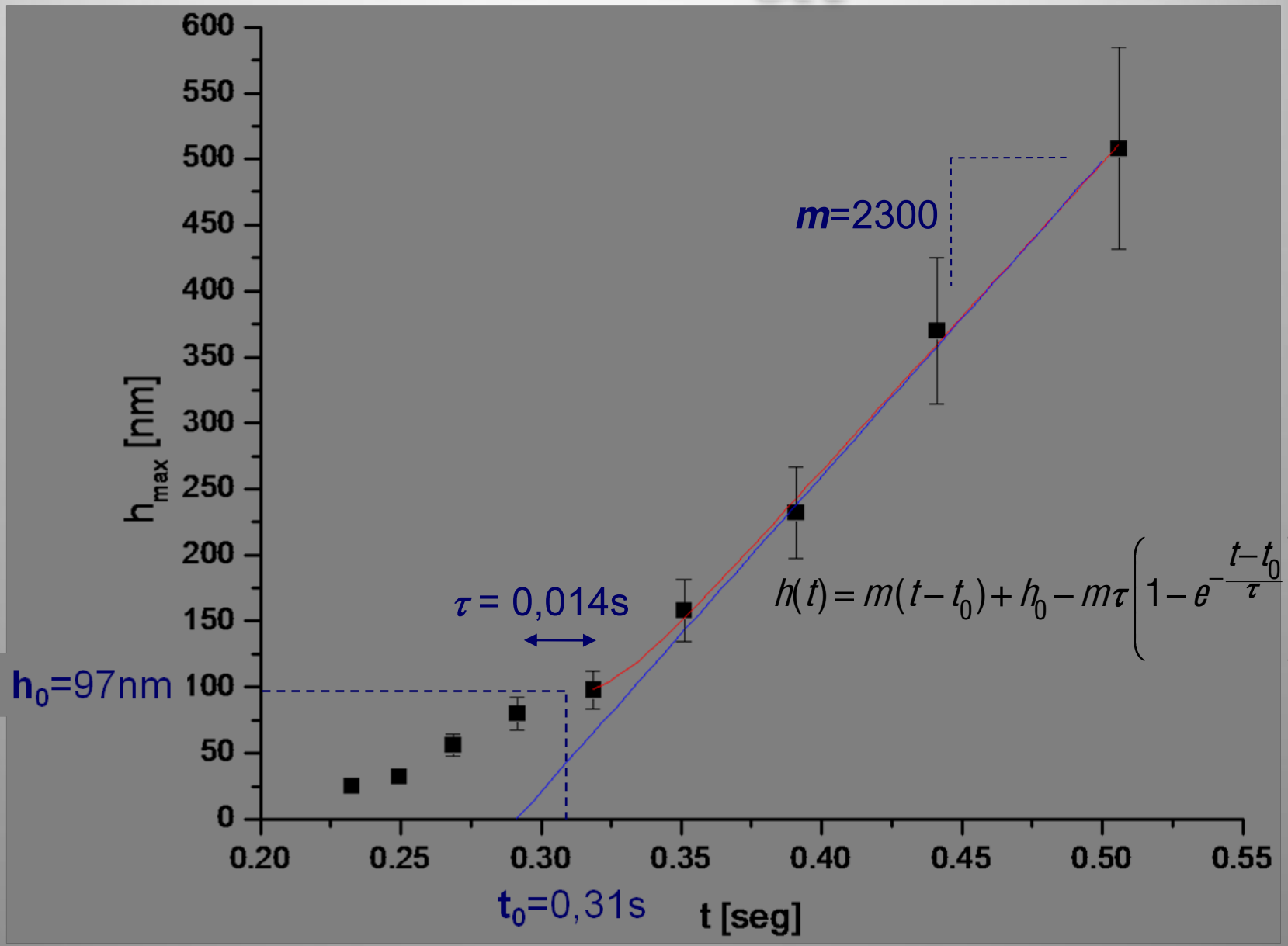
Process Dynamics



$$\begin{cases} d\rho/dt = \alpha C(\rho_0 - \rho) - \kappa\rho - \Phi_P \sigma I(t)\ \rho \\ dh/dt = v\ \Phi_P \sigma I(t)\ \rho \end{cases}$$

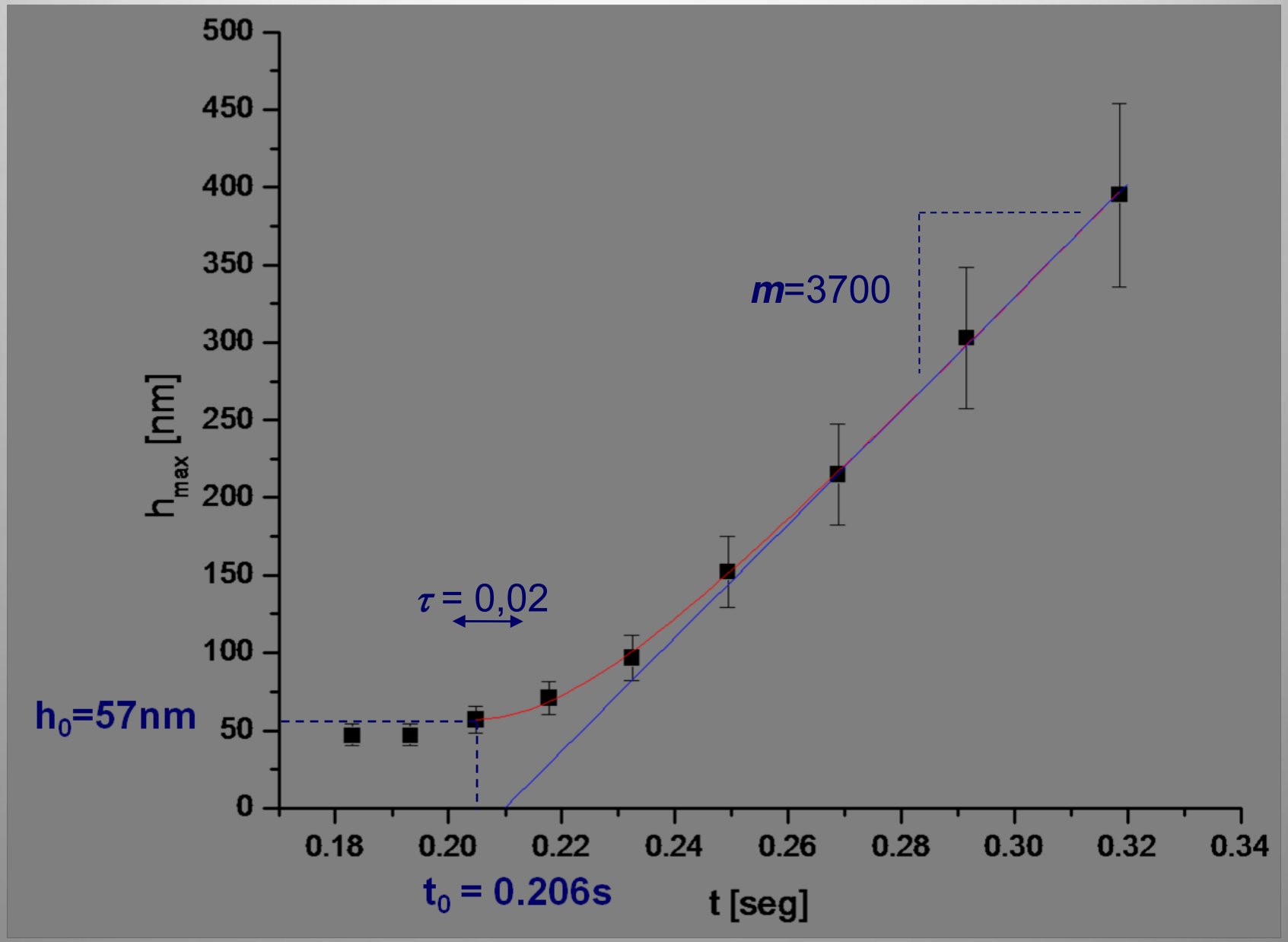
C = 50μM

$$\Phi_p = \frac{1}{\sigma I \tau} \cong (7 \pm 2) 10^{-7}$$



C = 100μM

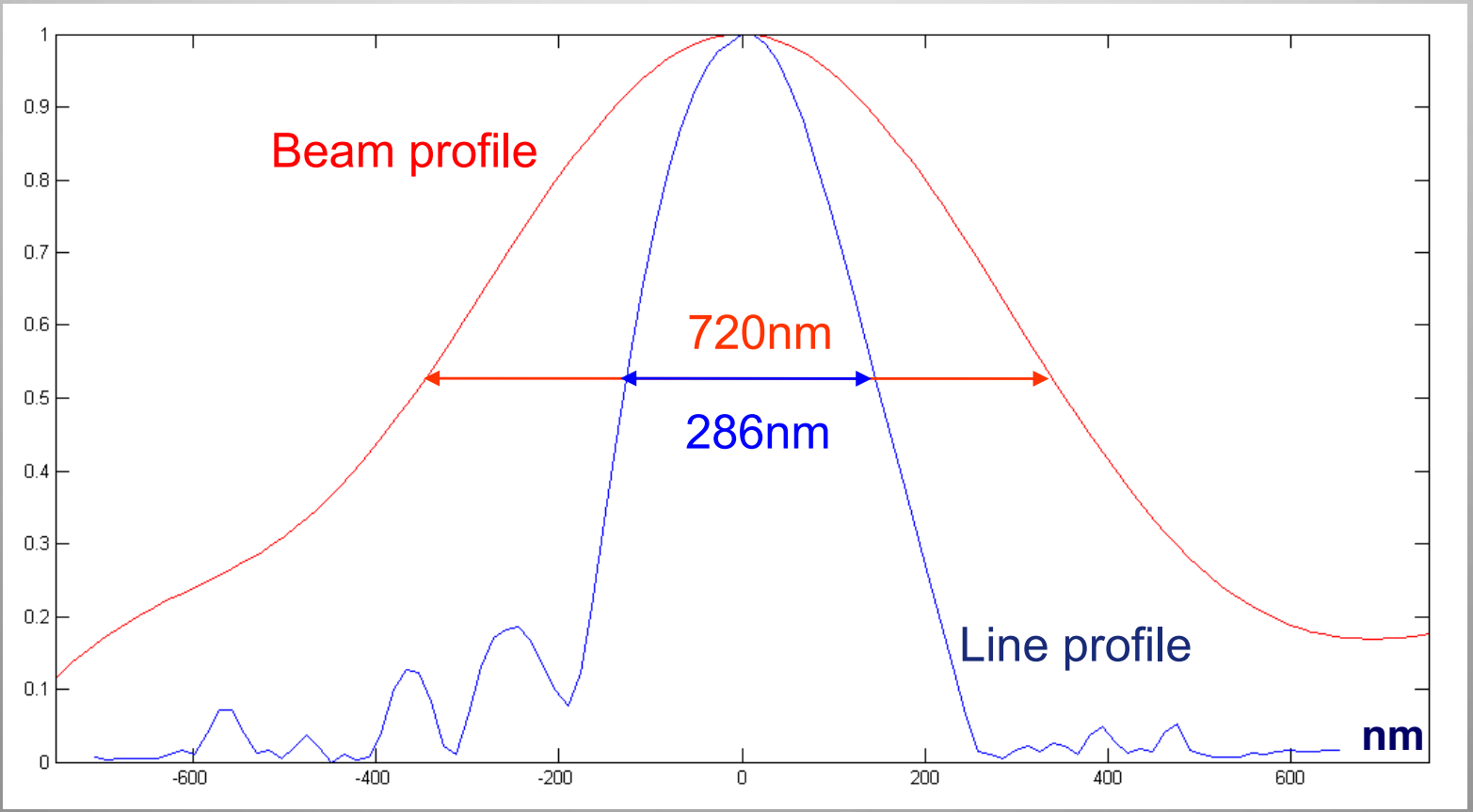
$$h(t) = m(t - t_0) + h_0 - m\tau\left(1 - e^{-\frac{t-t_0}{\tau}}\right)$$



Results

720nm/285nm = 2.5

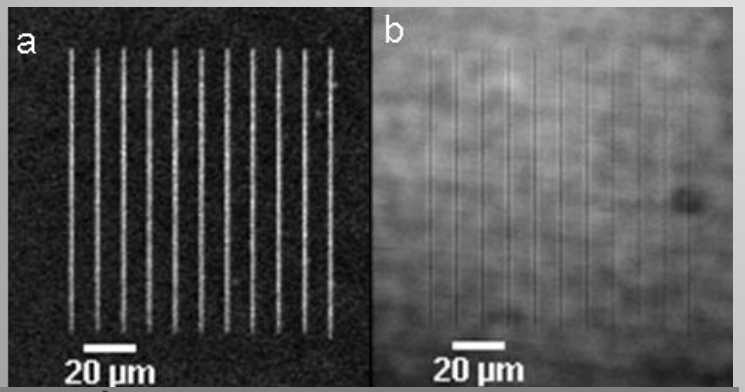
- Line profile vs Pump beam profile

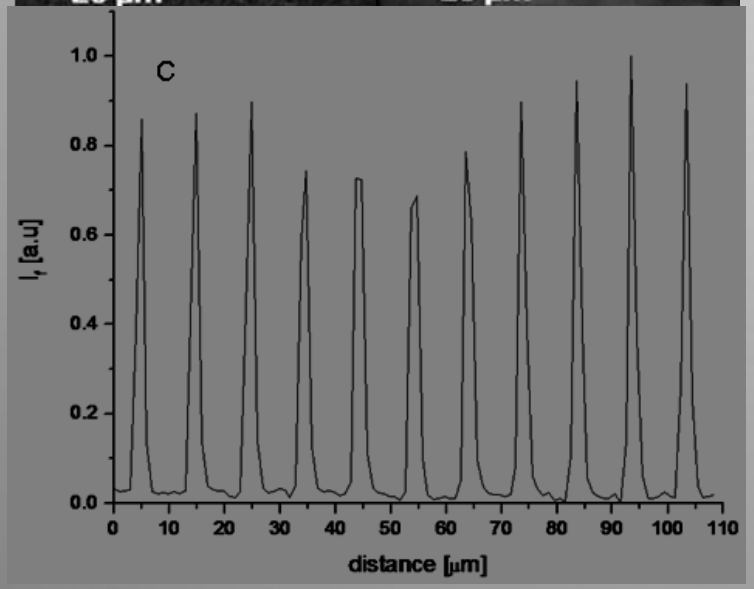


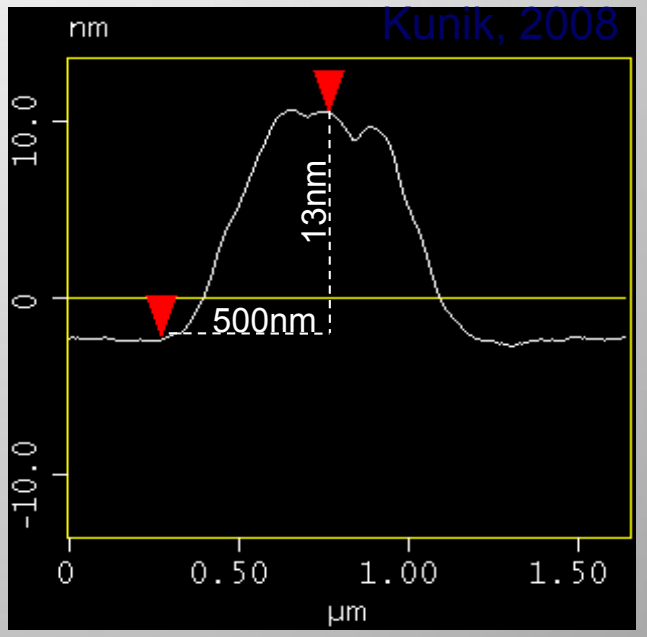
The lateral diffraction barrier can be broken

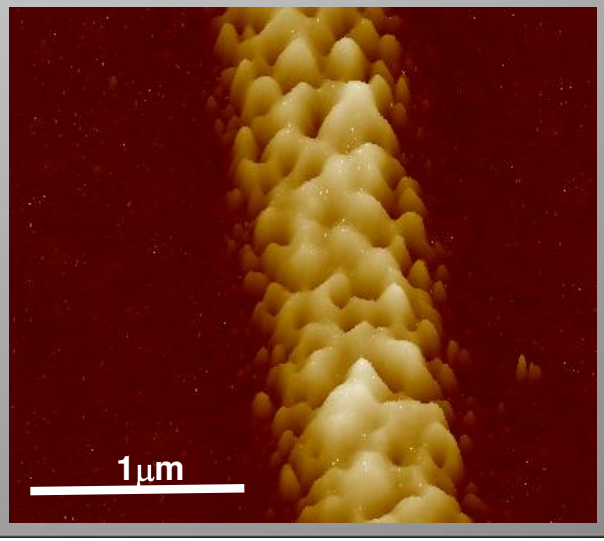
Applications

- Fluorescent structures with h<15nm



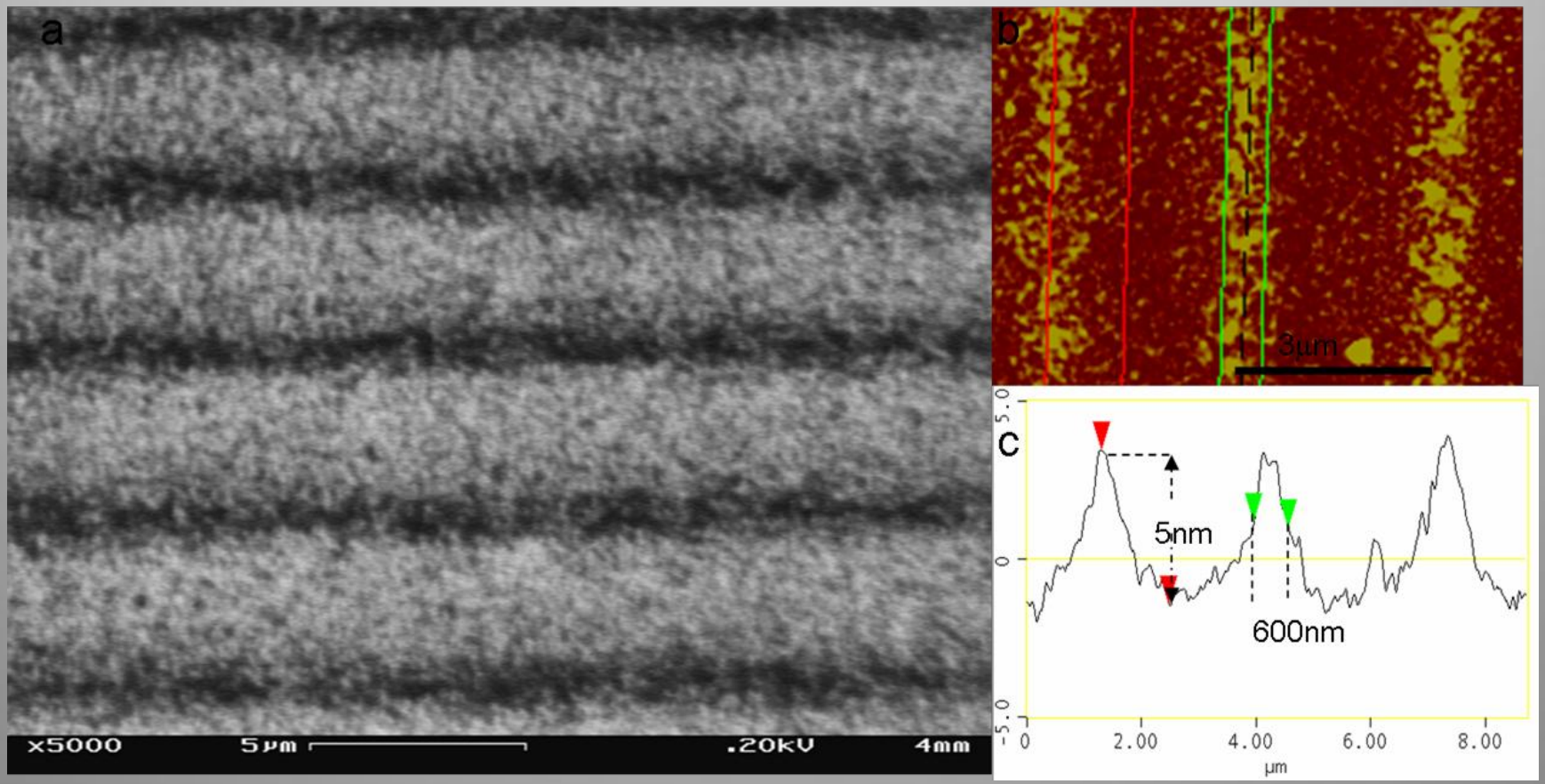






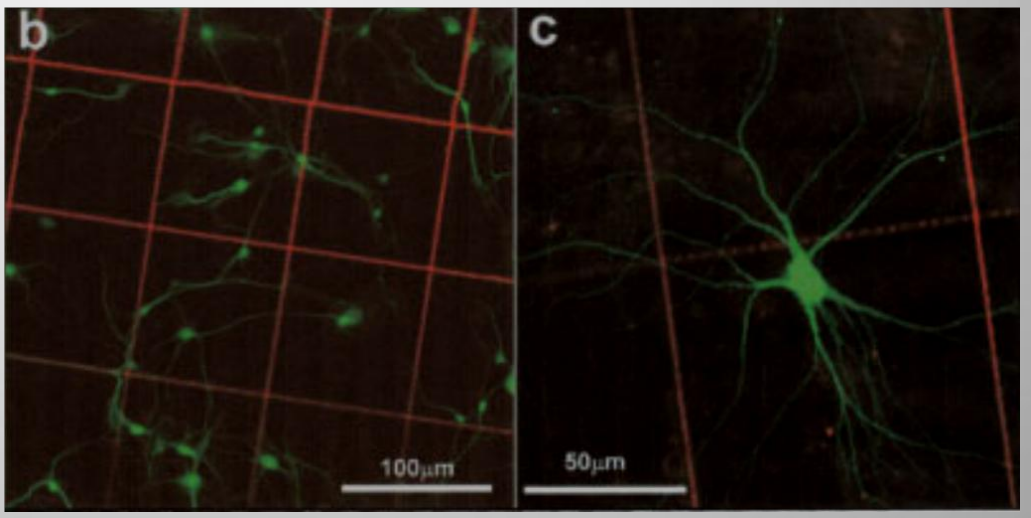
Applications

- Growth on gold substrate (Au ~ 30nm)



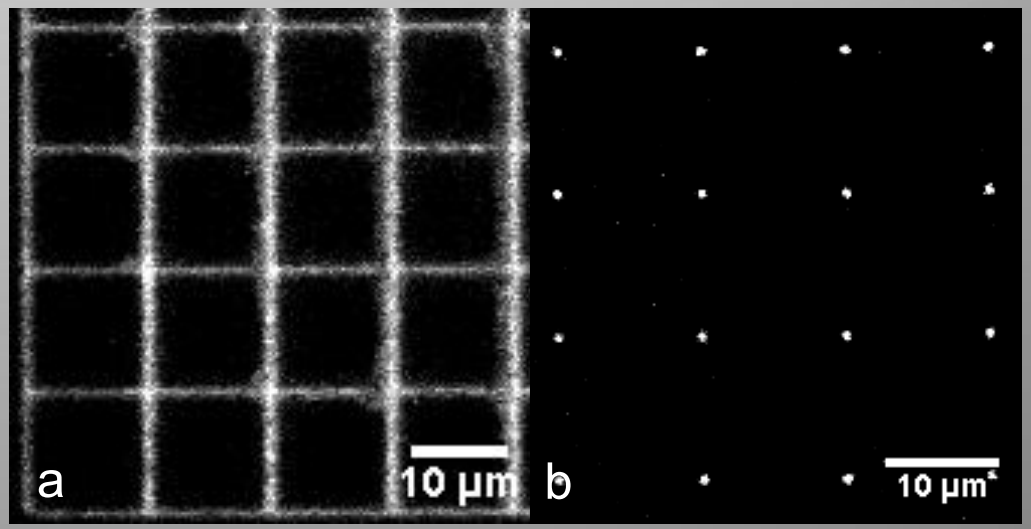
Applications

- Neuron growth on fluorescent grid



Costantino et al, 2005

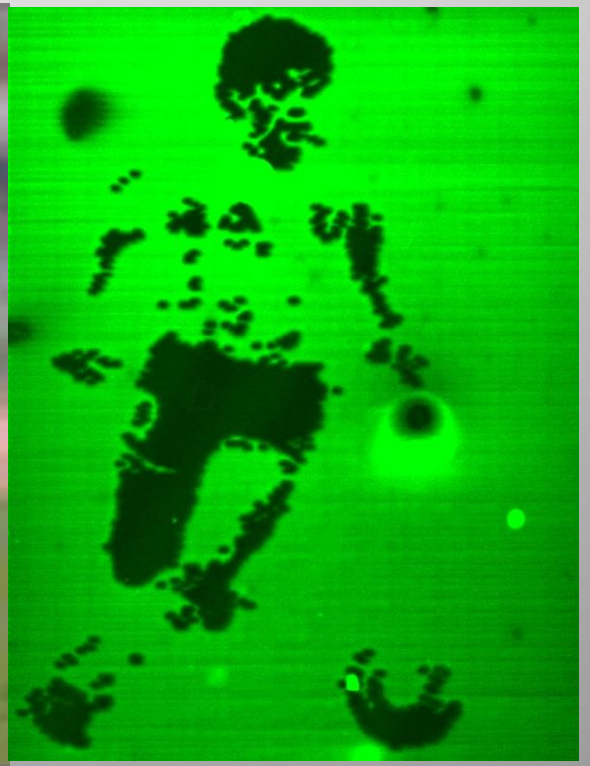
- Grid made on a comercial confocal microscope



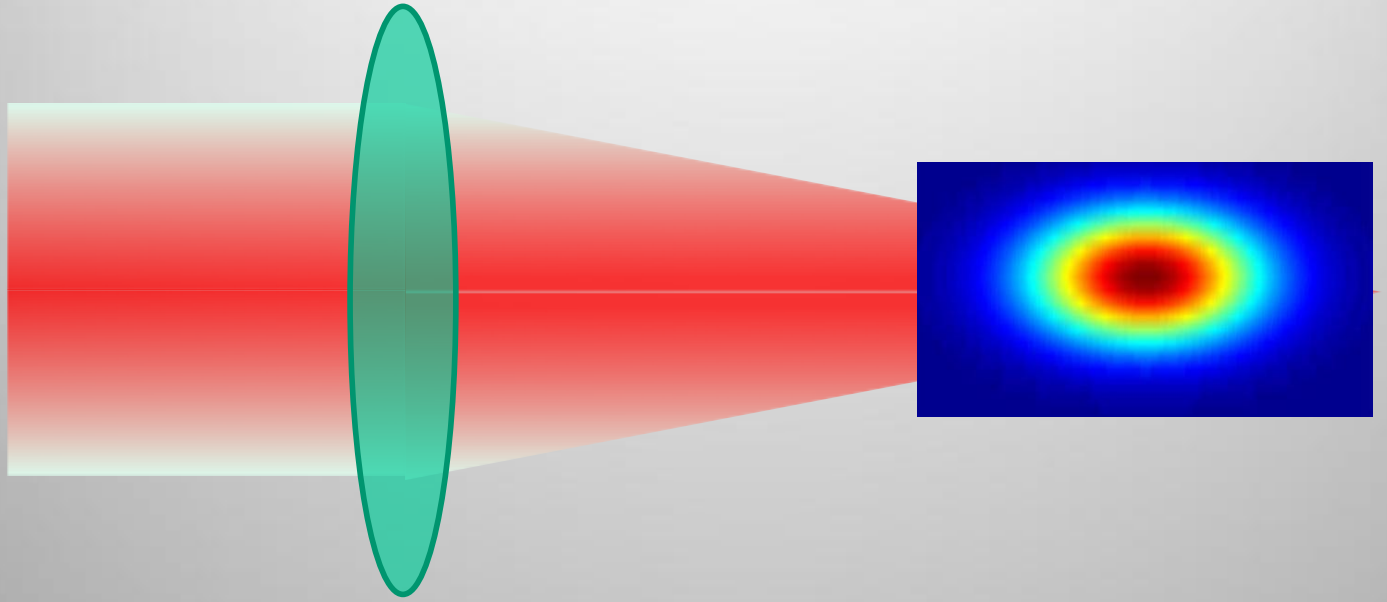
Kunik, 2008

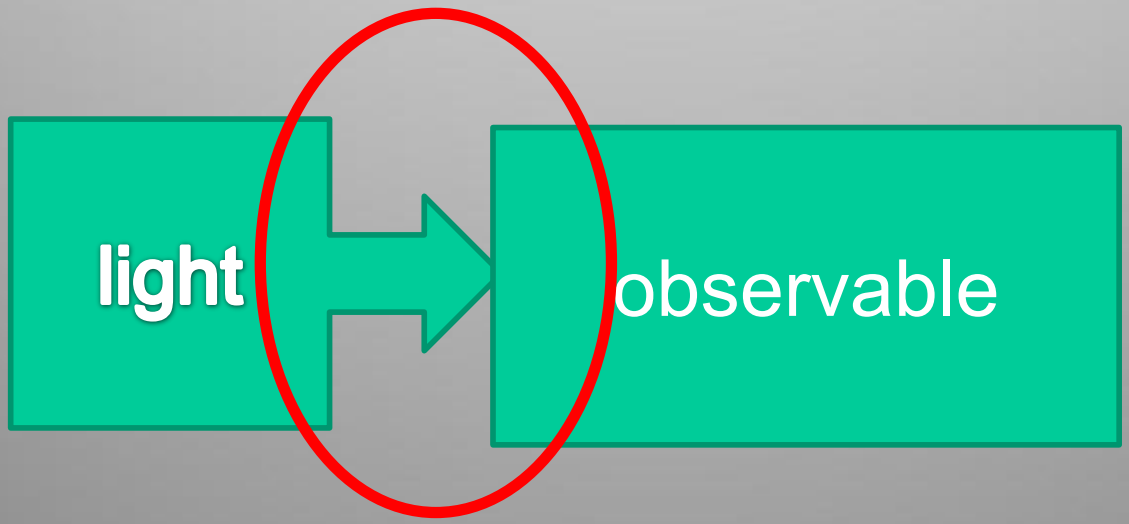
Applications

- And also...

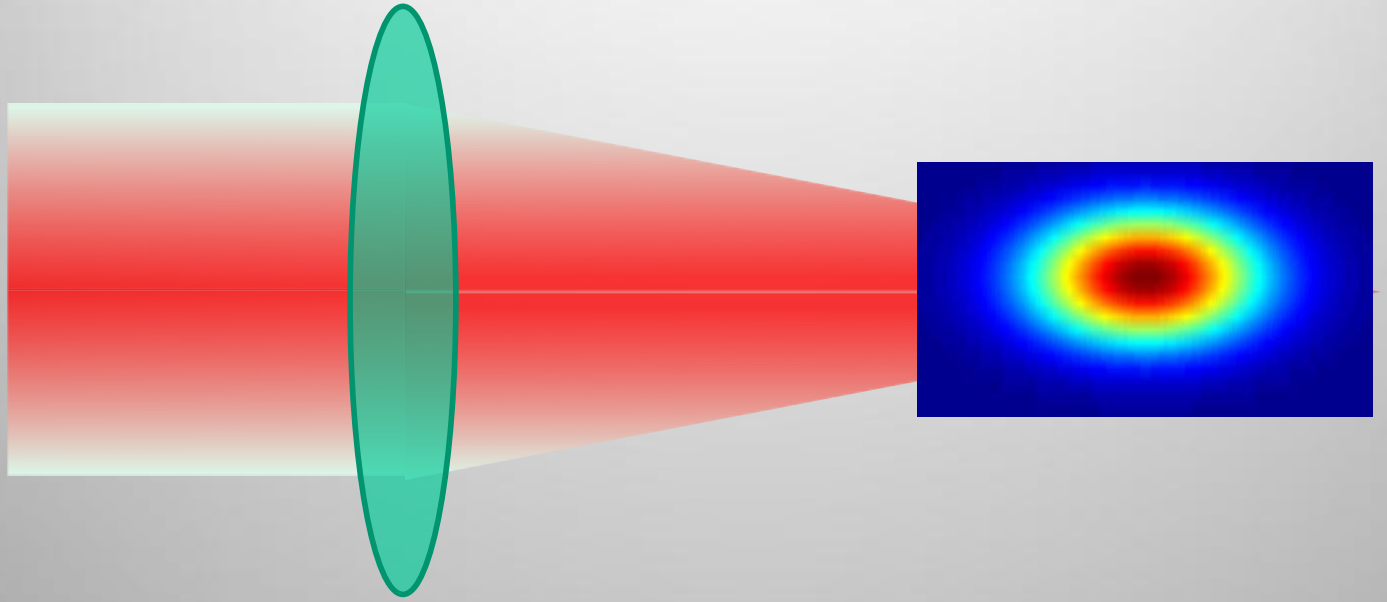


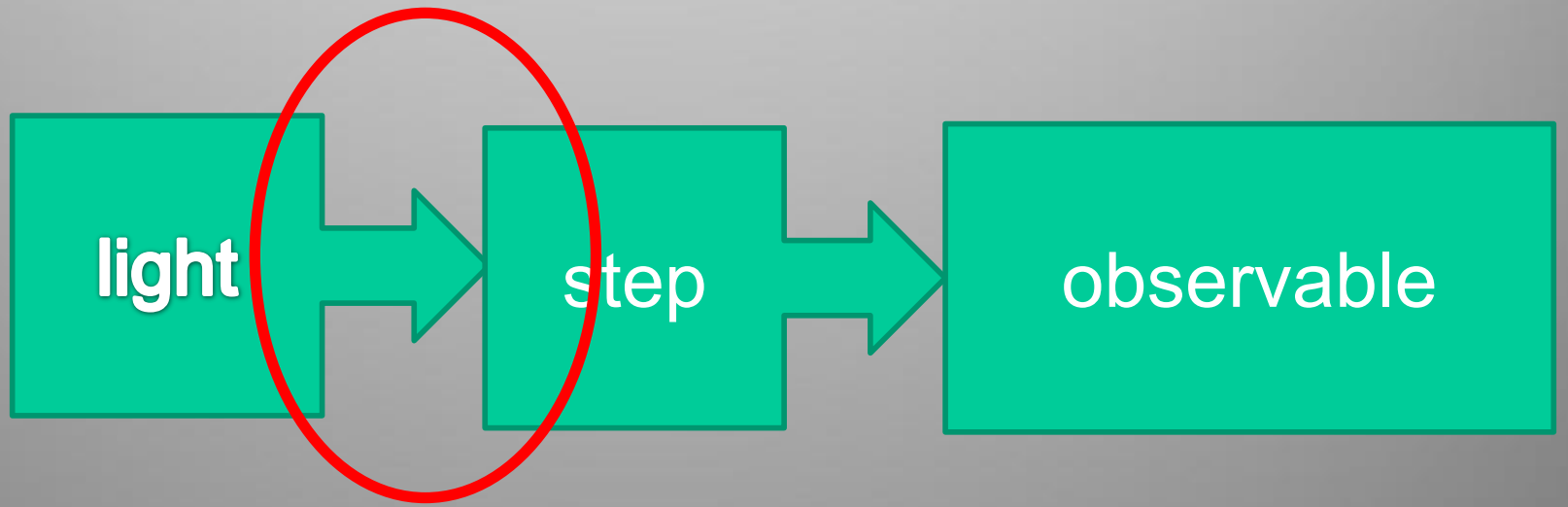
Diffraction limit



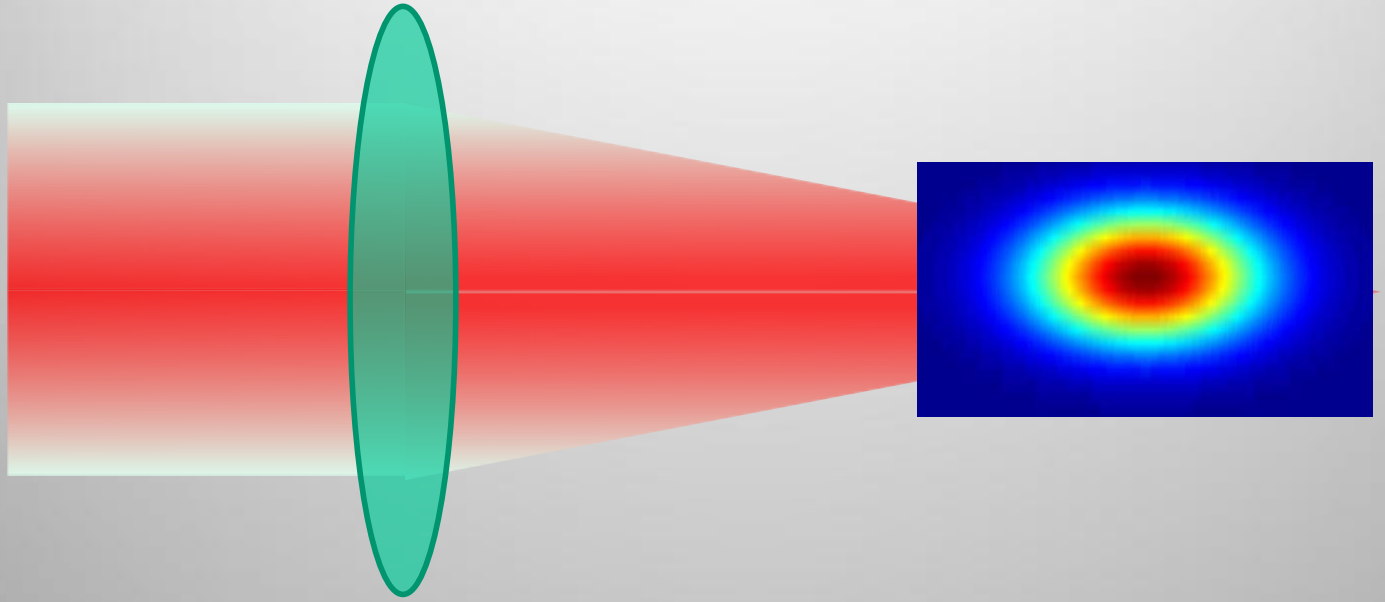


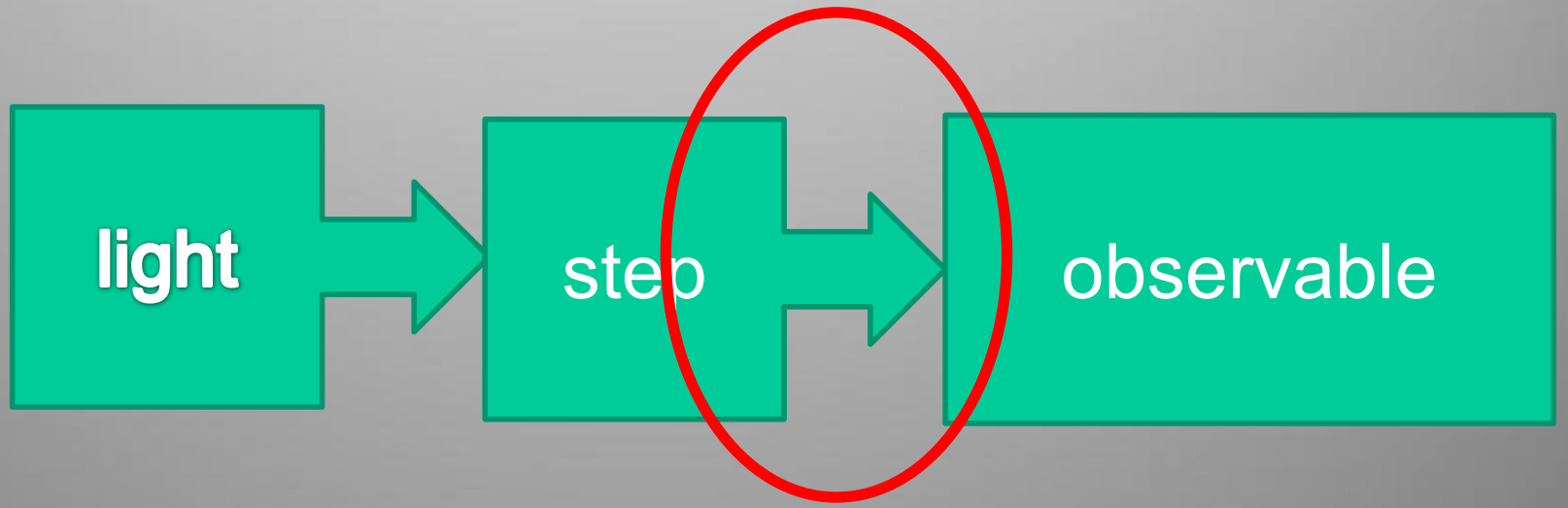
Diffraction limit

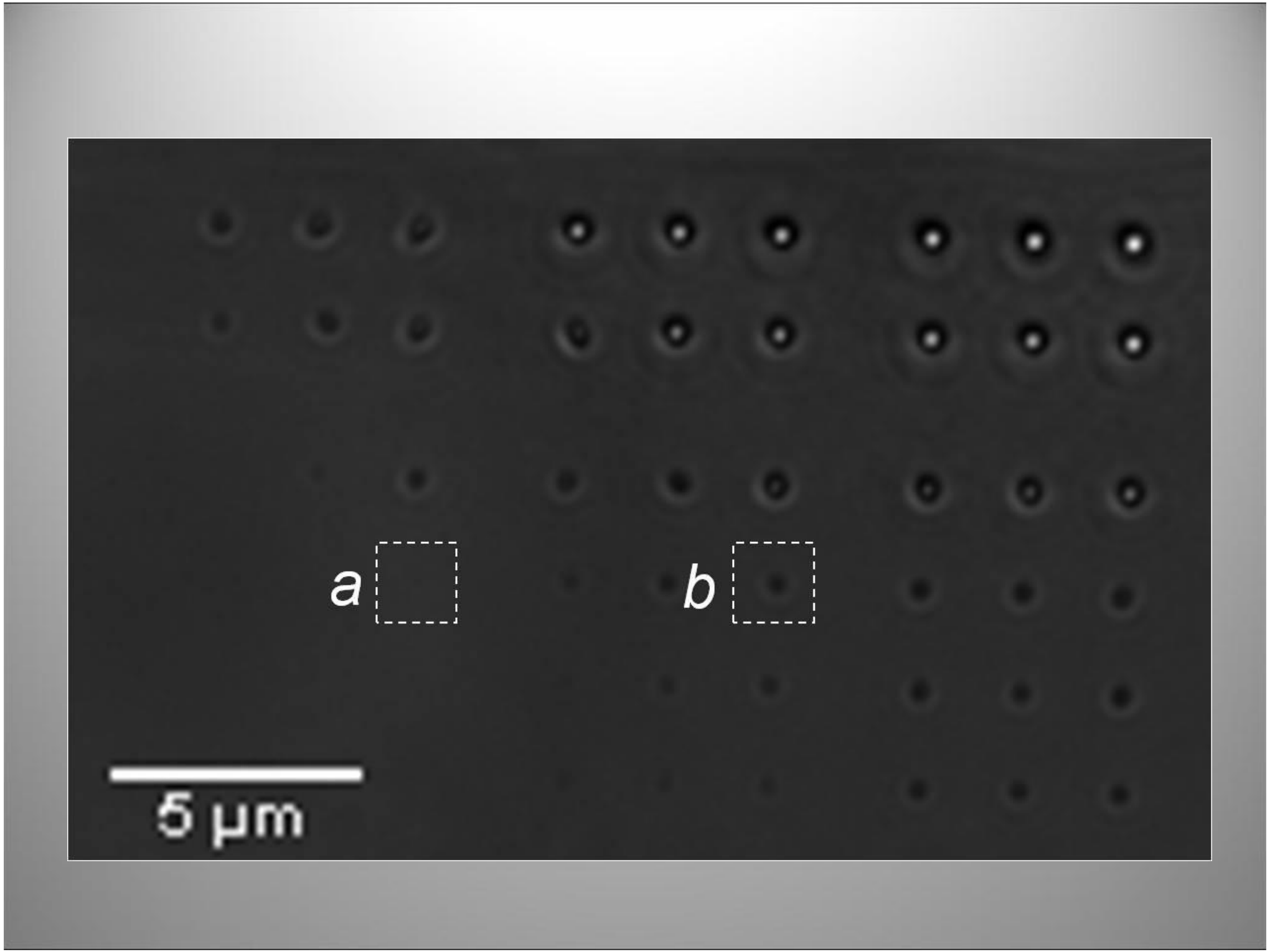


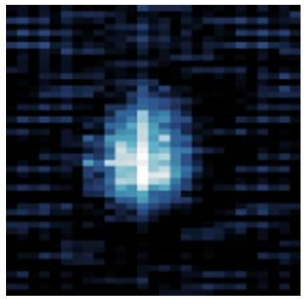


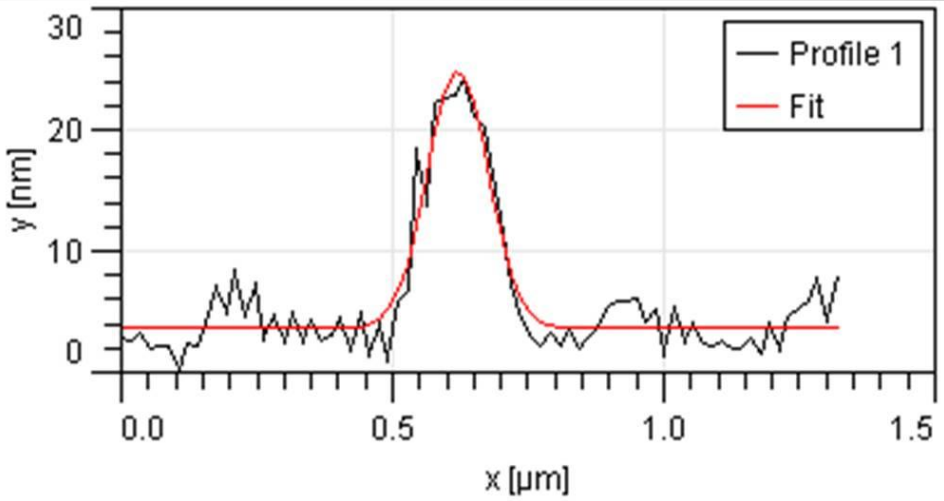
Diffraction limit

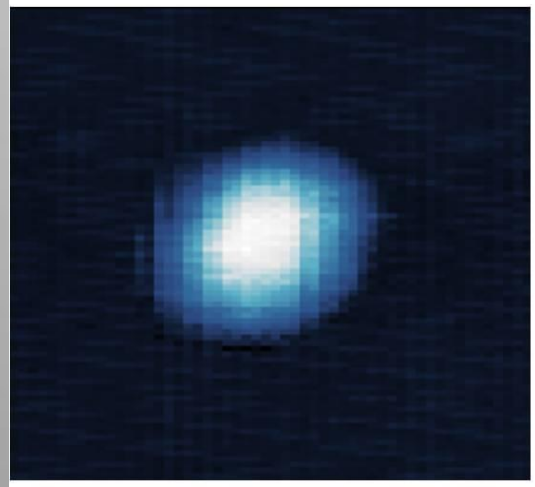


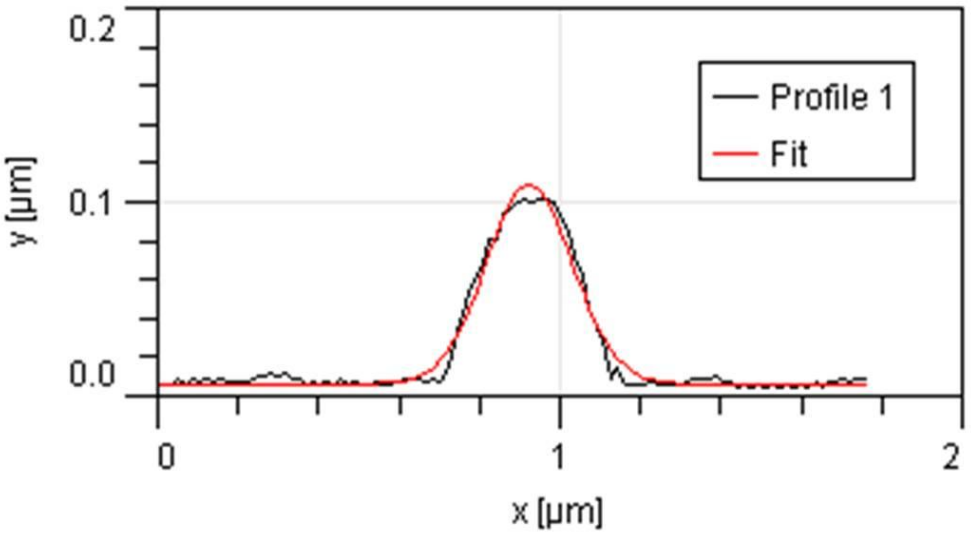



a
b
5 µm

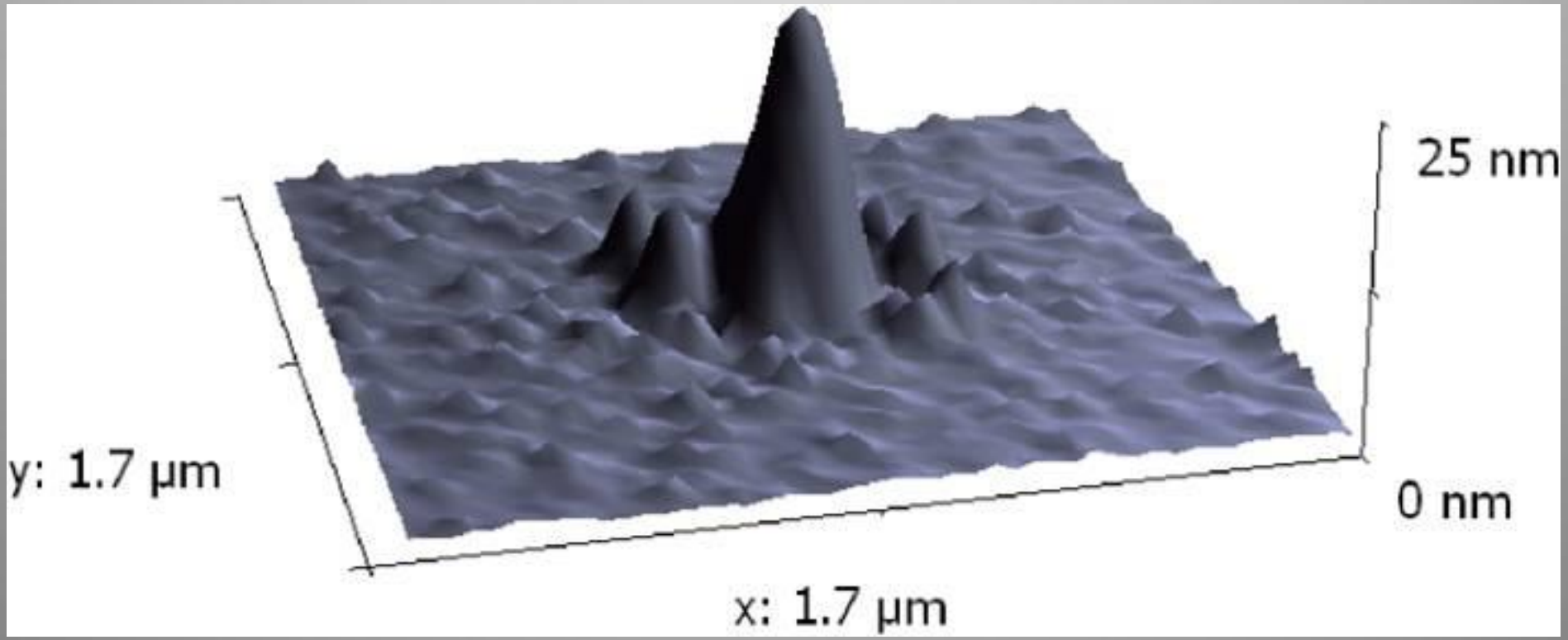



30
20
10
0
y [nm]
0.0
0.5
1.0
1.5
x [µm]
Profile 1
Fit




0.2
0.1
0.0
y [µm]
0
1
2
x [µm]
Profile 1
Fit

profile	h	b	w
1	24.1	109	154
2	23.1	105	148



Conclusions

SPAG places the nonlinearity at the growth mechanism, not the light-matter interaction.

Diffraction (linear response) is no longer a limit.

10nm axial resolution in growth

2.5 times smaller than beam size in lateral dimensions.

People that did the work shown

- Darío Kunik
- Francisco Balzarotti
- Pedro Aramendía
- Lía Pietrasanta
- Santiago Costantino

Papers in Physics, Vol 1 (2009)

D. Kunik, L. I. Pietrasanta, O. E. Martínez

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Optical protein patterning, micro-engineering the cellular environment using lasers

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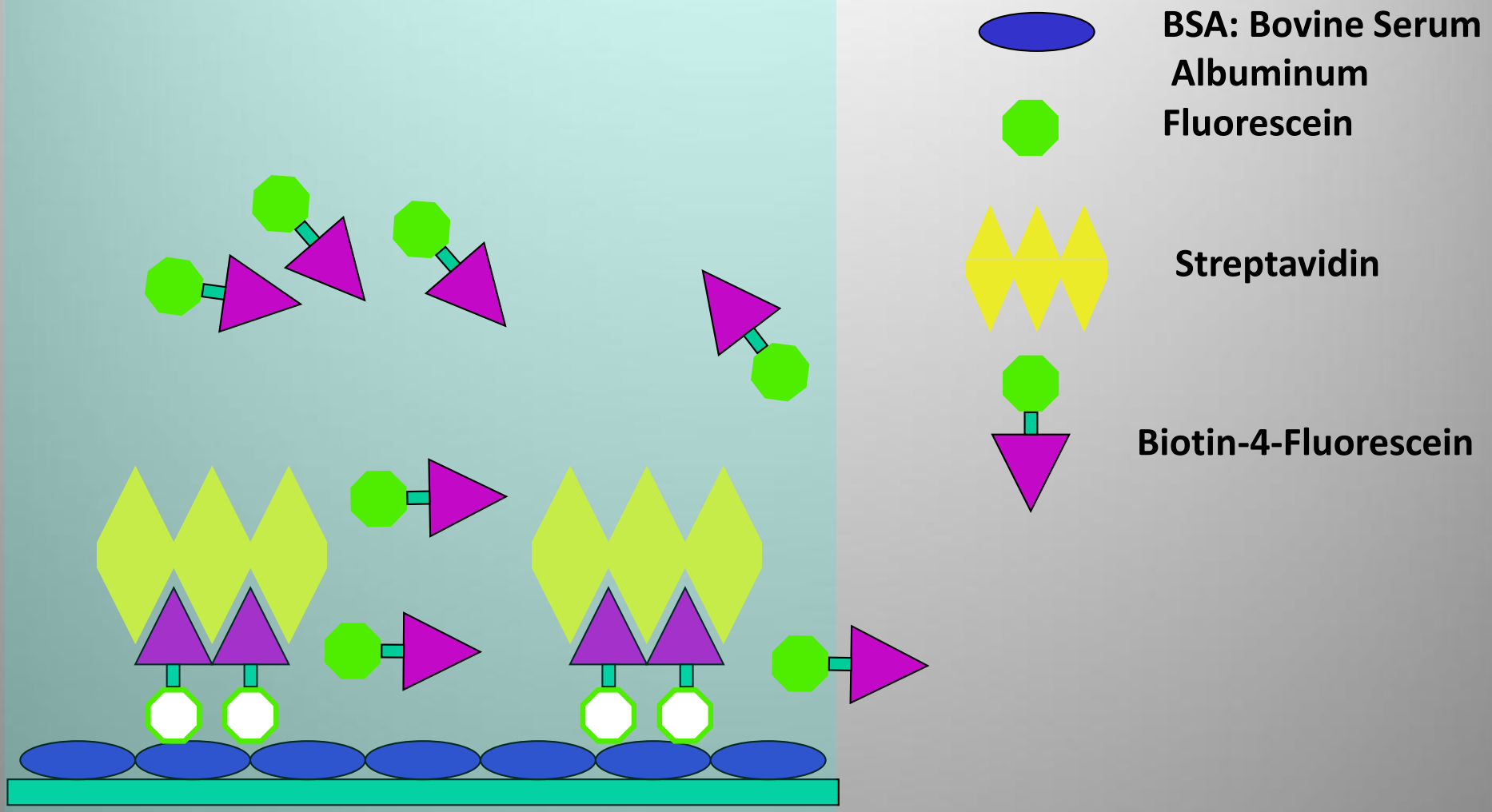
Biomedical Engineering Institute

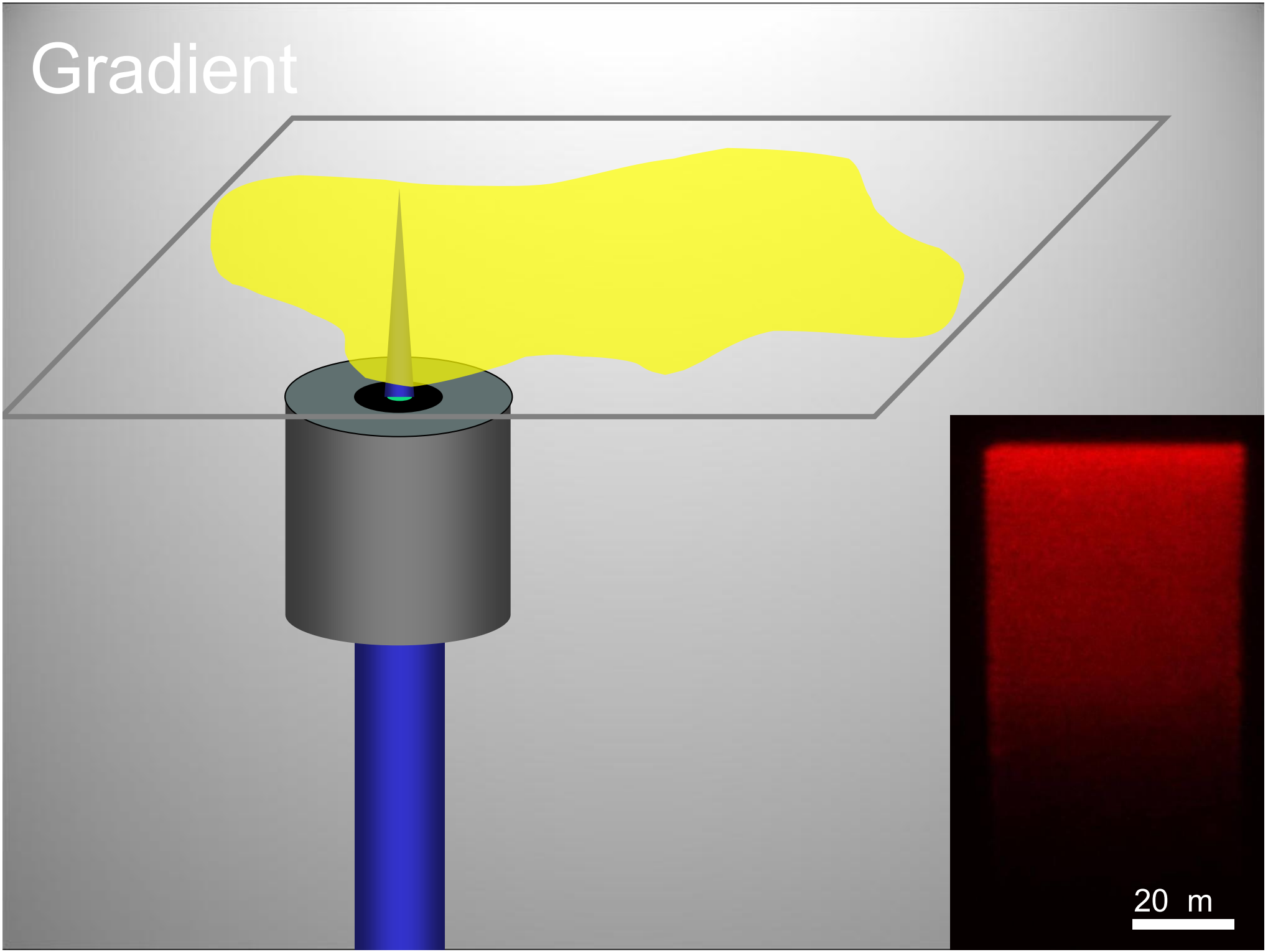
Hôpital Maisonneuve-Rosemont
Centre affilié à l'Université de Montréal

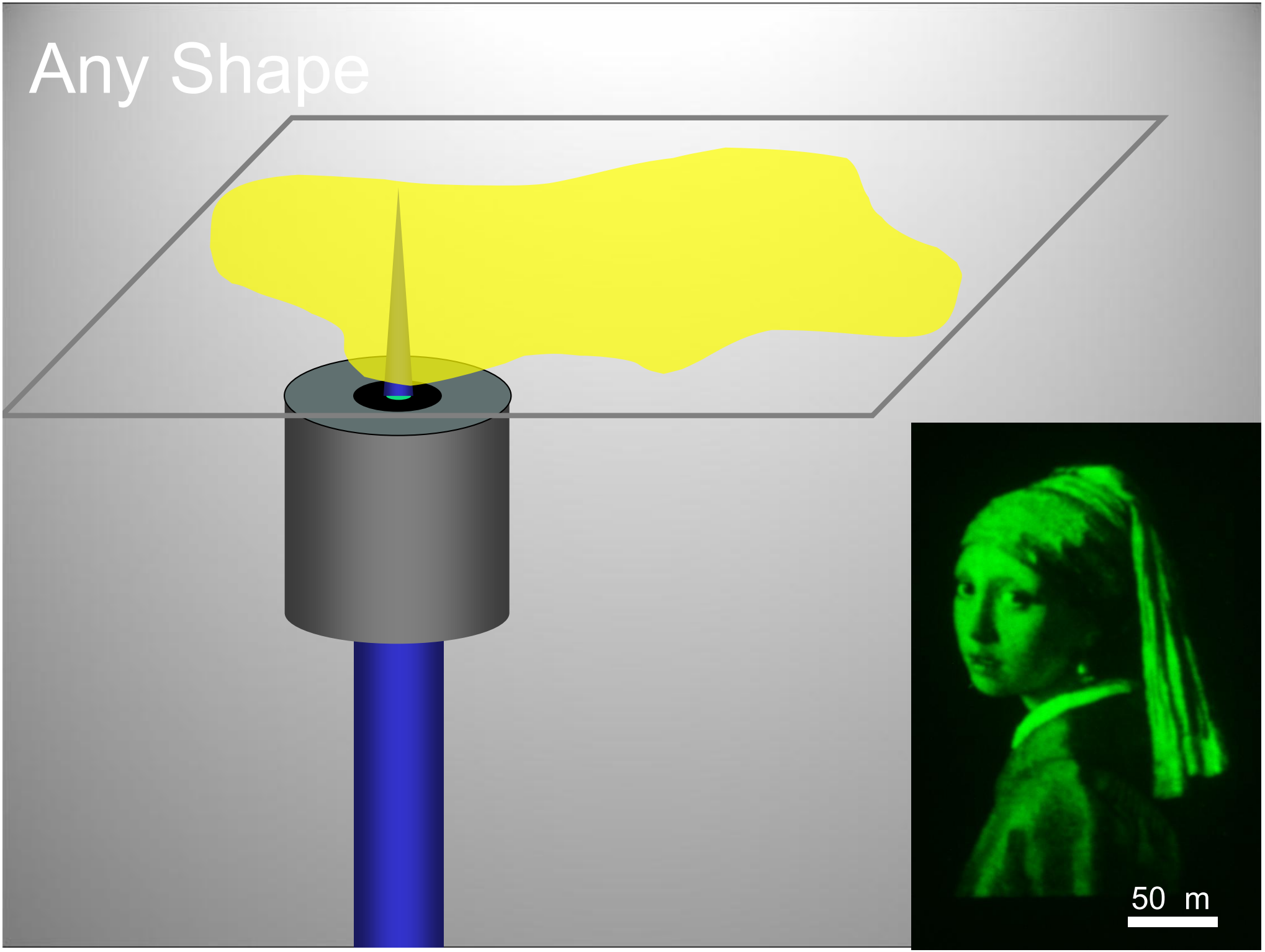
Université de Montréal

Laser Assisted Protein Adsorption by Photobleaching

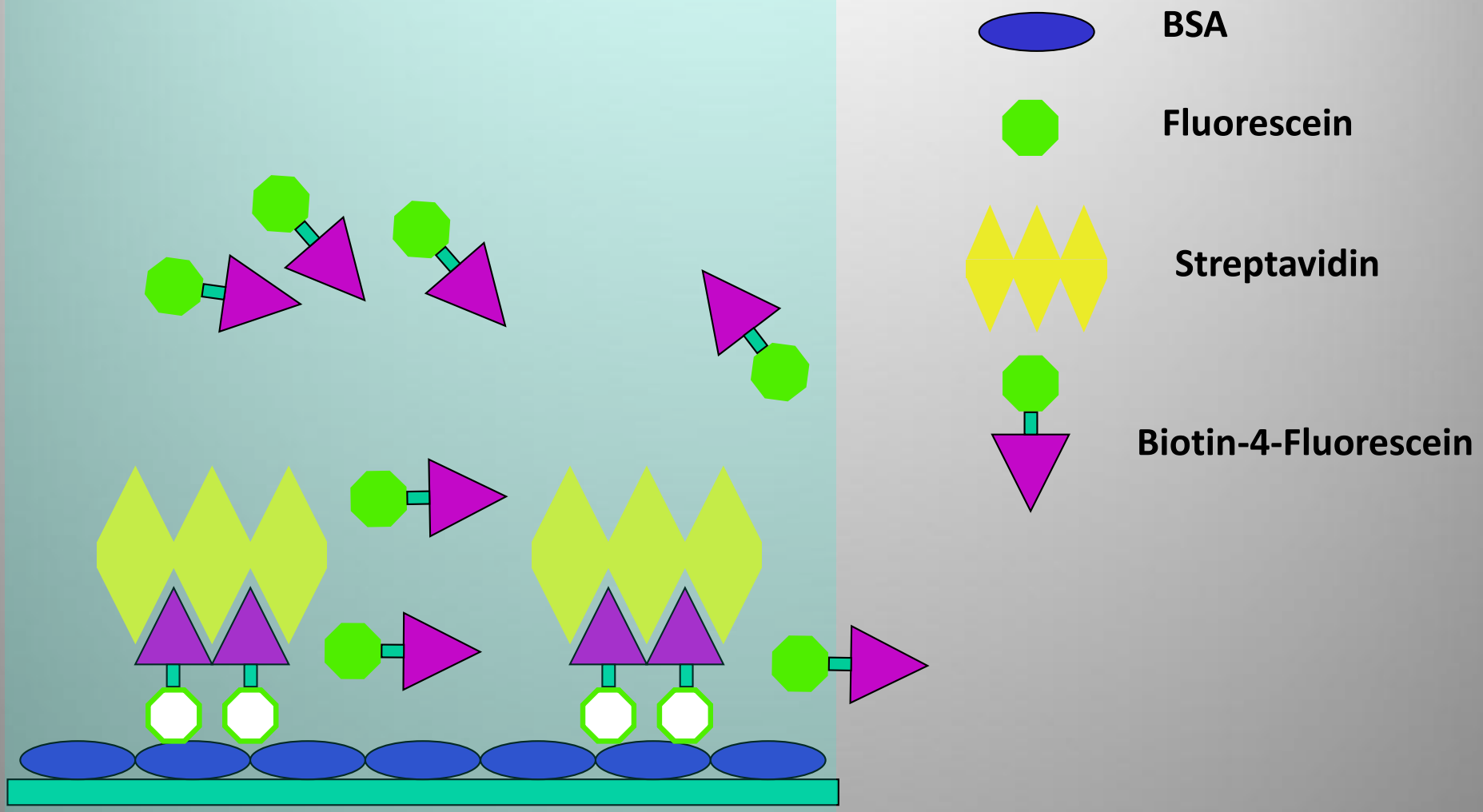


M. A. Holden and P. S. Cremer, J. Am. Chem. Soc., 2003, 125, 8074-8075.


Gradient
20 m


Any Shape
50 m

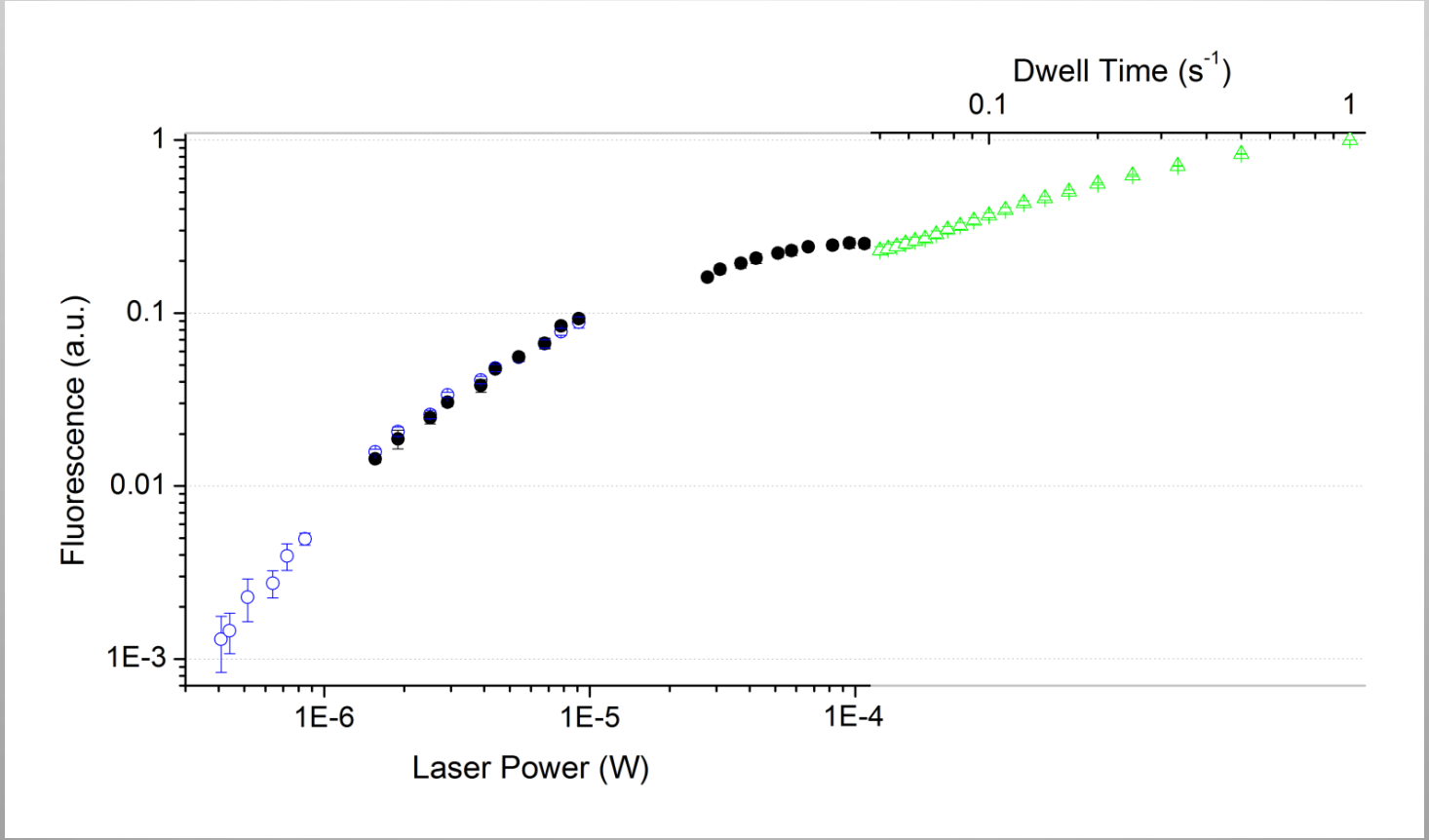
Laser Assisted Protein Adsorption by Photobleaching

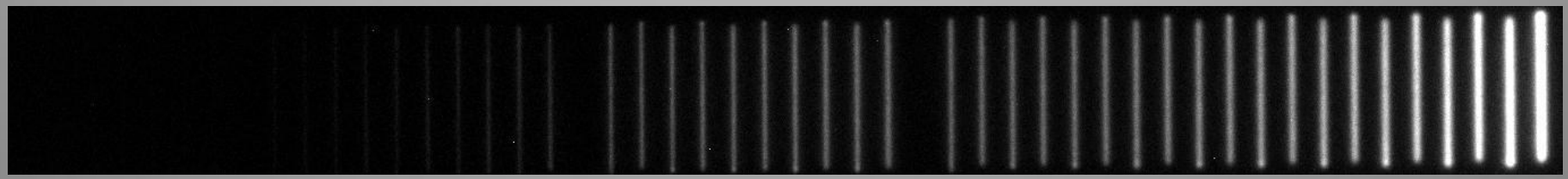


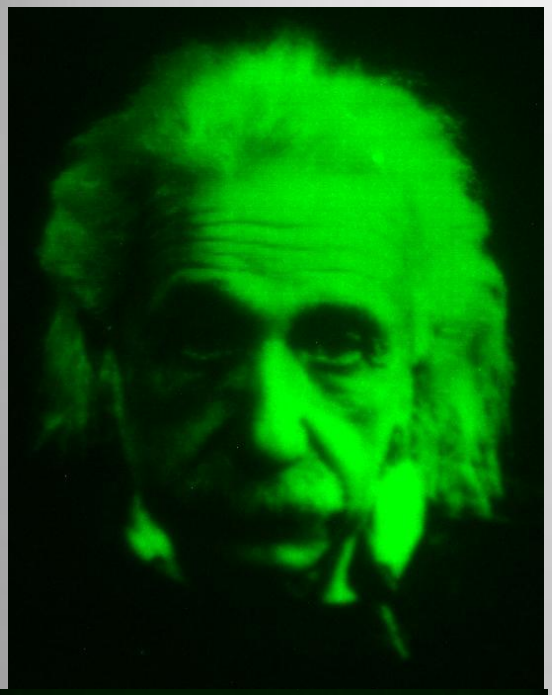
M. A. Holden and P. S. Cremer, J. Am. Chem. Soc., 2003, 125, 8074-8075.

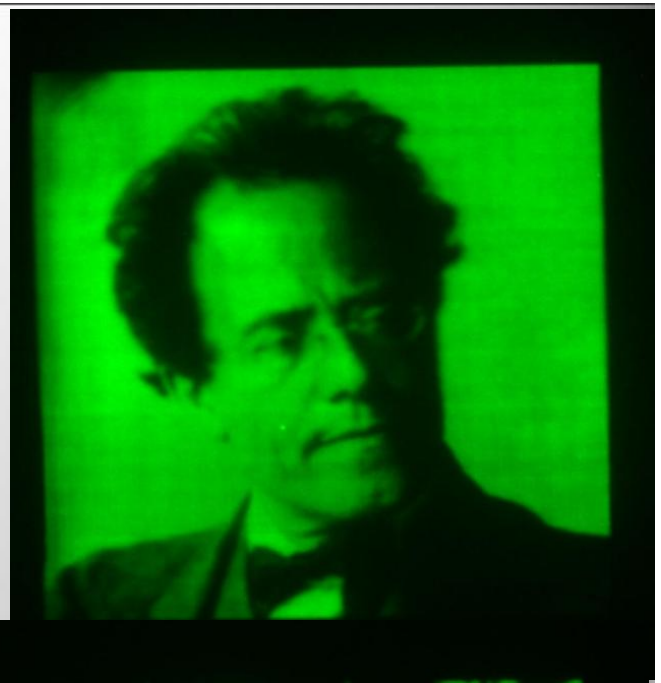
Characterisation of LAPAP

Dwell Time and Laser Power



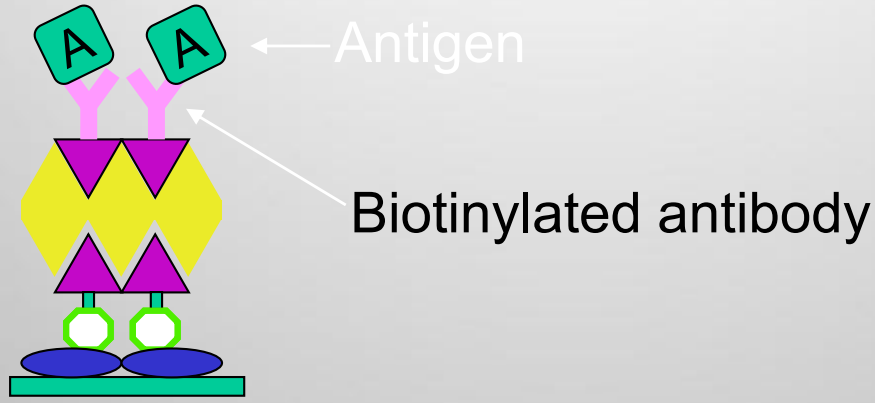




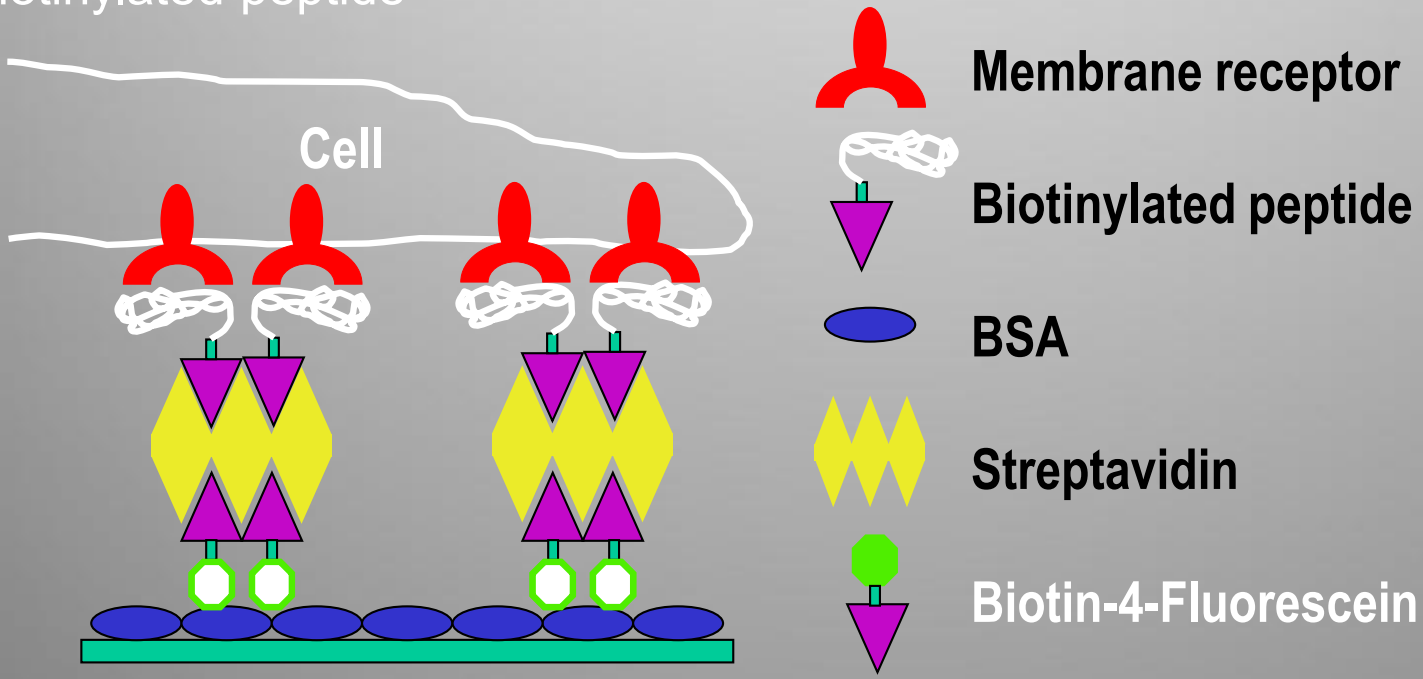


Functionality

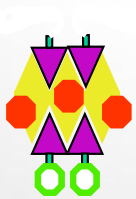
Biotinylated antibody and its antigen

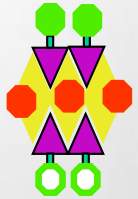


Biotinylated peptide

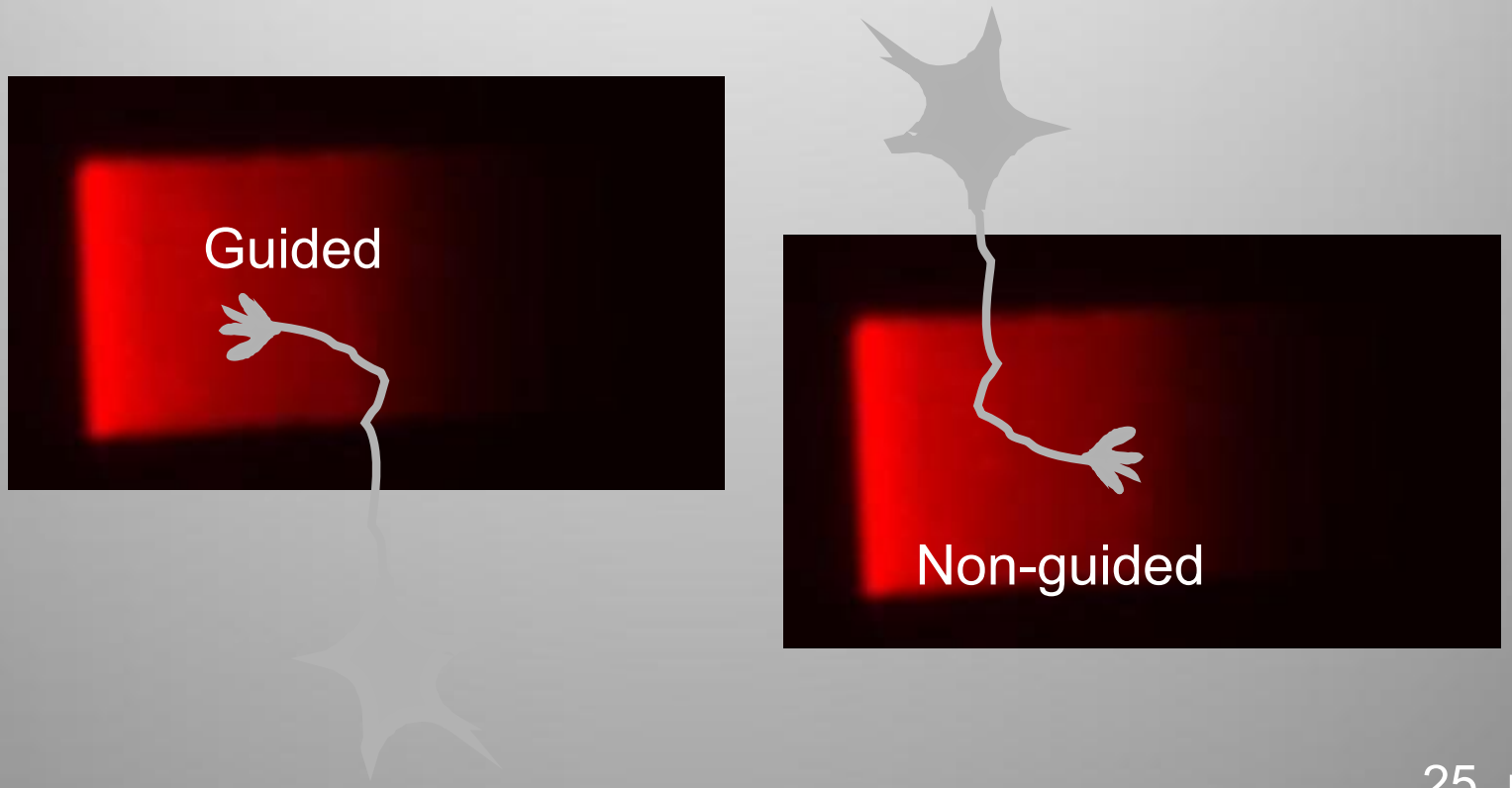


Functionality





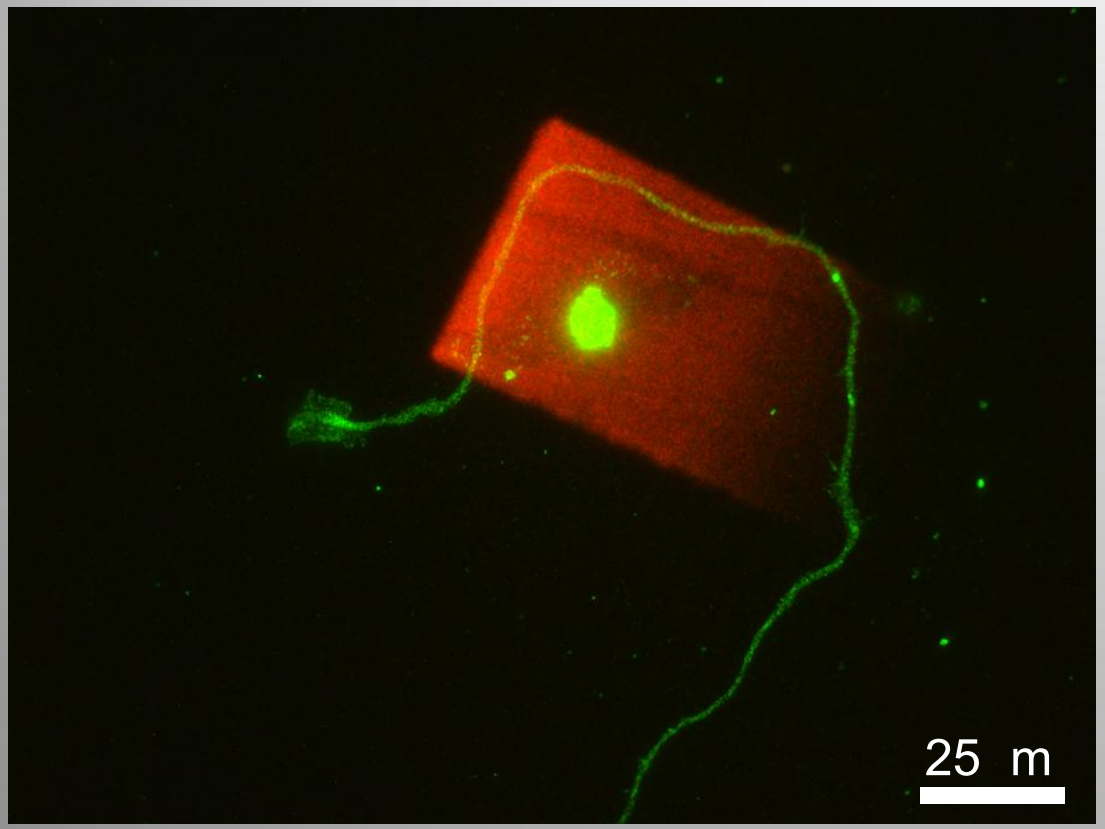
1) 400 gradients : 200 IKVAV peptide and 200 control (biotin-4-fluorescein)
2) Cultured DRG on these gradient for 24 to 36 hours
3) Imaged all the gradients
4) Images randomly numbered and analyzed by a blind observer

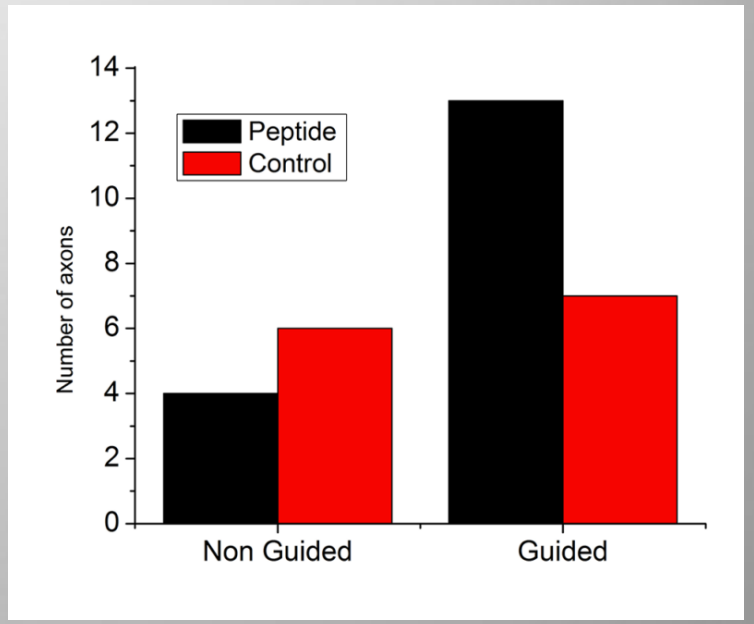


J. M. Belisle, J. P. Correia, P. W. Wiseman, T. E. Kennedy and S. Costantino, *Lab Chip*, 2008, **8**, 2164-2167.

Functionality

Example of guided axon

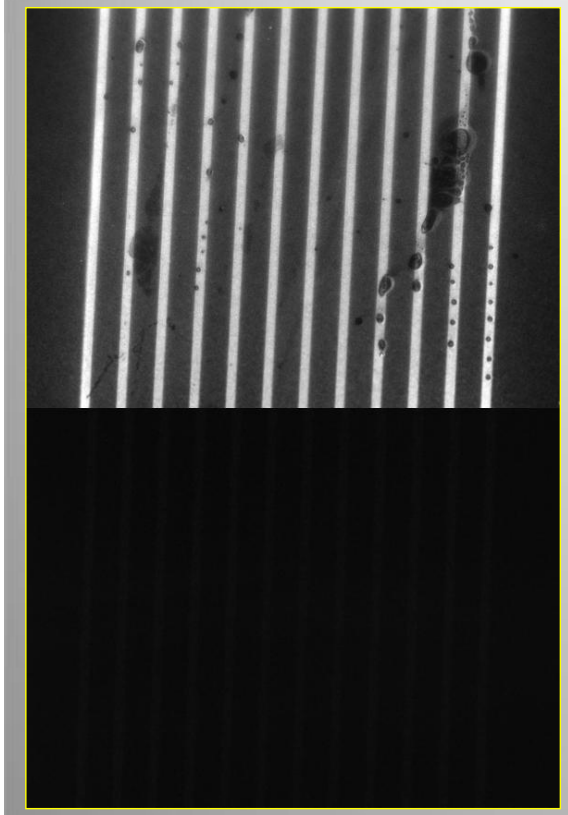




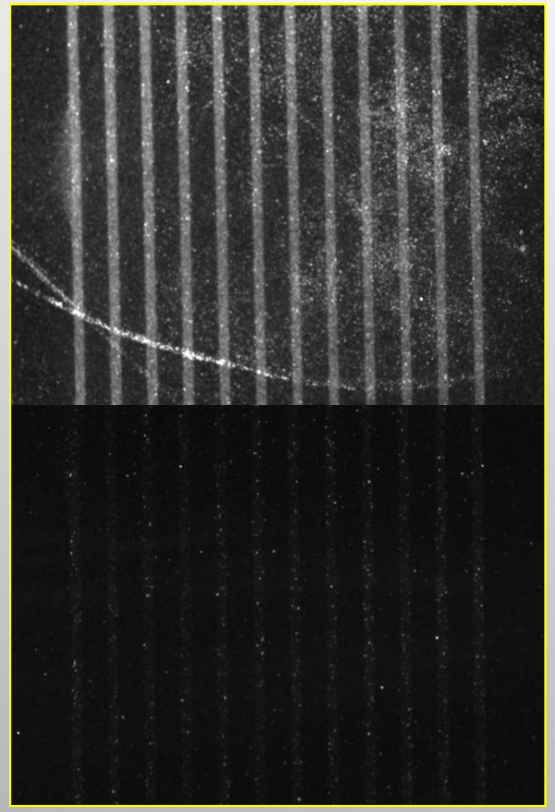
SRARKQAASIKVAVSARD

J. M. Belisle, J. P. Correia, P. W. Wiseman, T. E. Kennedy and S. Costantino, *Lab Chip*, 2008, **8**, 2164-2167.

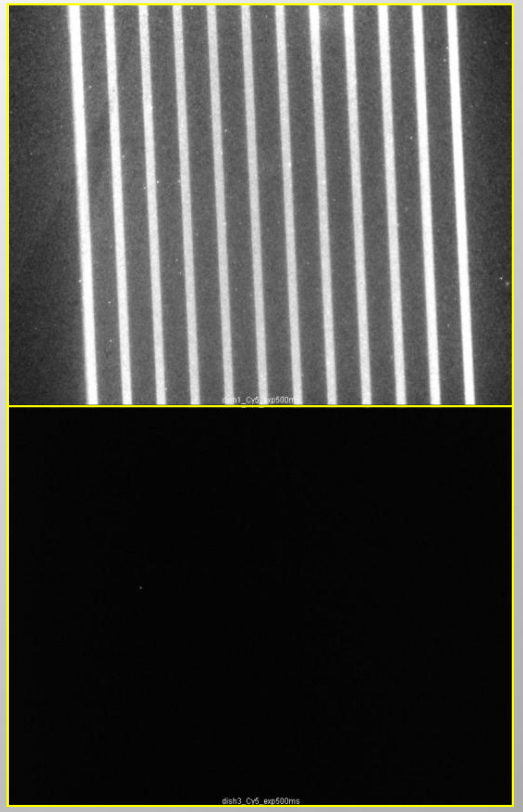
Full protein patterns



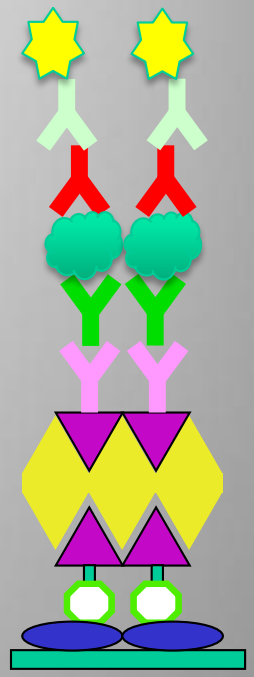
Sonic hedgehog
F. Charron, IRCM

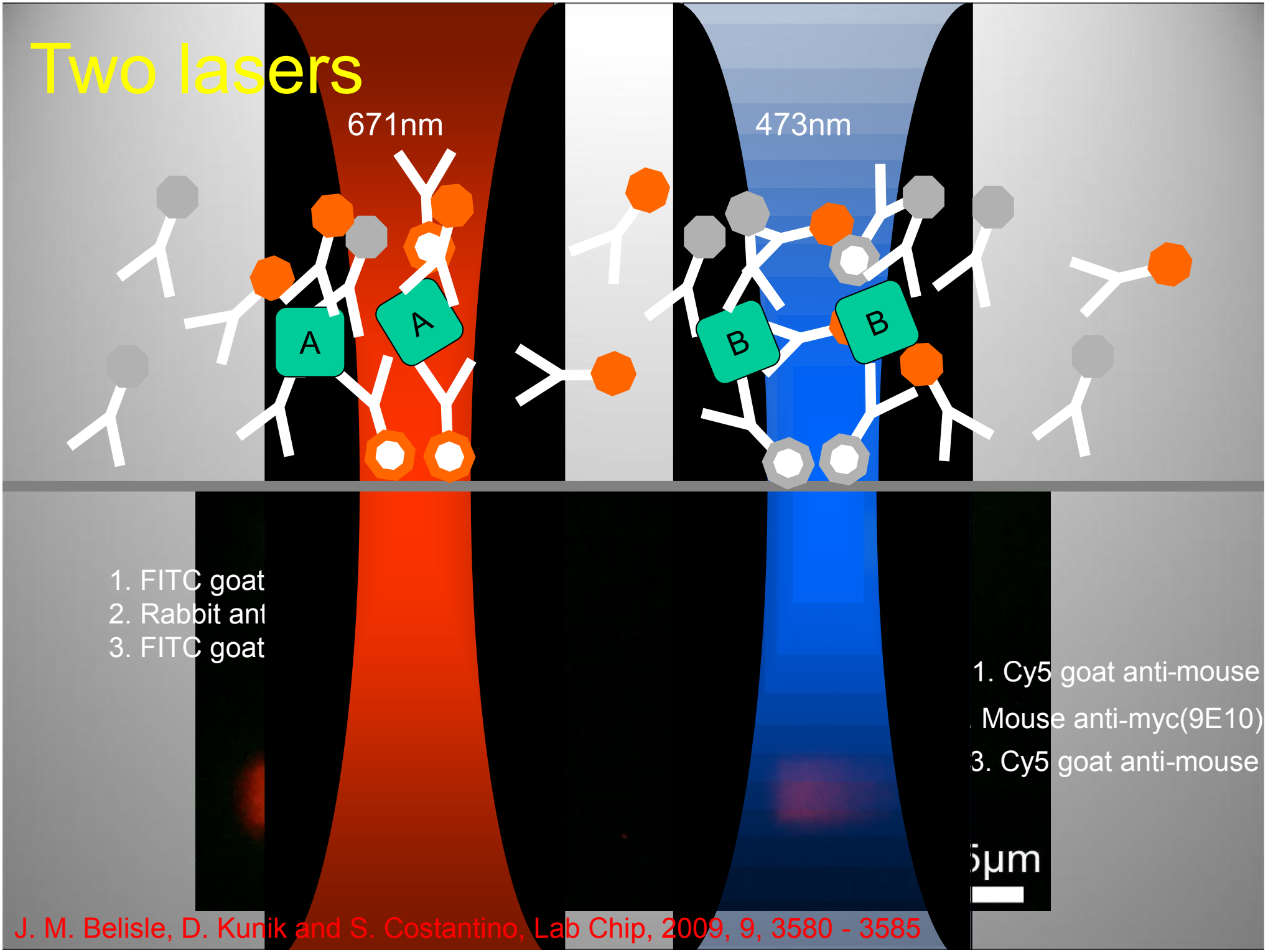


Netrin-1
T. Kennedy , MNI



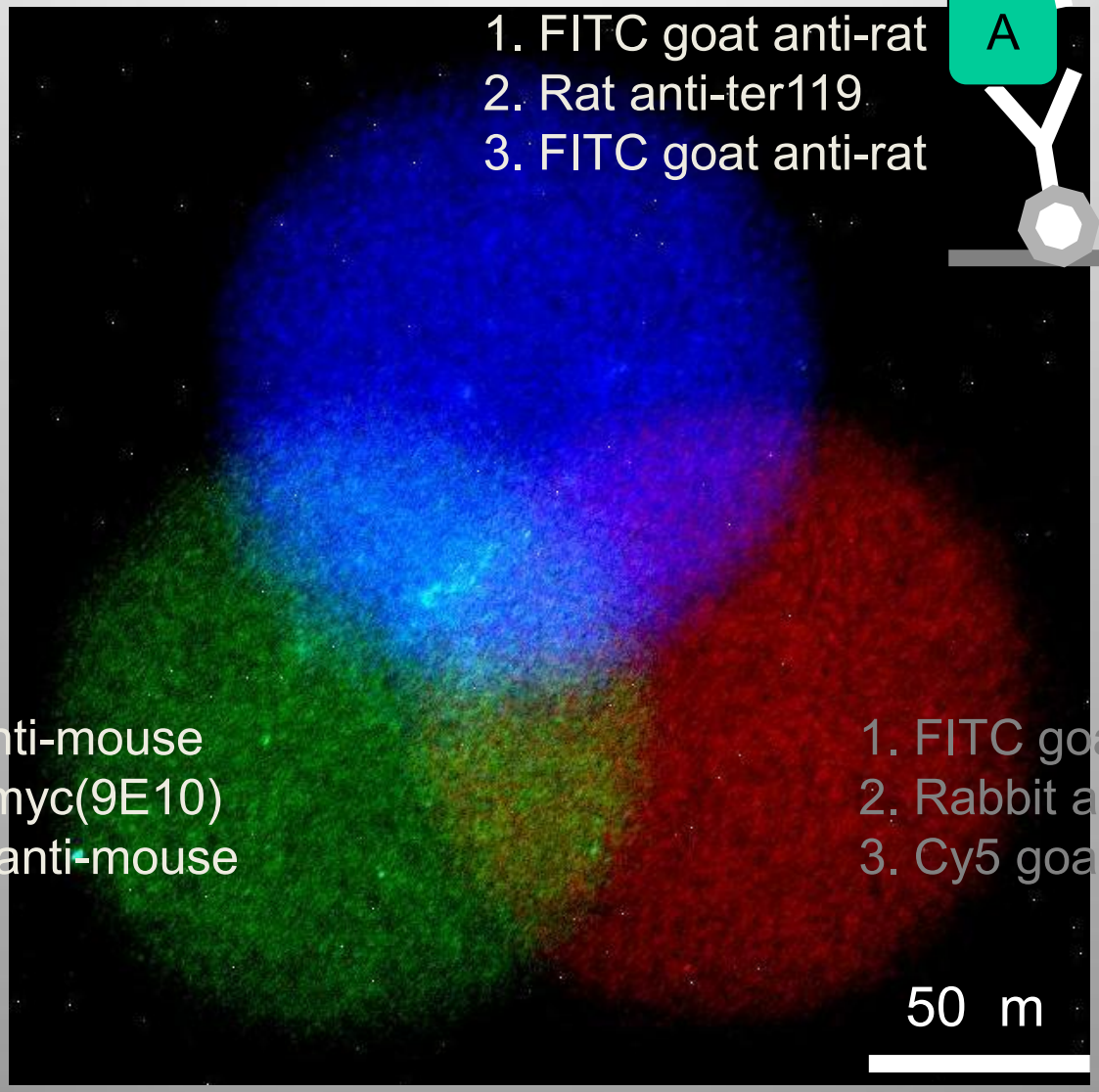
Laminin
L. Levin, UdeM

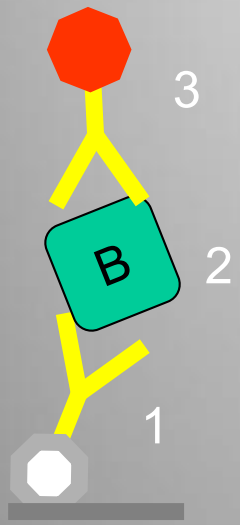


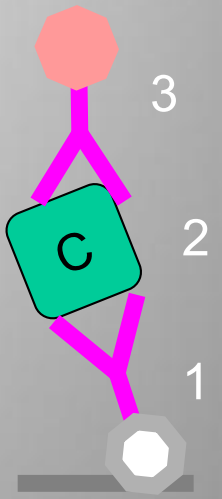


J. M. Belisle, D. Kunik and S. Costantino, Lab Chip, 2009, 9, 3580 - 3585

Subsequent illumination





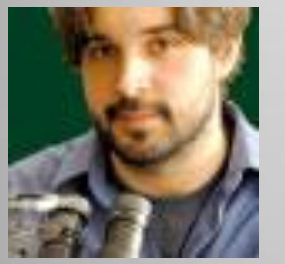


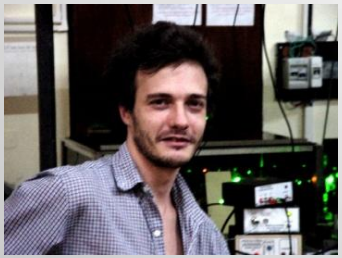
1. FITC goat anti-mouse
2. Mouse anti-myc(9E10)
3. TRITC goat anti-mouse

1. FITC goat anti-rabbit
2. Rabbit anti-laminin
3. Cy5 goat anti-rabbit

J. M. Belisle, D. Kunik and S. Costantino, Lab Chip, 2009, 9, 3580 - 3585

Acknowledgements


Jonathan Bélisle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CIHR IRSC
Canadian Institutes of Health Research
Instituts de recherche en santé du Canada

NSERC CRSNG

Canada Foundation for Innovation
Fondation canadienne pour l'innovation

Fonds de recherche sur la nature et les technologies Québec

Université de Montréal

Hôpital Maisonneuve-Rosemont
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Manipulating forces at the nanoparticles

Laser printing single gold nanoparticles

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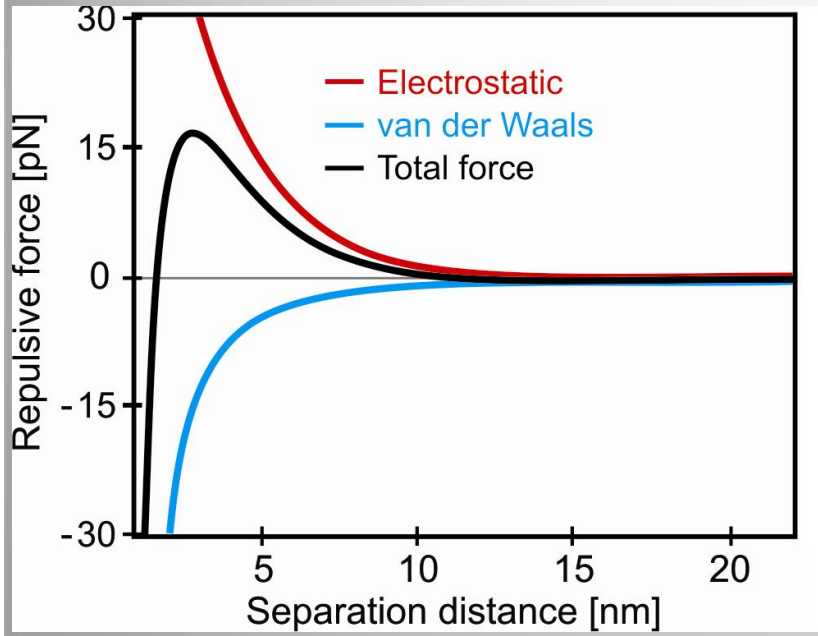
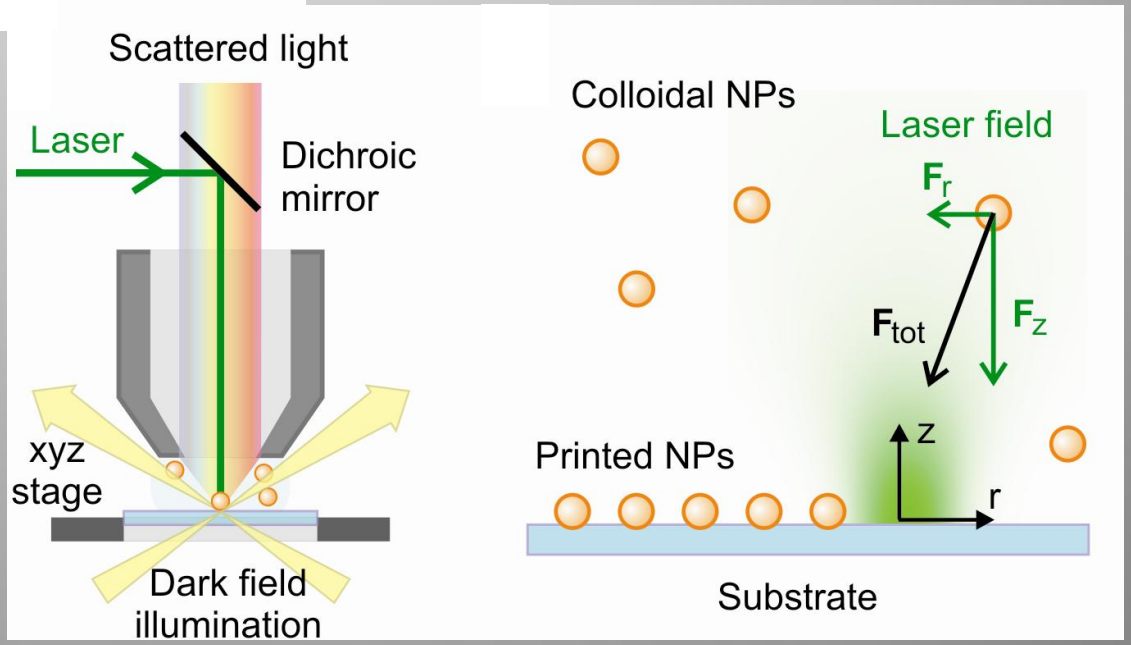
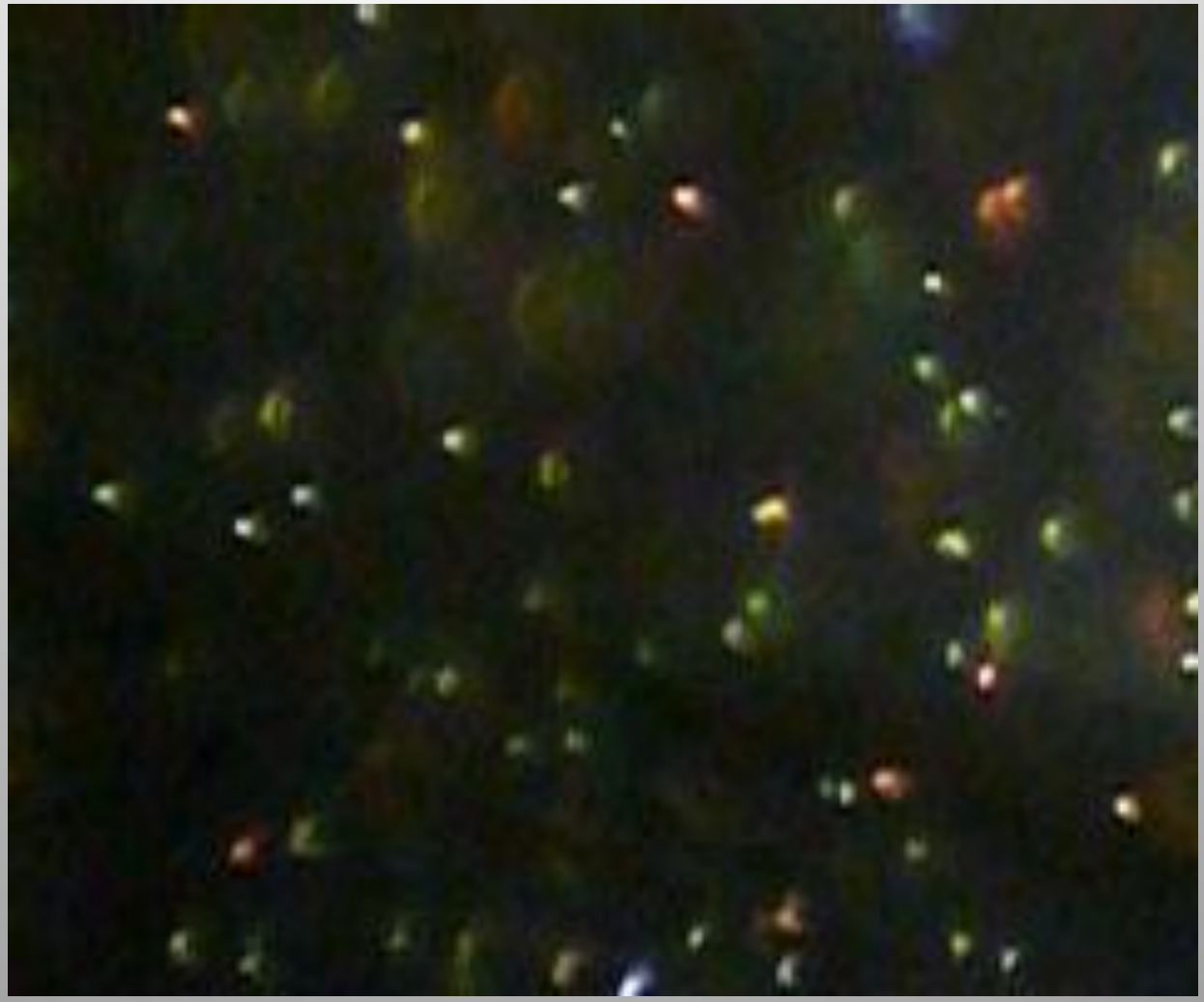
Colloidal interactions



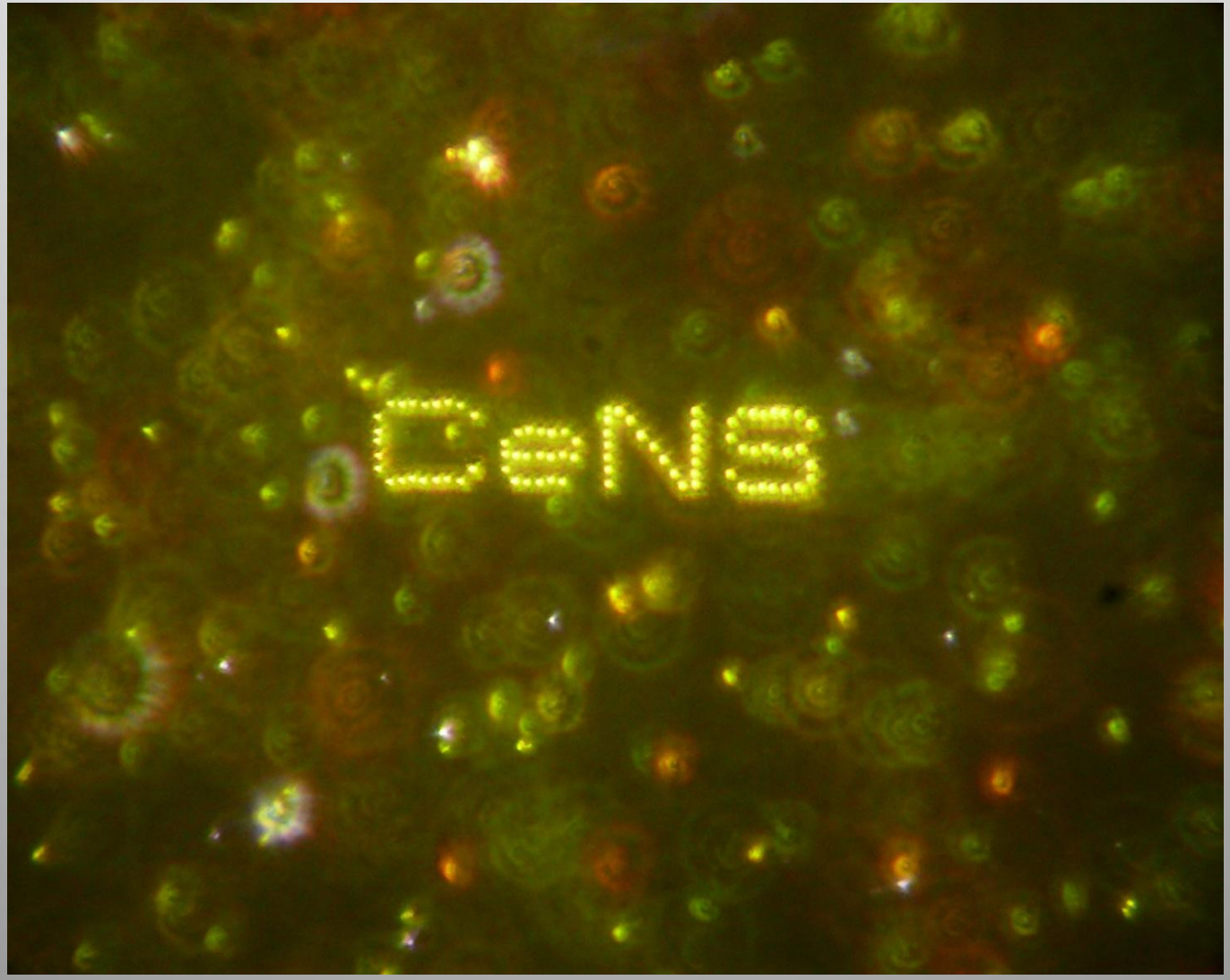


Nano Lett. 2010, 10, 4794–4798

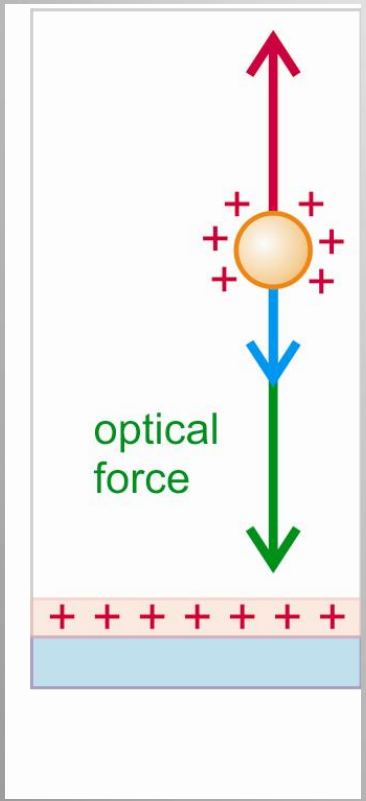
Laser printing single nanoparticles

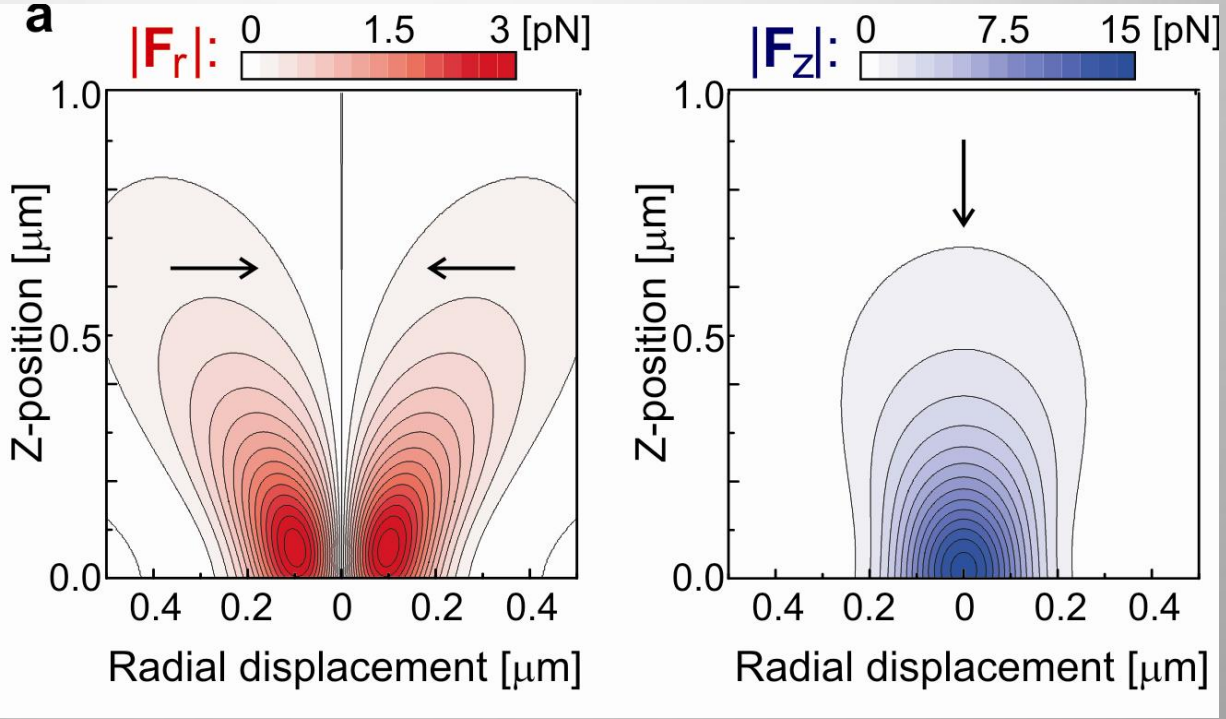


Laser printing single nanoparticles



Printing accuracy





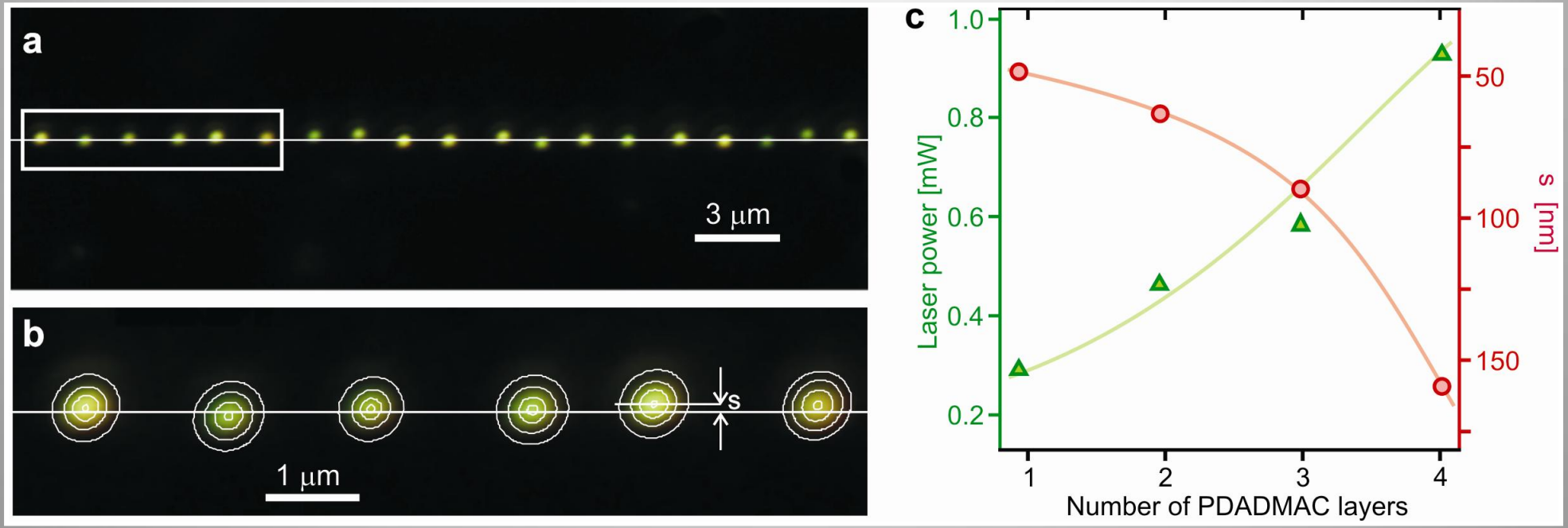
Printing accuracy:

- Beam size and intensity
- Brownian motion

Printing individual gold nanoparticles (Au NPs) using optical forces. (a) Calculated radial (left) and axial (right) optical forces acting on an Au NP with a diameter of 80 nm as a function of the position in a Gaussian focused beam (532 nm, 10 mW).

Nano Lett. 2010, 10, 4794–4798

Printing accuracy



<u>There is no fundamental limit!</u>

- Increase solution viscosity
- Tighter focusing
- Microinjection

<u>In addition:</u>

- Orientation control by polarization

Urban et al. *Submitted* (2010)

Grupo de Fotónica de Nanomateriales

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Conclusions