Integration of optofluidic functionalities

J. C. Galas, Q. Kou, C. Péroz, J. Shi, and Y. Chen

Laboratoire de Photonique et de Nanostructures, CNRS, Marcoussis, France

École Normale Supérieure, Paris, France

Ens

Information Society Technologies

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Outline

I. Microfluidics

II. Optofluidic functionalities

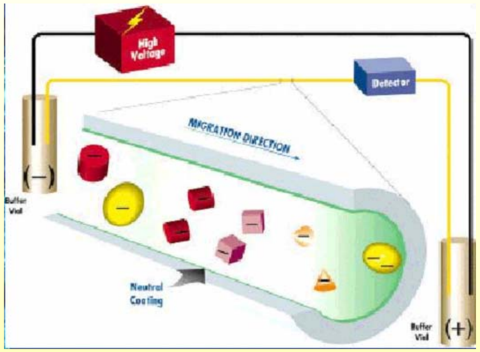
- Liquid core wave guides
- Integrated optical components
- Microfluidic dye lasers
- Inter cavity absorption

III. Conclusions

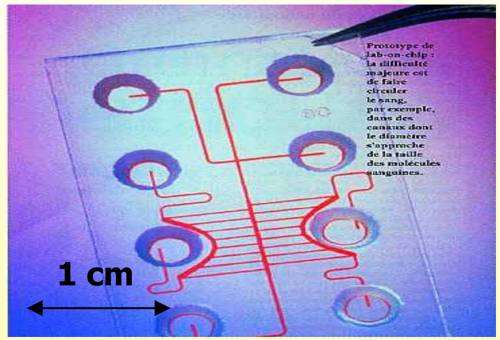
I. Microfluidics

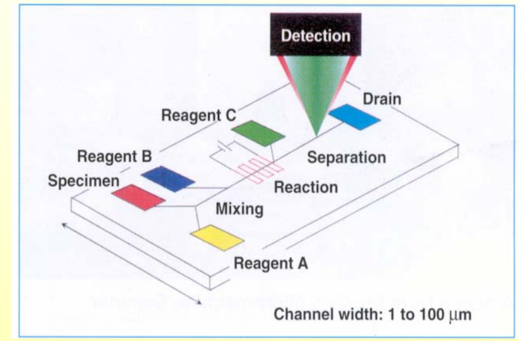
Importance of microfluidics

From capillary electrophoresis to lab-on a chip micro-systems

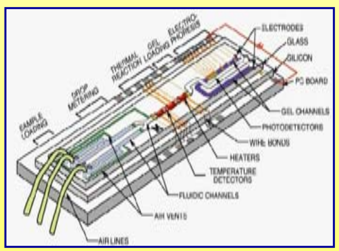


1992



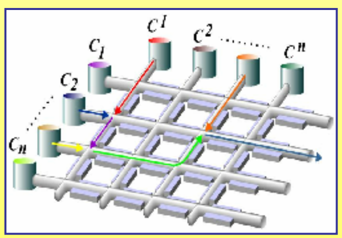


Integration

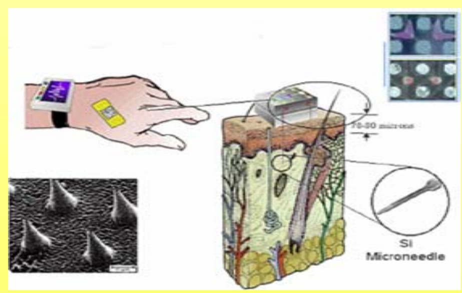


Sequential

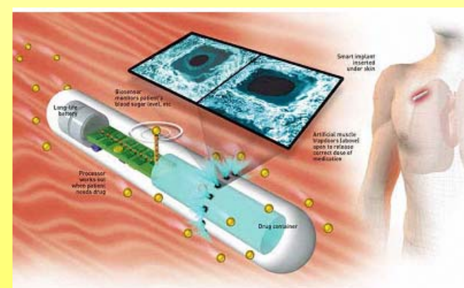
Parallel



Portable



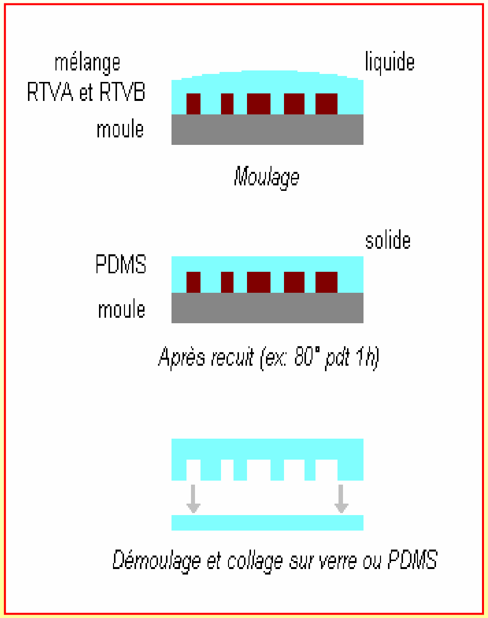
Implantable



Art of control and manipulation of micro-flow, cells, and bio-molecules

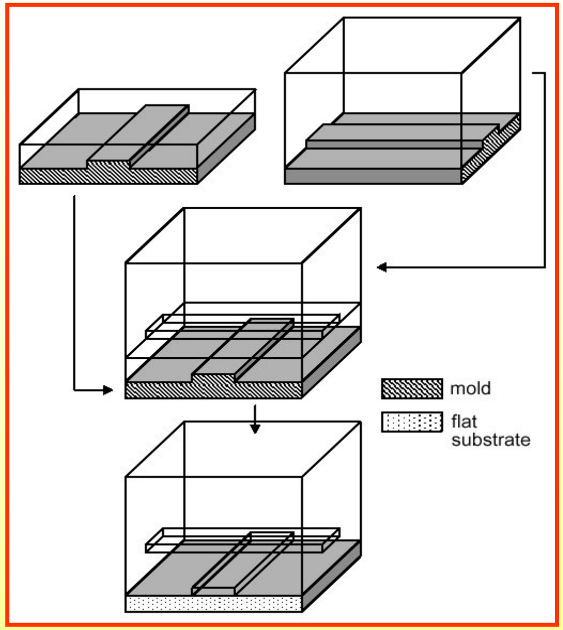
Fast prototyping by soft lithography

Single layer device



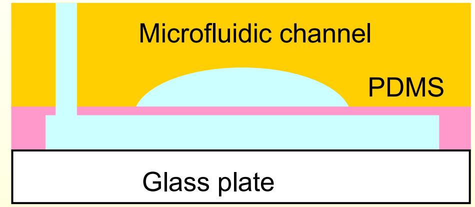
G.W. Whitesides, Harvard

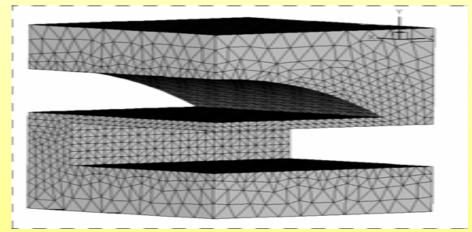
Double layer device



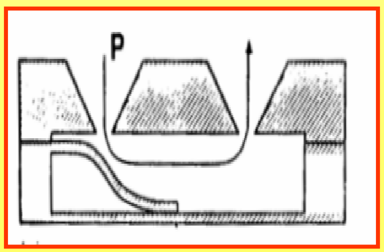
S. Quake, CALTECH

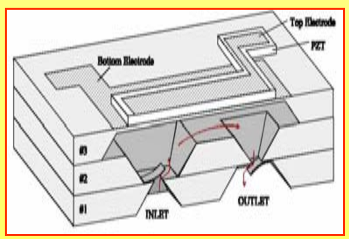
Valves



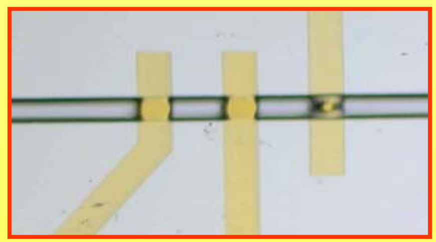


Comparison to Silicon MEMS technology

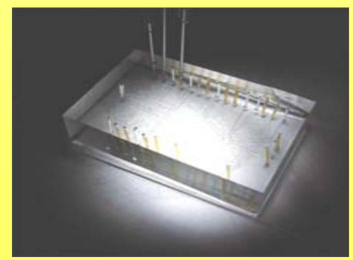




Micro pump



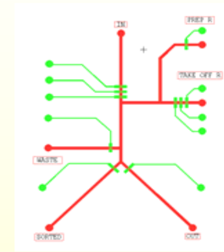
Connections



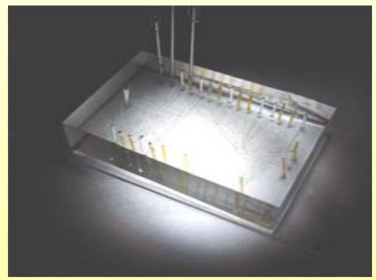
Typical workflow

Conception study

Process planning



Observation & reporting



Mask patterns design

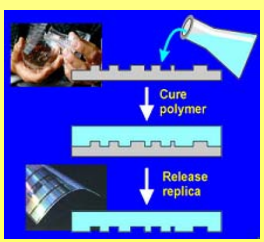
Device assembling

Mask/mould making

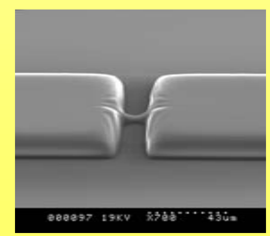
Fast prototyping

Soft lithography

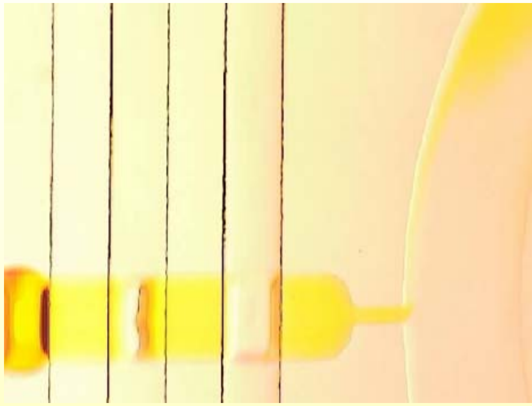
Optical lithography



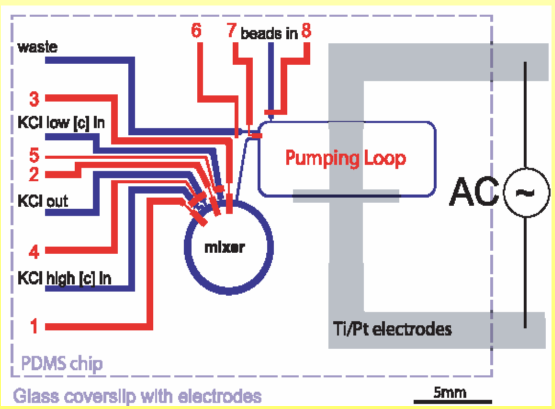
Nanoimprint lithography



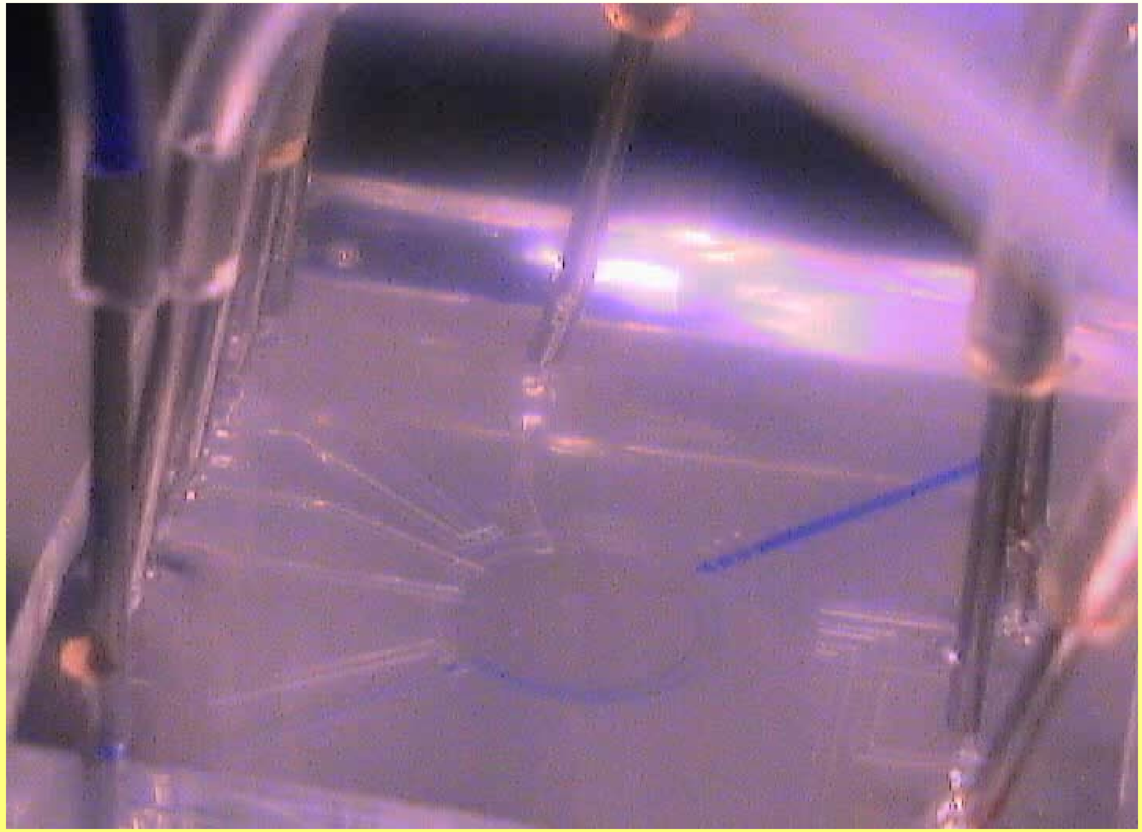
Device example: Micro reactor



Micro injecter

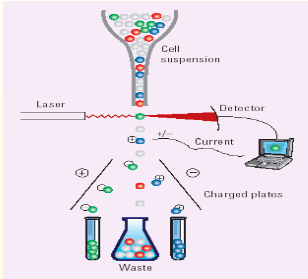


Device for AC kinetic pumping



V. Studer et al, μTAS 04, p375, Analyst 129, 944 (05)

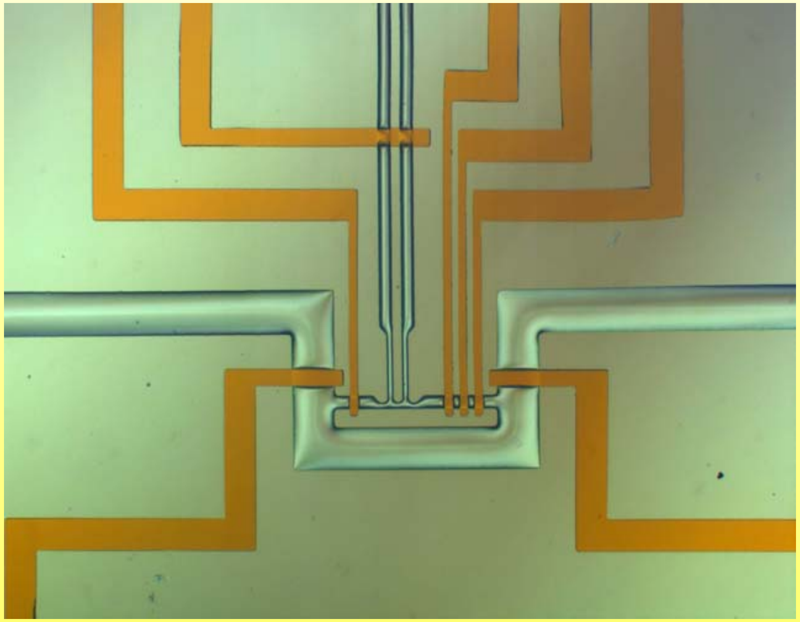
Device example: (Rare) cell sorter



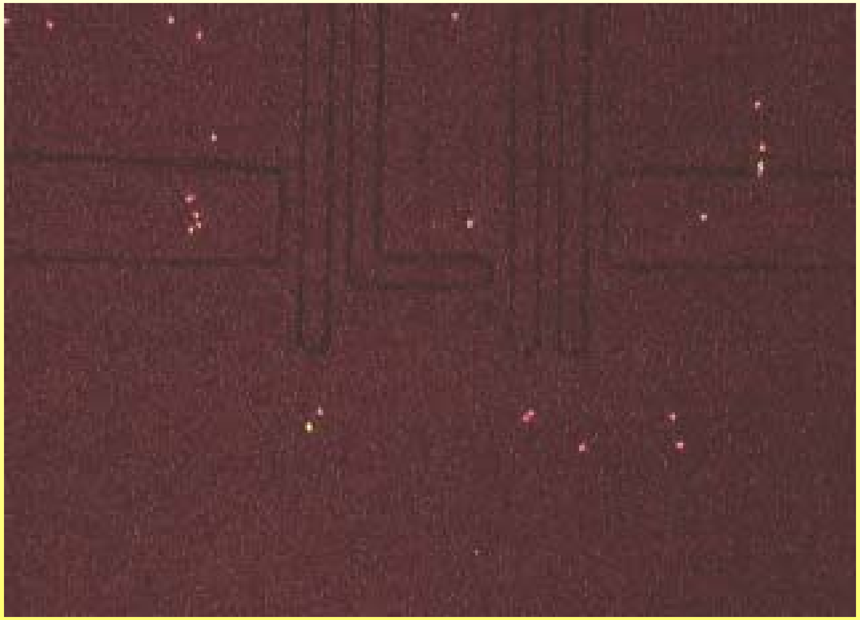
Challenge :

Sorting one cell among ten millions during one hour.

Approach : A two stage design for rapid & precise sorting



High throughput sorter



Single cell manipulation

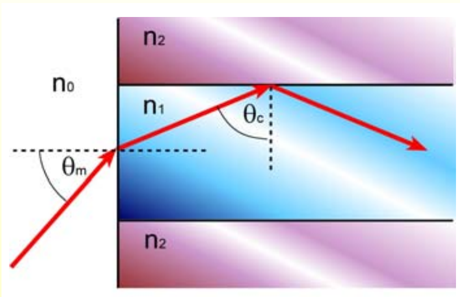
V. Studer et al, Microelectron. Eng. 73-74, 852 (05)

II. Optofluidic Functionalities

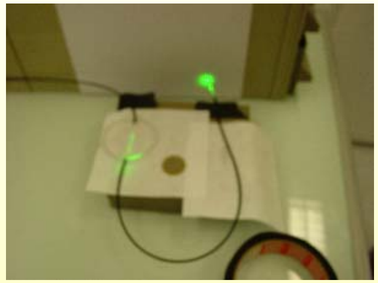
Liquid core - PDMS cladding wave guide

Liquid core wave guide

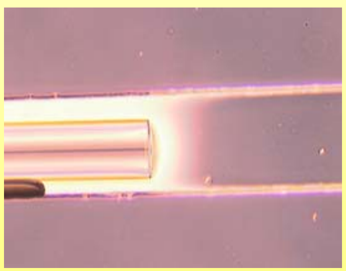
$n_{PDMS} = 1.42$, $n_{oil} = 1.52$

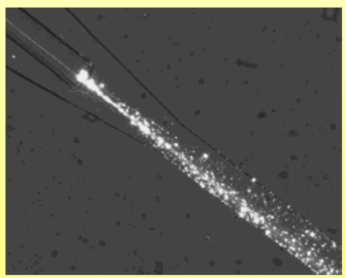


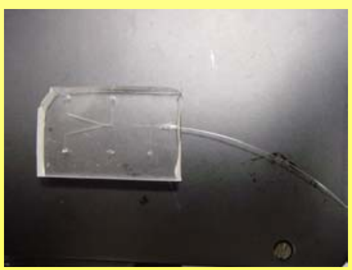
$NA = n_0 \sin \theta_m = (n_1^2 - n_2^2)^{1/2}$

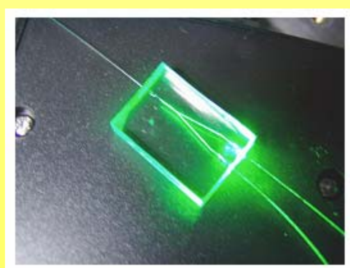


Optic-fiber coupling

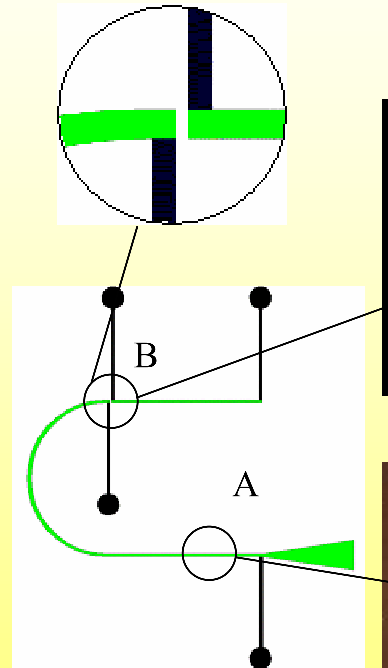


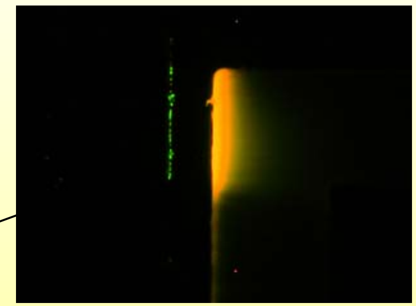


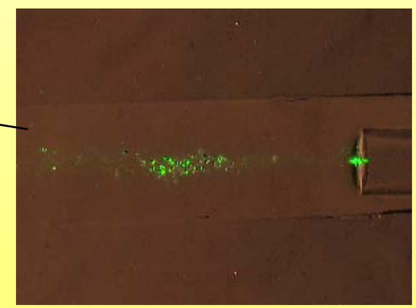




R6G luminescence





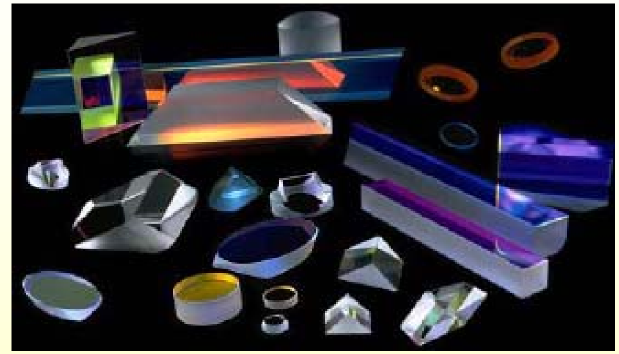


Excitation @ 532nm

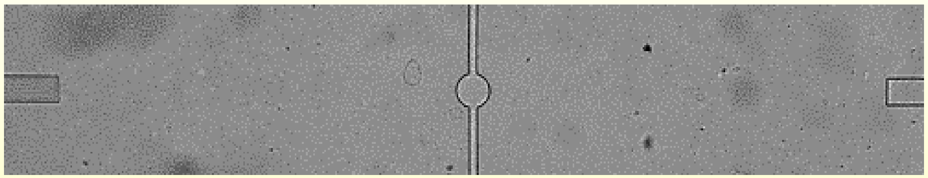
Q. Kou et al, LPN, MNE (2003)

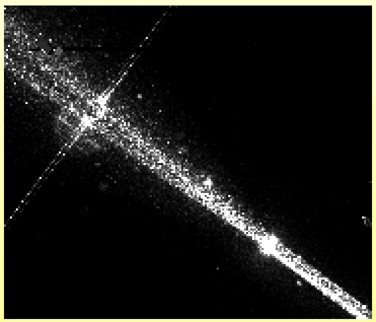
Optical components

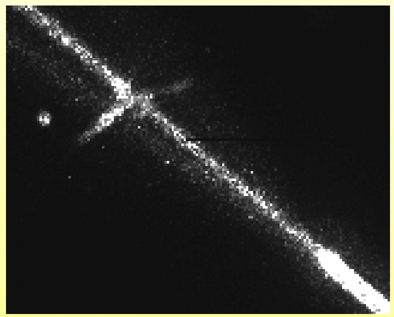
Small size and re configurable



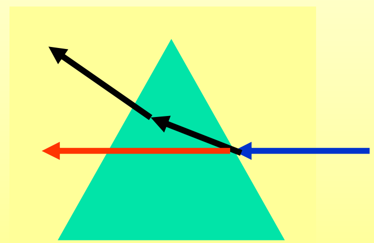
Micro lenses

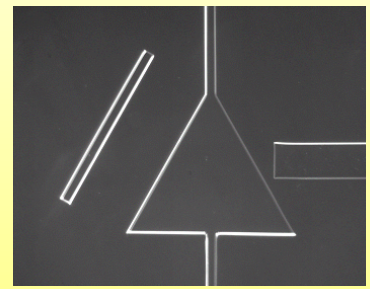




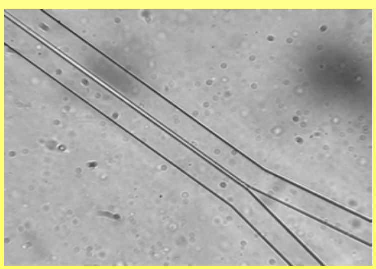


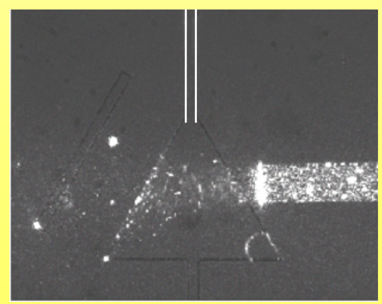
Micro prism



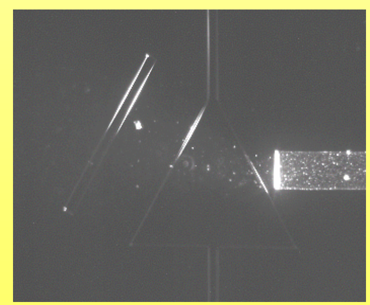


Micro coupler and beam splitter





With liquid



Without liquid

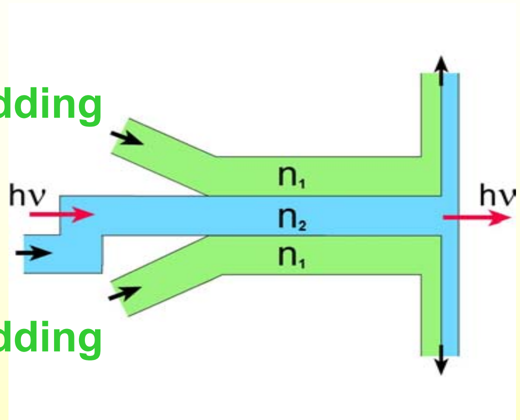
Liquid-core liquid cladding wave guide

Liquid cladding

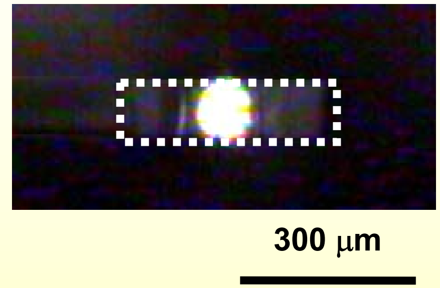
Couple light in

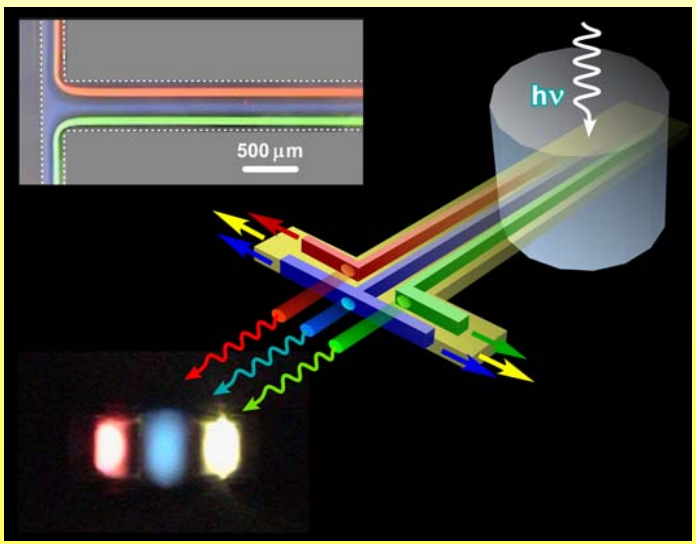
Liquid core

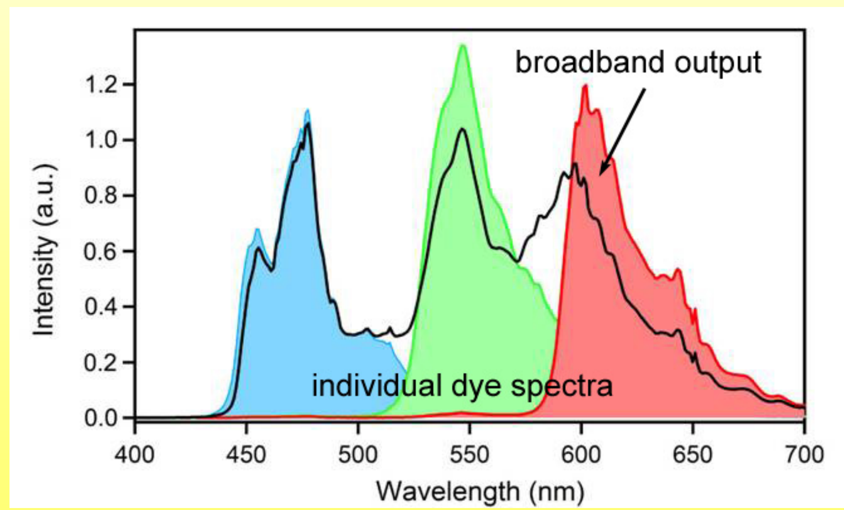
Liquid cladding



Couple light out

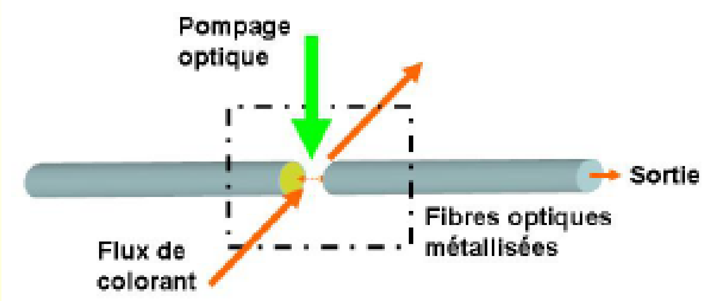




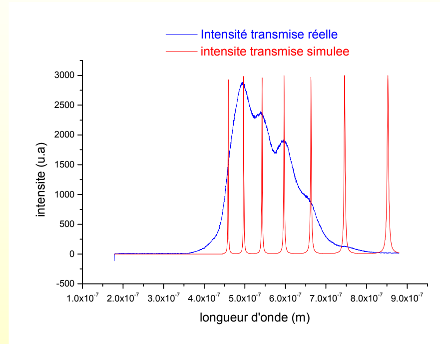


Vezenov, Harvard, Appl. Phys. Lett. 2005

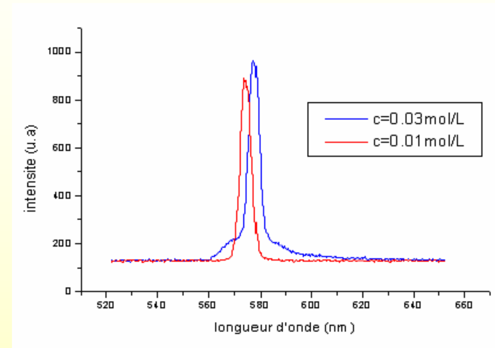
Microfluidic dye laser

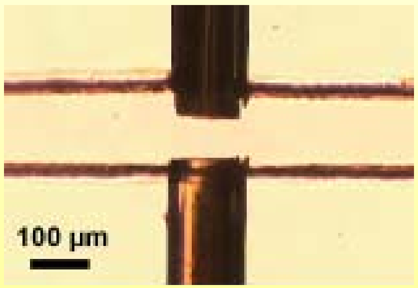


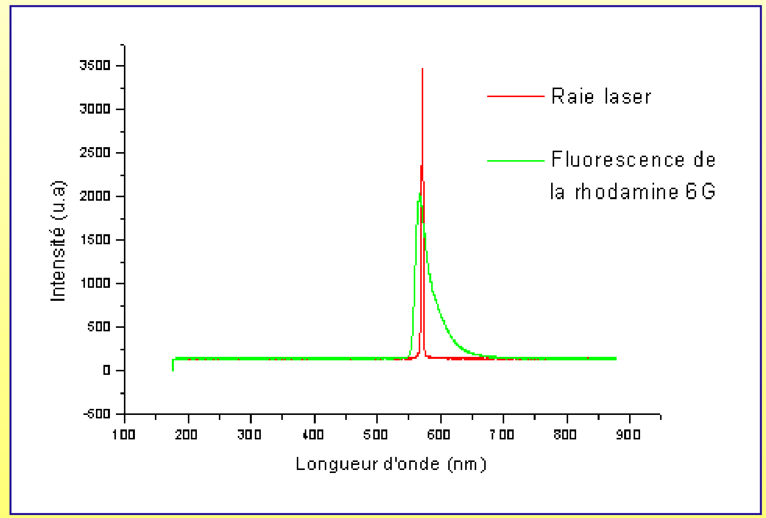
Cavity modes



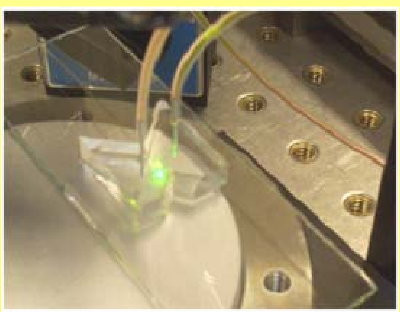
λ shift



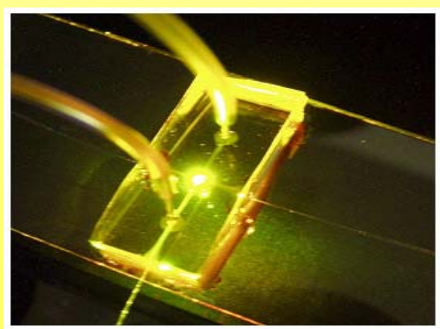




Outside pumping



On chip pumping

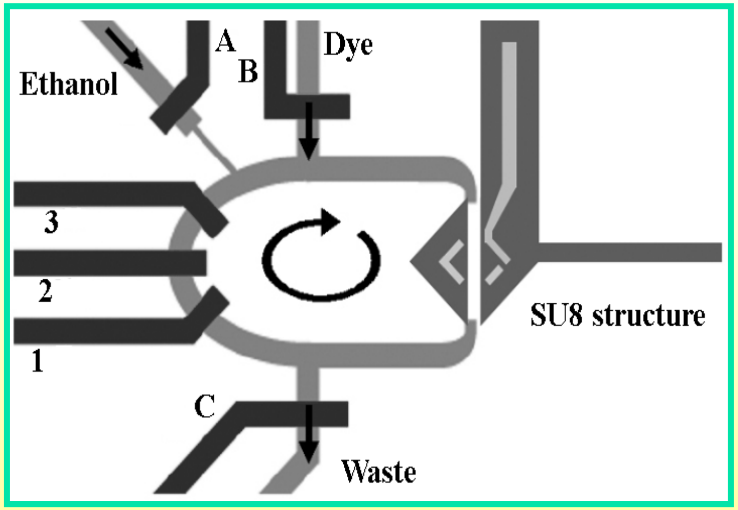


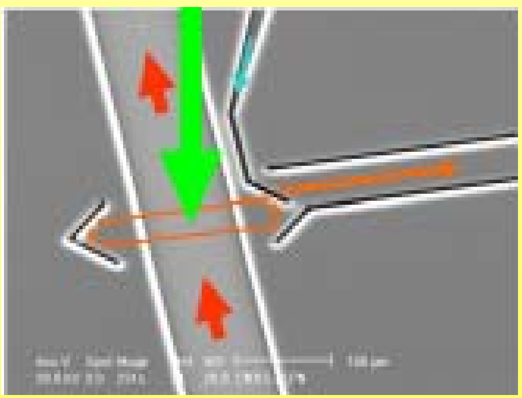
Spontaneous and stimulated emission

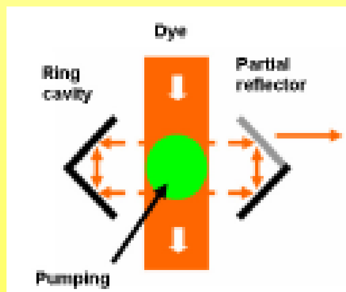
Kou et al, LPN/CNRS SPIE 5641-33 (2004)

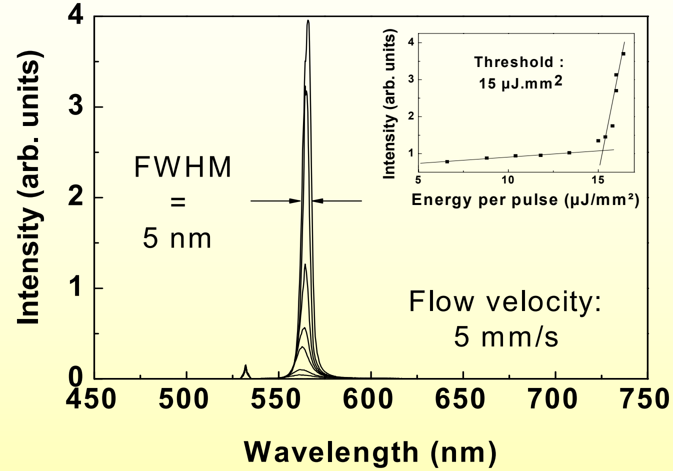
Close loop & ring resonator lasers

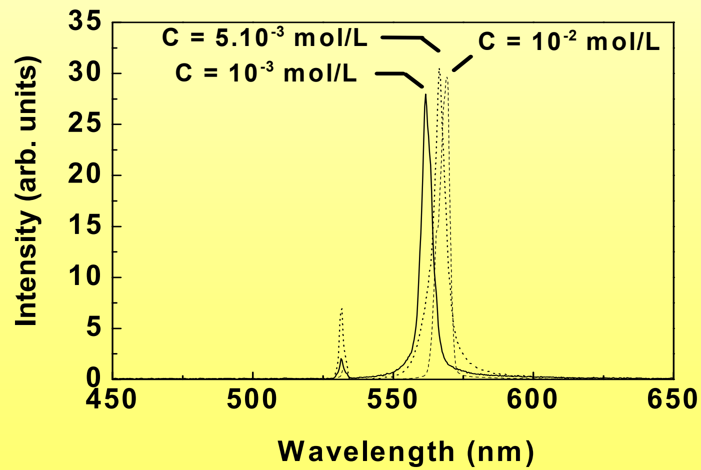
Nano liter and tunable ring cavity laser





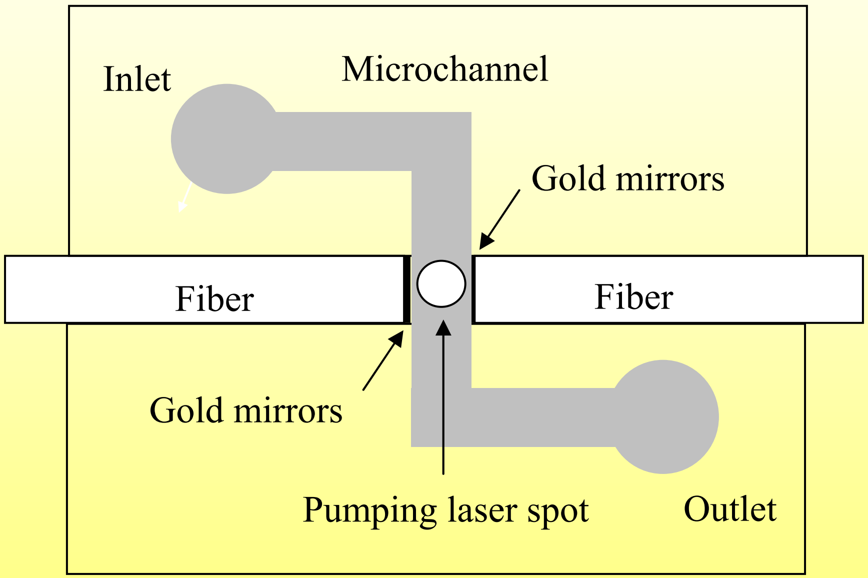


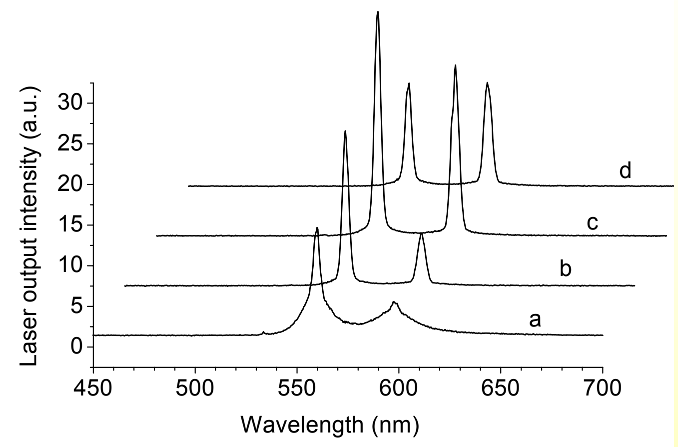


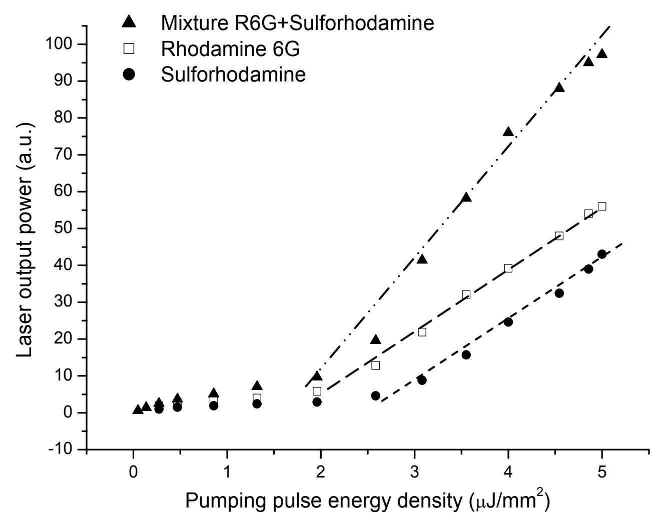


J.C. Galas et al, Appl. Phys. Lett. 2005

Collinear dual-color laser

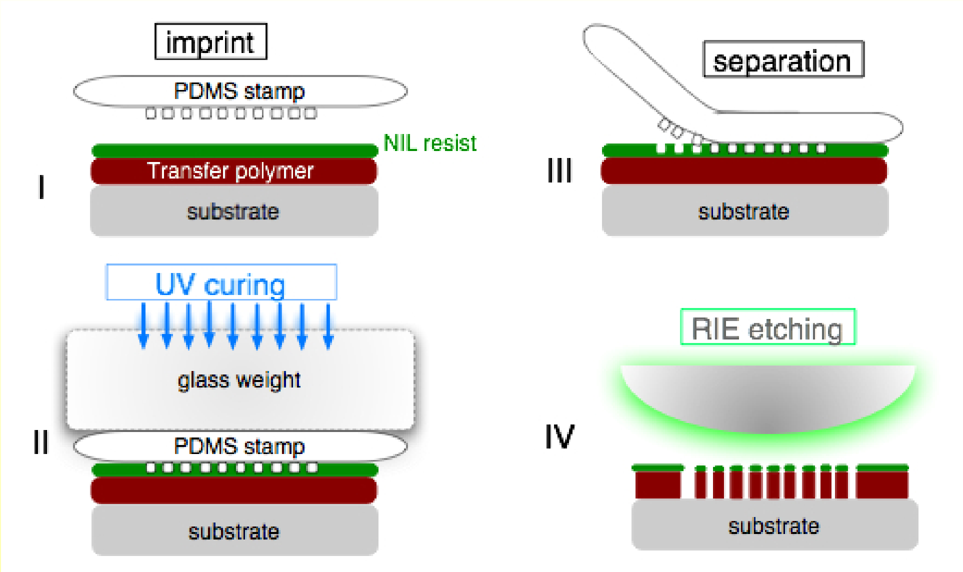


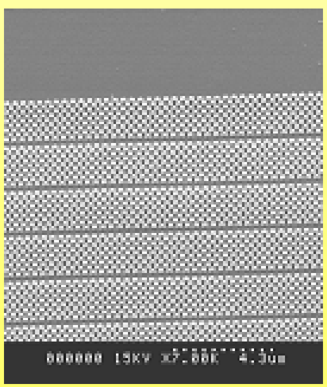


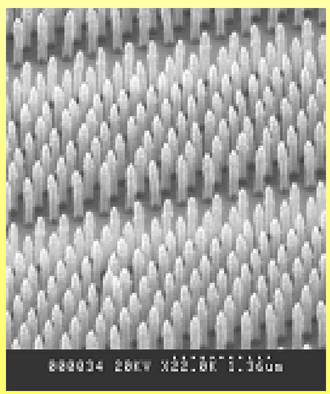


Kou et al, LPN, Appl. Phys. Lett. 2006

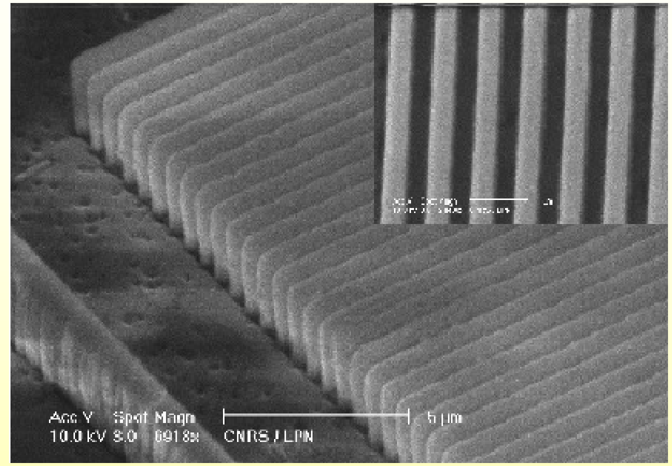
UV nanoimprint lithography

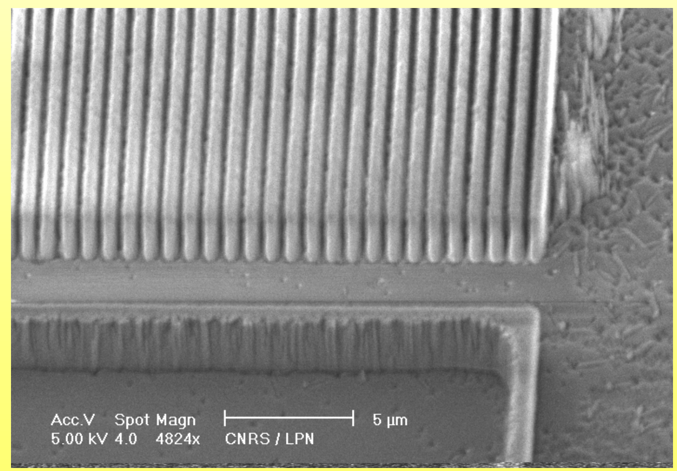






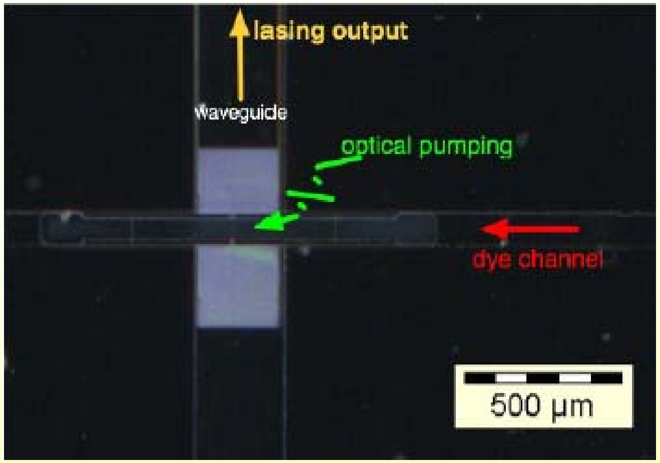
Imprinted and etched resists

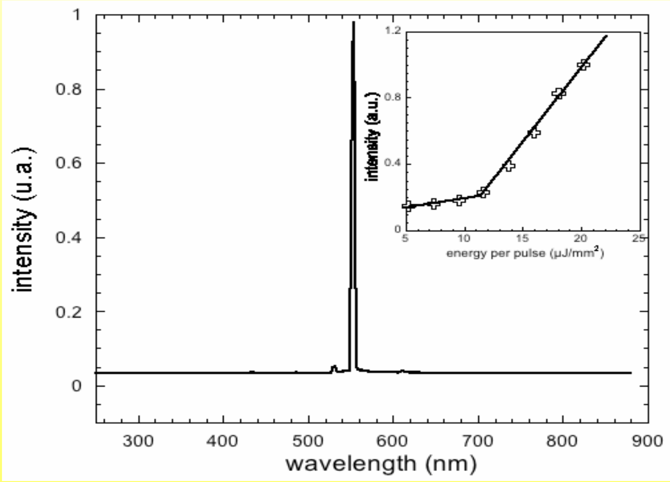


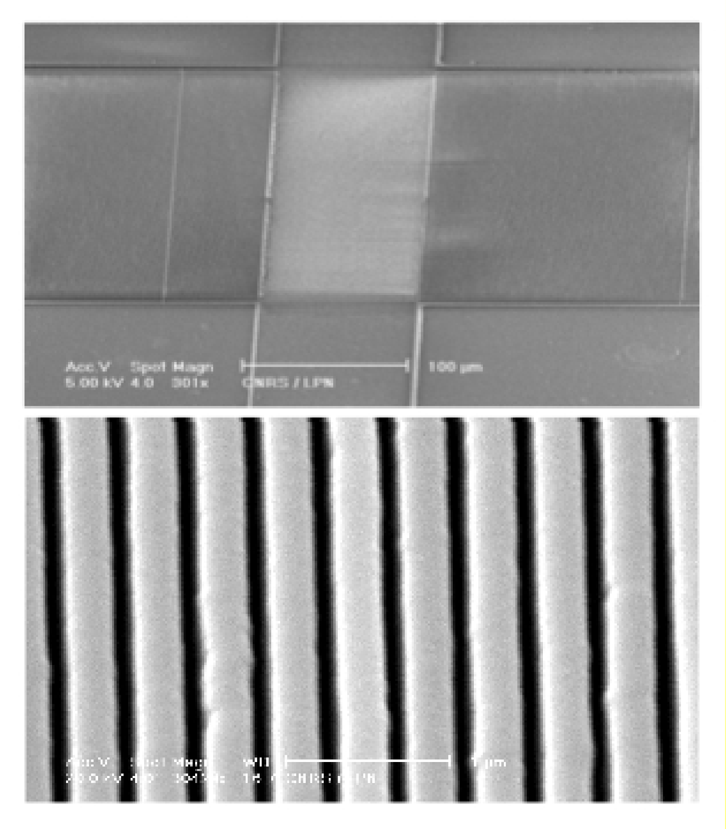


3rd order Bragg grating etched in quartz

2nd order Bragg gratings laser







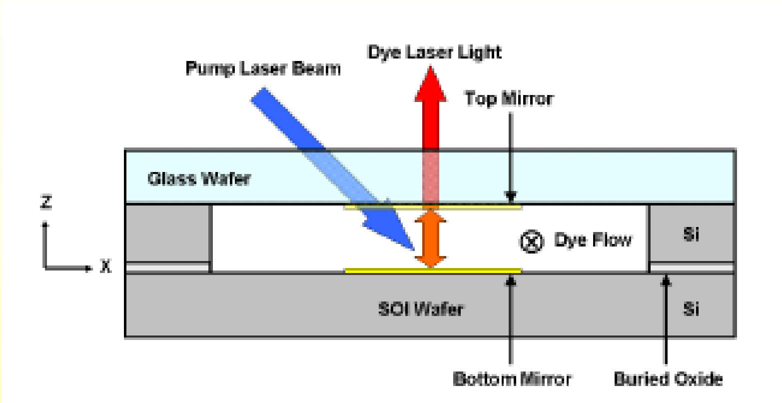
Bragg grating of 400 nm pitch grating, obtained by soft UV nanoimprint and etched into a quartz plate

Threshold pump fluence 12 µJ/mm².

C. Péroz et al, LPN, MNE (2006)

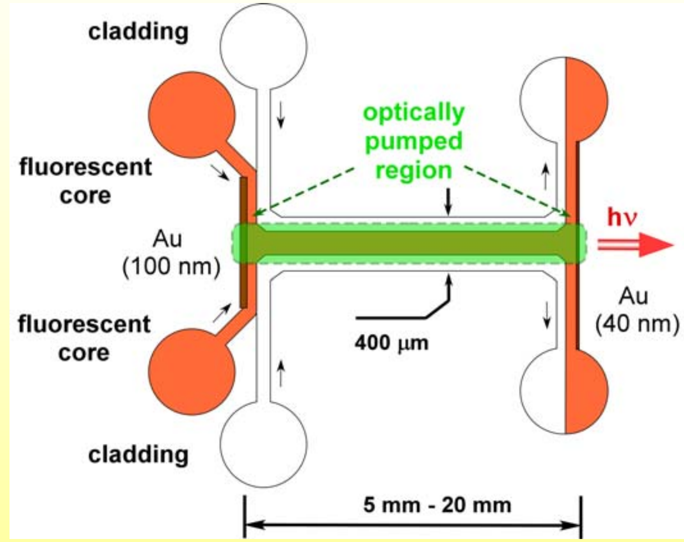
Other dye laser configurations

Vertical microfluidic laser

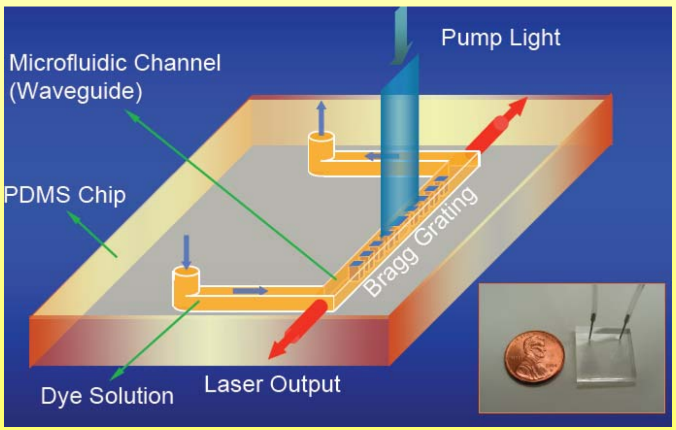


B Helbo et al. , Denmark, 2003

Liquid wave guide laser



D. V. Vezenov et al. , Harvard, 2005



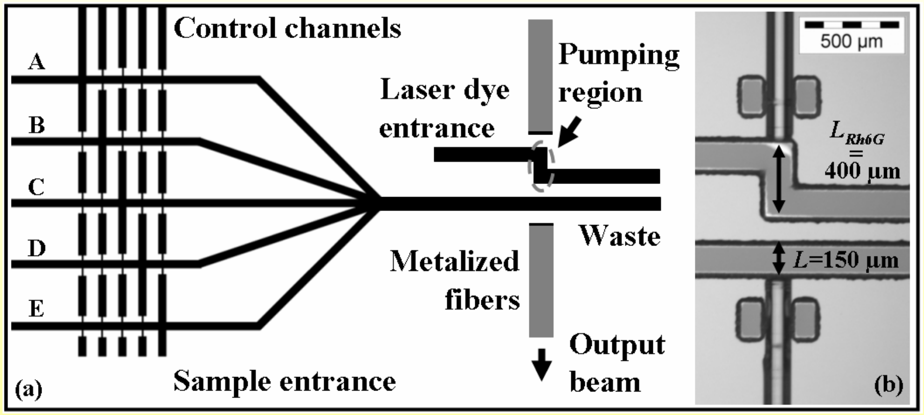
Li et al , Optics Express, Feb 2006

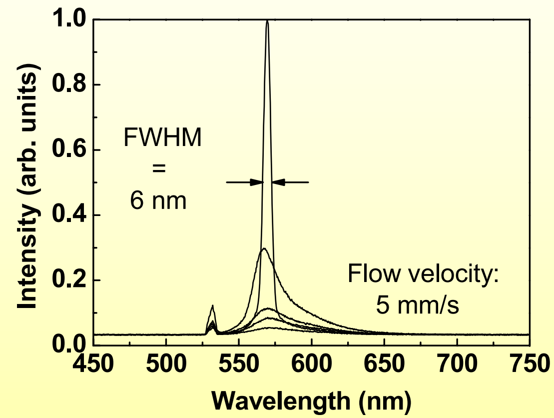
Soft lithography defined 15th order DBR laser

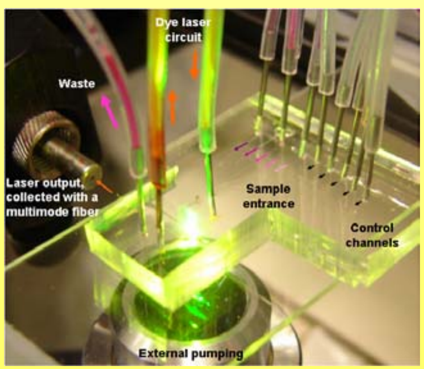
Intra cavity laser absorption

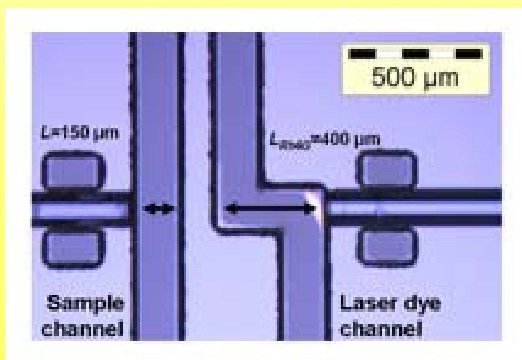
Light extinction: $$I(v) = I_0(v)\left[F\right] e^{-\alpha(v)LC}$$

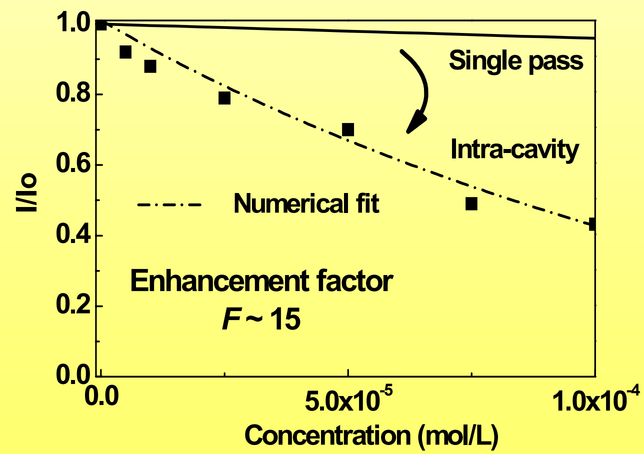
$$F = \frac{g_{0} \times L_{rh6G}}{\left(g_{0} \times L_{rh6G} - T\right) \times \left(\alpha \times L \times C_{1} + T\right)}$$











J.C. Galas et al, to be published

Conclusions

- **Optofluidic functionalities can be easily obtained on chip.**
- **Dye layer emissions can be observed with different device configurations.**
- **Intra cavity absorption largely enhances the detection sensibility of chemical solutions.**
- **Intra cavity absorption can also be used for sensitive cell analyses.**
- **Other functionalities can be obtained on the same chip for a very broad application field.**