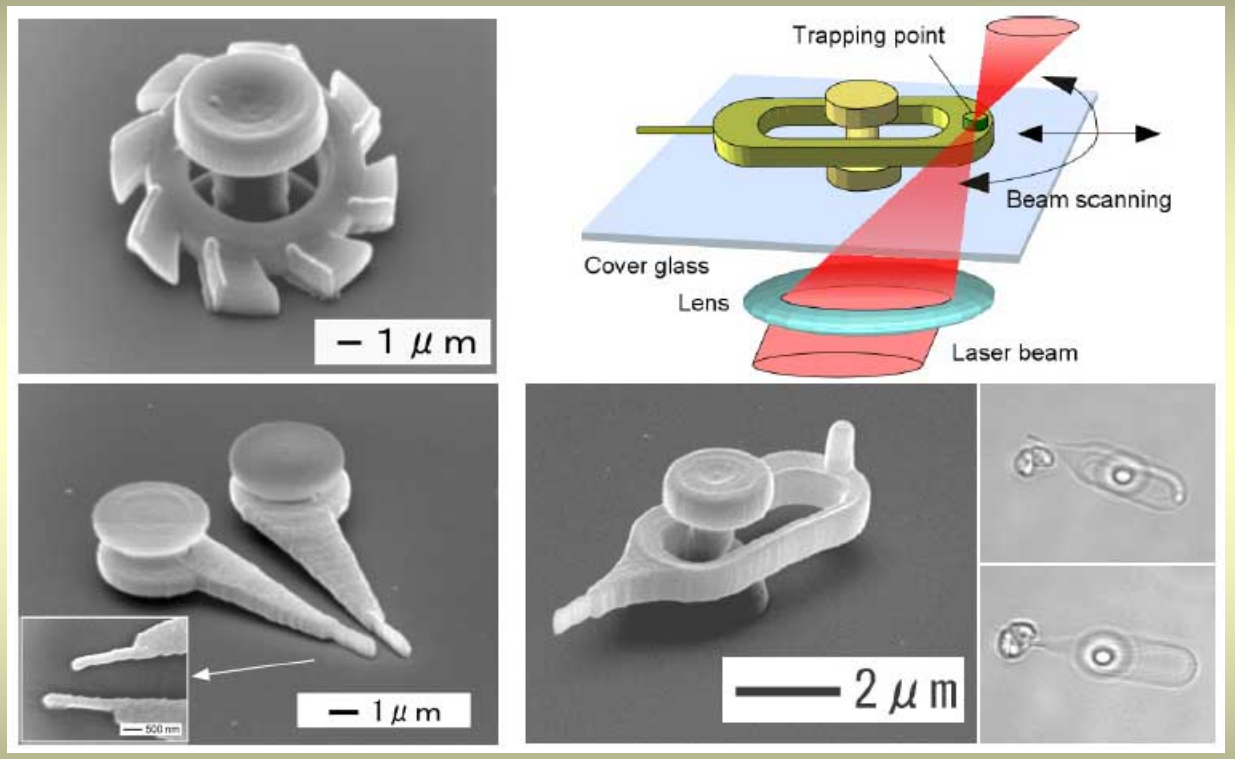
STEREOLITHOGRAPHIE
pour les micro- et nano-technologies



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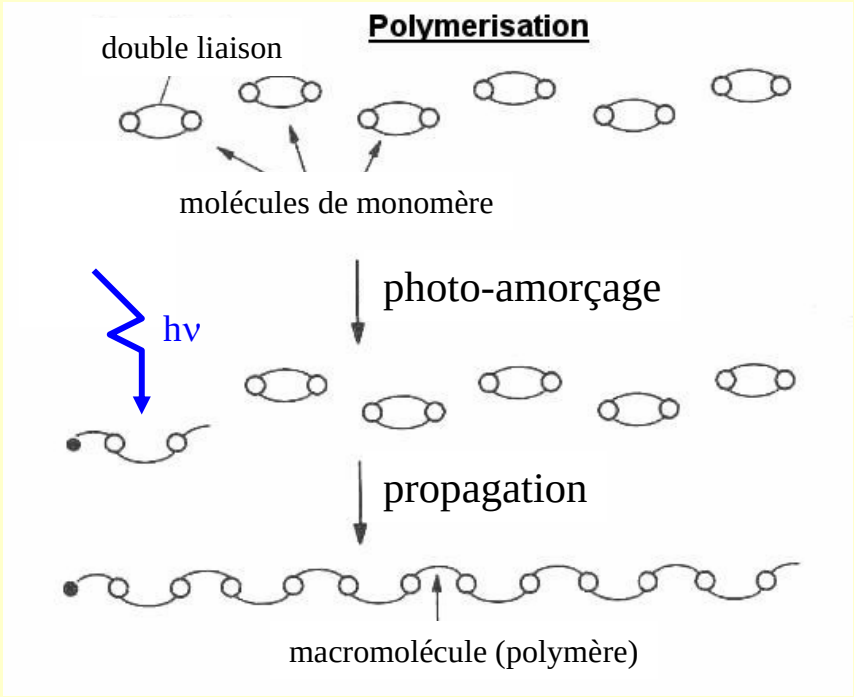
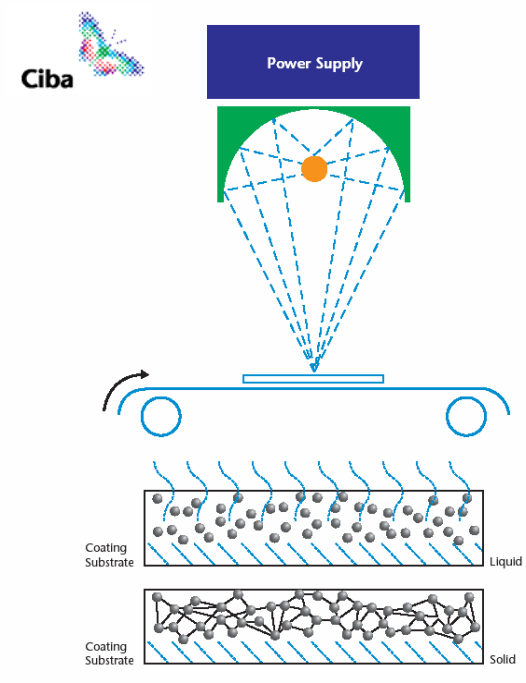
CNRS CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

La réaction de photopolymérisation

liquide + lumière ⟶ solide





A photoinitator can be categorized in different ways

According to its mechanism
· free radical
· cationic

According to its product form
· liquid
· solid

According to its absorption
· UV light
· visible light

According to its application
· clear
· pigmented
· white

According to the depth of cure
· thick layers
· thin layers

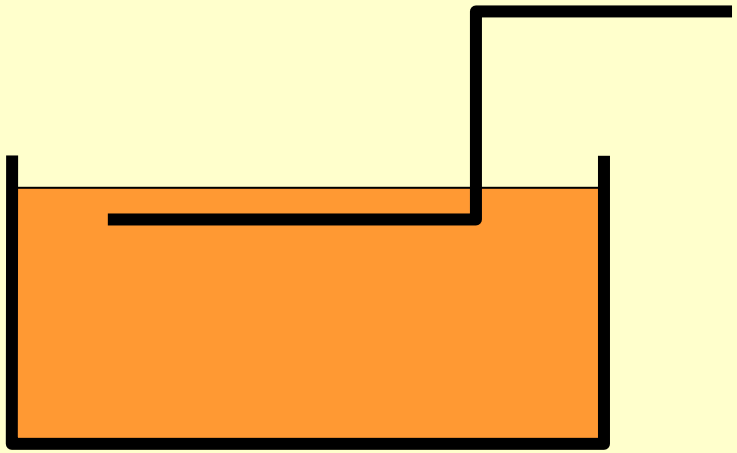
Fabrication d’objets par photopolymérisation

1) Source lumineuse, avec une raie spectrale autour de λ_0

Fabrication d’objets par photopolymérisation

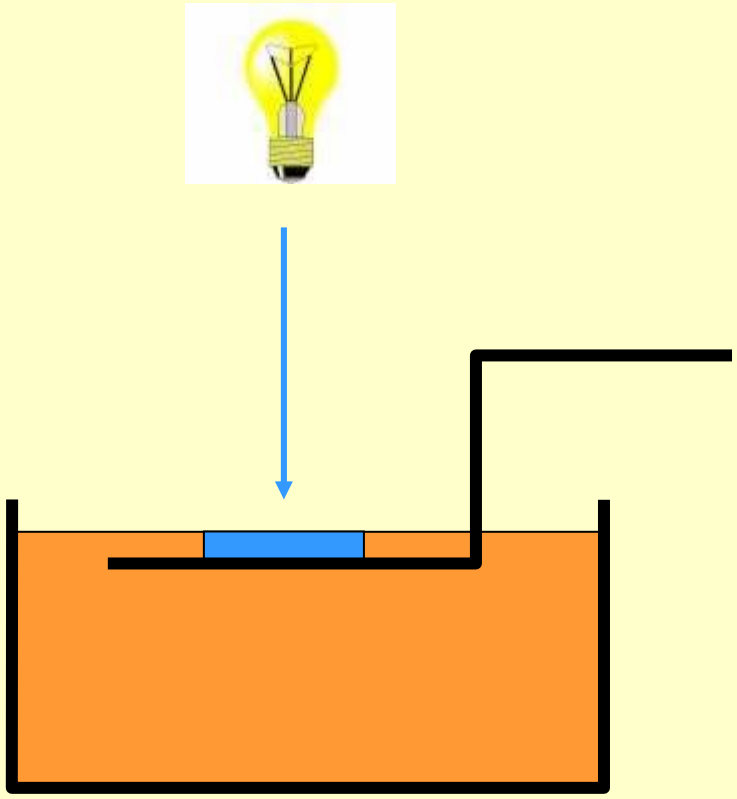
2) Résine photosensible, comprenant un photoinitiateur actif pour λ_0

Fabrication d’objets par photopolymérisation



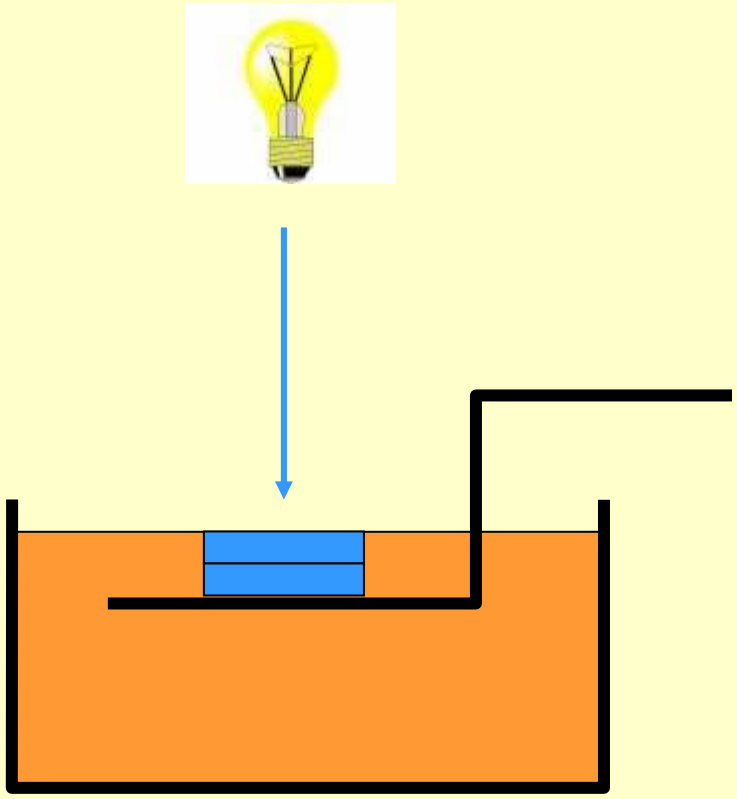
3) Un plateau-support mobile

Fabrication d’objets par photopolymérisation



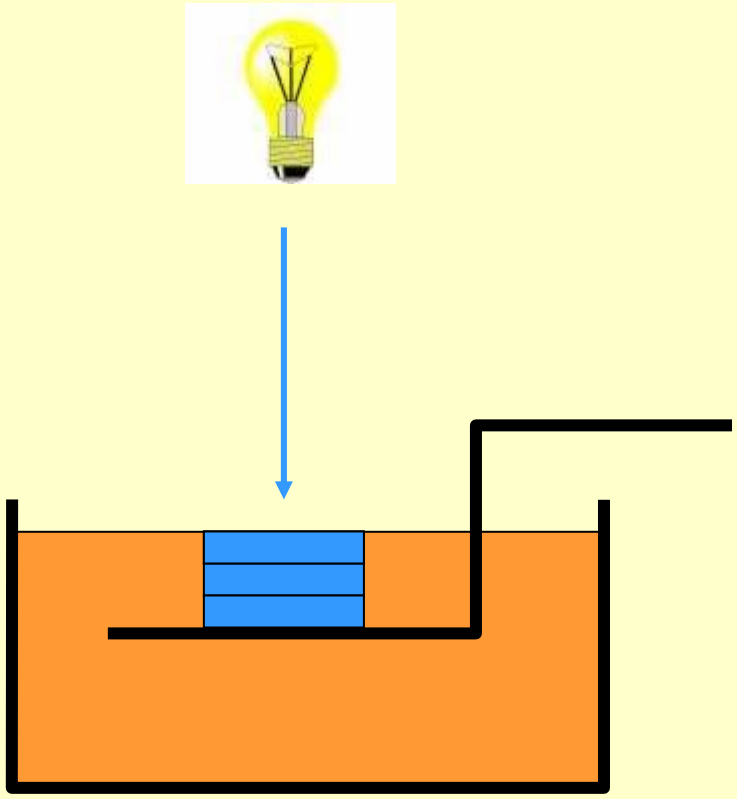
Irradiations successives

Fabrication d’objets par photopolymérisation



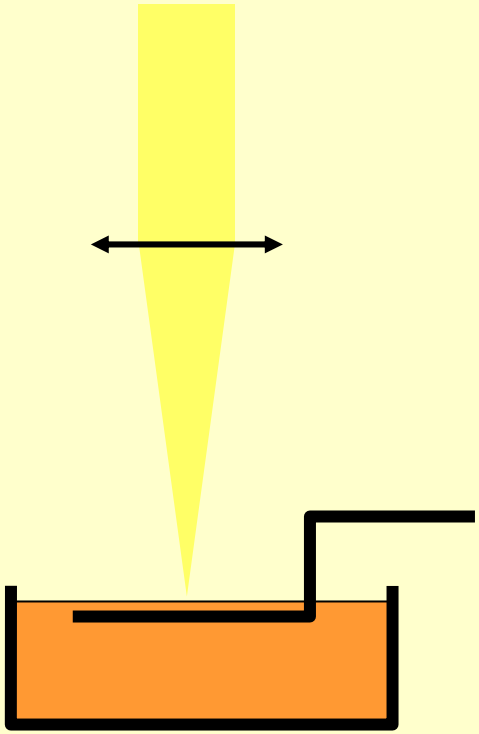
Irradiations successives

Fabrication d’objets par photopolymérisation

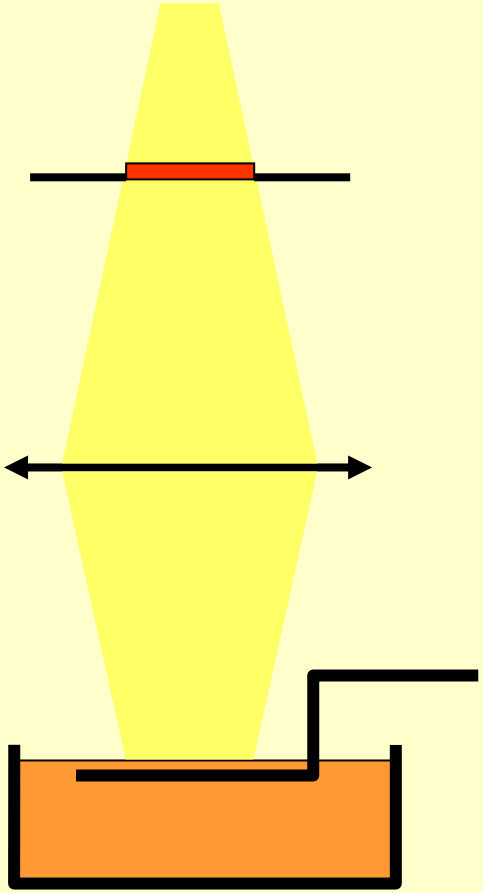


Irradiations successives

Comment résoudre la photopolymérisation dans l'espace ?

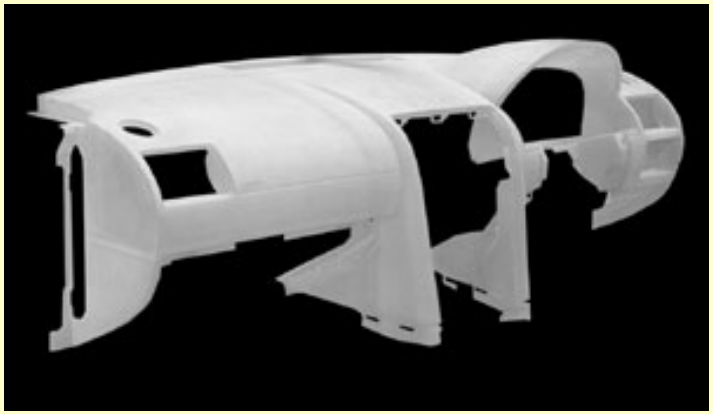


par « écriture vectorielle »



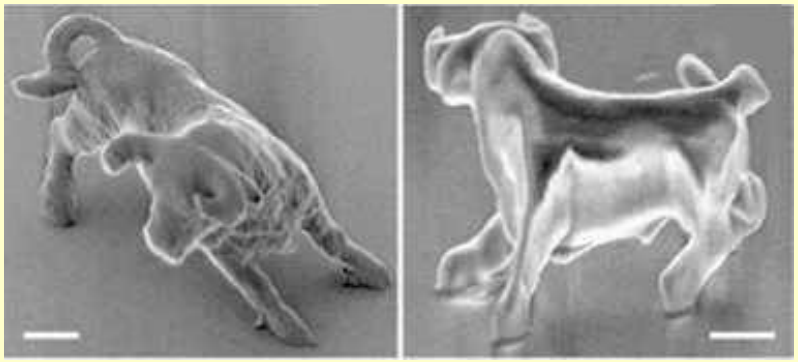
par projection de masques

Les techniques de SL : des procédés de photopolymérisation …



… rapides, par balayage laser, sur de grandes dimensions et avec une résolution typique de 0.1 mm

… rapides, par masquage dynamique, sur quelques mm^2 et avec une résolution typique de 10 µm



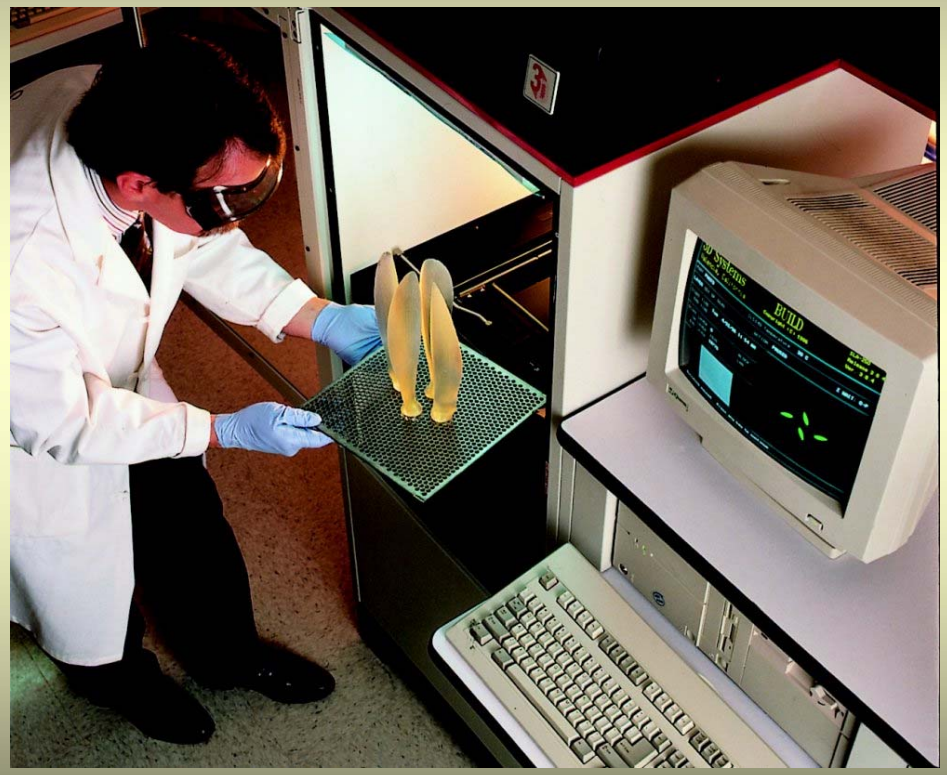
… lents, par balayage laser associé à une photopolymérisation à 2 photons avec une résolution typique de 0.1 µm

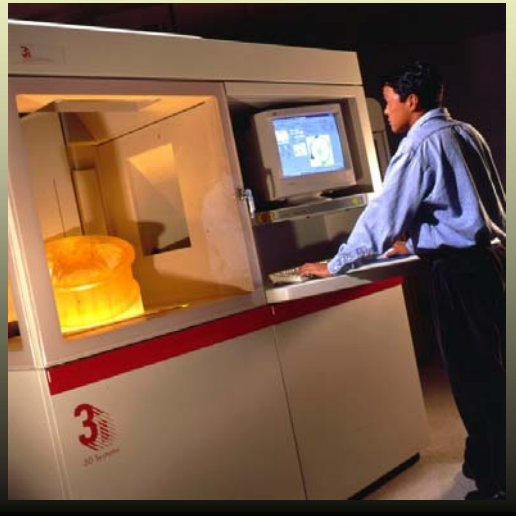
Plan de l'exposé

- **Procédé conventionnel de stéréolithographie**
- **Microstéréolithographie par masques dynamiques**
- **Procédés de réplication**
- **Nanostéréolithographie par absorption multi-photons**

+ **une plate-forme du CNRS pour les laboratoires**

Procédé conventionnel de SL

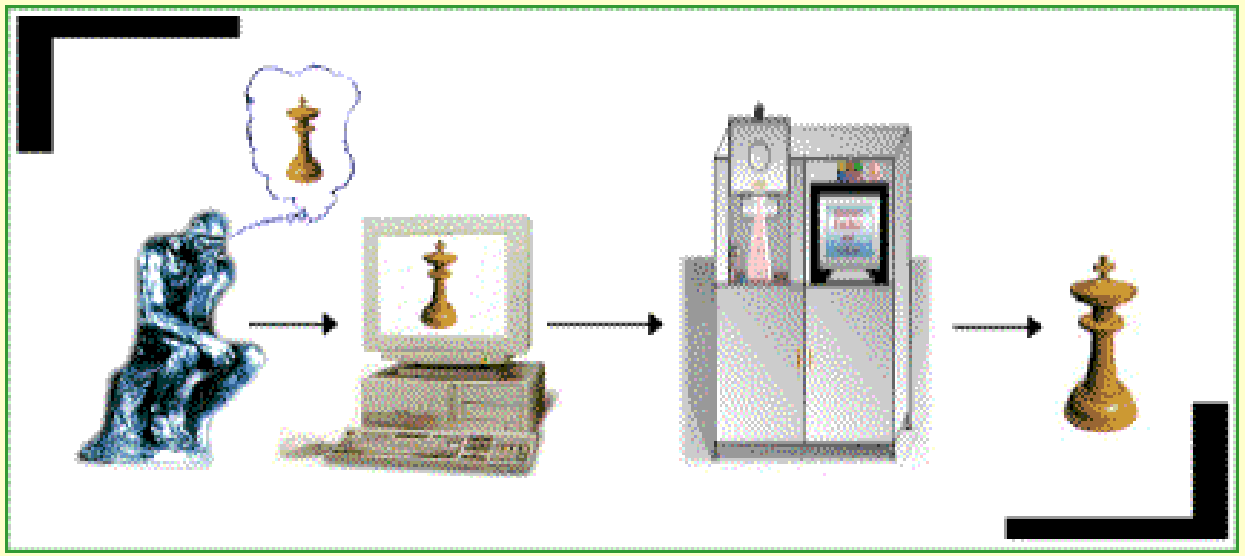


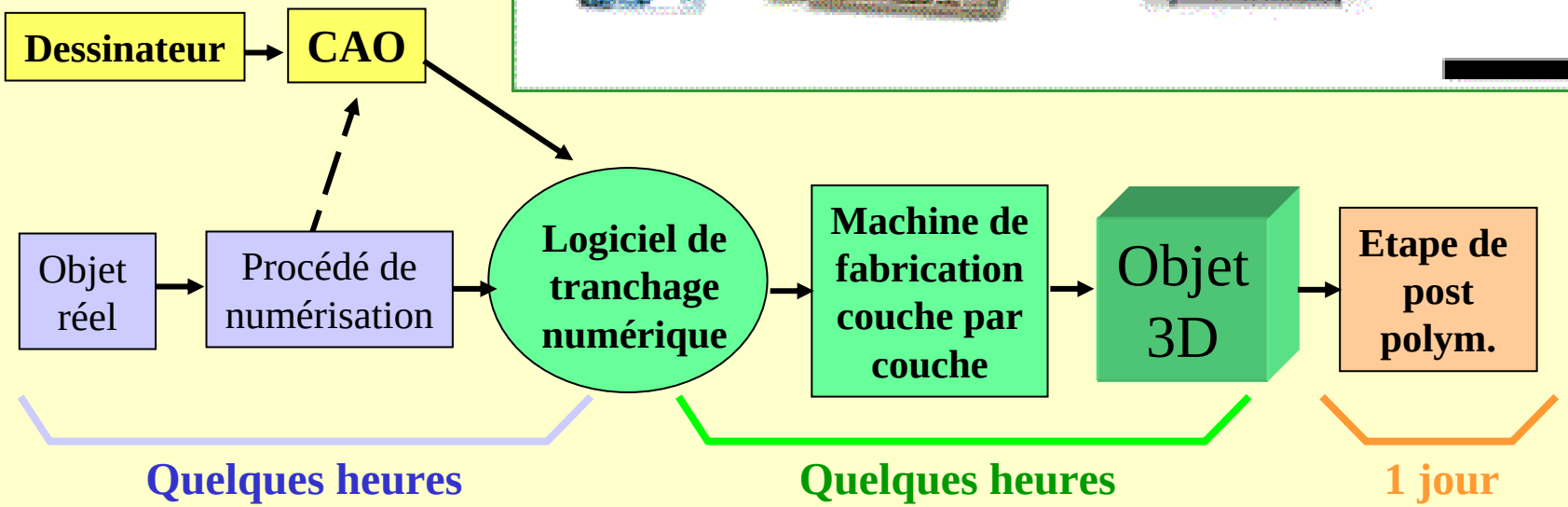


3D-Systems, SLA 7000

Procédé conventionnel de SL

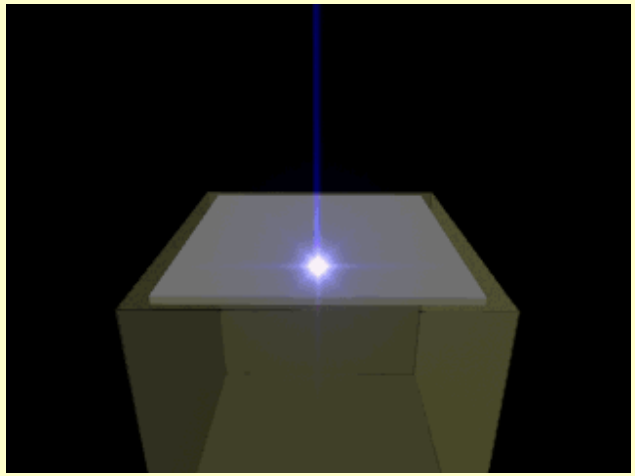
Un procédé de prototypage rapide :

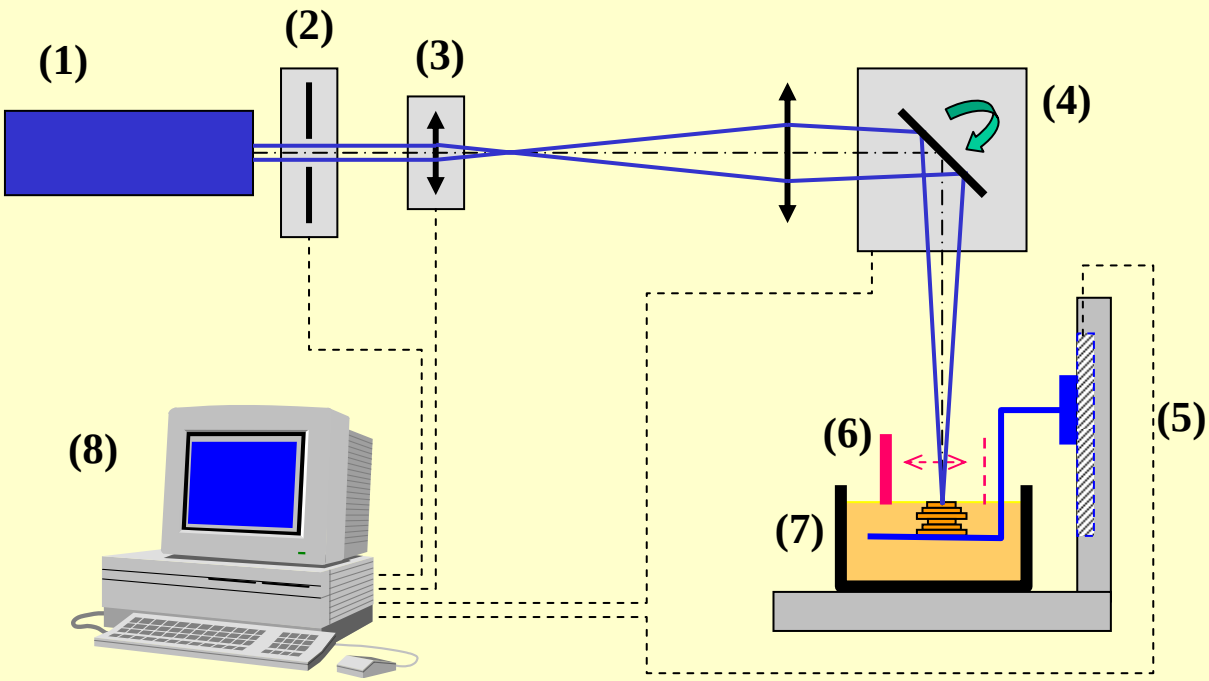




Procédé conventionnel de SL

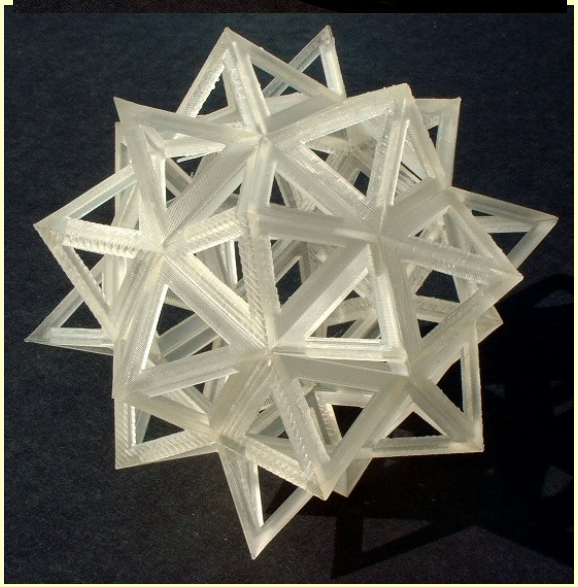
Une fabrication couche par couche par solidification photoinduite (photopolymérisation) résolue dans l'espace, d'une résine liquide.





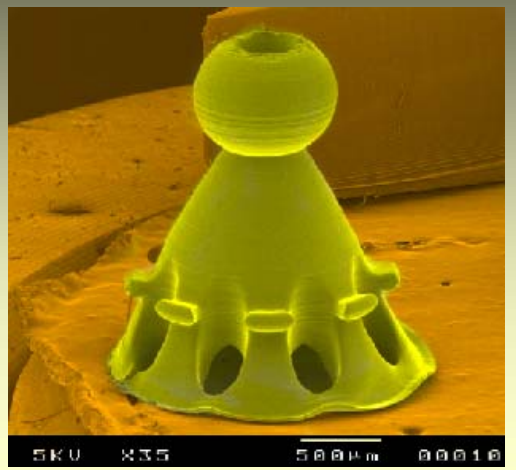
(1) Laser UV
(2) Obturateur
(3) Focalisation dynamique
(4) Miroirs galvanométriques
(5) Positionnement vertical
(6) Racleur
(7) Photoréacteur
(8) Ordinateur de commande

Pièces réalisées par des machines industrielles

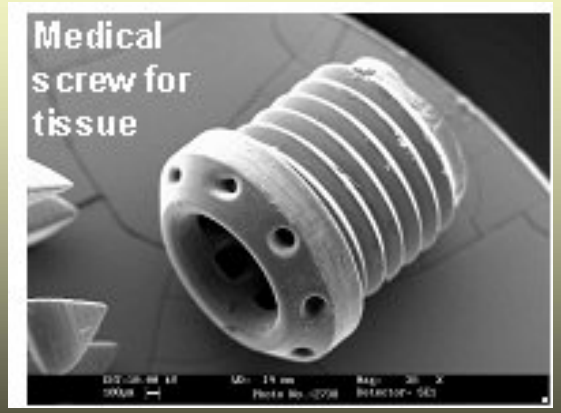


Procédés de micro-SL par masque dynamique

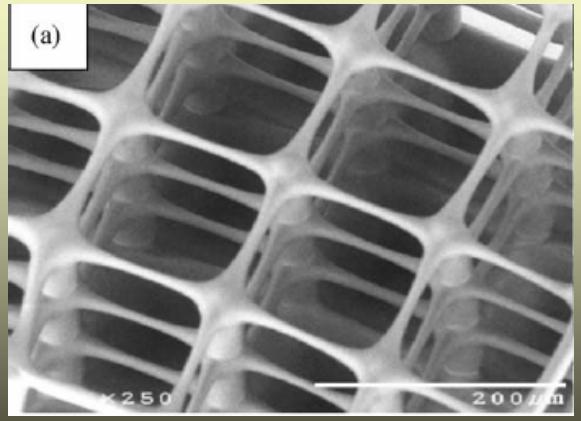
EPFL, Lausanne, CH



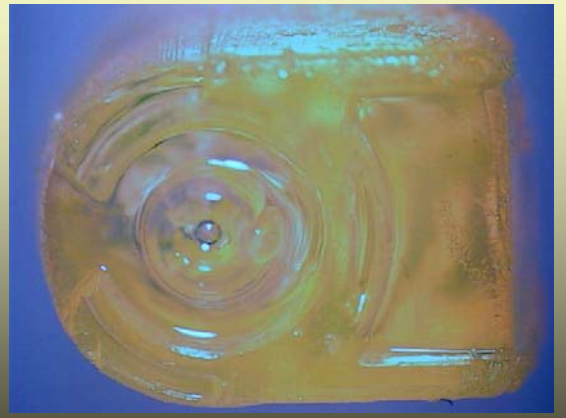
DCPR, Nancy, F



CMF, Birmingham, GB



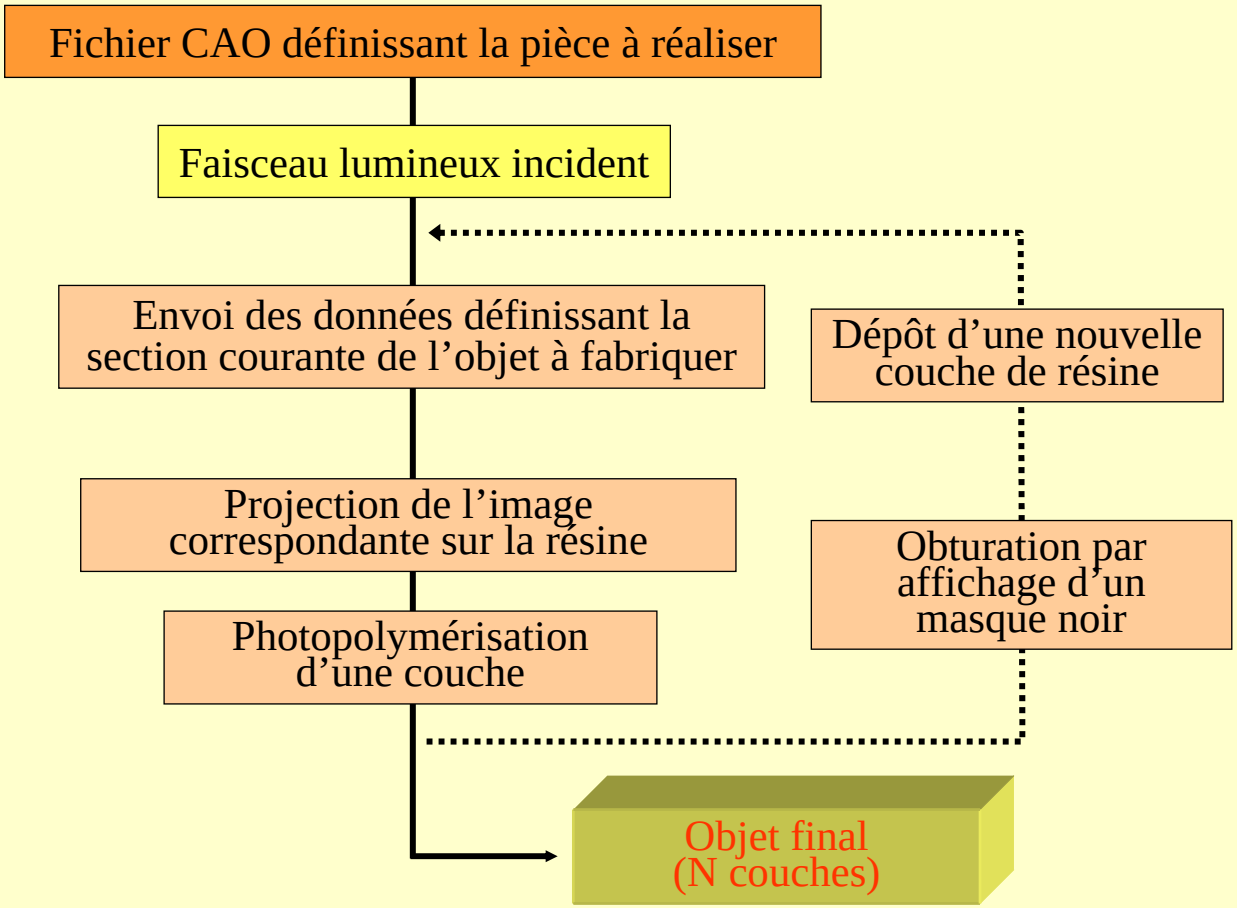
California univ., USA

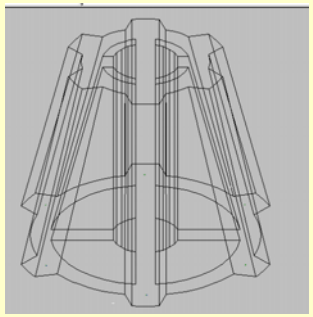


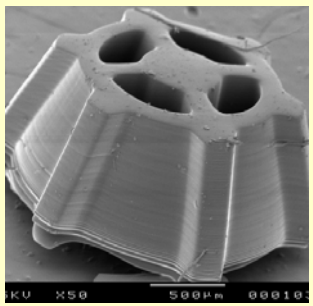
Inst. Fresnel, Marseille, F

Principe

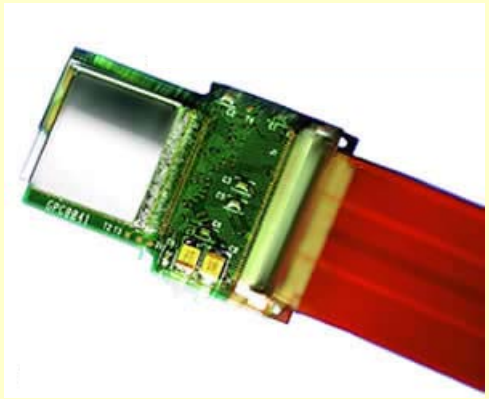
Les étapes principales du procédé de mise en forme :

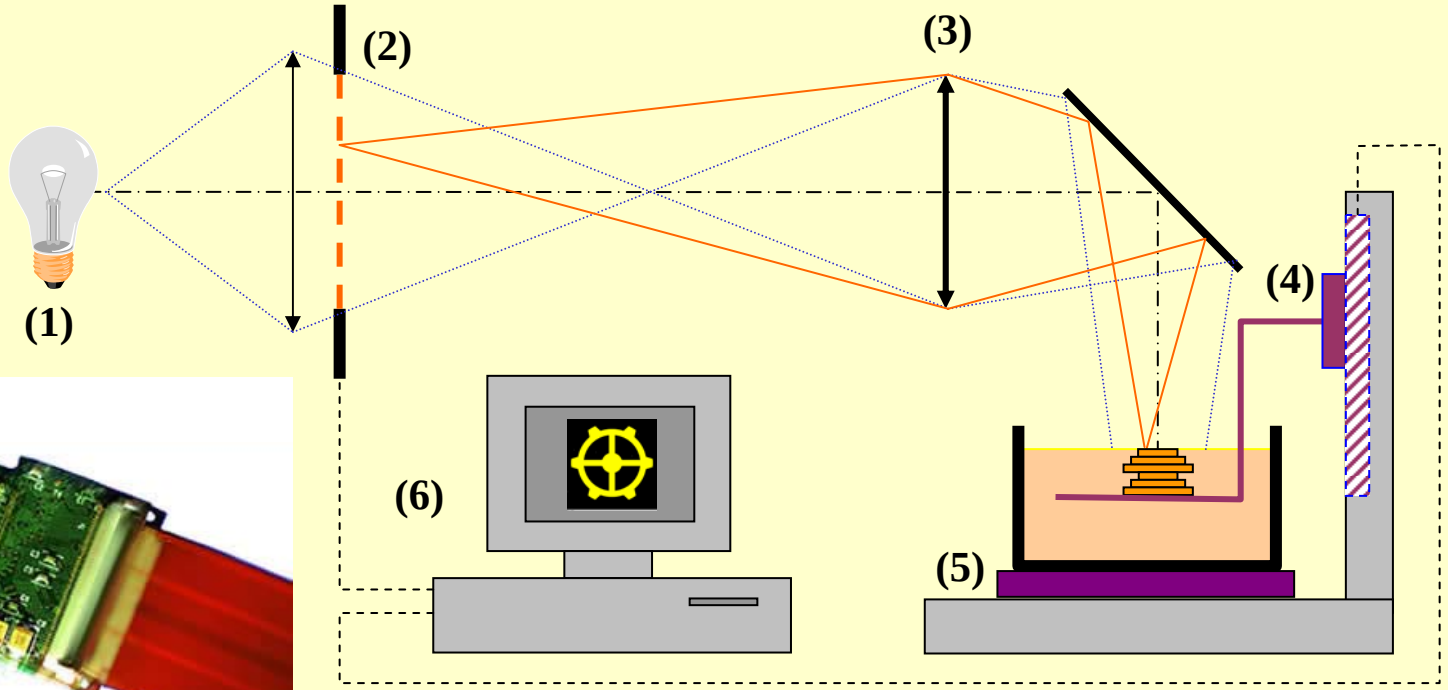






Masque dynamique à cristaux liquides - DCPR





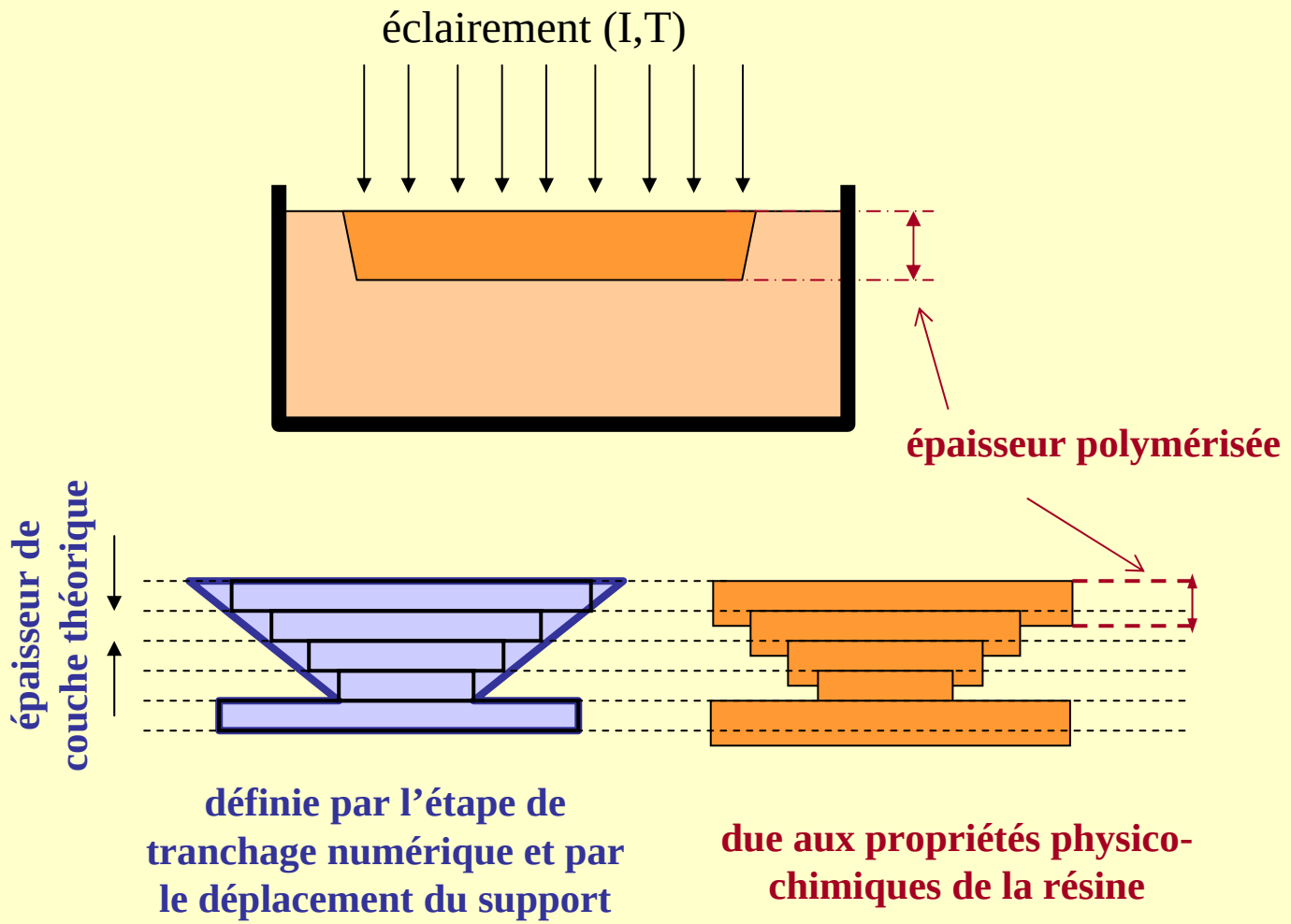
Projection directe d'images

(1) Lampe à arc, haute pression (Hg)
(2) Masque dynamique à cristaux liquides
(3) Système optique imageur
(4) Micropositionnement vertical
(5) Régulation de température
(6) Ordinateur de commande

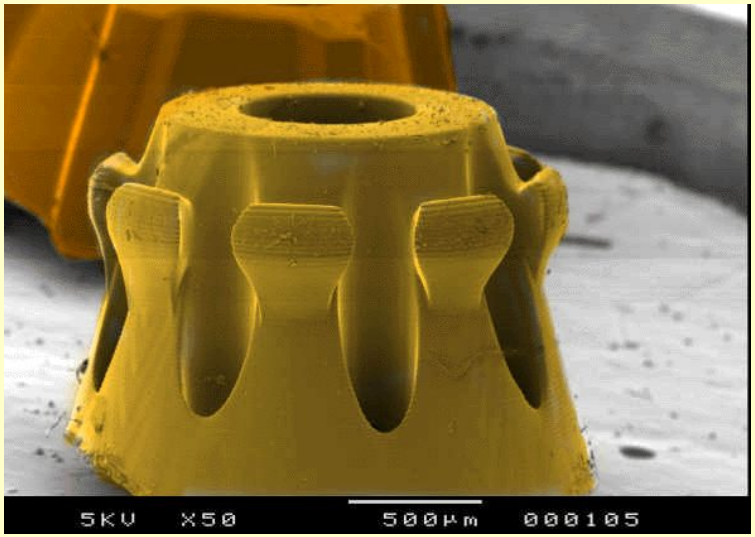
V. Loubère, S. Monneret, S. Corbel, *"Microstéréolithographie utilisant un écran générateur de masques" Revue Internationale de CFAO et d'Informatique Graphique* ***13****, 31-43, (1998) .*

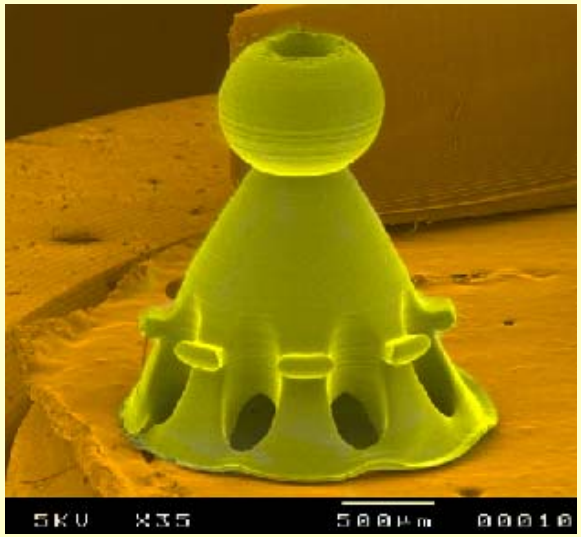
Résolution verticale : un problème crucial en microSL

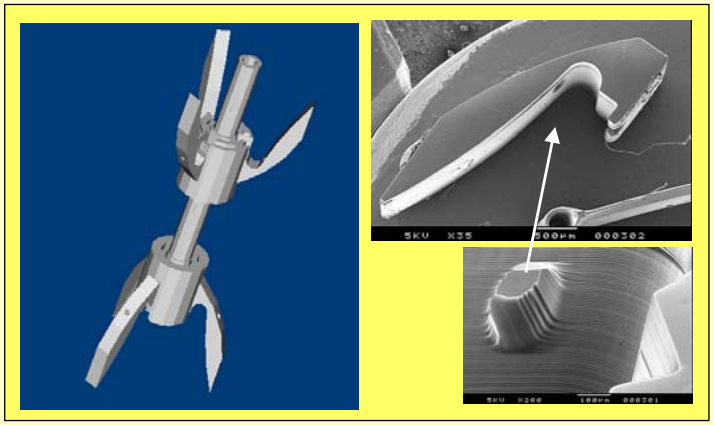
La résolution verticale du procédé dépend fortement du matériau utilisé :

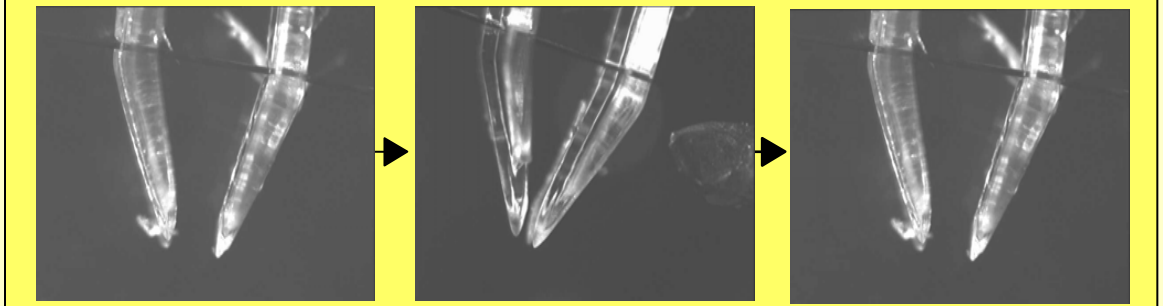


Exemples de réalisations en polymère - DCPR



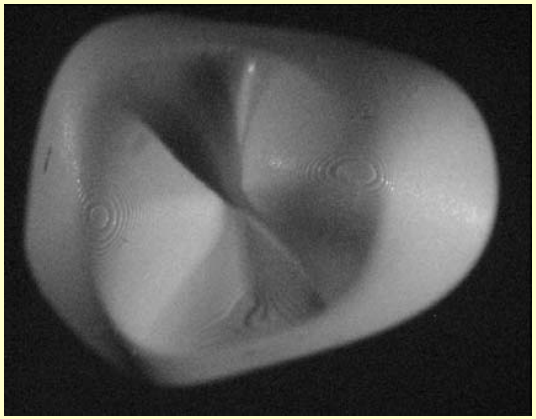
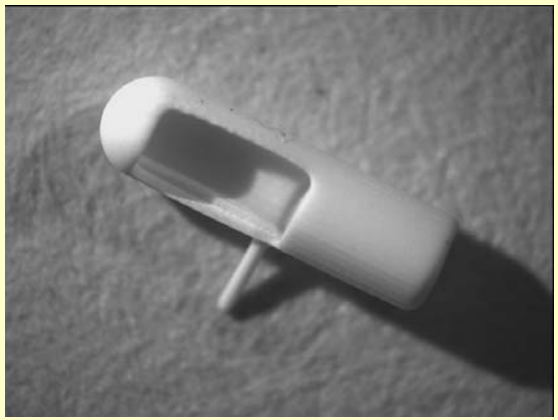
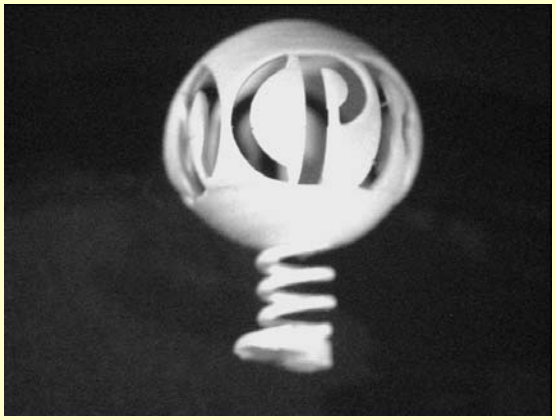
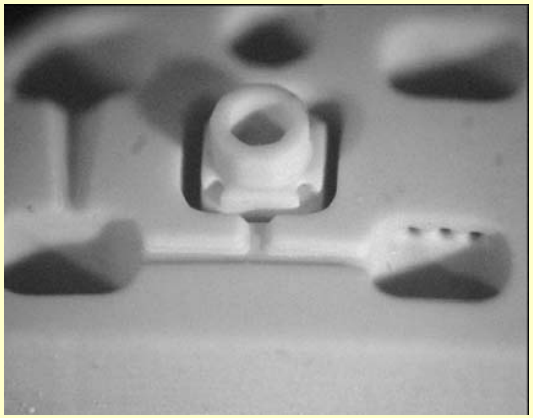
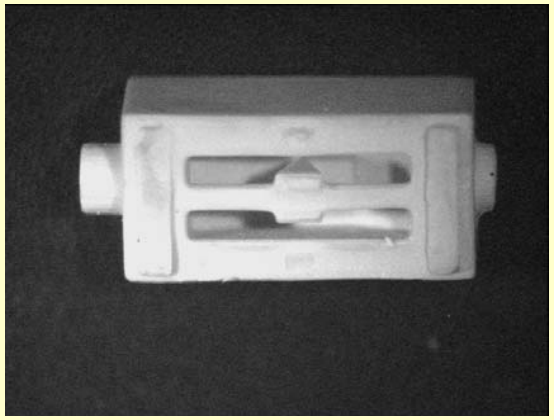






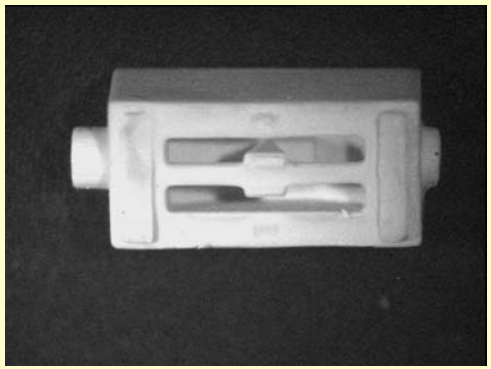
V. Loubère, S. Monneret, H. Le Gall, S. Corbel, *"Microstereolithography using a dynamic mask for microactuators fabrication", Revue Internationale de CFAO et d'Informatique Graphique* ***15***, *229-243, (2000)*

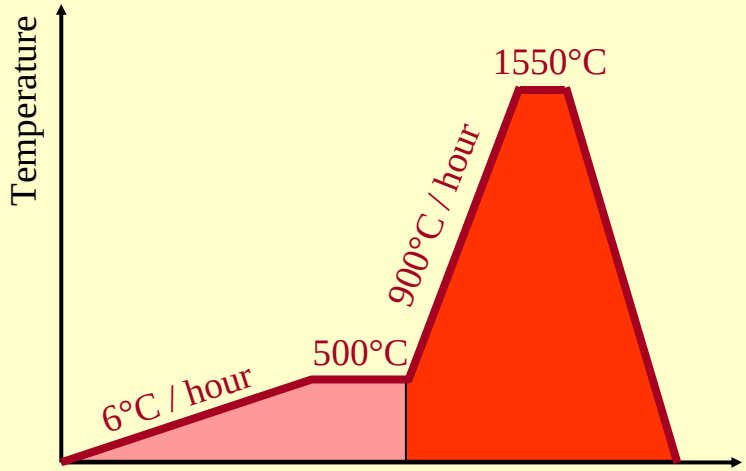
Réalisations en composite alumine / polymère - DCPR

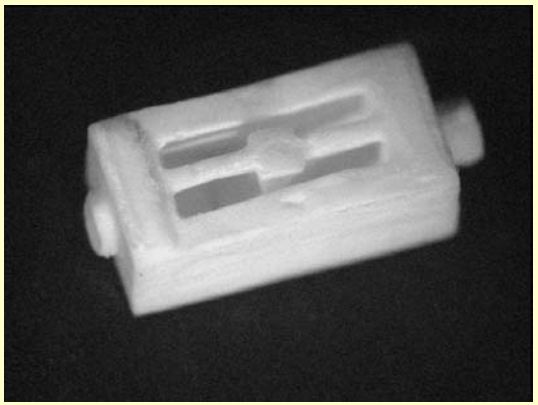







S. Monneret, C. Provin, H. Le Gall, S. Corbel, *"Microfabrication of freeform and articulated alumina-based components" Microsystem Technologies 8, 368-374 (2002).*

Réalisations en alumine pure - DCPR



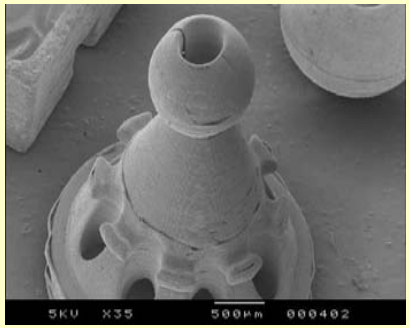


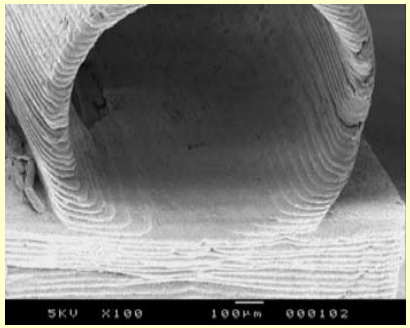


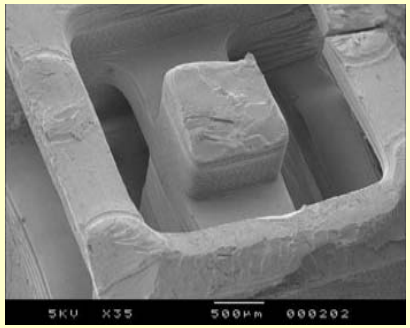
Composite polymère/alumine (65% wt.)

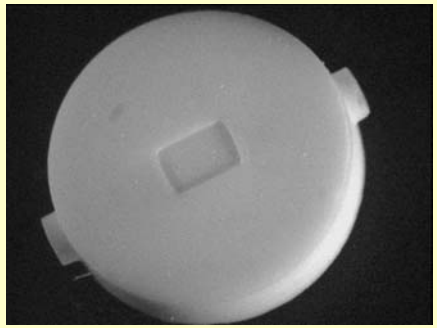
Déliantage + frittage

alumine pure



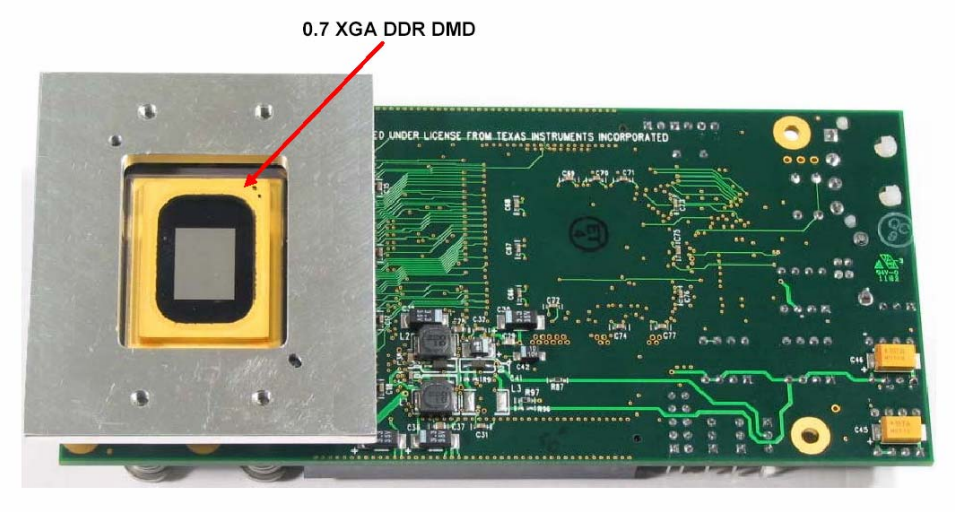


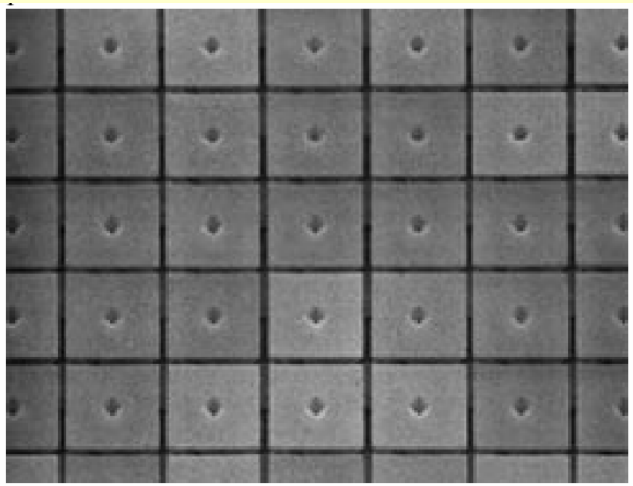


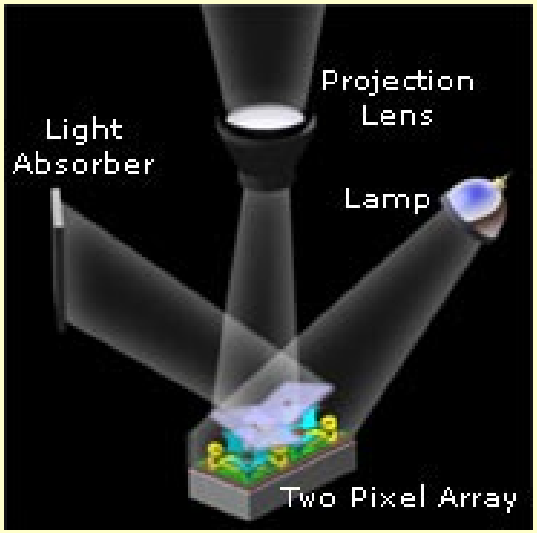


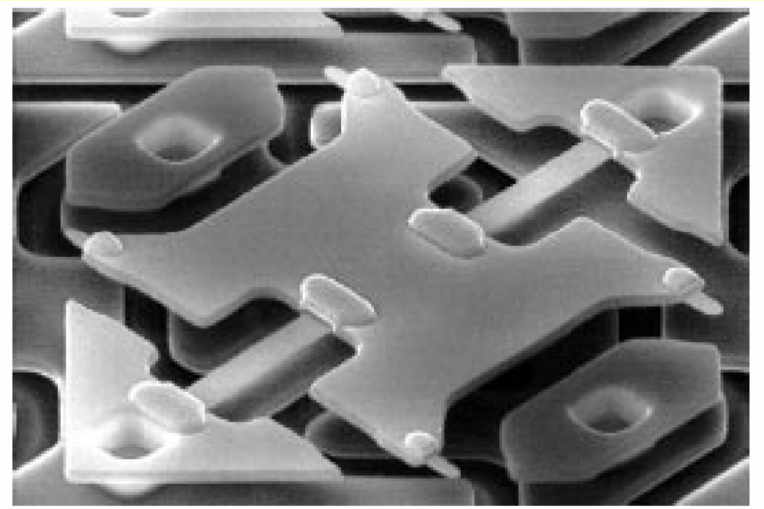
C. Provin, S. Monneret, H. Le Gall, S. Corbel, *Three-dimensional ceramic microcomponents made using microstereolithography", Advanced Materials 15 (12), 994-997 (2003).*

Masque dynamique à micro-miroirs (DMD®)







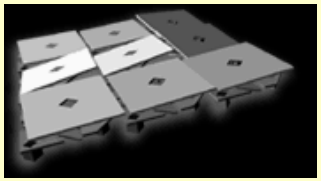


Masque dynamique à micro-miroirs (DMD®)

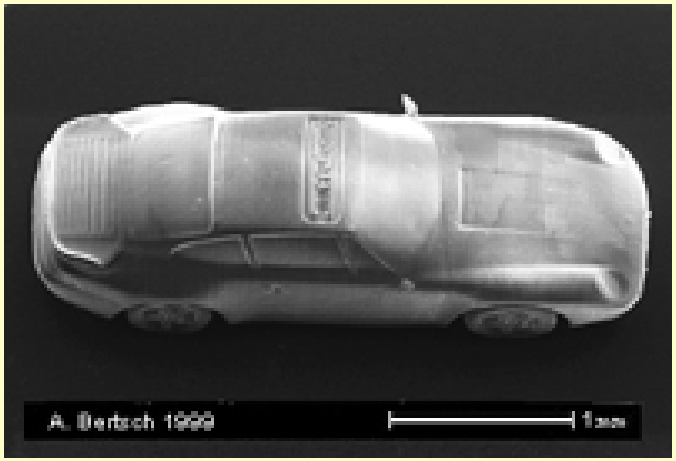
Comparison between DMD and LCD

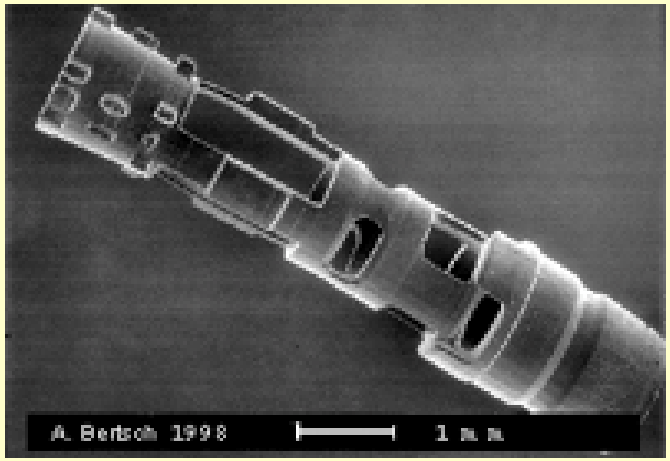
	LCD	DMD
UV compatibility	No	Yes
Modulation efficiency	12.5% (transmission)	88% (reflection)
Pitch size	26 μm × 24 μm	14–17 μm
Pixel size	33 μm × 33 μm	13–16.2 μm
Filling ratio	57%	91%
Contrast	100:1	350:1
Switching speed	20 ms	20 μs

Exemples de réalisations - EPFL

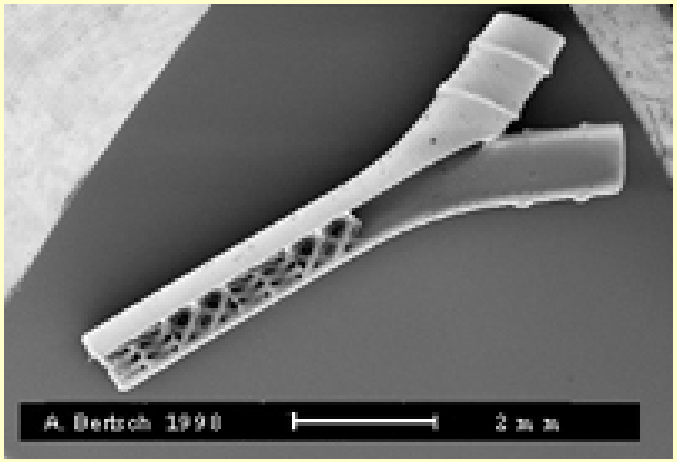


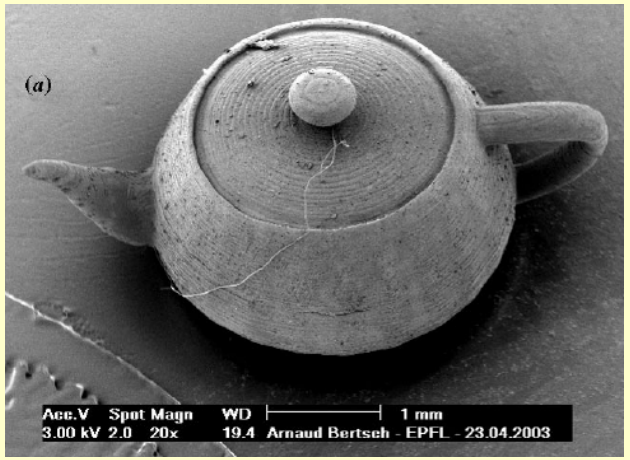
Polymère :
couches jusqu'à 5 µm





Alumine :
couches de 10 µm

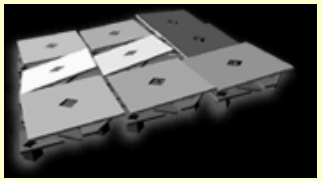




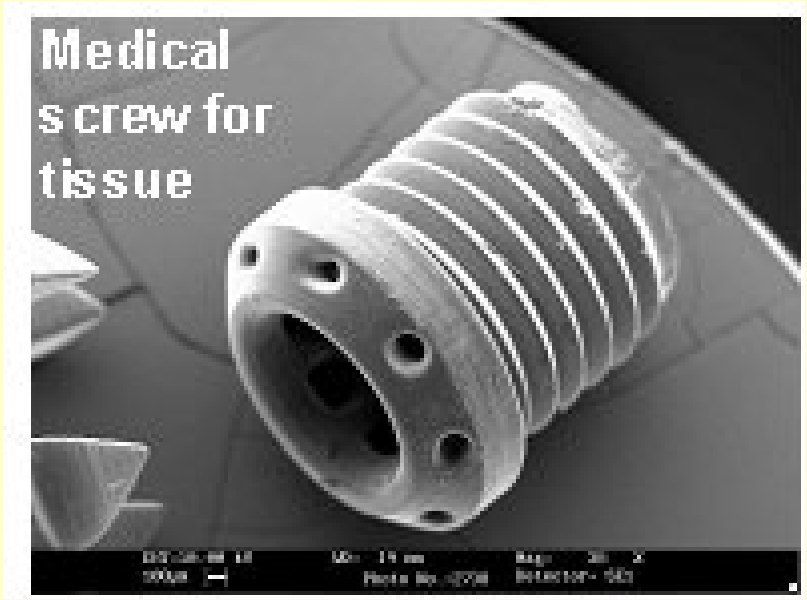
295 couches de 10 µm, 90 min

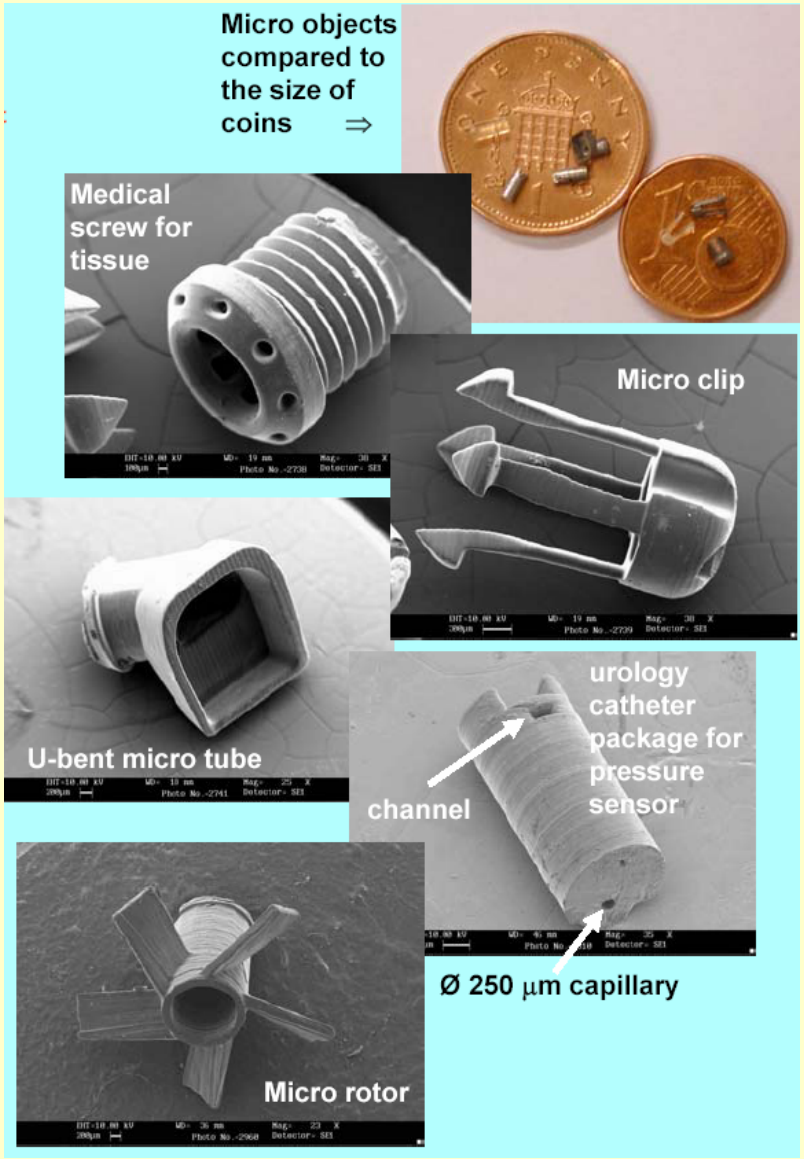
A. Bertsch, S. Jiguet, P. Bernhard, P. Renaud, *"Microstereolithography : a review", Mat. Res. Soc. Symp. Proc. vol. 739 (2003).*

Exemples de réalisations - CMF



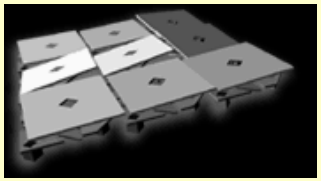
Polymère uniquement



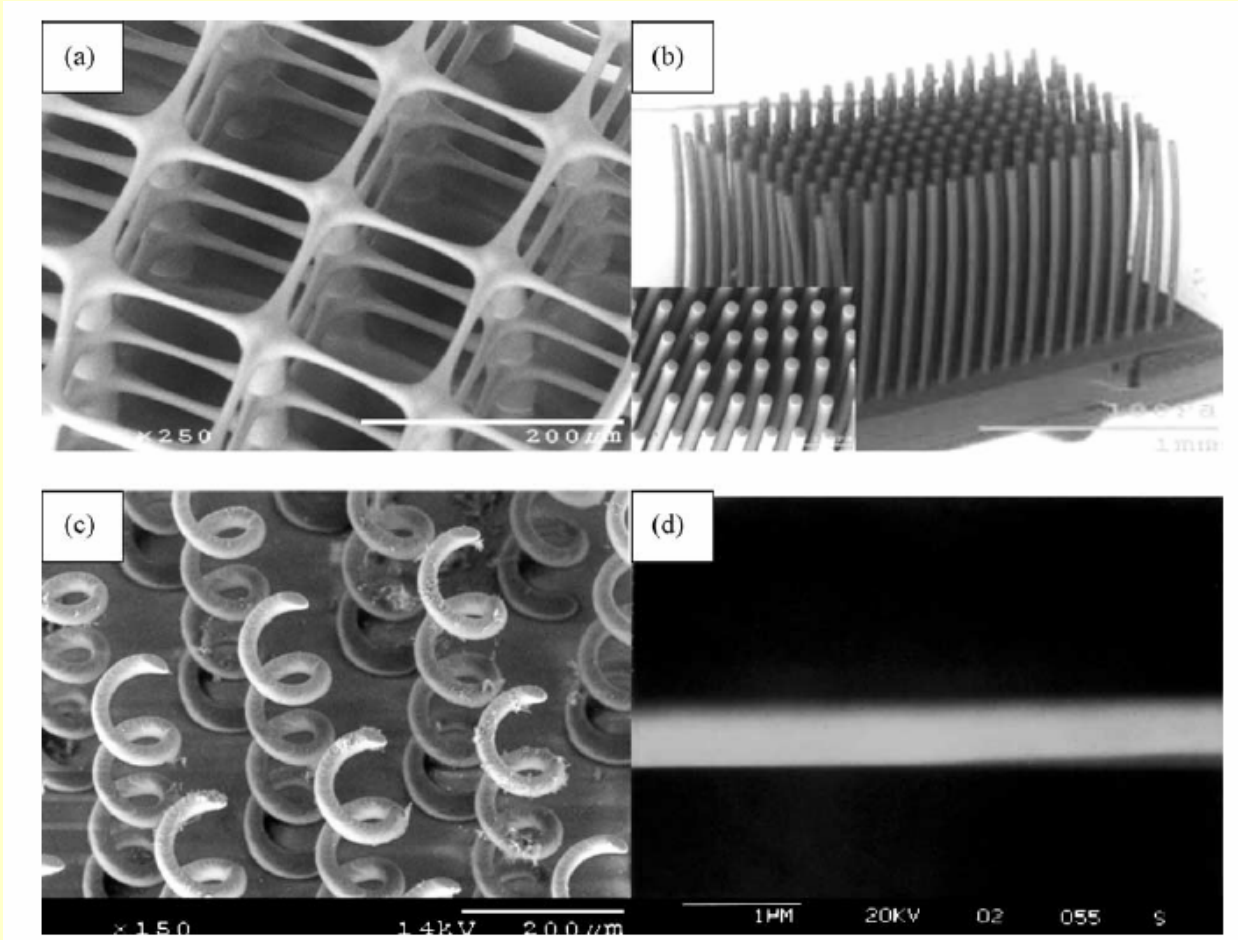


- **Lateral and Vertical resolution: 10µm**
- **Maximum field size: 10.24mm x 7.68mm**
- **Structural height: up to 5mm**

Exemples de réalisations – Univ. Californie

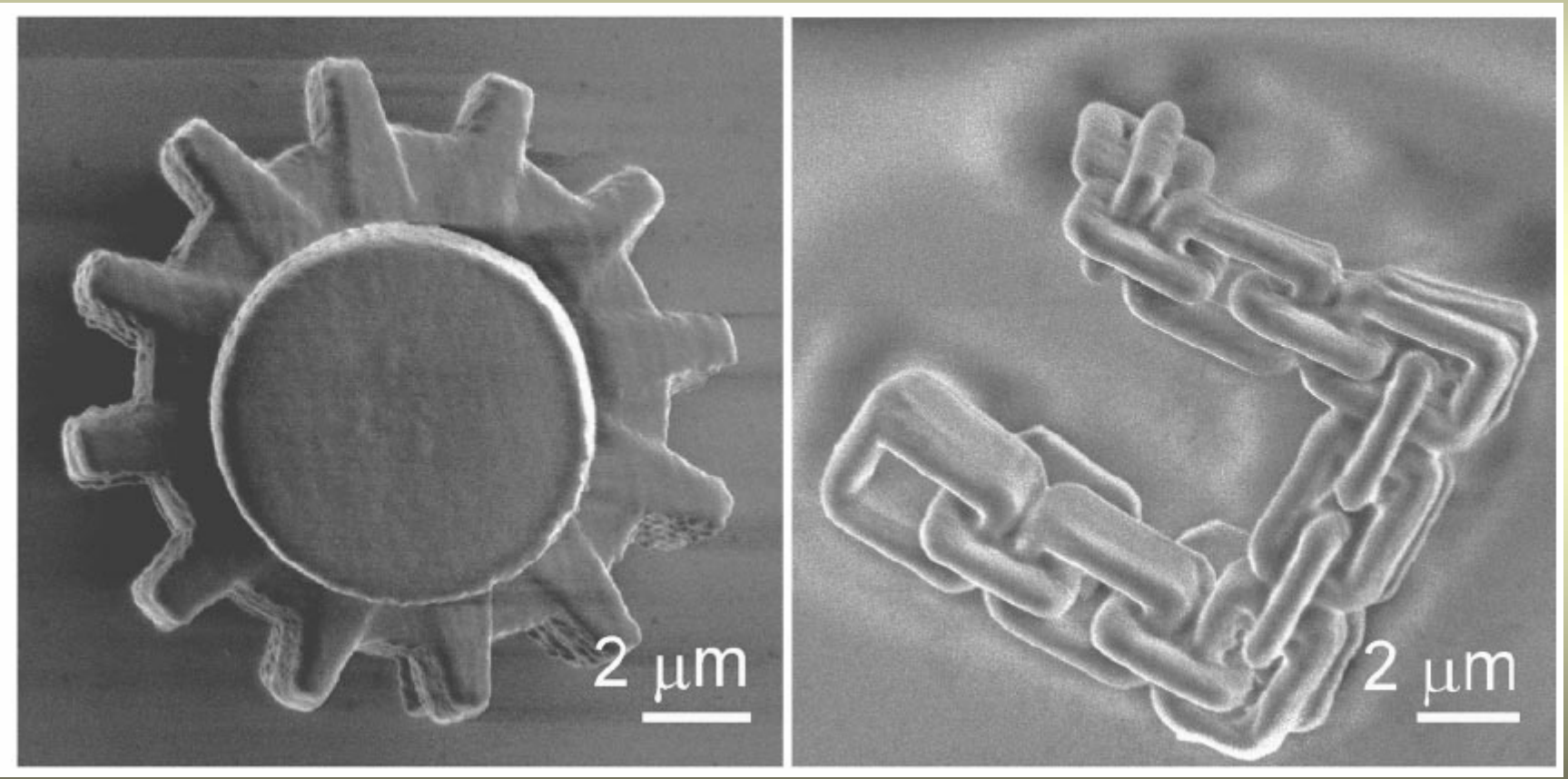


Polymère uniquement



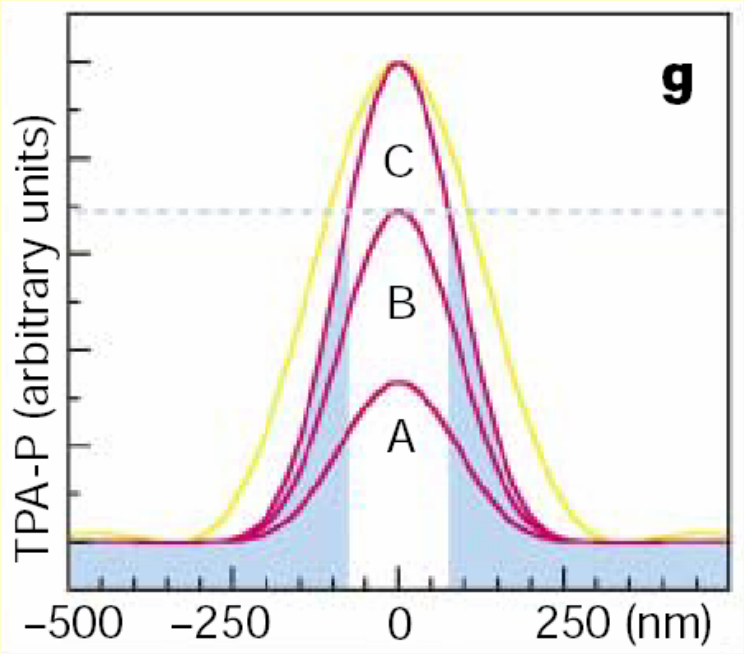
C. Shu et al. / Sensors and Actuators A 151 (2009) 113–150

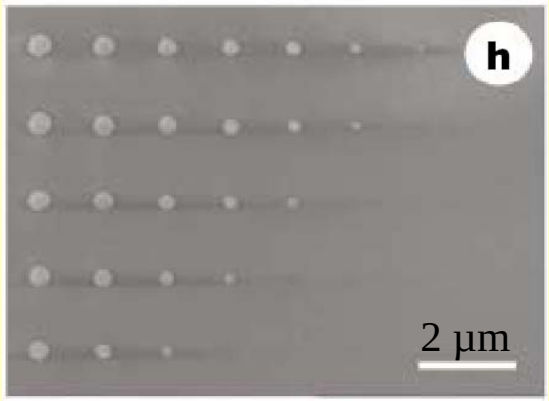
« nano-SL » par absorption à 2 photons

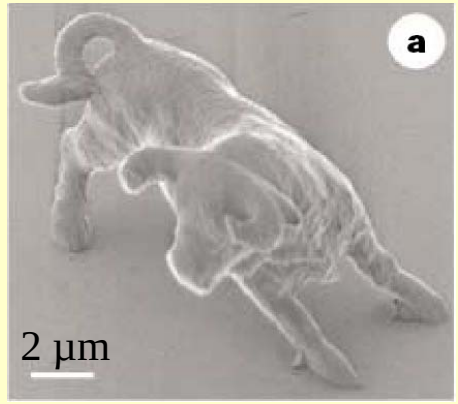


Tanaka, Sun, and Kawata Appl. Phys. Lett., Vol. 80, No. 2, 14 January 2002

Principe – montage de l'université d'Osaka (Japon)



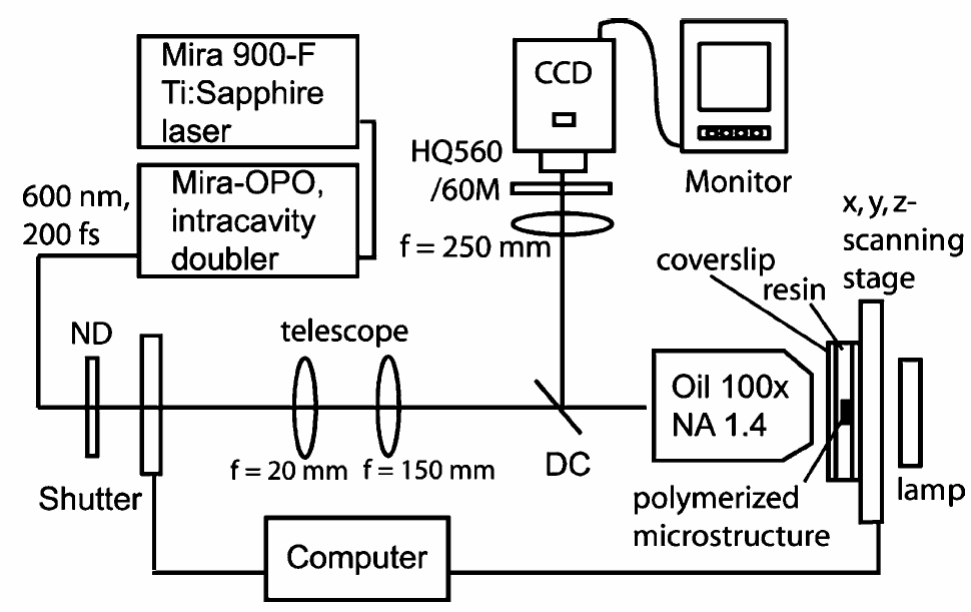


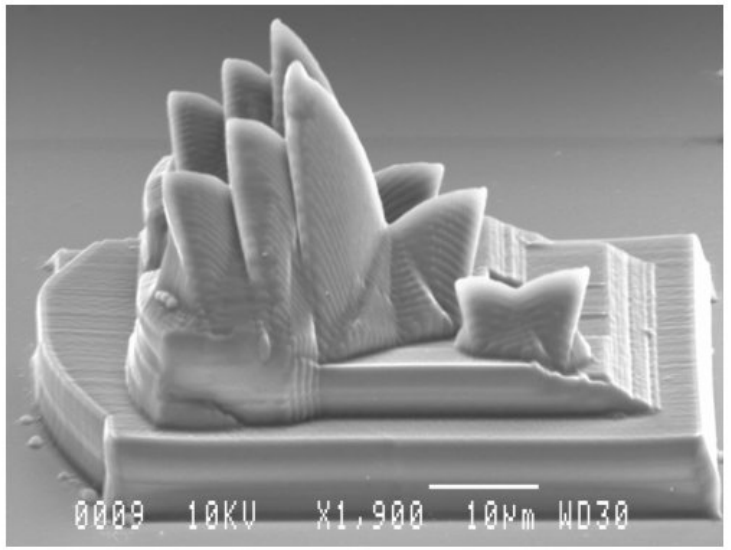


The fabrication system was similar to that previously used. The exposure source employed was a 780 nm (λ) mode-locked Ti:Sapphire laser, capable of producing laser pulses of ~150 fs at a repetition rate of 76 MHz, which was focused into the sample of SCR 500 resin by a high NA (~1.4, oil immersion) objective lens. The laser spot was scanned on the focal plane by a two-galvano-mirror set, and along the optical axis by a piezo stage, both controlled by a computer.

Satoshi Kawata, Hong-Bo Sun, Tomokazu Tanaka, Kenji Takada
Department of Applied Physics, Osaka University, Suita, Osaka 565-0871, Japan

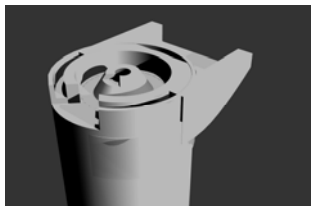
Montage de l'université de Swinburne (Australie)



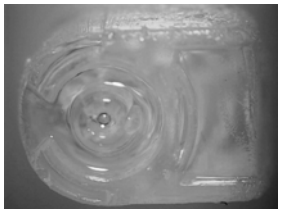


M. Straub et al. / Optical Materials 27 (2004) 359–364

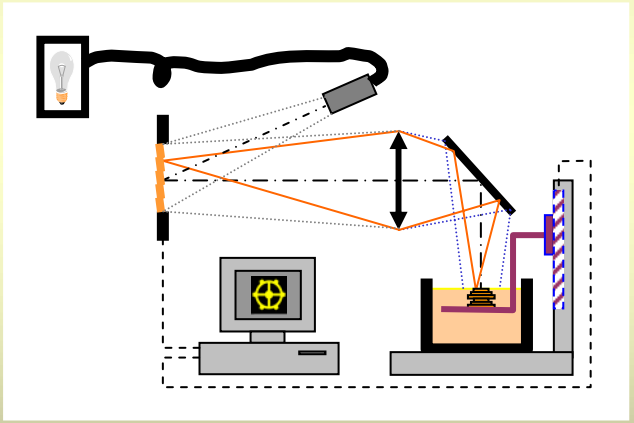
Vers une plate-forme de microstéréolithographie pour les unités du CNRS



CAO



Réalisation



Institut FRESNEL MARSEILLE

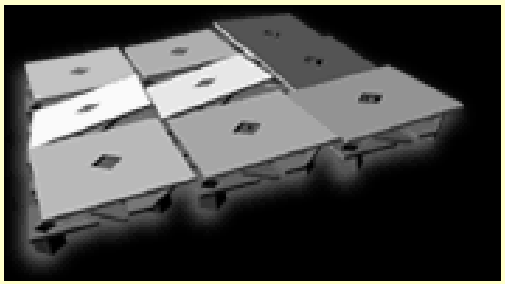
sciences et technologies de l'optique l'électromagnétisme et l'image

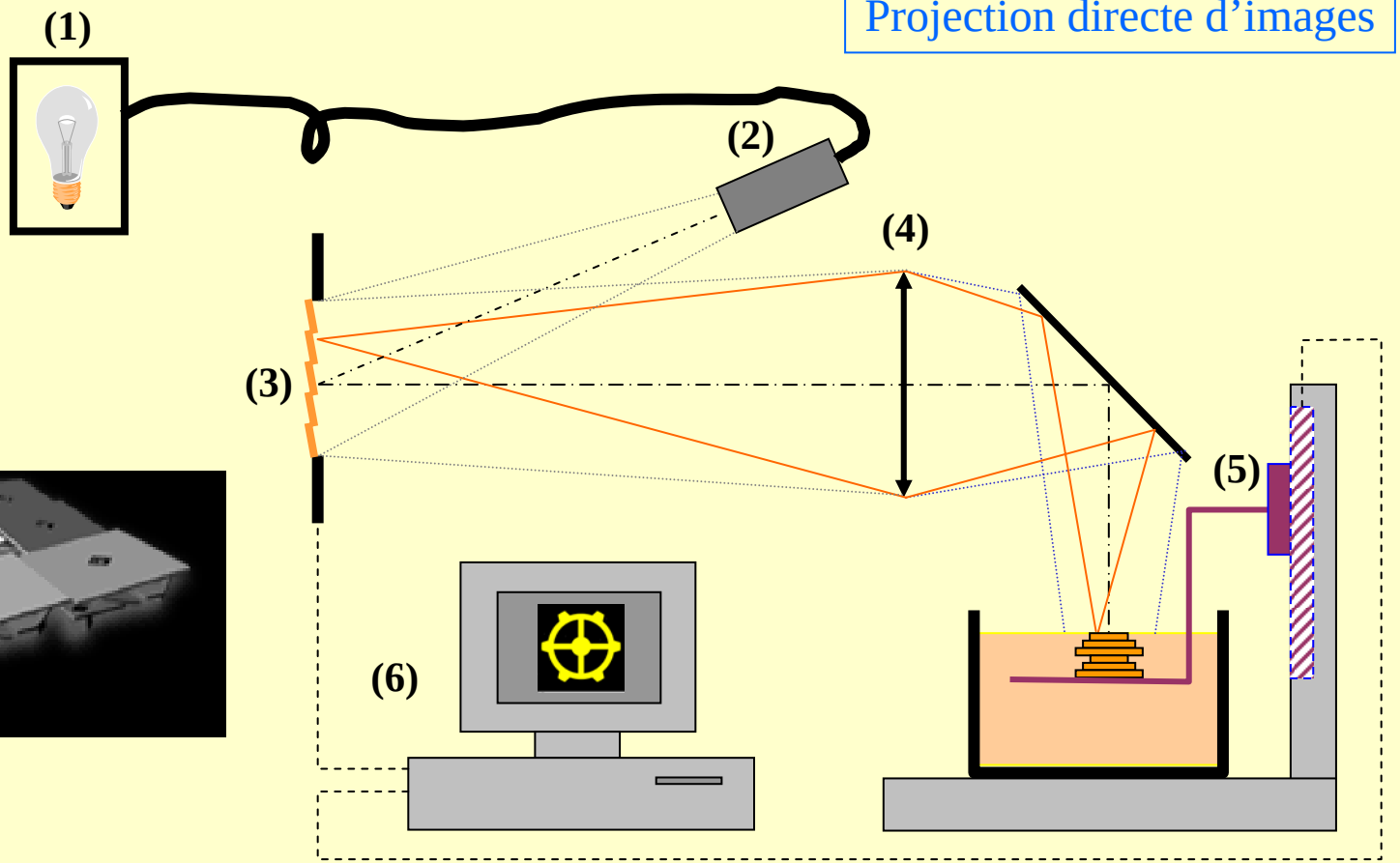
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

MISSION RESSOURCES COMPETENCES TECHNOLOGIQUES

Montage à base de DMD® - Inst. Fresnel

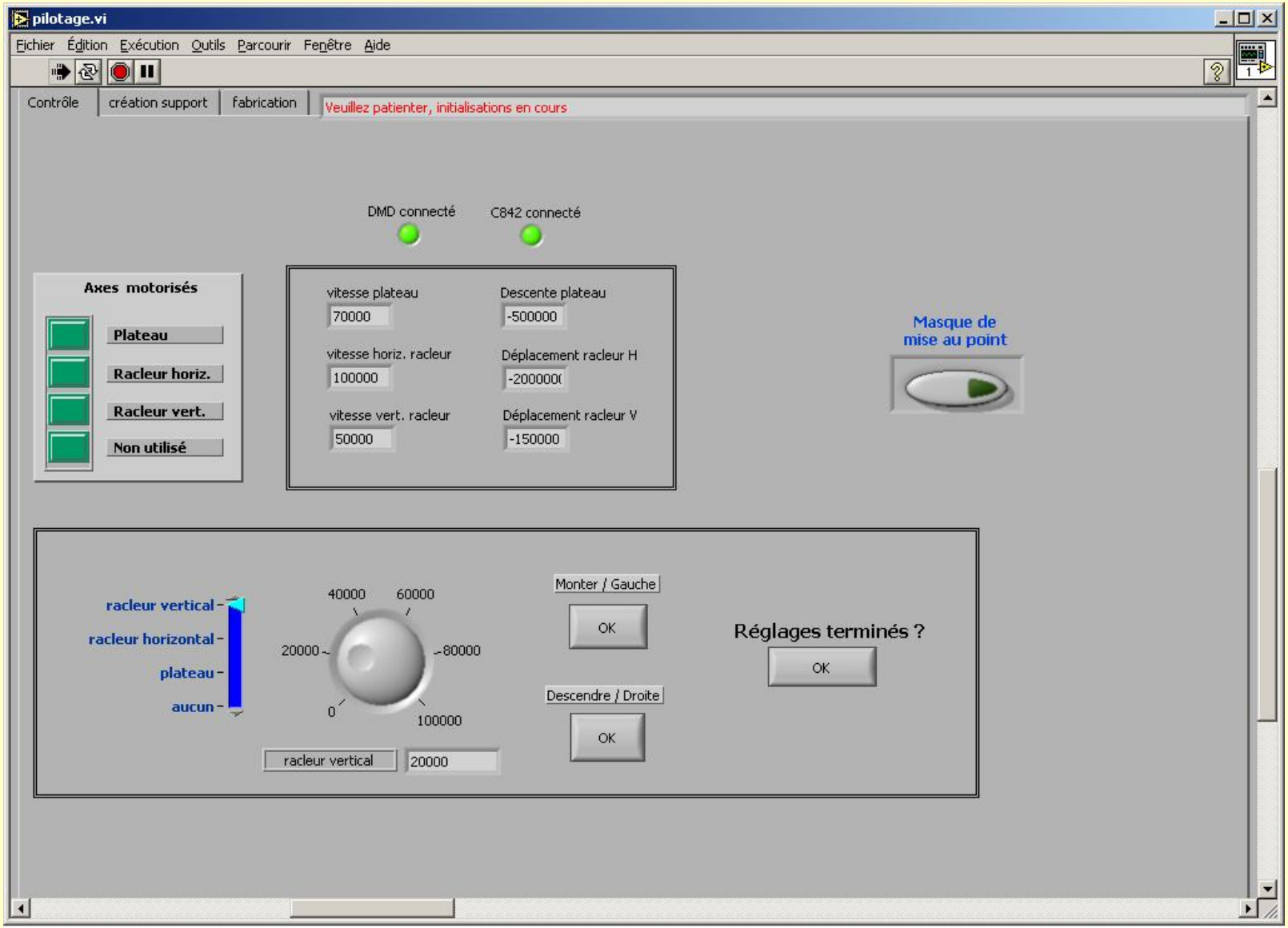
Projection directe d'images



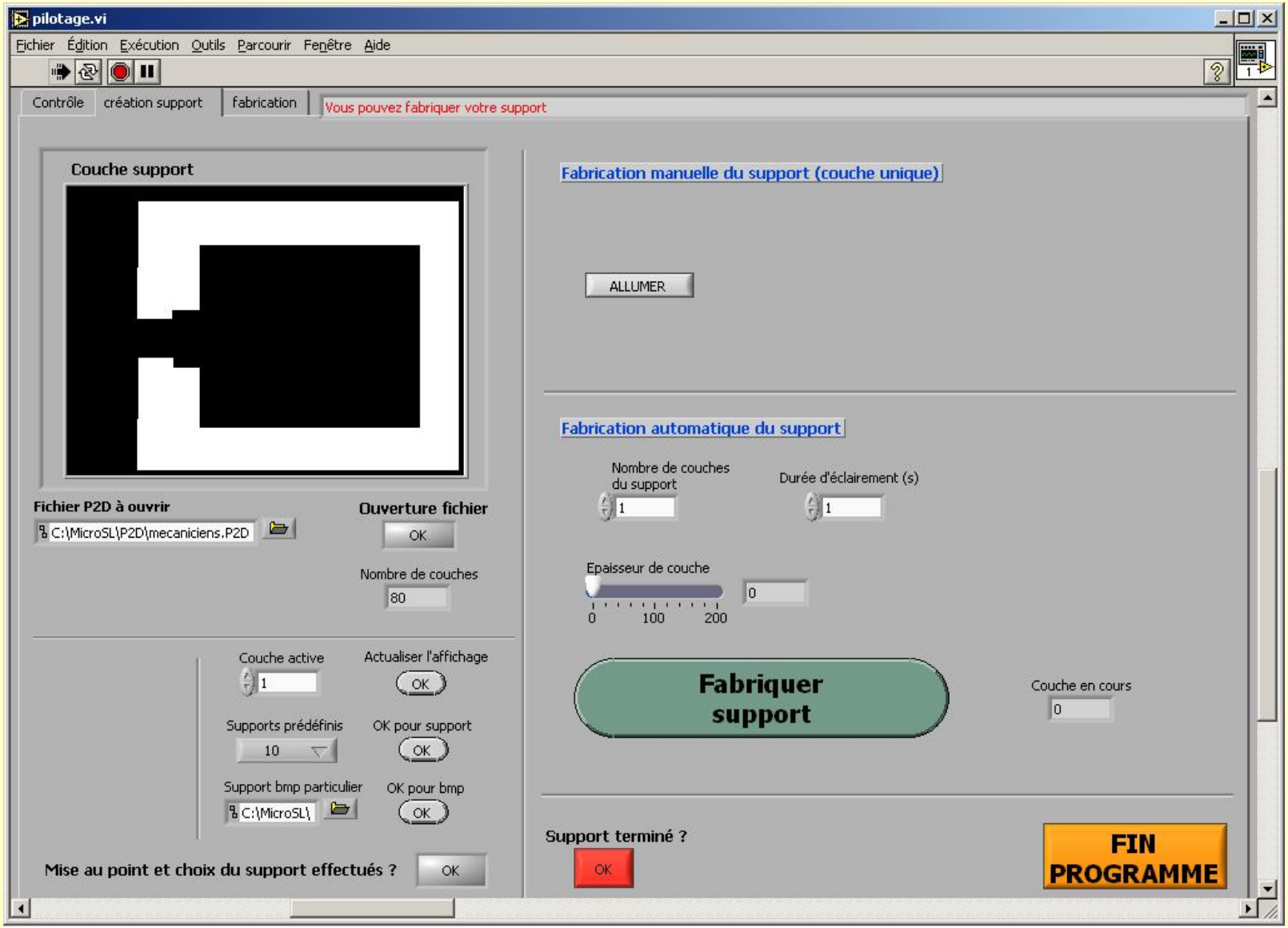


(1) Source fibrée, haute pression (Hg)
(2) Système pour homogénéisation lumineuse
(3) Masque dynamique à micro-miroirs
(4) Système optique imageur
(5) Micropositionnement vertical
(6) Ordinateur de commande

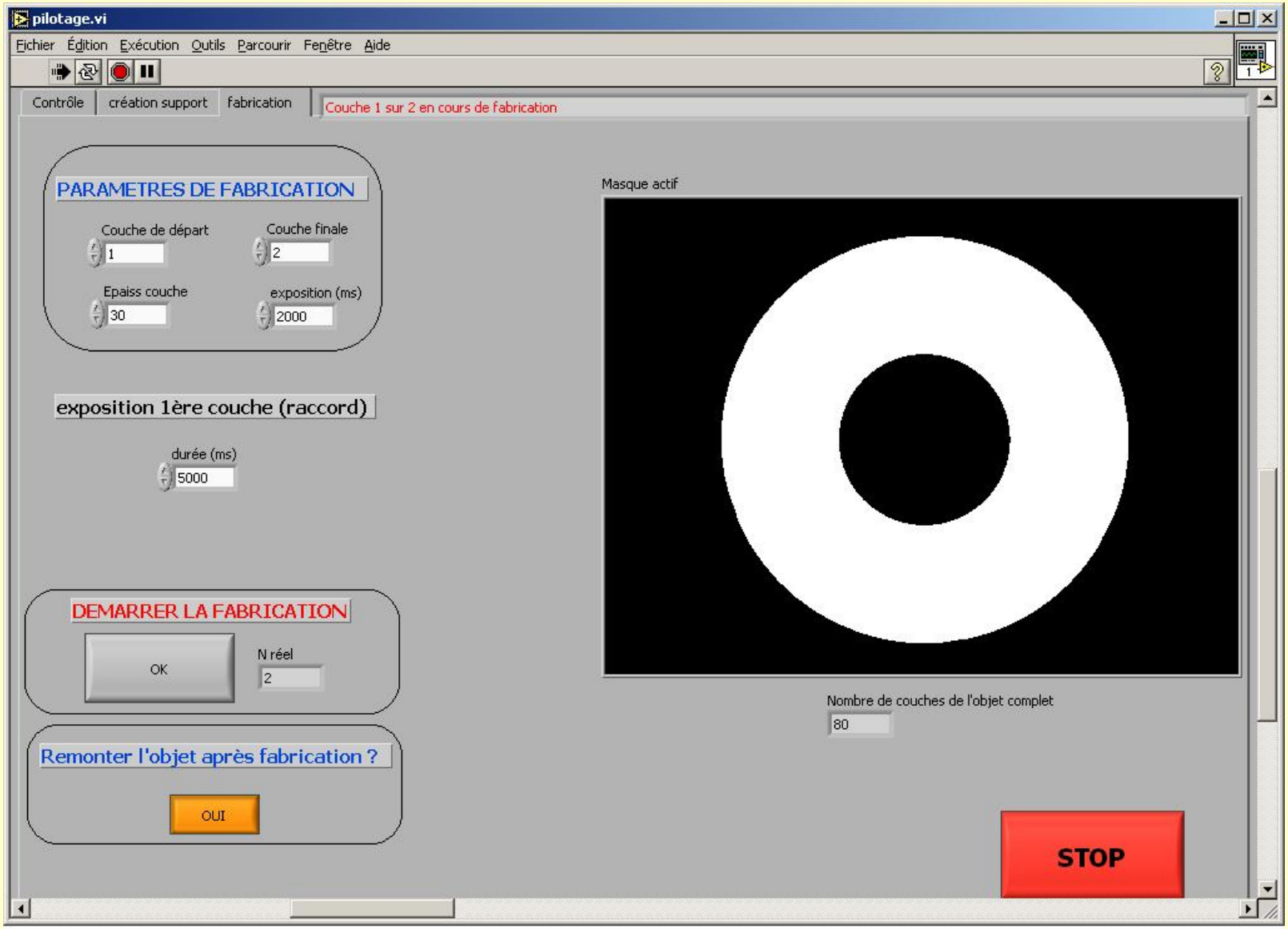
Logiciel de fabrication



Logiciel de fabrication



Logiciel de fabrication



Exemple de réalisation