Automated microassembly using an active microgripper with sensorized end-effectors and hybrid force/position control

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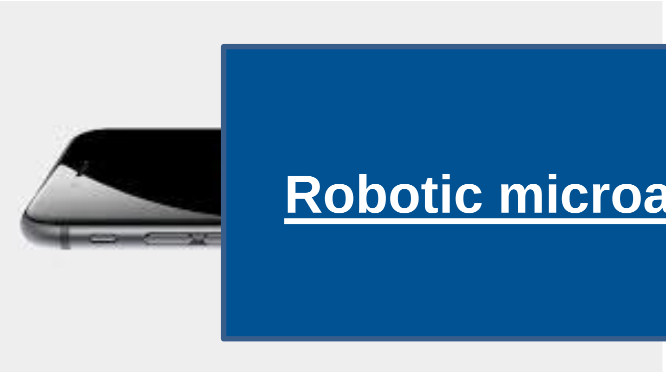
Motivations – Miniaturization

Robotic microassembly approach chosen

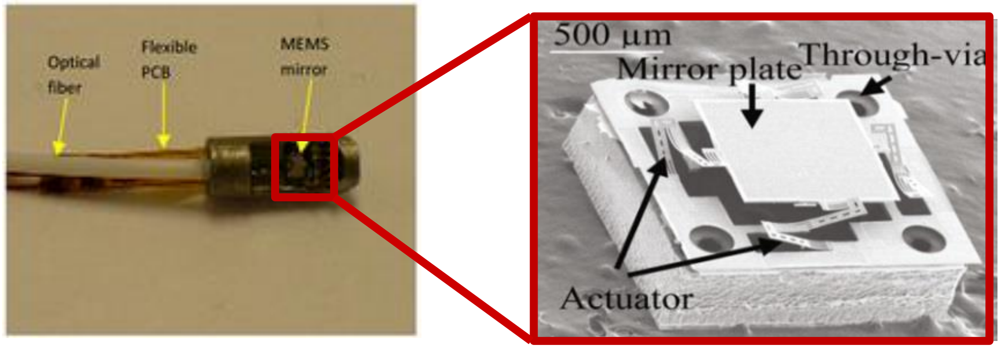


Smartphone

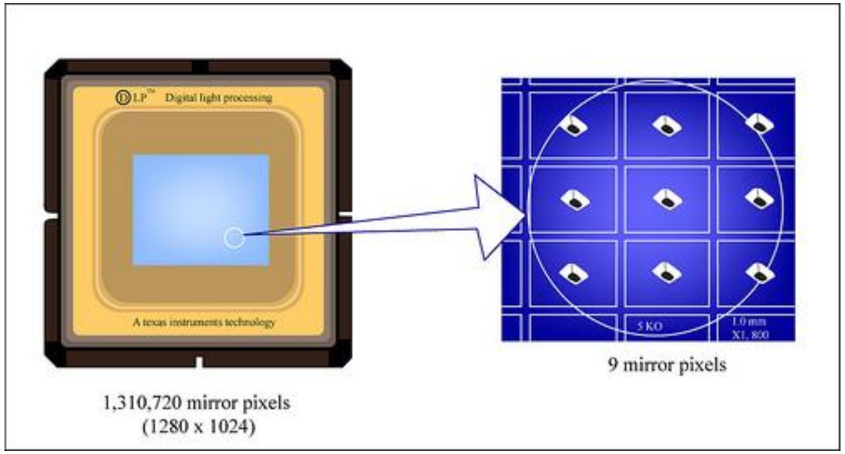
Video projector

Watch

Assembly of watches



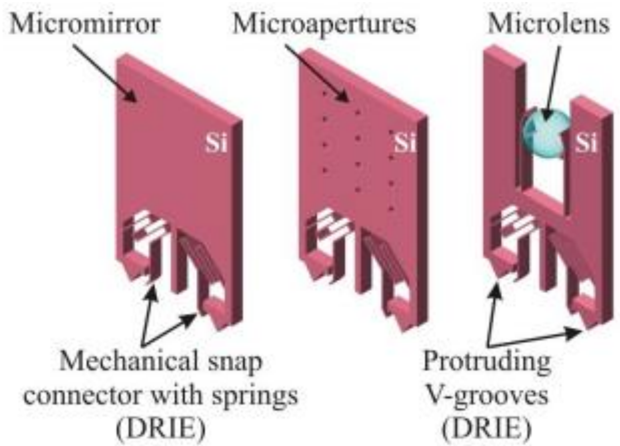
OCT probe with micromirror

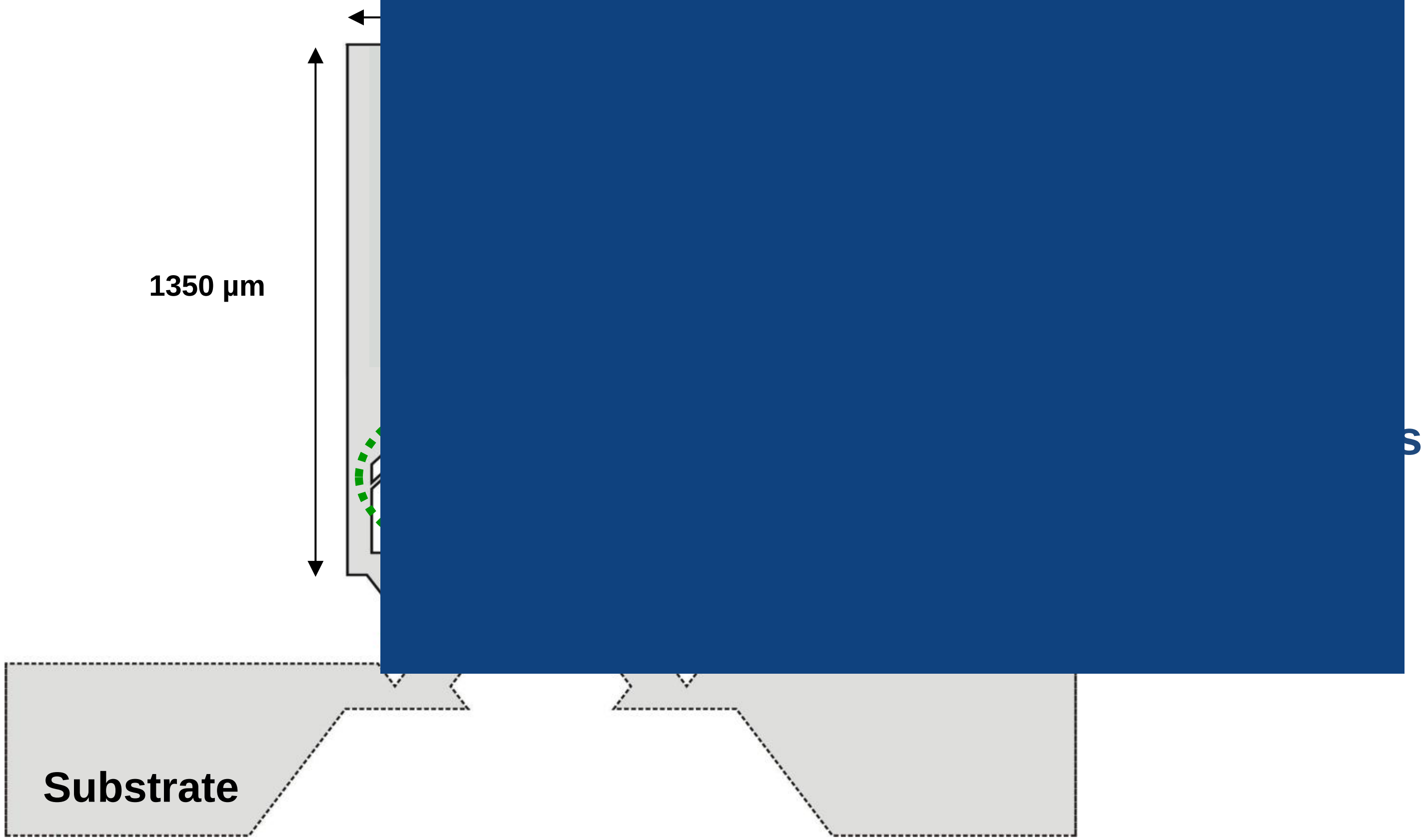


Digital Micromiror Device (DMD)

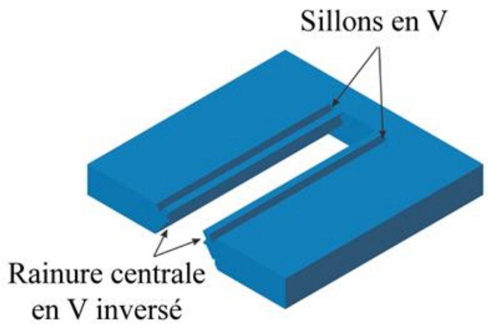
Fabrication of 3D hybrid MOEMS

Library of Basic Micro-Optical components



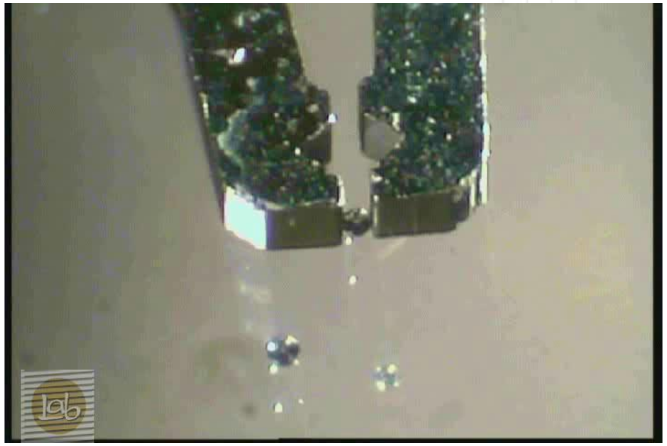


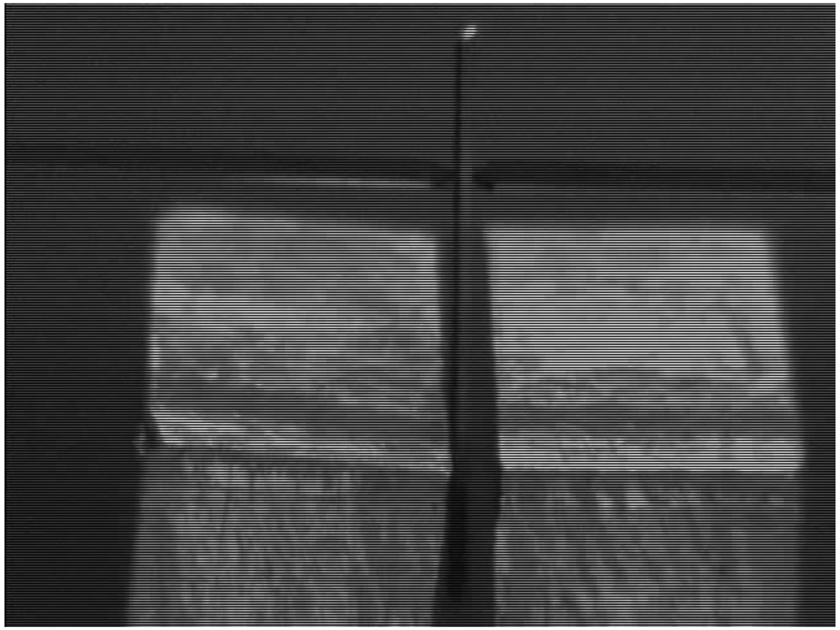
Silicon baseplate



Microscale specificities

- Predominance of contact and surface forces (pull-off force)
- High dynamics of microsystems
- Lack of suitable sensors (resolution, range, multi-DoF, etc)





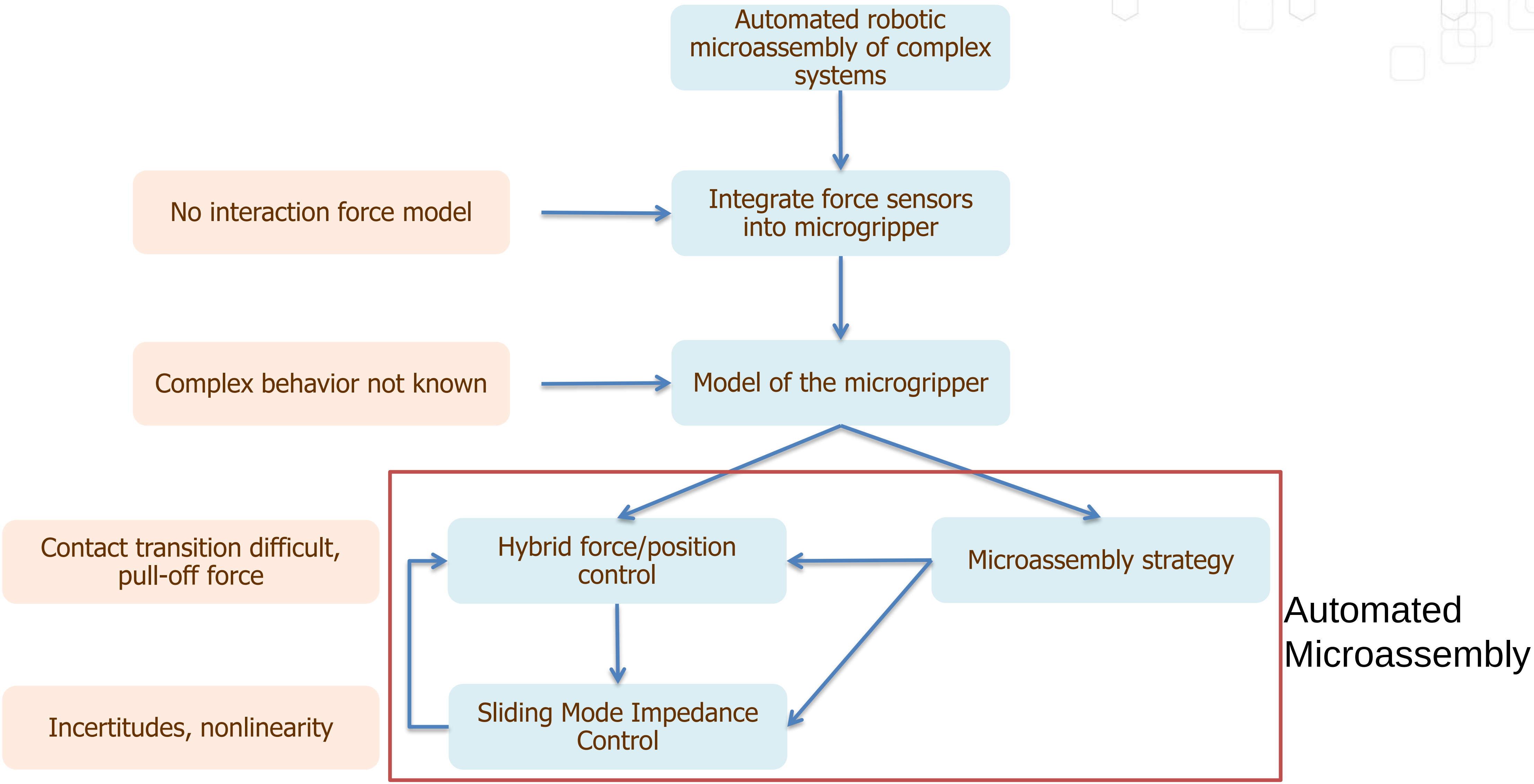
Pull-off force

Integrate force measurement inside microgripper

Small free size for sensor integration

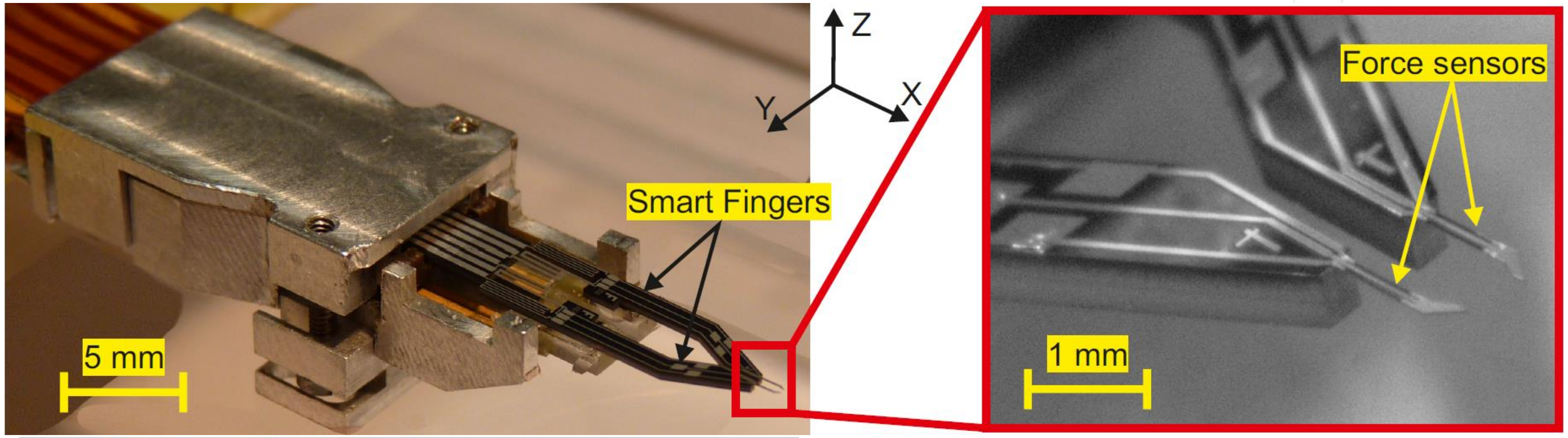
High dynamics of microsystems

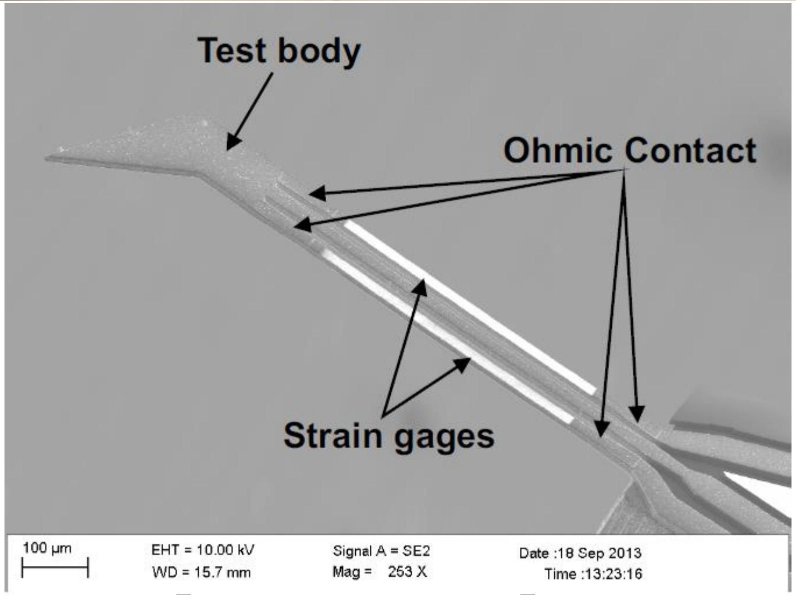
Chosen approach



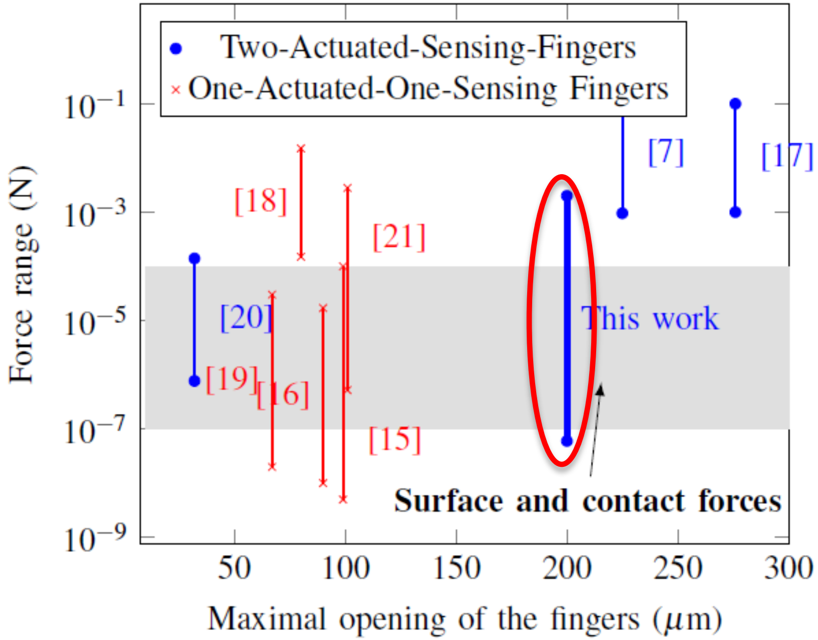
Two Smart Finger Microgripper (TSFM)

- Microassembly of complex systems
- **Integrate force sensors into microgripper**
- Model of the microgripper
- Hybrid force/position control
- Sliding Mode Impedance Control





[JMM2014]



Model of the TSFM [T-MECH2015, AIM2014]

Microassembly of complex systems

Integrate force sensors into microgripper

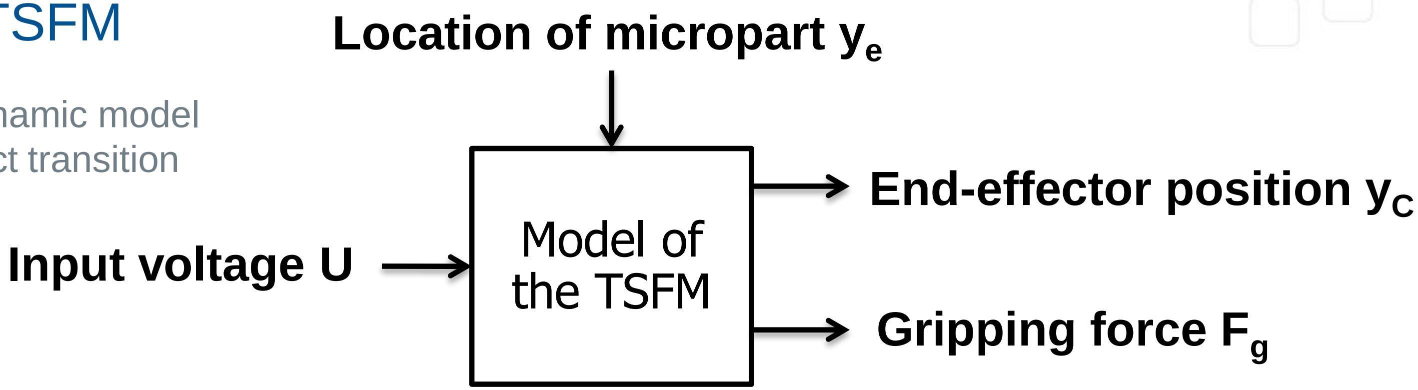
Model of the microgripper

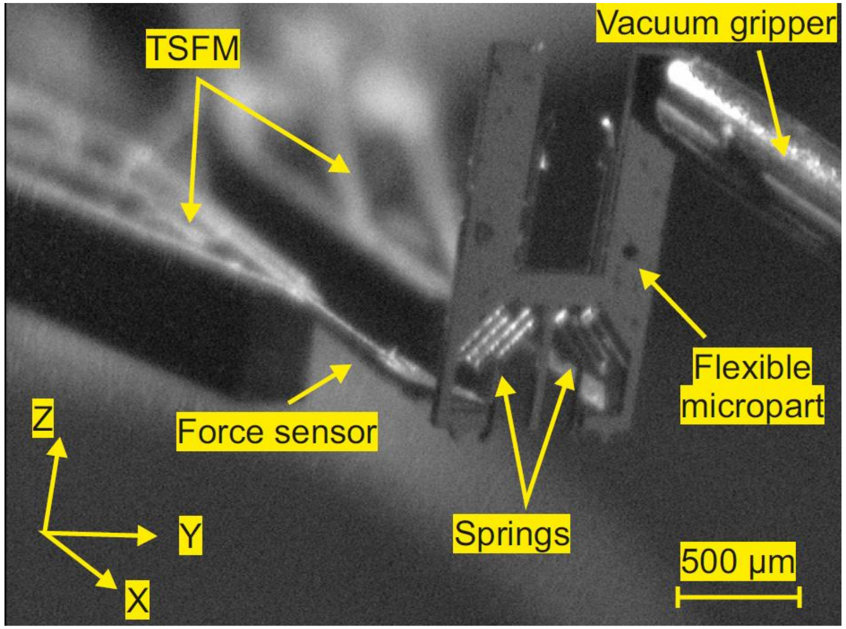
Hybrid force/position control

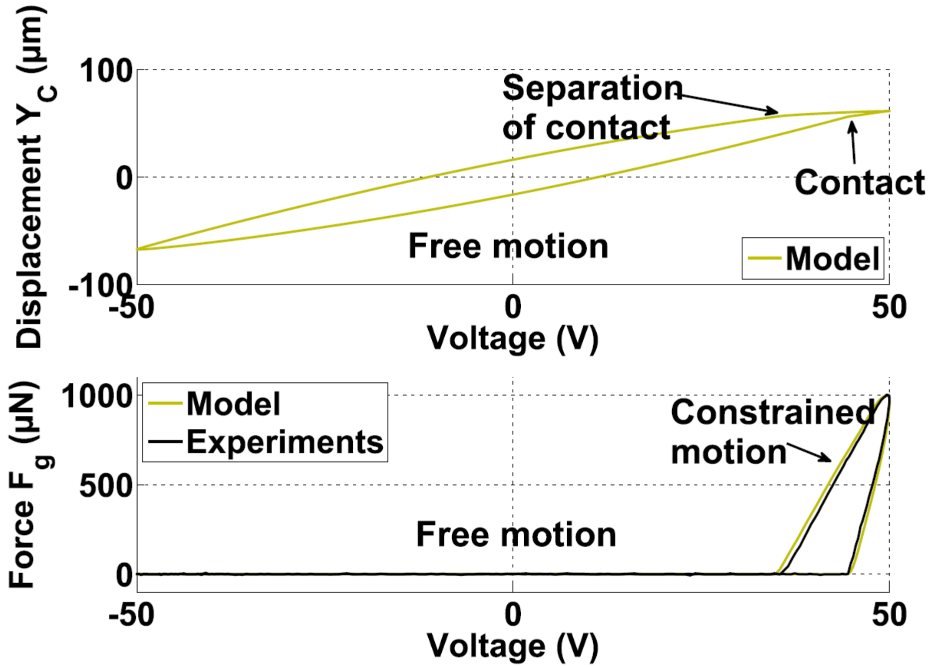
Sliding Mode Impedance Control

Model of the TSFM

- Nonlinear and dynamic model
- Contact/no contact transition







Automated microassembly

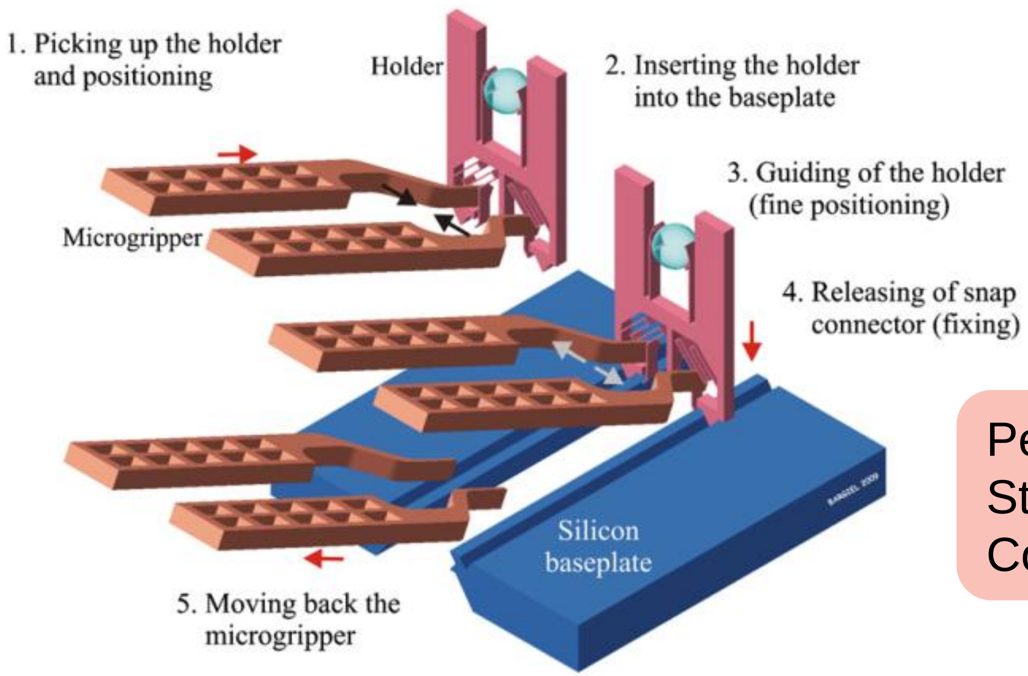
Microassembly of complex systems

Integrate force sensors into microgripper

Model of the microgripper

Hybrid force/position control

Sliding Mode Impedance Control



3 main microassembly tasks:

- Grasping
- Guiding
- Releasing

Perform precise positioning
Stability of the grasp
Control the dynamics of interaction

Hybrid force/position control

Hybrid force/position control [T-ASE2015, 2013]

Microassembly of complex systems

Integrate force sensors into microgripper

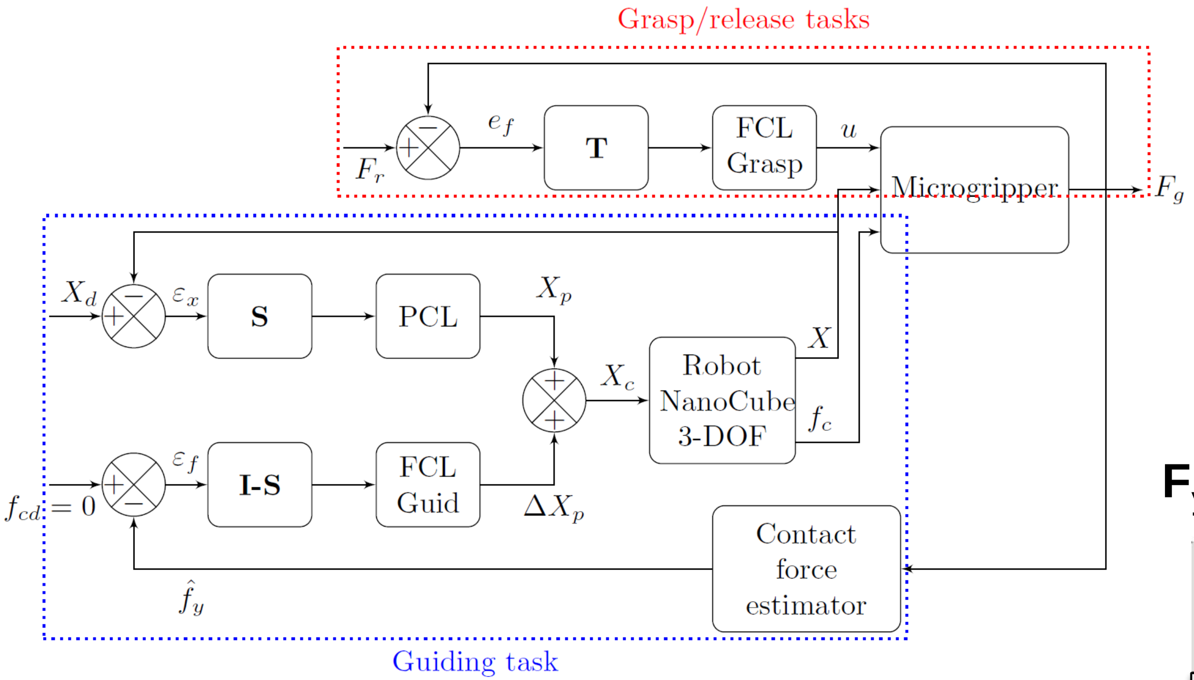
Model of the microgripper

Hybrid force/position control

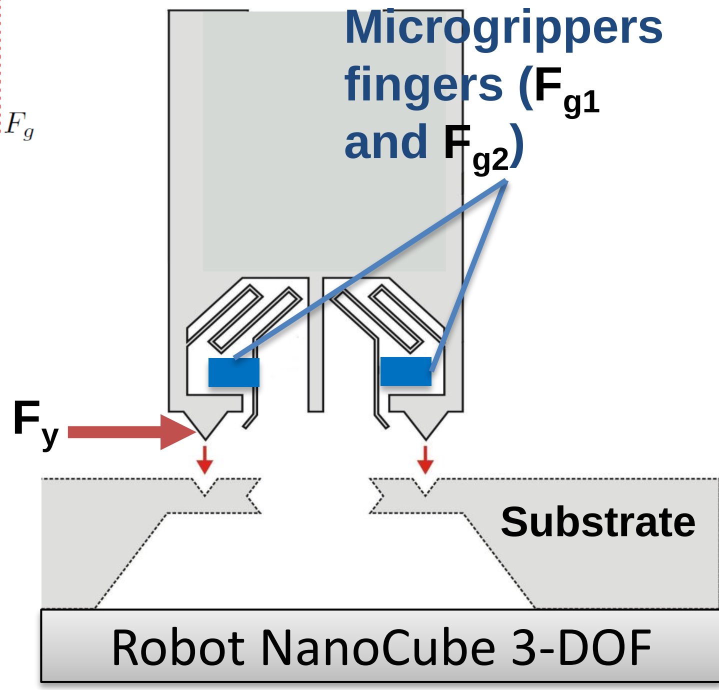
Sliding Mode Impedance Control

Hybrid force/position control

- S selection matrix for position controlled axis, I-S for force controlled axis
- PCL is position control law and is PID
- FCL is sliding mode impedance control to control the dynamics of the interaction



Hybrid force/position control



Sliding Mode Impedance Control [T-ASE2015]

Microassembly of complex systems

Integrate force sensors into microgripper

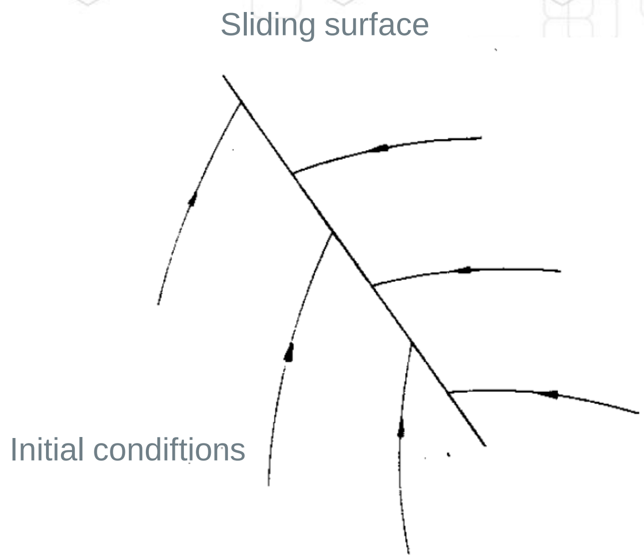
Model of the microgripper

Hybrid force/position control

Sliding Mode Impedance Control

Objectives:

- SMC: Nonlinear, stable and robust control
- Impedance: Control the dynamics of interaction



SMIC:

- The mechanical impedance:

$$Z = \frac{force\ error}{displacement\ error} = \frac{e_f}{e_y}$$

- A dynamic relation is set:

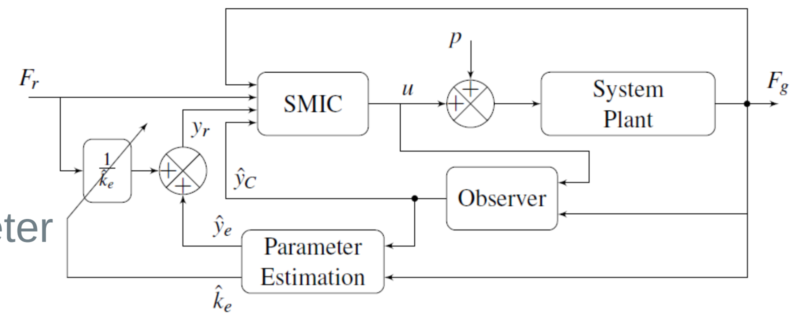
$$M_d(\ddot{y}_r - \ddot{y}) + D_d\,(\dot{y}_r - \dot{y}) + K_d\,(y_r - y) = F_r - F_e$$

- The impedance is:

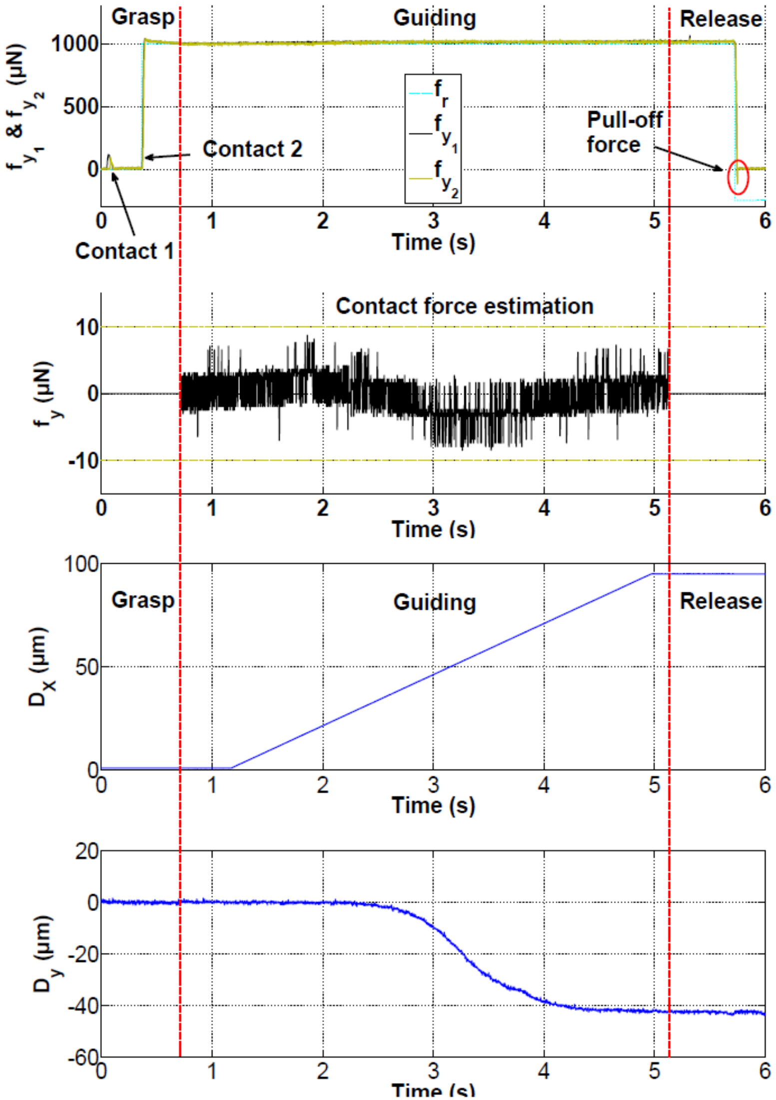
$$Z = M_d\, s^2 + D_d\, s + K_d$$

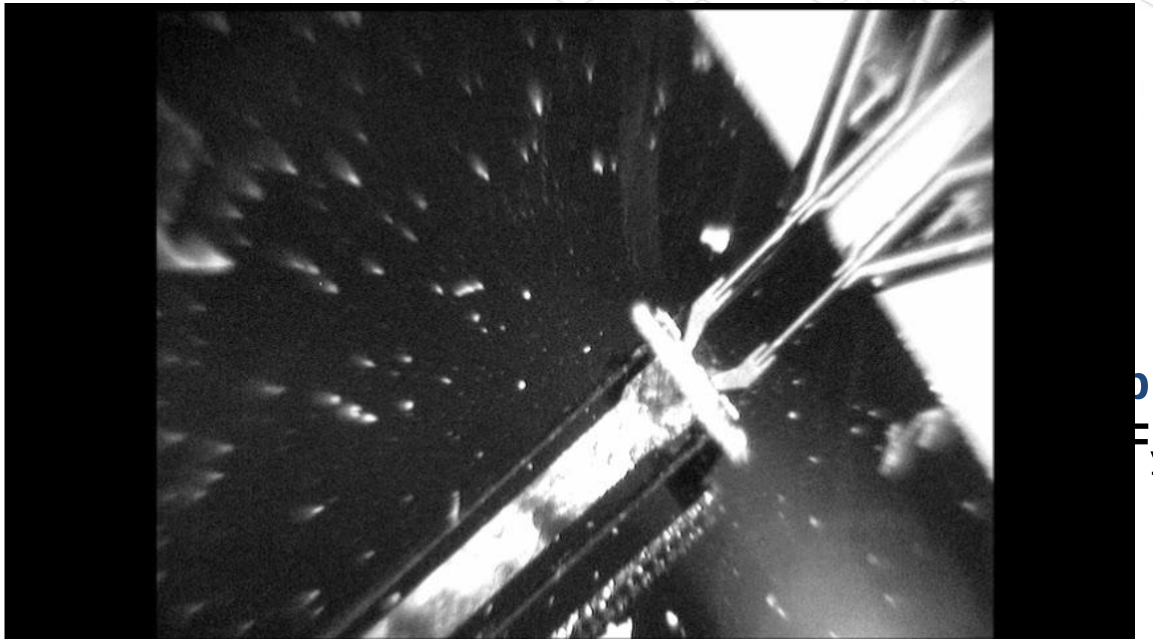
- Sliding surface chosen according to impedance parameter

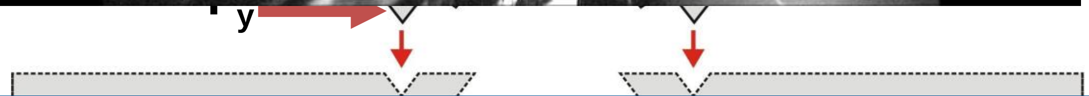
Chosen force control scheme



Experimental results for the assembly





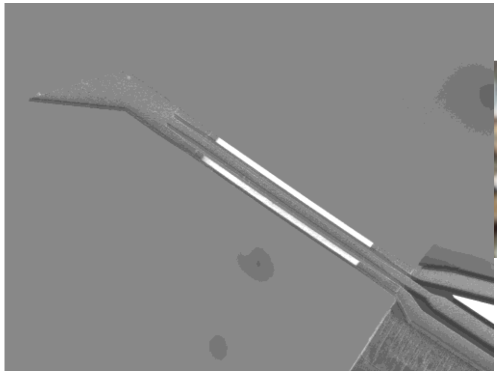


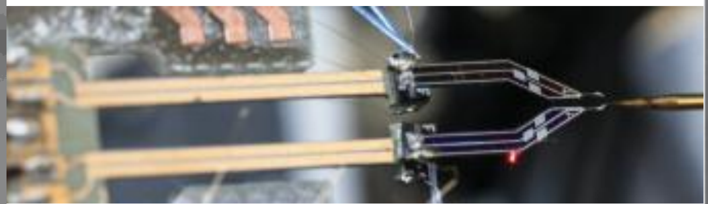
Automated microassembly:

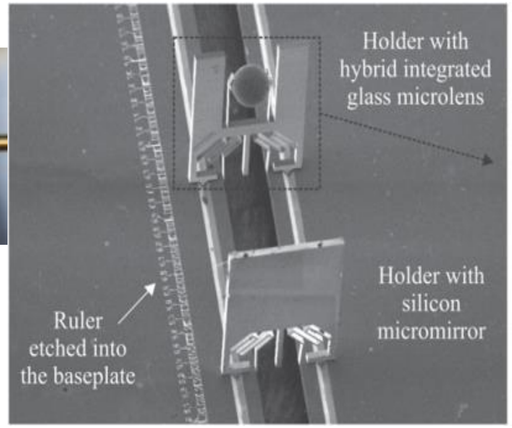
- Automated grasp/release within 20 ms
- Automated guiding task with misalignment for guiding speed along X axis up to 5 mm/s
- Nanometer positioning
- Strategy and control adapted to microscale specificities

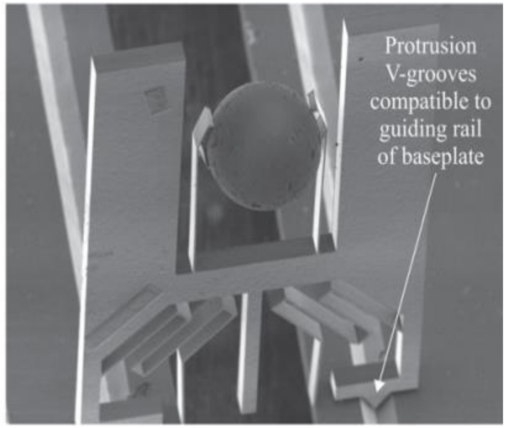
Conclusion and perspectives

- New microgripper with sensorized end-effectors
- Dynamic nonlinear model
- Propose a microassembly strategy and control adapted to microscale specificities
- Successful robotic microassembly with high dynamic capabilities









Perspectives

- Microsystems (improved performances, new class of assembled)
- Towards dexterous and multi-DoF microassembly
- Towards start up to commercialize force sensors

Thank you !!

Acknowlegments: Advisors (Philippe Lutz and Cédric Clévy), Jury, FEMTO-ST (Nicolas Chaillet), AS2M department (Michaël Gauthier), mes parents, mon épouse, ma fille, frère, amis

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