

EPFL Ecole polytechnique fédérale de Lausanne

EPFL MicroNanoFabrication Annual Review Meeting

Philippe Flückiger, EPFL, May 7th, 2019

Next editions :

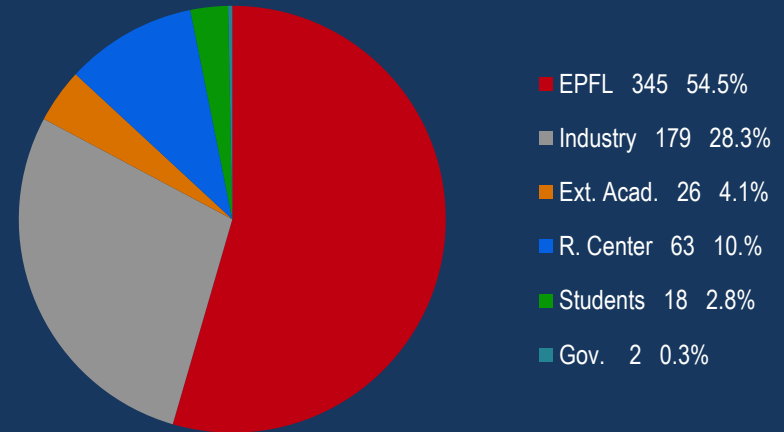
✘ 21st 05.05.2020

✘ 22nd 04.05.2021

Welcome & thanks

- Welcome to the 20th edition of the CMi MicroNanoFabrication Annual Review Meeting
- 633 participants registered (with 30% from industry)
- Many thanks for your participation

- Global companies
- Local industry
- Startups
- Suppliers
- Government Agencies
- Researchers
- Faculty members
- Colleagues from other academic cleanrooms



- -> Traveling from 11 different countries
- -> Networking

Outline

- Users
- Finances
- Governance
- Staff
- Cleanroom
- Tools
- Projects



Users in 2018

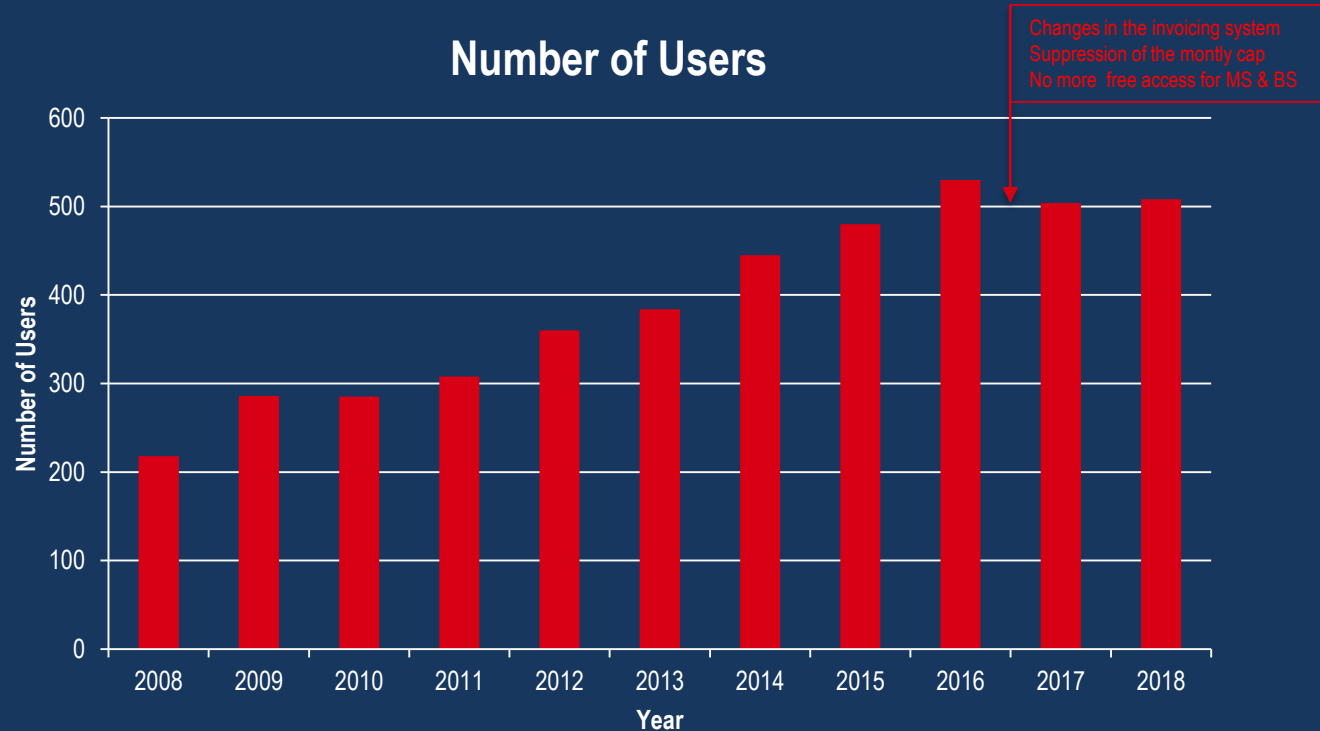
EPFL Engineering Sc.		Basic Sc.	Life Sc.	Ext. Ac.	Companies	
CMi	STI-IMT-LAI	SB-CIME	SV-BMI-UPRAMDYA	EXT-CERN	EXT-Aleva	EXT-Synova
STI-IBI-BIOS	STI-IMT-LAPD	SB-IPHYS-GCMP	SV-GHI-UPKIN	EXT-CSEM_E1	EXT-Asulab	EXT-ValFleurier
STI-IBI-CLSE	STI-IMT-LMIS1	SB-IPHYS-GR-GA	SV-IBI-UPDEPLA	EXT-CSEM_T1	EXT-Bruker	EXT-VORTEX
STI-IBI-LBEN	STI-IMT-LMIS2	SB-IPHYS-LASPE	SV-IBI-UPLUT	EXT-CSEM_T2	EXT-Efficconseil	EXT-Xsensio
STI-IBI-LBNC	STI-IMT-LMIS4	SB-IPHYS-LEB	SV-IBI-UPOATES	EXT-CSEM-Muttentz	EXT-EXALOS	
STI-IBI-LBNI	STI-IMT-LMTS	SB-IPHYS-LPMC	SV-ISREC-UPGON	EXT-EMPA	EXT-H.Glass	
STI-IBI-LHTC	STI-IMT-LO	SB-IPHYS-LPMV	SV-ISREC-UPHUELSKEN	EXT-ETHZ_(APS)	EXT-INTEL	
STI-IBI-LNE	STI-IMT-LPMAT	SB-IPHYS-LPN		EXT-HEIG-VD-MNT	EXT-LakeDiamond	
STI-IEL-GR-SCI	STI-IMT-LSBI	SB-IPHYS-LPQM1		EXT-HESGE	EXT-Ligentec	
STI-IEL-LANES	STI-IMT-NAM	SB-IPHYS-LQM	IC-IINFCOM-LS11	EXT-UNI-KOC	EXT-LSPR	
STI-IEL-LSM	STI-IMT-OPT	SB-IPHYS-LUMES		EXT-UniFribourg	EXT-Mackinac	
STI-IEL-NANOLAB	STI-IMX-FIMAP	SB-ISIC-LAS		EXT-UNIGE-GAP	EXT-MCH-processing	
STI-IEL-POWERLAB	STI-IMX-INE	SB-ISIC-LEPA	ENAC-IIC-LESO-PB	EXT-Wyss_Center	EXT-Meister-Abrasive	
STI-IGM-EMSI	STI-IMX-LMGN	SB-ISIC-LND			EXT-Metas	
STI-IGM-FLEXLAB	STI-IMX-LMM	SB-ISIC-LPDC			EXT-Morphotonix	
STI-IGM-LFMI	STI-IMX-LMOM	SB-ISIC-LPI			EXT-Nanoworld_Tech.	
STI-IGM-LRESE	STI-IMX-LMSC	SB-ISIC-LSCI			EXT-Novagan	
STI-IGM-MICROBS	STI-IMX-LP	SB-ISIC-LSPM			EXT-Piemacs	
STI-IGM-NEMS	STI-IMX-LPAC	SB-ISIC-LSU			EXT-Preciflex	
STI-IGM-RRL	STI-IMX-QMAT	SB-ISIC-SCI-MN			Ext-Rheon_Medical	
STI-IMT-AQUA	STI-IMX-SMAL	SB-MATH-STAP			EXT-Rolex	
STI-IMT-ESPLAB	STI-SCI-PM	SB-SCI-RH			EXT-Simplinext	
STI-IMT-GALATEA					EXT-Spryngs	
STI-IMT-GR-QUA					EXT-SwissFlexMicro	
344 (46)		63 (22)	30 (9)	33 (13)	38 (28)	

- Total: 508 users operating the CMi tools
- (Total: 118 labs or companies)

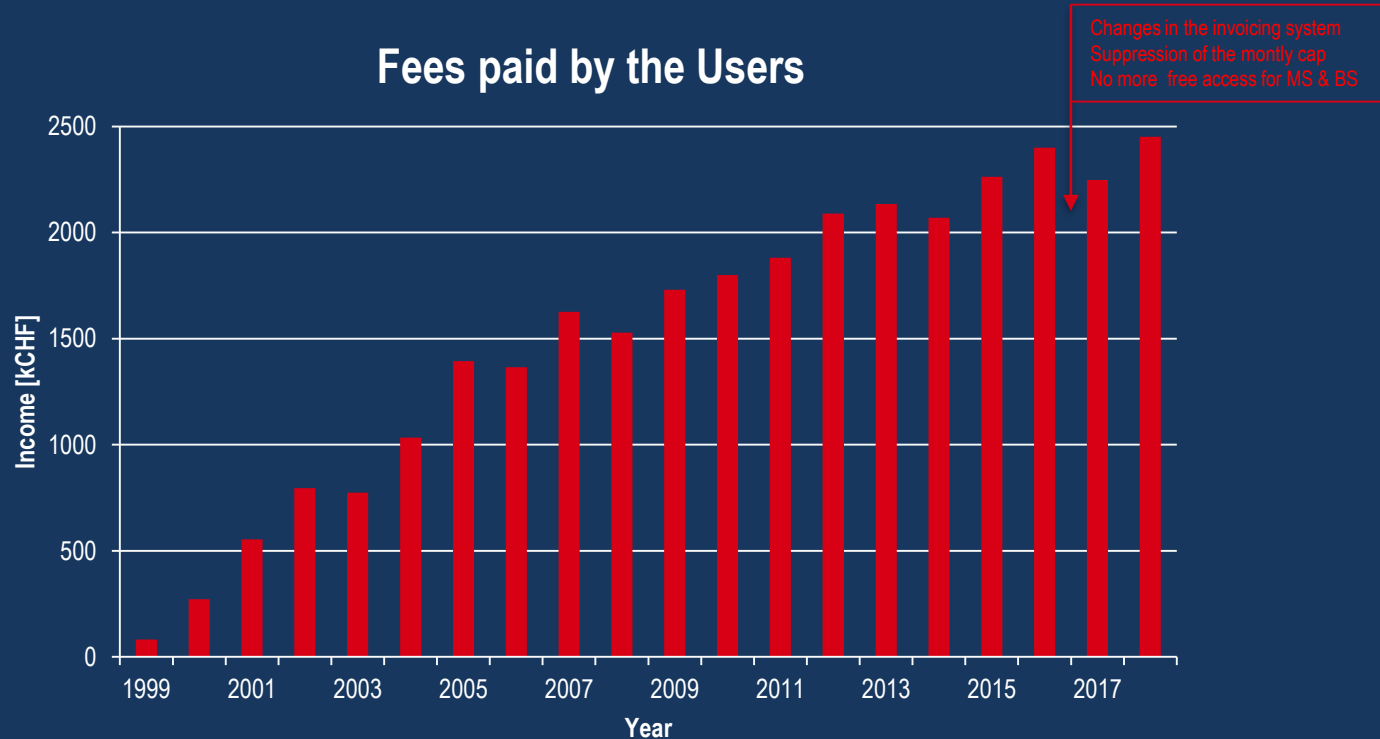
Users in 2018

EPFL Engineering	Sc.	Basic Sc.	Life Sc.	Ext. Ac.	Companies																	
CMi	STI-IMT-LAI	SB-CIME	SV-BMI-UPPAMDYA	EXT-CERN	EXT-Aleva	EXT-Synova																
Bio Engineering (Interschool)	STI-BIO	SB-IPHYS-GCMP	Bio Engineering (Interschool)	EXT-CSEM_E1	EXT-Asulab	EXT-ValFleurier																
	STI-IMT-LAPD	SB-IPHYS-GR-GA		EXT-CSEM_T1	EXT-Bruker	EXT-VORTEX																
	STI-IMT-LMIS1	SB-IPHYS-GR-GA		EXT-CSEM_T2	EXT-Efficonseil	EXT-Xsensio																
	STI-IMT-LMIS2	SB-IPHYS-GR-GA		EXT-CSEM_T3	EXT-Efficonseil	EXT-Xsensio																
Electrical Engineering	STI-IMT-LMIS3	SB-IPHYS-GR-GA	Experimental Cancer Research	EXT-CSEM_T4	EXT-EX	Startups SMEs Big companies																
	STI-IMT-LMIS4	SB-IPHYS-GR-GA		EXT-CSEM_T5	EXT-EX																	
	STI-IMT-LMIS5	SB-IPHYS-GR-GA		EXT-CSEM_T6	EXT-EX																	
	STI-IMT-LMIS6	SB-IPHYS-GR-GA		EXT-CSEM_T7	EXT-EX																	
Mechanical Engineering	STI-IMT-LMIS7	SB-IPHYS-GR-GA	Chemical Sciences and Engineering	EXT-CSEM_T8	EXT-EX	Startups SMEs Big companies																
	STI-IMT-LMIS8	SB-IPHYS-GR-GA		EXT-CSEM_T9	EXT-EX																	
	STI-IMT-LMIS9	SB-IPHYS-GR-GA		EXT-CSEM_T10	EXT-EX																	
	STI-IMT-LMIS10	SB-IPHYS-GR-GA		EXT-CSEM_T11	EXT-EX																	
STI-IMT-LMIS11	SB-IPHYS-GR-GA	EXT-CSEM_T12	EXT-EX	EXT-H.C	EXT-INT	EXT-Lak	EXT-Lig	EXT-LSPR	EXT-Mackinac	EXT-MCH-processing	EXT-Meister-Abrasive	EXT-Metas	EXT-Morphotonix	EXT-Nanoworld_Tech.	EXT-Novagan	EXT-Piemacs	EXT-Preciflex	Ext-Rheon_Medical	EXT-Rolex	EXT-Simplinext	EXT-Spryns	EXT-SwissFlexMicro
STI-IMT-LMIS12	SB-IPHYS-GR-GA	EXT-CSEM_T13	EXT-EX	EXT-KOC	EXT-LSPR	EXT-Mackinac	EXT-MCH-processing	EXT-Meister-Abrasive	EXT-Metas	EXT-Morphotonix	EXT-Nanoworld_Tech.	EXT-Novagan	EXT-Piemacs	EXT-Preciflex	Ext-Rheon_Medical	EXT-Rolex	EXT-Simplinext	EXT-Spryns	EXT-SwissFlexMicro			
STI-IMT-LMIS13	SB-IPHYS-GR-GA	EXT-CSEM_T14	EXT-EX	EXT-UNIFRIBOURG	EXT-Mackinac	EXT-MCH-processing	EXT-Meister-Abrasive	EXT-Metas	EXT-Morphotonix	EXT-Nanoworld_Tech.	EXT-Novagan	EXT-Piemacs	EXT-Preciflex	Ext-Rheon_Medical	EXT-Rolex	EXT-Simplinext	EXT-Spryns	EXT-SwissFlexMicro				
STI-IMT-LMIS14	SB-IPHYS-GR-GA	EXT-CSEM_T15	EXT-EX	EXT-UNIGE-GAP	EXT-Mackinac	EXT-MCH-processing	EXT-Meister-Abrasive	EXT-Metas	EXT-Morphotonix	EXT-Nanoworld_Tech.	EXT-Novagan	EXT-Piemacs	EXT-Preciflex	Ext-Rheon_Medical	EXT-Rolex	EXT-Simplinext	EXT-Spryns	EXT-SwissFlexMicro				
STI-IMT-LMIS15	SB-IPHYS-GR-GA	EXT-CSEM_T16	EXT-EX	EXT-WYSS_CENTER	EXT-Mackinac	EXT-MCH-processing	EXT-Meister-Abrasive	EXT-Metas	EXT-Morphotonix	EXT-Nanoworld_Tech.	EXT-Novagan	EXT-Piemacs	EXT-Preciflex	Ext-Rheon_Medical	EXT-Rolex	EXT-Simplinext	EXT-Spryns	EXT-SwissFlexMicro				
STI-IGM-RRLL	STI-IMX-QMAT	SB-ISIC-SCI-MN																				
STI-IMT-AQUA	STI-IMX-SMAL	SB-MATH-STAP																				
STI-IMT-ESPLAB	STI-SCI-PM	SB-SCI-RH																				
STI-IMT-GALATEA																						
STI-IMT-GR-QUA																						
	344 (46)	63 (22)	30 (9)	33 (13)		38 (28)																

- Total: 508 users operating the CMi tools
- (Total: 118 labs or companies)



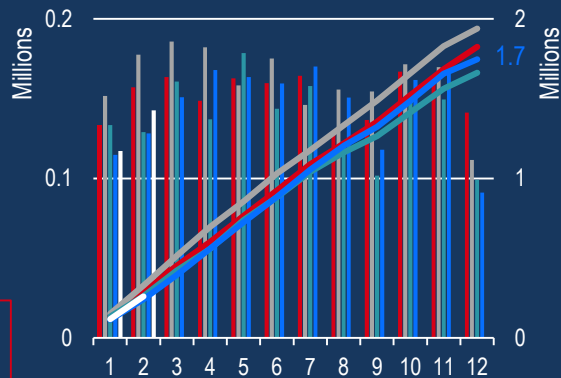
- In 2017 a correction of -5% occurred due to the changes in the invoicing system
- In 2018 we observe a growth of 1% (which is expected to strengthen)



- In 2017 a correction of -6% occurred due to the changes in the invoicing system.
- In 2018 we observe a growth of 9%.

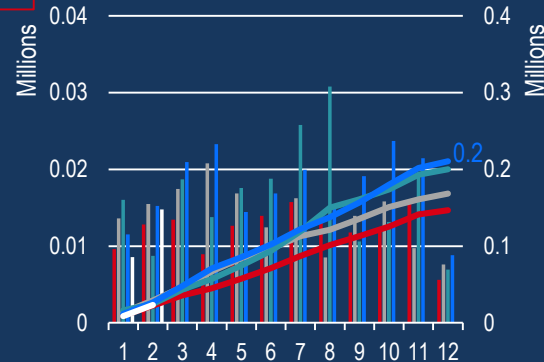
Finances

EPFL Users



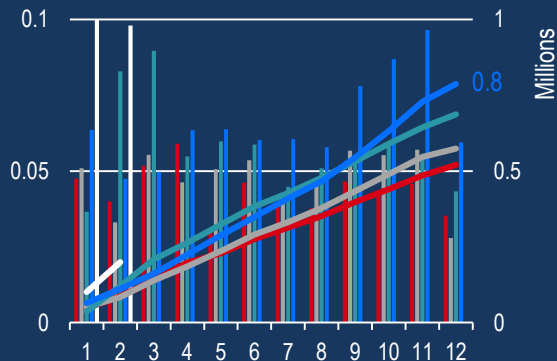
Affected by the new invoicing rules since 2017

Ext. Academics Users



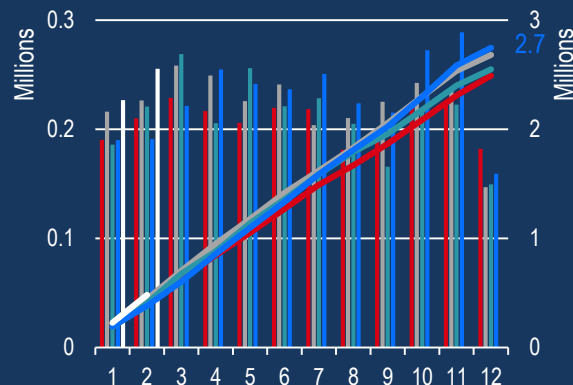
Regular yearly progression

Companies



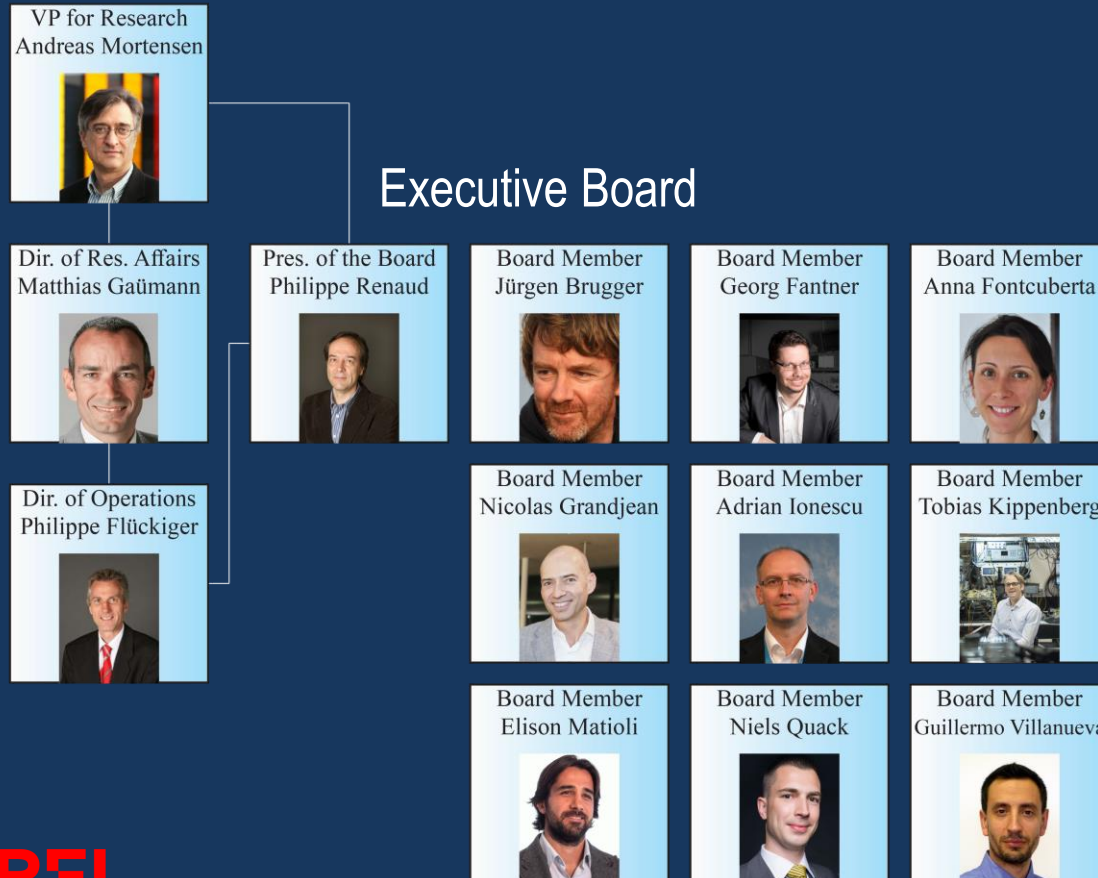
Regular yearly progression

Total



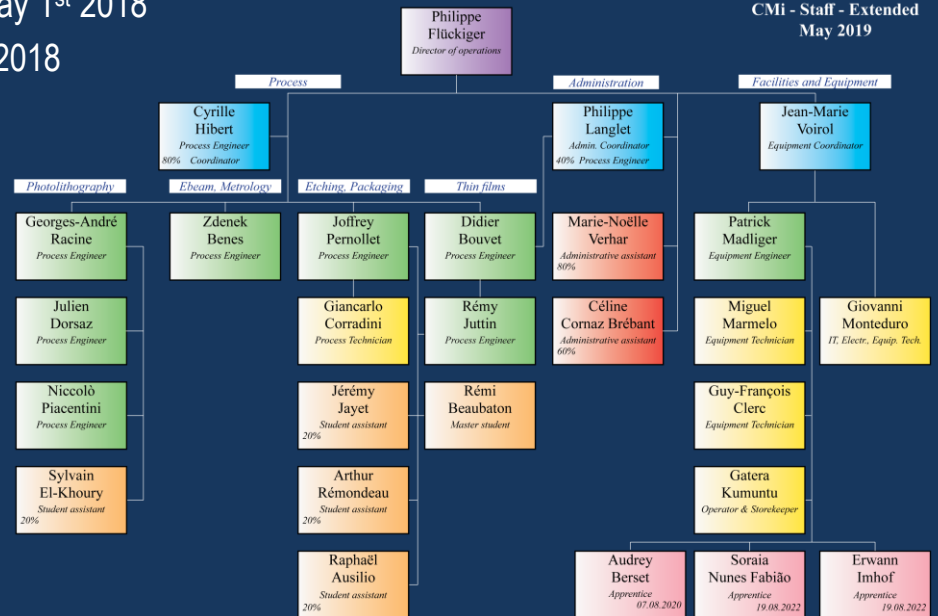
- Monthly monitoring of the invoicing to the 3 categories of users
- Contribution from companies raised from 21% in 2015 to 29% in 2018

- In summary
 - A new invoicing system was introduced on October 1st 2016 based on transparent and auditable direct and indirect costs calculations in order to make our costs eligible to internal and external clients as well as to funding research bodies.
- Since then
 - No more free access for the master & semester projects (replaced now by capped subsidies)
 - No more cap per academic user and per month (previously CHF 1600.- / academic user / month)
- The benefits
 - CMi has now an SNSF compatible transparent cost accounting methodology (CMi bills are eligible)
 - CMi has more available capacity, less bottlenecks on the tools
- Side effects
 - In 2017 a correction of the # of users (-5%) and of the fees paid by the users (-6%)
 - In 2018 a growth of the # of users (+1%) and of the fees paid by the users (+9%)
- 2018
 - Estimated operating expense 2018 : 8MCHF
 - Fees paid by the users 2018 : 2.5MCHF
 - Operating result 2018 : - 100 KCHF



- Since June 2017 the CMi reports to the Vice-President for Research (instead of reporting to the dean of the school of engineering)
- Our executive board is composed of 10 Professors including our president
- Members nominated for a period of 4 years from 01.11.2018 until 31.10.2022

- Staff composed of 17.6 FTE employees
- Whole staff under permanent positions since May 1st 2018
- 5 CDD were transformed into 5CDI on May 1st 2018
- Employ 4 student assistants (part time)
- Train 3 apprentices
- 1 trainee



New tools installed in 2019

- × DUV Stepper lithography system – Delivered 11.12.2018
 - + ASML PAS 5500/350C (248nm)
 - + SNSF R'Equip grant 206021-170750 Prof. Tobias Kippenberg
 - + Resolution <150nm, Overlay accuracy <30nm, Productivity >100wph



- × 7x Optical Microscopes – Delivered 26.02.2019
 - + Leica DM8000 M

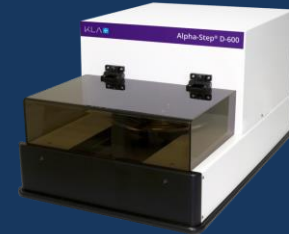


- × Film Thickness Measurement System – Delivered 10.01.2019
 - + Filmetrics F54
 - + Automatic mapping
 - + (Filmetrics was acquired by KLA in March 2019)

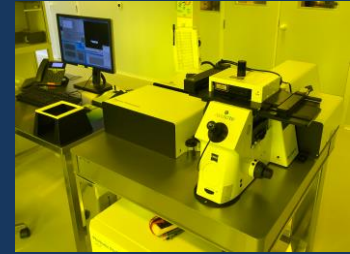


New tools installed in 2018

- ✗ Stylus Profiler – Delivered 05.10.2018
 - + KLA-Tencor AlphaStep D-600
 - + 2D and 3D step heights measurements
 - + From few nm to 1200um



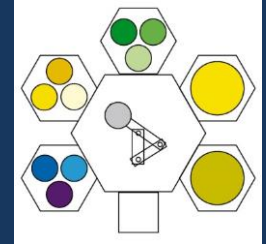
- ✗ 3D Laser lithography System– Accepted 16.02.2018
 - + Nanoscribe Photonic Professional GT
 - + ETH Board SFA grant CERAMIC X.0 Prof. Jürgen Brugger
 - + Highest resolution commercially available micro 3D printer (x-y 300nm; z 800nm)
 - + Non-linear two-photon absorption process from an infrared femtosecond laser (780nm)



Tools under evaluation & Budget requests for 2019

- × DUV Photoresist Coater & Developer
 - + Dedicated to DUV stepper lithography
 - + Call for tender to be published in Q2 2019

- × Physical Vapor Deposition Cluster Tool (sputtering)
 - + Submission deadline SNSF R'Equip :15.05.2019
 - + Prof. Guillermo Villanueva
 - + Deposition of dielectric materials
 - + Multilayers & Bragg reflectors
 - + Co-sputtering of metals, nitrides & oxides



Tools under evaluation & Budget requests for 2019

× Optical Profiler

× Upgrade IBE

× Flash Annealing System

× Post CMP Cleaner

× ICP Etcher

× High Temperature CVD Oxide Deposition

× ICP PECVD Oxide and nitride deposition

Tools to be transferred from other/closing labs

× LPCVD Furnace - ATV PEO 603

× EBL System - Raith 150

× Mask Aligner - SUSS MA/BA8

× Mask Aligner - SUSS MJB4

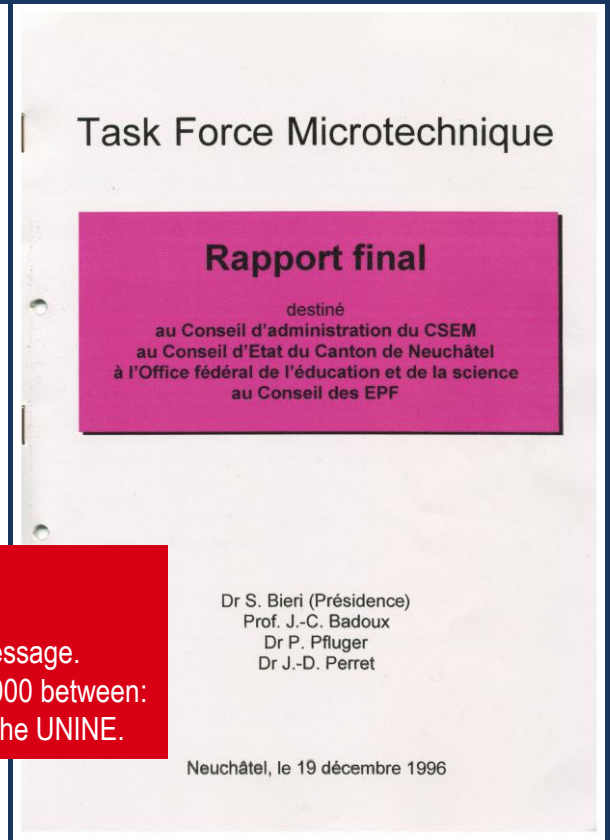
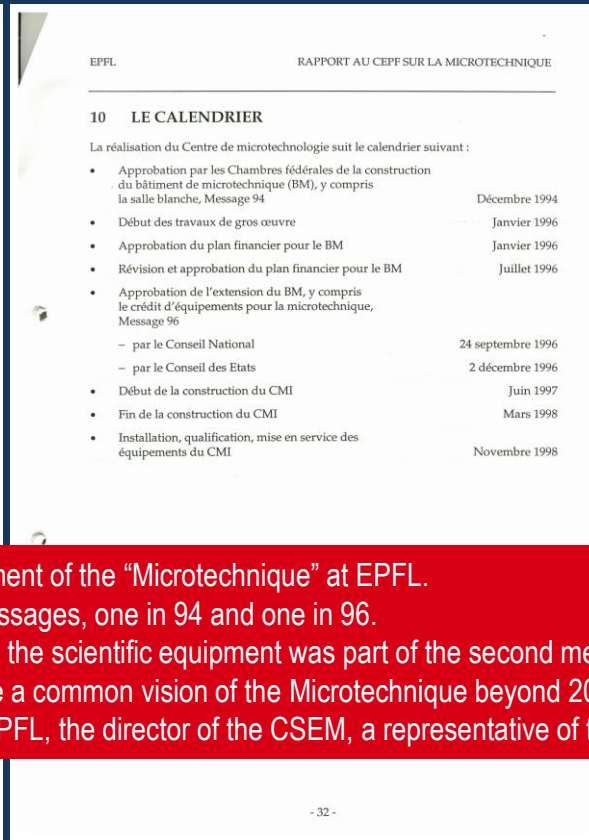
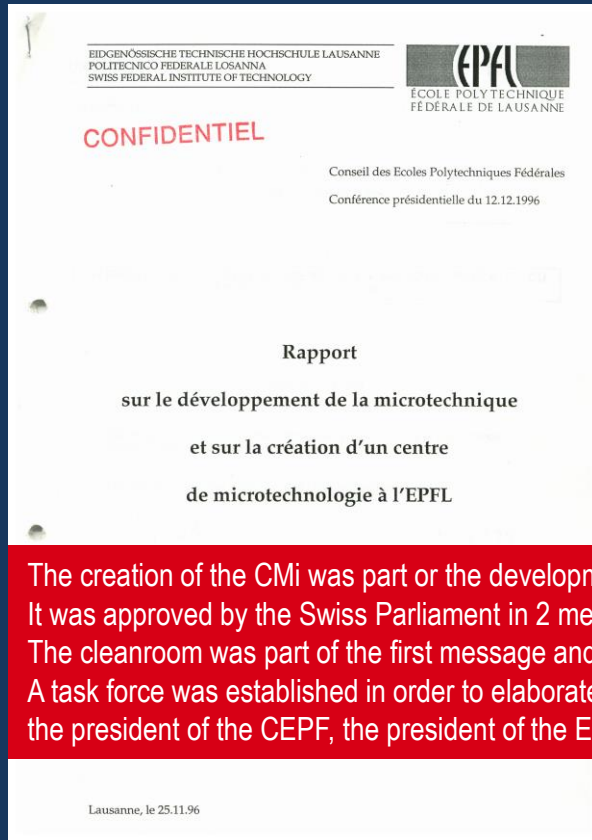
× Wafer Bonder - EVG 520

× Wafer Bonder - EVG 501

EPFL turns 50 !

CMi turns 20 !

A bit of history



The creation of the CMI was part of the development of the "Microtechnique" at EPFL. It was approved by the Swiss Parliament in 2 messages, one in 94 and one in 96. The cleanroom was part of the first message and the scientific equipment was part of the second message. A task force was established in order to elaborate a common vision of the Microtechnique beyond 2000 between: the president of the CEPF, the president of the EPFL, the director of the CSEM, a representative of the UNINE.

Historical Milestones

IC & MEMS

1998

- CMi created in 1998 & Cleanroom opened in March 1999
- Basic Microelectronics processes
- MEMS processes like Deep silicon etching & SU-8

Nano

2007

- Electron Beam Lithography acquired in 2007
- Focused Ion Beam in 2004
- Atomic Layer Deposition in 2011

Cleanroom extension 24/7

2010

- Cleanroom extension opened in 2010 for more flexibility and cheaper access
- **Operated now in 24/7 mode** since 2012
- PDMS, SU-8, Chemistry, Metrology, Non-conventional processes

Materials Diversity

2013

- Ion Beam Etching
- Chemistry

More Capabilities & Renewal

2014

- Photolithography: Mask Fabrication – Coater & Developer – Mask Aligner
- PVD & ALD & PLD
- Dry Etching

DUV Stepper lithography

2019

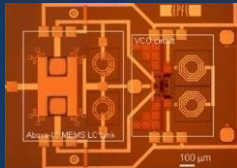
- DUV stepper
- Renewal of aging tools & Adding new capabilities
- Envision the acquisition of a second EBEAM at the horizon of 2022

Evolution

CMi tools ...



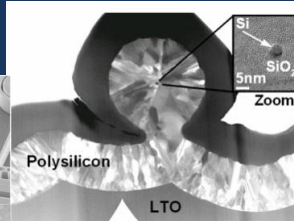
IC



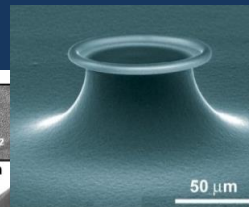
MEMS



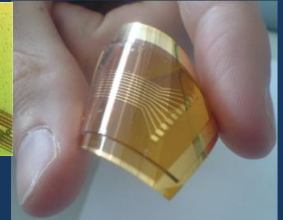
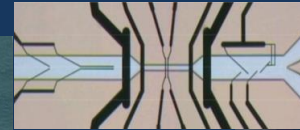
Nano



Bio

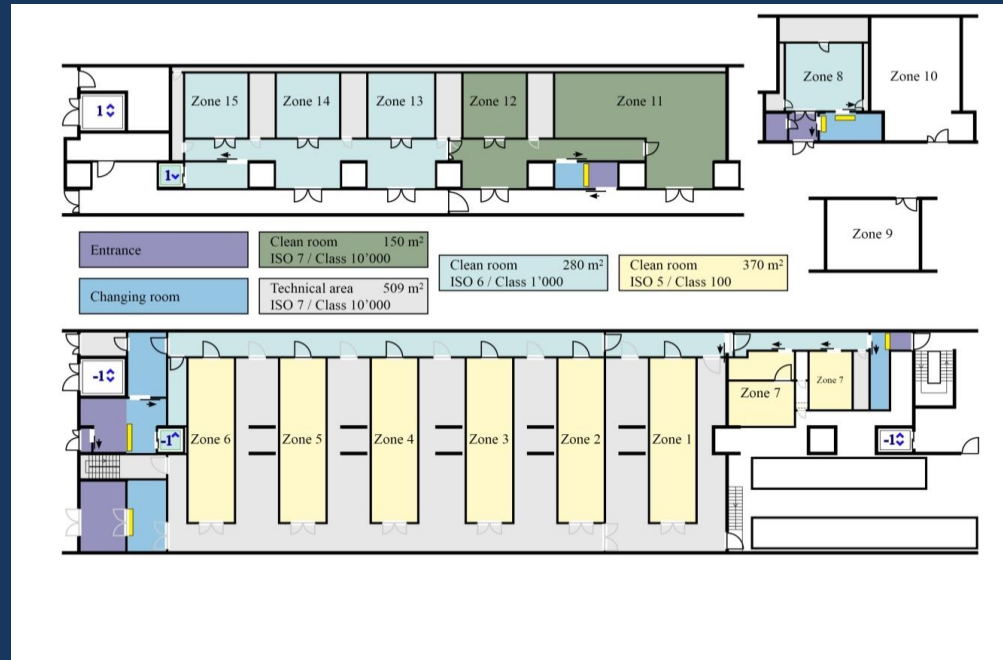


Materials



CMi projects ...

Cleanroom



Initial surface (1998)

Extension (2010)

Extension (2017)

Total surface

1000m²

300m²

100m²

1400m²

Capital investment

- Processing Equipment

Scientific Equipment Level -1	28 MCHF
Scientific Equipment Level +1	3 MCHF
Total	31 MCHF

- Cleanroom Infrastructures

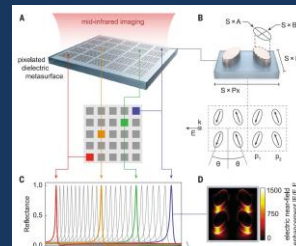
Cleanroom Infrastructures Level -1	12 MCHF
Cleanroom Infrastructures Level +1	7 MCHF
Total	19 MCHF

- Total 50MCHF



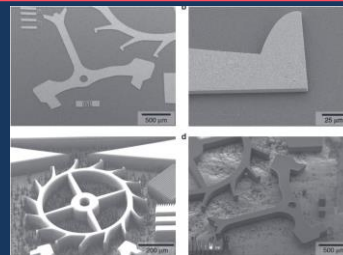
- × Prof. Altug
- × Science (8 June 2018)
- × DOI: 10.1126/science.aas9768

Bionanophotonic systems
for molecular detection



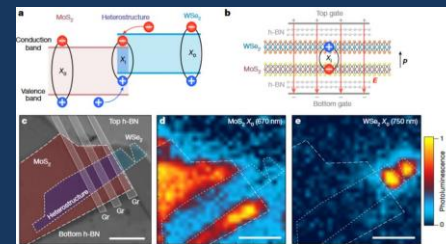
- × Prof. Quack
- × Nature Microsystems & Nanoengineering (18 June 2018)
- × DOI 10.1038/s41378-018-0014-5

Diamond mechanical parts



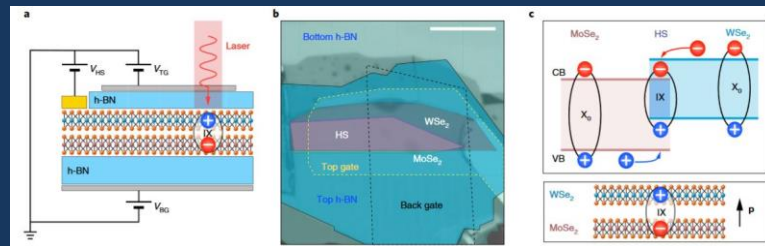
- × Prof. Kis
- × Nature (16 August 2018)
- × DOI : 10.1038/s41586-018-0357-y

Excitonic devices
working at room temperature
based on atomically thin
semiconductor

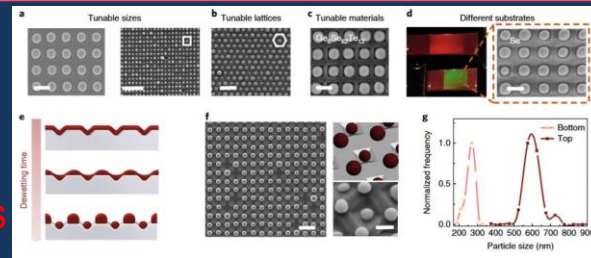


Publication highlights

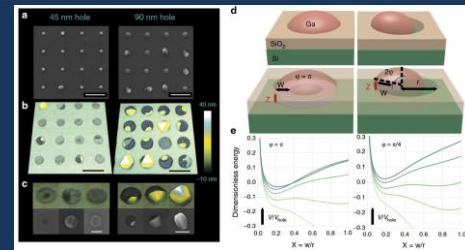
- ✗ Prof. Kis Excitonic devices
- ✗ Nature Photonics (31 December 2018)
- ✗ DOI : 10.1038/s41566-018-0325-y



- ✗ Prof. Sorin & Prof. Haltug Self-assembly of nanostructured glass metasurfaces via templated fluid instabilities
- ✗ Nature Nanotechnology
- ✗ DOI : 10.1038/s41565-019-0362-9



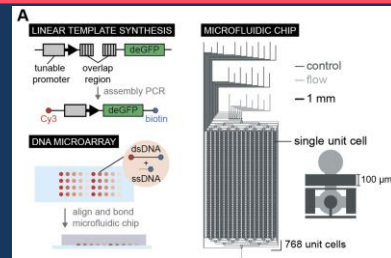
- ✗ Prof. Fontcuberta Growth of III/V nanowires on Si
- ✗ Nature Communications (20 February 2019)
- ✗ DOI : 10.1038/s41467-019-08807-9



Publication highlights

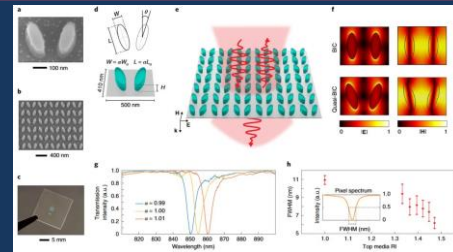
- × Prof. Maerkl
- × PNAS (7 February 2019)
- × DOI : 10.1073/pnas.1816591116

Microfluidic platform
for cell-free gene-regulatory
network



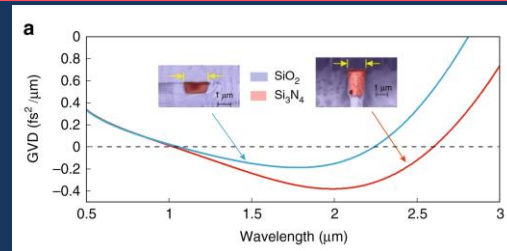
- × Prof. Haltug
- × Nature Photonics (01 April 2019)
- × DOI : 10.1038/s41566-019-0394-6

Nanophotonics biosensing



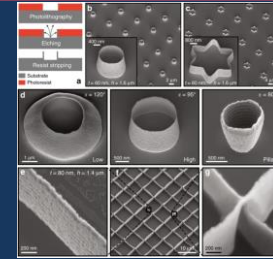
- × Prof. Kippenberg & Prof. Brès
- × Nature Communications (04 April 2019)
- × DOI : 10.1038/s41467-019-09590-3

Photonic spectroscopy



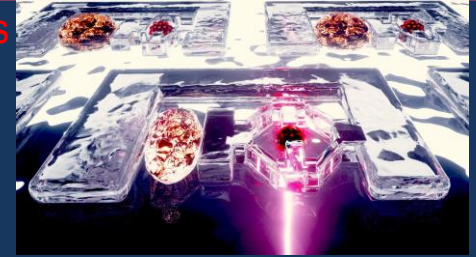
Publication highlights

- × Prof. Renaud **3D nanostructure manufacturing**
- × Nature Microsystems & Nanoengineering (22 April 2019)
- × DOI 10.1038/s41378-019-0052-7



- × Prof. Sakar
- × ERC Starting Grants 714609
- × ROBOCHIP
- × 1 March 2017 – 28 February 2022

Robotic micromanipulation systems
to perform automated operations
on 3D biological samples



- × Prof. Kippenberg
- × ERC Advanced Grant
- × ExCOM-cCEO
- × Announced 21 March 2019

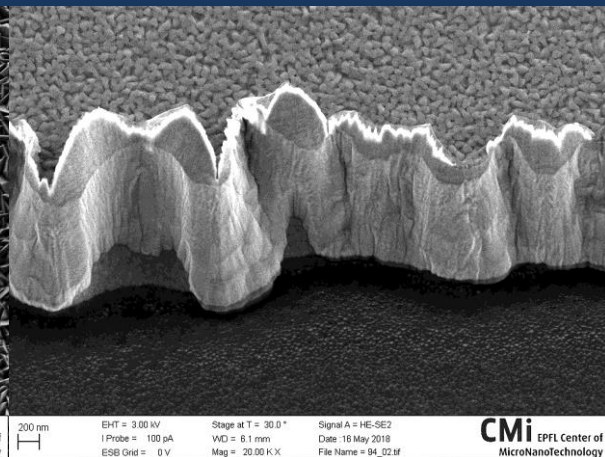
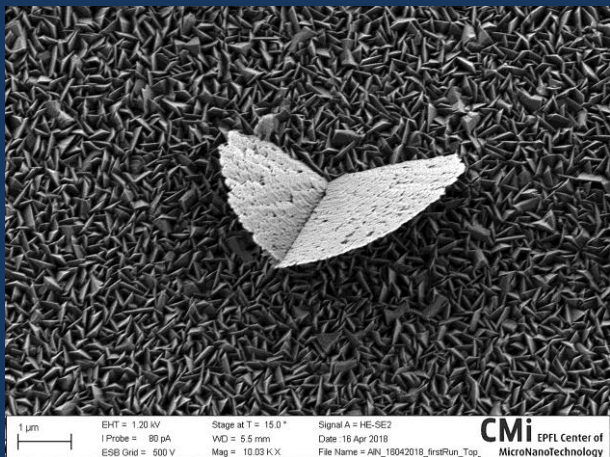
Extremely Coherent Mechanical Oscillators
and circuit Cavity Electro-Optics

- × Prof. Kippenberg
- × ERC Proof of Concept Grant
- × PhoMEC
- × Announced 03.05.2019

Photonic integrated optical frequency combs

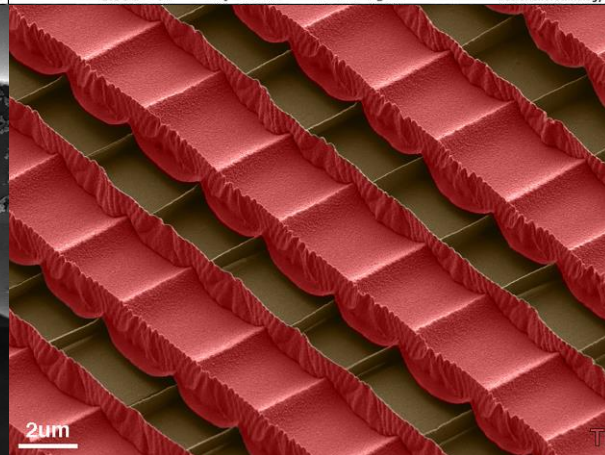
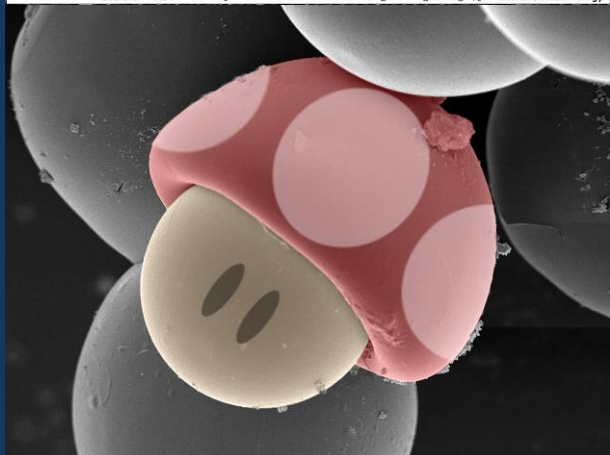
Picture of the month

AIN butterfly
Bahareh Ghadiani
LPQM, April 2018



Cliffs of Etretat
Richard Meunier
Aleva, May 2018

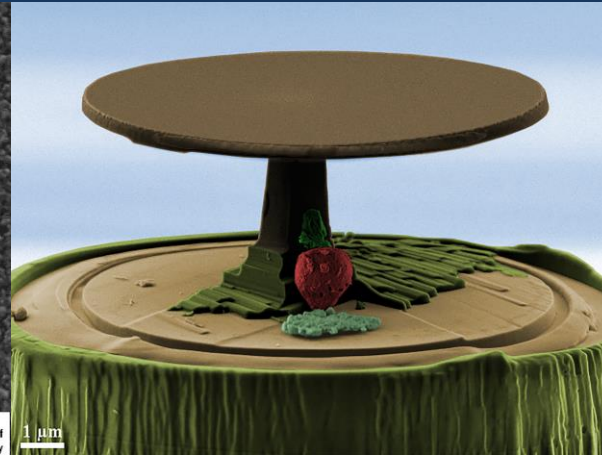
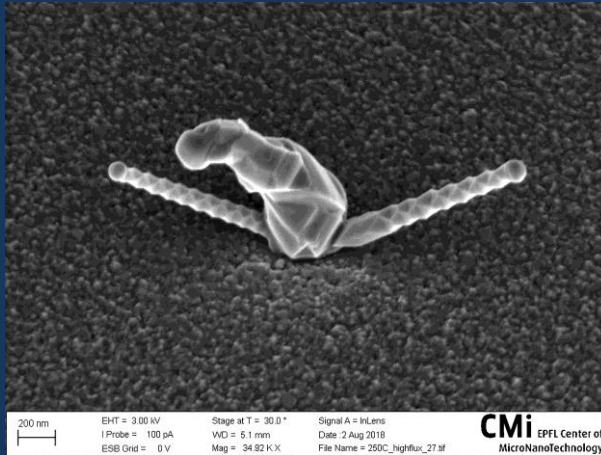
Toad from SuperMario
Antoine Vian
Mathias Steinacher
SMaL, June 2018



The opera house
Benoît Desbiolles
LMIS4, July 2018

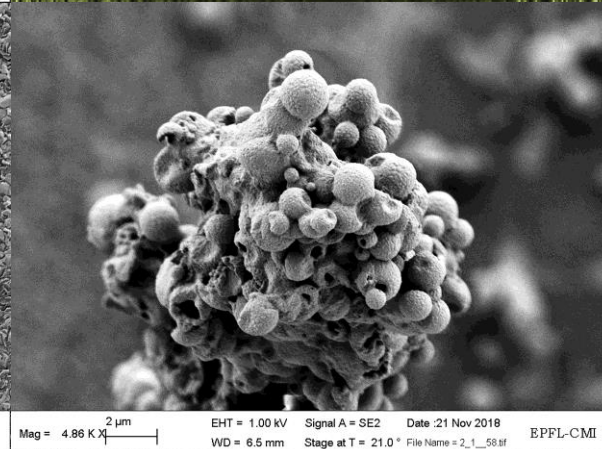
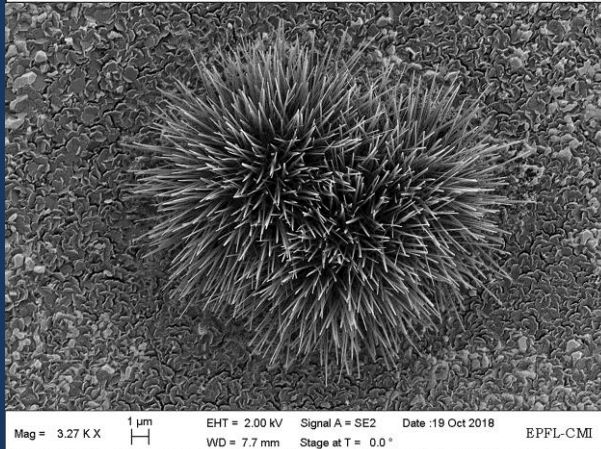
Picture of the month

Attack of the Gnomes
Simon Escobar Steinvall,
LMSC, August 2018



Strawberry & Mushroom
Teodoro Graziosi
Q-Lab, September 2018

MgO urchin on Mg coral
Matthieu Rüegg
Lorenz Hagelüken
LMIS1, October 2018



Rare coral
Anastasiia Glushkova
LPMC, November 2018

Picture of the month

Ancient Carvings

Amin Hodaei
SMal, December 2018



Mag = 500 X EHT = 3.00 kV Signal A = InLens Chamber Status = at HV
20 µm WD = 5.1 mm Aperture Size = 30.00 µm Chamber = 5.24e-01 Pa
Image Pixel Size = 223.3 nm Stage at T = 0.0 ° Date : 7 Dec 2018



2 µm EHT = 3.00 kV Stage at T = 20.7 ° Signal A = InLens
I Probe = 100 pA WD = 6.5 mm Date : 25 Jan 2019
ESB Grid = 0 V Mag = 4.26 K X File Name = im_26.tif

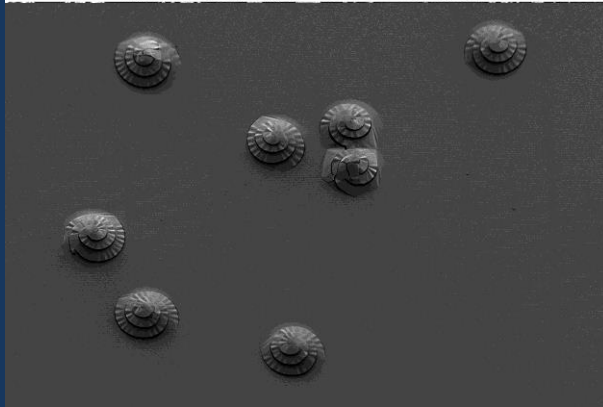
CMi EPFL Center of
MicroNanoTechnology

Manhattan Skyline

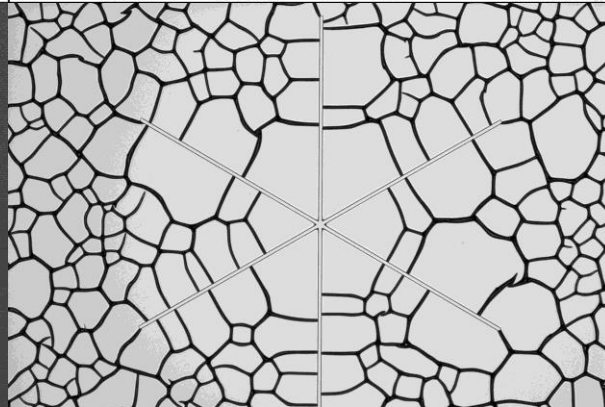
Riyaz Mohammed Abdul,
Remco van Erp
PowerLab, January 2019

Alumina Sea Snails

Alain Yuji Takabayashi
Q-Lab, February 2019



100 µm EHT = 1.00 kV Stage at T = 30.0 ° Signal A = HE-SE2
I Probe = 200 pA WD = 5.5 mm Date : 11 Feb 2019
ESB Grid = 0 V Mag = 188 X File Name = image_14.tif




CMi EPFL Center of
MicroNanoTechnology


Metallic spider web

Lucas Güniat,
LMSC, March 2019



Mag = 240 X  20 μ m
EHT = 10.00 kV Signal A = SE2 Date :3 Apr 2019
WD = 15.8 mm Stage at T = 60.0 ° File Name = catherine_3072px_03.tif EPFL-CMI



Mag = 566 X  10 μ m
EHT = 10.00 kV Signal A = SE2 Date :3 Apr 2019
WD = 17.0 mm Stage at T = 60.0 ° File Name = catherine_3072px_10.tif EPFL-CMI

Abstracts 2019

- 220 posters collected in the brochure



Program

- Very exciting program
- 10 presentations
- Spanning an exceptionally broad range
- Try to be different every year
- Not always invite the heavy users
- Emphasize on the new Professors @ EPFL
- Sometimes also some exotic users
- One common point:
 - MicroNanoFabrication

MicroNanoFabrication Annual Review Meeting

Date: Tuesday May 7th, 2019
Time: 09h30 – 17h00
Place: EPFL, Forum Rolex Learning Center, RLC E1 240

Program:

09h30-10h00	Coffees and Croissants, Distribution of Badges and Proceedings
10h00-10h15	Philippe Renaud & Philippe Flückiger (https://cmi.epfl.ch/), Introduction
10h15-10h30	Heike Riel , IBM Fellow, Department Head Science & Technology, IBM Research, Ruschlikon, Title of the talk to be announced soon
10h30-10h45	Vivek Subramanian (https://iaft.epfl.ch/), Additive fabrication of electronics and MEMS: From printable materials to integrated systems
10h45-11h00	Philip Moll , (https://qmat.epfl.ch/), Quantum materials: new electronic functionality on the micron-scale
11h00-11h30	Break
11h30-11h45	Olivier Martin , (https://nam.epfl.ch/), Alloyed nanostructures and metasurfaces
11h45-12h00	Guillermo Villanueva , (https://nems.epfl.ch/), Piezoelectric suspended microchannel resonators
12h00-12h15	Selman Sakar , (https://microbs.epfl.ch/), Soft robotic microsystems for biomedical applications
12h15-14h30	Lunch & Poster Session
14h30-14h45	Michael Graetzel , (https://ipi.epfl.ch/), Mesoscopic photosystems for the generation of electricity and fuels from Sunlight
14h45-15h00	Sandro Carrara , (http://icwww.epfl.ch/~scarrara/), Very recent advances on memristive sensors: the born of a new field of research
15h00-15h30	Break
15h30-15h45	Hatice Altug , (https://bios.epfl.ch/), Nanophotonic metasurfaces for next-generation biosensors
15h45-16h00	Yusuf Leblebici , (https://ism.epfl.ch/), Next-generation non-volatile memory technologies and 3D integration
16h00-17h00	Cocktails & Poster Session

Thank you to the CMI staff



Enjoy the conference

