



# Ecole polytechnique fédérale de Lausanne

## EPFL MicroNanoFabrication Annual Review Meeting

Philippe Flückiger, EPFL, May 8<sup>th</sup>, 2018

**CMi** EPFL Center of  
MicroNanoTechnology

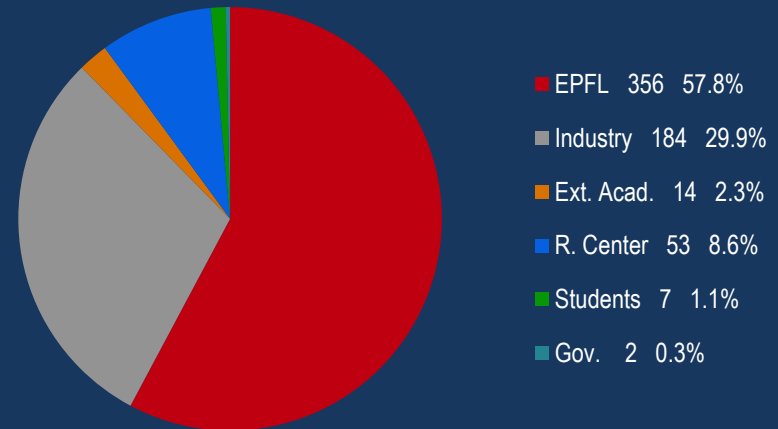
Next editions :

- ✘ 20<sup>th</sup> 07.05.2019
- ✘ 21<sup>st</sup> 05.05.2020

# Welcome & thanks

- Welcome to the 19<sup>th</sup> edition of the CMi MicroNanoFabrication Annual Review Meeting
- 616 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 cleanrooms



- -> Traveling from 14 different countries
- -> Networking

# Outline

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

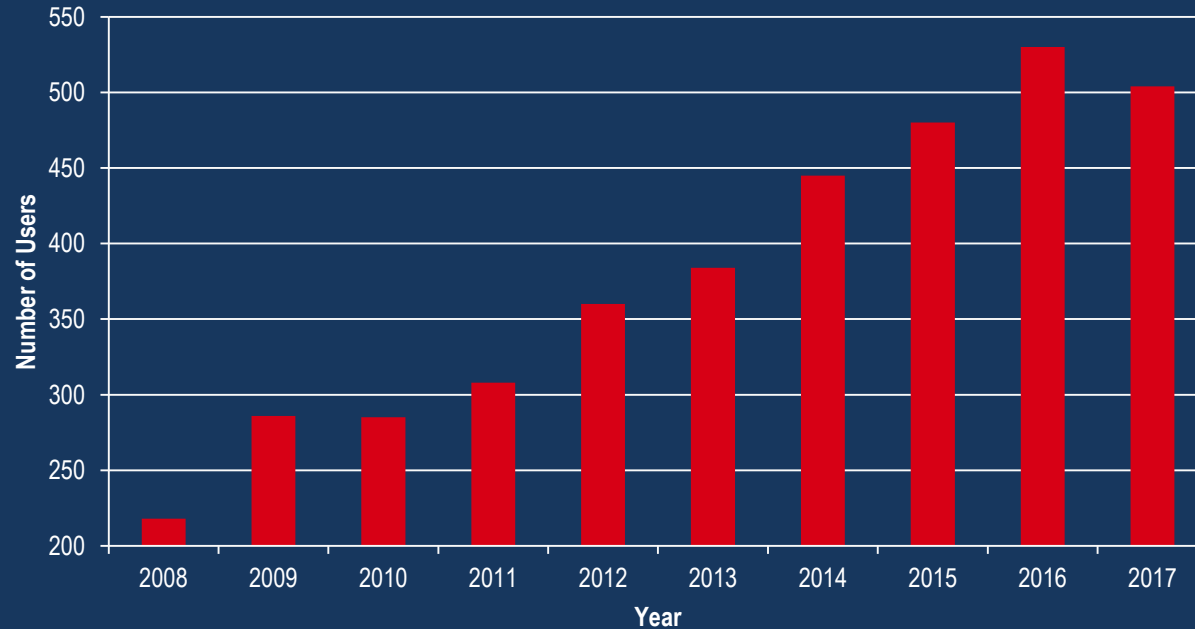


# Users in 2017

EPFL Engineering Sc.		Basic Sc.	Life Sc.	Ext. Ac.	Companies	
CMi	STI-IMT-LMIS4	SB-IPHYS-GCMP	SV-GHI-UPKIN	EXT-CERN	EXT-Aleva	EXT-Sofradir
STI-IBI-BIOS	STI-IMT-LMITS	SB-IPHYS-GR-GA	SV-IBI-UPDEPLA	EXT-CSEM_E1	EXT-Asulab	EXT-Synova
STI-IBI-CLSE	STI-IMT-LO	SB-IPHYS-LASPE	SV-IBI-UPLUT	EXT-CSEM_T1	EXT-Bruker	EXT-TESCAN
STI-IBI-LBEN	STI-IMT-LOB	SB-IPHYS-LEB	SV-IBI-UPNAE	EXT-CSEM_T3	EXT-Colibrys	EXT-Xsensio
STI-IBI-LBNC	STI-IMT-LSBI	SB-IPHYS-LOEQ	SV-ISREC-UPGON	EXT-CSEM-Muttentz	EXT-Efficonseil	
STI-IBI-LBNI	STI-IMT-NAM	SB-IPHYS-LPMC	SV-ISREC-UPHUELSKEN	EXT-EMPA	EXT-EXALOS	
STI-IBI-LHTC	STI-IMT-OPT	SB-IPHYS-LPMV		EXT-HEIG-VD-MNT	EXT-INTEL	
STI-IBI-LNE	STI-IMT-PV-LAB	SB-IPHYS-LPN		EXT-HESGE	EXT-Karmic	
STI-IEL-GR-SCI	STI-IMX-FIMAP	SB-IPHYS-LPQM1	IC-IINFCOM-LSI1	EXT-IMT_Bucharest	EXT-Ligentec	
STI-IEL-LANES	STI-IMX-INE	SB-IPHYS-LUMES		EXT-PSI	EXT-LSPR	
STI-IEL-LSM	STI-IMX-LMGN	SB-ISIC-LAS		EXT-UNIBE-Phys.	EXT-Lunaphore	
STI-IEL-NANOLAB	STI-IMX-LMM	SB-ISIC-LEPA	ENAC-IIC-LESO-PB	EXT-UniFribourg	EXT-Mackinac	
STI-IEL-POWERLAB	STI-IMX-LMOM	SB-ISIC-LND		EXT-UNIGE-GAP	EXT-MCH-processing	
STI-IGM-LRESE	STI-IMX-LMSC	SB-ISIC-LPI		EXT-UniZh	EXT-Meister-Abrasive	
STI-IGM-MICROBS	STI-IMX-LP	SB-ISIC-LSCI		EXT-Wyss_Center	EXT-Melexis	
STI-IGM-NEMS	STI-IMX-LPAC	SB-ISIC-LSPM			EXT-Morphotonix	
STI-IGM-RRL	STI-IMX-LTP	SB-NL-CMNT			EXT-Novagan	
STI-IMT-ESPLAB	STI-IMX-SMAL	SB-SPC-PP			EXT-Piemacs	
STI-IMT-GR-LVT	STI-IMX-SUNMIL				EXT-Preciflex	
STI-IMT-GR-QUA	STI-SCI-PM				Ext-Rheon_Medical	
STI-IMT-LAI					EXT-Rolex	
STI-IMT-LAPD					EXT-Sigatec	
STI-IMT-LMIS1					EXT-SilMach	
STI-IMT-LMIS2					EXT-Simplinext	
327 (44)		66 (18)	32 (8)	34 (15)	45 (28)	

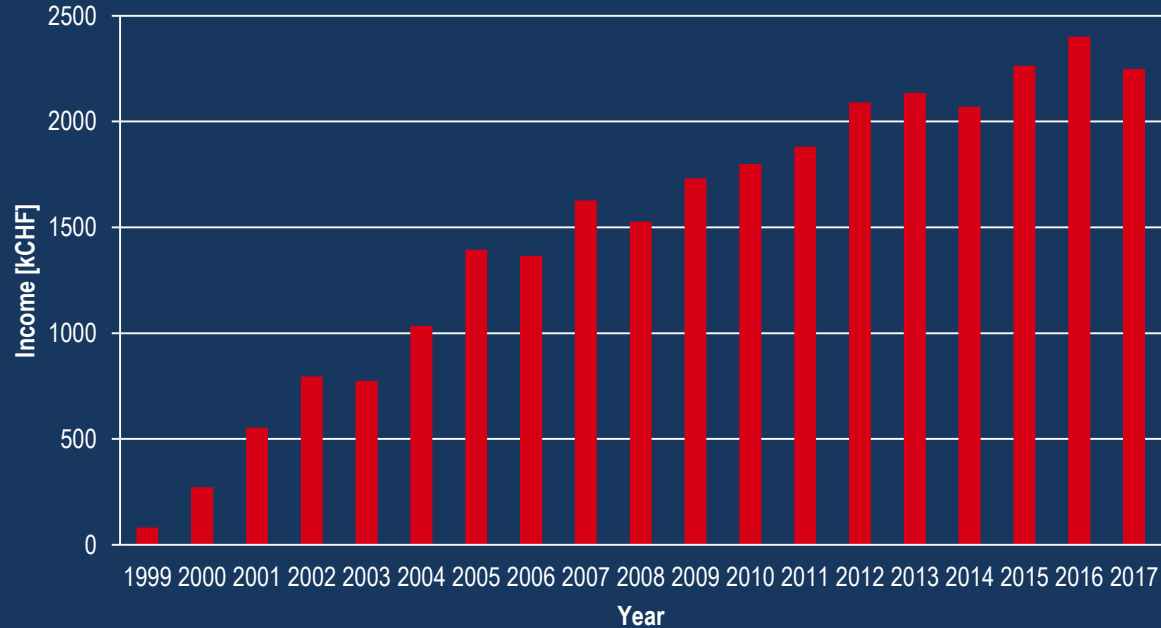
- Total: 504 users operating the CMi tools
- (Total: 113 labs or companies)

## Number of Users



- Correction by -12% of the number of Users occurred in 2017 (explained !)
- Growth expected to be back in 2018 for the next 10 years 😊

## Fees paid by the Users



- Correction by -8% of the fees paid by the Users occurred in 2017 (explained !)
- Growth expected to be back in 2018 for the next 10 years 😊



- Corrections (of #users & fees) explained by the new invoicing regime applied since October 1<sup>st</sup> 2016:
- 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)
- CMi has now an SNSF compatible transparent cost accounting methodology (CMi bills are eligible)
- CMi has more available capacity, less bottlenecks on the tools
- Growth expected to be back in 2018 for the next 10 years (many new labs starting to use the CMi)
- 2018 : 8% cut on the envelope A (salary) allocated to the CMi in 2018
- Estimated operating expense 2017 : 8MCHF
- Fees paid by the users 2017 : 2MCHF
- Operating result 2017 : - 200 KCHF

VP for Research  
Andreas Mortensen



## Executive Board

Dir. of Res. Affairs  
Matthias Gäumann



Pres. of the Board  
Philippe Renaud



Board Member  
Jürgen Brugger



Board Member  
Anna Fontcuberta



Board Member  
Nicolas Grandjean



Board Member  
Adrian Ionescu



Dir. of Operations  
Philippe Flückiger



Board Member  
Tobias Kippenberg



Board Member  
Andras Kis



Board Member  
Stéphanie Lacour



Board Member  
Yusuf Leblebici



Board Member  
Elison Matioli



Board Member  
Paul Muralt



Board Member  
Niels Quack



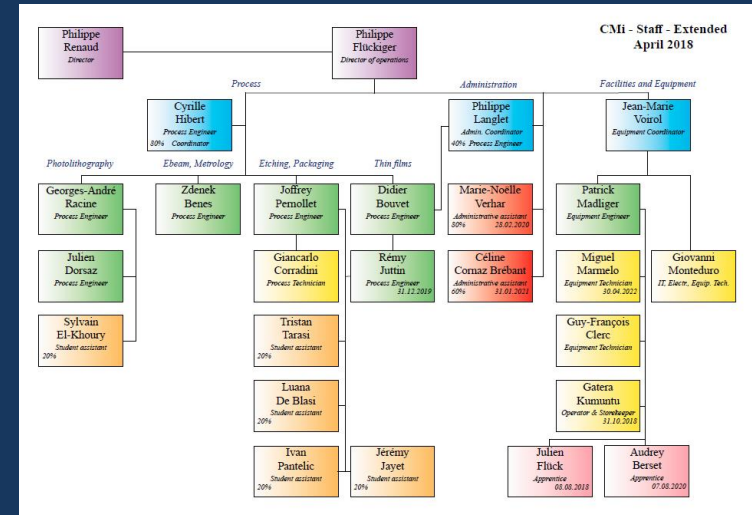
Board Member  
Guillermo Villanueva



- 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 currently composed of 13 Professors including our president



- Staff composed of 18.6 FTE employees
- Whole staff under permanent positions since May 1<sup>st</sup> 2018
- 5 CDD were transformed into 5CDI on May 1<sup>st</sup> 2018
- Employ 5 student assistants (part time)
- Train 2 apprentices



# New tools installed in 2017

- ✗ Dry HF Vapor Release Tool – Accepted 23.06.2017
  - + SPTS UEtch
  - + SNSF R'Equip grant 170759 Prof. Niels Quack
  - + Sacrificial SiO<sub>2</sub> layers etching, well controlled etch rate, high selectivity
  - + Release of silicon microstructures in MEMS devices without stiction



- ✗ Reactive Ion Etching system – Accepted 06.07.2017
  - + TOKYO ELECTRON UNITY Me w/1 DRM & w/1 SCCM chamber
  - + SNSF R'Equip grant 206021-164014 Prof. Tobias Kippenberg
  - + Low roughness SiO<sub>2</sub> & Si<sub>3</sub>N<sub>4</sub>
  - + High selectivity
  - + High aspect ratio



- ✗ 2<sup>nd</sup> Atomic Layer Deposition System - Accepted August 2017
  - + BENEQ TFS200
  - + SNSF R'Equip grant 0910-3395 Prof. Jeremy Luterbacher
  - + Coating of particles with Al<sub>2</sub>O<sub>3</sub> TiO<sub>2</sub> MgO
  - + Deposition of magnetic materials(e.g. NiFe CoFe)



# New tools installed in 2017

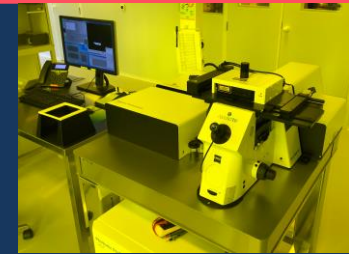
- ✗ Glovebox Workstation – Accepted 30.10.2017
  - + MBRAUN MB-Unilab Plus SP
  - + For ALD precursors conditioning
  - + With large main antechamber and vacuum pump
  - + Less than 1 ppm oxygen and moisture



- ✗ Pulsed Laser Deposition System – Accepted 20.12.2017
  - + SOLMATES SMP800
  - + H2020 ERC advanced grant 695459 “Milli-Tech” Prof. Adrian Ionescu
  - + 2 chambers
  - + VO<sub>2</sub>, HfO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>
  - + PZT, LaNiO<sub>3</sub>



- ✗ 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)

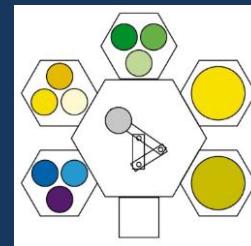


# Tools under evaluation & Budget requests for 2018

- × DUV Stepper lithography system
  - + SNSF R'Equip grant 206021-170750 Prof. Tobias Kippenberg
  - + Call for tender published on 09.02.2018 and closed on 21.03.2018
  - + Technical evaluation
  - + Cost evaluation

- × DUV Photoresist Coater & Developer
  - + Dedicated to DUV stepper lithography

- × Physical Vapor Deposition Cluster Tool (sputtering)
  - + Submission deadline SNSF R'Equip :15.05.2018
  - + Prof. Guillermo Villanueva
  - + Deposition of dielectric materials
  - + Multilayers & Bragg reflectors
  - + Co-sputtering of metals, nitrides & oxides



# Tools under evaluation & Budget requests for 2018

- × High Density Plasma Enhanced Chemical Vapor Deposition System
  - + Prof. Tobias Kippenberg

- × Chemical Mechanical Polishing System & Post CMP cleaner
  - + Prof. Tobias Kippenberg

- × Metrology tools
  - + Spectro-Reflectometer
  - + Mechanical Profiler
  - + 3 Optical Microscopes

# 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

2018

- DUV stepper
- Second EBEAM at the horizon of 2022

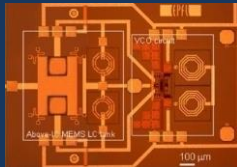


# Evolution

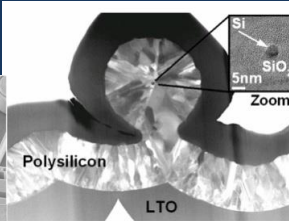
CMi tools ...



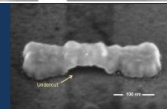
IC



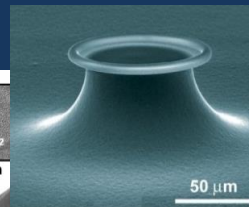
MEMS



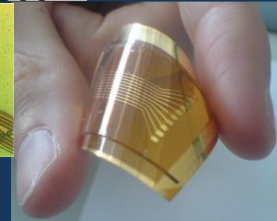
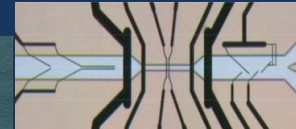
Nano



Bio

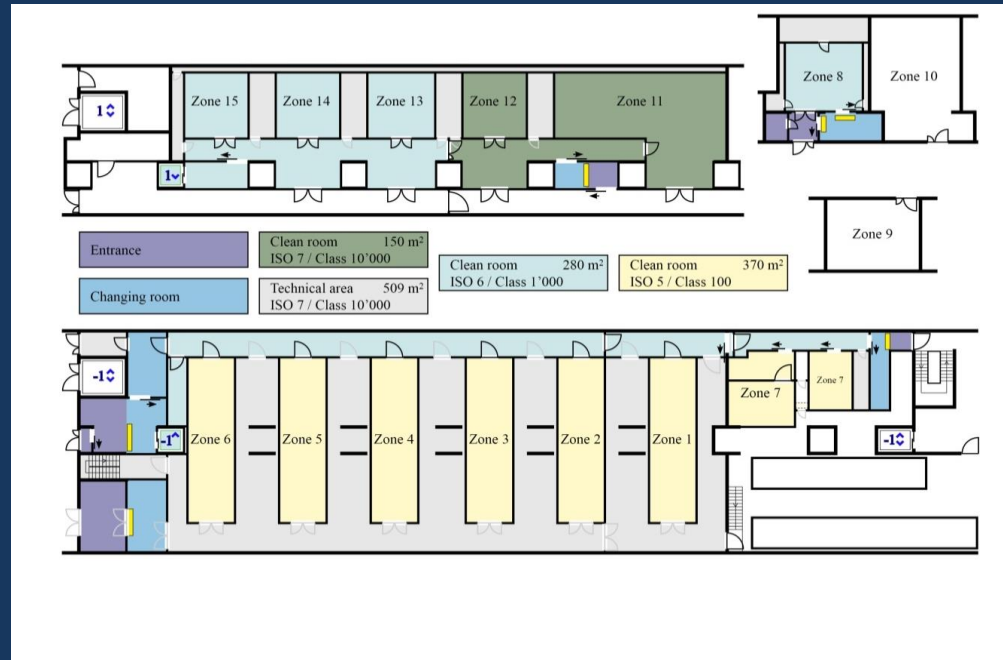


Materials



CMi projects ...

# Cleanroom



**Initial surface (1998)**

**Extension (2010)**

**Extension (2017)**

**Total surface**

1000m<sup>2</sup>

300m<sup>2</sup>

100m<sup>2</sup>

1400m<sup>2</sup>

# Capital investment

- Processing Equipment

Scientific Equipment Level -1	28 MCHF
Scientific Equipment Level +1	3 MCHF
<b>Total</b>	<b>31 MCHF</b>

- Cleanroom Infrastructures

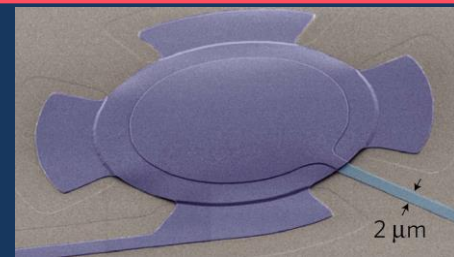
Cleanroom Infrastructures Level -1	12 MCHF
Cleanroom Infrastructures Level +1	7 MCHF
<b>Total</b>	<b>19 MCHF</b>

- Total 50MCHF

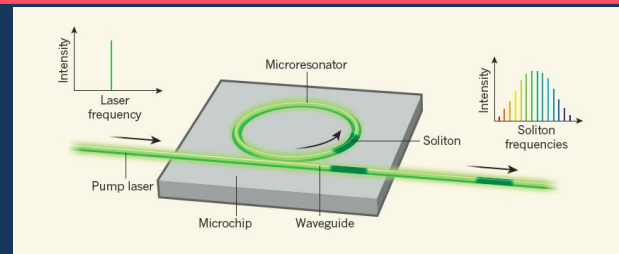


# Publication highlights

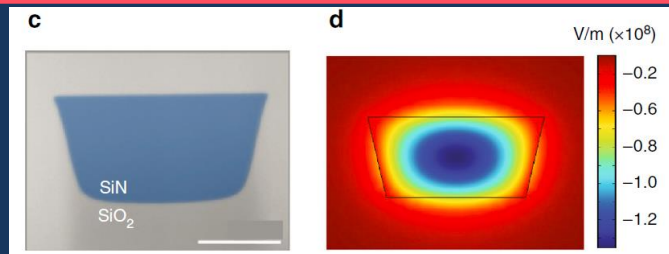
- × Prof. Kippenberg
- × Nature Physics (15 May 2017)
- × DOI: 10.1038/NPHYS4121



- × Prof. Kippenberg
- × Nature Volume 546 (8 June 2017)
- × doi:10.1038/nature22387

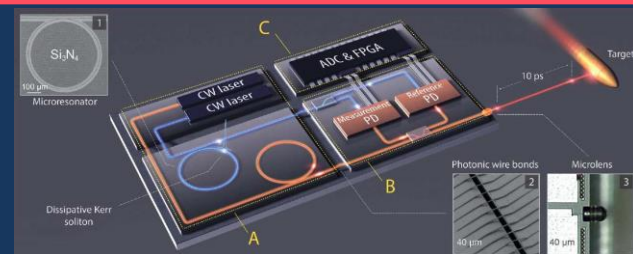


- × Prof. Brès & Prof. Kippenberg
- × Nature Communication (18 October 2017)
- × DOI: 10.1038/s41467-017-01110-5

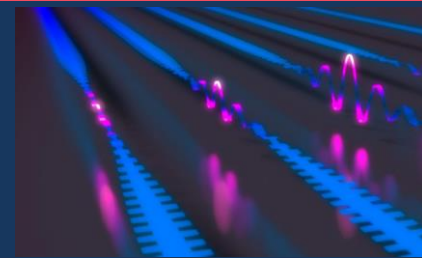


# Publication highlights

- ✗ Prof. Kippenberg
- ✗ Science 359 (6378), 887-891 (23 February 2018)
- ✗ DOI: 10.1126/science.aao3924

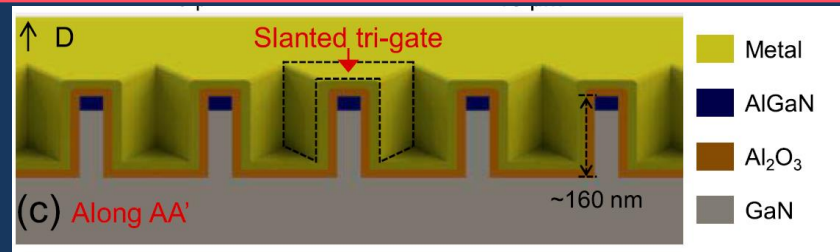


- ✗ Prof Kippenberg
- ✗ Science (12 April 2018)
- ✗ DOI: 10.1126/science.aar6939

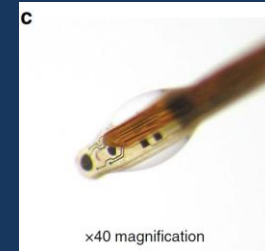


# Publication highlights

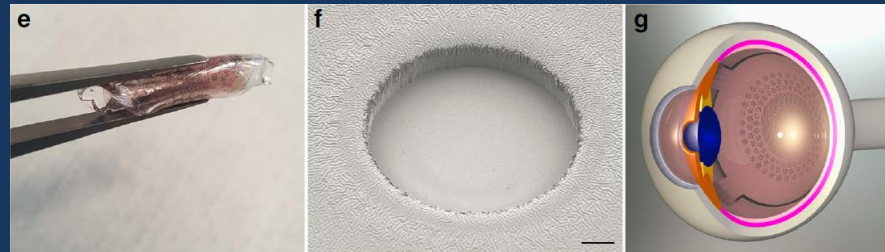
- × Prof. Matioli
- × IEEE Electron Device Letters (25 July 2017)
- × DOI: 10.1109/LED.2017.2731799



- × Prof. Renaud
- × NATURE COMMUNICATIONS (01 Nov. 2017)
- × DOI: 10.1038/s41467-017-01419-1



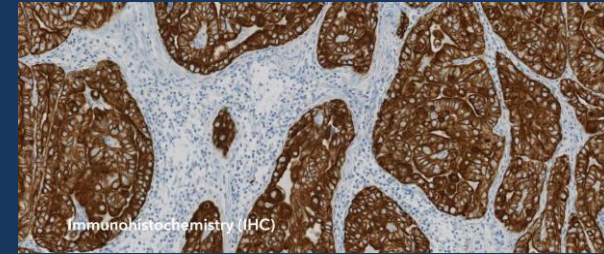
- × Prof. Ghezzi
- × NATURE COMMUNICATIONS (08 March 2018)
- × DOI: 10.1038/s41467-018-03386-7





# Press releases

- × La start-up lausannoise Lunaphore lève 6 millions de francs
- × 4 octobre 2017
- × (Tissue Diagnostics)



- × Aleva Neurotherapeutics lève 13 millions de dollars
- × 6 octobre 2017
- × (Deep Brain Stimulation)



- × Intel's new smart glasses hands-on (5<sup>th</sup> February 2018) 😊
- × Intel is giving up on its smart glasses (18<sup>th</sup> April 2018) ☹️
- × (Smart Glasses)



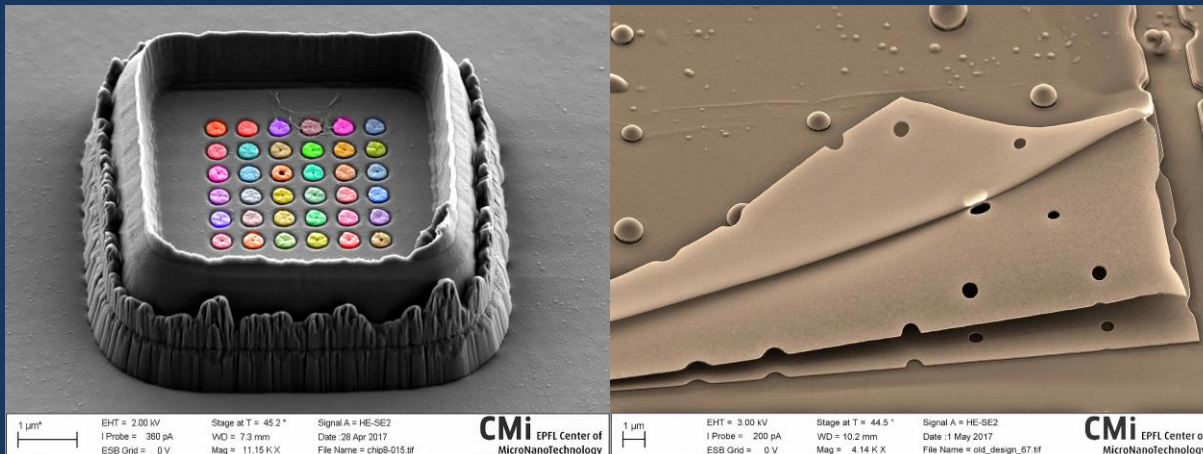
# Publication highlights

- × Nagi Biosciences
- × Organism-on-Chip technology
- × EPFL Press Release
- × May 1st 2018



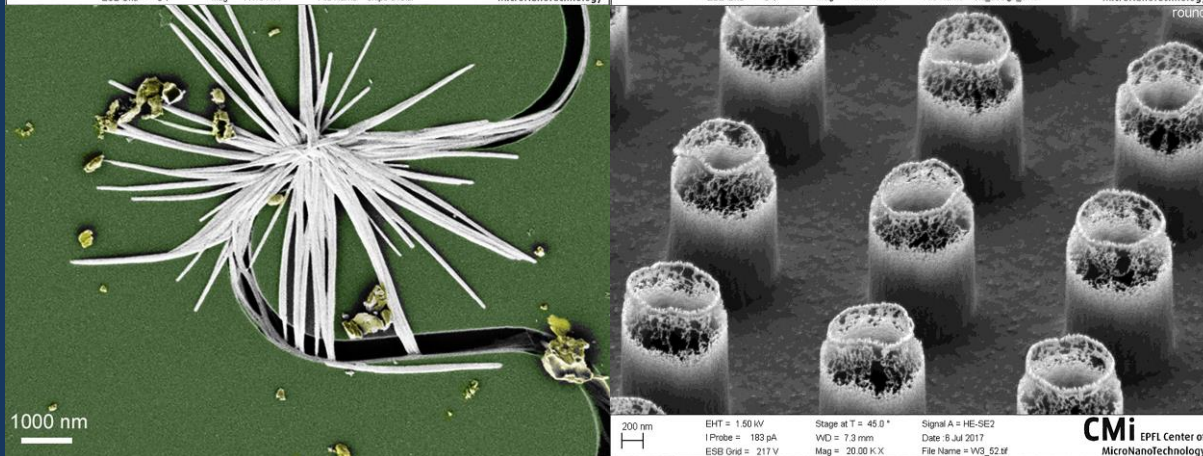
# Picture of the month

**Makeup palette**  
Elmira Shahrabi  
LSM, April 2017



**Emmental CMI AOP**  
Michael Graf  
LBEN, May 2017

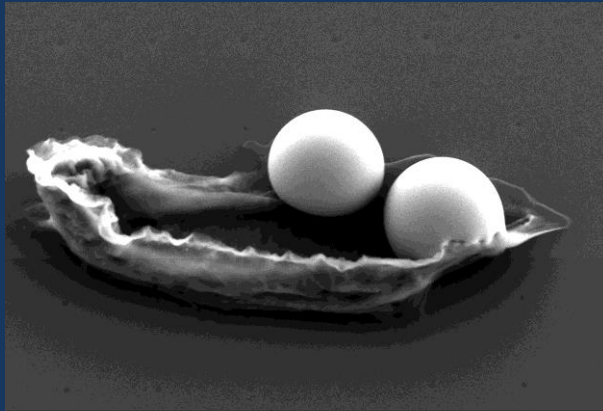
**Edelweiss and its pollen**  
Anastasiia Glushkova  
LPMC, June 2017



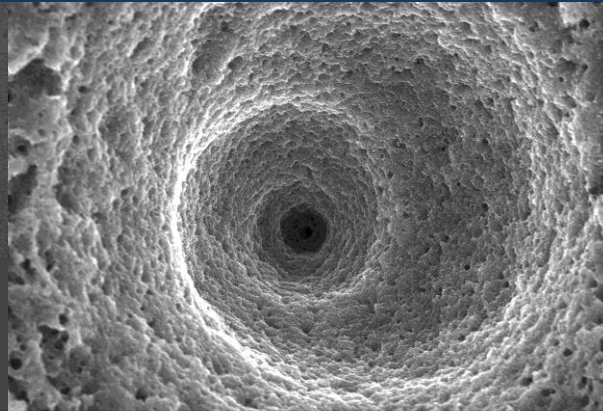
**HSQuid**  
Stefano Varricchio  
LMIS4, July 2017

# Picture of the month

**Haricots gris**  
Wonjong Kim,  
LMSC, August 2017



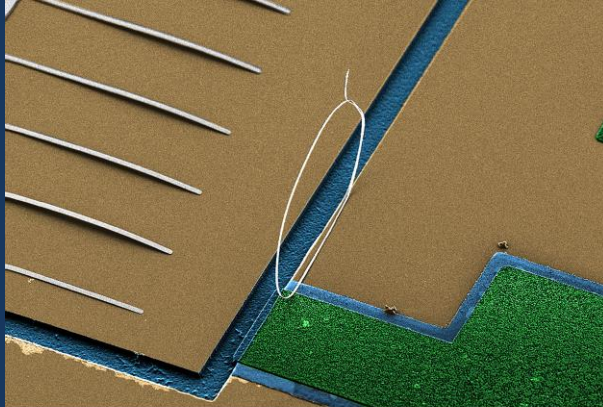
200 nm EHT = 3.00 kV Stage at T = 20.0 ° Signal A = HE-SE2  
I Probe = 180 pA Date :31 Aug 2017  
ESB Grid = 0 V Mag = 22.00 K X File Name = 800 nm pitch\_45 nm hole18.tif



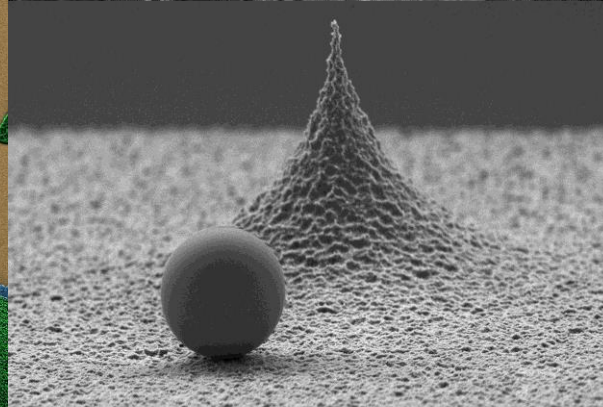
1 µm EHT = 10.00 kV Stage at T = 0.0 ° Signal A = InLens  
I Probe = 110 pA Date :6 Sep 2017  
ESB Grid = 0 V Mag = 9.33 K X File Name = vr990\_016.tif

**Nano-tornado**  
Clémentine Lipp  
CERN, September 2017

**Cantilever Rodeo**  
Kaitlin Howell  
NEMS, October 2017



Mag = 665 X 20 µm EHT = 3.00 kV Signal A = SE2 Date :20 Oct 2017  
WD = 7.2 mm Stage at T = 45.0 ° File Name = sem\_19.tif EPFL-CMI



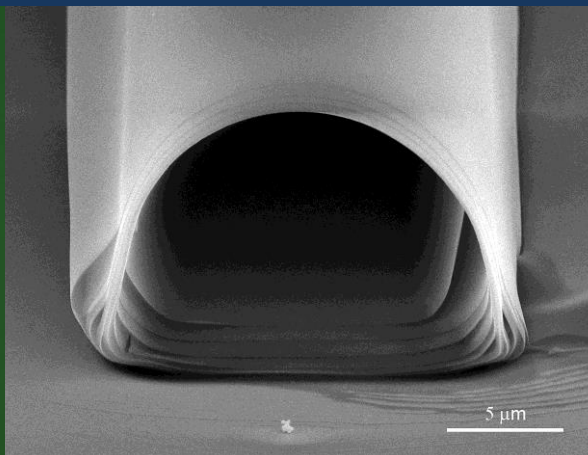
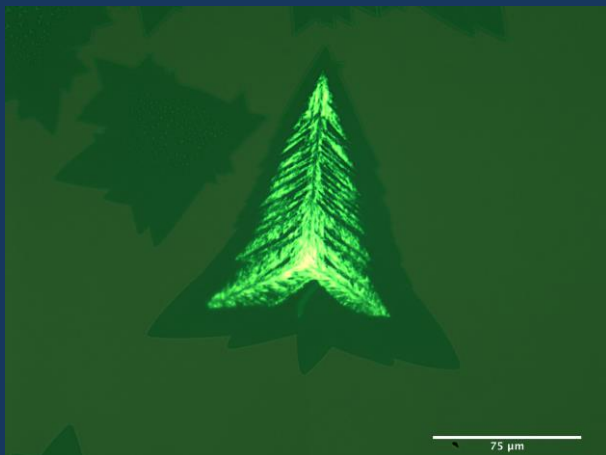
2 µm EHT = 3.00 kV Stage at T = 10.0 ° Signal A = InLens  
I Probe = 8 pA Date :22 Nov 2017  
ESB Grid = 0 V Mag = 3.50 K X File Name = sample\_16\_80deg\_1.tif

**Micro-golf in the CMI**  
Hendrik Schütz  
LPQM, November 2017



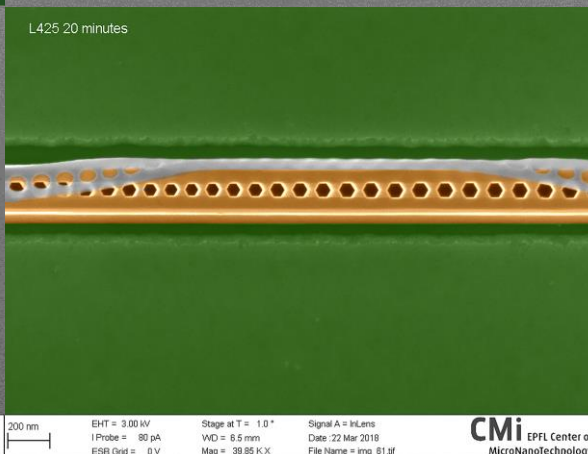
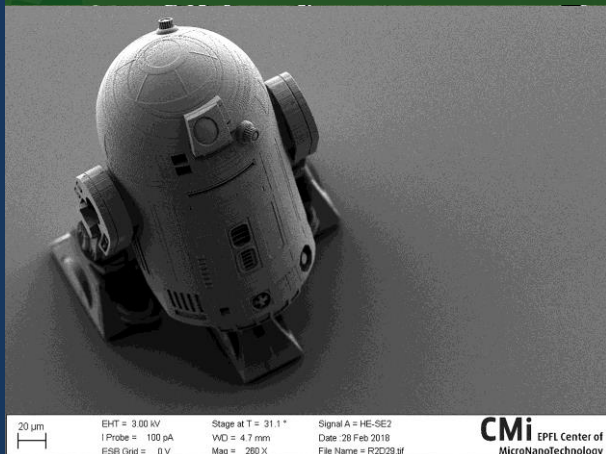
# Picture of the month

**MoS2 in Christmas mood**  
Martina Lihter  
LBEN, December 2017



**Micro puff pastry roll**  
Esteban Bermudez  
AMI, January 2018

**Micro R2-D2**  
Julien Dorsaz  
CMi, February 2018



**A snake sheds its skin**  
Ian Rousseau  
LASPE, March 2018

# Abstracts 2017

- 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 8<sup>th</sup>, 2018  
Time: 09h30 – 17h00  
Place: EPFL, Forum Rolex Learning Center, RLC E1 240

### Program:

<b>09h30-10h00</b>	Coffees and croissants, distribution of badges and proceedings
10h00-10h15	<b>Philippe Renaud &amp; Philippe Flückiger</b> ( <a href="http://cmi.epfl.ch">http://cmi.epfl.ch</a> ), Introduction
10h15-10h45	<b>Julia Greer</b> , (California Institute of Technology), Materials by design: 3-dimensional nano-architected meta-materials
10h45-11h15	<b>Franz Laermer</b> , (Robert Bosch GmbH, Stuttgart), BOSCH microfabrication technologies shaping MEMS
<b>11h15-11h45</b>	<b>Break</b>
11h45-12h00	<b>Jürgen Brugger</b> , ( <a href="https://imis1.epfl.ch/">https://imis1.epfl.ch/</a> ), Nano-engineering using a heated scanned probe
12h00-12h15	<b>Niels Quack</b> , ( <a href="https://q-lab.epfl.ch">https://q-lab.epfl.ch</a> ), Carving micro- and nanostructures in single crystal diamond
12h15-12h30	<b>Tobias Kippenberg</b> , ( <a href="https://k-lab.epfl.ch">https://k-lab.epfl.ch</a> ), Quantum optomechanics and optical frequency combs with microresonators
<b>12h30-14h45</b>	<b>Lunch &amp; Poster session</b>
14h45-15h00	<b>Demetri Psaltis</b> , ( <a href="https://lo.epfl.ch">https://lo.epfl.ch</a> ), Microfluidic devices for electrolysis
15h00-15h15	<b>Elison Matioli</b> , ( <a href="http://powerlab.epfl.ch">http://powerlab.epfl.ch</a> ), Nanoscale technologies for efficient power conversion
<b>15h15-15h45</b>	<b>Break</b>
15h45-16h00	<b>Philippe Renaud</b> , ( <a href="http://imis4.epfl.ch">http://imis4.epfl.ch</a> ), From the lab to the fab: how simple technologies translate into innovative products
16h00-16h15	<b>Jamie Paik</b> , ( <a href="https://rrl.epfl.ch">https://rrl.epfl.ch</a> ), Soft origami robots
16h15-16h20	<b>Jochen Zimmer</b> , ( <a href="https://www.nanoscribe.de">https://www.nanoscribe.de</a> ), Materializing ideas by additive microfabrication
<b>16h20-17h00</b>	<b>Cocktails &amp; Poster session</b>

# Enjoy the conference

