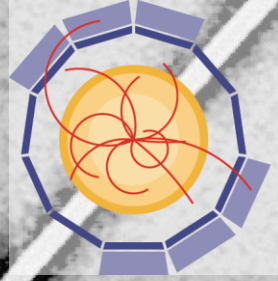


AIDA 2020

Development and production of silicon micro-channels prototypes: Paris contribution

Marco Bomben, LPNHE & UPD, Paris

AIDA 2020, 2nd annual meeting

4-7/4/2017, LPNHE-Paris

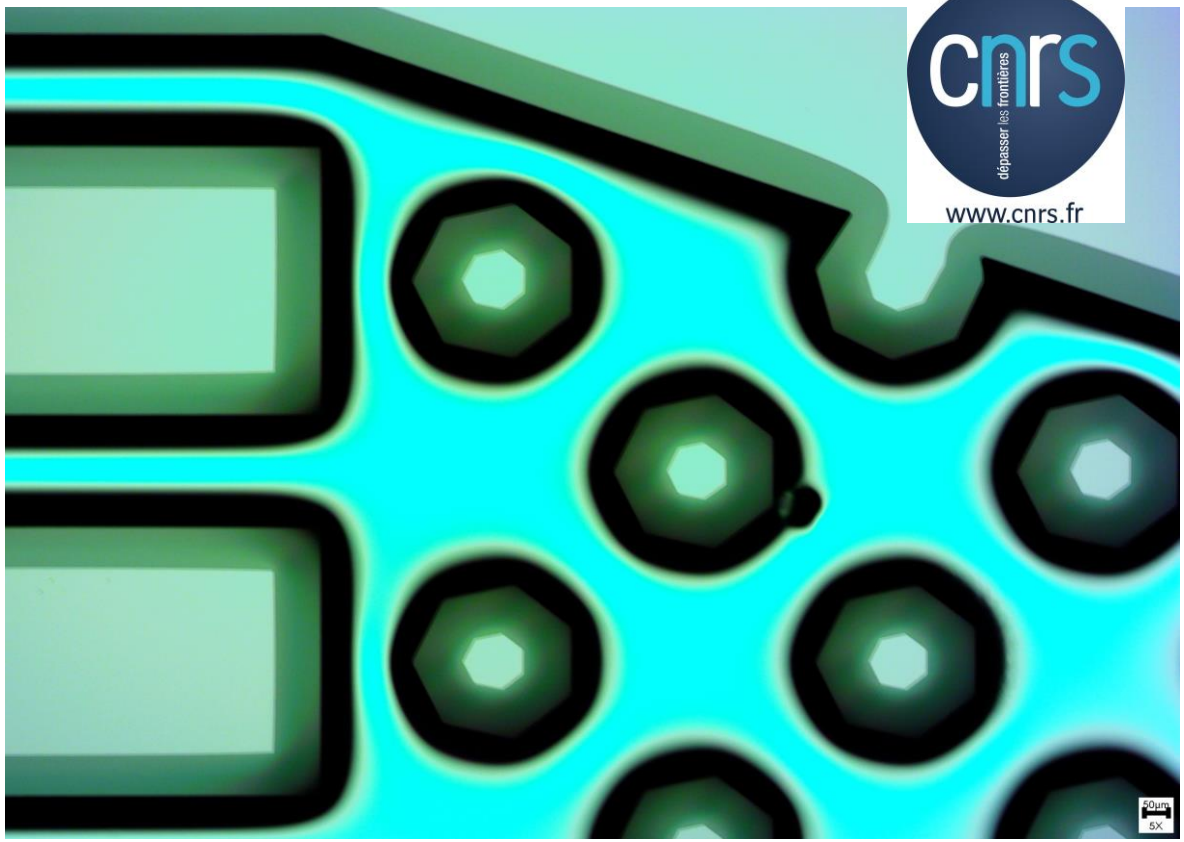
Outline

REFLECS projects

REFroidissement LÉger au CO_2 en Silicium

Financed by CNRS through the call "L'instrumentation aux limites"

- Reflecs & Reflecs2: partners
- The project
- Actions
- Status
- Conclusion & Outlook



Reflecs & Reflecs2: partners

AIDA 2020

REFLECS

REFroidissement LÉger au CO_2 en Silicium

M. Bomben[1], S. Bortolin[2], M. Boscardin[3], G. Calderini[1], M. Crivellari[3], J. R. Coudevylle[4], D. Del Col[2], A. Mapelli[5], P. Petagna[6], G. Romagnoli[6], S. Ronchin[3]

1 LPNHE, Paris – France ; 2 DII, Padova – Italy ; 3 FBK, Trento - Italy; 4 IEF, Orsay – France ; 5 PH-DT-EO (CERN), Meyrin – Switzerland ; 6 PH-DT-DI (CERN), Meyrin - Switzerland

www.cnrs.fr

The Reflecs & Reflecs2 project

- Two main research axes

1. Develop cooling building blocks for HEP and more
   - Not only using CO_2 (*e.g.* R1234ze(E))

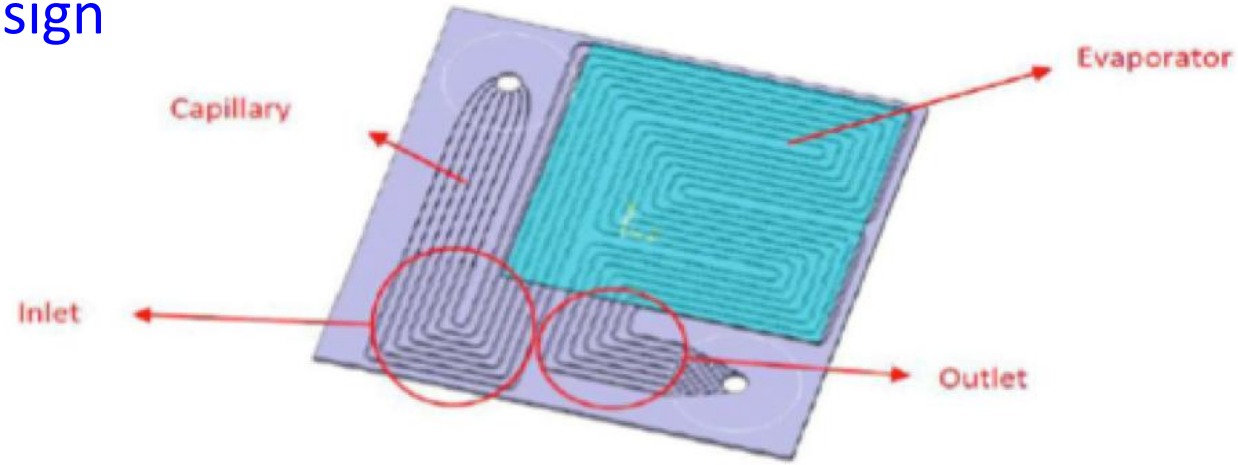
2. Study fundamental properties of 2-phase fluids in micro-channels
   - ➢ In particular in high pressure* regime
   - * 30-100 bars: lack of data and models in literature

The Reflecs & Reflecs2 project

- Two main research axes

1. Develop cooling building blocks for HEP and more

- Not only using CO_2 (*e.g.* R1234ze(E))
  - SNAKE design

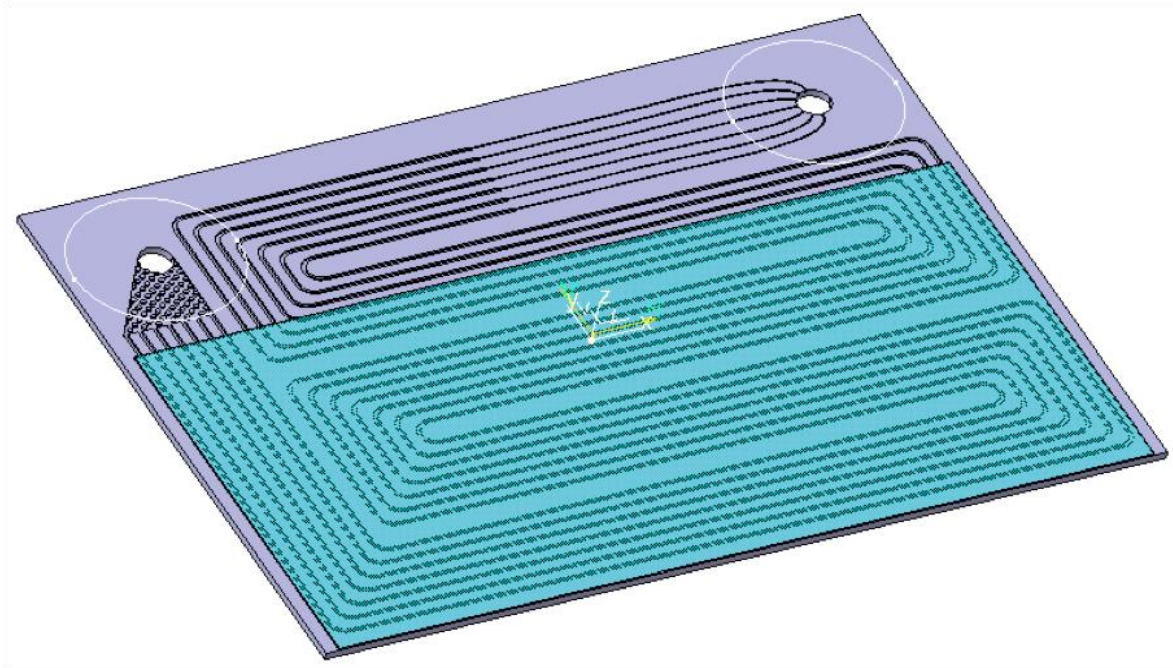


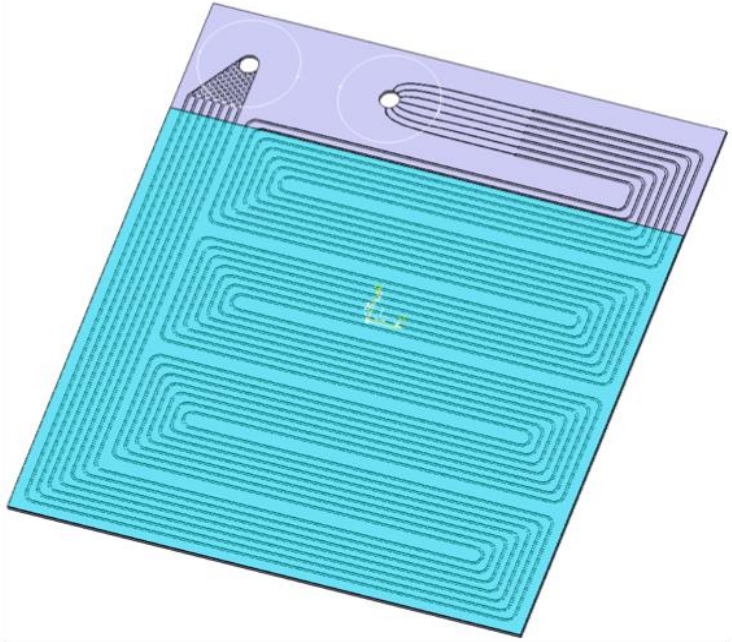
Dimensions optimized thanks to DII-Padua colleagues

7 parallel 120 µm deep, 200 µm wide channels, with a 700 µm pitch.

The Reflecs & Reflecs2 project

"Snake" design microchannel cooling unit size		
Design	Width [mm]	Height [mm]
Single	30.0	30.0
Double	30.0	41.3
Quad	42.4	48.0





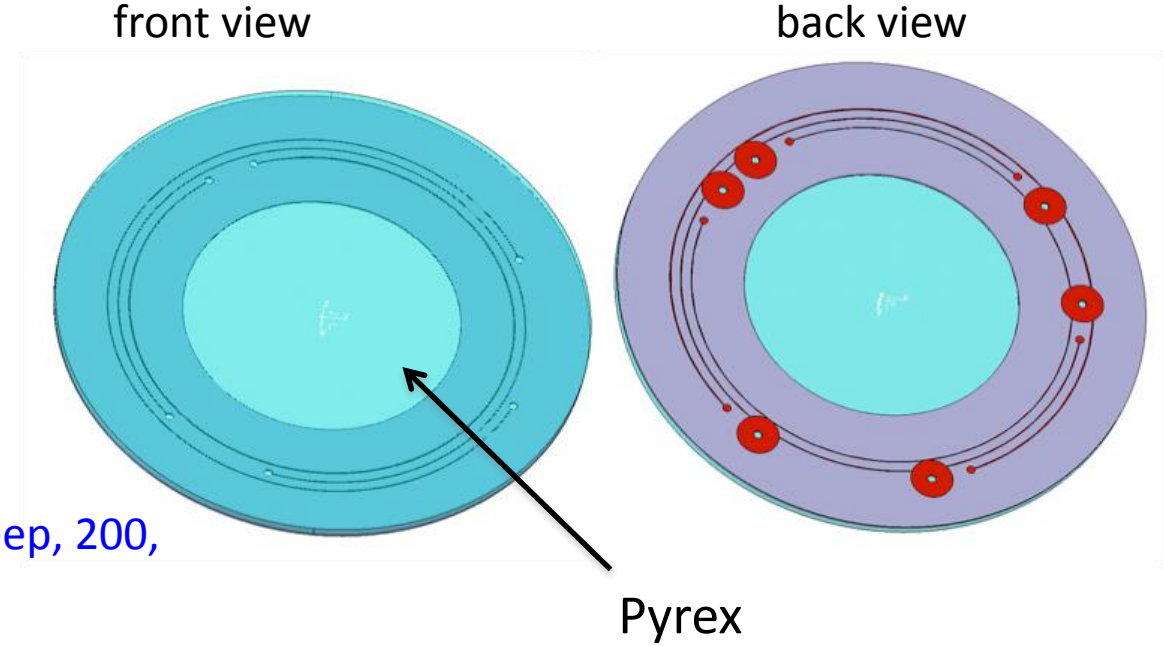
The Reflecs & Reflecs2 project

- Two main research axes

2. Study fundamental properties of 2-phase fluids in micro-channels

2. In particular in high pressure* regime
3. 30-100 bars: lack of data and models in literature

- Doughnut design



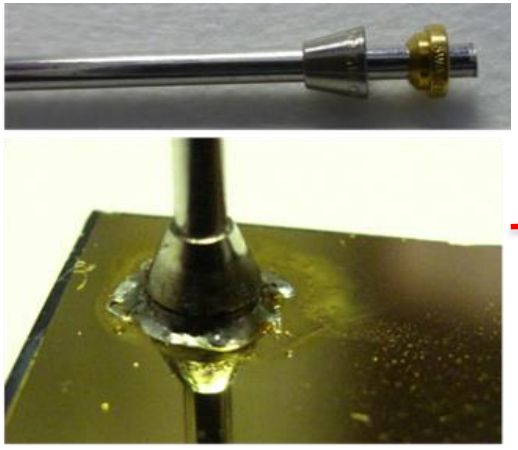
Three concentric circular channels, 200 µm deep, 200, 150 and 100 µm wide

The Reflecs & Reflecs2 project

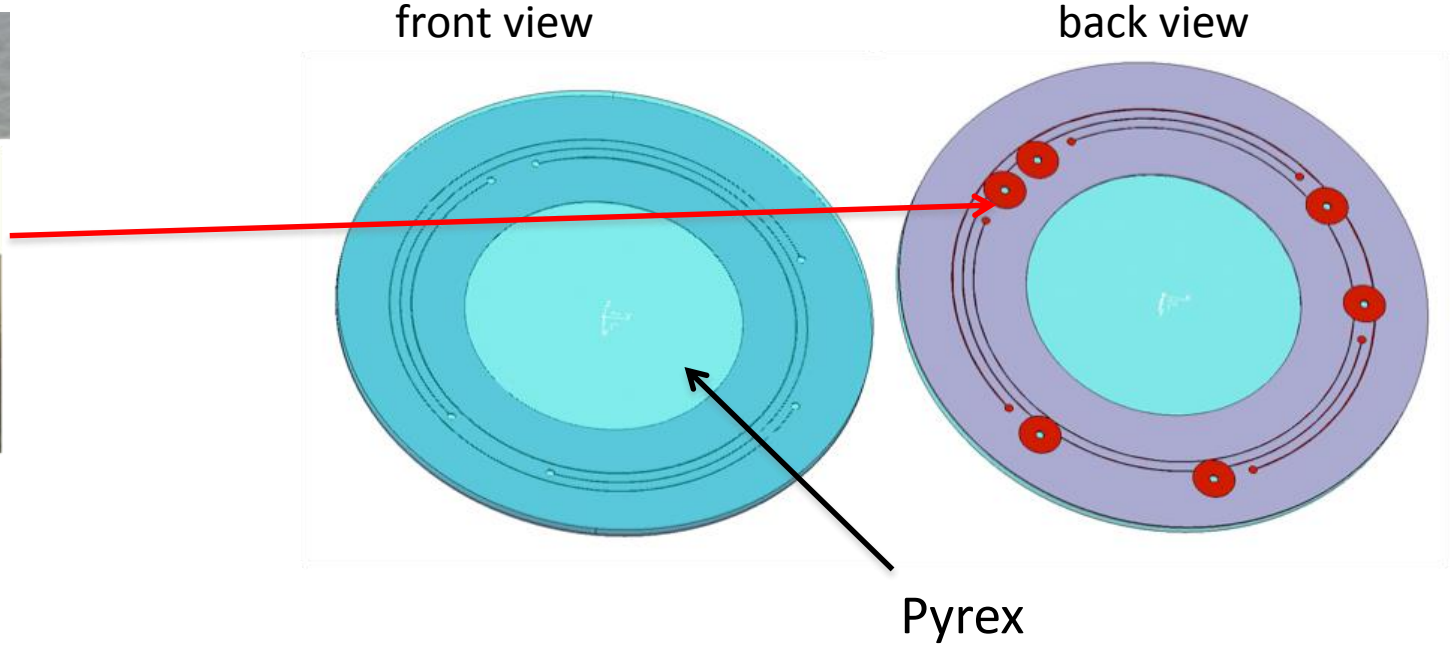
- Two main research axes

2. Study fundamental properties of 2-phase fluids in micro-channels

2. In particular in high pressure* regime
3. 30-100 bars: lack of data and models in literature

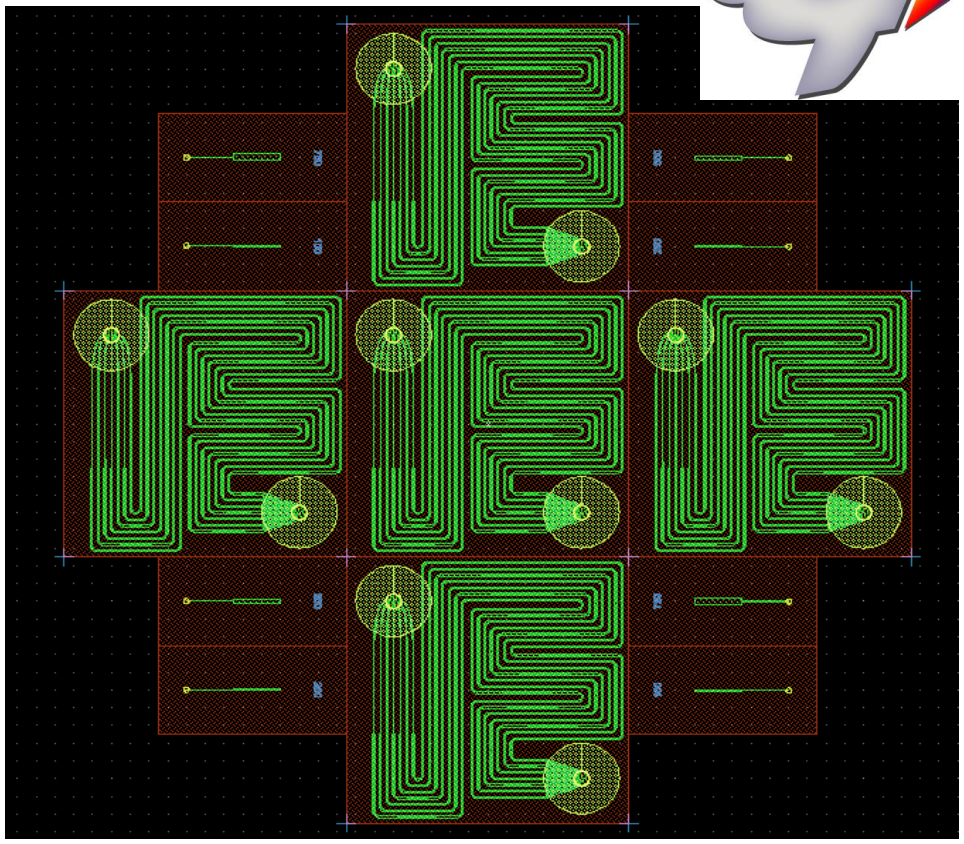


External connection for tests



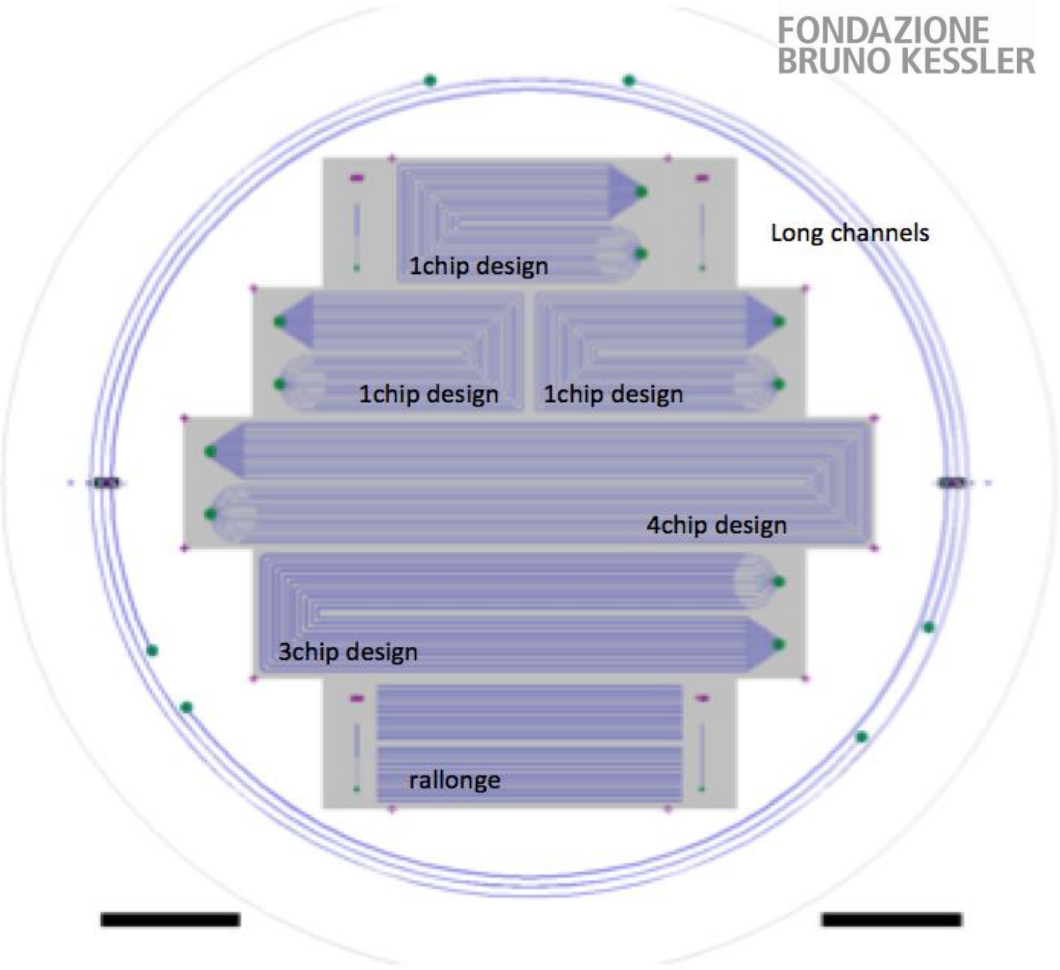
Two productions of silicon µ-channels

- IEF, Orsay



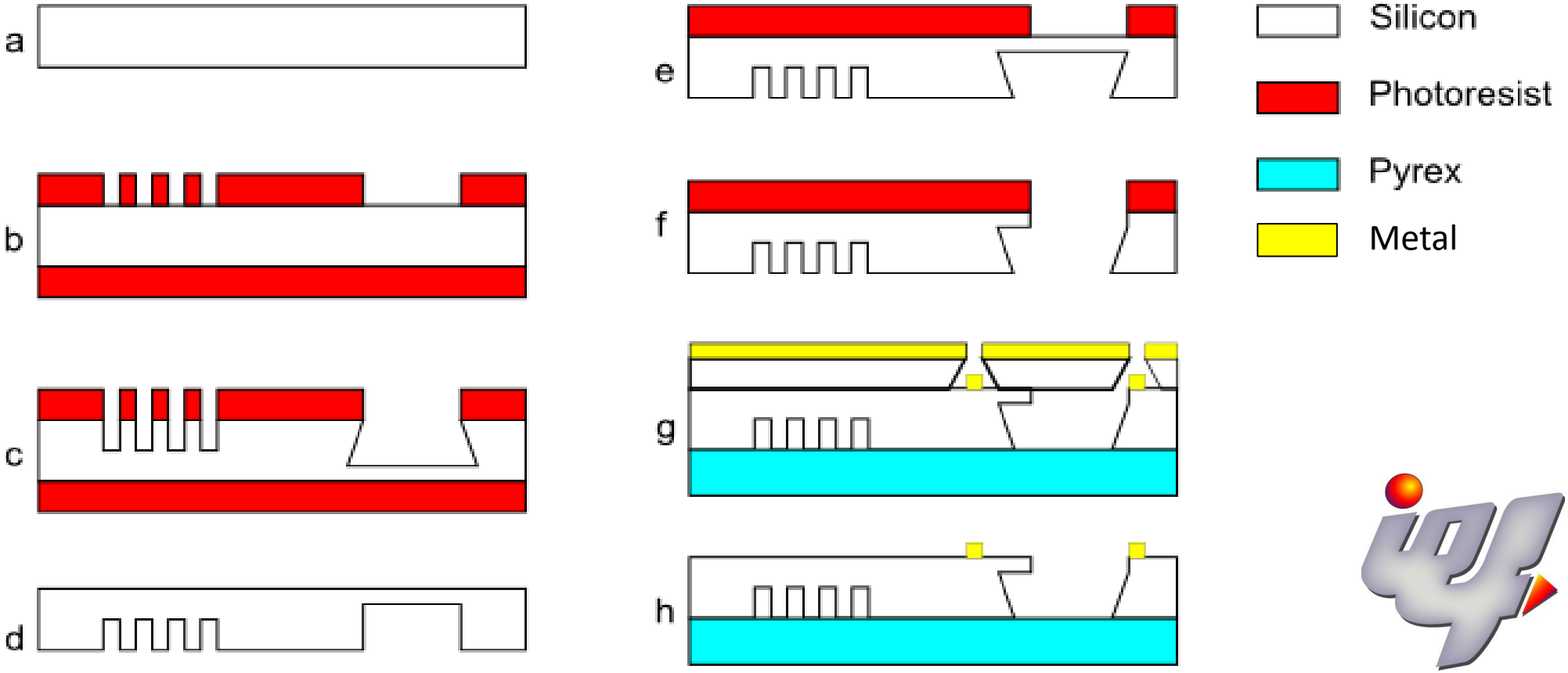
- On 4” wafers
  - Single channel wafers too

- FBK, Trento – Italy



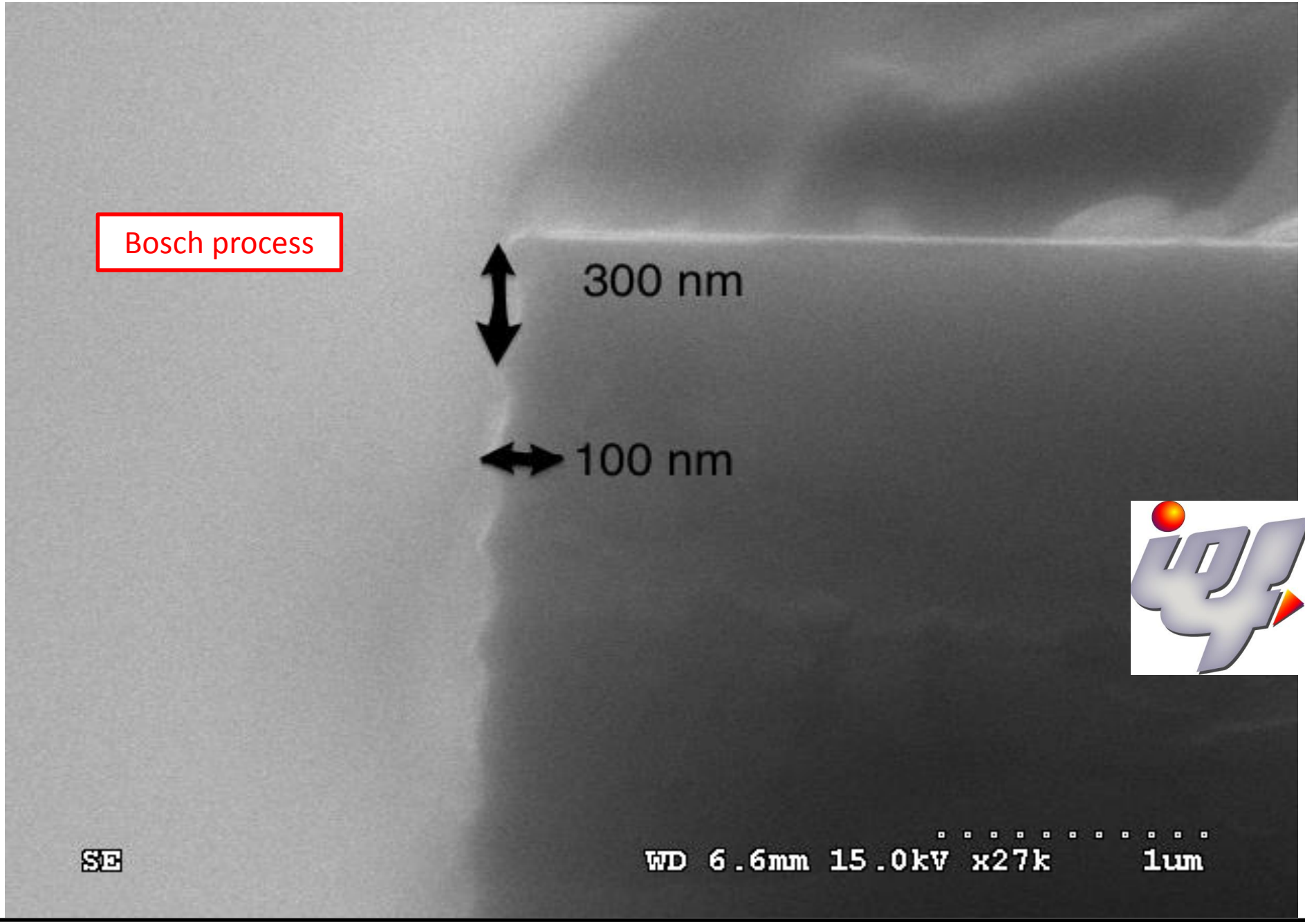
- On 6” wafers

Fabrication process

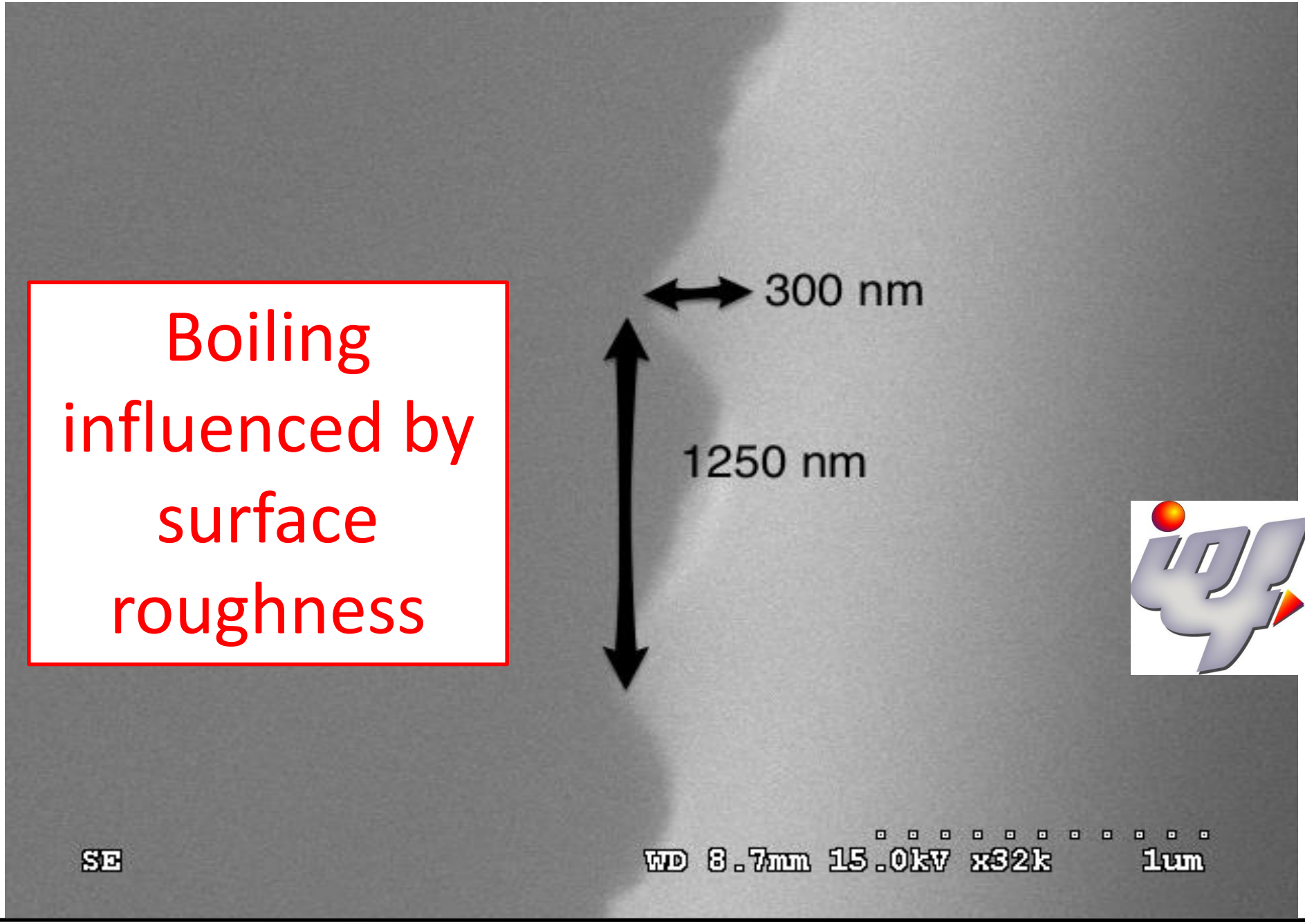


Similar at FBK

Scalloping



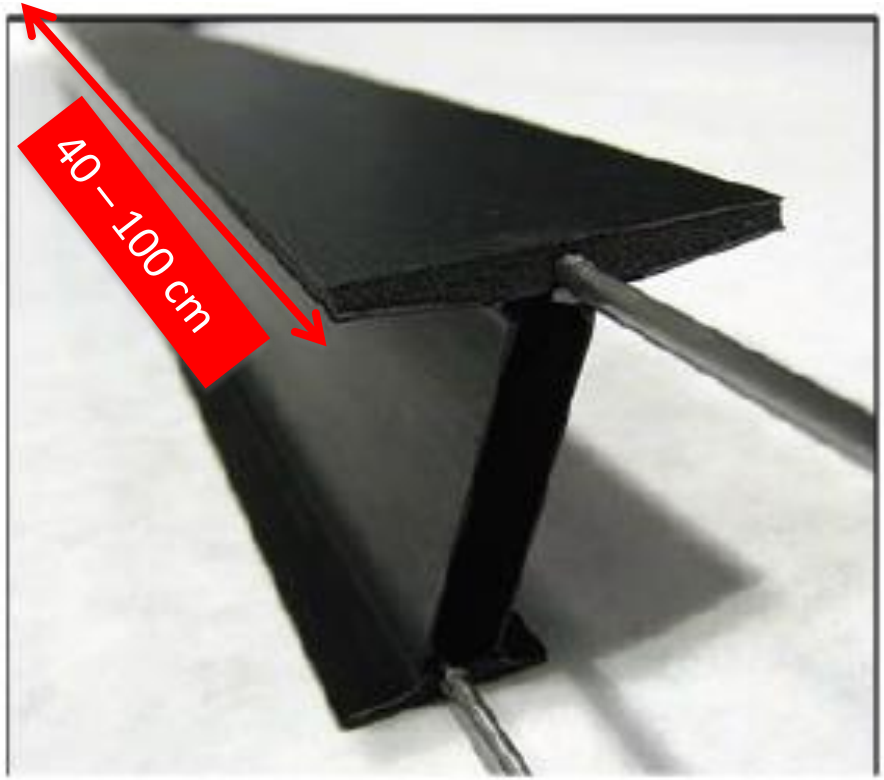
Scalloping

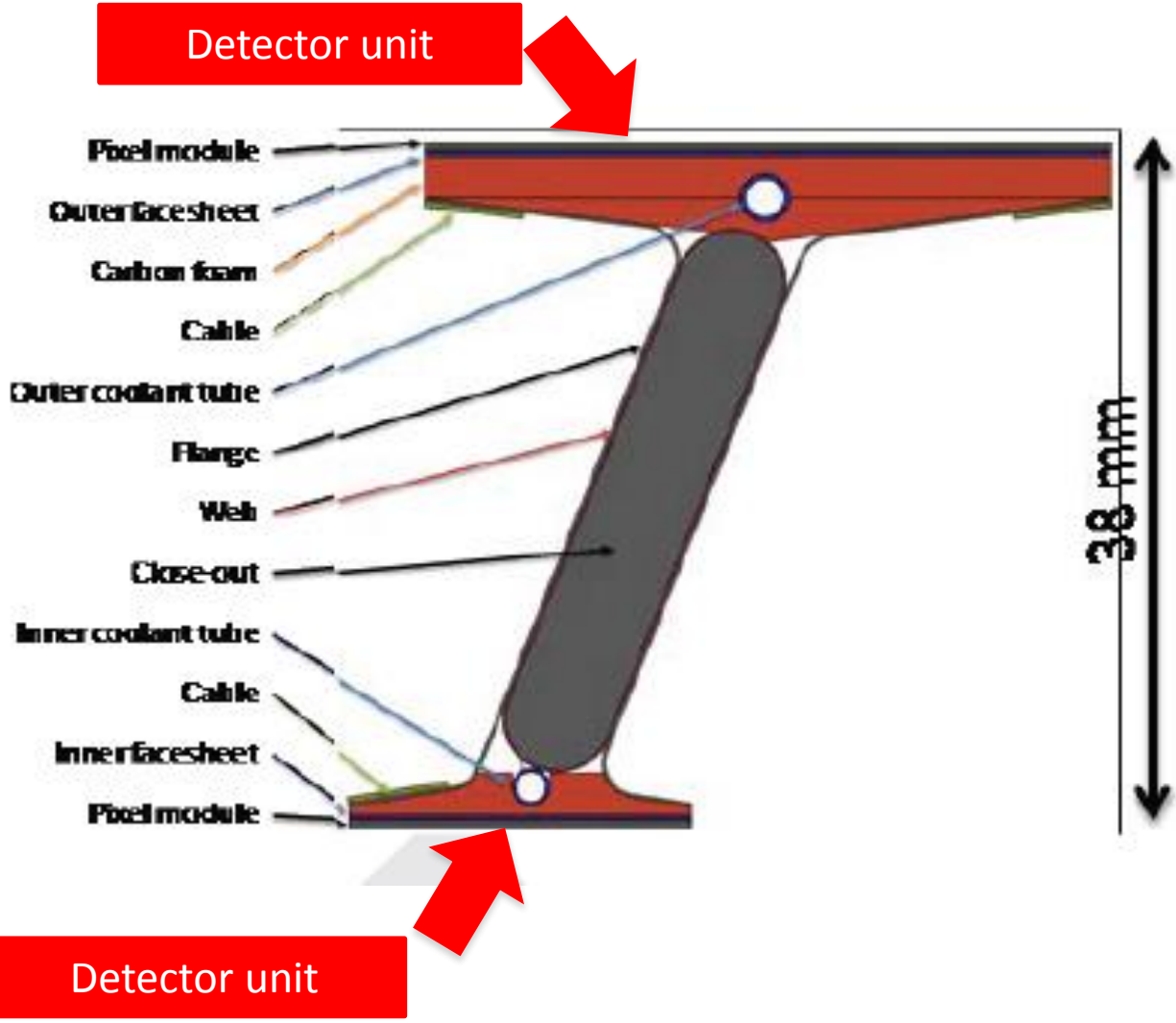


Boiling influenced by surface roughness

ATLAS new stave

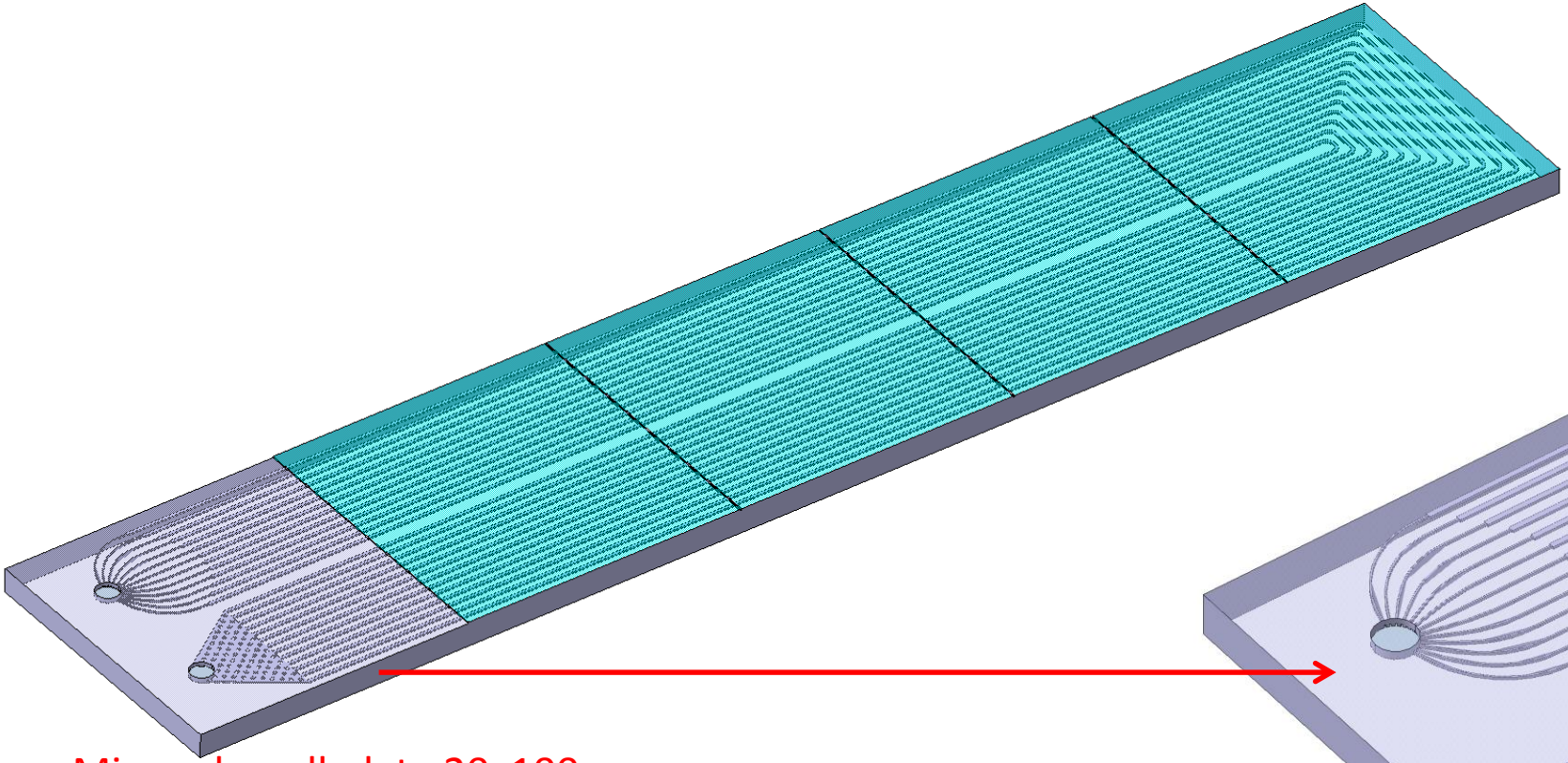
- Stave example

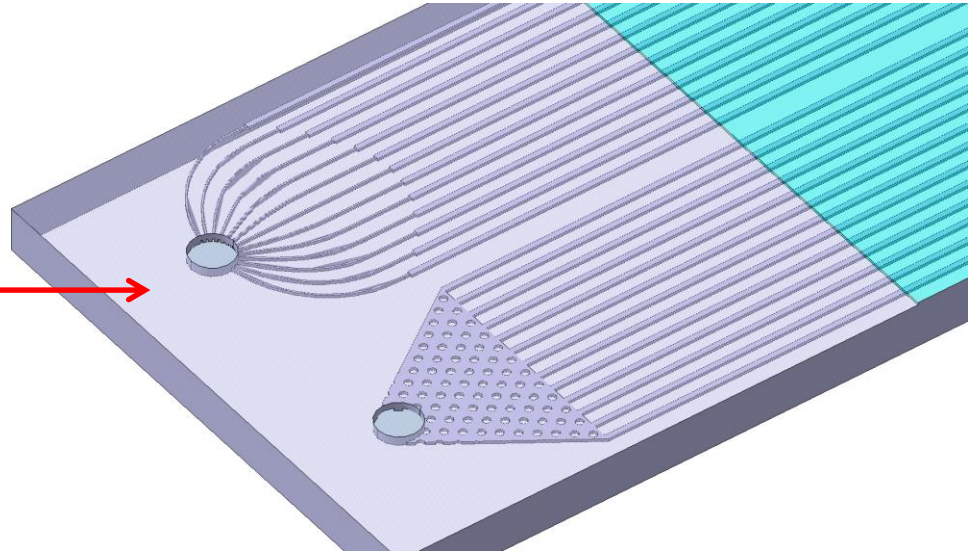




- 40-100 cm long

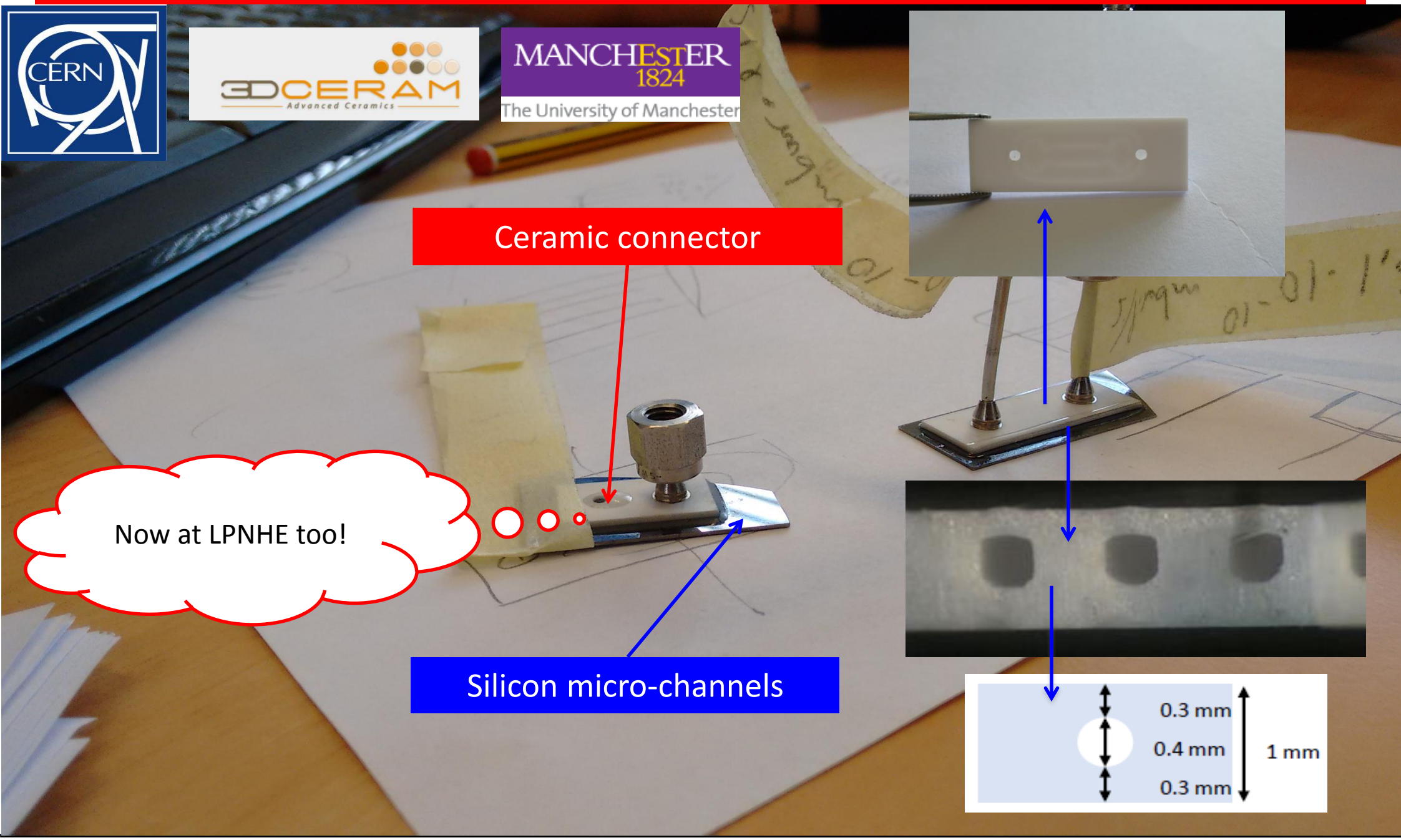
FBK production: mini-stave for 4 modules



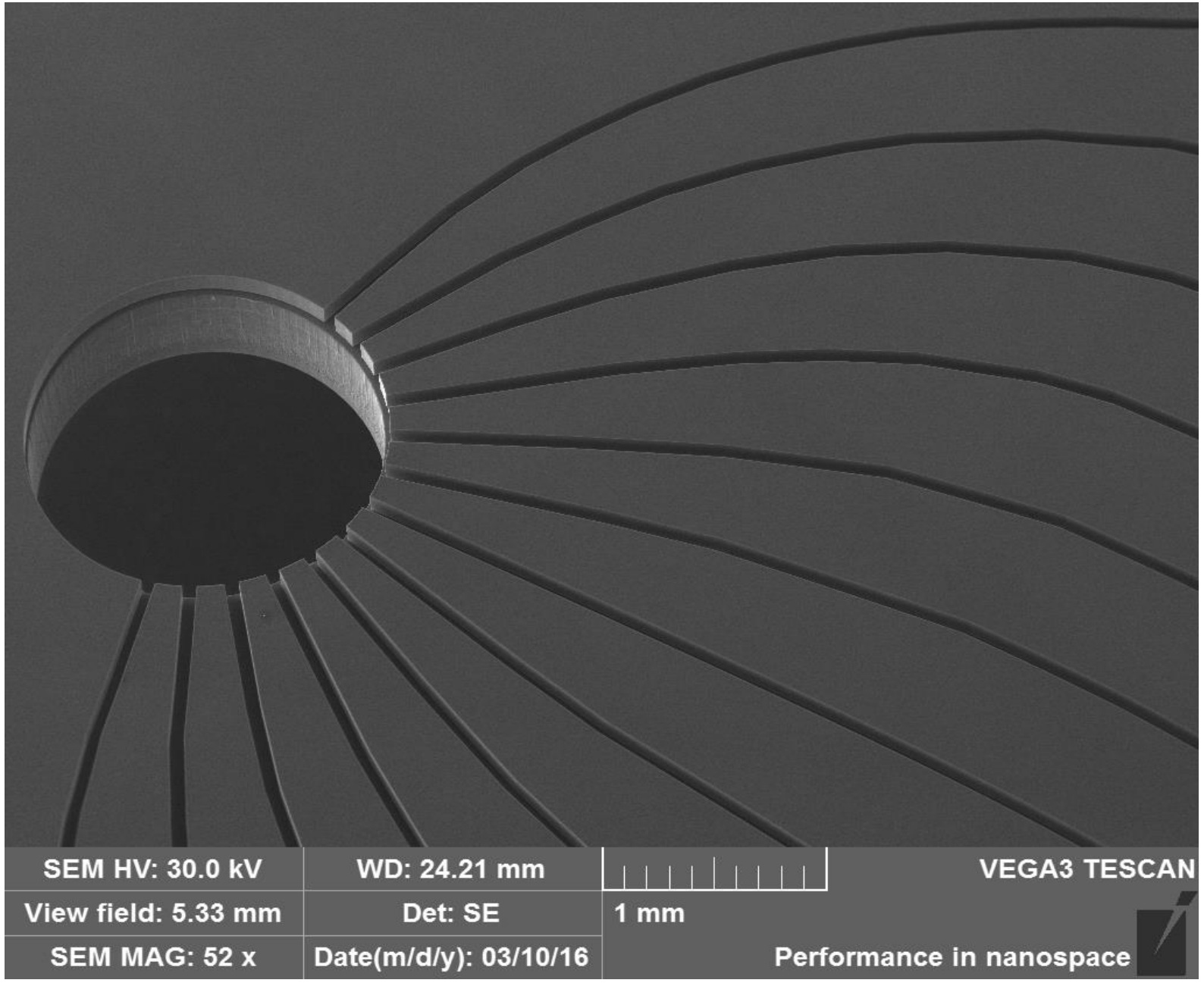


Micro-chanell plate 20x100mm
13 channels 200x120 um
Silicon walls 500um
Inlet restrictions 60x120um: same lenght 6mm for all
Inlet outlet holes 1.6 mm diameter
Pillars in the outlet: 350um diameter
Shortest channel: 165 mm
Longest channel: 199 mm

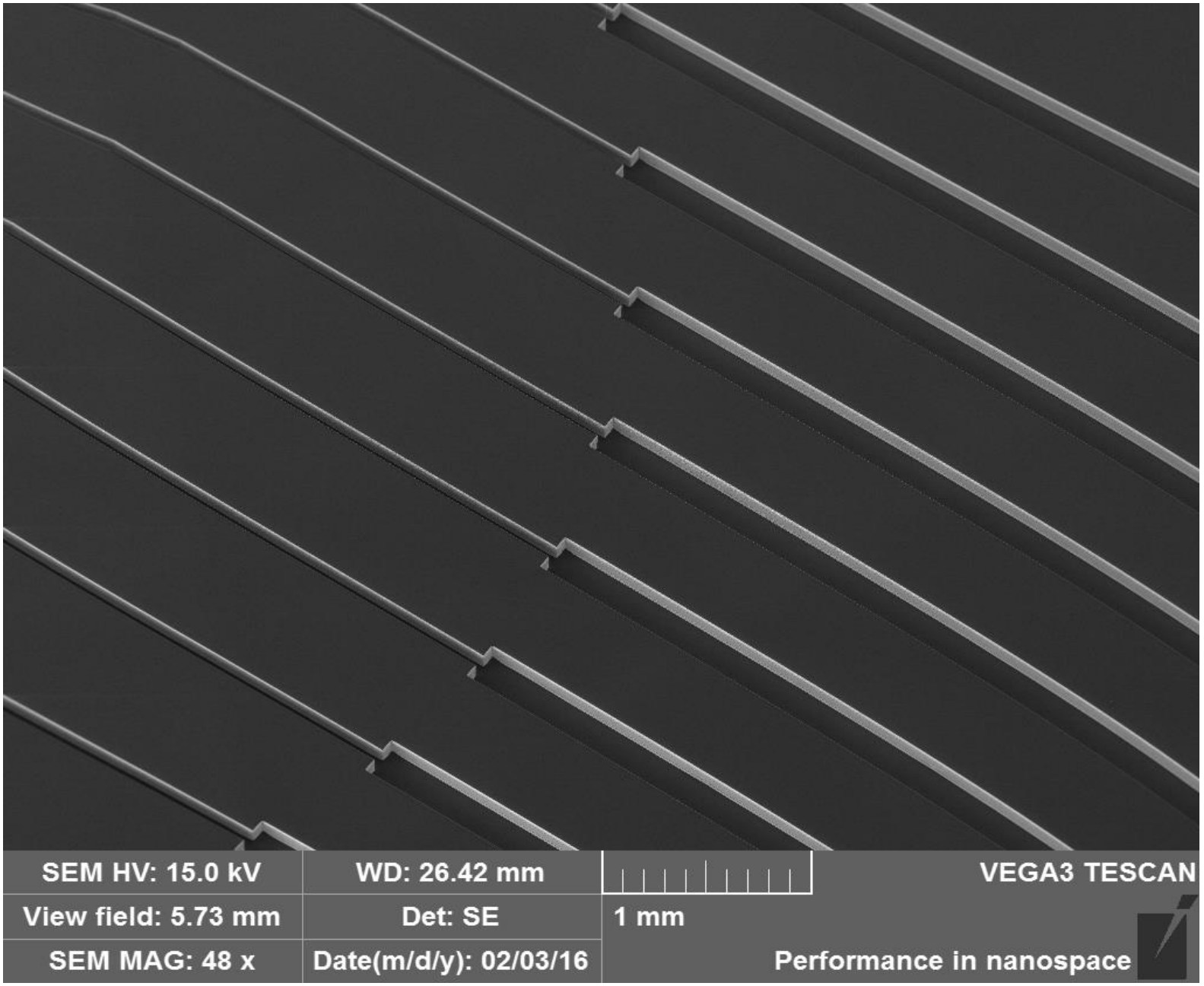
Ceramic connectors (and microchannels)



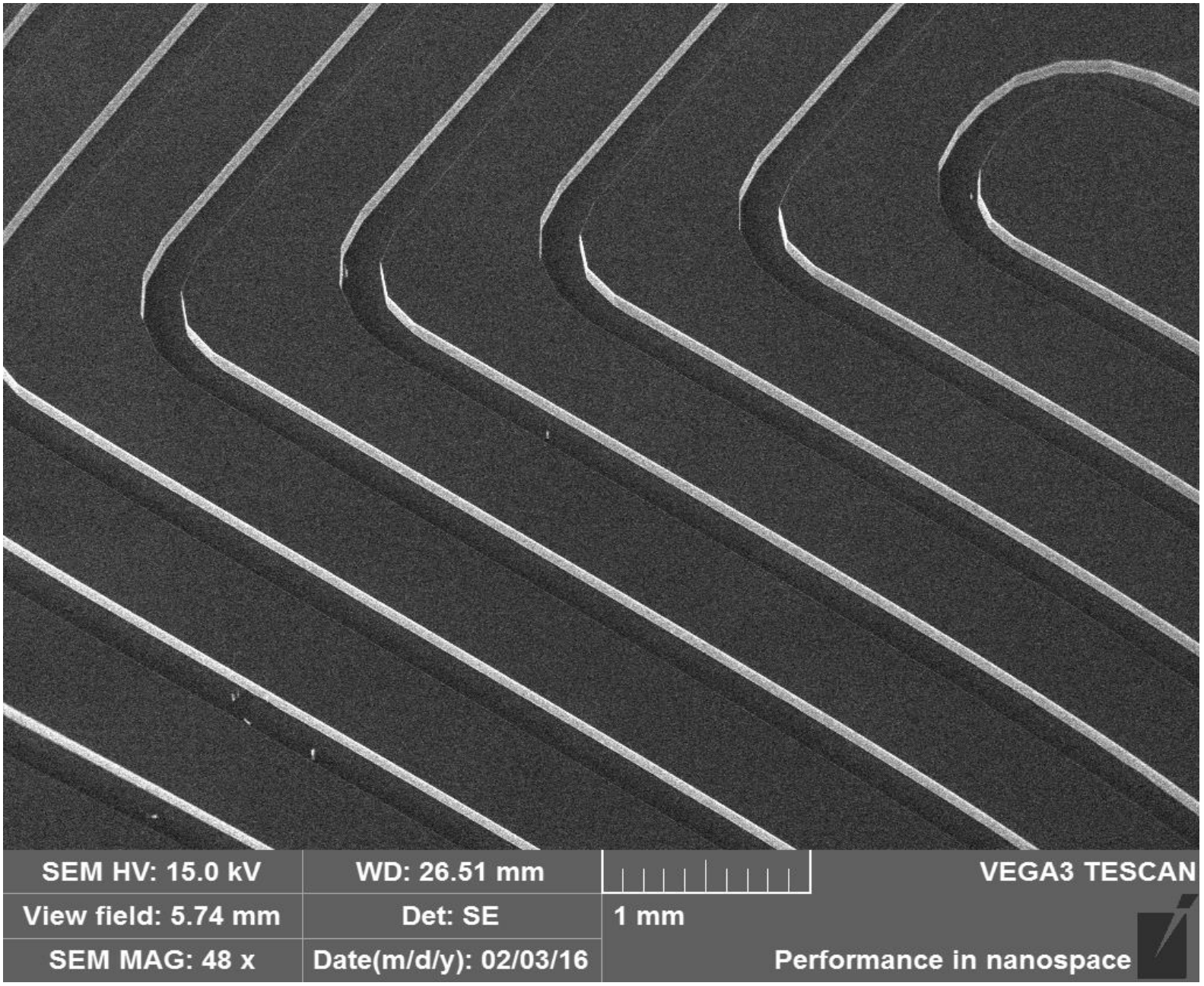
Pictures from FBK - inlet



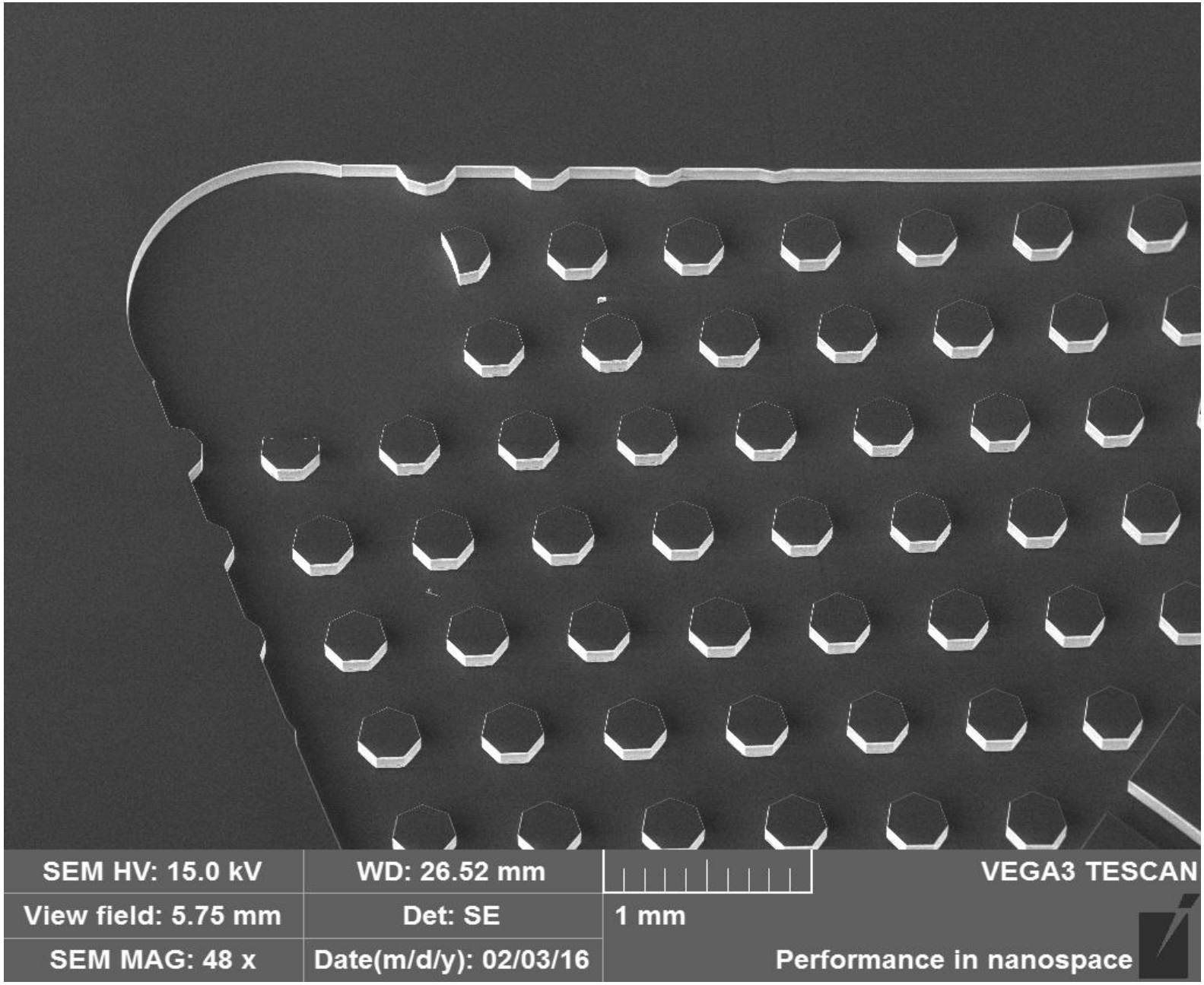
Pictures from FBK – channels restrictions



Pictures from FBK – curved channels

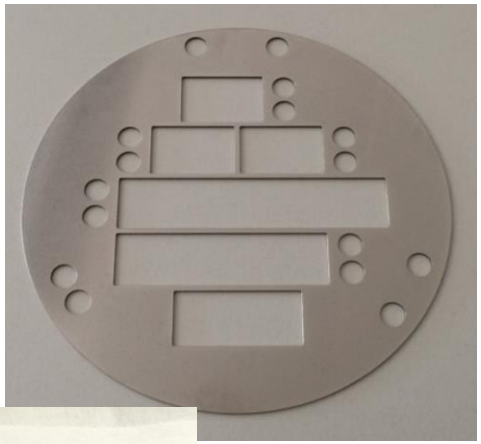


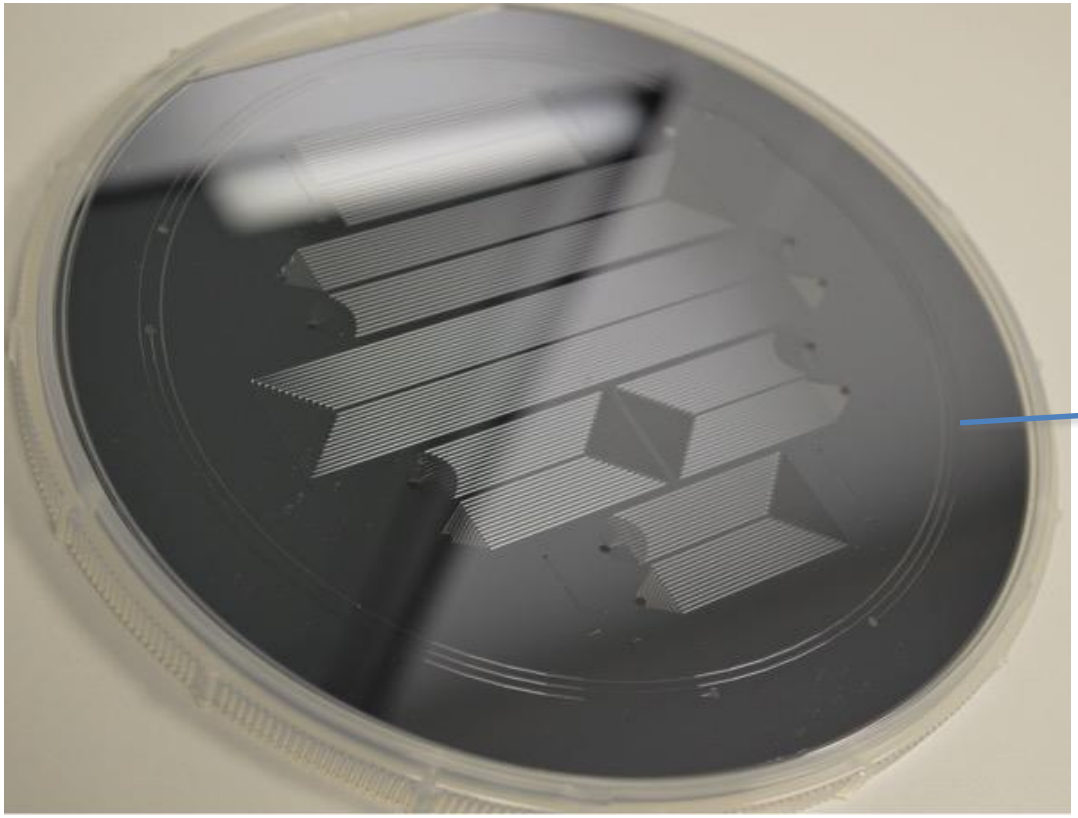
Pictures from FBK - outlet

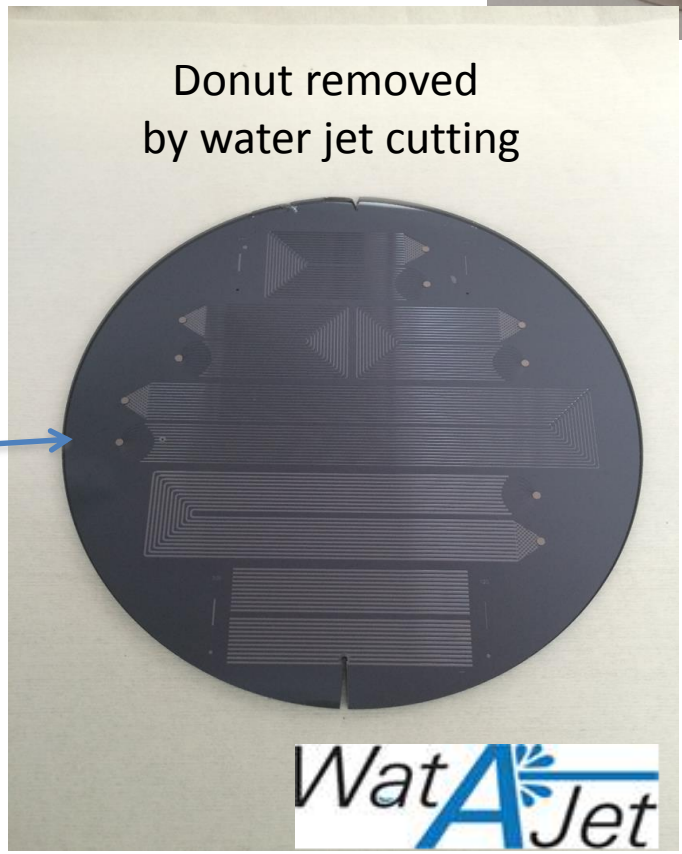


FBK production – developments

- First three wafers received
- Metal deposition (TiNiAu) on squared devices and inlets: for heating purposes and soldering the connectors
- with hard mask
- Cutting of the donut

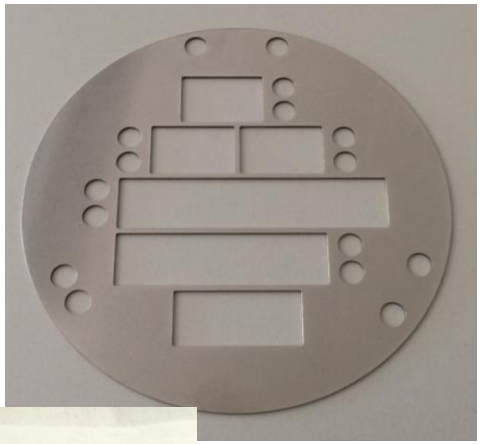


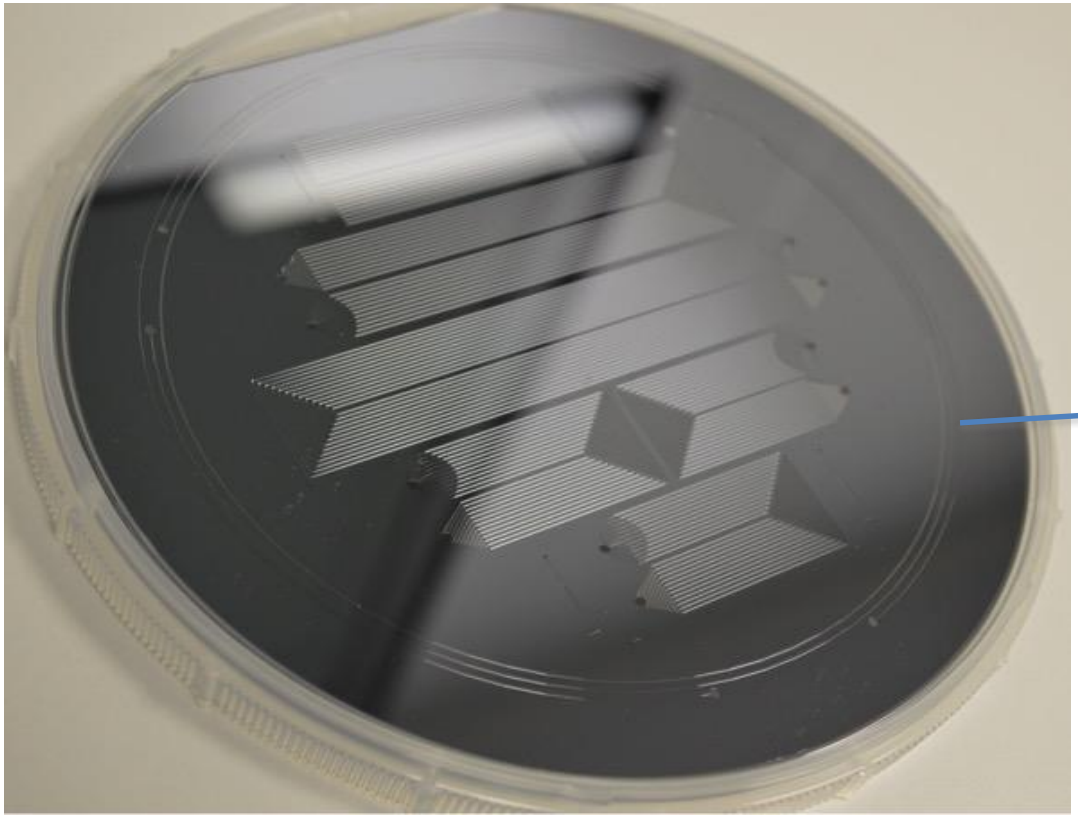


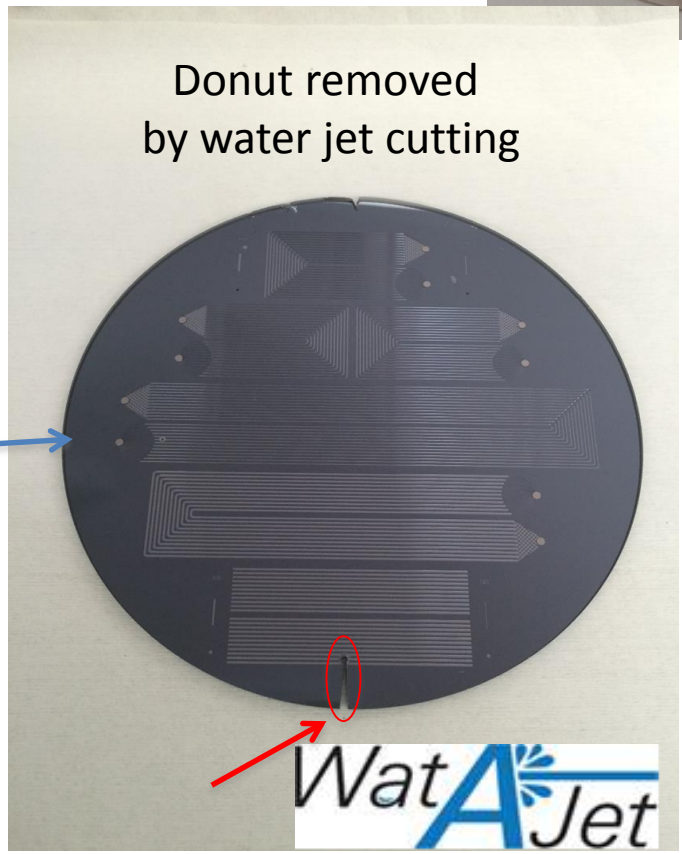


FBK production – developments

- First three wafers received
- Metal deposition (TiNiAu) on squared devices and inlets: for heating purposes and soldering the connectors
- with hard mask
- Cutting of the donut



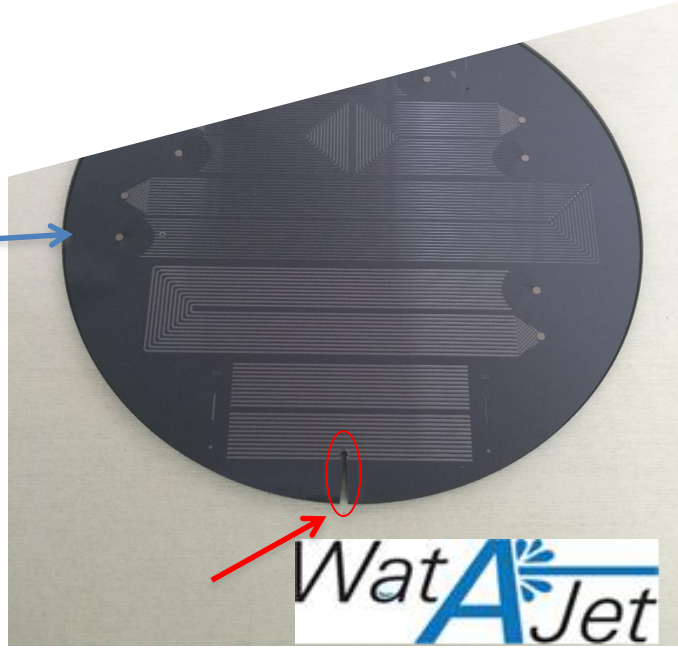




FBK production – developments

- First three wafers received
- Metal deposition (TiNiAu) on squared devices and inlets: for heating purposes and soldering the connectors
- with hard mask
- Cutting of the donut

Lesson learned: always send clear pictures of all features, never rely on understanding of what seems obvious to you.



Status

- First μ-channel production being completed at IEF
- New μ-channel production started at FBK
- Ceramic microfludic connectors received
- Miscellanea: metallic connectors, thermic and pressure sensors for pressure tests received

➢ Now: assembly first modules to test basic properties

➢ Then: acquire data on flowing and boiling in microchannels to build new numeric models

Conclusions

- The REFLECS & REFLECS2 projects study a microchannel based cooling solution
- It assures:
  1. high thermal performance
  2. high uniformity
  3. low material budget
  4. virtually no CTE mismatch.
- Within the project microchannel cooling units have been designed and produced.
- The next steps will involve the thermal tests on these units, the development of a numerical method for the high-pressure two-phase fluid flow in microchannels and the study of high-pressure rated connections among many units


LPNHE
PARIS
université
PARIS
DIDEROT
PARIS 7
FONDAZIONE
BRUNO KESSLER
CERN
AIDA
2020
THANK YOU FOR
YOUR ATTENTION
Reflecs & Reflecs2
Marco Bomben, LPNHE & UPD, Paris

Backup

Colliders & Space-Born High Energy Physics

- **@Future Hadronic Colliders**
- To avoid negative annealing future sensors must be operated well below 0 ° C ➔ ideally: -20 ° C
- Sensor+chip will dissipate ~ W/cm^2
- A very efficient cooling system is needed
- Important constraint: very low material budget envisaged (< 1% X_0)

- **Space-Born experiments**
- Silicon detectors require:
- a high degree level of temperature homogeneity across the apparatus
- a cooling system capable of working for several years without possibility of intervention for the many years of the space mission

Colliders & Space-Born High Energy Physics

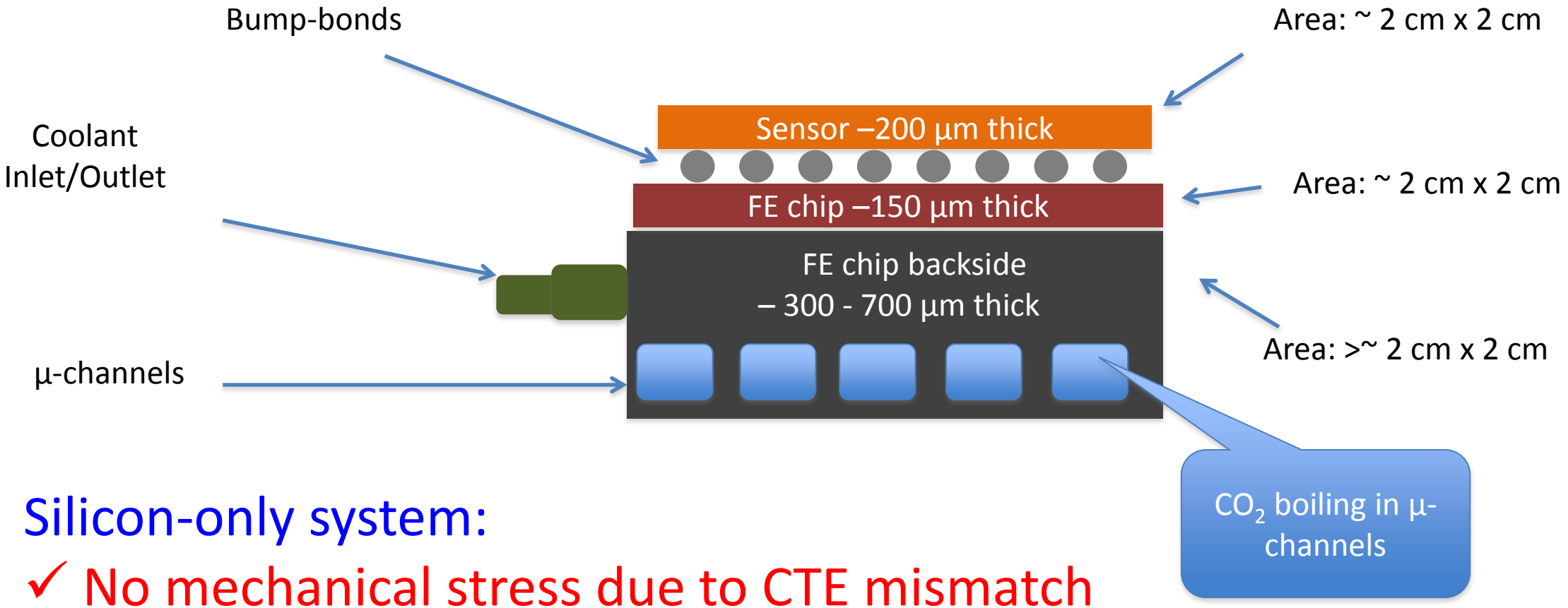
- **@Future Hadronic Colliders**
- To avoid negative annealing future sensors must be operated well below 0 ° C ➔ ideally: -20 ° C
- Sensor+chip will dissipate ~ W/cm^2
- A very efficient cooli
  system is neede
- Importa
  low

- **Space-Born experiments**
- Silicon detectors re
- a high degr
  temp

Promising solution: micro-channel based cooling using CO_2

system capable of
ing for several years
without possibility of
intervention for the many
years of the space mission

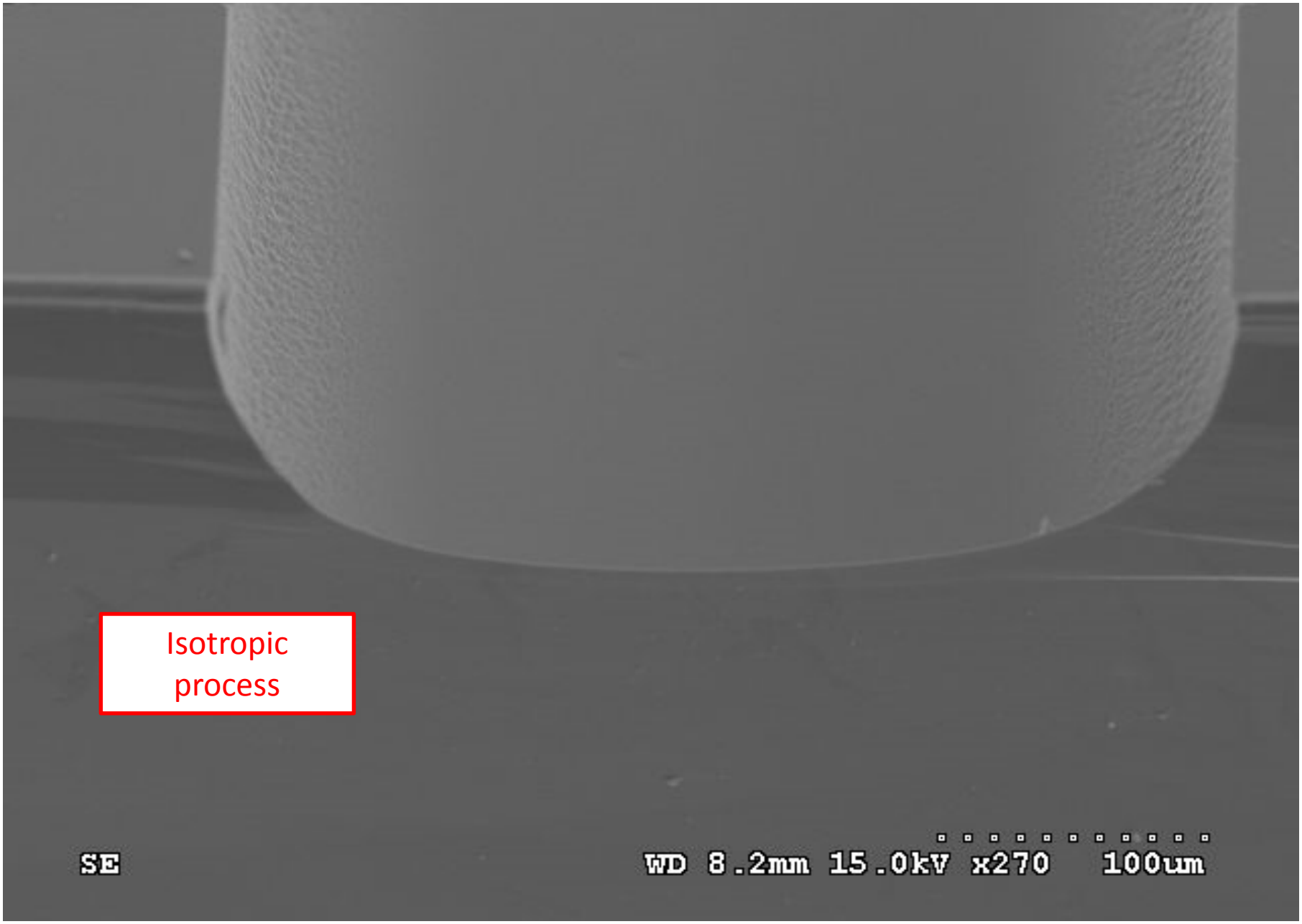
The μ-channels solution



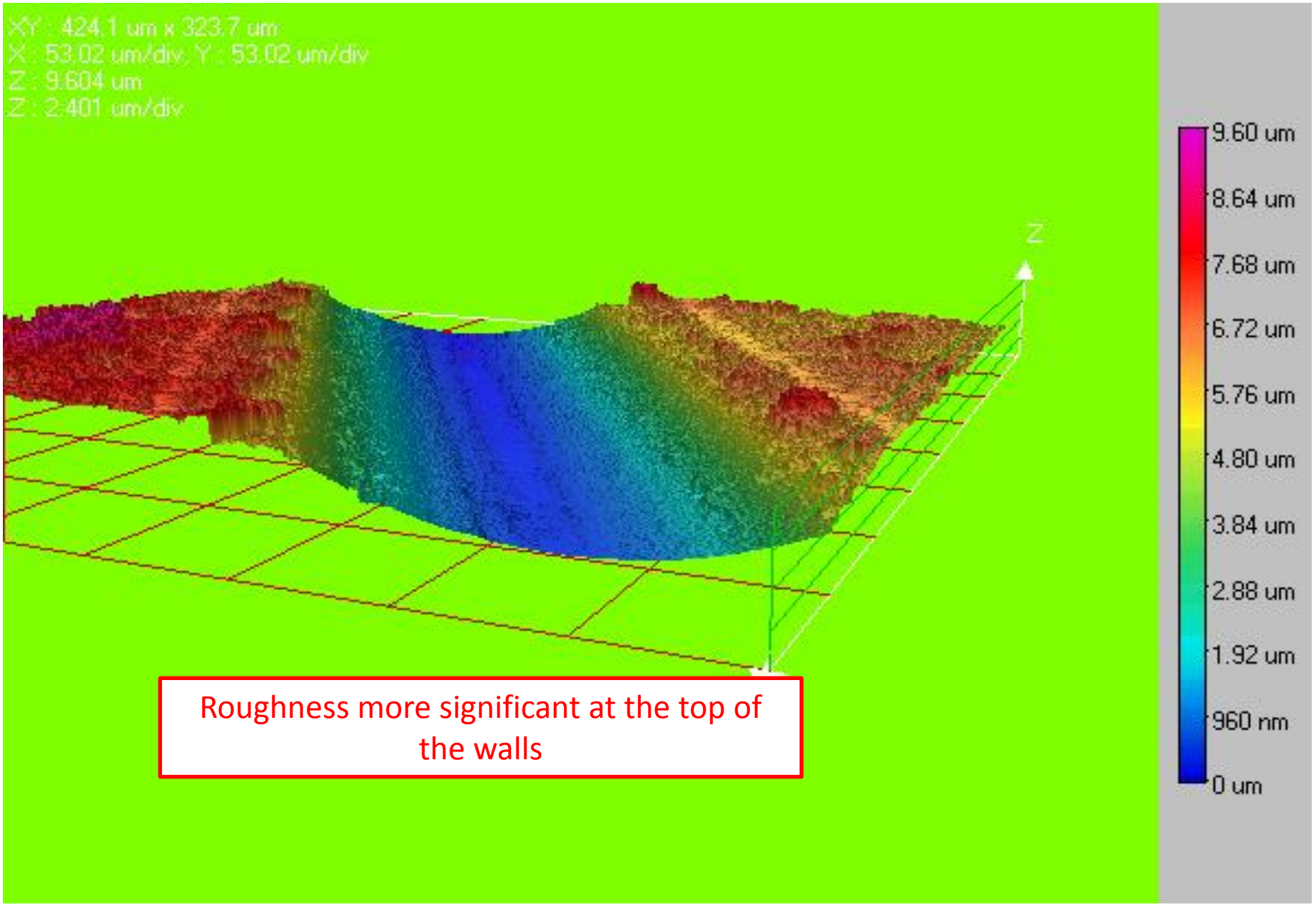
Silicon-only system:

- ✓ No mechanical stress due to CTE mismatch
- ✓ Low mass
- ✓ Customizable layout of the channels ➔ more efficient and unifo cooling
  - Very important to avoid thermal runaway after irradiation

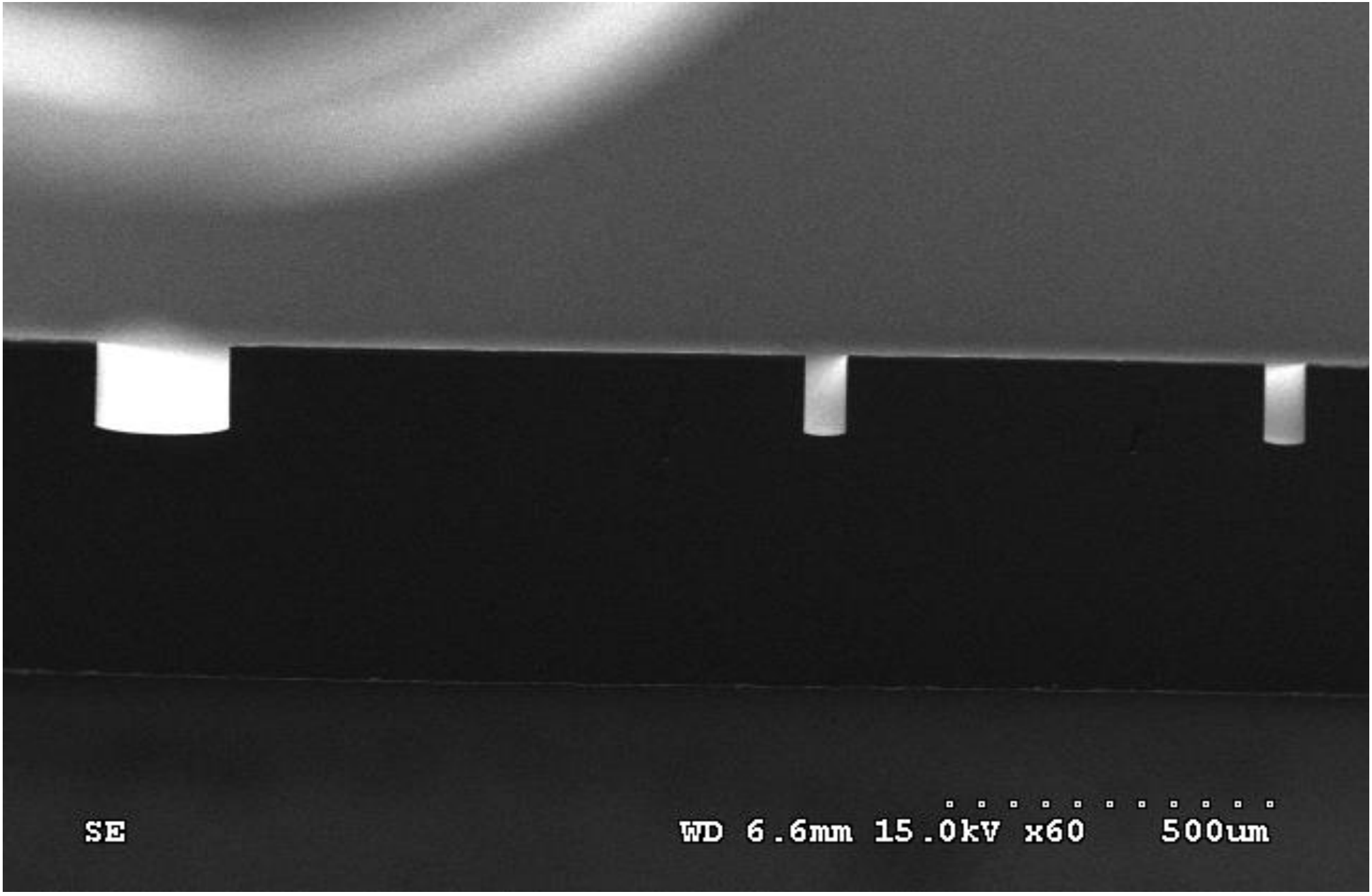
One channel



One channel – roughness measurement



Three circular channels: section



South of Paris, June 2016