Thermo-mechanical measurements on thin ladders under air-cooling or micro-channel cooling

(work performed within the DEPFET collaboration)

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M. Vos

Outline

- MCC introduction

- Test setup

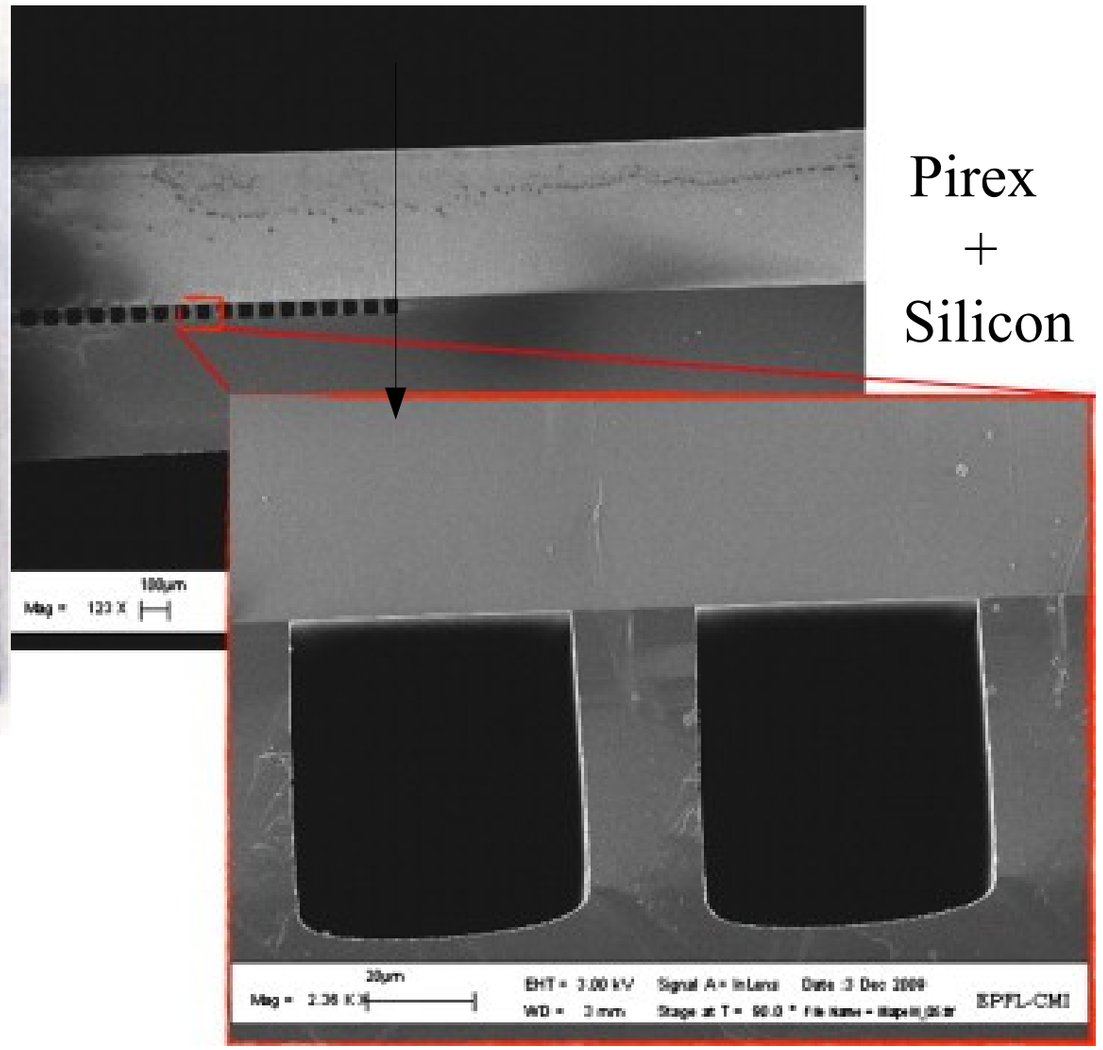
- Test results:
  - -Thermal results
  - -Mechanical results

- Conclusions

Introduction

Current R&D: LHCb*

MCC of 60-70 mm DH

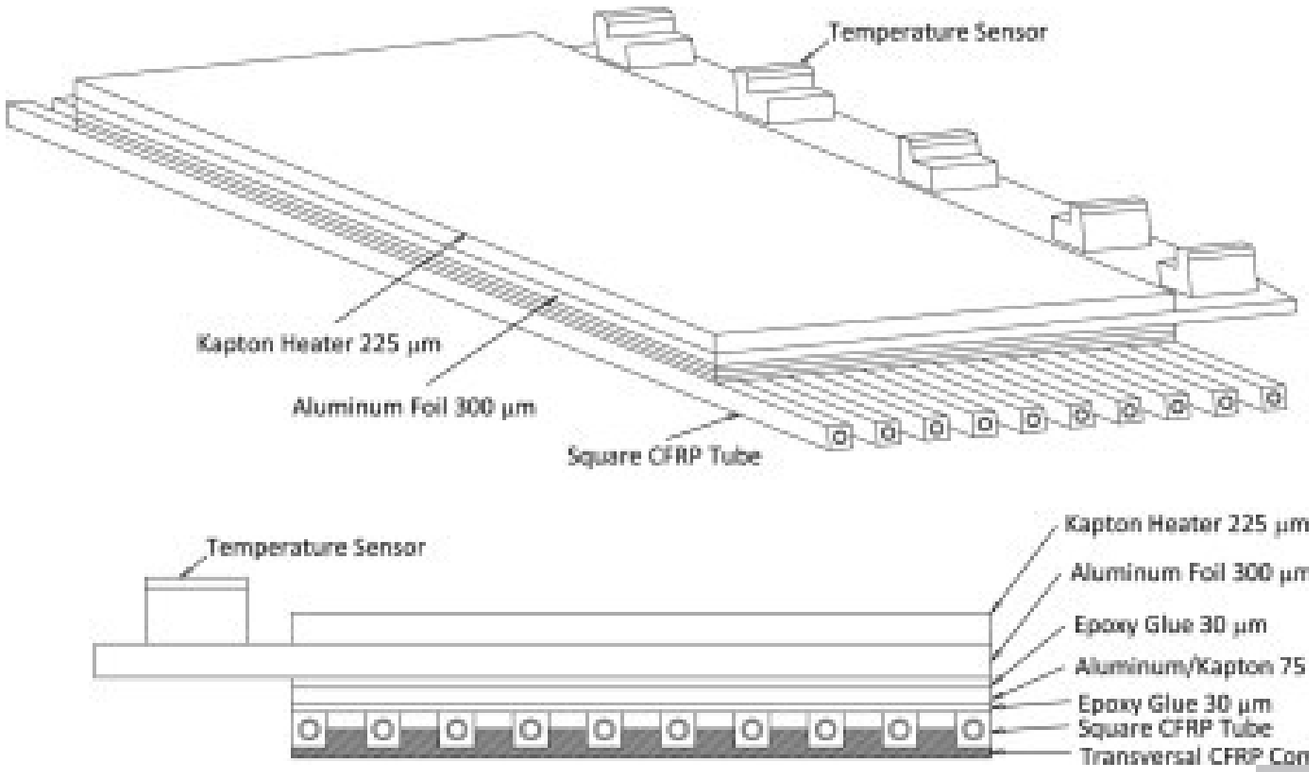


- Low T<-20ºC → two phase CO2
- 1,8W/cm^2
- Out-of-plane connexion

*J. Buytaert, et al..”Micro channel evaporative CO2 cooling for the upgrade of the LHCb vertex detector”, 2013, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Vol. 731

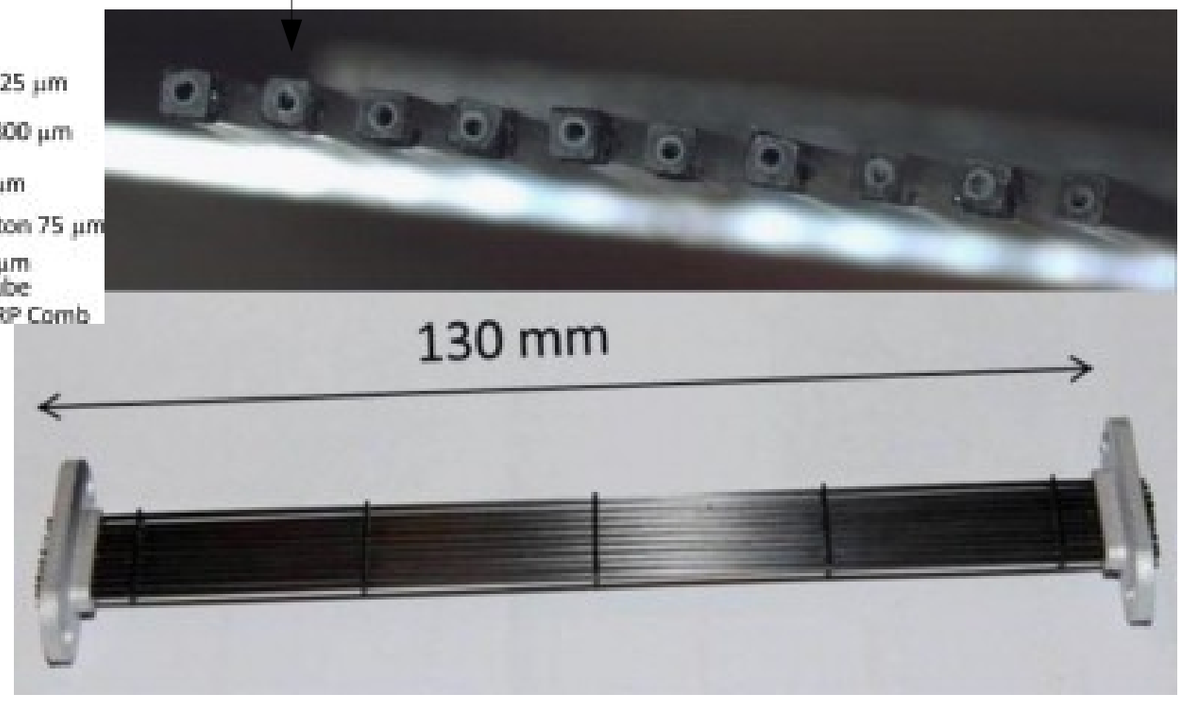
Introduction

Current R&D: SuperB Silicon Vertex Tracker*



CFRP + aluminium

MCC of 0,3 mm
DH

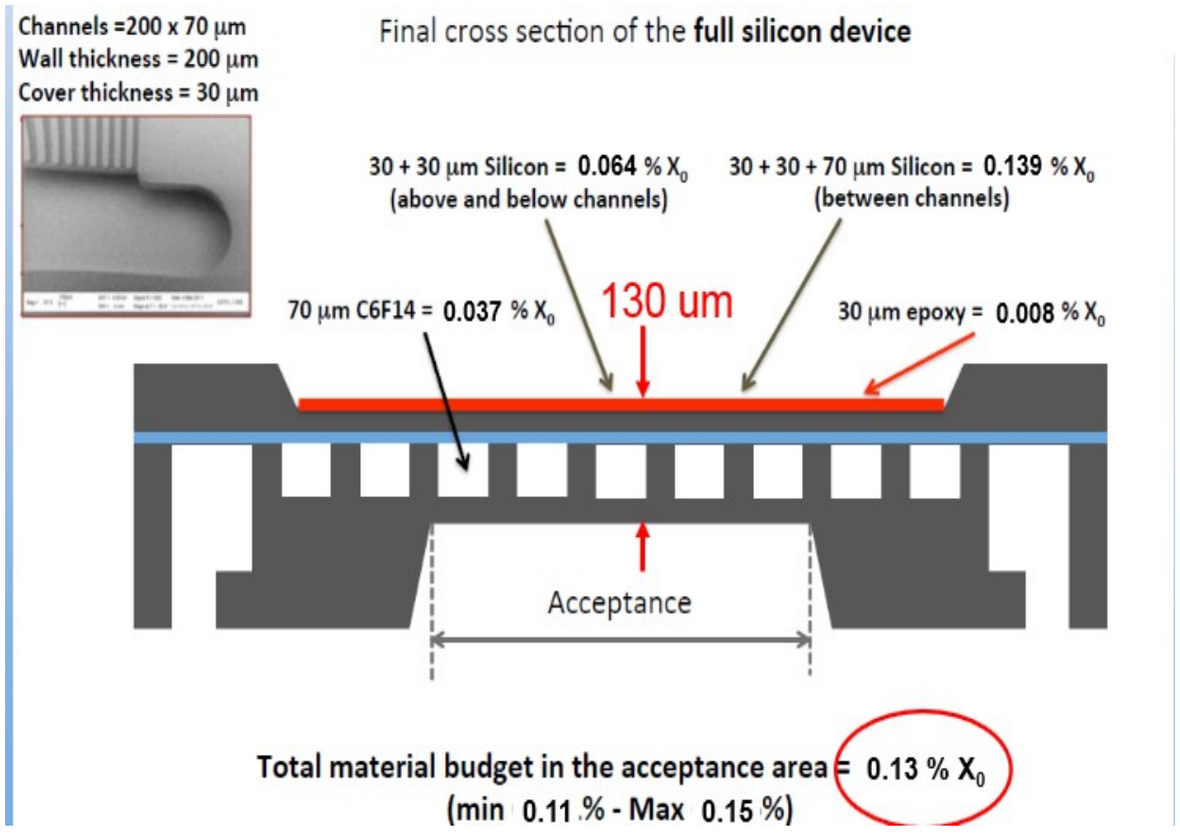


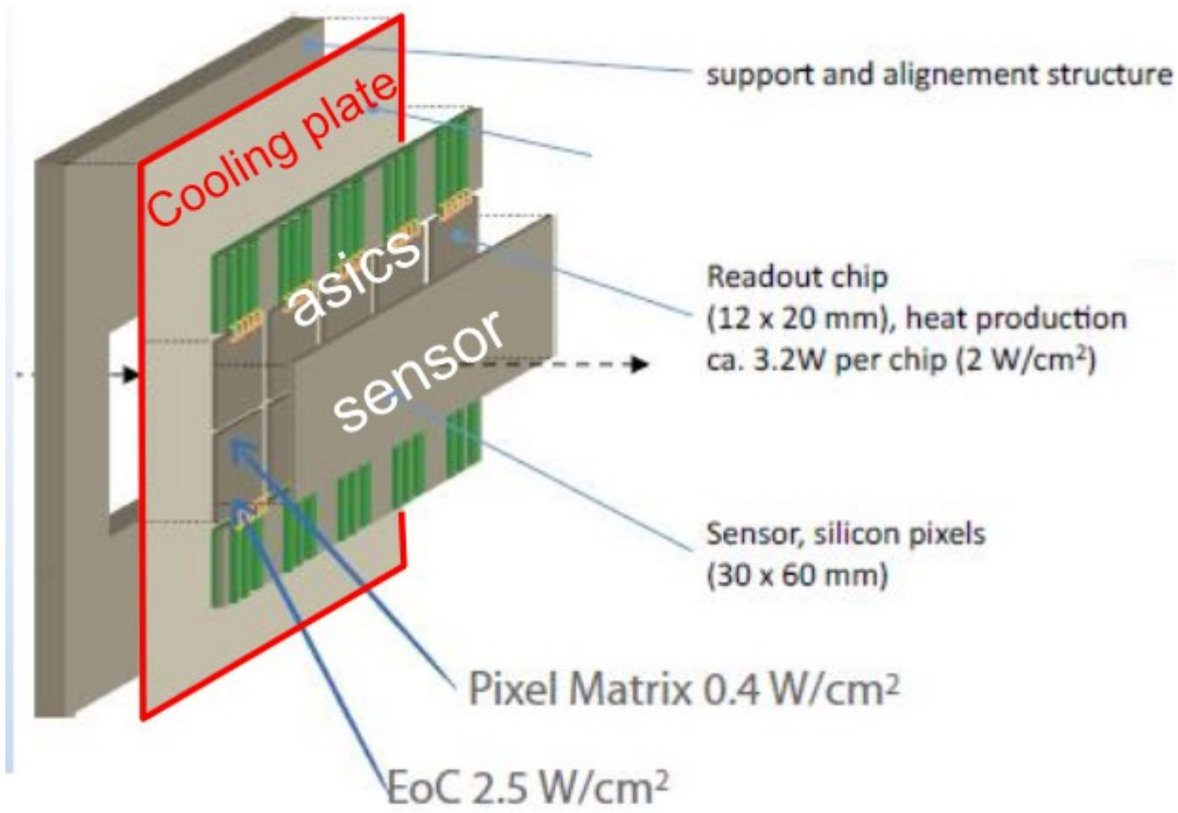
- Single phase coolant (50%water, 50% ethylene glycol)
- About 1-3W/cm^2 of heat dissipation
- In-plane connexion

*F. Bossi, et al..”Light prototype support using micro-channel technology as high efficiency system for silicon pixel detector cooling”, 2011, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Vol. 650

Introduction

Current R&D: NA62 GTK*



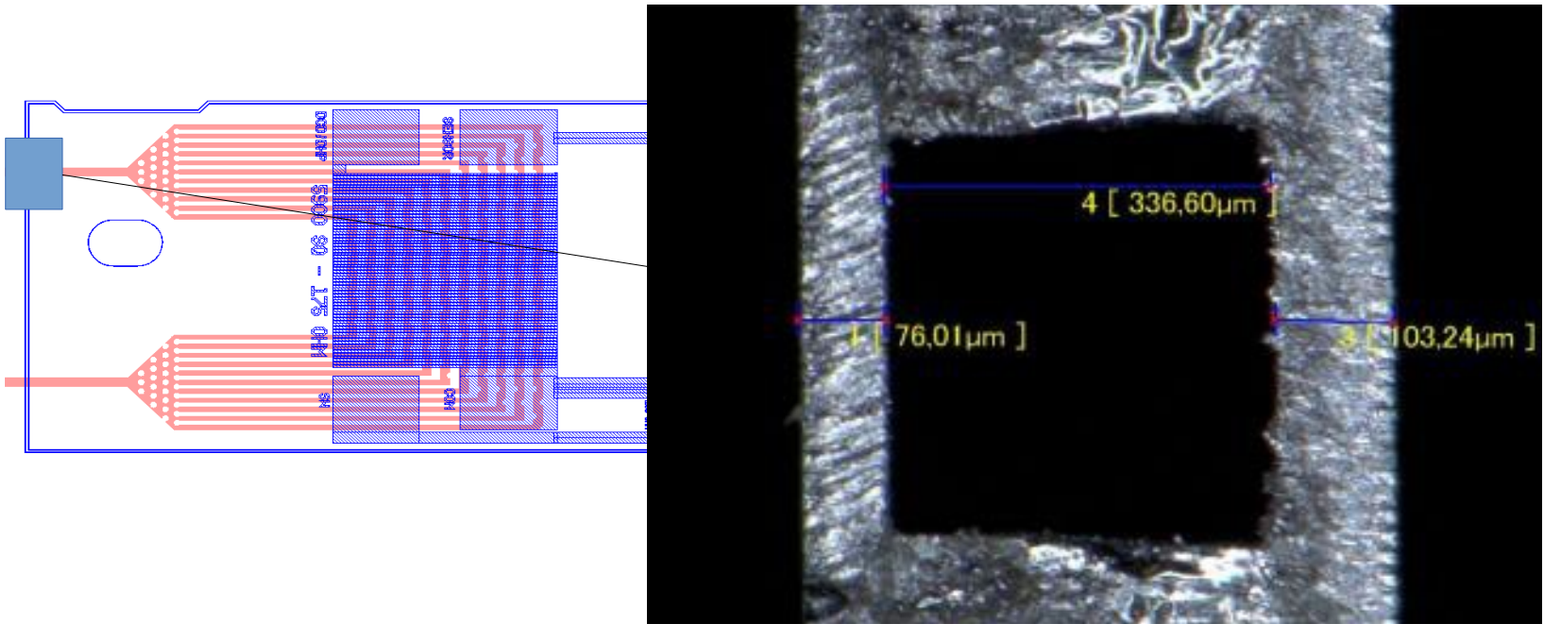


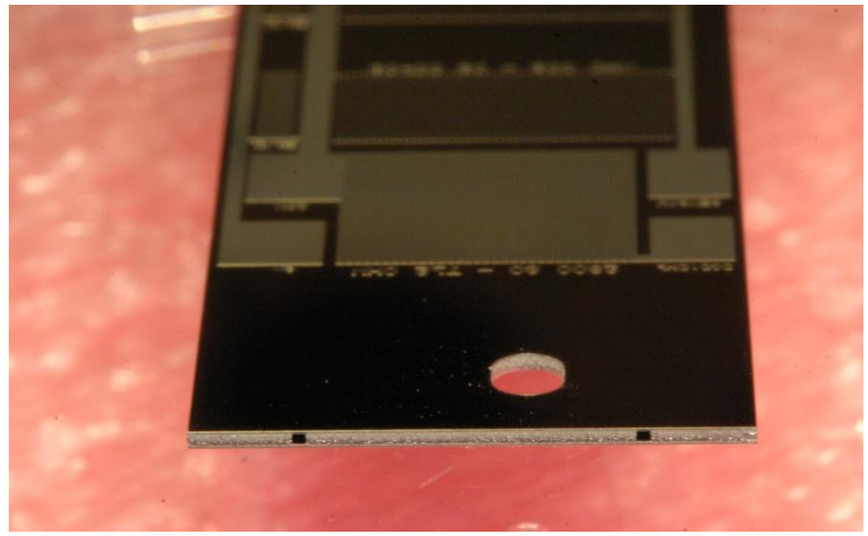
- Single phase coolant C6F14 T<-20ºC
- 2,5W/cm^2 of heat dissipation
- Out-of-plane connexion

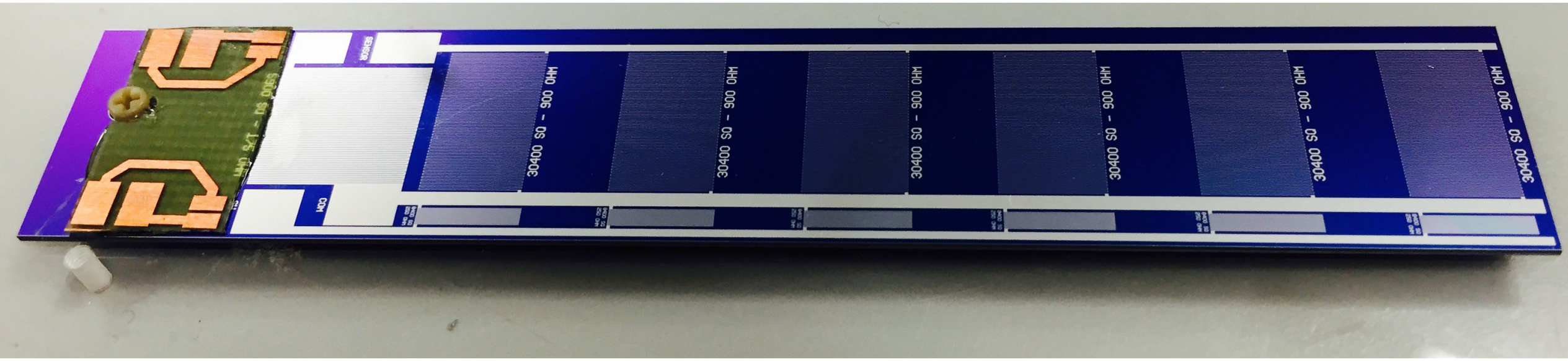
*G. Nüßle, A. Mapelli, M. Morel, P. Petagna, G. Romagnoli, and K. Howell (2014) NA62 GigaTracKer Cooling with Silicon Micro Channels. Astroparticle, Particle, Space Physics and Detectors for Physics Applications: pp. 525-530

Introduction

Silicon ladder with MCC embedded in the sensor







Test setup

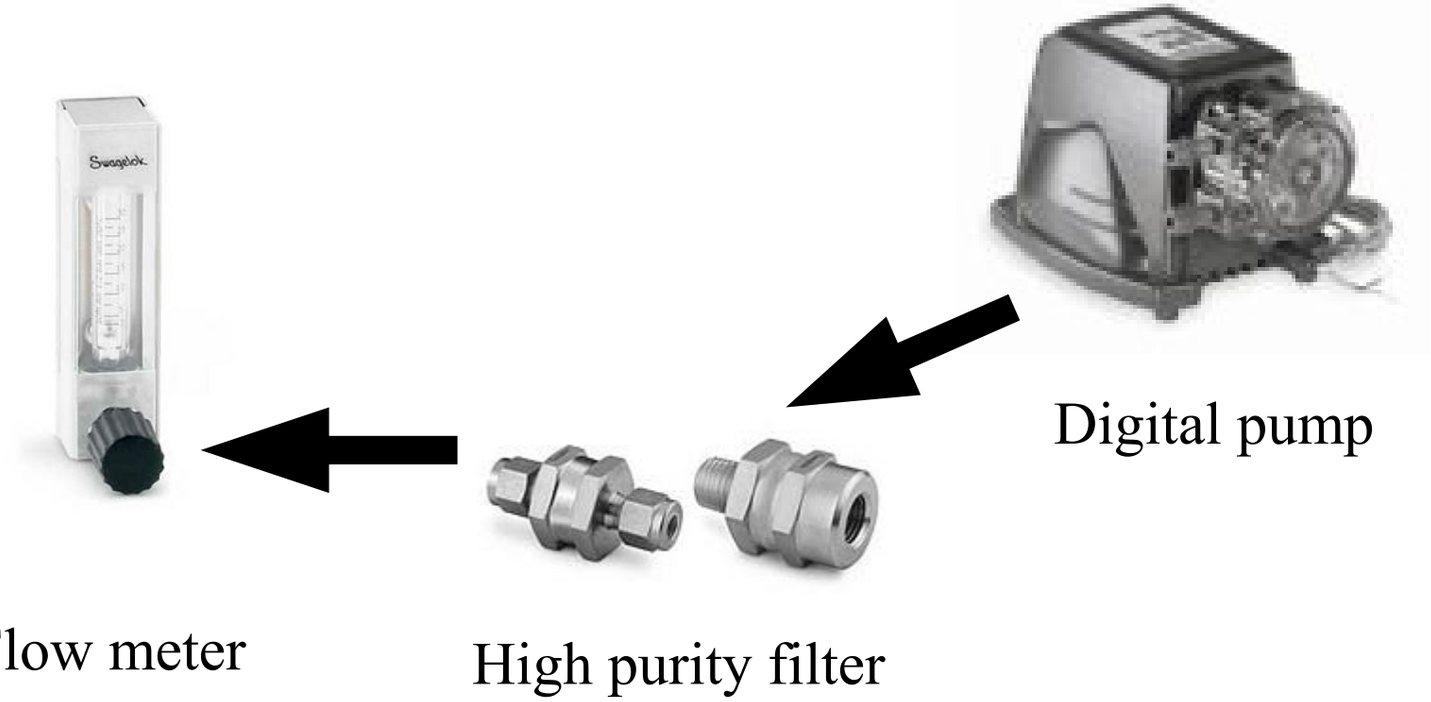
Digital pump

Test setup

Digital pump

High purity filter

Test setup



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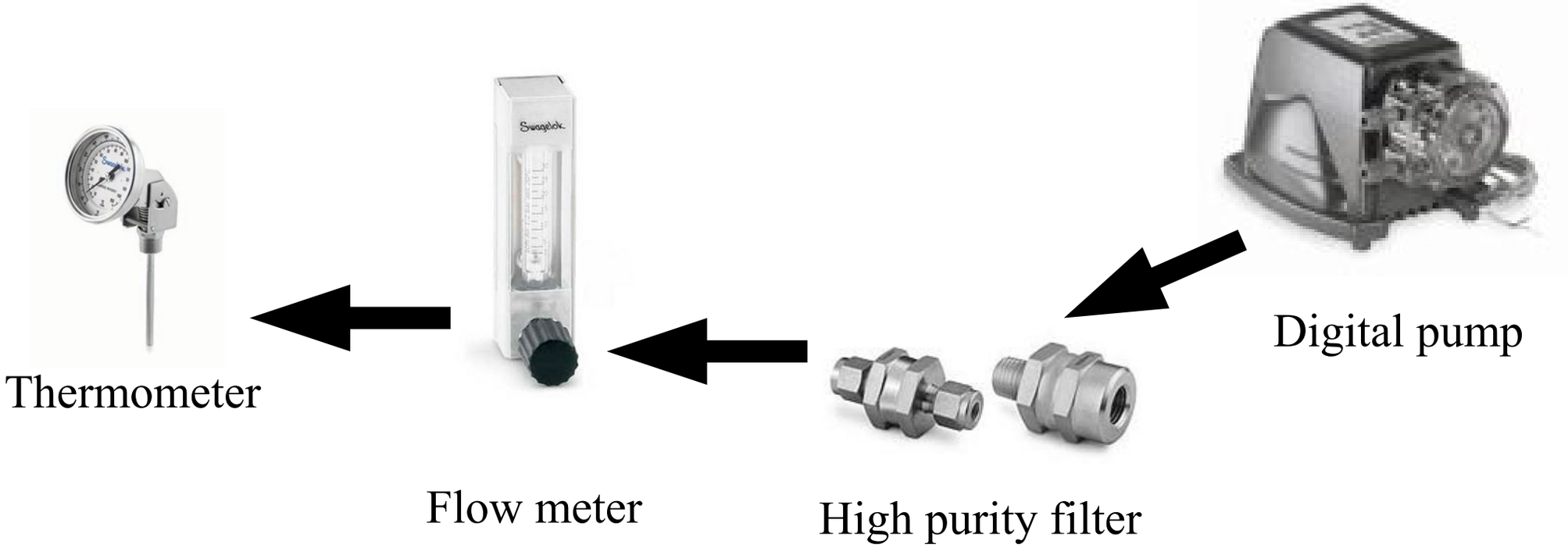
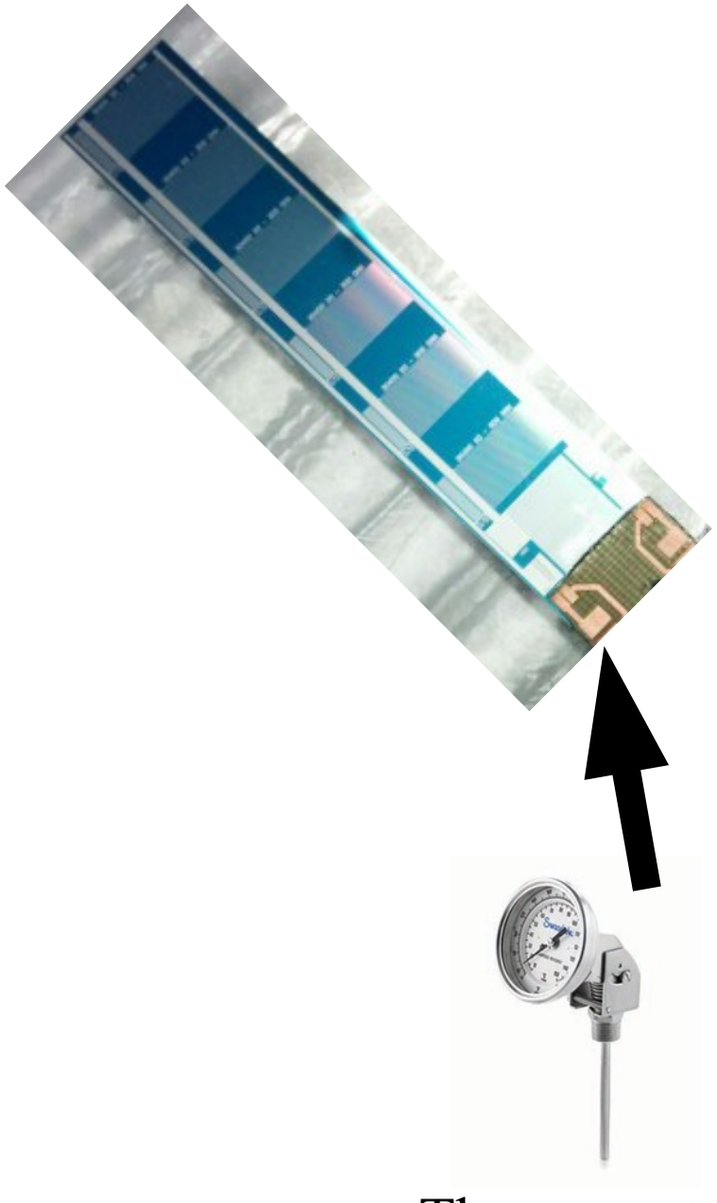


Test setup



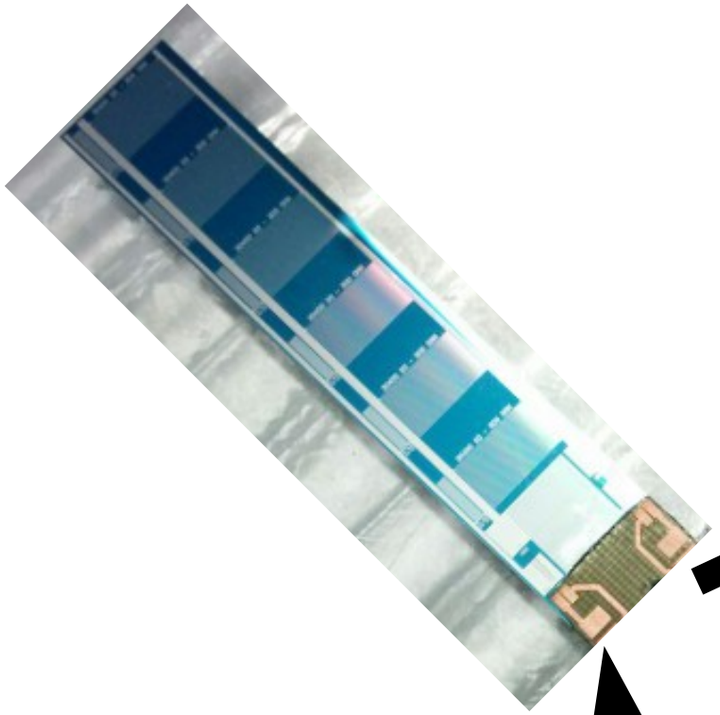
Thermometer

Flow meter

High purity filter

Digital pump

Test setup



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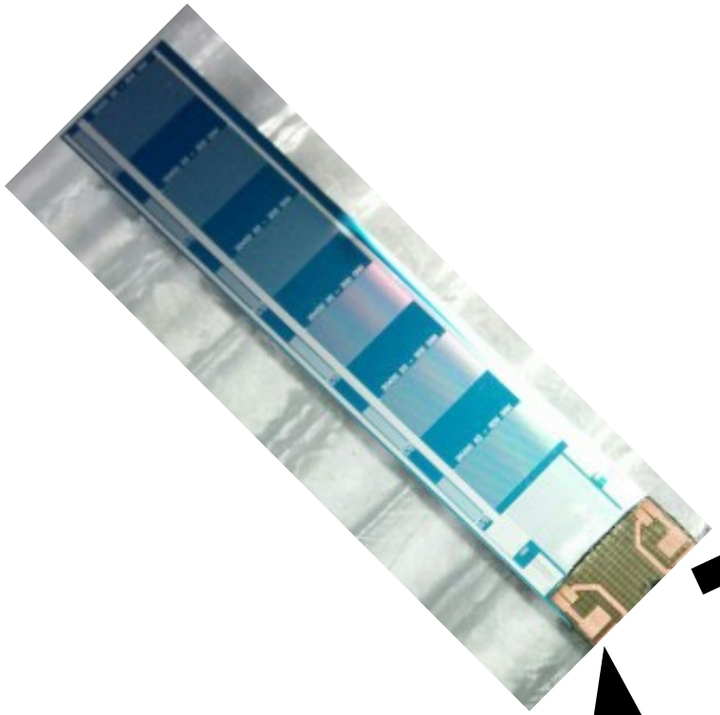
Thermometer

Flow meter

High purity filter

Digital pump

Test setup



Thermometer

Fluid storage

Digital pump

High purity filter

Flow meter

Thermometer

Test setup

Thermometer

Fluid storage

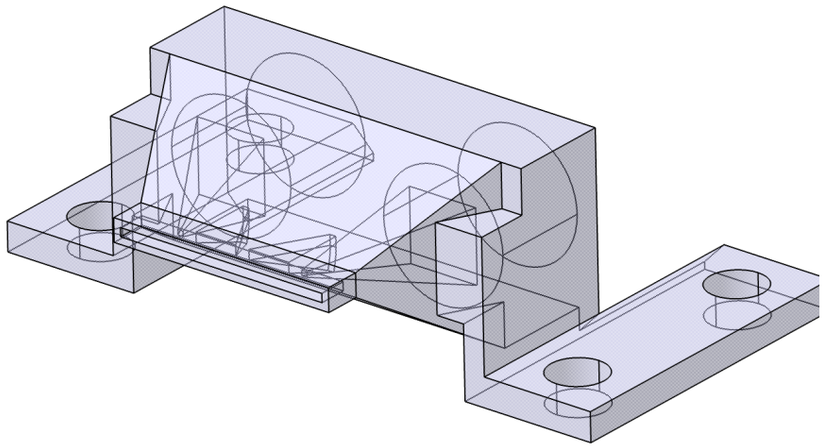
Digital pump

High purity filter

Flow meter

Thermometer

Test setup



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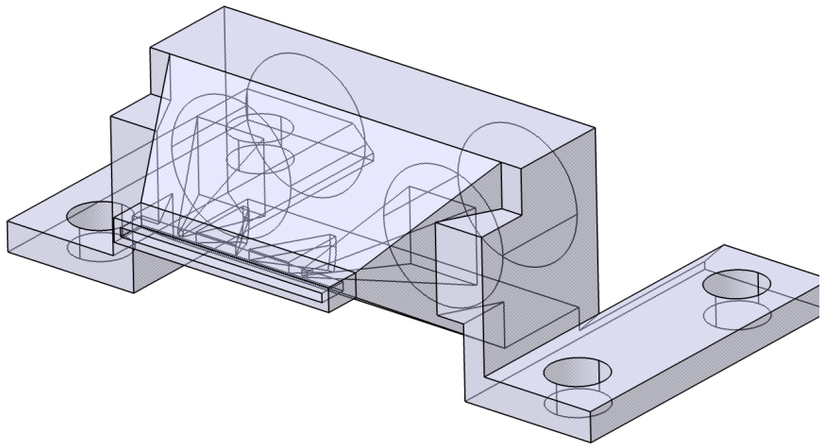

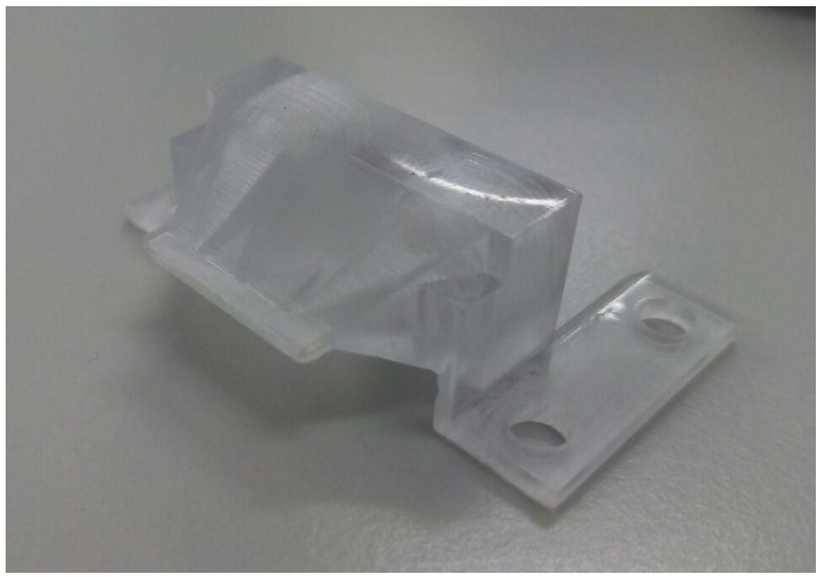

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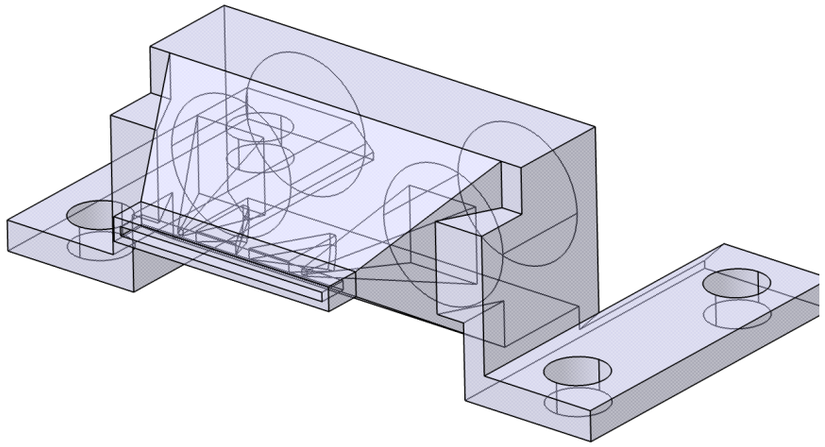
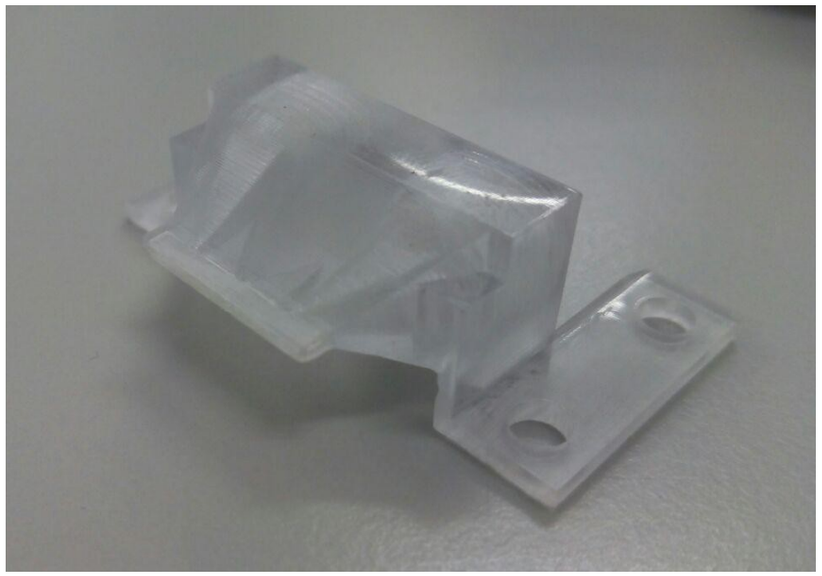
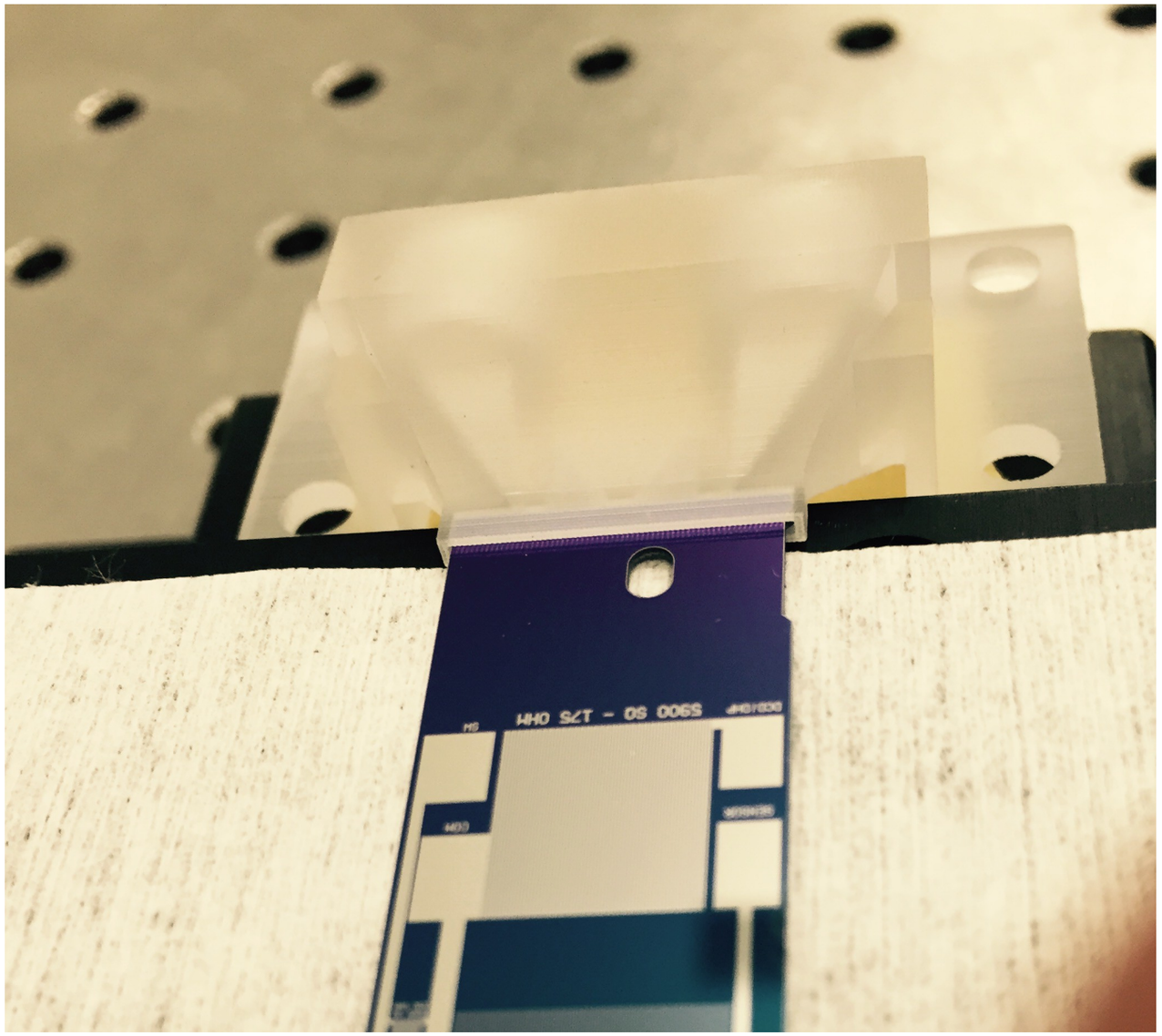
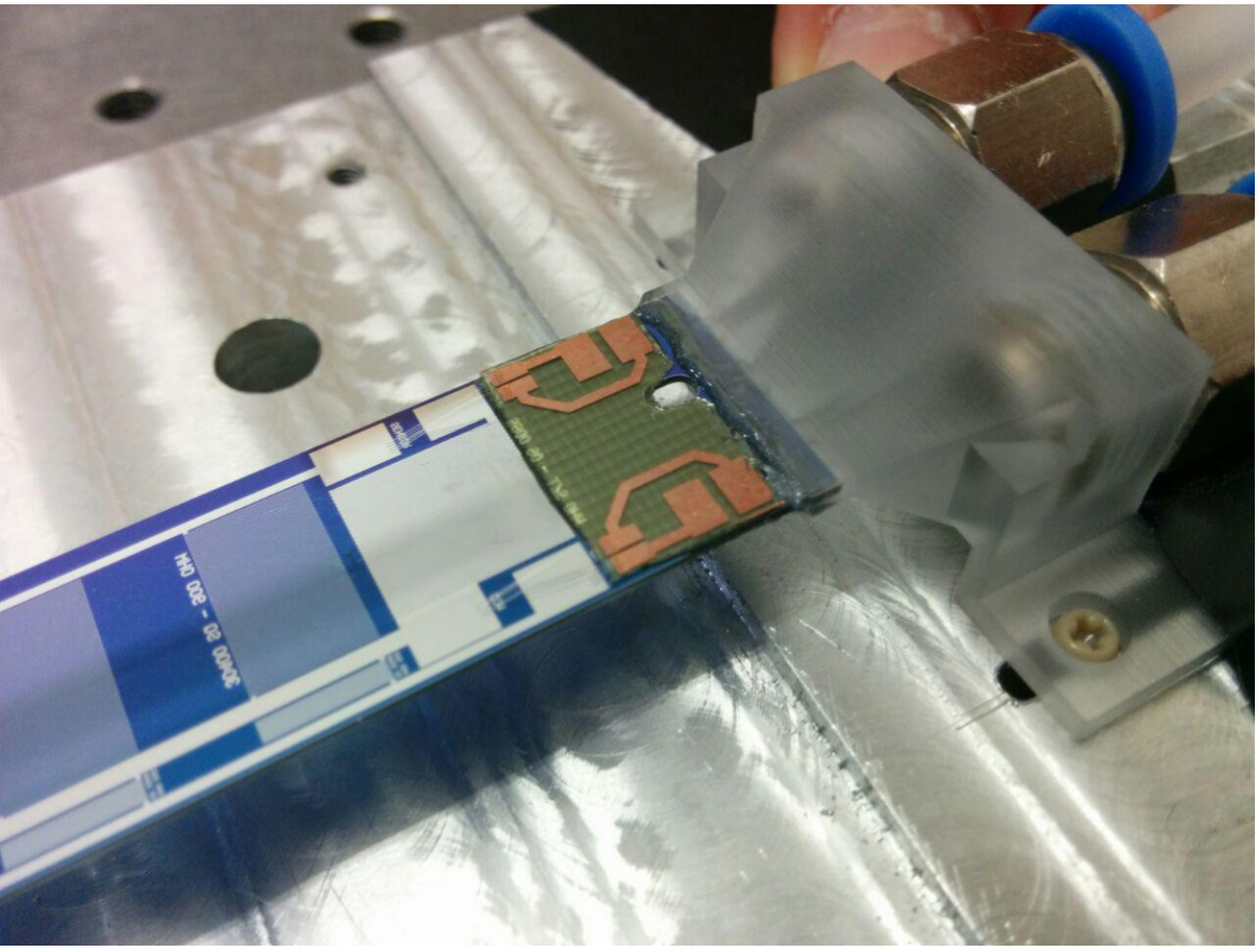


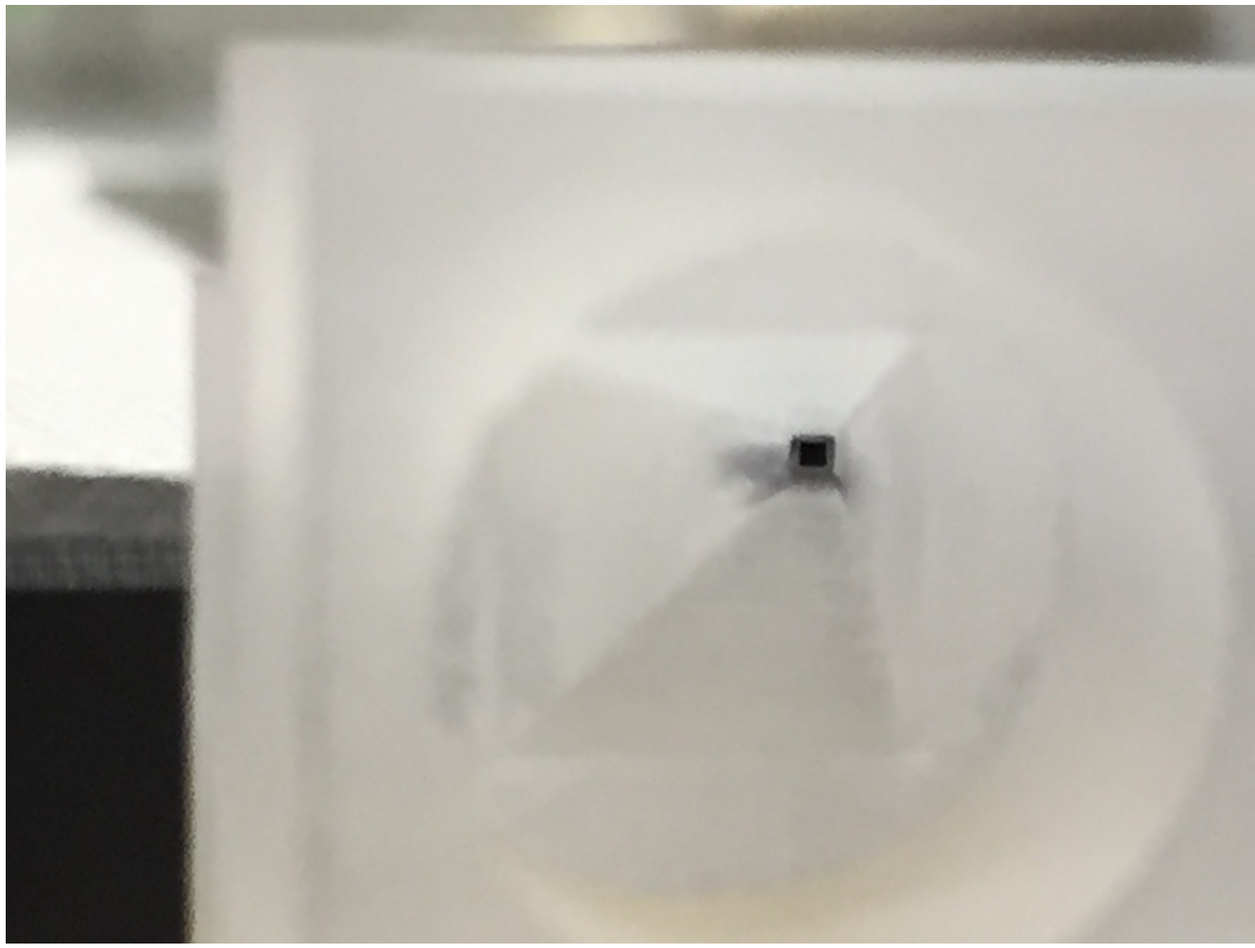




- Stereolithography technology:
  - 15µm precision
  - 300 µm per layer

Test setup





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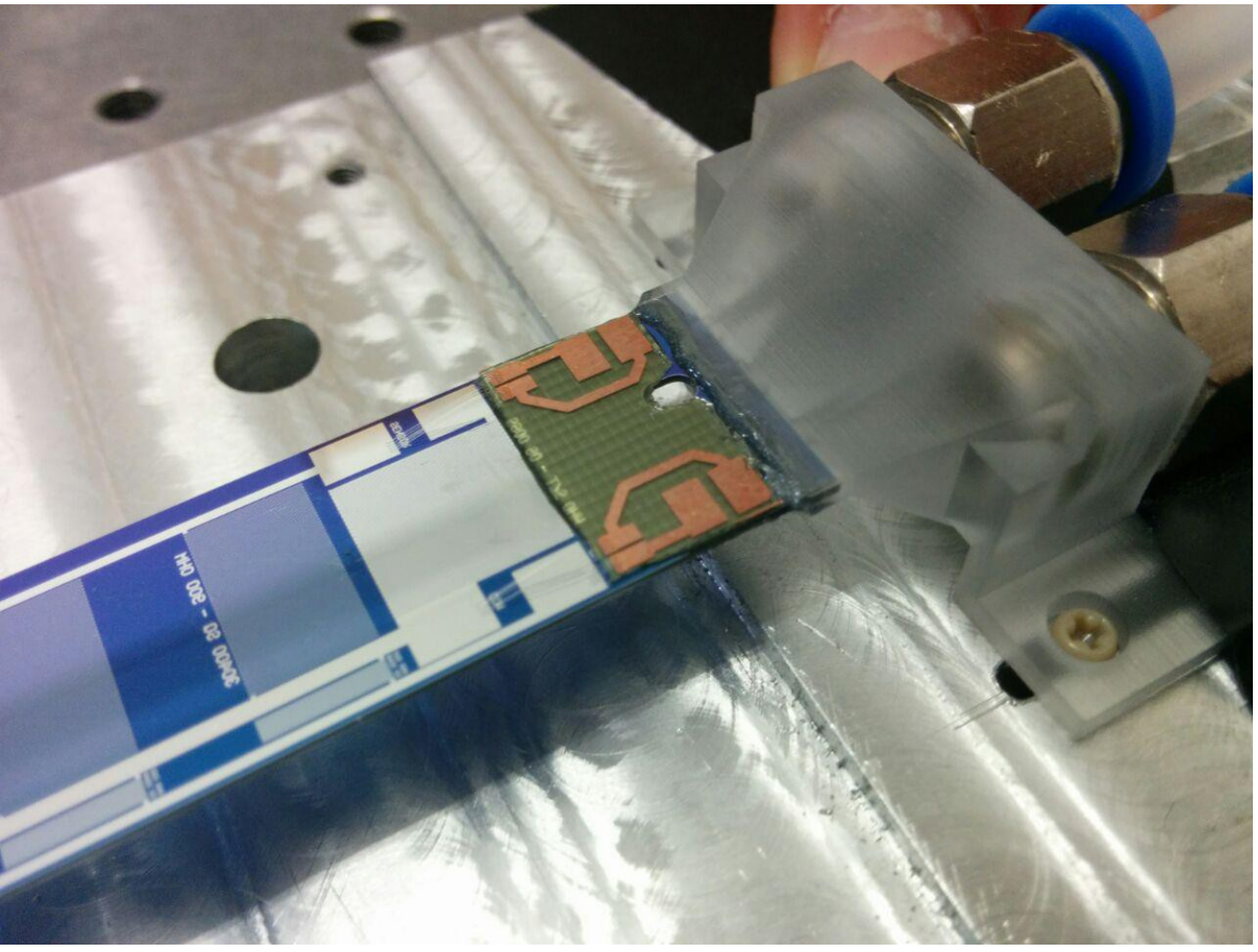
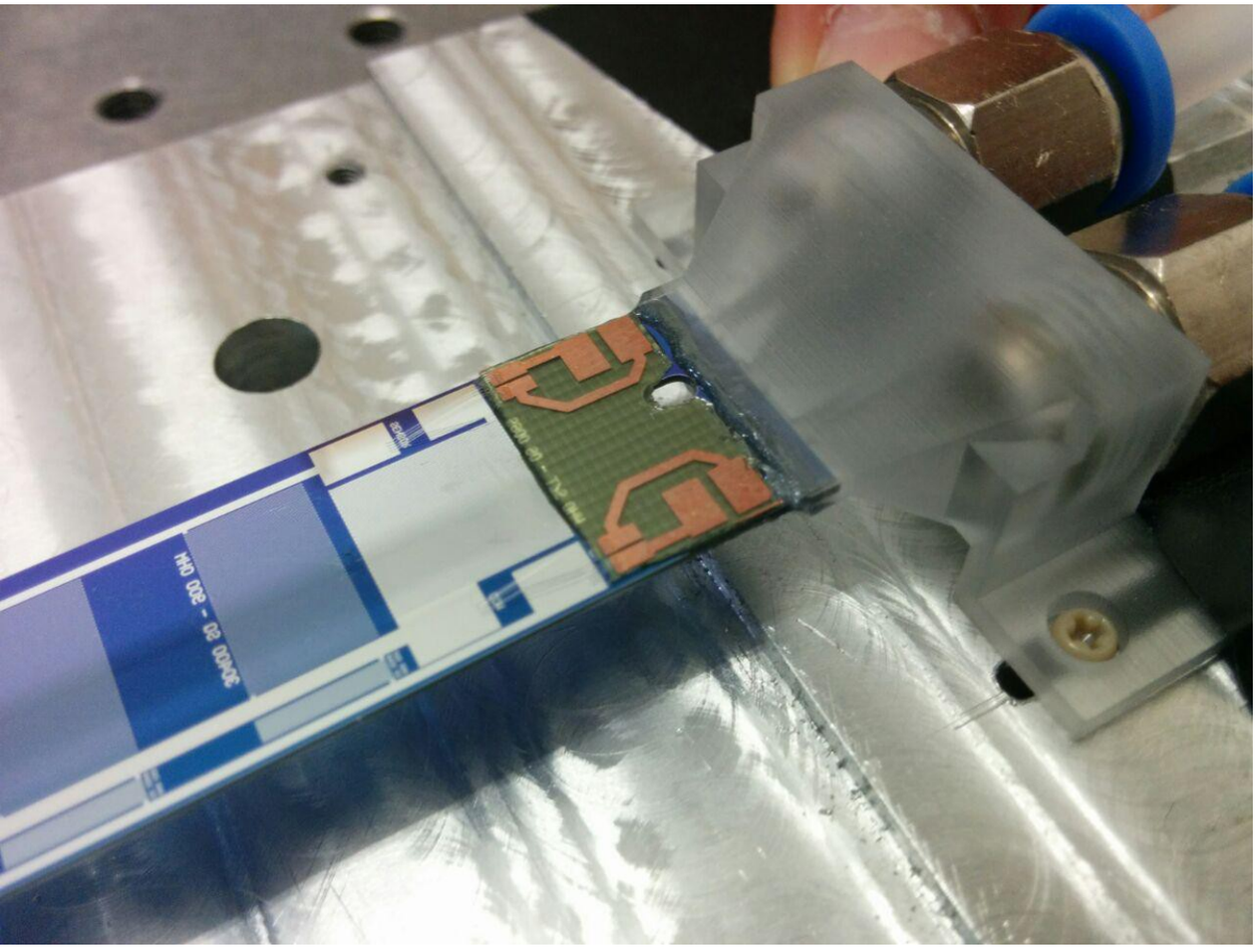
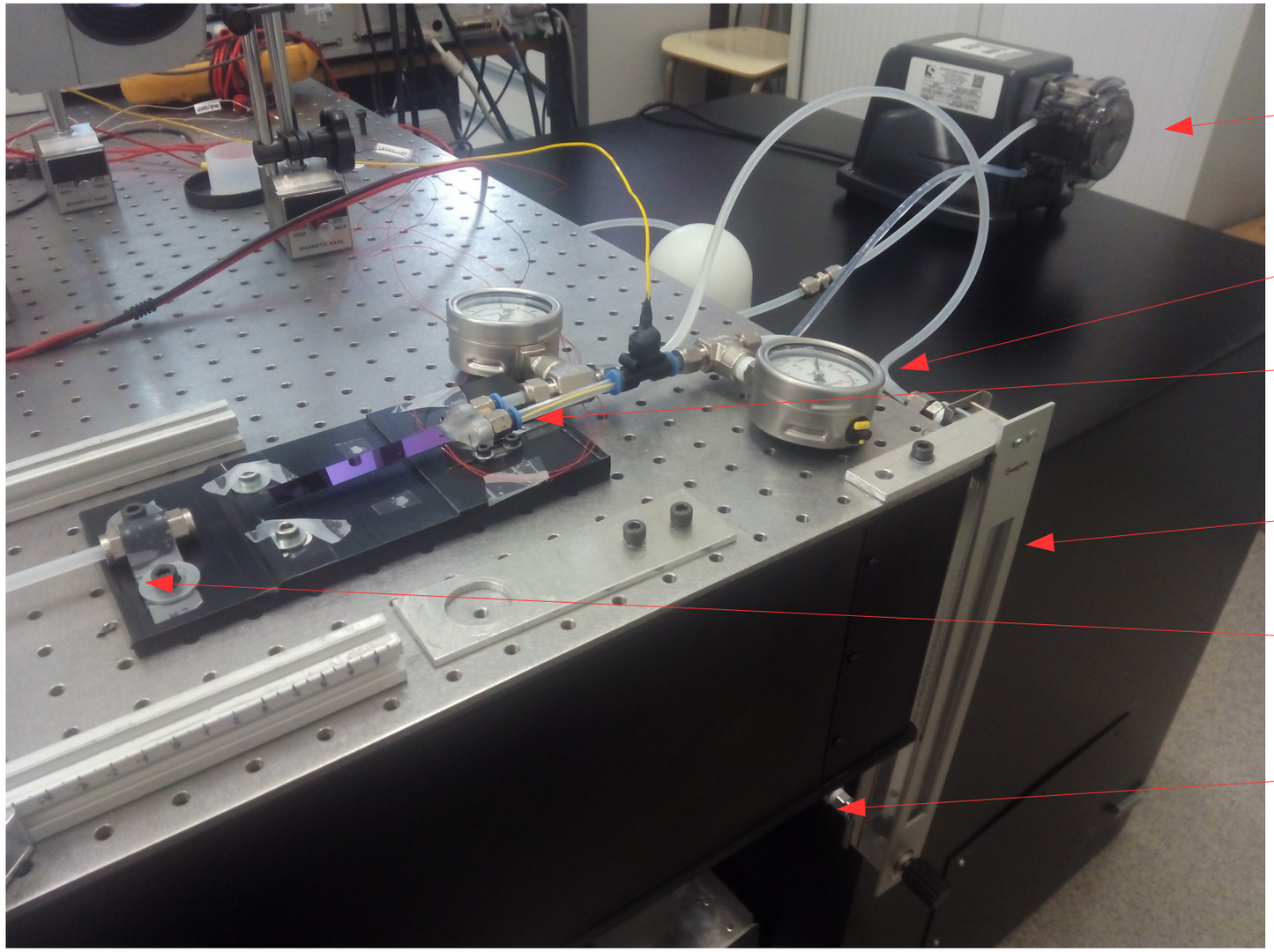


Test setup

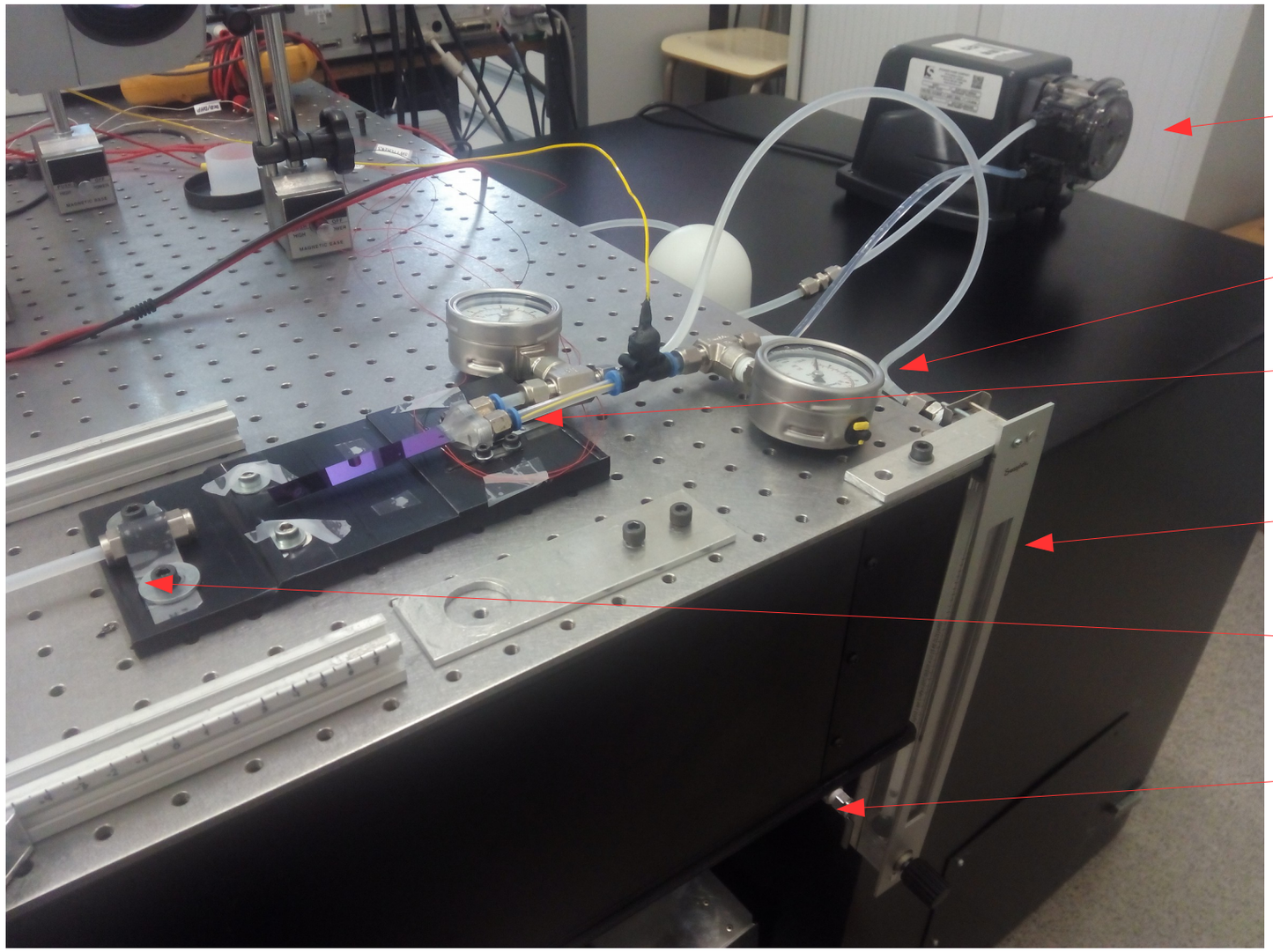


- Self-aligning
- Sealed with glue
- Success rate 3/3
- Adaptor from high pressure commercial elements to MCC Si-detector application

Test setup


Water pump
Pressure gauges
Pt100 (Temperature)
Flow meter
Air cooling (0,5m/s)
Filter

Test setup

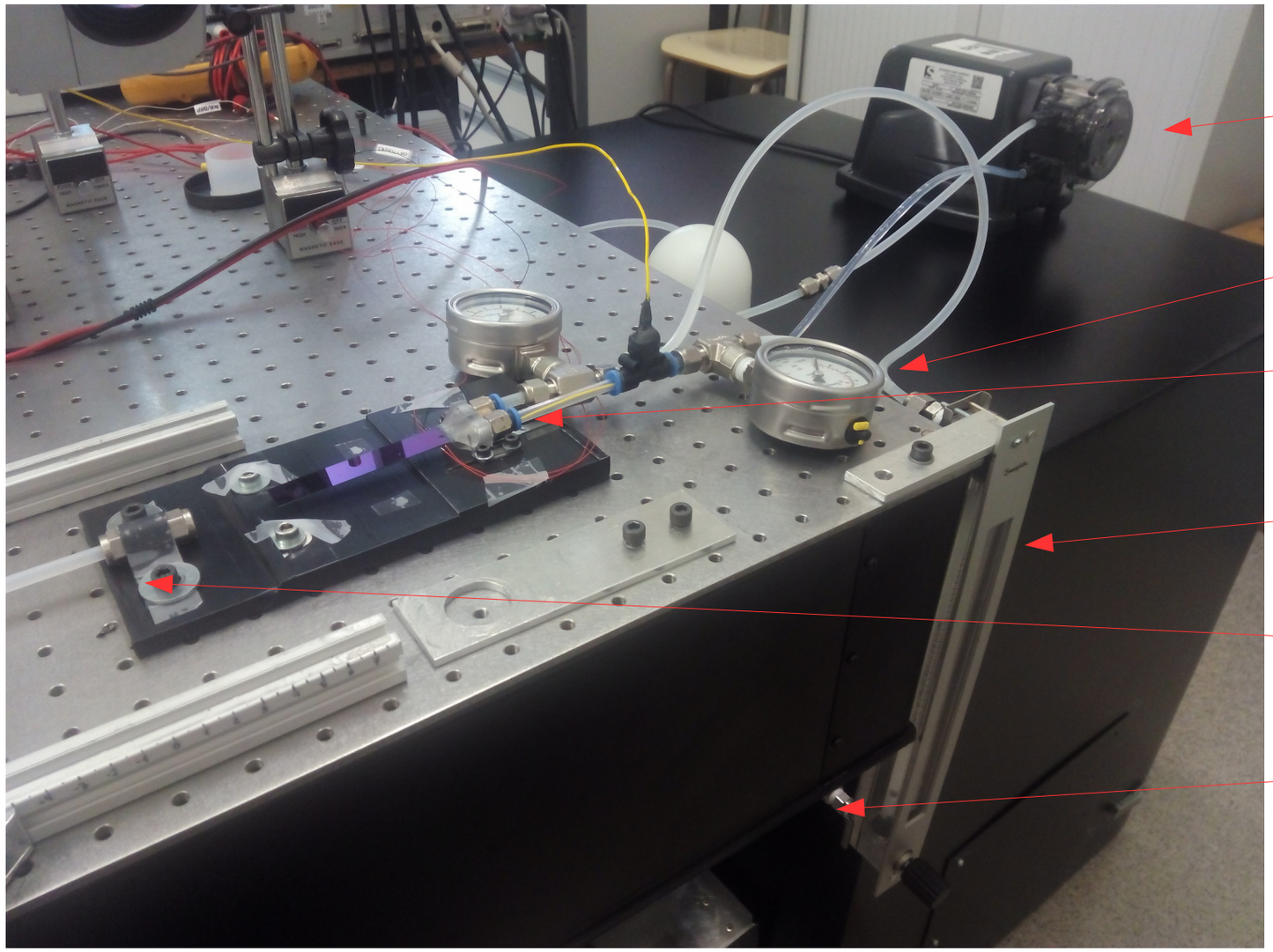


- For Si-sensors operating above 0ºC mono-phase fluid is chosen (water)

- Controlled environment to quantify cooling performance

- Operated non-stop for a week with **no leaks, no clogging**

Test setup



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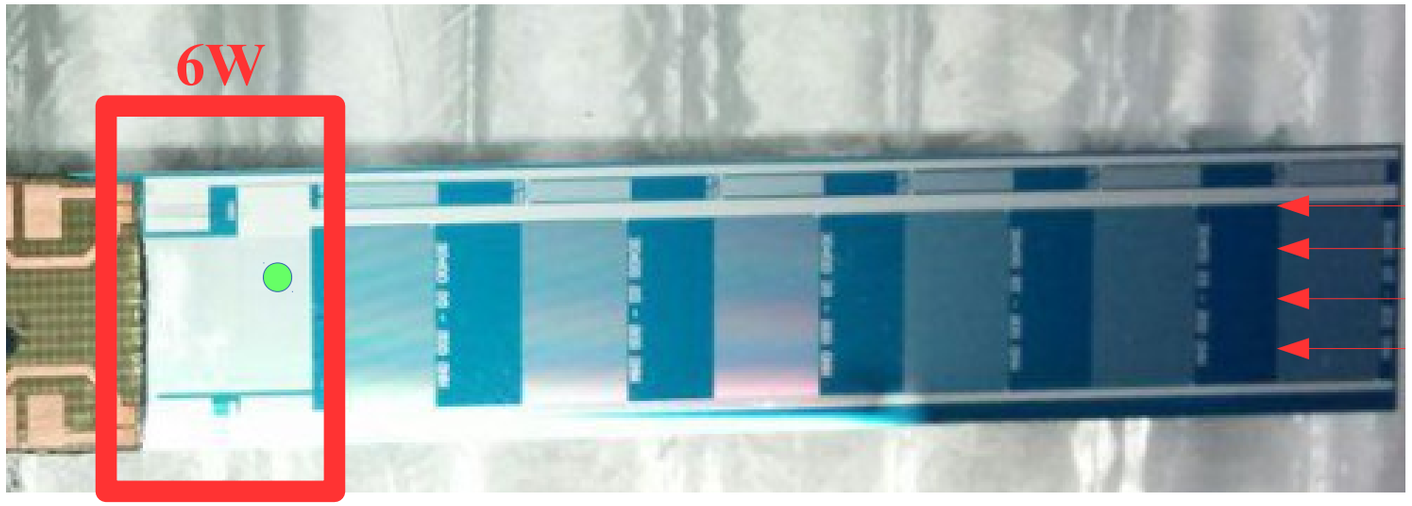
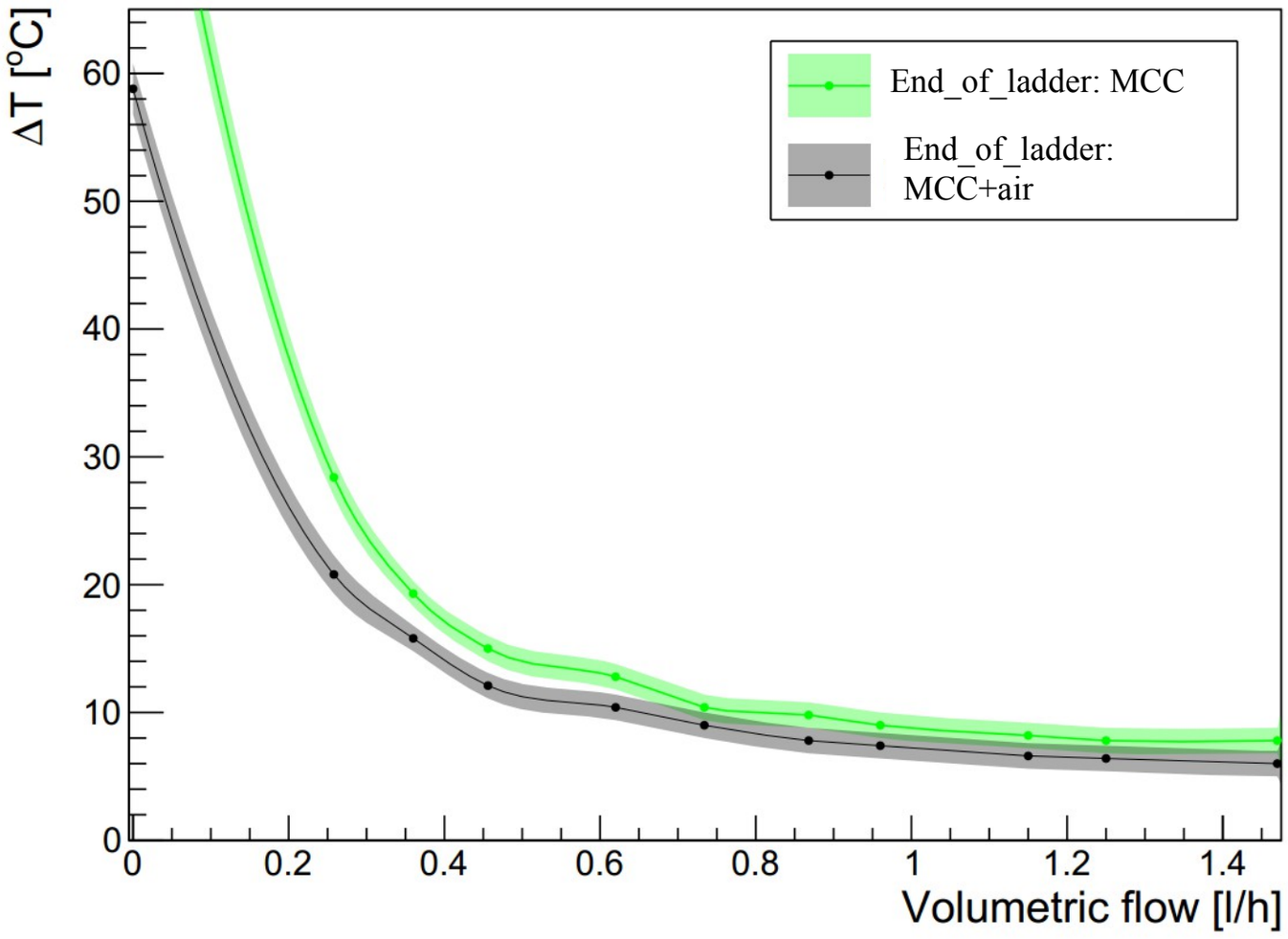
Test results: MCC+air (MCC region)



Air (0,5 m/s)



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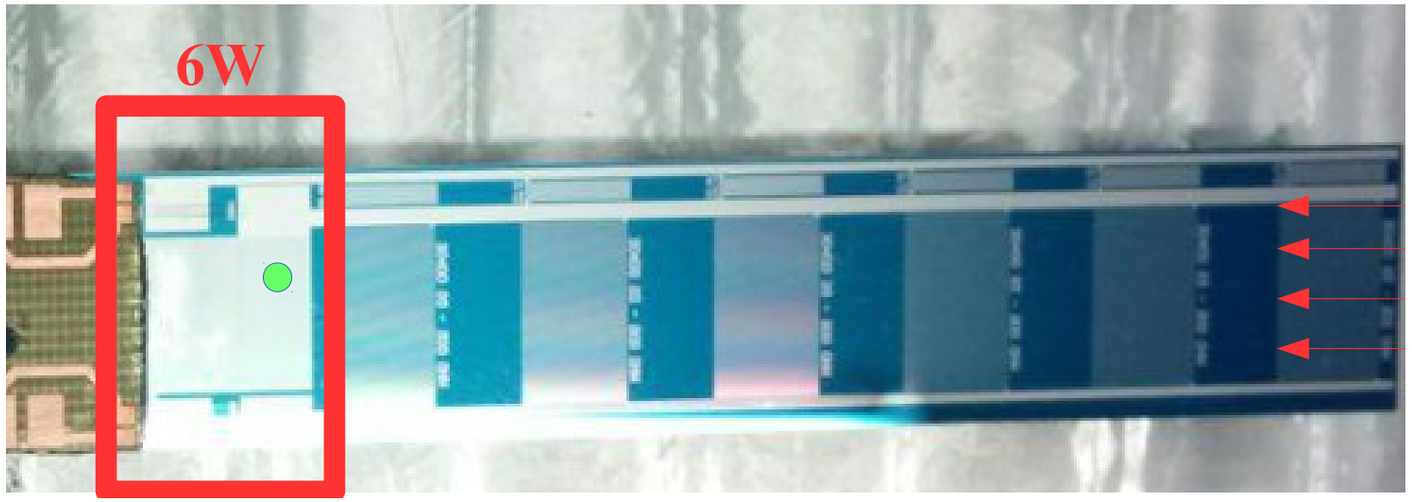
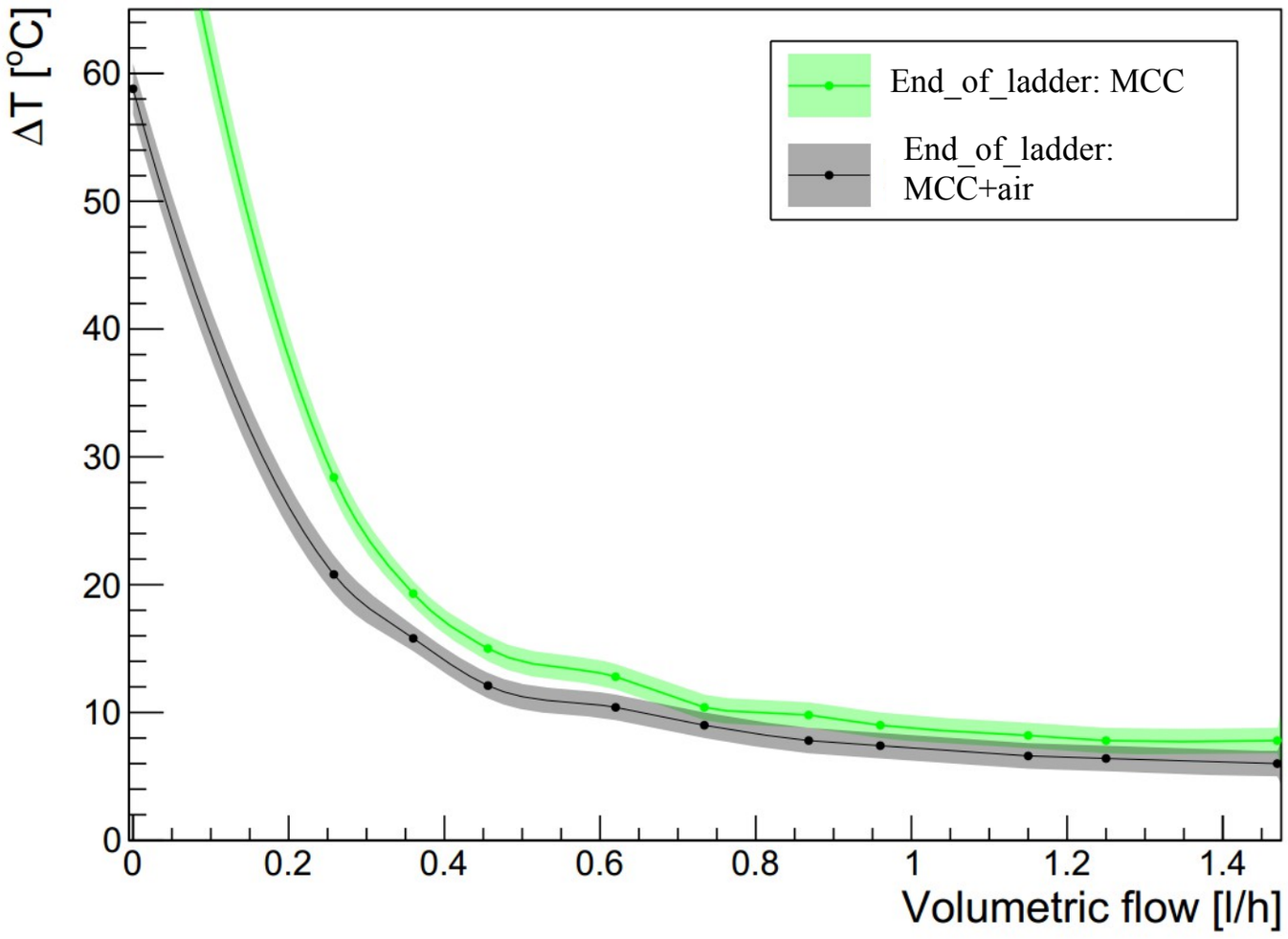


Air (0,5 m/s)



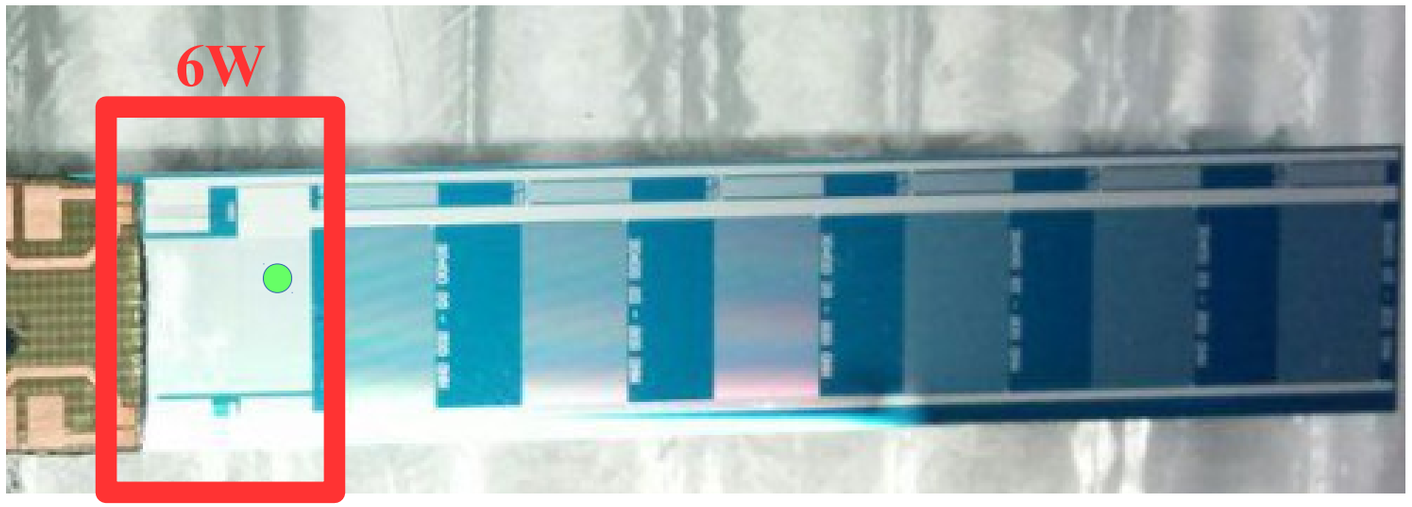
- Farthest regions to the air inlet are not affected by

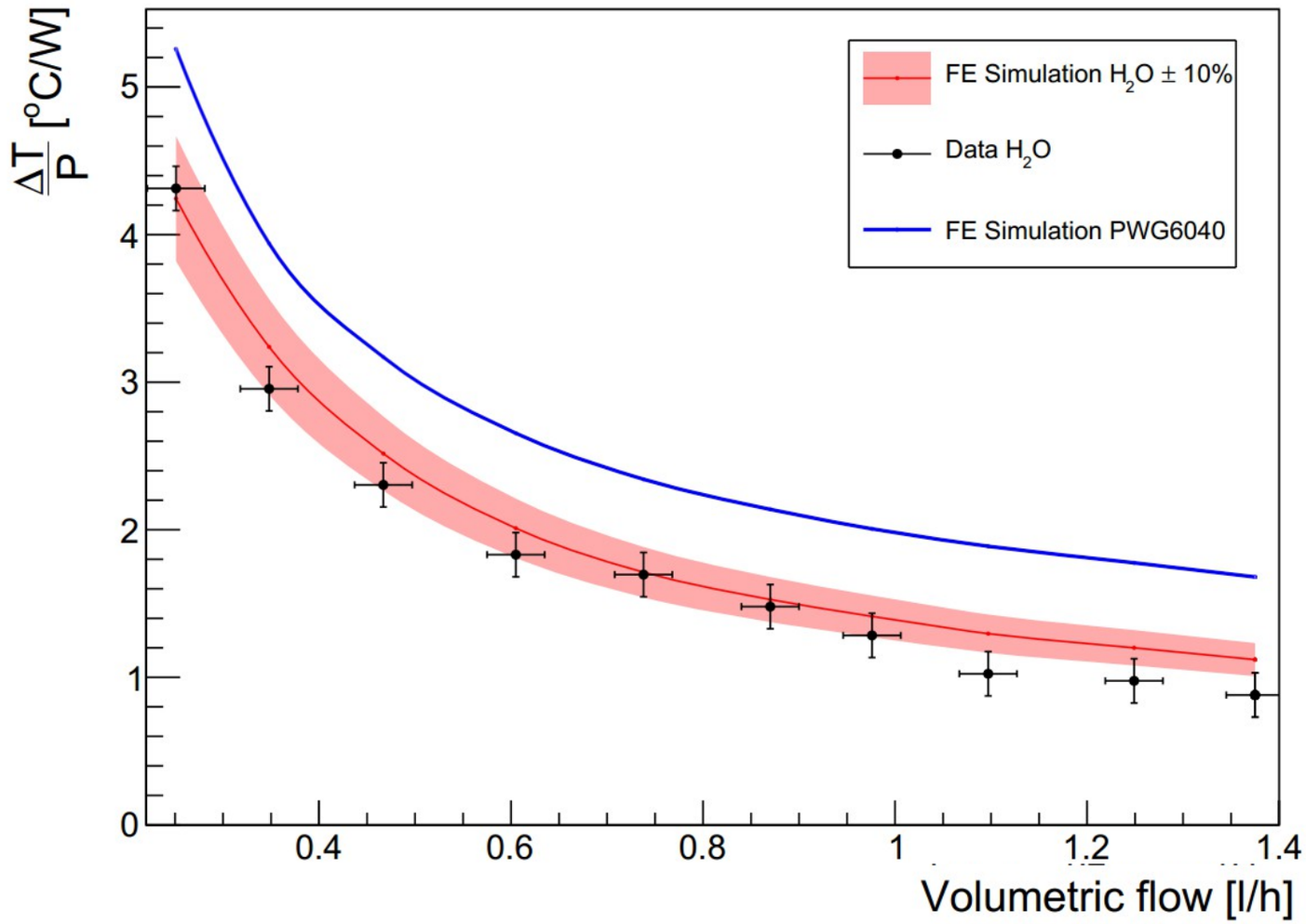
- No big difference between MCC and MCC+air

- Even with low vol. **water** Flow, high cooling

- 93% of total heat cooled by MCC

Test results: MCC



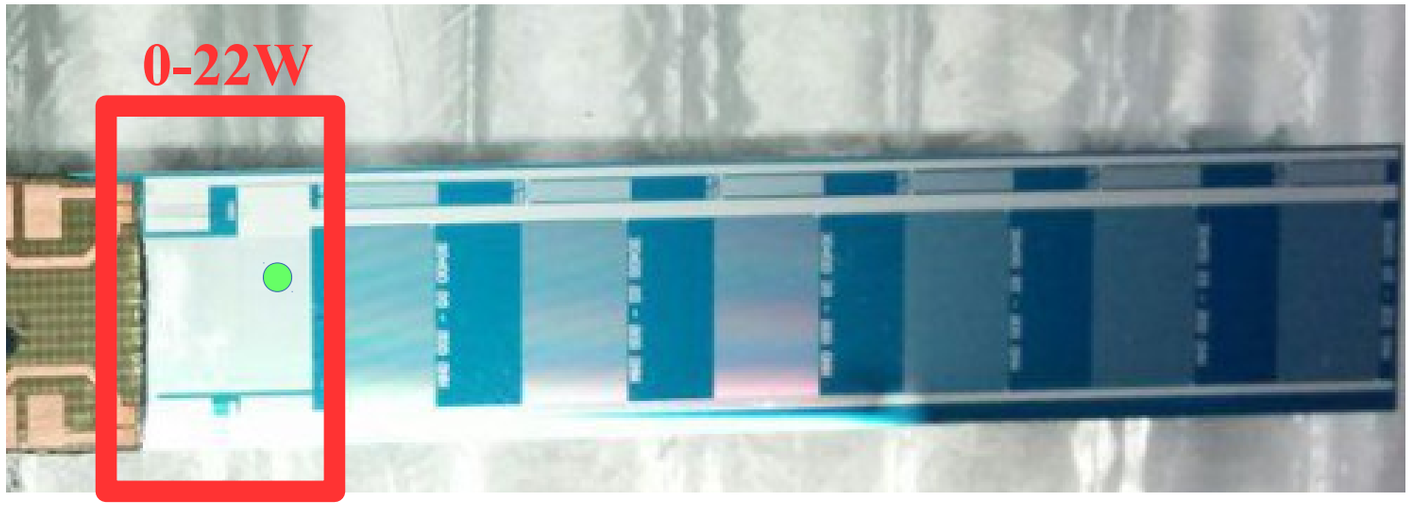


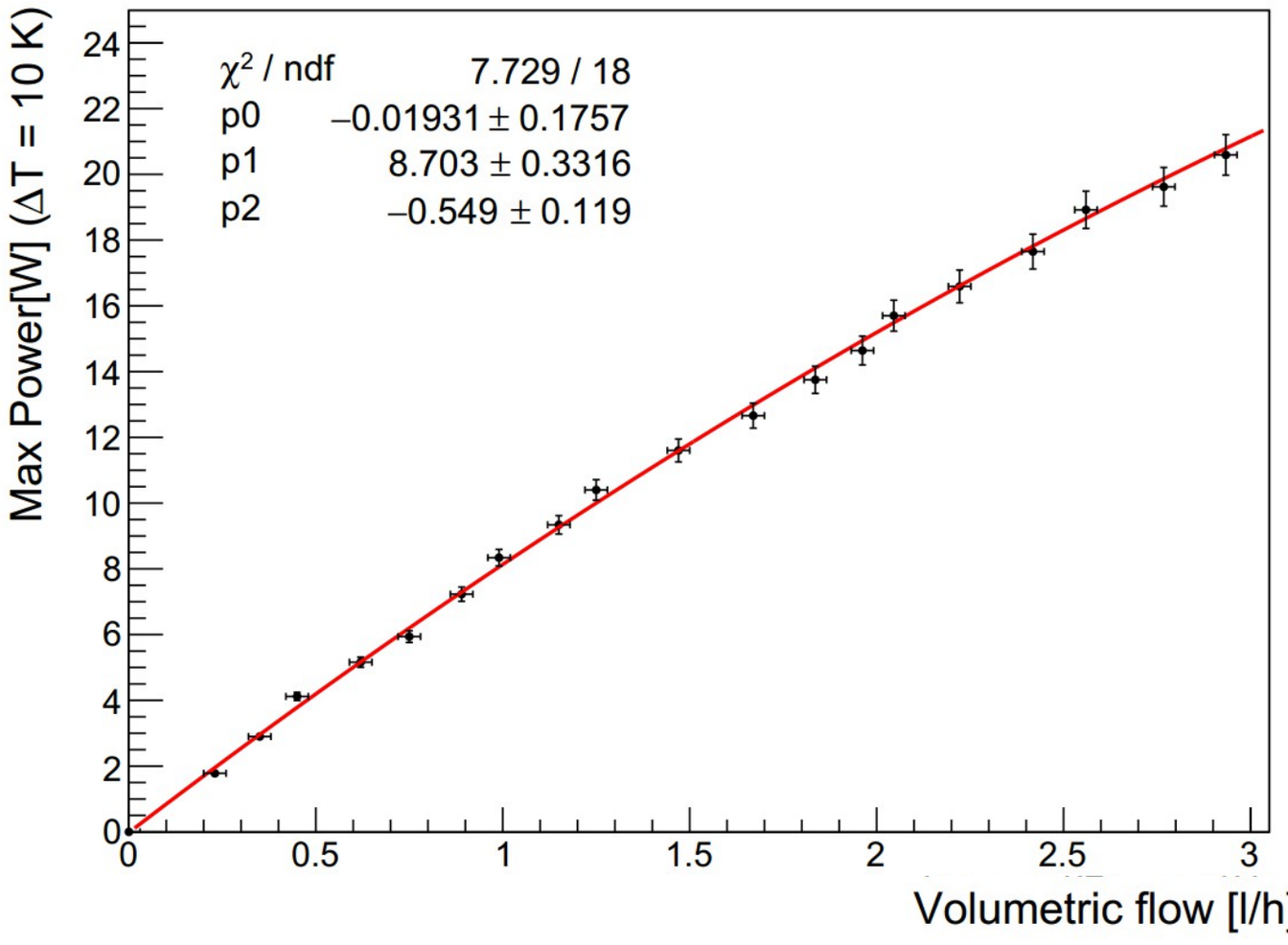
- Good agreement with simulation inside a 10% area

- Additional coolant simulated (60% glycol + 40% water)

- Measurement errors:
1% Power
1ºC Temp
+/- 0,02 l/h

Test results: MCC for ΔT=10K



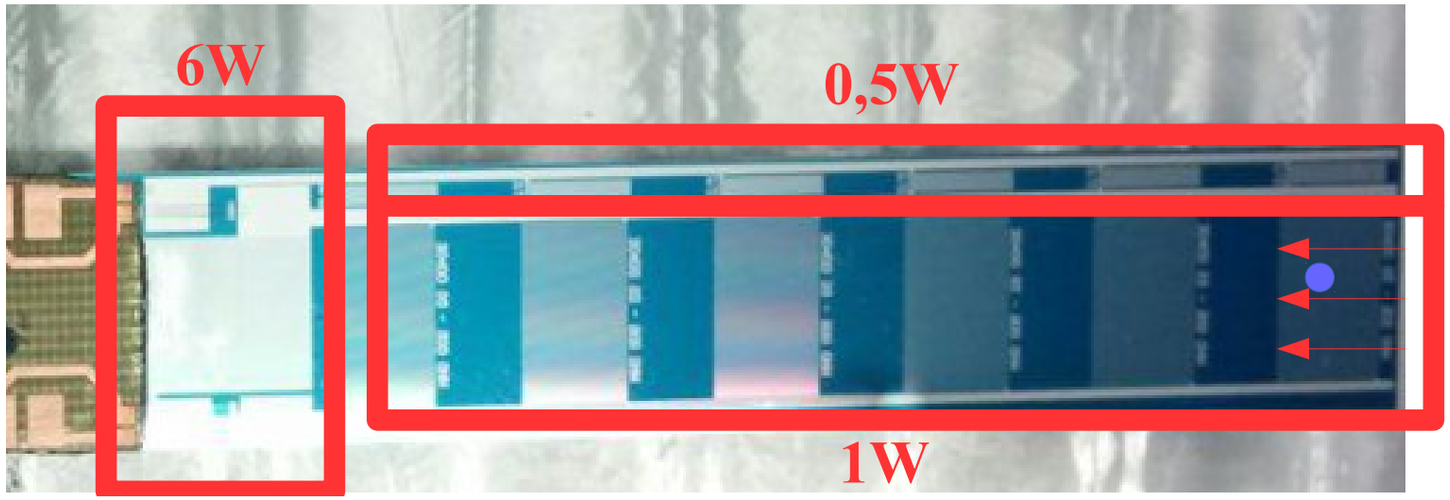


- T stability even with 25W/cm^2

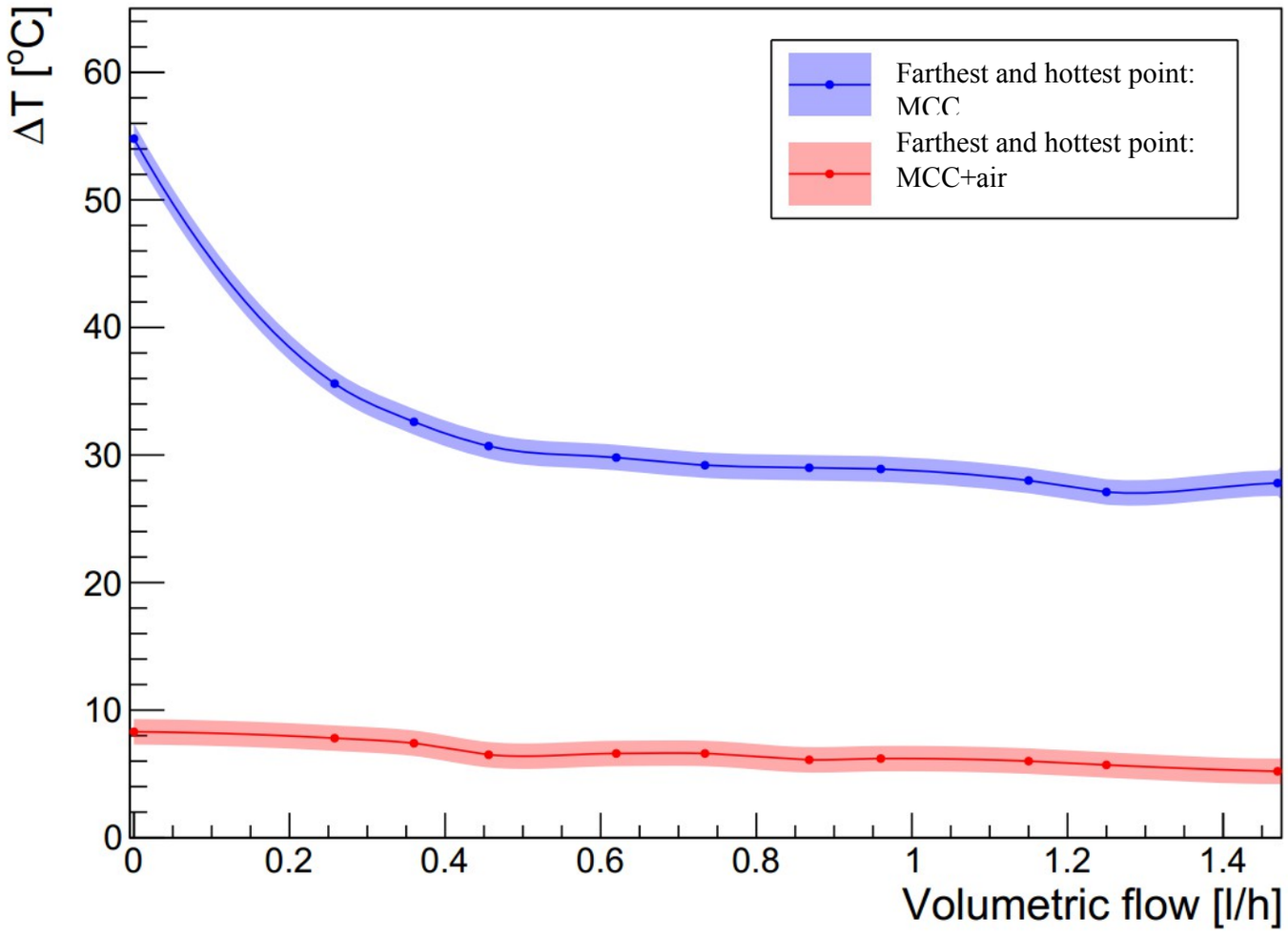
- ΔT(hottest point)/P vs Q at max. pump power: limit not in sight

- Low pressure drop: about 1,5 bar

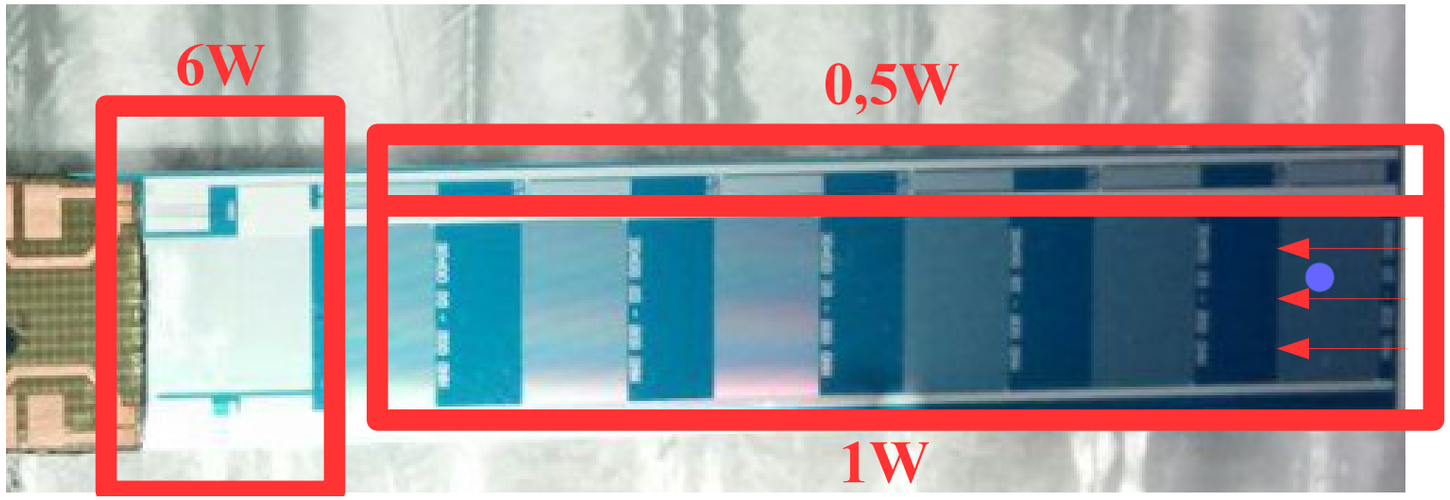
Test results: MCC+air (far from MCC region)



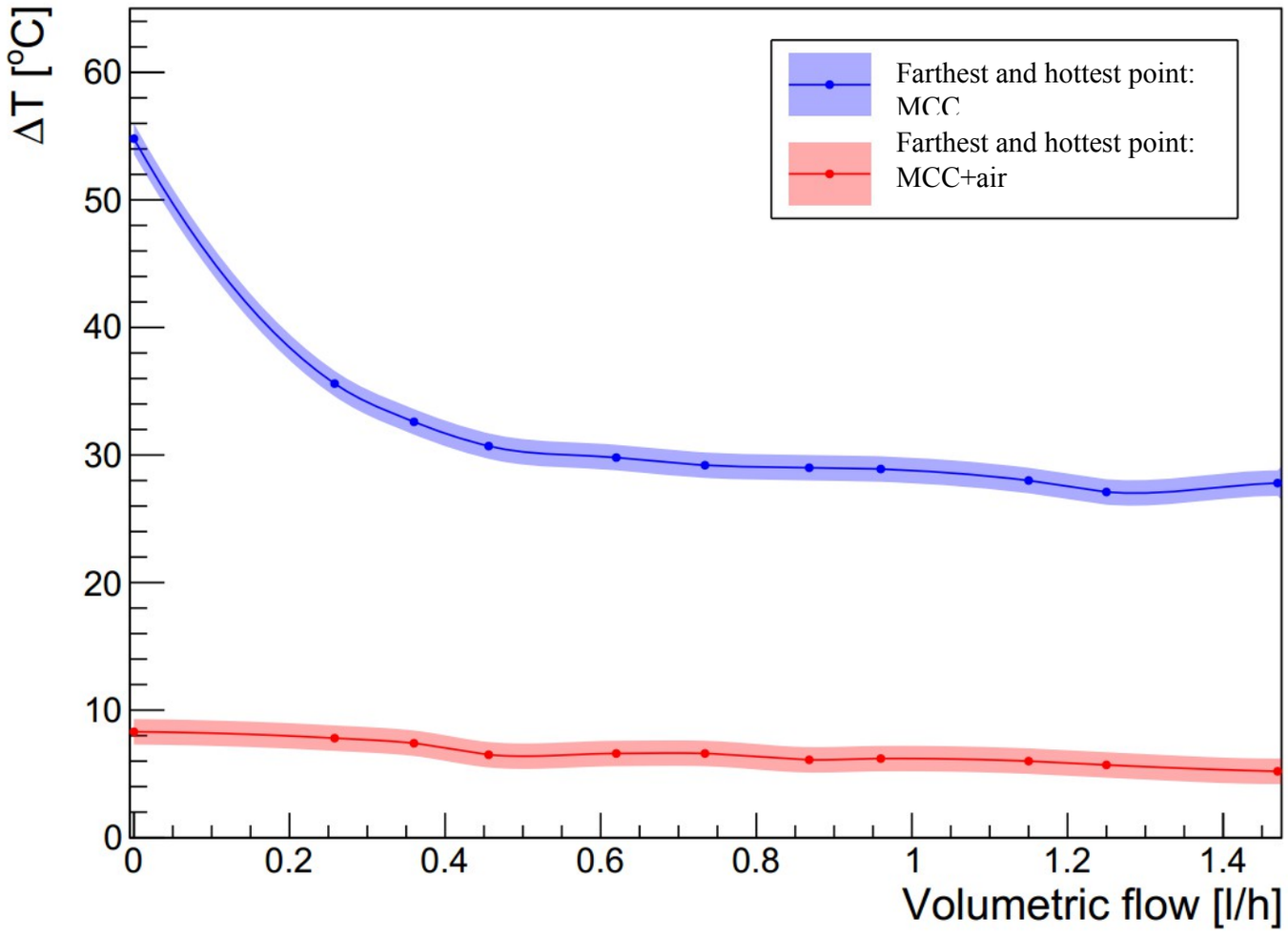
Air
(0,5 m/s)



Test results: MCC+air (far from MCC region)



Air
(0,5 m/s)

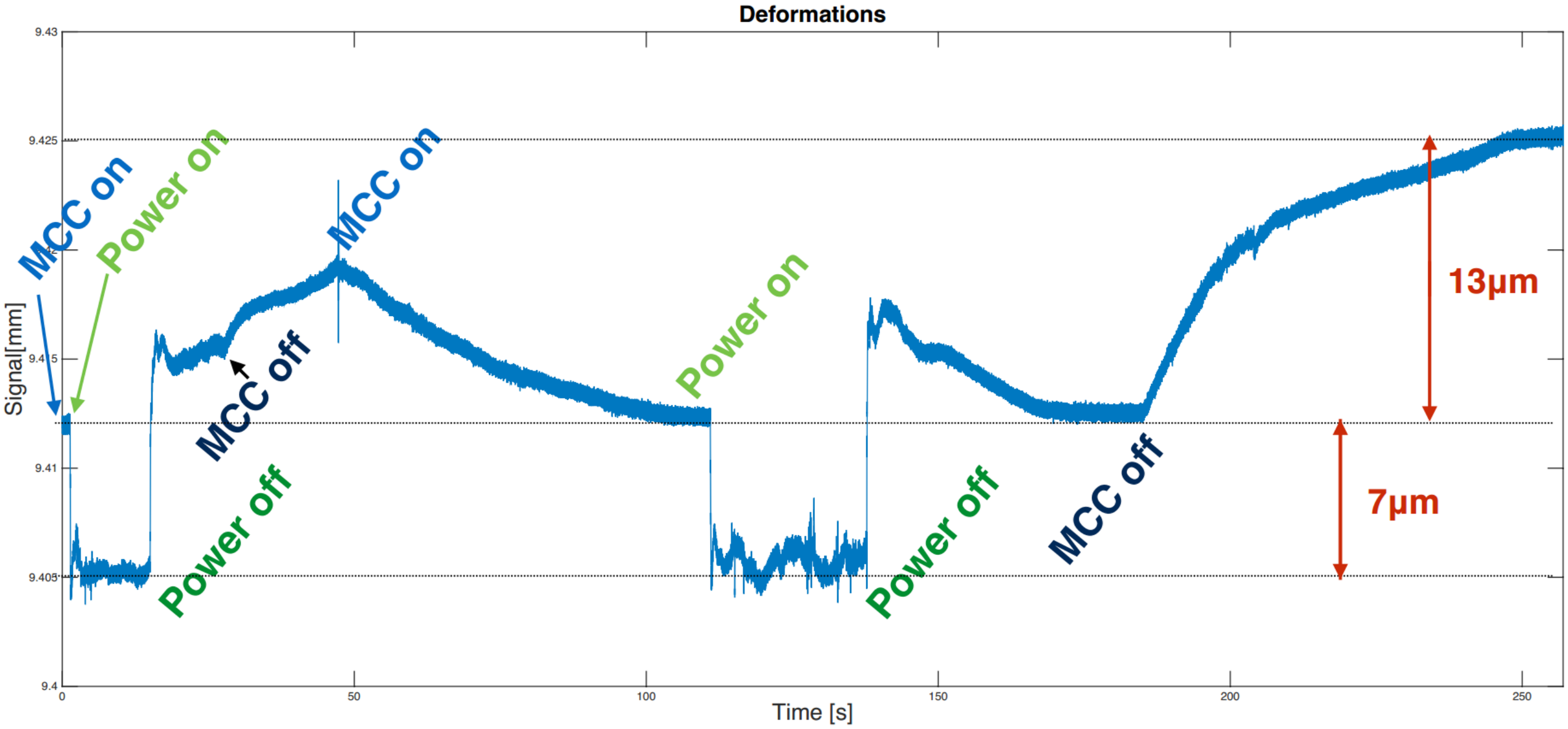


- Nearest regions to air input is sufficient

- Big difference between MCC and MCC+air

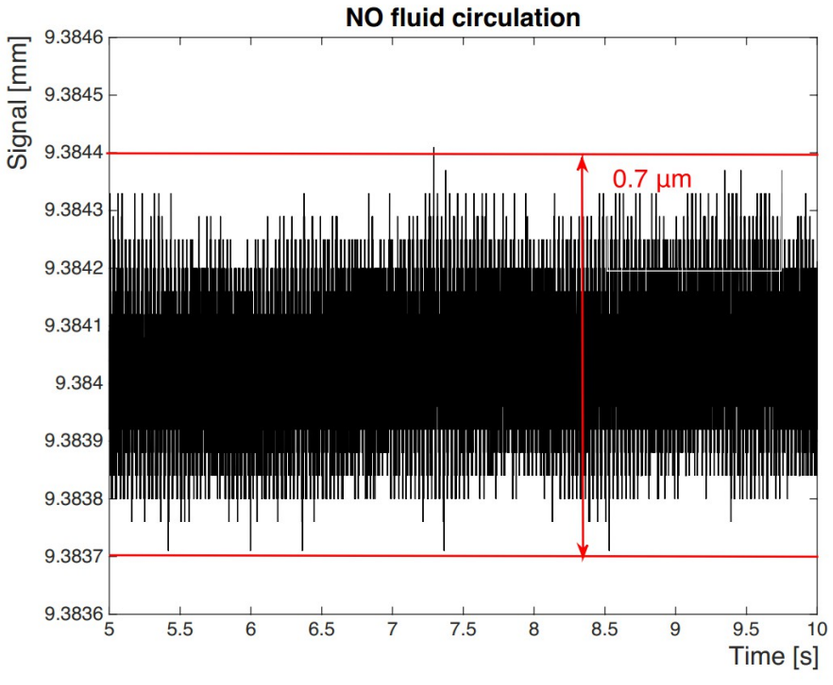
- Even with low vol. **Air** flow, high cooling

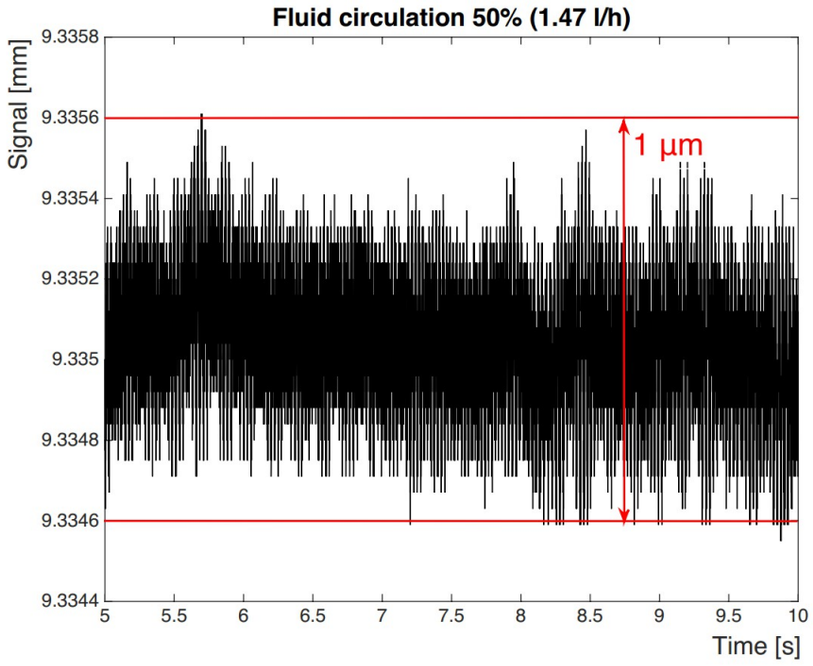
Test results: out-plane static deformation

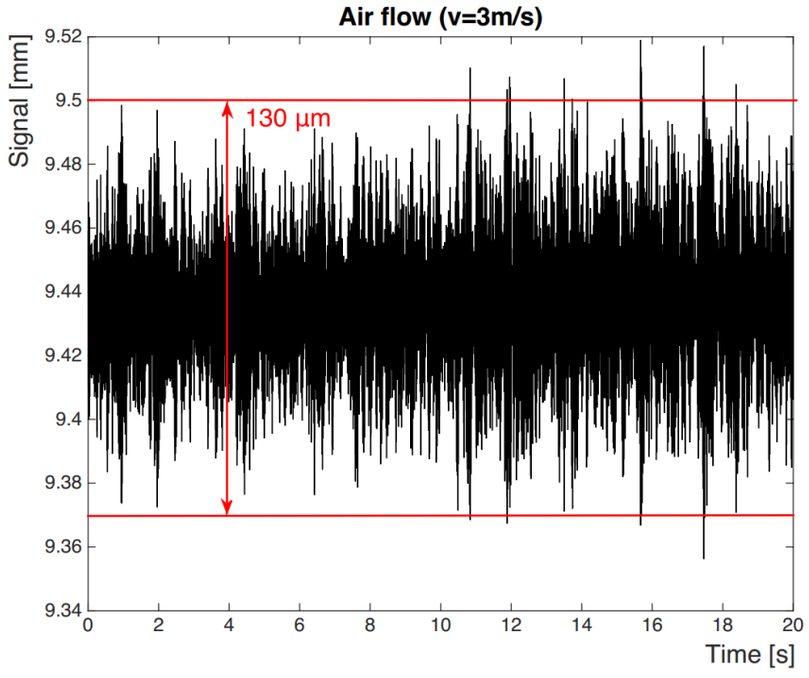


- Minor deformations observed in transitions regions
- Mechanical stability after cycles
- 7µm between power on-off

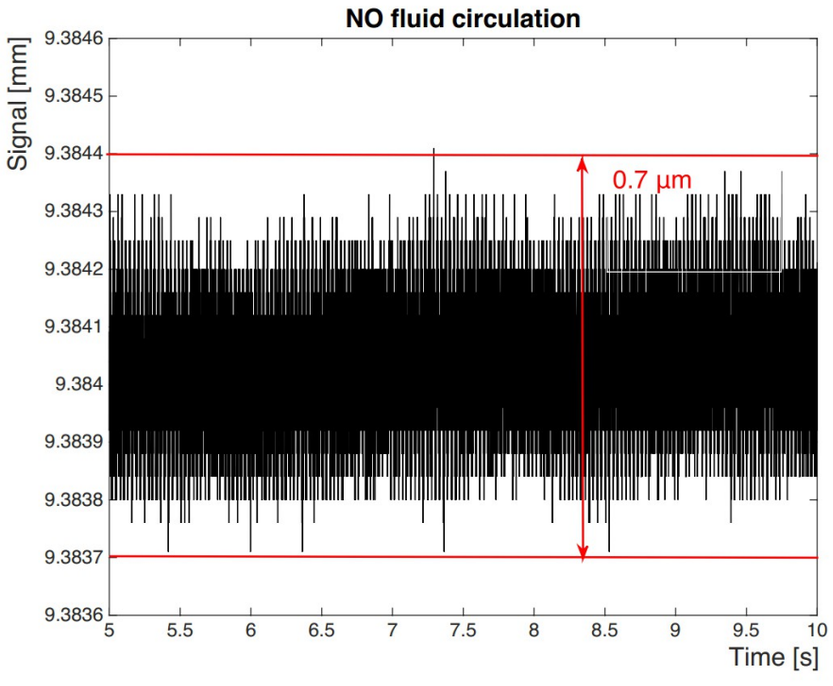
Test results: out-plane dynamic deformation

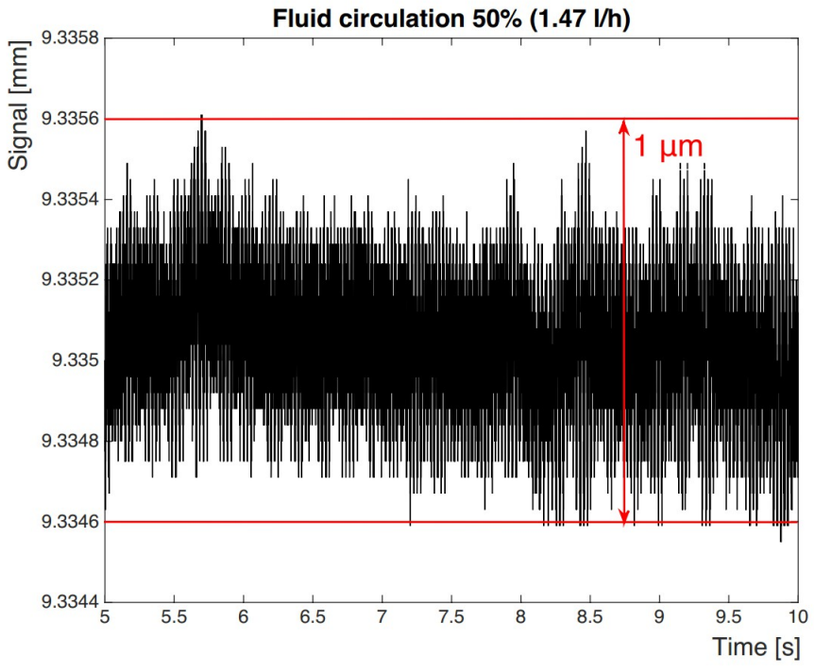


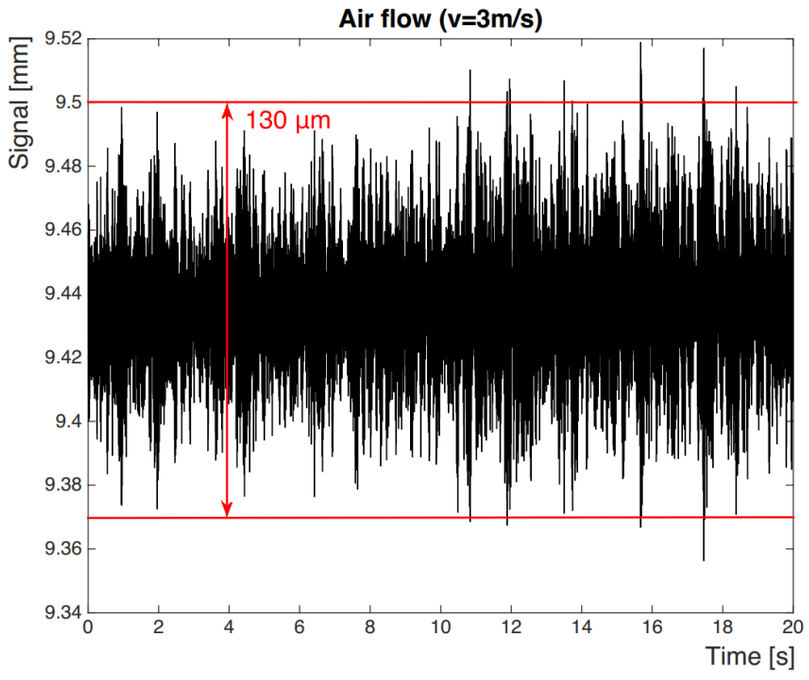




Test results: out-of-plane dynamic deformation







- MCC has no significant impact on mechanical stability

- In Clamped-Free (Cantilever) configuration air deformations are about 130µm if v=3m/s

- RMS (no circulation): 0,3µm
  RMS (liquid circulation): 0,5µm
  RMS (air cooling 3m/s): 57µm

Conclusions

- we have presented a low-pressure single phase MCC solution with in-plane connections

- reliable connections to conventional circuit -> controlled measurements

- very efficient cooling; up to 25 W/cm2 with minimal temperature increase (10ºC) in MCC region

- thermal measurements are in good agreement with FE simulation

- MCC minimal impact on mechanical stability

- Easy and robust assembly (3/3) with a 3D printed adaptor

- MCC embedded in a Si sensor is a real option