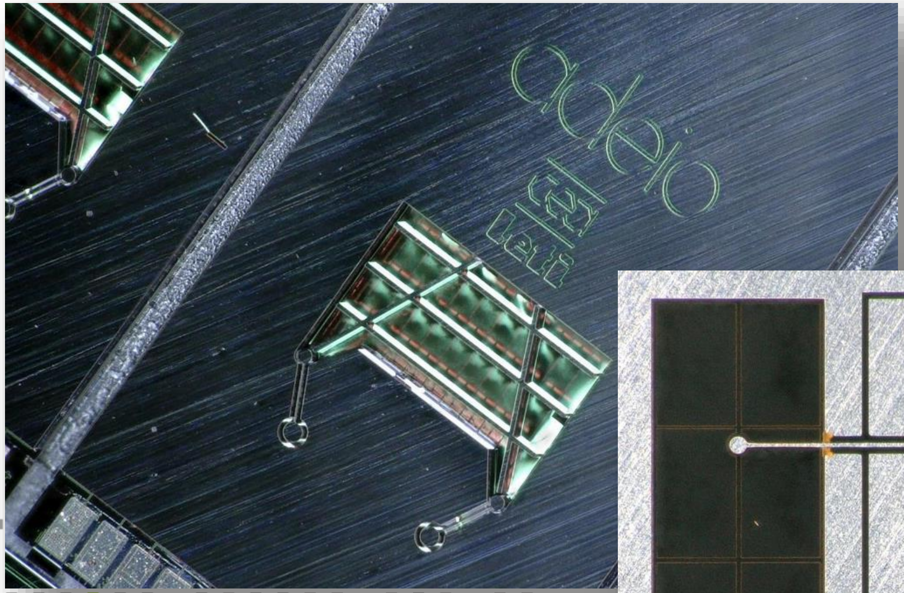
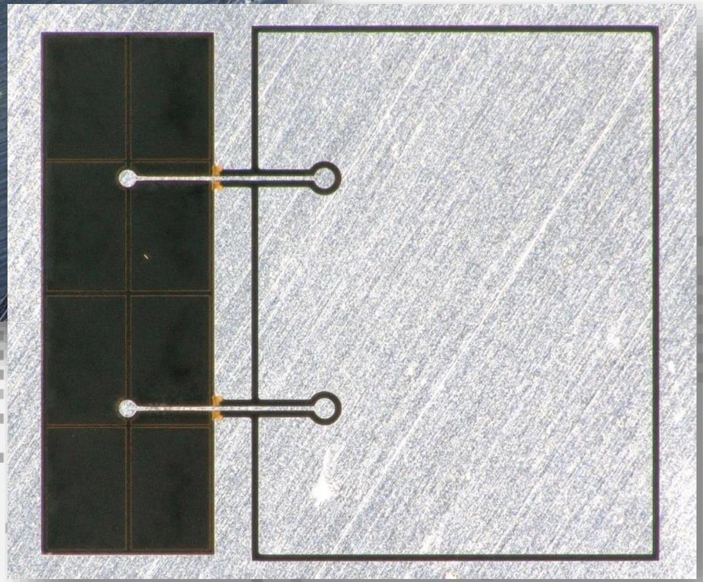




A BREAKTHROUGH MEMS MICROPHONE CONCEPT

Loïc JOET

Leti MEMS Workshop, June 25 2019, Estrel Congress Center, Berlin

A GROWING MARKET, REQUIRING HIGHER PERFORMANCES

A better SNR …

- **High fidelity** conversation/video
- **Noise cancelation** enhancement
- **Range** increase
- **Speech recognition** improve
- **New applications**: surveillance

Maintaining the AOP

Extending the bandwidth to 20kHz

Maintaining the size

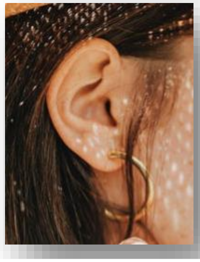

$0dB_{SPL}$
Human threshold

$25dB_{SPL}$

$94dB_{SPL}$
= 1Pa

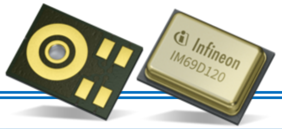
$135dB_{SPL}$

SOUND PRESSURE LEVEL



noise

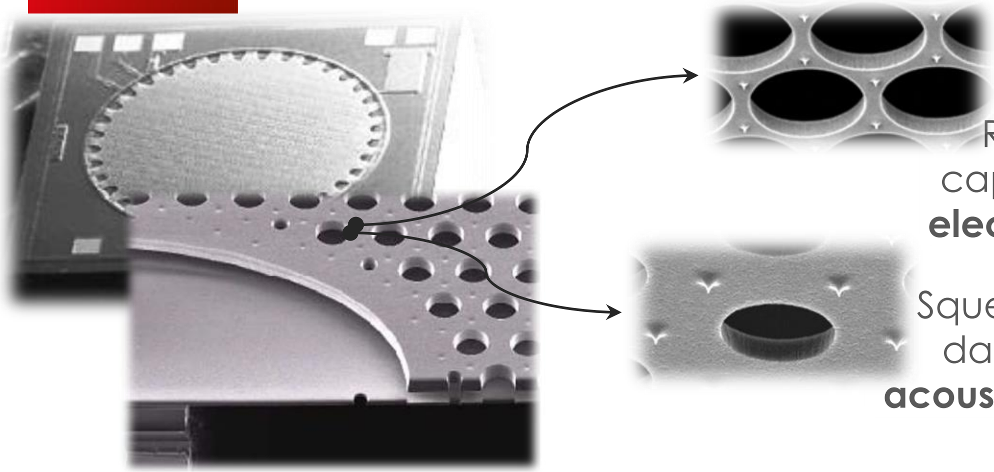
$69dB_A$ SNR



10%
saturation

110 dB dynamic

CURRENT CAPACITIVE MICROPHONES HAVE REACHED THEIR LIMITS

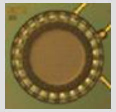
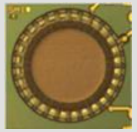
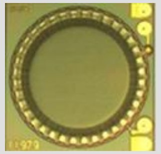
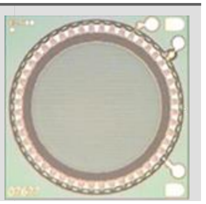


Reduced capacitance, **electrical noise**

Squeeze film damping, **acoustical noise**

2006 — Capacitive microphone evolution →

Today highest perf.

SNR	59dB(A)	60dB(A)	61dB(A)	64dB(A)	**66dB(A)**
Sample					
Die size	0.64mm²	0.81mm²	1.0mm²	1.44mm²	**1.96mm²**
Back volume	1.1mm³	1.1mm³	1.1mm³	3.0mm³	**3.0mm³**

Alfons Dehé *et al.*, AMA Conferences 2013

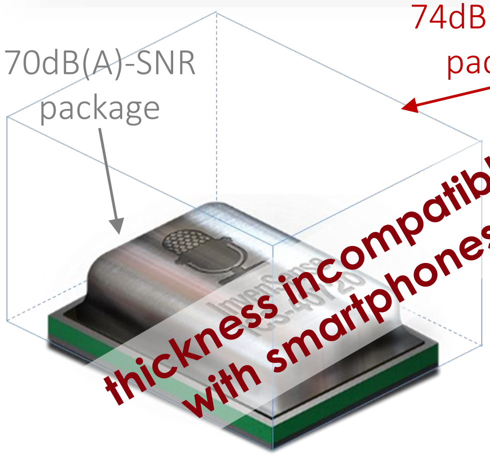
Infineon

- **69dB(A) SNR**
- 4 x 3 x 1.2 mm³
  ~ 10mm³ BV

TDK

- **74dB(A) SNR**
- 4.7 x 3.8 x 3.5 mm³
  ~ 45mm³ BV

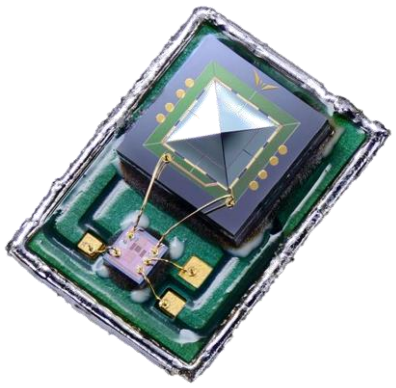
74dB(A)-SNR package



A breakthrough is required …

Backplate must be removed!

PIEZOELECTRIC MICROPHONES STRUGGLE TO PROVIDE MORE PERFORMANCES



63dB(A)-SNR:

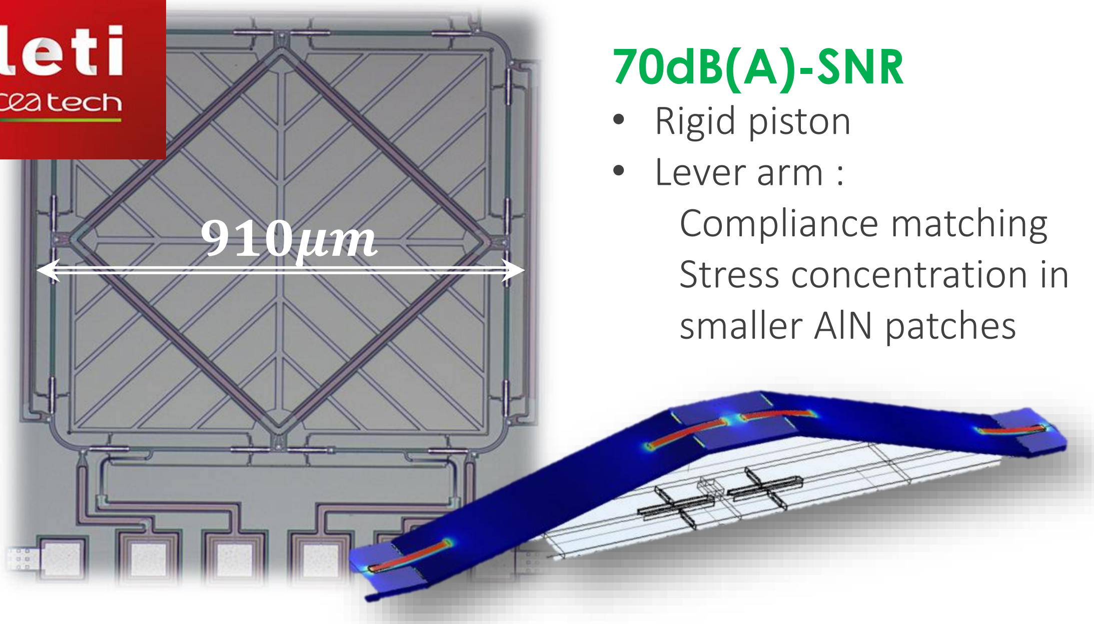
6dB lower than Infineon (same package)

- small amount of charges / large capa
- leaks between flaps (roll-off @ 85Hz)
- tan(δ) intrinsic noise

Vesper punch line:

~~**“very high performances”**~~

“very low power consumption”



70dB(A)-SNR

- Rigid piston
- Lever arm :
  Compliance matching
  Stress concentration in smaller AlN patches

Low cost / good performances…

Not the breakthrough!

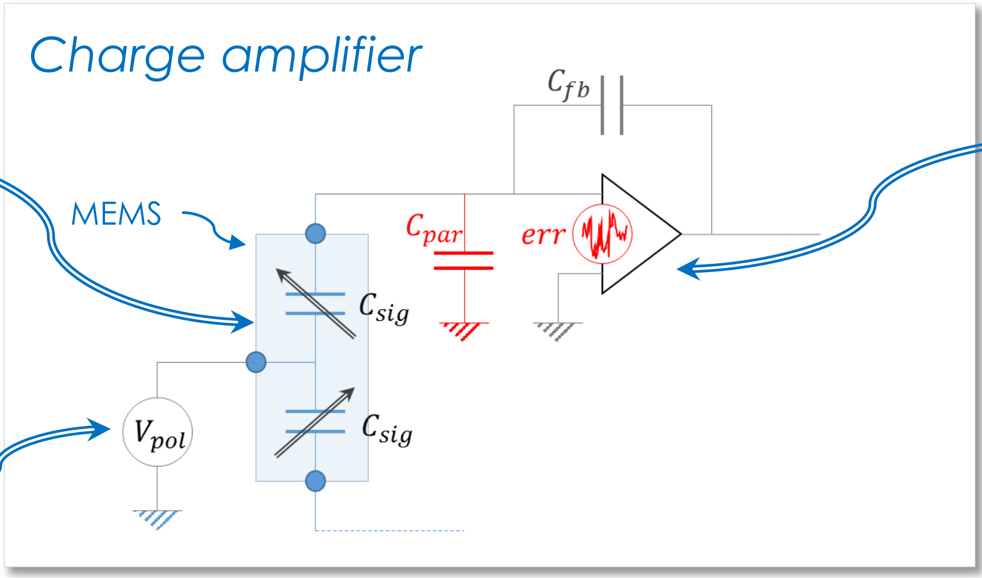
CAPACITIVE TRANSDUCTION IS REALLY EFFICIENT

$$\left(\frac{\delta C_{sig}}{C_{sig}}\right)_{max} = 10\%$$

non linearity < 5%

15V polarization

Main advantage!



10nV/√Hz input noise amplifier

Conventional ...

120dB dynamic reachable! $\Rightarrow \dfrac{C_{sig}}{C_{par} + C_{fb}} = 1.1$

Capacitive transduction efficiency without the backplate noise?

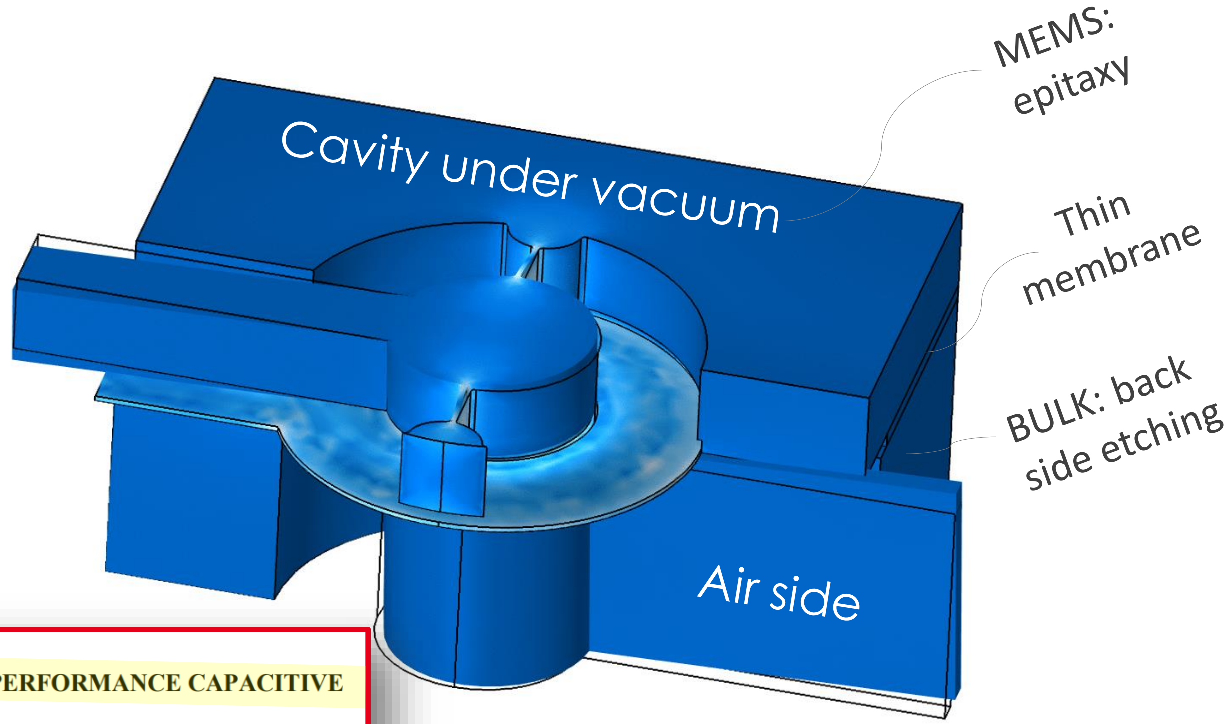
LET'S PUT THE ELECTRODES INTO VACUUM!

A simple idea …

… masking a complex implementation!

An innovative
<u>air-to-vacuum hinge:</u>

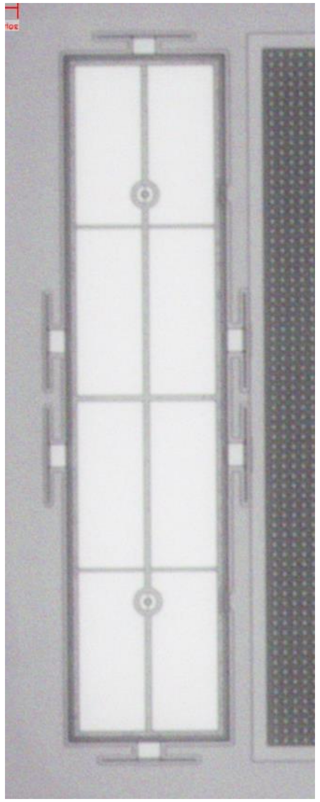
- Transmit displacement to vacuum,
- Resist to 10bars,
- Stay insensitive to atmospheric pressure variation
- …



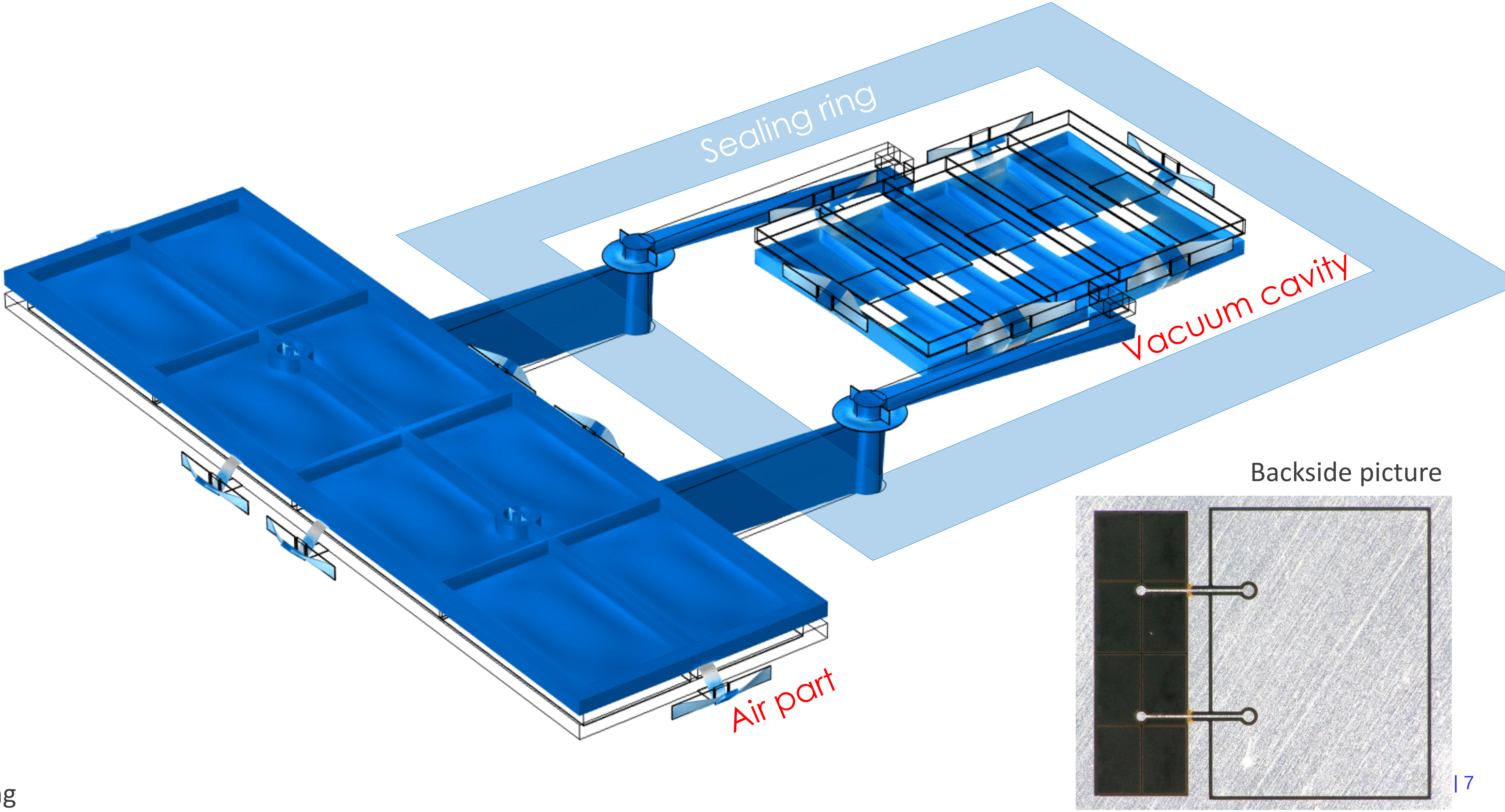
17:30 - 17:45
W4E.005 NOVEL HINGE MECHANISM FOR VACUUM TRANSDUCTION HIGH PERFORMANCE CAPACITIVE MEMS MICROPHONES
Samer Dagher[1,2], Carine Ladner[1], Stéphane Durand[2], and Loic Joet[1]
[1]University of Grenoble, Aples CEA-Leti, FRANCE and [2]LAUM UMR-CNRS, FRANCE

Design, fabrication and first experimental results of a microscale hinge mechanism allowing the mechanical transfer of a force between two atmospheres. Applied to the design of a capacitive MEMS microphone, this mechanism divides the device into two separate parts: a pressure harvesting membrane in air, linked to a capacitive transducer sitting in vacuum. Theoretically this separation should increase overall microphone performance (SNR>75dB(A)) while maintaining a small device footprint (<2mm2).

FROM HINGES TO MICROPHONE

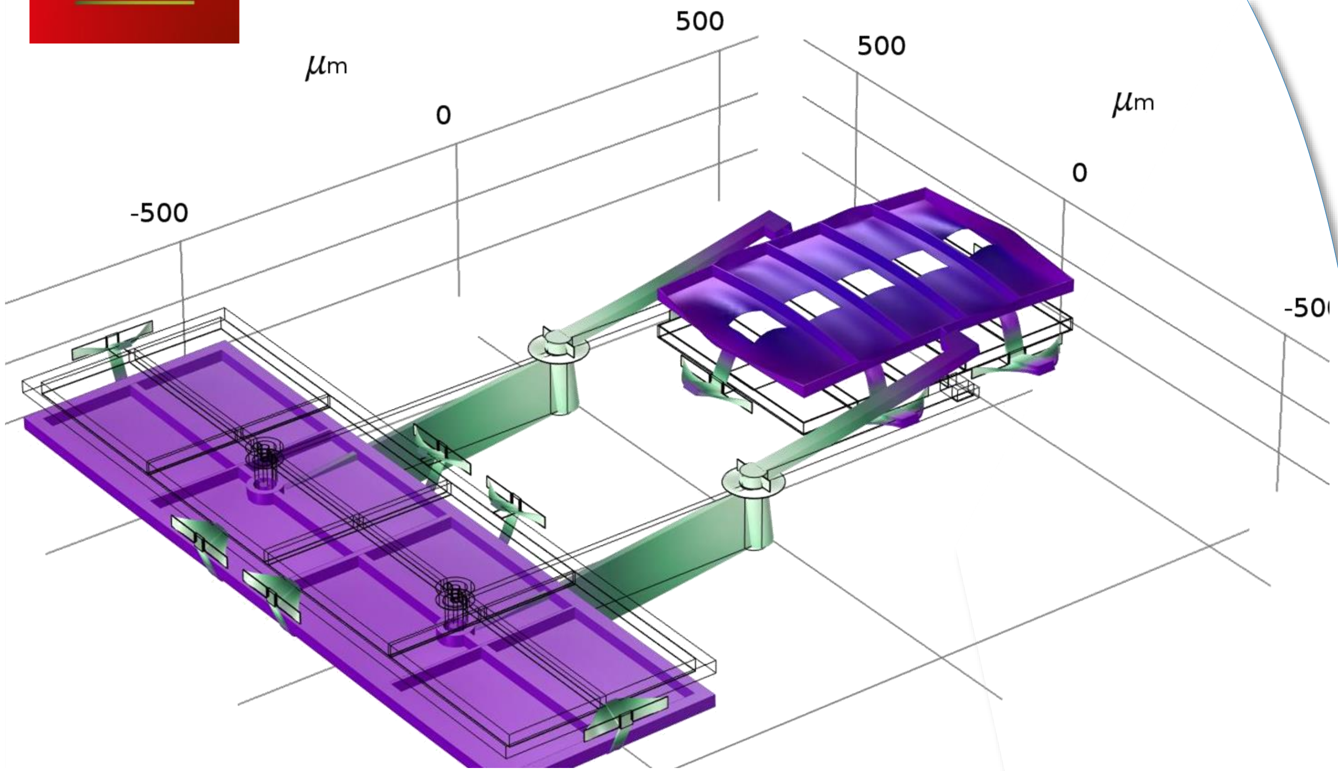


MEMS IR picture
before cap sealing



Backside picture

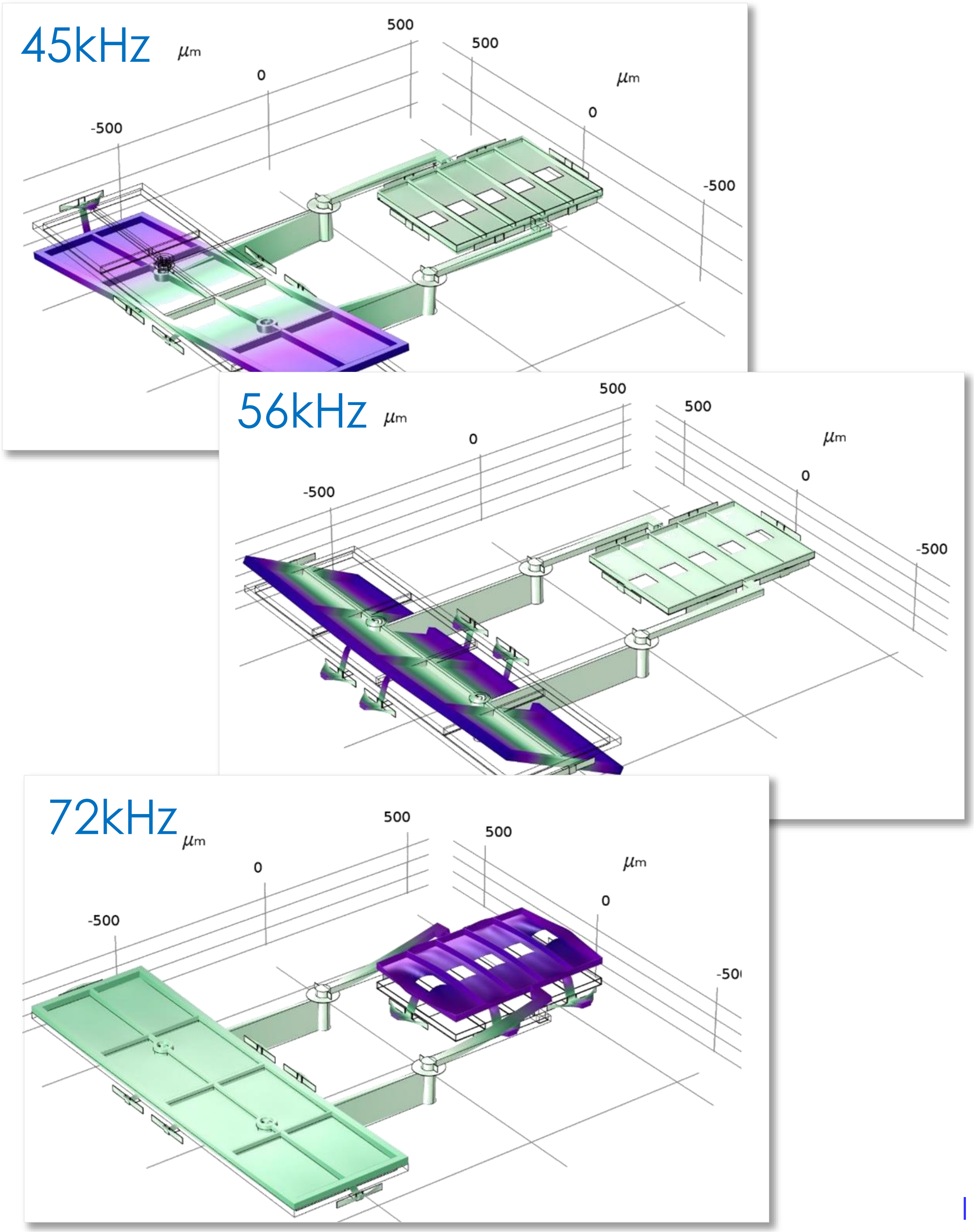
MECHANICAL PART: COMPATIBLE WITH HI



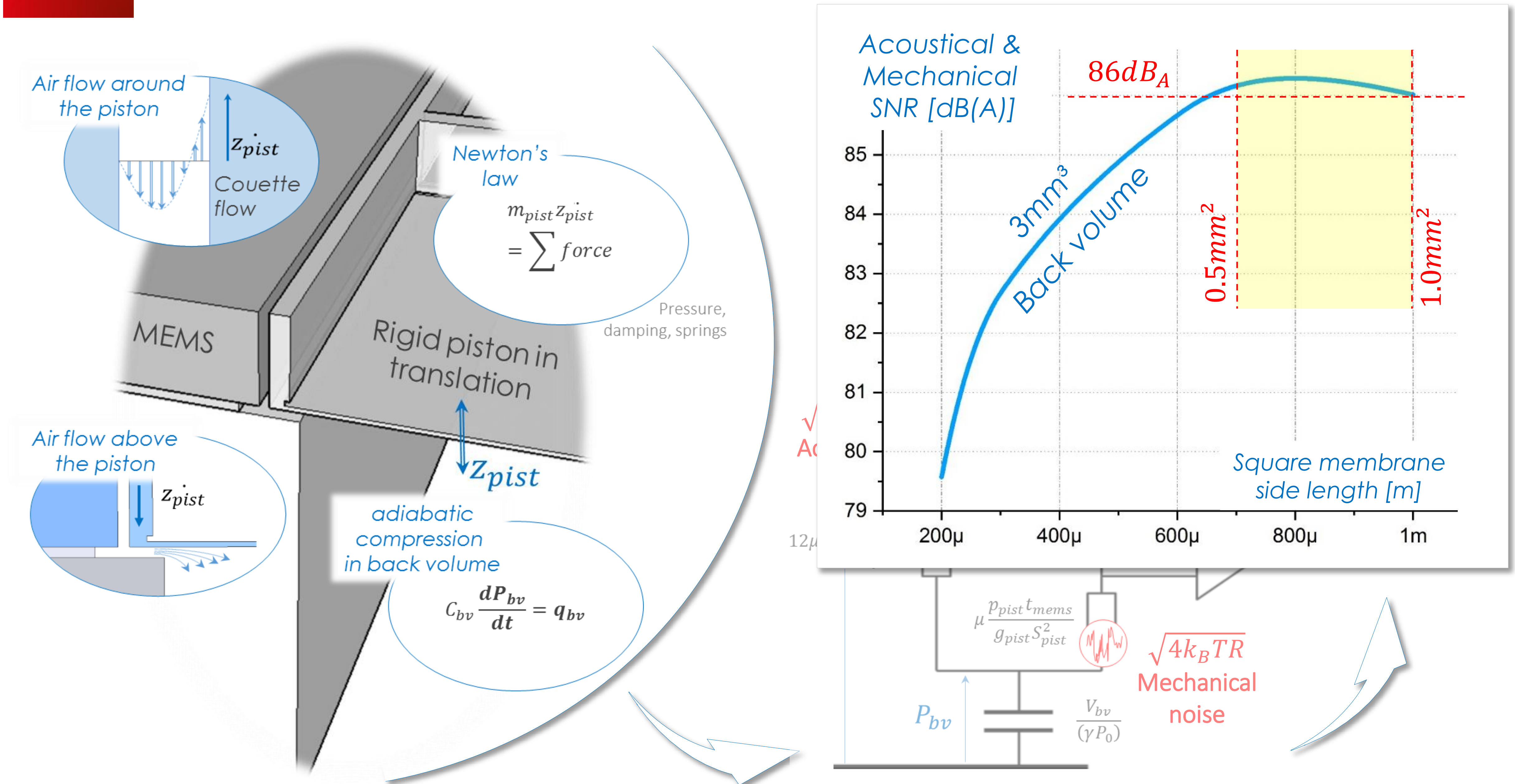
1st mode at **36kHz** = useful mode

Stiff and light

- 1µm piston / electrode
- 20µm MEMS Skeleton

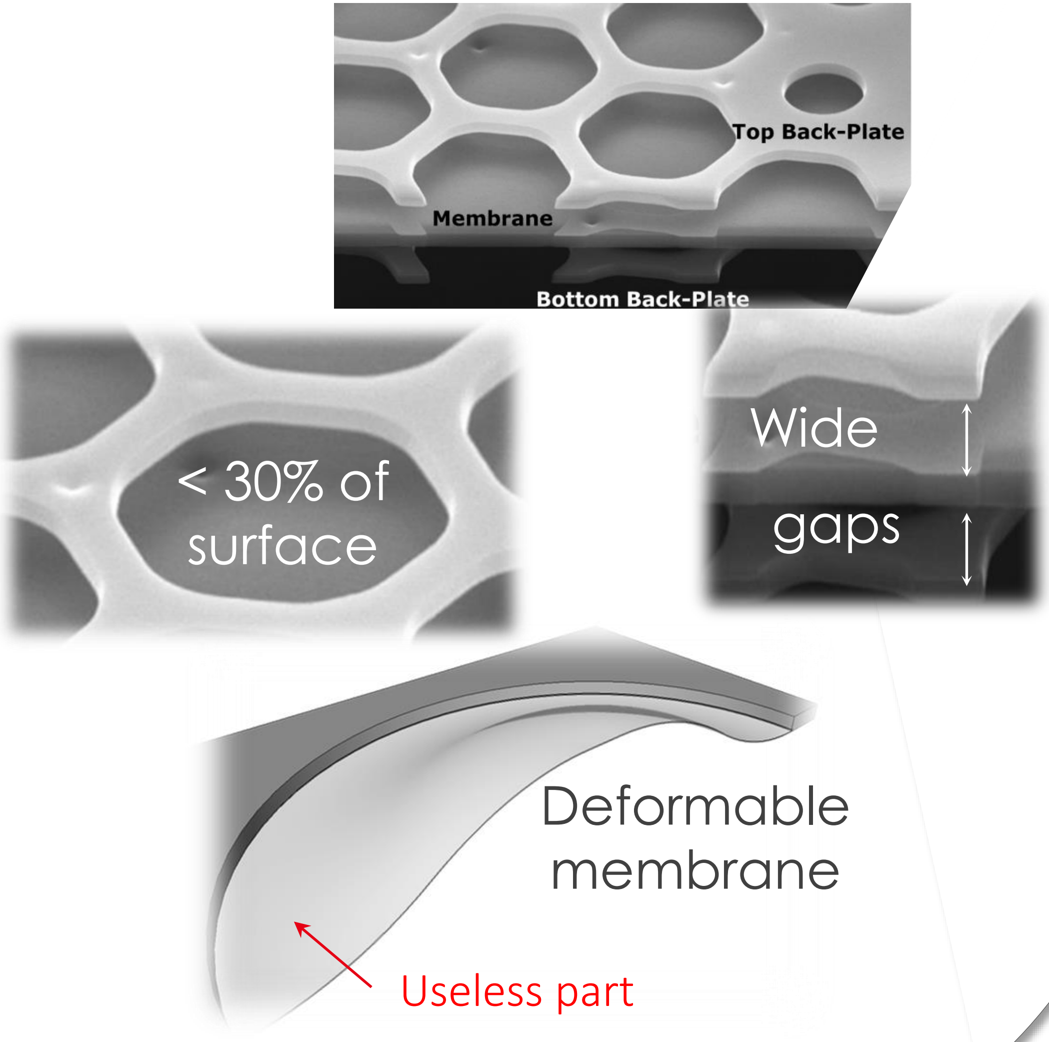


ACOUSTICAL PART: COMPATIBLE WITH HIGH SNR

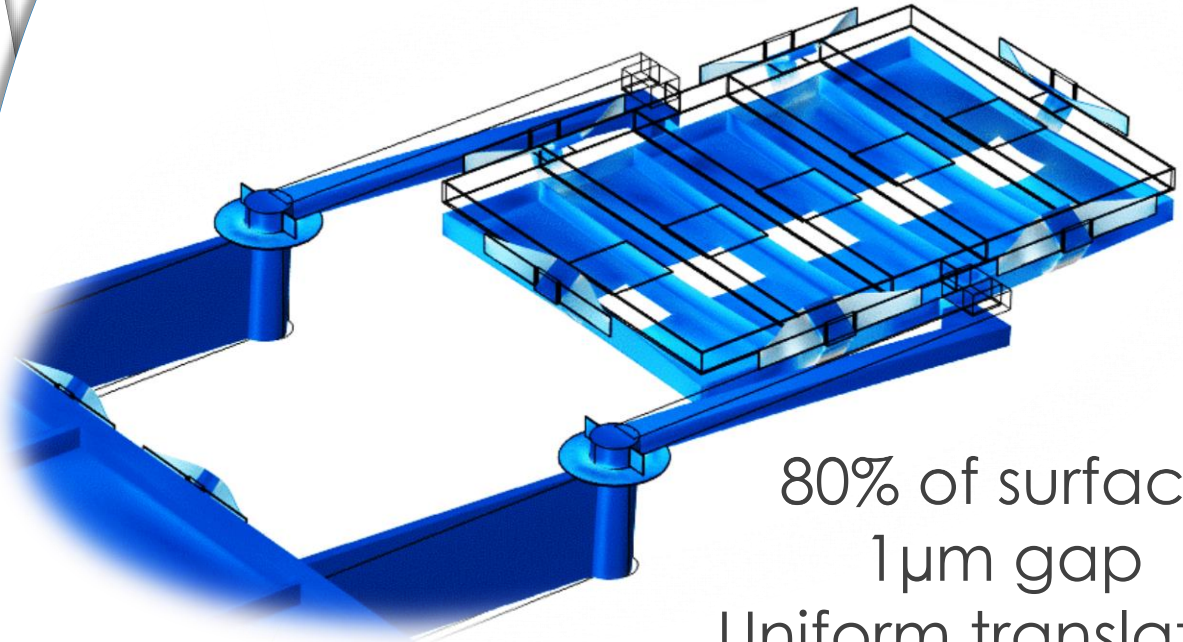


ELECTRICAL PART: COMPATIBLE WITH HIGH CAPACITANCE DENSITY

Squeeze film damping reduction



Capacitive transduction optimization



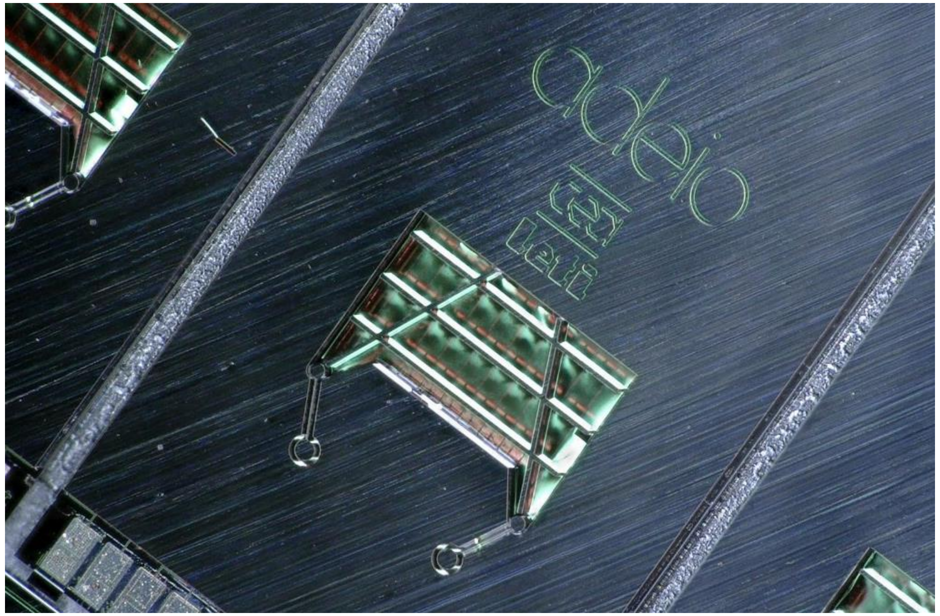
80% of surface
1µm gap
Uniform translation

8x higher capacitance density

Dynamic > **120dB** reachable

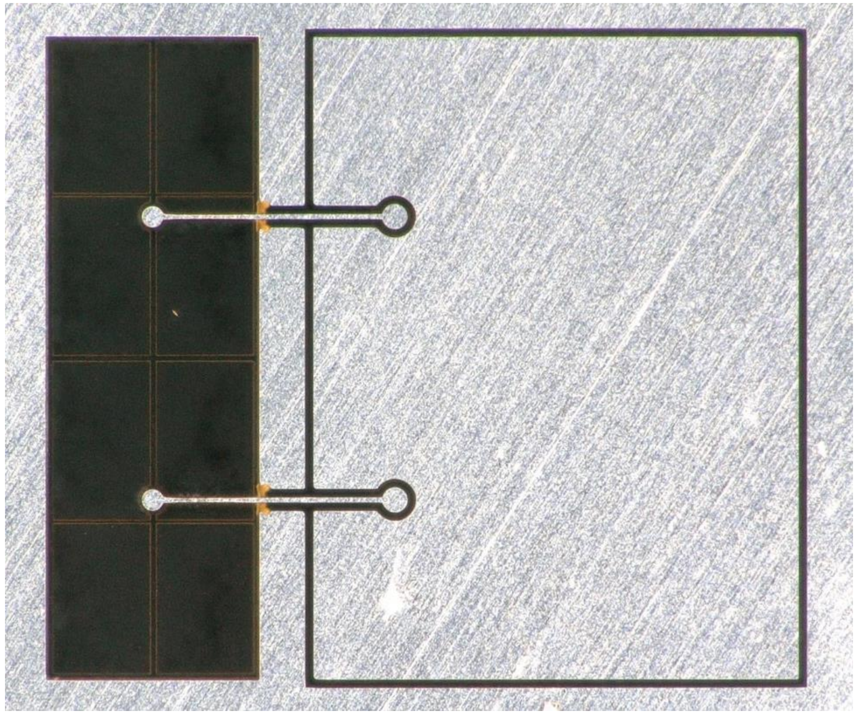
PROJECT STATUS

2018: first realization



Proof-of-concept of
air-to-vacuum transmission

Currently in clean room



Expected performances:

- 75dB(A)-SNR
- $3mm^3$ backvolume
- $135dB_{SPL}$ AOP (10% saturation)
- 20kHz bandwidth