HAPTIC
A PROMISING NEW SOLUTION FOR AN ADVANCED HUMAN-MACHINE INTERFACE

Leti MEMS Workshop | June 20, 2017

F. Casset

OUTLINE

1 Haptic definition and main applications

2 Haptic state of the art

3 Our solution: Thin-film piezoelectric actuators

4 Vibrotactile button development at the CEA

5 Squeeze-film plates for complex haptic effects

6 Conclusion

HAPTIC DEFINITION AND MAIN APPLICATIONS

- **Haptic: Interact with environment by the sense of touch**
- **Many applications can be enabled by high performances haptic feedback interfaces**

→ Promising solution for an advanced human-machine interface

Better immersion for gaming

New way to purchase (online)

Smartphone, Tablet : New way to interact

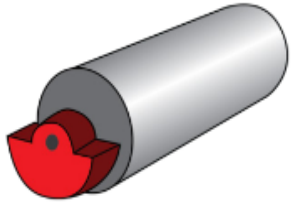
Industry or medicine

New practice of driving (receive information keeping attention on the road)

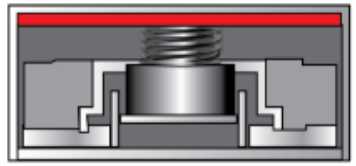
HAPTIC STATE-OF-THE-ART

- **Existing commercialized haptic solutions → Limited feedback effect (vibration)**

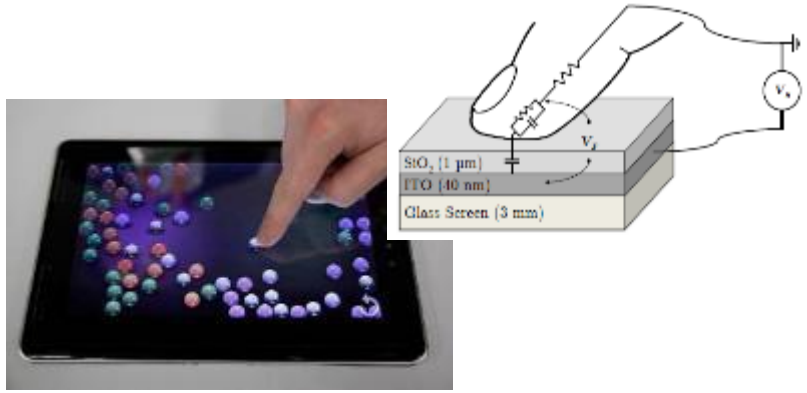
Eccentric Rotating Mass (ERM)



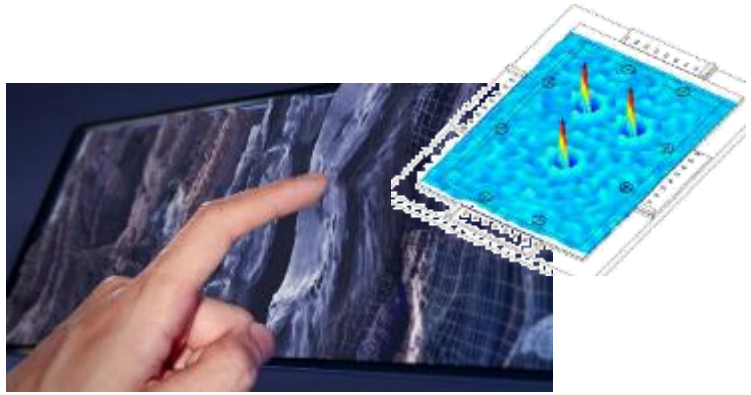
Linear Resonant Actuator (LRA)



- **Some developments to promote complex haptic effects**



Friction modulation
Senseig® Development Kit (2014)
Electrostatic actuation (1kV)

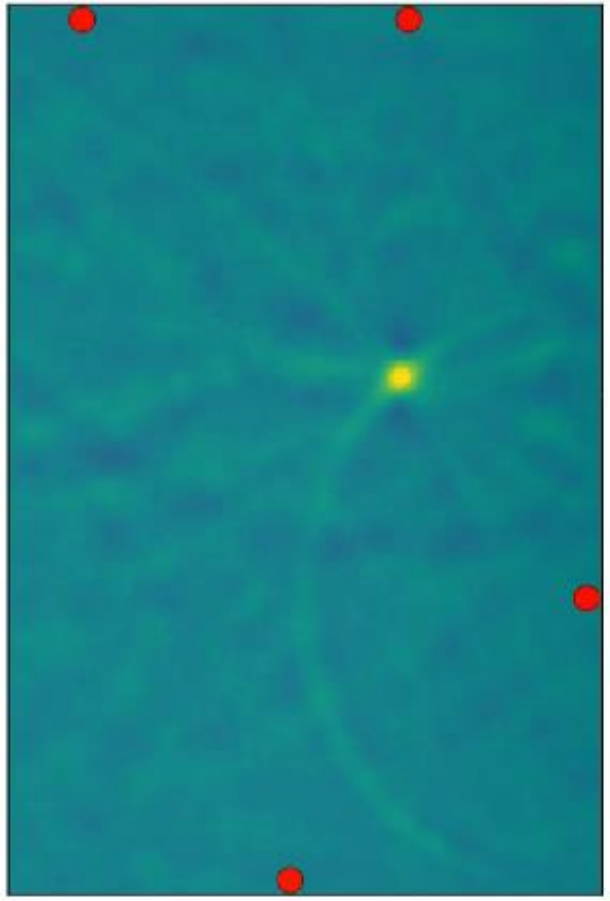


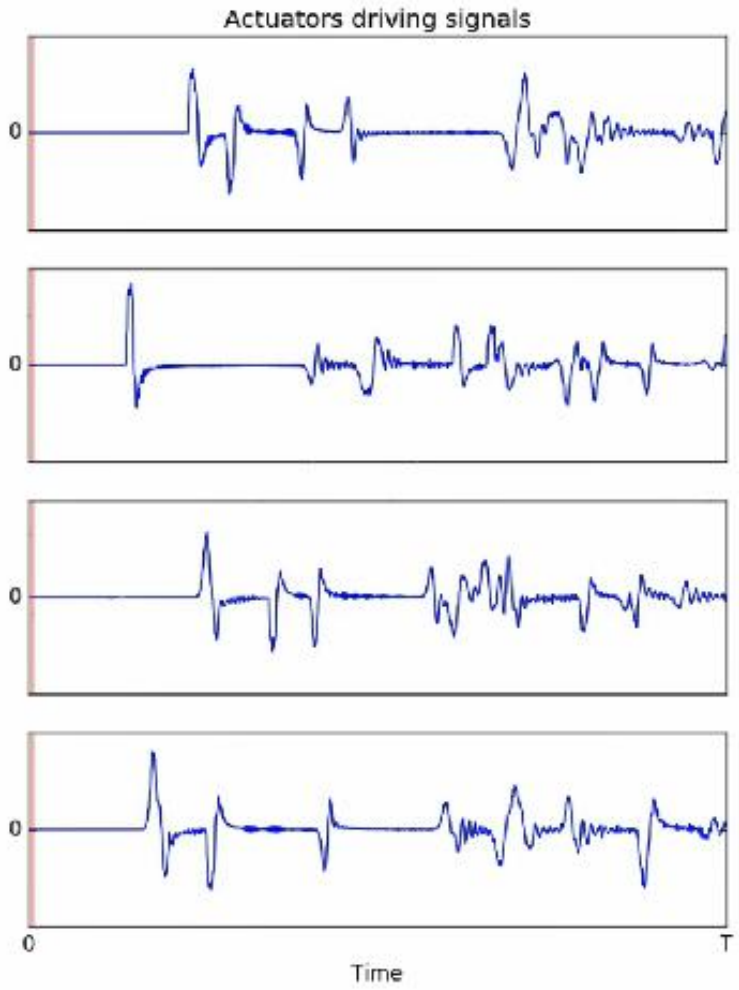
Time-reversed acoustics
CEA-LIST [M. Hafez]
Piezo ceramic actuators

Friction modulation
Hap2U, Lille University (L2EP)
Piezo ceramic actuators

HAPTIC STATE-OF-THE-ART

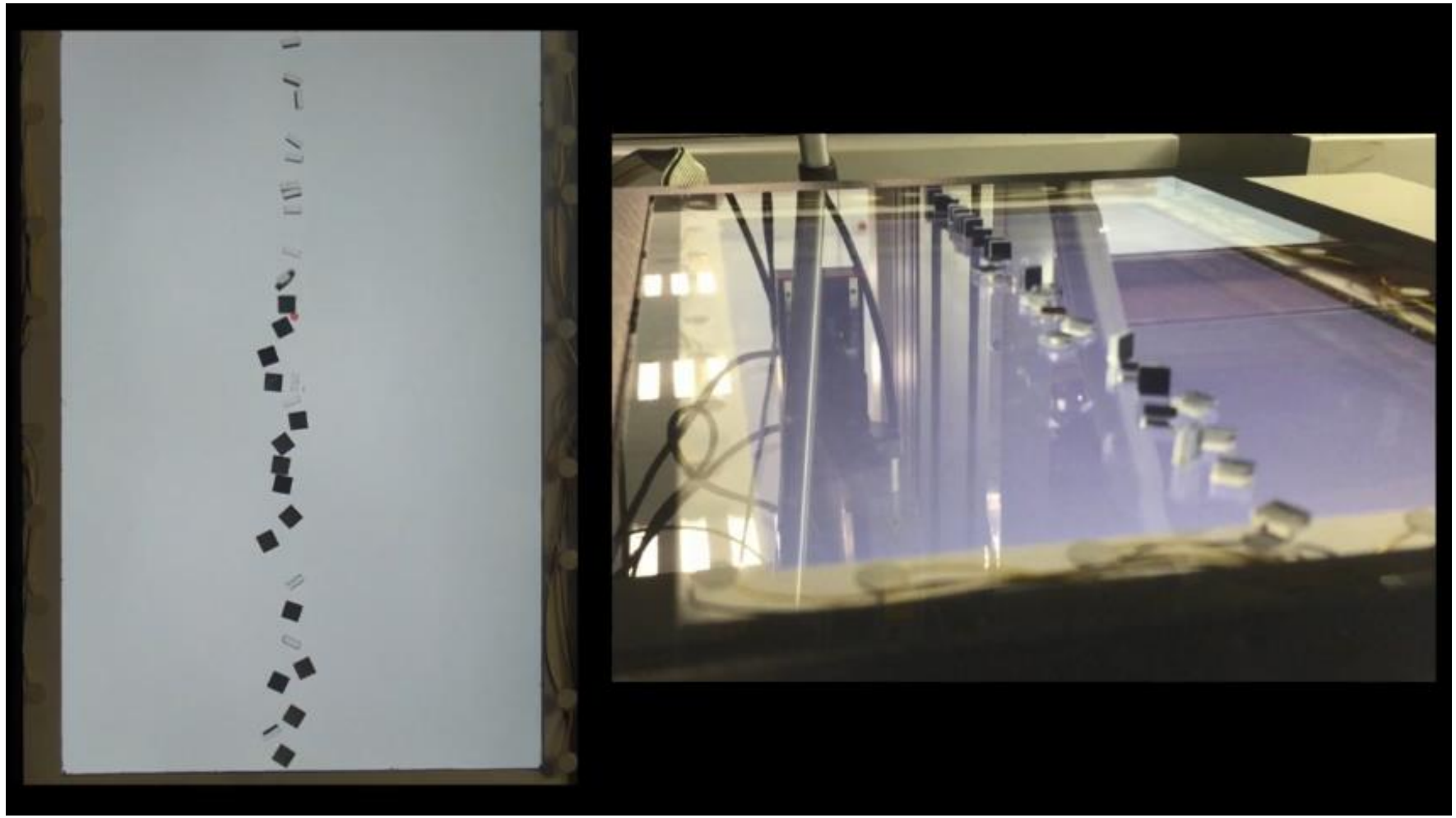
- **Time reversal solution [CEA-LIST] - Calibration**





HAPTIC STATE-OF-THE-ART

- Time reversal solution [CEA-LIST] – Local vibration stimulation



HAPTIC STATE-OF-THE-ART

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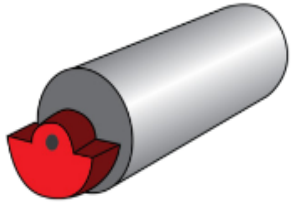

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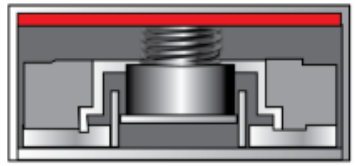

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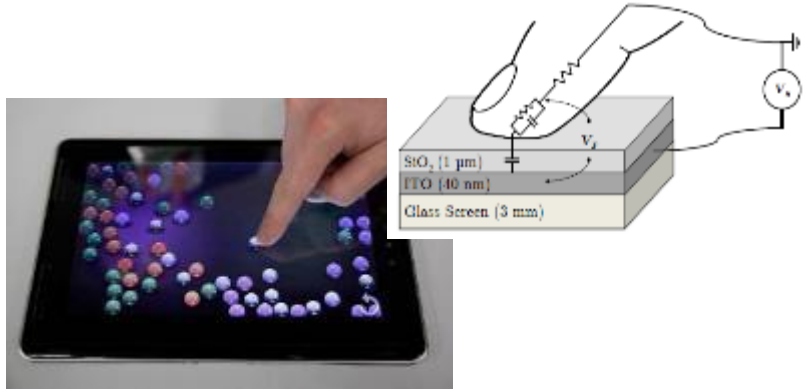
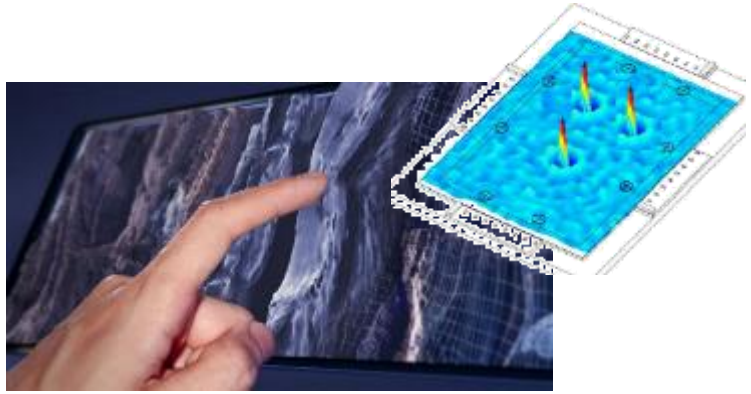


Friction modulation
Senseig® Development Kit (2014)
Electrostatic actuation (1kV)



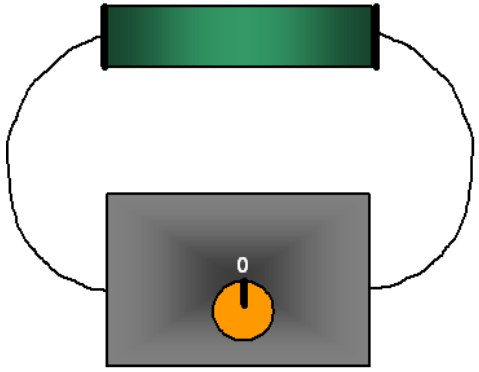
Time-reversed acoustics
CEA-LIST [M. Hafez]
Piezo ceramic actuators

Friction modulation
Hap2U, Lille University (L2EP)
Piezo ceramic actuators

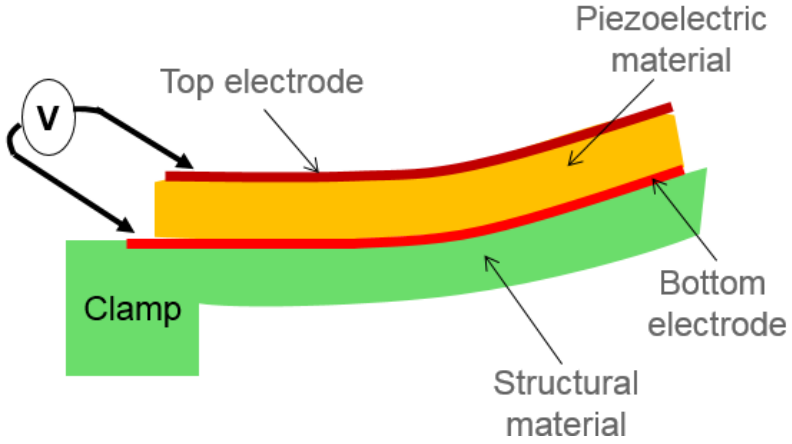
OUR SOLUTION: THIN-FILM PIEZOELECTRIC ACTUATORS

- **Indirect piezoelectric and unimorph effects**

An applied voltage induces deformation



Piezo stack on a structural material to promote out-of-plane deformation



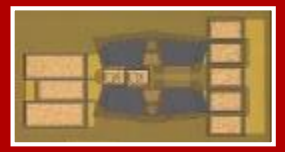
- **Thin-film piezoelectric materials**

PZT
(LEAD ZIRCONIUM TITANATE)

- Properties:
  - ✓ High piezo coefficient
  - ✓ High K
  - ✓ Low mechanical properties

ALN
(ALUMINIUM NITRIDE)

- Properties:
  - ✓ Low piezo coefficient
  - ✓ High mechanical properties
  - ✓ High temp. stability



ELECTRO-ACTIVE POLYMER

- Properties:
  - ✓ Low piezo coefficient
  - ✓ Low mechanical properties
  - ✓ Low cost / Large scale

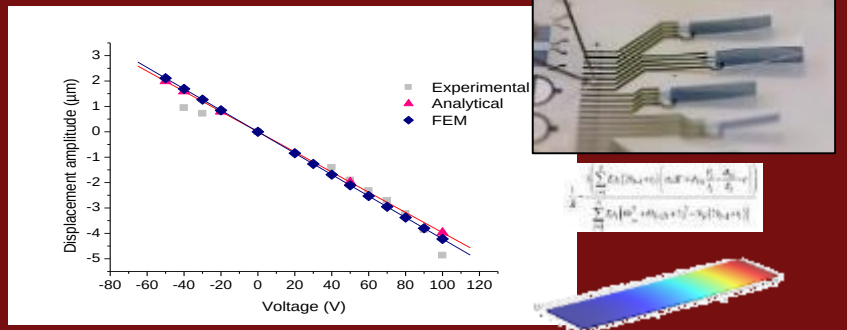
To develop
→ Vibrotactile button
→ Squeeze-film plate

VIBROTACTILE BUTTON DEVELOPMENT AT CEA

- **Model calibration & Circular button design**

MODEL CALIBRATION

- From the comparison between model & measurement → d31, E…

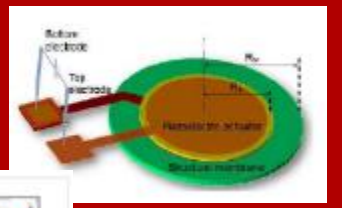


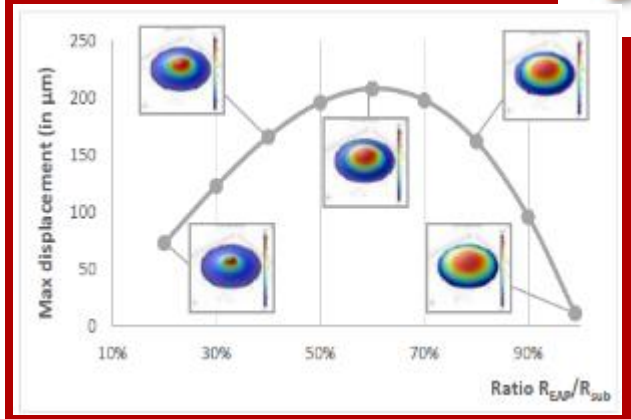
Propriety	Value
Elastic modulus	2 GPa
Poisson's ratio	0.33
Density	1780 kg/m^3
Permittivity	9,4
Piezoelectric coefficient d_{31}	- 3 pC/N

Material data base precision for "Predictive model"

DESIGN

- Circular membrane design using FEM approach

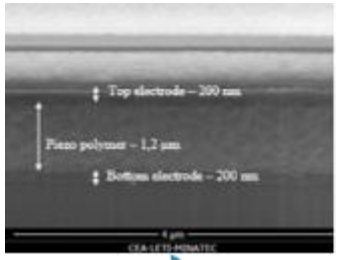


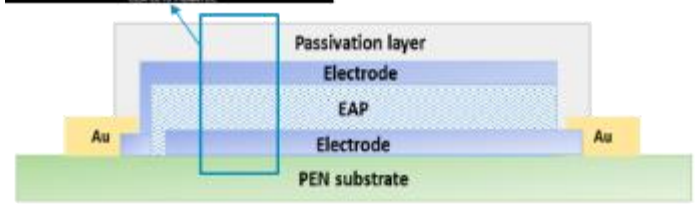


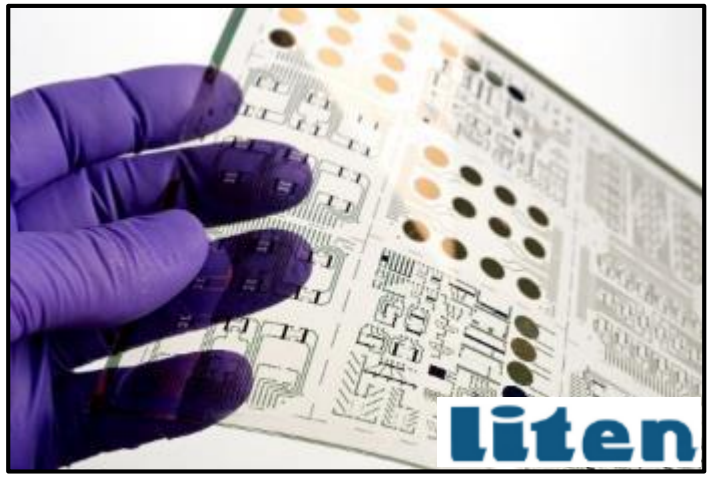
Design rule:
$R_{Actuator}/R_{Membrane}$=60%

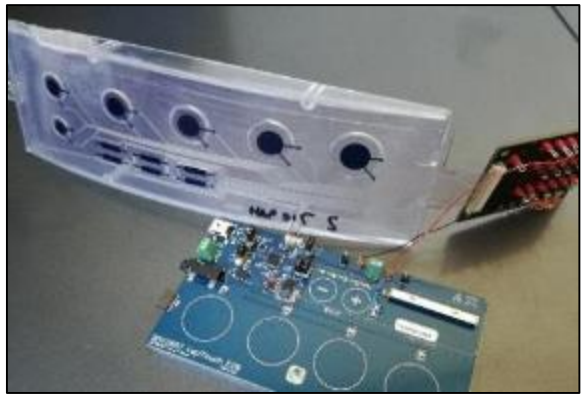
VIBROTACTILE BUTTON DEVELOPMENT AT CEA

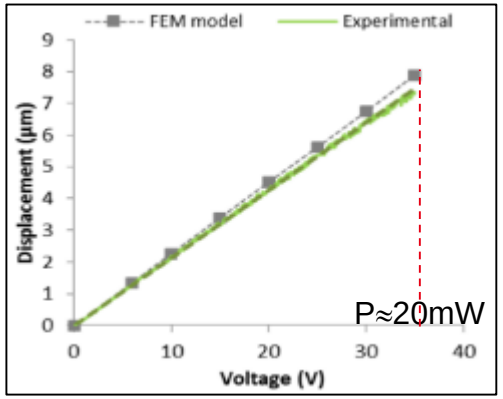
- **Polymer buttons realization using screen printing and polymer technologies**
  - PVDF actuator (Arkéma) on PEN substrate (CEA-LITEN technology)

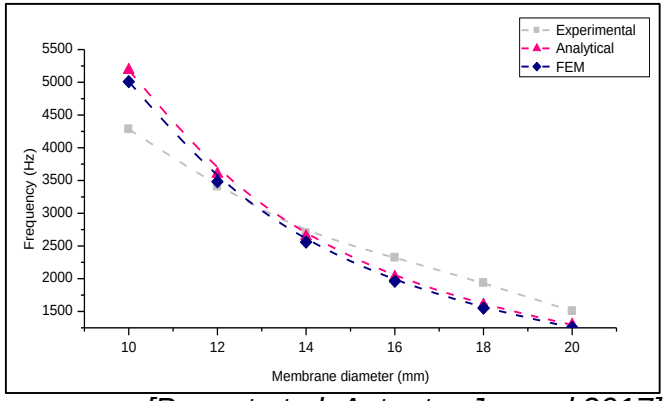




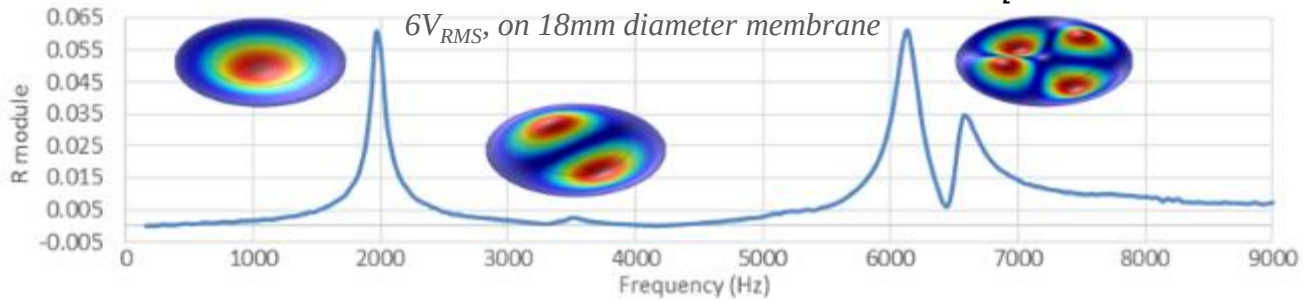








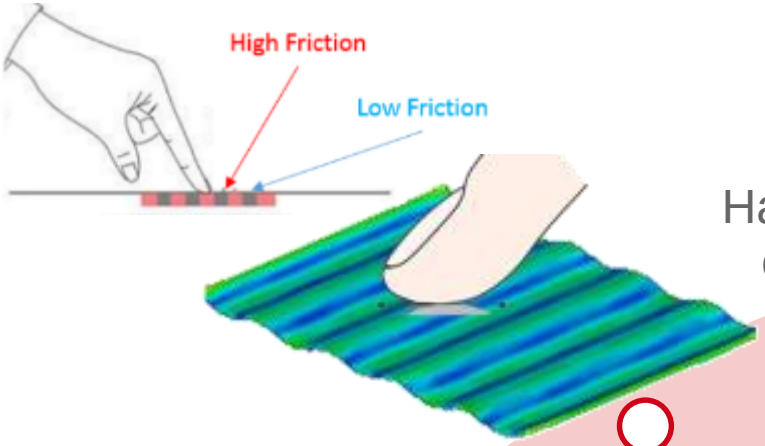
[Poncet et al. Actuator Journal 2017]



Good agreement model/measurement
Interesting performances (displacement, sound!)
Vibrotactile effect proof-of-concept using low voltage (<35V_{RMS})

SQUEEZE-FILM PLATES FOR COMPLEX HAPTIC EFFECTS

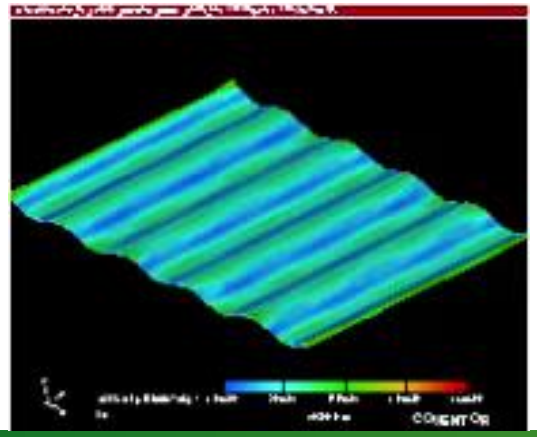
- Lamb mode plate
- Thin-film piezoelectric actuator & unimorph effect

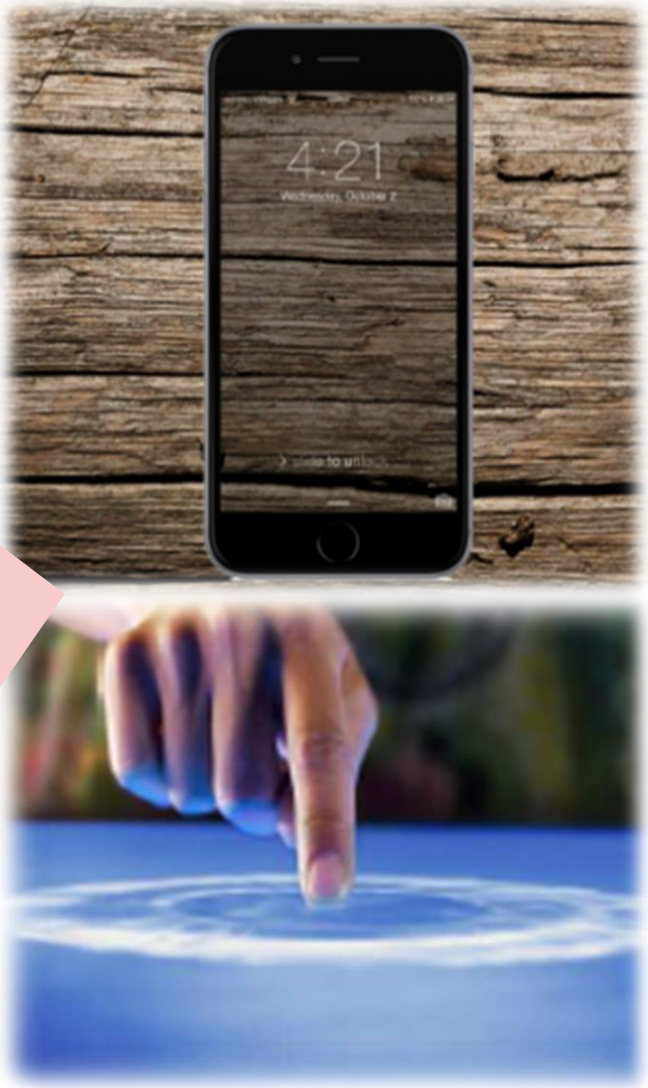


Haptic effect ➔ Feeling of textured surfaces

Thin air layer between finger and plate
Overpressure that tries to lift the finger
➡ Modification of the friction of the plate

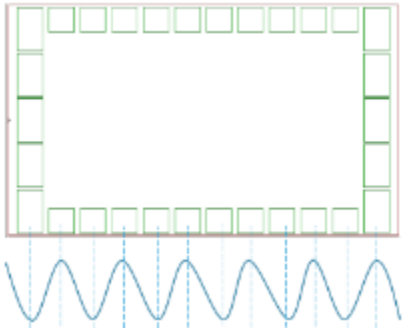
Lamb mode vibrating plate
Vibration amplitude > ± 2µm

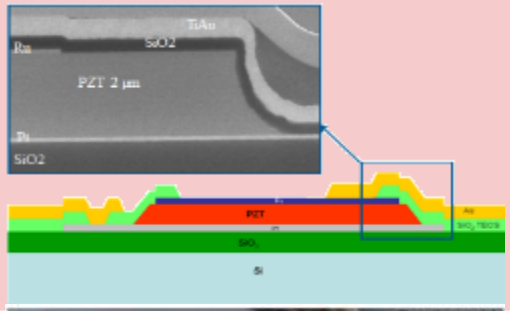
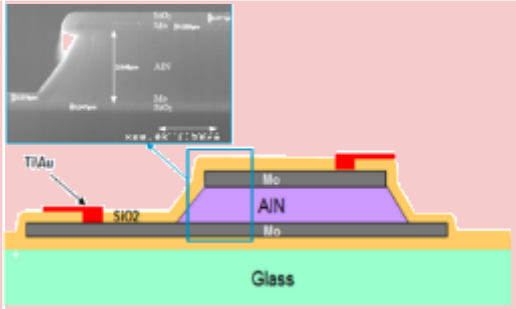
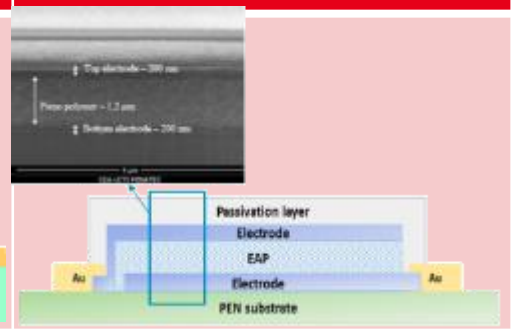
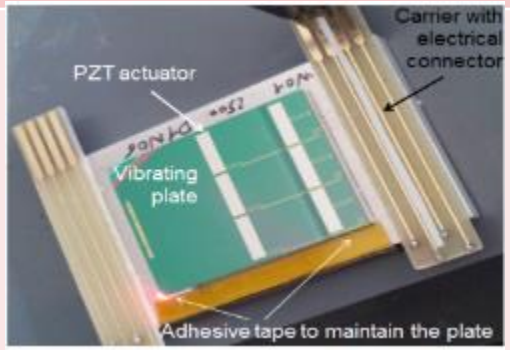
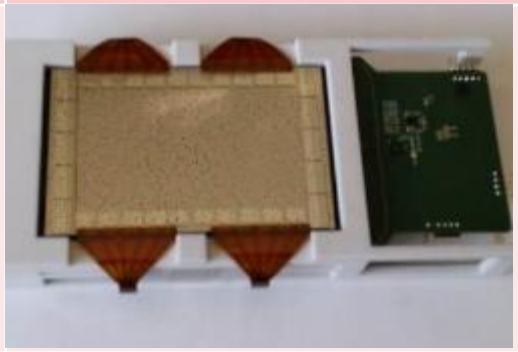
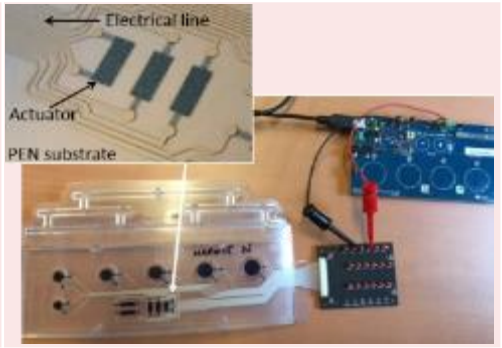




SQUEEZE-FILM PLATES FOR COMPLEX HAPTIC EFFECTS

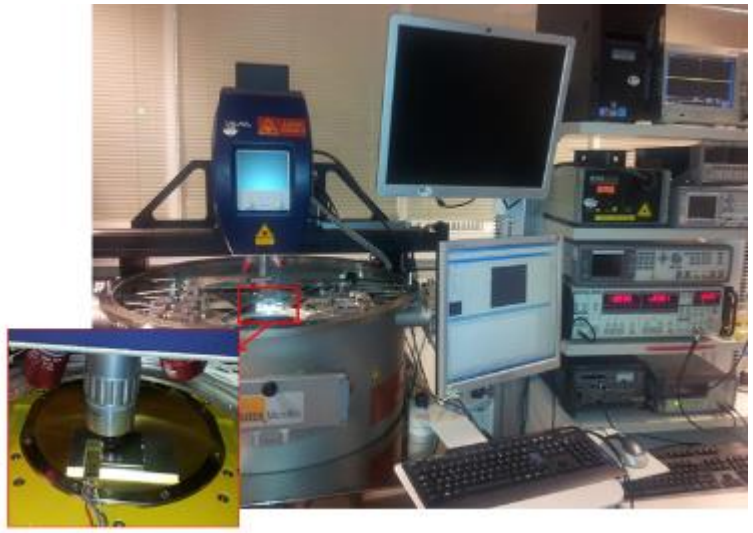
- Design rule → Fit actuator position with the maximum plate displacement amplitude areas
- Haptic demonstrators using various thin-film piezoelectric technologies



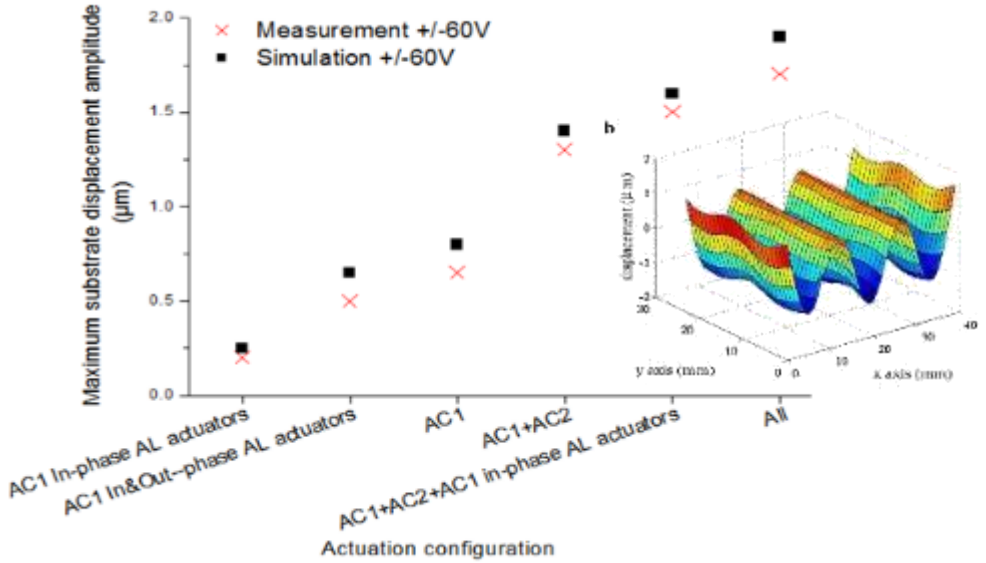
Material	PZT	AlN	PVDF
Technology			
Example			
Plate size (mm²)	40 × 30	110 × 65	15 × 10
	[Casset, Transducers 2013]	*[Casset, Mechatronics 2016]*	*[Casset, MME 2016]*

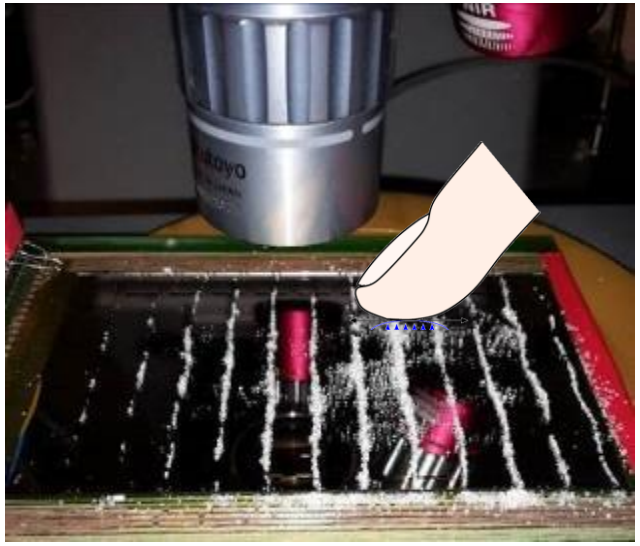
SQUEEZE-FILM PLATES FOR COMPLEX HAPTIC EFFECTS

- **Squeeze-film plate characterization in good agreement with FEM models**
  - Laser vibrometer (POLYTEC MSA400) measurements



AlN on glass example: ±60V @ 23.02 kHz
→ Power consumption ≈ 200mW

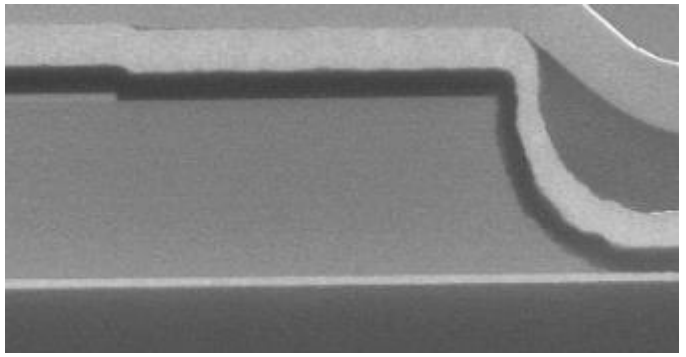




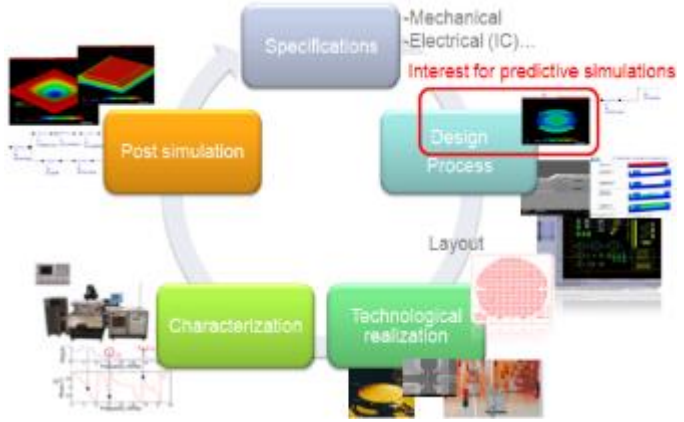
Haptic feedback effect was felt with the finger
Proof of concept using thin-film piezoelectric actuators (actuation modulated@10Hz)
Low power consumption solution (200mW)

CONCLUSION

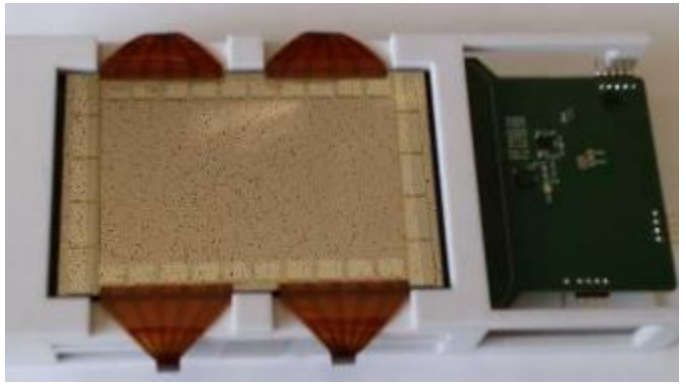
- **Thin film piezoelectric material & technology knowledge for haptic applications (or MEMS applications…)**
  - PZT, AlN, PVDF on Si, Glass or Polymer substrate



- **Generic design methodology & design rules**
  - Analytical calculation, FEM models



- **Haptic demonstrators**
  - Feedback effect proof-of-concept: Squeeze-film plates, Vibrotactile buttons
  - Perspectives: Hap2U collaboration for thin-film piezo demonstrator
    CEA-LIST collaboration for thin-film time reversal solution



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