MEMS Micro-actuators enabling new and unforeseen applications

STMicroelectronics

AME Microsystems Product Marketing

2017

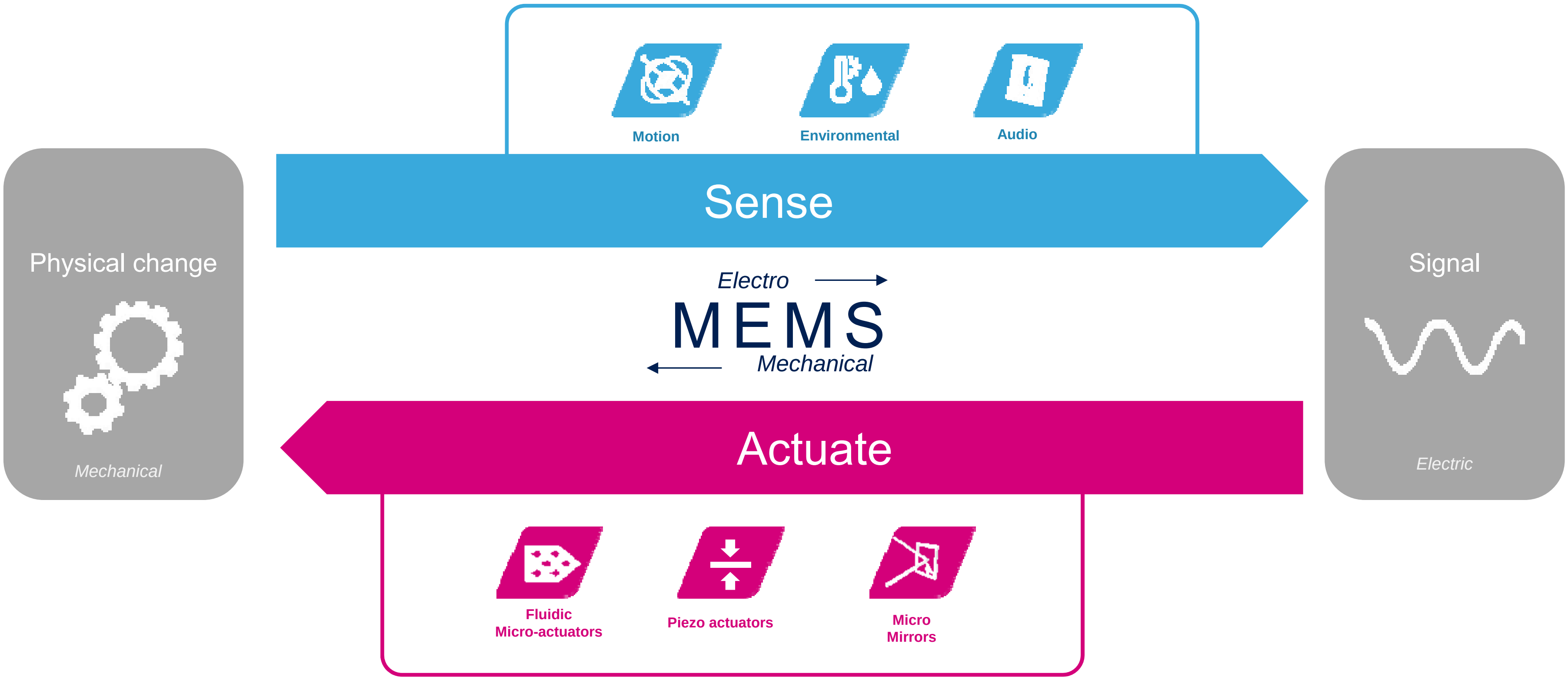
life.augmented

Technology Tour 2017

Agenda

- MEMS Sensors and Actuators at ST: introduction and history
- Technologies for MEMS Micro-actuators: four pillars
- Changing the MEMS Landscape: innovative applications
- In-depth: Micro-Mirrors and Laser Beam Scanning Engines

MEMS Sensors & Actuators at ST

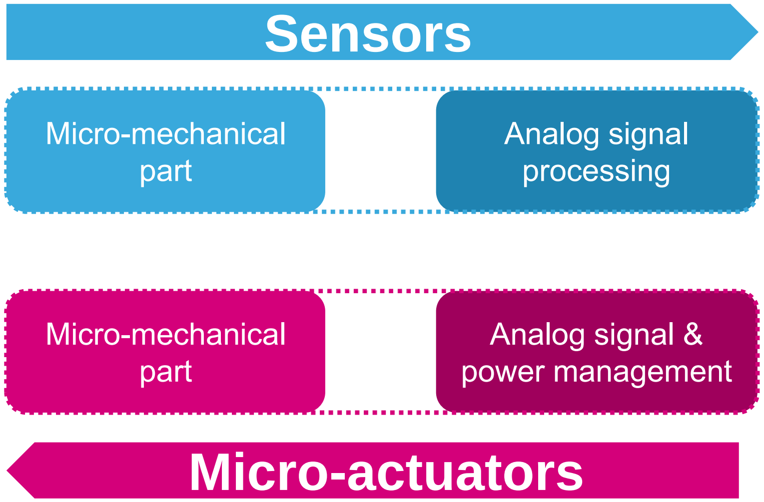


Building Micro-Actuators

MEMS micro-actuators & MEMS sensors use the **same principles** and **same basic processes**

MEMS sensors have **ultra-low power analog** signal processing parts

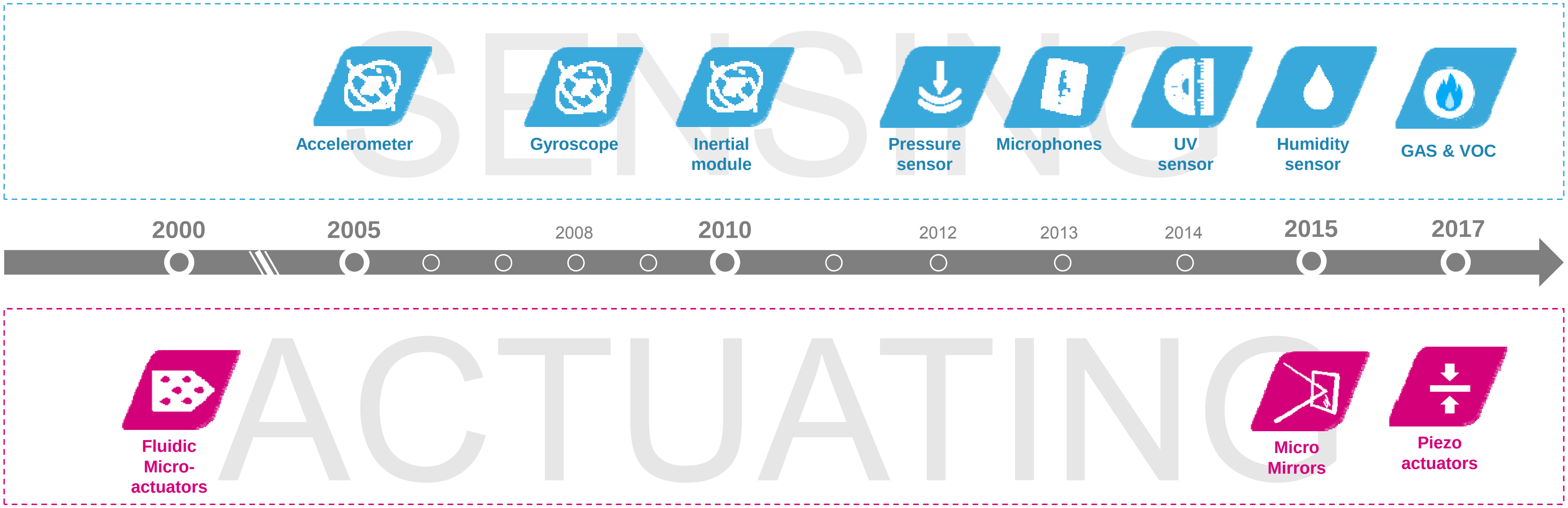
MEMS micro-actuators have **high voltage/current analog** and **power management** parts
(since higher voltages required for some applications)



Leveraging our BCD technologies

20 Years of MEMS Sensors & Actuators

ST Innovations



20 Years of MEMS Sensors & Actuators

Iconic Products

life.augmented

Agenda

- MEMS Sensors and Actuators at ST: introduction and history
- **Technologies for MEMS micro-actuators: four pillars**
- Changing the MEMS Landscape: innovative applications
- In-depth: Micro-Mirrors and Laser Beam Scanning Engines

Micro-Actuation Technologies

Enabling Multiple Applications

Camera autofocus
Speakers
PMUT
Commercial Inkjet print head
Vaporizer/Atomizer

Piezo-Electric

Electrostatic

Micro-mirrors
3D scanning
Mobile projection

Consumer Inkjet print head
Vaporizer/Atomizer

Thermal

Electro-Magnetic

Micro-mirrors
3D Scanning
Mobile projection

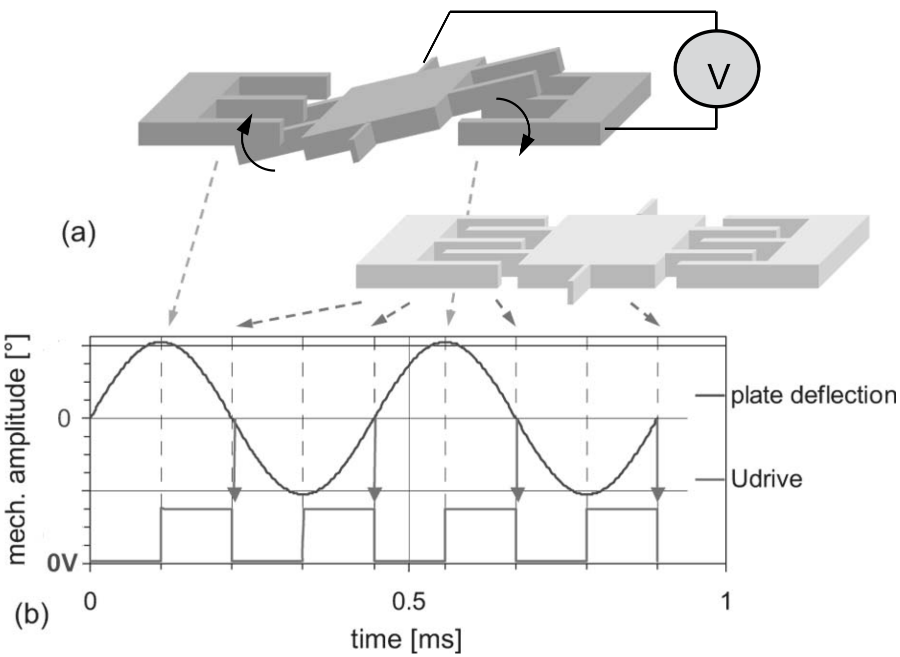
life.augmented

Electrostatic

Working principle

Electrostatic

- Electrostatic force is used as actuation mechanism by means of a comb drive structure, i.e. interdigitated silicon fingers, which apply a torque moment on the MEMS.



Electrostatic torque on mirror structure
→ Voltage control

Energy stored in a Capacitor

$$E = \frac{1}{2} C V^2$$

Differentiating to get Comb Drive Forcing Moment:

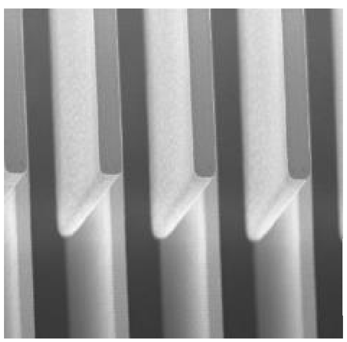
$$M_{forcing} = \frac{1}{2} \frac{dC_{comb}}{d\theta} V^2$$

Electrostatic

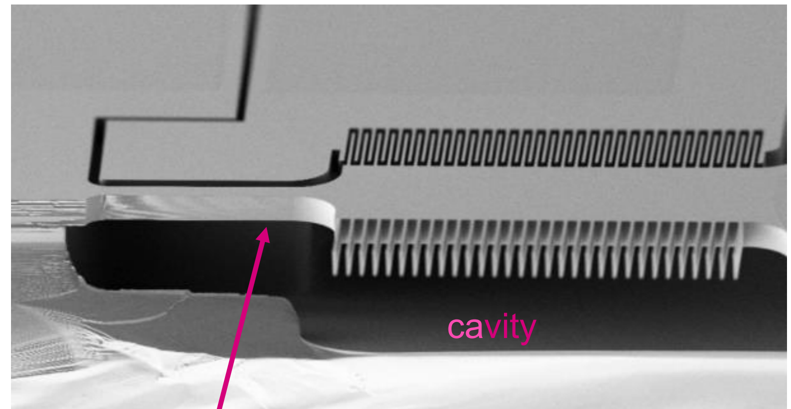
Sample Images

Electrostatic

Torsional spring
for **linear**
actuation

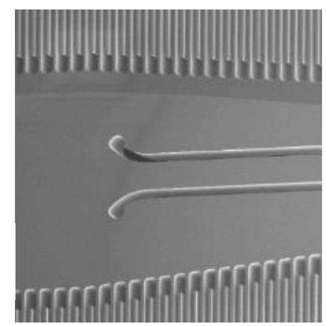


Staggered comb
finger for **linear**
Micro-Mirror



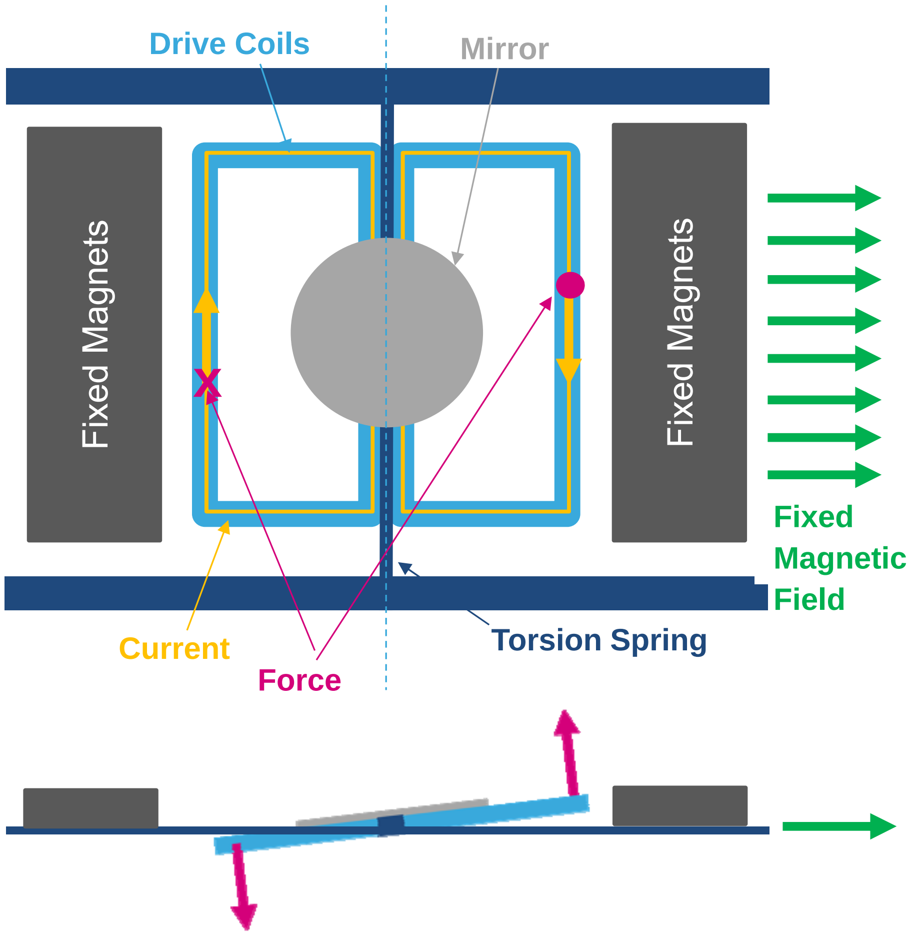
Torsional spring
for **resonant**
actuation

In-plane comb
finger for **resonant**
Micro-Mirror



Electro-Magnetic

Actuation Principle



Electromagnetic actuation on mirror structure

Current flows into Drive coils part of the moving structure

Device houses magnets which induce fixed magentic field on the structure

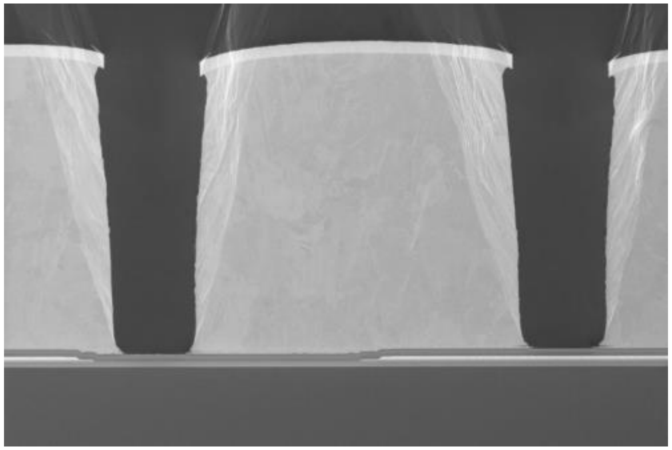
Actuation Based on Lorentz Force:

$$\boldsymbol{F} = q(\boldsymbol{E} + \boldsymbol{v} \times \boldsymbol{B})$$

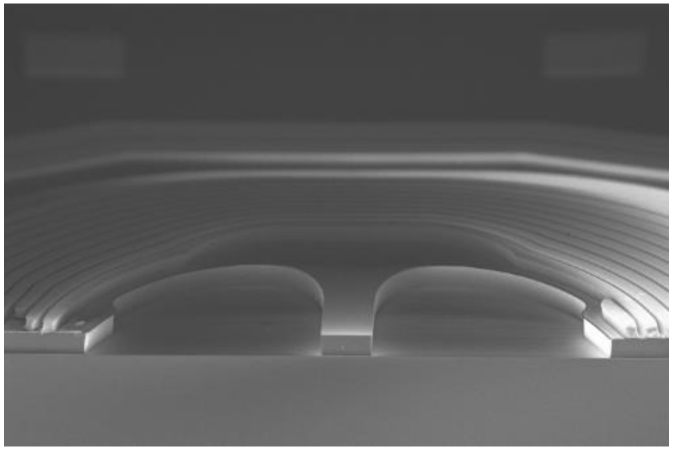
Electro-Magnetic

Sample Images

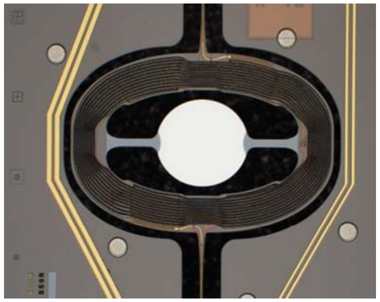
Electro-magnetic



Coil Wire for magnetic actuation. Thick ECD growth (>20um)



View of **Coils** and **Torsional Spring**



Top View with **Coils** and **Springs**

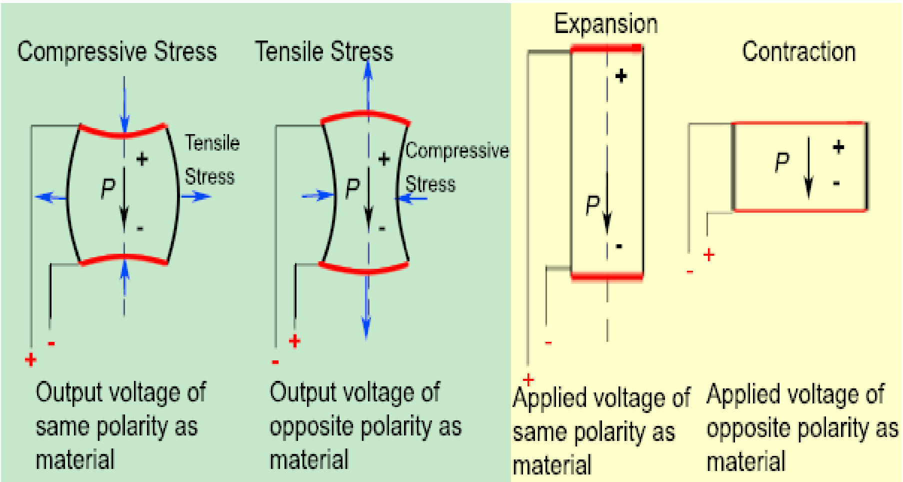
MicroVision, Inc. 720p Bi-axial mirror

life.augmented

Thin-Film Piezo

Actuation Principle

Piezo-Electric



The piezo element generates a voltage when deformed

Direct piezoelectric effect:
Strain → Charge

Sensors

If a voltage is applied across the piezo element, it will deform

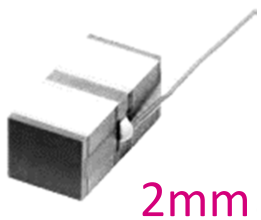
Reverse piezoelectric effect:
Voltage → Stress/Strain

Actuators

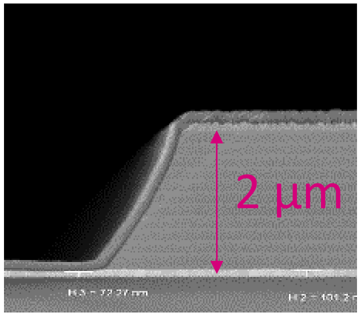
Thin-Film Piezo

Bulk Piezo vs Thin-Film Piezo

Piezo-Electric



Bulk Piezo	Thin Film Piezo
• Large Form Factor • High Power Consumption • Mechanical assembly requires high capital or low volume manufacturing	• Micron thick layers produce 2D form factor • Lower drive voltages for similar mechanical displacements • Integrated into fab processing for very high volume manufacturing



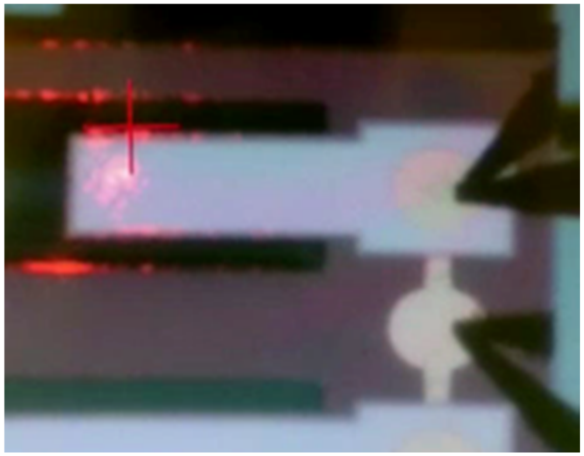
life.augmented

Thin-Film Piezo

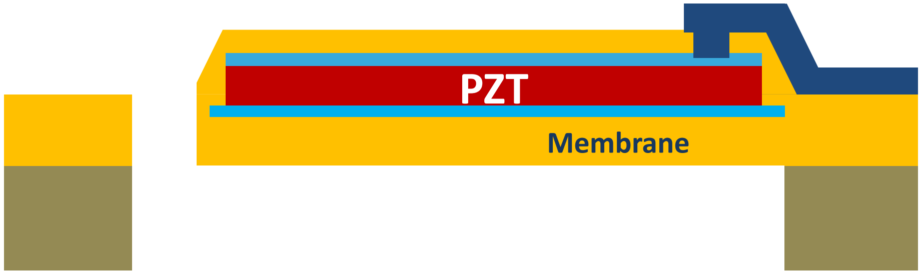
PZT Actuation Structure

Piezo-Electric

- ST-Agrate has developed an industrial “Thin Film PZT” process which is able to address a wide range of applications



20V, 1Hz → 30µm displacement

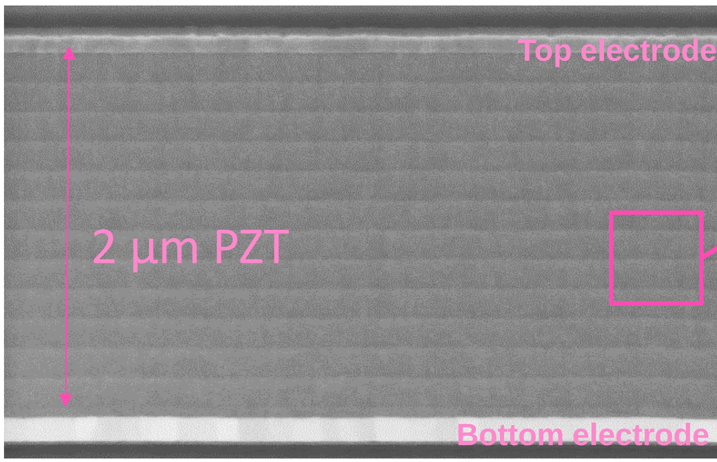


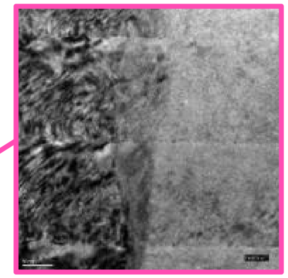
life.augmented

Thin-Film Piezo

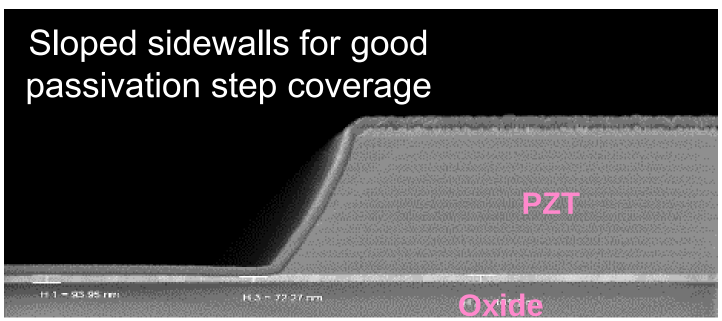
Sample Images

Piezo-Electric

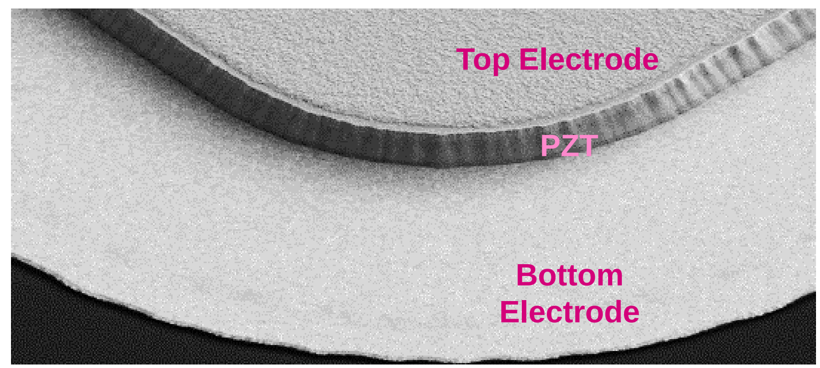




Very dense film structure
No defects/voids
Film is flat with very small grains



PZT and the metallic electrodes patterned by dry-etch



life.augmented

Agenda

- MEMS Sensors and Actuators at ST: introduction and history
- Technologies for MEMS Micro-actuators: four pillars
- **Changing the MEMS Landscape: innovative applications**
- In-depth: Micro-Mirrors and Laser Beam Scanning Engines

Changing the MEMS Landscape

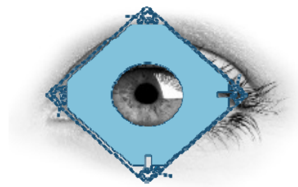
Strategic Partnerships

ST technologies

Piezo-Electric	Electrostatic
Thermal	Electro-magnetic

Piezo Autofocus

poLight



Micro-mirror Projection

MicroVision

MEMS Loudspeaker

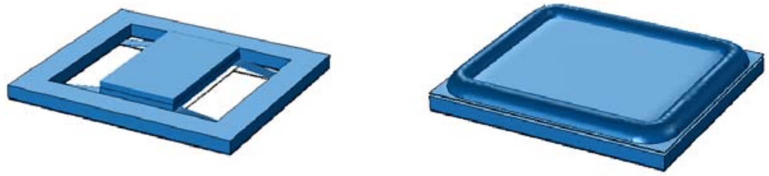
USOUND

life.augmented

MEMS Loudspeakers

U))SOUND

STMicroelectronics and USound Agree to Make World's First Spectacular-Sounding MEMS Speakers



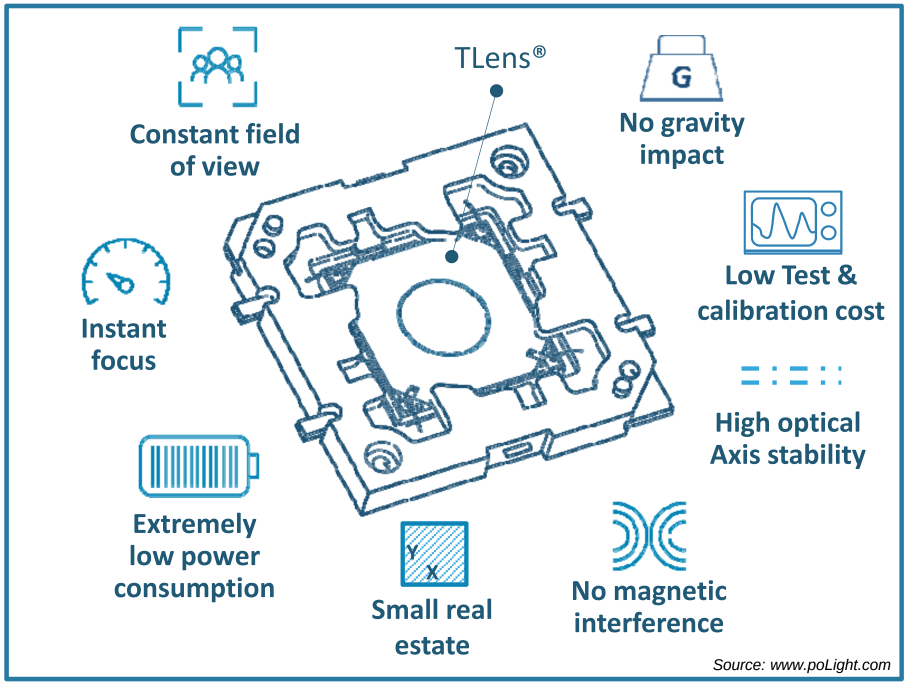
Feb. 21st 2017

"Compared to standard speakers, our piezo-MEMS devices offer unprecedented mechanical precision, improving audio reproduction fidelity and device reliability in very thin form factors. As the first-of-its-kind device, our MEMS "Moon" speaker targets earphone applications, bringing superior performance to the audio world at a competitive price"

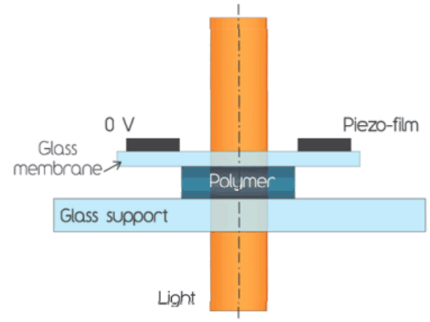
http://www.st.com/content/st_com/en/about/media-center/press-item.html/p3914.html

life.augmented

Autofocus



TLens® uses a piezoelectric to change the shape of a transparent polymer film, imitating the functioning of the human eye

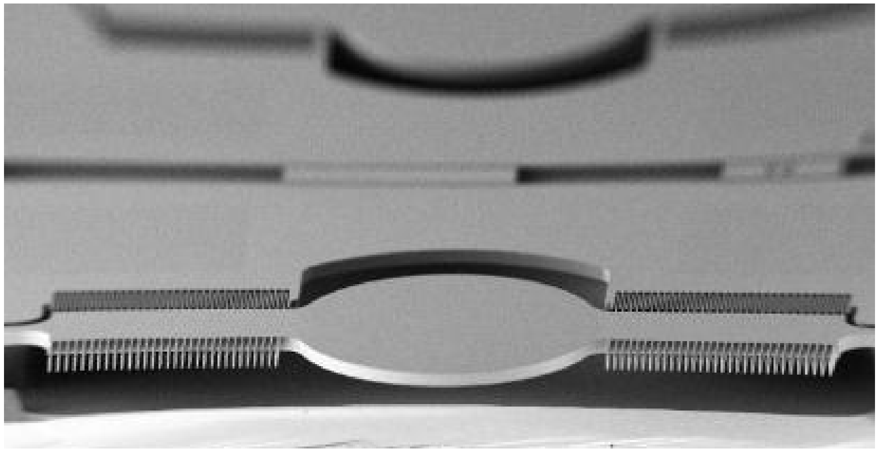


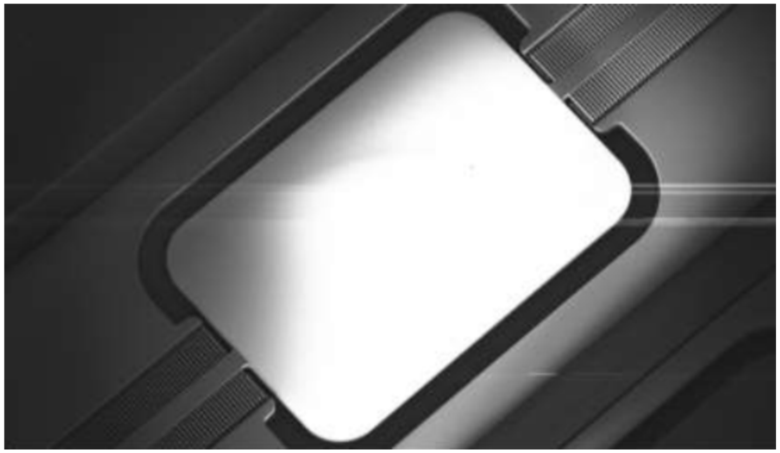
Agenda

- MEMS Sensors and Actuators at ST: introduction and history
- Technologies for MEMS Micro-actuators: four pillars
- Changing the MEMS Landscape: innovative applications
- **In-depth: Micro-Mirrors and Laser Beam Scanning Engines**

What is a MEMS µMirror Scanner?

- Tiny reflective mechanical device that swings at a given frequency
- Applications spanning from Visible to Invisible (IR typically)





Technology Comparison

ELECTROSTATIC

PROS:

- Simpler Technology (resonant)
- MEMS Power Consumption

CONS:

- High Voltage Required
- Quasi-Static Operation Requires More Complex Technologies

PERFORMANCE:

- Total Force: Low
- Force Density: Low

ELECTROMAGNETIC

PROS:

- Low Voltage
- Very Good for Linear Operation

CONS:

- MEMS Power Consumption
- External Magnets

PERFORMANCE:

- Total Force: High
- Force Density: Medium/Low

PIEZOELECTRIC

PROS:

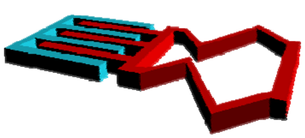
- Mid Voltage
- High Fidelity Feedback
- MEMS Power Consumption

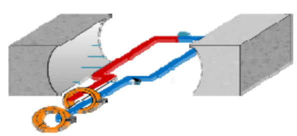
CONS:

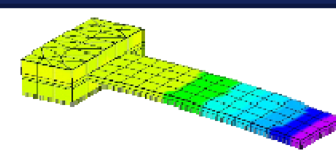
- PZT Small Displacements
- Just Resonant Operation

PERFORMANCE:

- Total Force: Medium/High
- Force Density: High





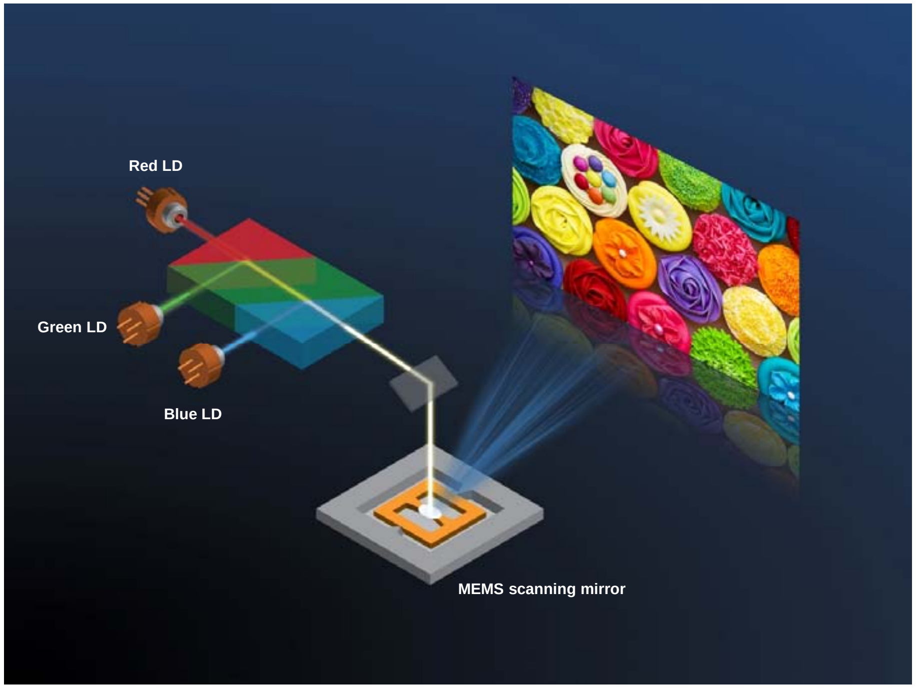


life.augmented

Laser Beam Scanning (LBS)

Technology Principles and Applications

- Principles:
  - Light from one/multiple **lasers** is combined into a single beam
  - Beam is relayed onto **MEMS scanning mirror(s)**
  - Mirror(s) scan the beam in a raster pattern
  - A **projected image** is created by modulating the lasers synchronously with the position of the scanned beam
- Applications:
  - **Pico-projection** and **heads-up display** (HUD)
  - **Virtual** and **Augmented Reality** (VR, AR)
  - **3D Sensing** and **Advanced Driver Assistance Systems** (ADAS)



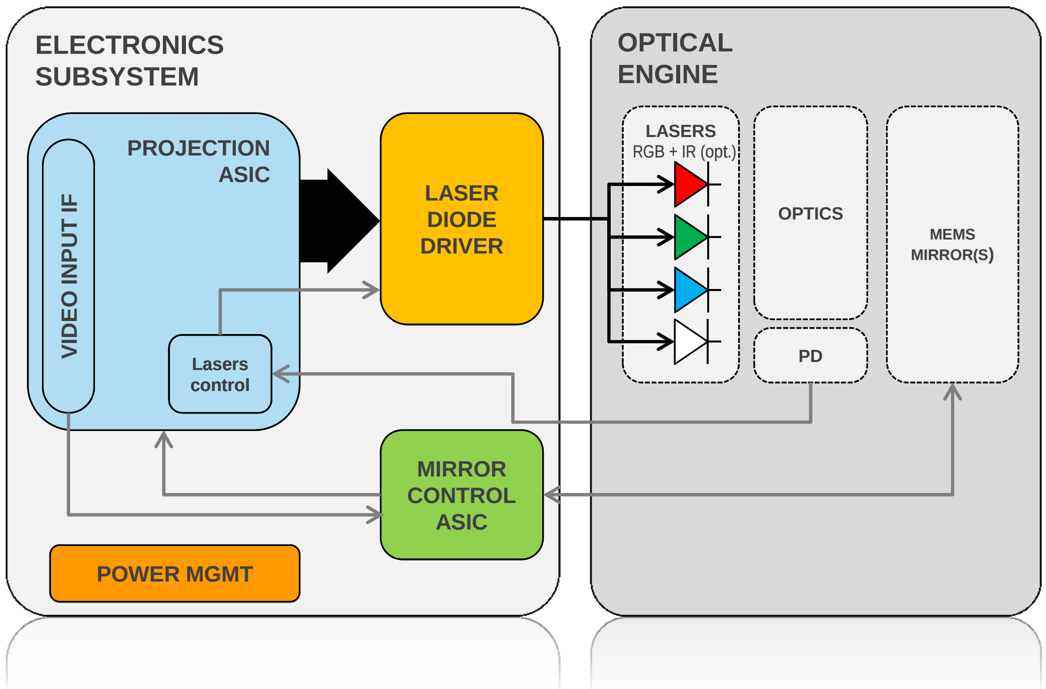
Courtesy of Microvision

Laser Beam Scanning (LBS)

Display Systems: Block Diagram

Complete System: Scanning Engine

- Electronics Subsystem
  - Mirror(s) Drivers
  - Laser Drivers
  - Video Projection ASIC
  - Power Management
- Optical Engine
  - Lasers
  - Optics
  - Photodetectors
  - MEMS Mirror(s)



Laser Beam Scanning (LBS)

Key Benefits for Pico-Projection Applications

Focus Free Operation
Enhances the user experience, eliminates mechanical focus wheels

Ultra Compact Engine Size
Very small and thin all-in-one package; does not require additional focus lenses; smaller than any DLP solution achieving same resolution

Low Power Consumption
Extremely power efficient even at maximum brightness

1.2 **Short Throw Ratio** for variable screen sizes from a short distance – from 12” to 120” and beyond

Wide Color Gamut Range
Laser diode light sources provide the widest color gamut for vivid images

Industry leading **Intense Contrast Ratio** of over 80,000:1 and pure black for striking images; pixel level modulation (no backlight) eliminates background glow effect

life.augmented

MicroVision

life.augmented

ST & MicroVision Co-Marketing Agreement

On Nov 10, 2016, ST and MicroVision entered a co-marketing agreement:

http://www.businesswire.com/news/home/20161110005439/en/

ST is a worldwide leader in MEMS

- More than **12 billion MEMS** shipped
- Mass production of **Electrostatic and Electromagnetic** MEMS **µ-mirrors**
- Biz Model is to supply **µ-mirrors** and **ASICs**

Microvision is a leader in LBS Technology

- More than **20 years** of experience
- More than **500 patents** in LBS components and applications
- Biz model is to supply **Engines/Components**

Create a strong market position and better serve our customers:

- Cooperate in marketing MEMS scanner based solutions
- Continue to work closely on new markets and products
- Cooperate in joint Technology development and roadmap

MicroVision LBS Engines

Small Form Factor Display Engine: PSE-0403

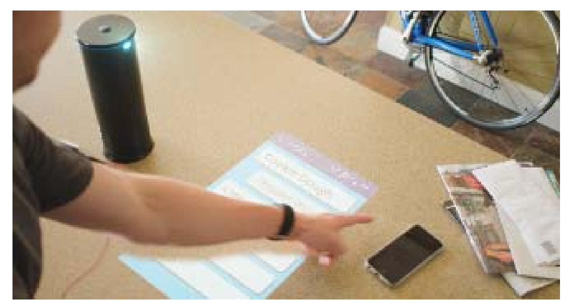
H1 2017

- Products: Pico Projection for Small devices

Display Engine With 3D Sensing for Interactivity

H2 2017

- Products: Interactive display applications: mobile and IoT

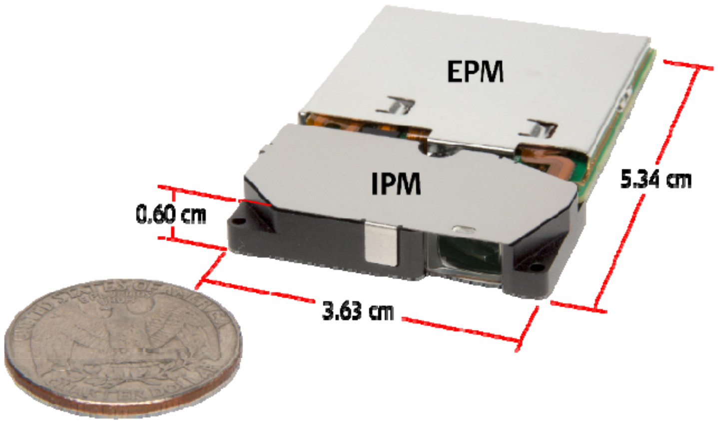


life.augmented

Small Form Factor Display Engine

PSE-0403-101/102 - Key Features

- **MicroVision's PSE-0403 display engines** offer an industry leading combination of made-for-mobile features in a small form factor
- High definition, focus free images even in motion
- Vivid, saturated colors
- Laser brightness and power efficiency
- Thinner than a pencil
- Intense contrast ratio
- Industry leading throw ratio
- Short focal length option



Short Throw Interactive Display Engine

PSE-0403sti-101 – Key Features

MicroVision is combining

Projected Display + 3D Sensing

into a single, integrated scanning engine

for

Interactivity with projected content

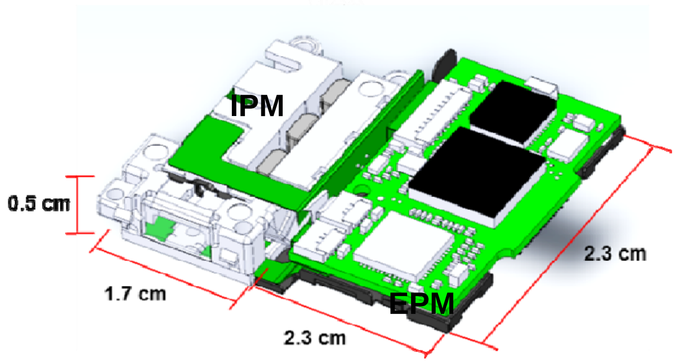
Enables new and exciting products by mimicking a Windows 10 or Android touch screen display or providing access to intermediate point cloud data

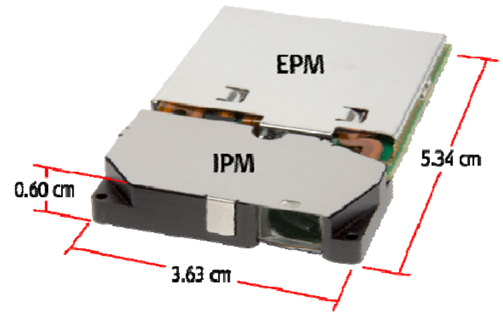
- Short Throw projection
- **Multi-touch** interactivity
- High definition **always-in-focus** images
- Vivid saturated colors
- Intense contrast ratio with true black
- Multi-mode operation:
  - Display: table top and wall mode
  - Interact: touch and point cloud modes

life.augmented

Small and Ultra Small Engines

Side by Side Comparison

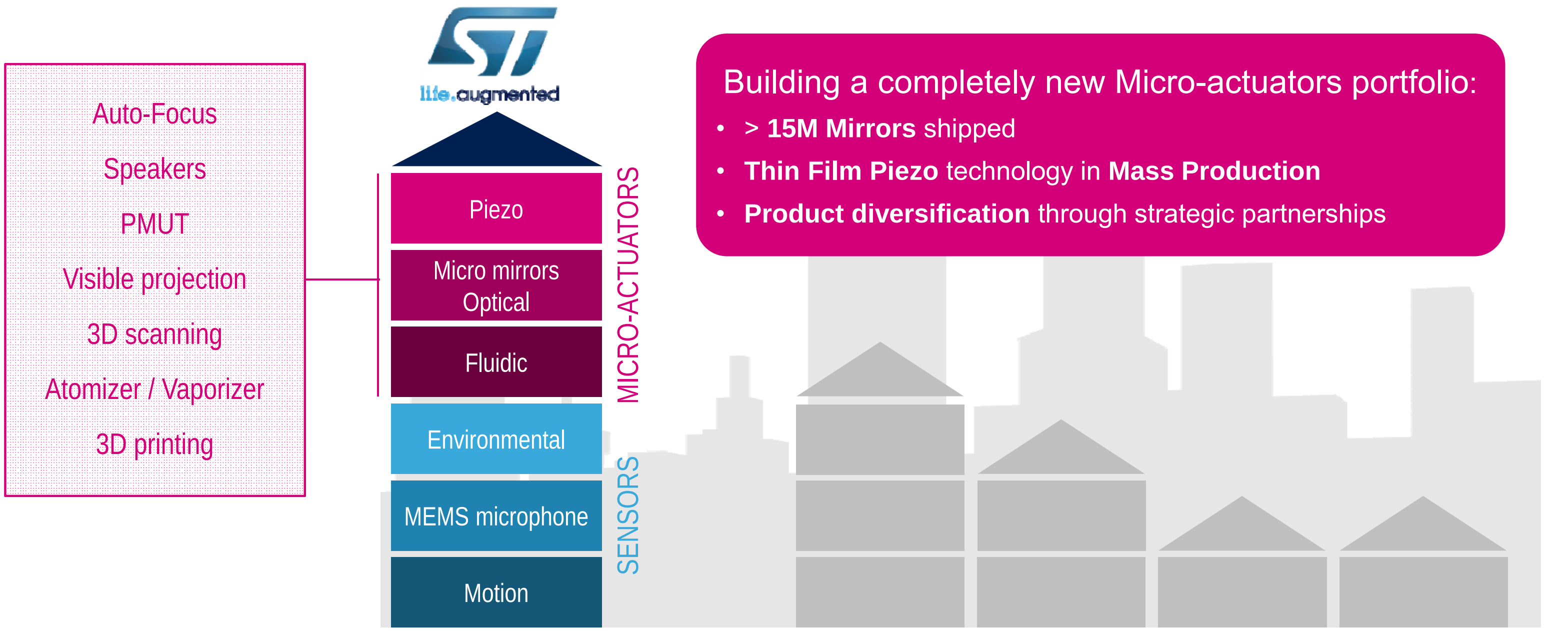




Ultra Small Form Factor Reference Design Based on ST **Mono-axial Electrostatic Mirrors**	Small For Factor Display Engine Based on MVIS **Bi-axial Electromagnetic Mirror**
Volume = 3.45 cm^3 Thickness = 0.5cm → fits very slim and very small **Mobile Devices**	Volume = 11.63 cm^3 Thickness = 0.6cm → fits slim, small **Mobile Devices**
Ultra Low Power consumption	**Low Power** consumption
25 Lumens	**35 Lumens**
Good Image Quality: 600p	**Superb Image Quality:** 720p HD

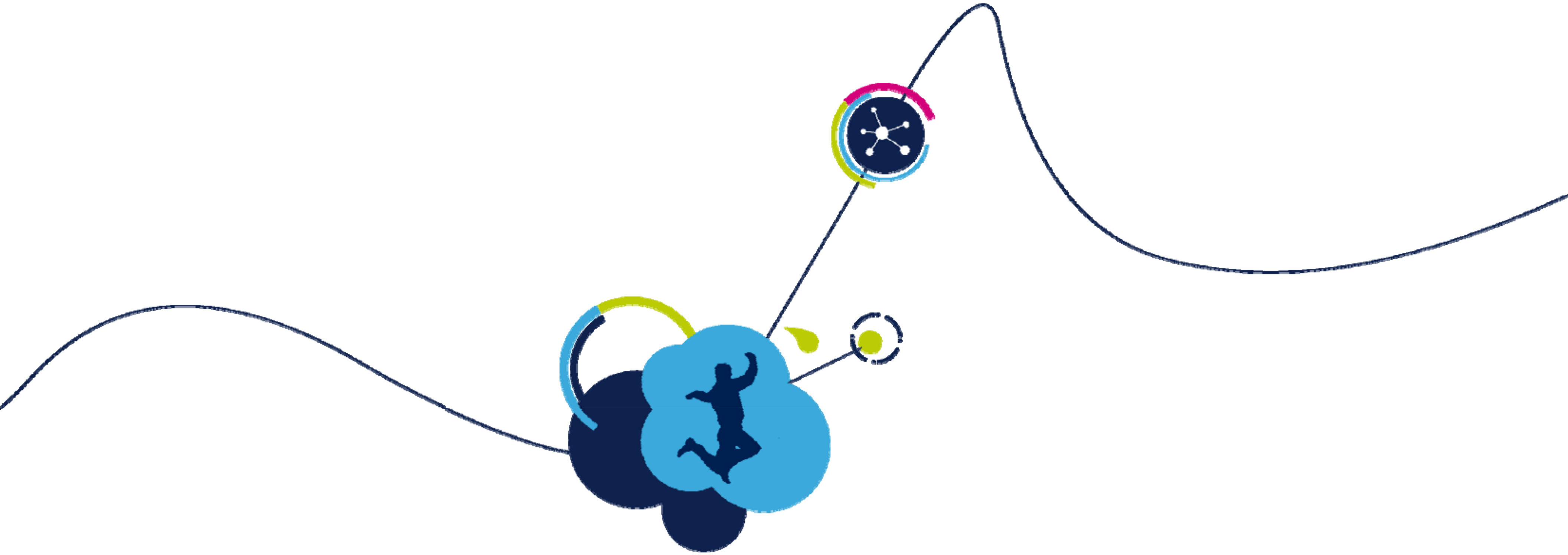
life.augmented

Changing the MEMS Landscape



Building a completely new Micro-actuators portfolio:

- > **15M Mirrors** shipped
- **Thin Film Piezo** technology in **Mass Production**
- **Product diversification** through strategic partnerships



Thank you