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MEMS ScanAR™: ST LBS solutions enabling ultracompact “light” engines for AR

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Micro Actuators Business Unit

March 31st, 2021

SPIE.ARVRMR



Laser Beam Scanning: a mature technology

Visible Light Projection:

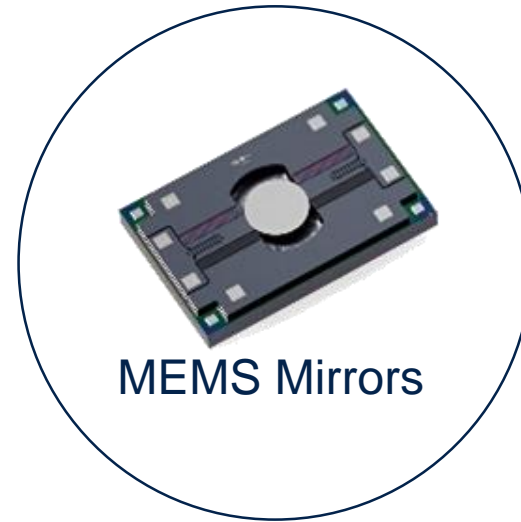
i.e: AR / XR: Head Mounted Displays, All-day-Wearable Glasses



InfraRed 3D Sensing:

i.e: Consumer, Industrial, Automotive LiDAR:

<https://www.intelrealsense.com/lidar-camera-l515/>



MEMS Mirrors

Sense and Display:

i.e: Medical AR (vein detector)

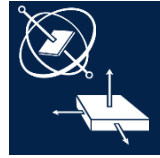
<https://www.accuvein.com/why-accuvein/ar/>



20 Years of MEMS at ST



Accelerometer



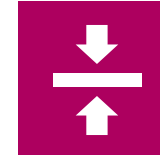
Inertial module



Pressure sensor



Micro-mirror actuators



Piezo actuators



Machine Learning Core



Fluidic Micro-actuators



Gyroscope



Magnetometer



Microphone



Humidity sensor



Waterproof Pressure Sensor

2000

2005

2010

2015

2019

2020



Smart Things



Smart Home & City



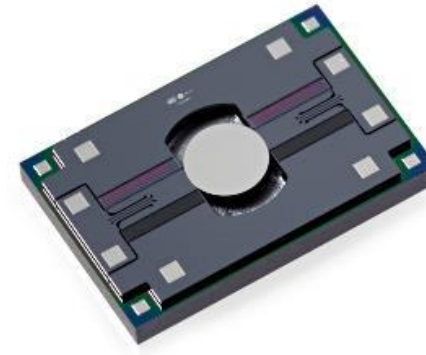
Smart Industry



Smart Driving



From zero to billions...



#1 50% Market Share** in Motion MEMS in Personal Electronics & Automotive telematics

#1 Micromachined actuators For ink-jet printing

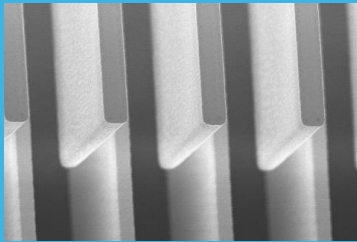
#1 MEMS Mirrors For XR and 3D scanning (**)



ST MEMS Mirrors Technologies

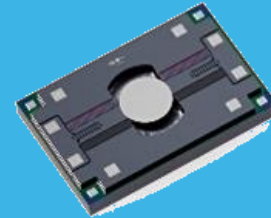
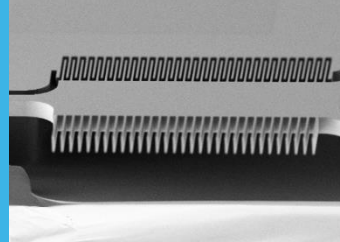
ST is Worldwide #1 manufacturer of MEMS based LBS solutions

ELECTROSTATIC



Staggered comb fingers

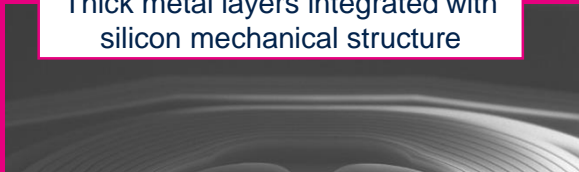
In-plane comb fingers



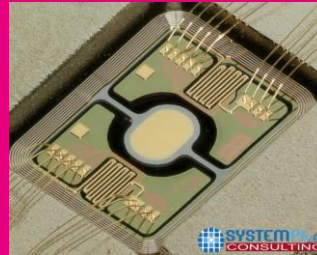
- High aspect ratio DRIE silicon etch for comb drive actuators (silicon thickness $\geq 40\mu\text{m}$), allowing both quasi-static and resonant operation
- Use of wafer-to-wafer bonding techniques to realize 3D integrated structures

ELECTROMAGNETIC

Thick metal layers integrated with silicon mechanical structure



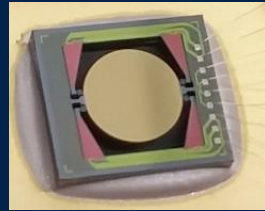
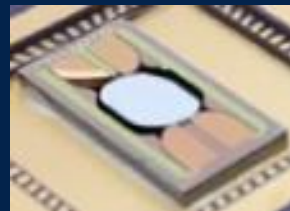
Thick metal cross section for coil



- Thick metal ECD growth ($>25\mu\text{m}$) to allow low resistance coil actuator
- Integrated piezoresistive position sensors
- Thin ($160\mu\text{m}$) finished holed wafers in production

PIEZO
ELECTRIC

Thin Film PZT Mirror



- Thin Film PZT ($\leq 2\mu\text{m}$), in Mass Production
- Integrated piezoresistive position sensor
- Use of wafer-to-wafer bonding for 3D integrated structures

ST Laser Beam Scanners: A success story



ST Commitment to LBS Continues

ST Establishes World's First "Lab-in-Fab" to Advance Adoption of **Piezo MEMS** in Singapore in Partnership with A*STAR and ULVAC



Oct '20

ST and Quanta join effort to develop a reference design for volume manufacturing of AR glasses



Nov '20

World's Smallest Micro-Mirror Scanning Technology from ST Chosen for **Intel® RealSense™** High-Resolution LiDAR Depth Camera L515



Mar '21



STMicroelectronics Launches **LaSAR**, an Ecosystem to Accelerate Development of Augmented-Reality Eyewear Applications

ST and Oqmented to collaborate on the advancement of the technology for Augmented Reality and 3D-sensing markets



Several Undisclosed Custom Developments on-going

Requirements for All-Day-Wearables AR Glasses

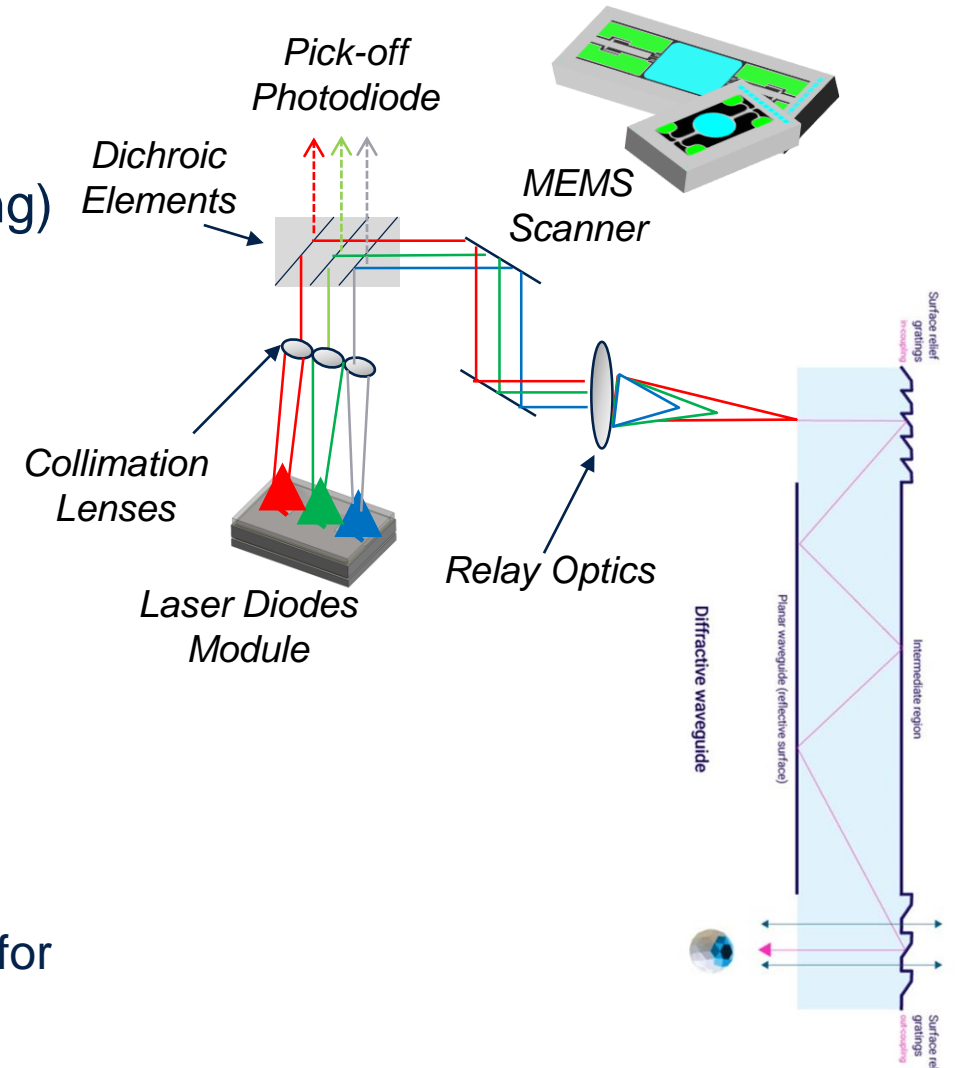
Target	Parameters	Values
All-Day-Wear	Lightweight	<60gr
All-Day-Wear	Form Factor	fashionable
All-Day-On	Low Power Display	<1W (<0.5W)
Outdoor Usage	Brightness	>1,000nits
Performances: Display	Field of View	30 – 50 deg
Performances: Display	Resolution	720p
Easy Fit (one size fits all)	Eye-Box	> 10mm x 10mm

ST Laser Beam Scanning Solutions enable All-Day-Wearable AR Glasses

Laser Beam Scanning for Near-to-Eye-Display

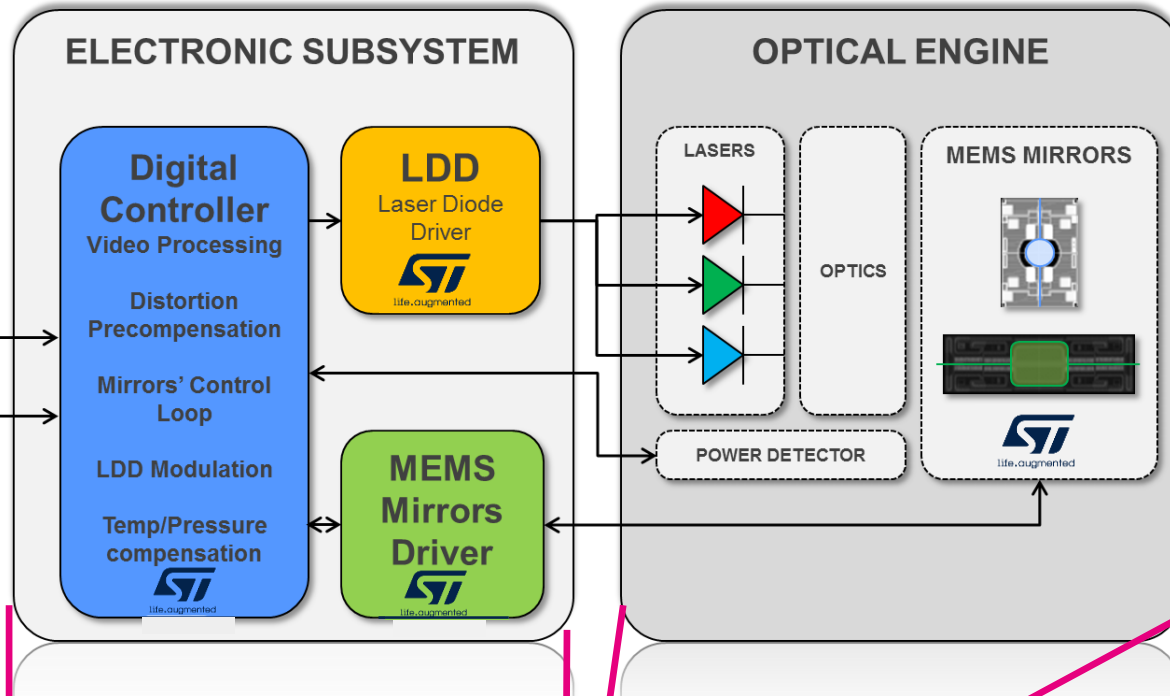
- **LBS vs Fixed Pixel Displays**

- **Low persistency** (10nsec vs msec) / Low Blur
- **Low Latency** (pixel by pixel rendering vs frame buffering)
- **Brightness** (10^6 nits from laser sources)
- **Power Efficiency:**
 - Flying spot / per pixel illumination
 - System: line buffering vs frame buffering
 - ST energy recovery drivers for Piezo mirrors
 - ST Laser Driver with look-ahead logic for fast on/off transitions when few consecutive pixels are off.
- **Real Estate:** volume occupation and weight
- Field of View and Resolution **Scalability**
 - size and consumption reduction with ST process roadmap for actuation

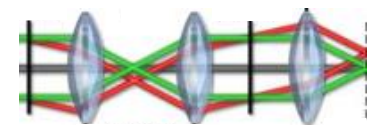
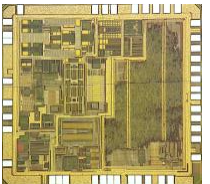
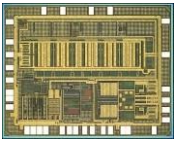




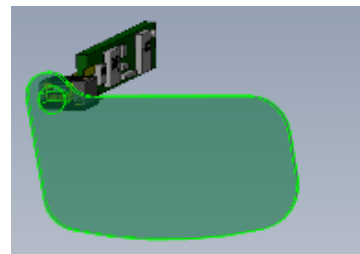
ST MEMS ScanAR™: one stop shop for LBS



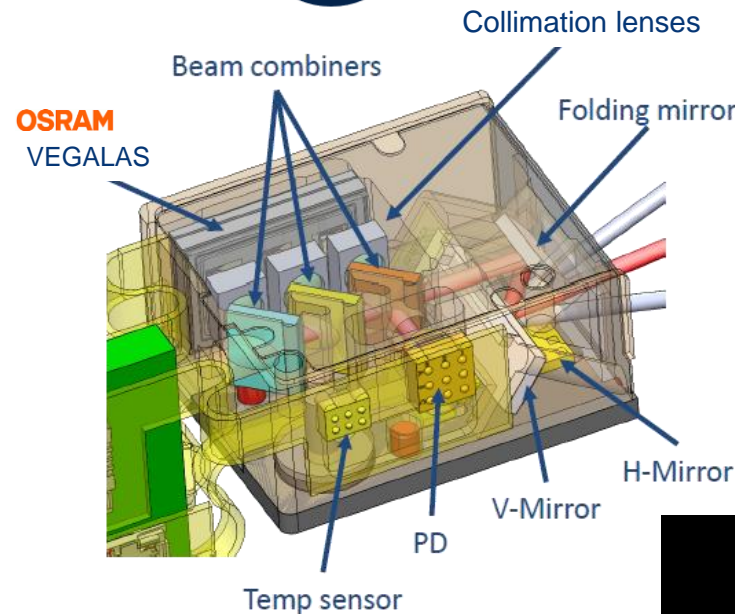
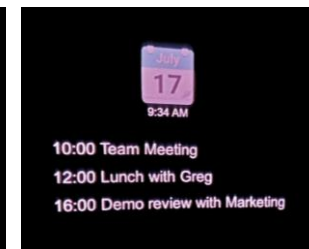
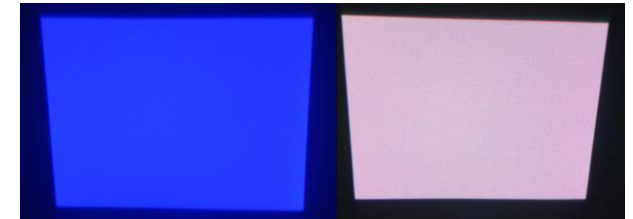
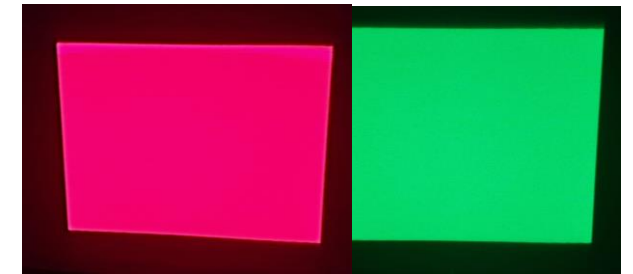
- **MEMS Mirrors**
- **Mirrors Drivers**
 - Electrostatic, Magnetic, Piezo drivers
 - High efficiency / Energy recovery drivers
- **Laser Diodes Drivers**
 - <500ps rise/fall time for crisp pixels
 - Ultra low power – Optimized for AR
 - 3 / 4 channels (RGB / + IR)
- **Control Loops and Video**
 - HW / SW Mirror control loop
 - Laser control loop
 - Calibration
 - Video processing
- **Relay Optics**
 - ST patented design to maximize performances with WaveGuides



STAR0 - Reference



ST Optical Engine: Reference Design

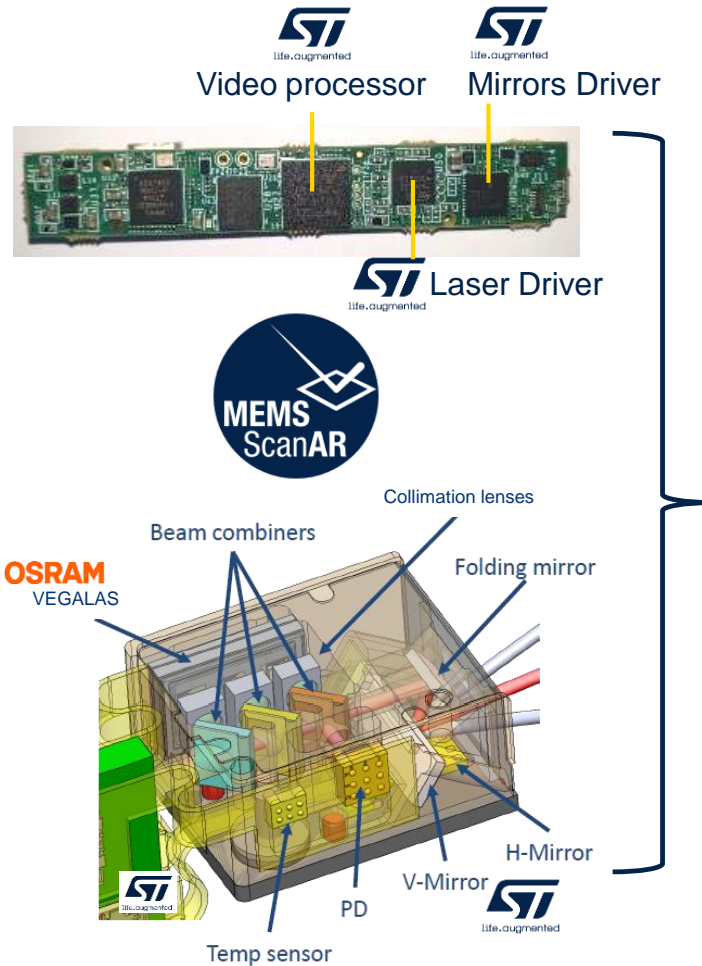


	ST OPTICAL ENGINE
Resolution	960x600 → 600p
Diagonal FOV	56°
Brightness	up to 10 lm
Mirror Actuation	Electrostatic - 200V
Power Consumption (MEMS + Driver)	200mW
Optical Engine Volume	0.75cc (@30deg FoV)
Weight	2.5gr

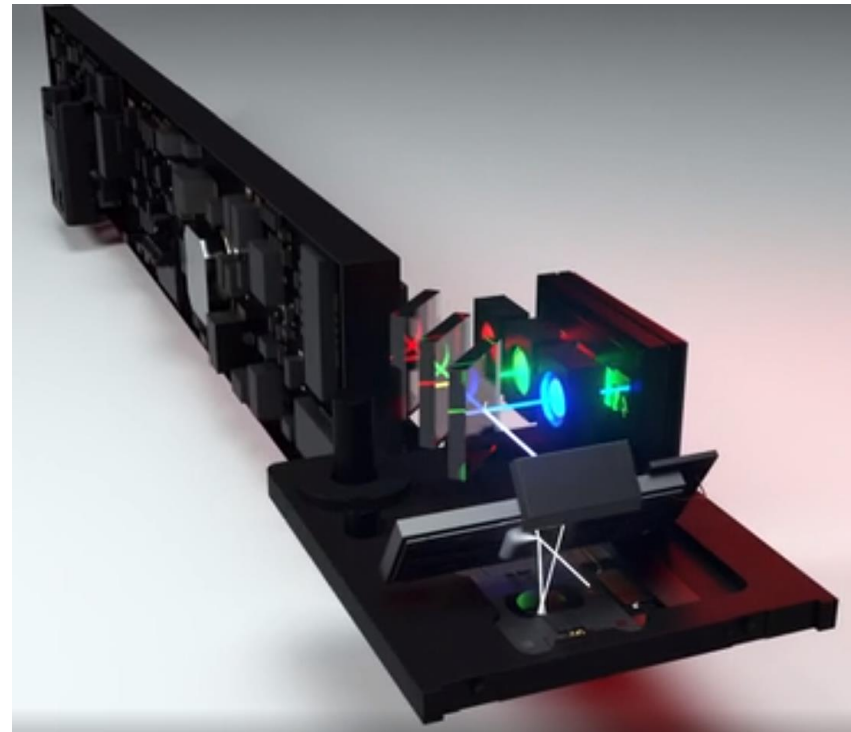


ST Mirrors in Mass Production - OE Samples Available - Mega1 and Quanta manufacturing partners

STAR0 Reference Integration: Demo

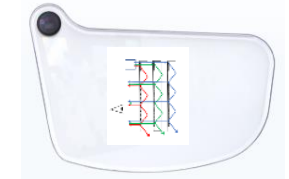


STAR0 Reference Design



Samples Now

dispelix



Demo Specifications

FOV (diagonal)	30°	24° (H) x 18° (V)
Brightness	1300	cd/m ²
Image aspect ratio	4:3	
Eyebow	10x10	mm
Color	RGB	
Resolution	33	pixels/deg
Refresh rate	60Hz	

MWC Shanghai: In-Person Event



Very Positive Feedbacks

Eyebox: 10mm - One size fits all

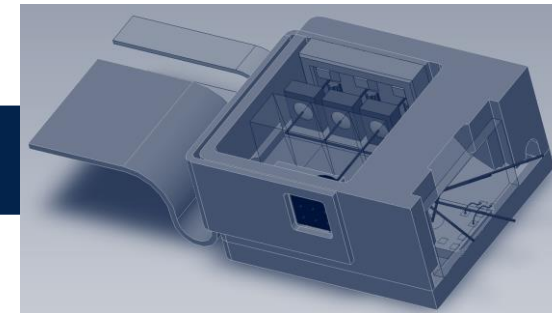
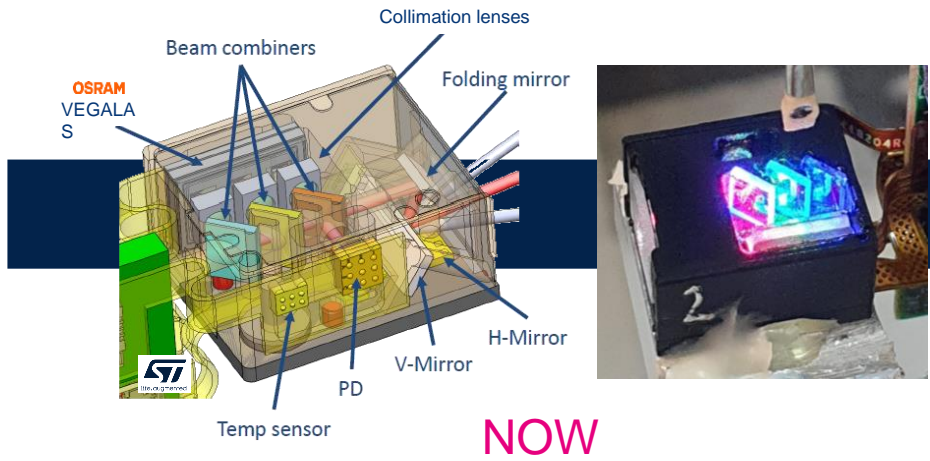
Weight: 58gr.

FoV: 30deg

Transparent Lenses

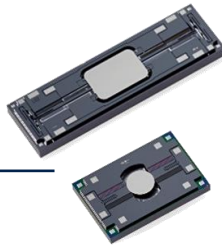


ST LBS Optical Engine: Roadmap



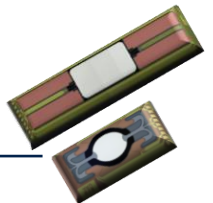
Optical Engine for STAR0

Helen OE FoV (Diag)	56°
Output Brightness	1.5 – 10 lm
Resolution	960 x 600p
Size	0.75 cc
MEMS Mirrors	Electrostatic



Optical Engine for STAR1

OE FoV (Diag)	65°
Output Brightness	1.5 – 10 lm
Resolution	1280 x 720p
Size	< 0.7 cc
MEMS Mirrors	Thin Film Piezo



Low Power Consumption
vs existing AR NED

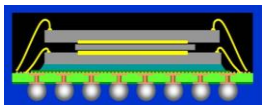
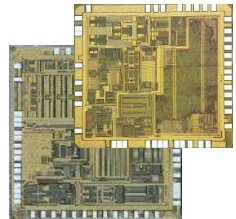
50% Less Power Consumption
than STAR0



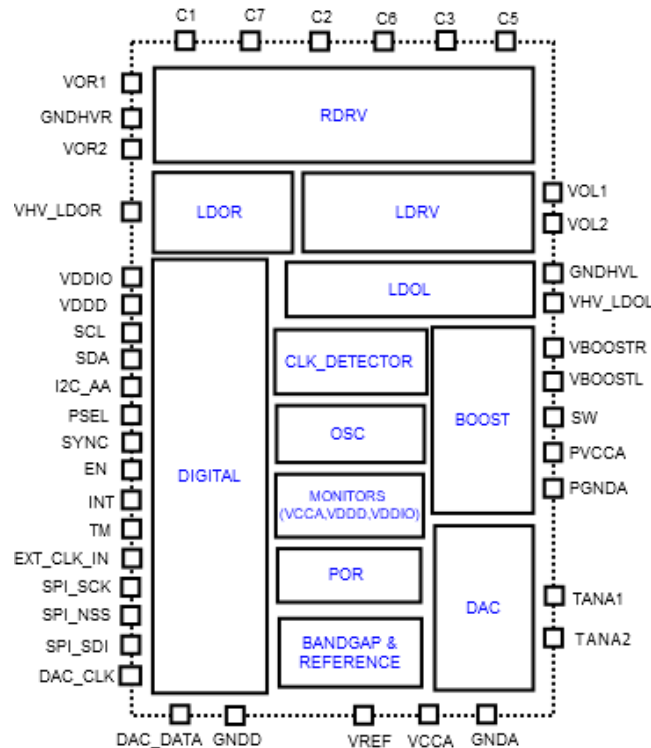
STAR1: Enabled by ST Thin Film PZT Actuation

STAR1: Piezo MEMS Mirrors Driver

- Mirror control loop
- Linear / Resonant Driver
- Energy Recovery Charge
- Low noise position sensing architecture
- Integrated safety circuitry
- Programmable master / slave video synch

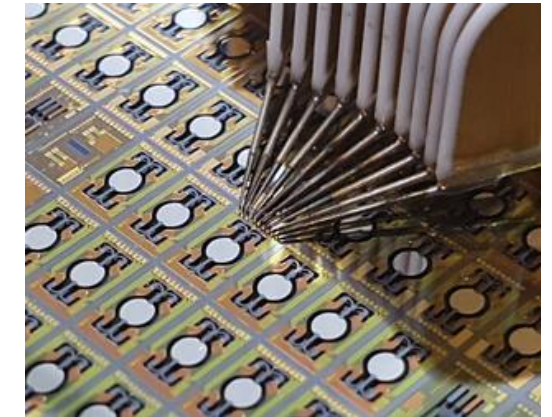
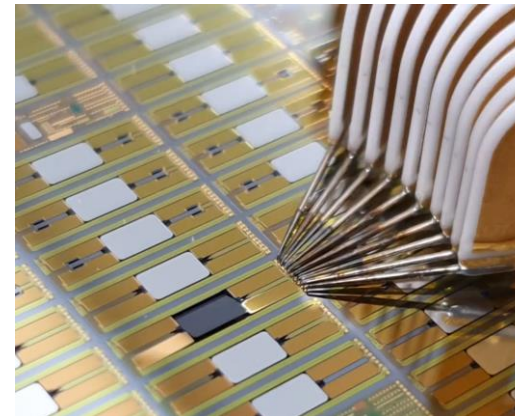


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STAR1: Thin Film PZT Resonant and Linear Mirrors

- ST PεTRA™ High Efficiency Thin Film PZT Process Technology
 - Mass Production
- Castor: 1.1mm diameter - 27kHz Resonant Frequency - ± 14deg opening angle
- Pollux: 2.5 mm x 1.5 mm – Linear - ± 8deg opening angle
- Piezoresistive position sensor



Engineering Samples Available to Key Partners
Preliminary validation aligned to specs

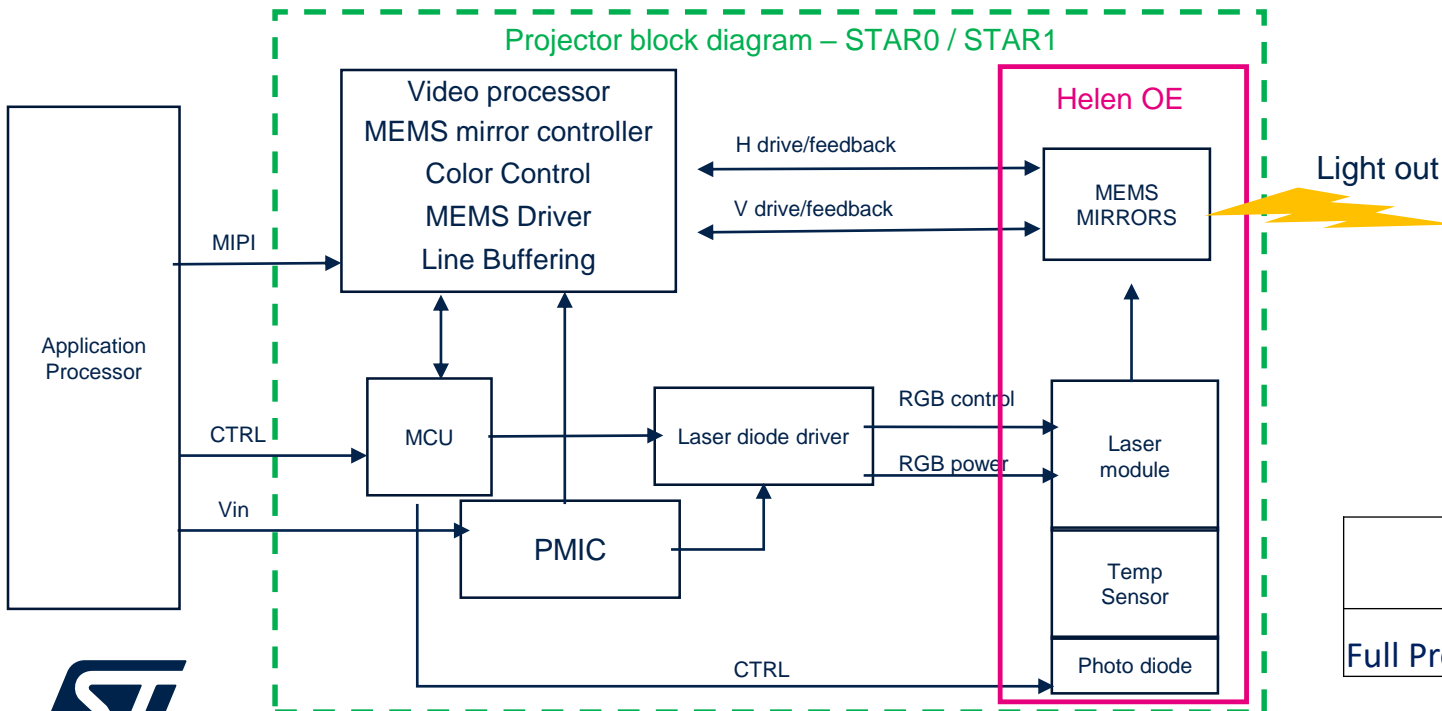
LBS Near-to-Eye-Display: Total Power Consumption

- Entire System LBS NED:
 - Lowest power consumption @ sparse content (AR) → All day wearable
 - High optical efficiency from lasers emitter to waveguide
 - Optical Engine + Electronics, including SW and Power Management

Specs for a fair display comparison

30deg FoV; 600p / 720p Resolution
 5 lm out brightness
 10mm Eyebbox (waveguide related)

↓
 To enable >1000 cd/m² (nits) out of a diffractive WG
 With eyebbox expansion to 10mm



	STAR0 (600p Resolution)		STAR1 (720p Resolution)	
	100% White [mW]	10% White [mW]	100% White [mW]	10% White [mW]
Full Projector System	1220	742	781	312



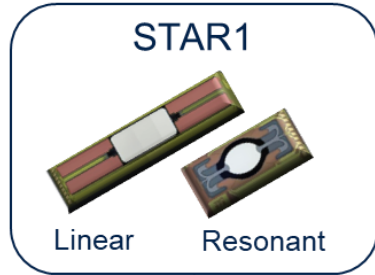
World's first Lab-in-Fab for Piezoelectric MEMS

ST Techno Park in Ang Mo Kio (Singapore)



ST Piezo Material Roadmap LBS Scalability

Actuation efficiency ↑



STARx

Same performances as STAR1
 Linear: = -30% die size
 Resonant: = -50% power consumption

or

Same size and consumption as STAR1
 1080p resolution or 90deg FoV



Higher actuation efficiency = die size reduction or increased performances



Now

Q2-2021
PeTRA 1.5

PeTRA 2.0

PeTRA 3.0

PeTRA 4.0

Time →

Thank you

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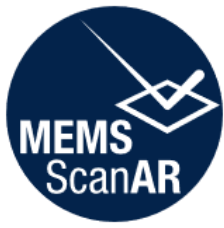
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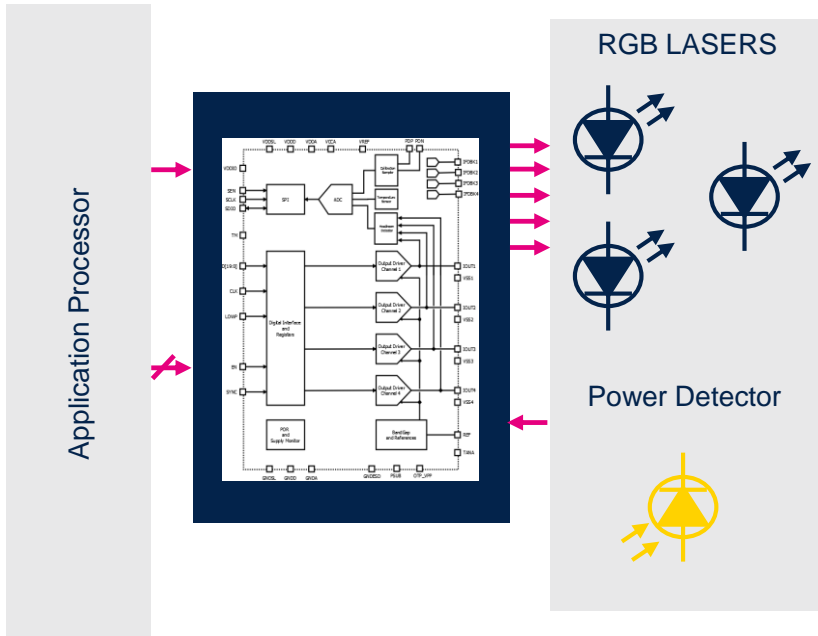


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MEMS ScanAR: Laser Diodes Driver

STLDDP: Laser Diode Driver



Hi-Resolution, Hi-Speed 3-channel laser driver

- 3 channel driver (R-G-B or CCC) for high resolution AR/VR projection.
- 10-bit programmable color depth gain up to 320mA
- 500ps rise/fall time
- <1% overshoot
- CSP package – 4.3 x 4.4 mm – 90 balls

Picture Quality

300MHz pixel rate, 10-bit color depth, 8 level PWM
500ps rise/fall time
Photodiode AFE for light power calibration

Crisp pixels, high contrast
1080p resolution, high dynamic range
Stable brightness and white point

System Integration

Automatic data aware power reduction algorithm
Laser diode headroom control
Fast switching in/out power save mode

Power optimization at component level (vs at AP level)
Power consumption optimization (headroom power)
<10 pixels time from low power to operative

Validated Final Samples Available





ST MEMS actuator technologies


5 Billion MEMS Actuators shipped during the past 20 years

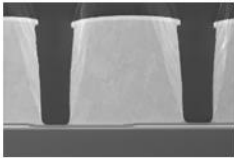
 **Thermal**


 **Inkjet Printhead
Dispenser, Atomizer**

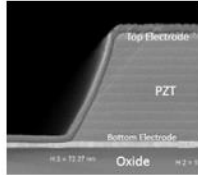
 **Electrostatic**

 **MEMS Mirror**

 **Electromagnetic**

 **MEMS Mirror**

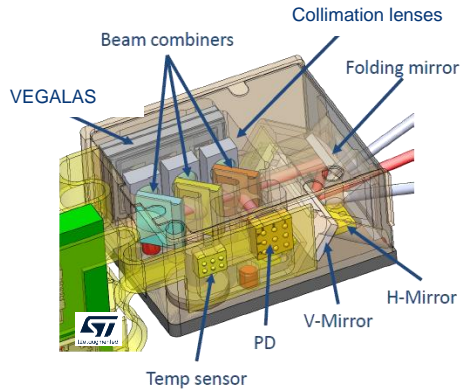
 **Piezoelectric**

 **Auto Focus Camera
Loudspeaker
MEMS Mirror**

Two 8" MEMS Fabs:
Two 8" BCD Fabs for Laser and Mirrors Drivers:

Milan, Singapore
Milan, Catania

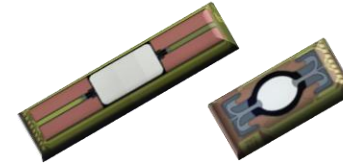
STAR1 vs STAR0: Zero Tradeoffs



Electrostatic



Thin Film Piezo



	STAR0 Optical Engine	STAR1 Optical Engine	
Resolution	960x600 → 600p	1280x720 → 720p	+60% <i>pixels</i>
Diagonal FOV	56°	65°	+14% <i>FoV</i>
Fast Scan Mirror Diameter	1mm	1.1mm	+21% <i>reflective area</i>
Brightness	2lm to 10lm	2lm to 10lm	–
Mirror Actuation	Electrostatic – 200V	Thin Film PZT – 40V	–80% <i>Driving Voltage</i>
Power Consumption (MEMS + Driver)	200mW	90mW	–55% <i>Power Consumption</i>
Optical Engine Volume	0.75cc (@30° FoV)	0.70cc (@30° FoV)	–7% <i>Volume occupation</i>
Weight	2.5gr	2.5gr	–

NOW

July 2021