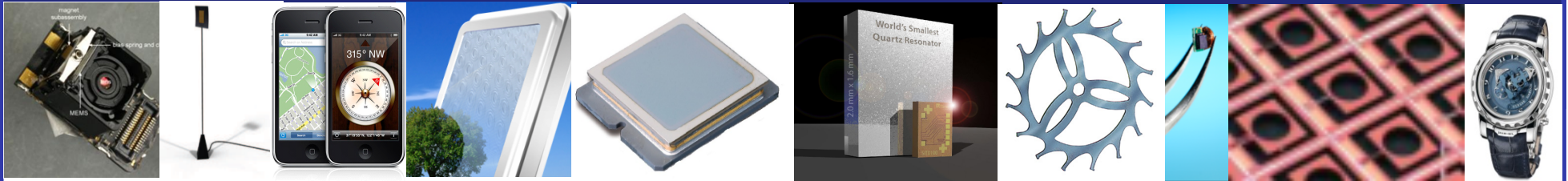


Status of the MEMS industry

New Drivers: the Path to New Opportunities

JC Eloy (eloy@yole.fr)



YOLE DÉVELOPPEMENT

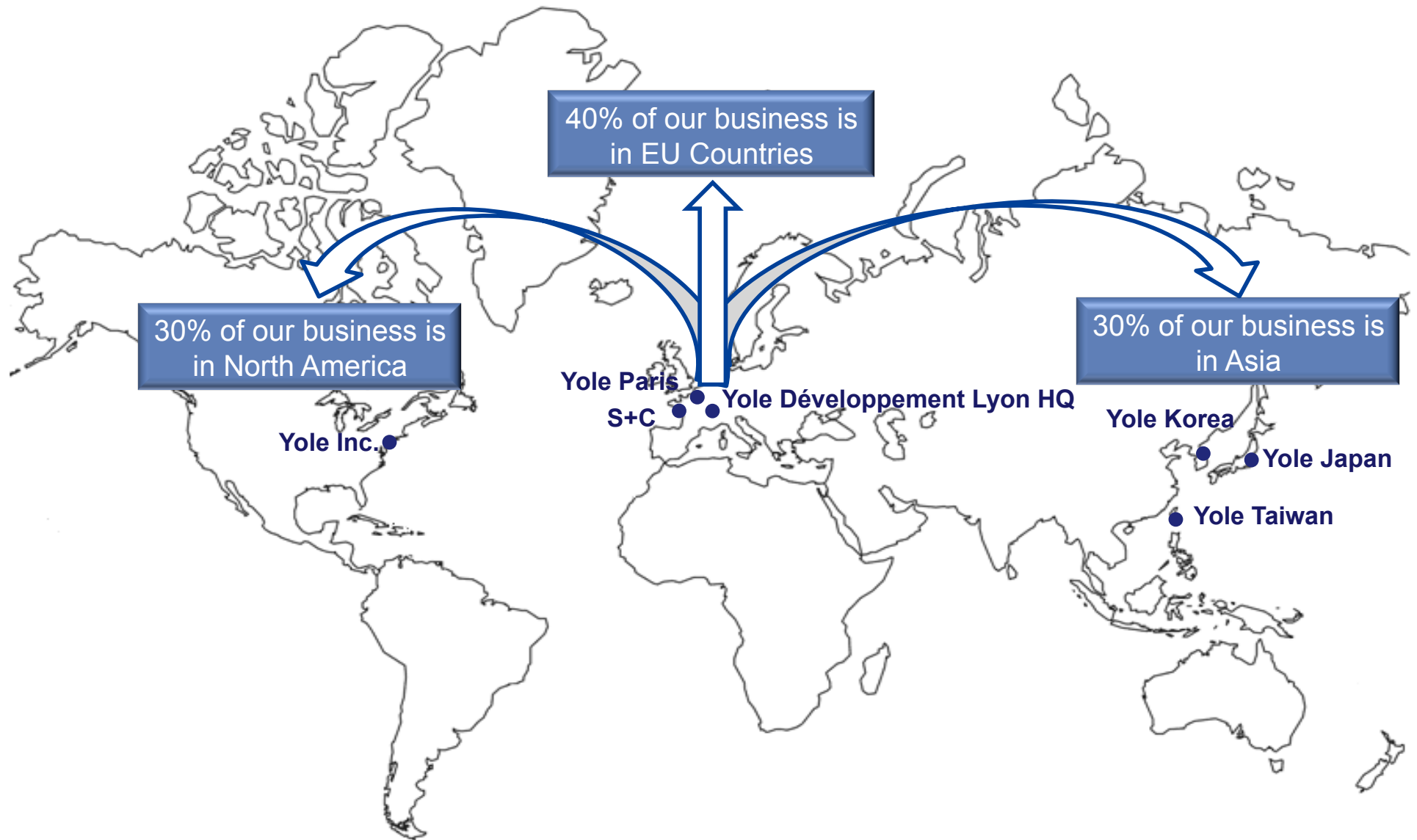
Yole Développement

- **Yole Développement is a market research, technology and strategy consulting company, founded in 1998 and involved in the following fields:**
 -  MEMS
 - Advanced packaging (3D IC, TSV, SoC, WLP...)
 - Power electronics
 - LED & HB LED
 - Compound semiconductor business (SiC, GaN, AlN, ZnO, Thick SOI...) at substrate and device level
 - Photovoltaic, from equipment and materials to cell business
 - Microfluidics and medical technologies
- **Our research is performed by in-house personnel conducting open-ended discussion based interviews.**
 - 30 full time analysts with technical and marketing degrees
 - Primary research includes over 3,500 interviews annually
- **Our customers' base and perspectives are global.**

4 business models

- **Custom analysis:**
 - Largest part of Yole activities
 - Covered by NDA agreement
 - From few days to several months of work, depending on subject
- **Report's publication:**
 - 35 to 40 reports published every year
 - Available by unit or under Annual Subscription
- **Media business: Publication of newsletters on 3D, PV, MEMS, PE, LED...:**
 - Advertising services in Yole magazines and webcasts
 - Take benefit of our 45 000+ subscribers to be visible and diffuse information on your company and products
- **Yole Finance services:**
 - M&A (buy side and sell side)
 - Due diligence
 - Fund raising services

Our Global Activity



MEMS MARKETS UPDATE

The 200+ MEMS applications tracked by Yole

IJH	Inkjet Head for Consumer	Consumer disposable heads
		Consumer fixed heads
	Inkjet Head for Industrial	Industrial heads
Pressure sensors	Pressure sensors for automotive	MAP
		BAP
		Boost
		Fuel Rail
		Cylinder Pressure
		Vacuum Boost Stop and Start
		Oil Pressure
		EGR
		Particle Filter
		Oil Transmission
		Fuel Vapor (Tank)
		Brake & ESP
		Suspension
		Steering
		Side Airbags
		TPMS
		HVAC fans
		HVAC Hydraulics
		Seat Occupancy (Weight)
		Pressure sensors for industrial
		Industrial HVAC
	Pressure sensors for consumer	Household application
		Cell phones
		Handheld consumer (non cell phones)
	Pressure sensors for medical	Blood monitoring disposable
		Blood monitoring equipment
		Ventilator & Anesthesia
		Respiratory equipment
		Kidney Dialysis
	Pressure sensors for aeronautics	Air Data
		FADEC
		Others

Si Microphones	Silicon Microphones for consumer	Mobile phone applications	
		Consumer Electronics (camera, camcorders ...)	
		Notebook	
		Earbud headset	
	Silicon Microphones for Medical	Hearing Aids	
	Silicon Microphones for Automotive	Automotive	
Accelerometers	Single accelerometers for consumer	Mobile phone	
		Tablets	
		Gaming	
		Remote controls	
		Cameras & camcorders	
		Laptop - HDD	
		Ebooks & PMP	
		Others (sport, handheld GPS, PC peripherals, toys...)	
		Accelerometers for automotive	Standalone airbag front sensor
			Airbag peripheral sensor
	ESC acceleration sensor		
	Roll over sensing		
	TPMS		
	Accelerometers for Medical	Other: integrated GPS, active suspension, safety, vibration, EPB	
		Accelerometer for pacemaker	
		Accelerometer for other healthcare applications	
		Accelerometers for industrial	Seismic - Geophones
			Antenna stabilization
	Industrial vibration monitoring		
	Inclinometers		
Offshore - Directional drilling + survey			
Accelerometers for aeronautics	GPS aiding, agriculture / mobile mapping		
	Other industrial applications		
	Aircraft backup instruments		
	AHRS		
	Other aero applis (flight control)		
Accelerometers for Defense	Missile Guidance		
	Precision Guided Munitions, Bombs & Rockets		
	Stab.		
	Other defense applications (navigation, flight control...)		

The 200+ MEMS applications tracked by Yole

Gyroscopes	Single Gyroscopes for Consumer	Mobile phone
		Tablets
		Gaming
		Remote controls
		Cameras & camcorders
		Ebooks & PMP
		Others (sport, handheld GPS, PC peripherals, toys...)
	Gyroscopes for Automotive	Roll over
		ESC gyroscope
		GPS navigation
	Gyroscopes for Industrial	Industrial process control & automotive testing
		Dynamic chassis control / Electronic stability
		Antenna / Camera stabilization & pointing
		GPS aiding, agriculture / mobile mapping
		Position and attitude compensation for racing or leisure vehicles
		Sports and healthcare: motion monitoring
		ROV guidance
	Gyroscopes for Aeronautics	Aircraft / UAV flight control
		AHRS
		Backup instrument
Gyroscopes for Defense	Platform stabilization, pointing	
	Aircraft / UAV flight control	
	Missile & munition guidance	
Magnetometers	Single Magnetometers for consumer	Cell phones
		Tablets
		Other consumer applications
	Magnetometers for automotive	Auto

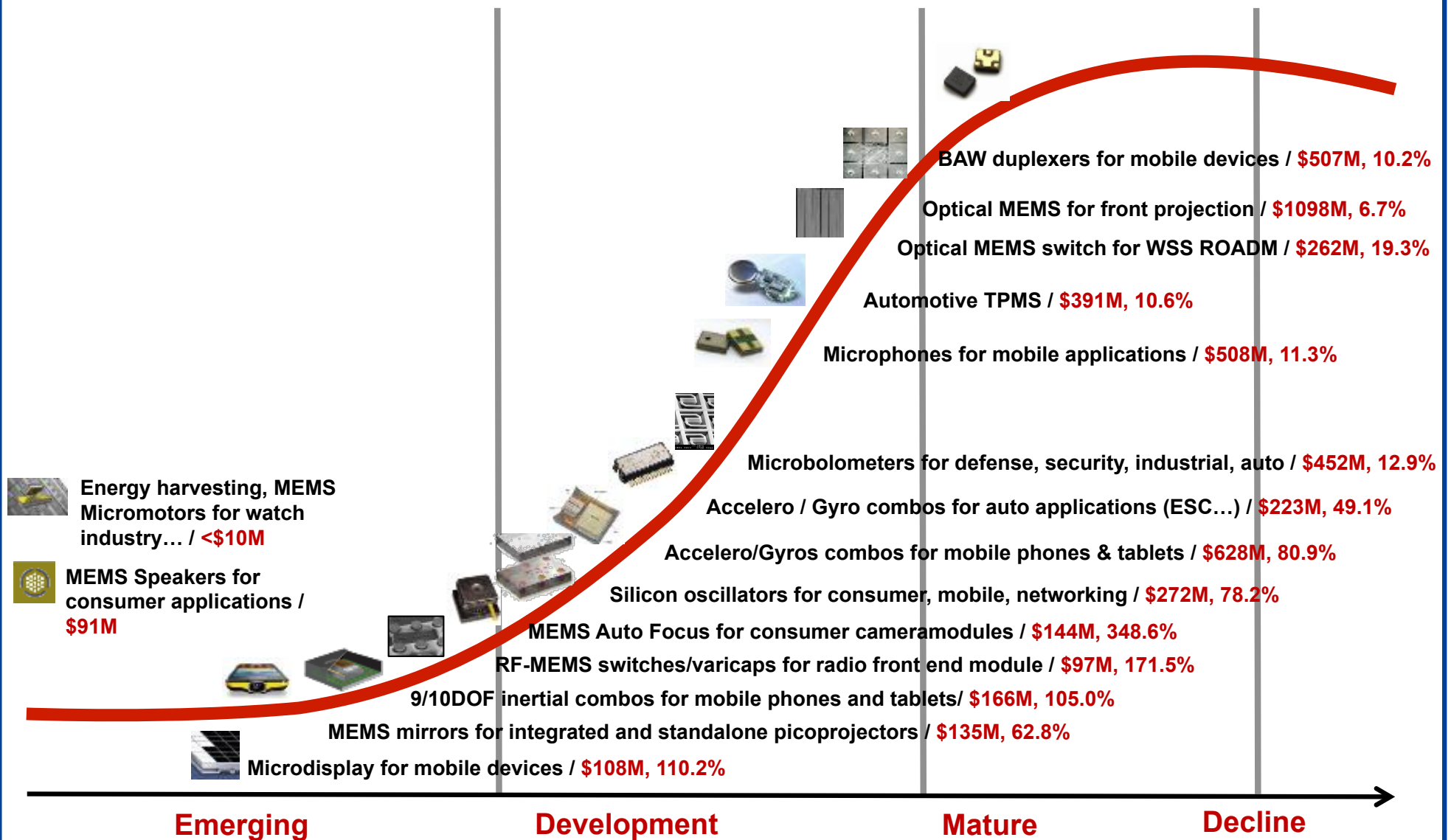
Inertial combos	Consumer Accel Gyro combos	Mobile phone inertial
		Tablets inertial combos
		Others inertial combos
	Consumer Accel Magneto combos	Mobile phone inertial
		Tablets inertial combos
Consumer 9/10 DOF combos	Mobile phone inertial	
	Tablets inertial combos	
Auto combos Accel Gyro	Others inertial combos	
	ESC combo	
Optical MEMS	Optical MEMS for Telecom	Other combo (rollover, with airbag sensors...)
		WSS ROADM
	Optical MEMS for Medical	VOAs
		Others (tunable filters, optical benches) optical MEMS
	Optical MEMS for Industry	Microspectrometers
		HMDs
		Others (endoscopy) optical MEMS
	Optical MEMS for Consumer	Adaptive Optics
		Bar code readers
		HMDs
Digital Cinema optical MEMS		
Optical MEMS for Defense	Front Projection	
	RPTV	
	Integrated pico-projectors	
Micro bolometers	Microbolometers for Automotive	Stand alone pico-projectors
		Auto focus
	Microbolometers for Industrial	Microbolometers for defense
		Night Vision bolometers
		Predictive maintenance bolometers
Microbolometers for Defense	Building Inspection bolometers	
	Process Control bolometers	
PIR & Thermopiles	Microbolometers for Security	Night Vision bolometers
		Night Vision (security, maritime & fire fighting) bolometers
	PIR	PIR
		Thermopiles

The 200+ MEMS applications tracked by Yole

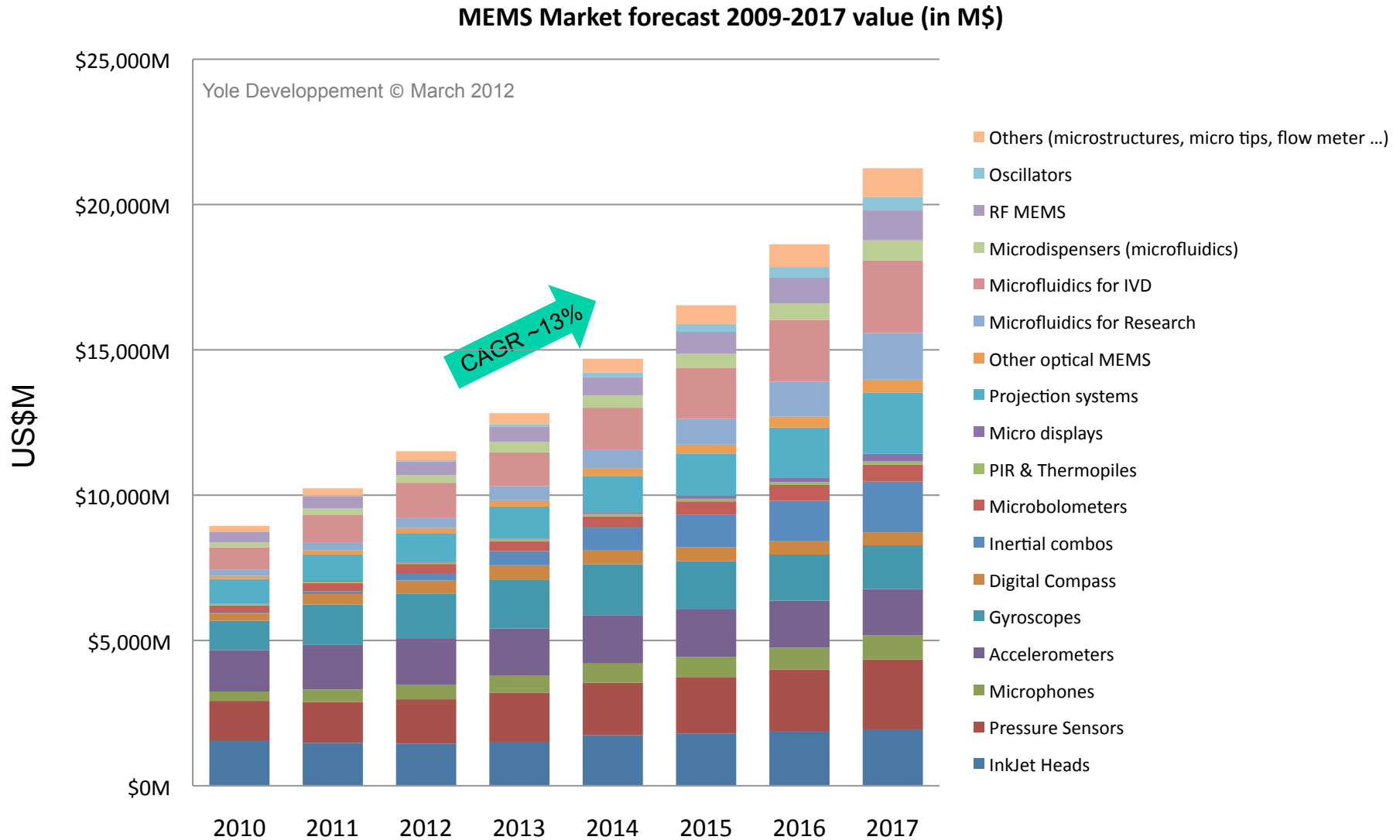
Micro Displays	Microdisplays for Consumer	Small size (cell phones)
		Large size (5-9" - ebooks, laptops ...)
Microfluidics	Microfluidics for Research	Pharmaceutical and Life Science research
		Clinical & veterinary diagnostics
	Microfluidics for In-Vitro Diagnostic	Human POC
		Analytical devices
		Environment and industrial testing
Microdispensers	Inhalers	
	Micropumps	
	Microneedles	
RF MEMS	Switch & Varicap for Consumer (mobile phone)	Antenna tuning
		Filters & duplexers tuning
		PA tuning
	Switch & Varicap for Telecom	Redundant Circuits
		Multiband modules
	Switch for Industrial	Femtocell
		ATE & RF Instrumentation
	Switch for Space	Redundant Matrix
		Commutation Matrix
	Switch for Aeronautic & Defense	Radars & Communications
Communications		
Filters	Radars	
	BAW Filters	
Oscillators	Oscillators	BAW Duplexers ...
		Oscillators
Micro tips	Micro tips & probes	Micro tips for AFM
		Probes for ATE
Flowmeter	Flow meter	flow meter for medical and Diagnostics
		flow meter for industrial
		Mass Air Flow (MAF)
Others	Others	Energy harvesting systems
		Micro structures
		Micro valves
		RF ID
		RF ID for medical
		Humidity sensors
		MRT Laboratories chips
		MRT production units
		Gas sensor
		Micro speaker
Micro fuel cells		

Maturity of selected MEMS devices in 2012

2015 revenue and CAGR



2011-2017 MEMS market forecast (in USM\$)



• We project the MEMS market to grow at ~13% CAGR in value from 2011 - 2017

2011-2017 MEMS market forecast (in USM\$)

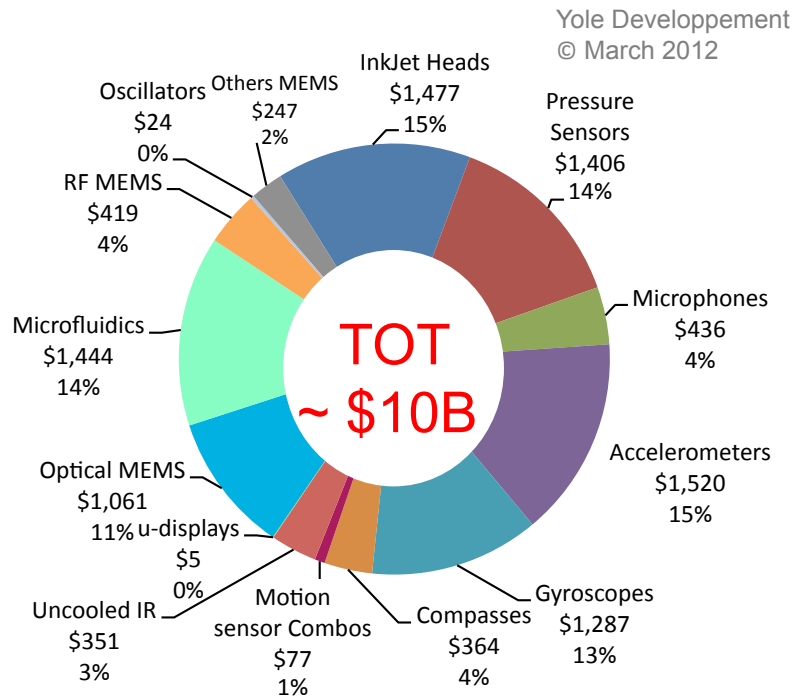
	2010	2011	2012	2013	2014	2015	2016	2017	CAGR
Others (microstructures, micro tips, flow meter ...)	\$198M	\$247M	\$306M	\$379M	\$474M	\$641M	\$782M	\$991M	26%
Oscillators	\$12M	\$24M	\$48M	\$88M	\$168M	\$272M	\$367M	\$463M	68%
RF MEMS	\$359M	\$419M	\$469M	\$527M	\$627M	\$762M	\$887M	\$1 028M	16%
Microdispensers (microfluidics)	\$174M	\$215M	\$261M	\$357M	\$418M	\$489M	\$572M	\$695M	22%
Microfluidics for IVD	\$758M	\$952M	\$1 197M	\$1 161M	\$1 438M	\$1 742M	\$2 125M	\$2 495M	19%
Microfluidics for Research	\$222M	\$277M	\$360M	\$487M	\$657M	\$887M	\$1 197M	\$1 604M	33%
Other optical MEMS	\$107M	\$143M	\$175M	\$215M	\$270M	\$308M	\$378M	\$452M	23%
Projection systems	\$858M	\$911M	\$987M	\$1 103M	\$1 233M	\$1 449M	\$1 716M	\$2 103M	14%
Micro displays	\$0M	\$5M	\$12M	\$27M	\$63M	\$108M	\$162M	\$261M	77%
PIR & Thermopiles	\$50M	\$61M	\$65M	\$73M	\$82M	\$90M	\$98M	\$107M	11%
Microbolometers	\$253M	\$290M	\$314M	\$332M	\$383M	\$452M	\$547M	\$589M	13%
Inertial combos	\$36M	\$91M	\$253M	\$485M	\$770M	\$1 125M	\$1 391M	\$1 743M	74%
Digital Compass	\$239M	\$364M	\$447M	\$491M	\$499M	\$485M	\$458M	\$448M	9%
Gyroscopes	\$1 010M	\$1 378M	\$1 539M	\$1 685M	\$1 759M	\$1 660M	\$1 586M	\$1 504M	6%
Accelerometers	\$1 425M	\$1 539M	\$1 593M	\$1 627M	\$1 648M	\$1 636M	\$1 620M	\$1 587M	2%
Microphones	\$322M	\$436M	\$509M	\$589M	\$659M	\$704M	\$752M	\$835M	15%
Pressure Sensors	\$1 355M	\$1 407M	\$1 527M	\$1 684M	\$1 809M	\$1 925M	\$2 135M	\$2 408M	9%
InkJet Heads	\$1 567M	\$1 477M	\$1 449M	\$1 514M	\$1 740M	\$1 799M	\$1 862M	\$1 939M	3%
TOTAL	\$8 945M	\$10 235M	\$11 510M	\$12 822M	\$14 696M	\$16 534M	\$18 635M	\$21 251M	

MEMS market forecast shipments (in Munits)

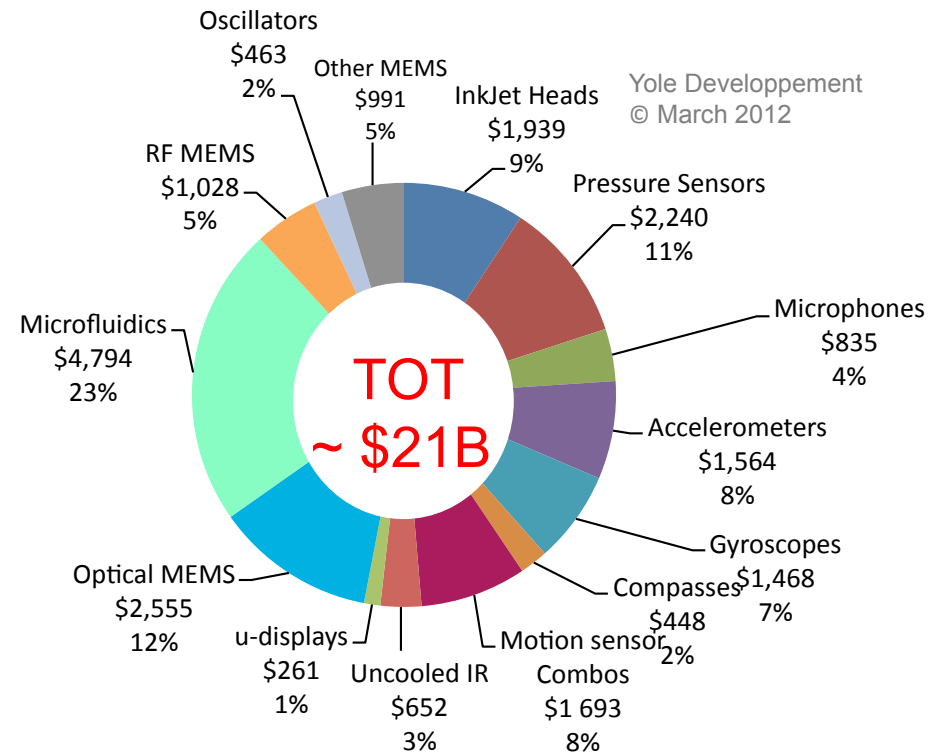
	2010	2011	2012	2013	2014	2015	2016	2017	CAGR
Others (microstructures, micro tips, flow meter ...)	28	43	53	71	105	173	245	347	44%
Oscillators	31	65	134	204	327	555	833	1 166	68%
RF MEMS	609	752	886	1 032	1 251	1 585	1 998	2 480	22%
Microdispensers (microfluidics)	25	25	30	35	42	49	57	68	15%
Microfluidics for IVD	188	233	302	425	551	837	1 056	1 428	34%
Microfluidics for Research	1	1	1	1	2	3	4	6	39%
Other optical MEMS	1	2	3	4	5	8	9	10	47%
Projection systems	4	5	8	35	63	146	260	411	91%
Micro displays	0	0	0	2	7	11	19	33	94%
PIR & Thermopiles	27	34	40	47	54	66	75	85	18%
Microbolometers	0	0	0	0	1	1	1	1	22%
Inertial combos	13	40	130	288	546	905	1 265	1 732	101%
Digital Compass	260	491	755	1 016	1 250	1 441	1 599	1 698	31%
Gyroscopes	353	555	725	920	1 076	1 119	1 164	1 134	18%
Accelerometers	1 233	1 531	1 798	2 036	2 188	2 245	2 282	2 244	9%
Microphones	820	1 145	1 422	1 767	2 098	2 396	2 763	3 240	22%
Pressure Sensors	485	524	607	747	907	1 115	1 549	2 150	24%
InkJet Heads	512	470	473	491	521	537	555	570	2%
TOTAL	4 589	5 917	7 368	9 122	10 992	13 193	15 733	18 801	

MEMS market value 2011 / 2017 (in M\$)

2011 MEMS Market Value Breakdown



2017 MEMS Market Value Breakdown



- We forecast that optical MEMS, microfluidic, pressure sensors and Motion sensor combo units (mixing gyroscope, accelerometers and magnetometer functionalities) will experience the highest 'grow versus volume' ratio in the next 5 years to come

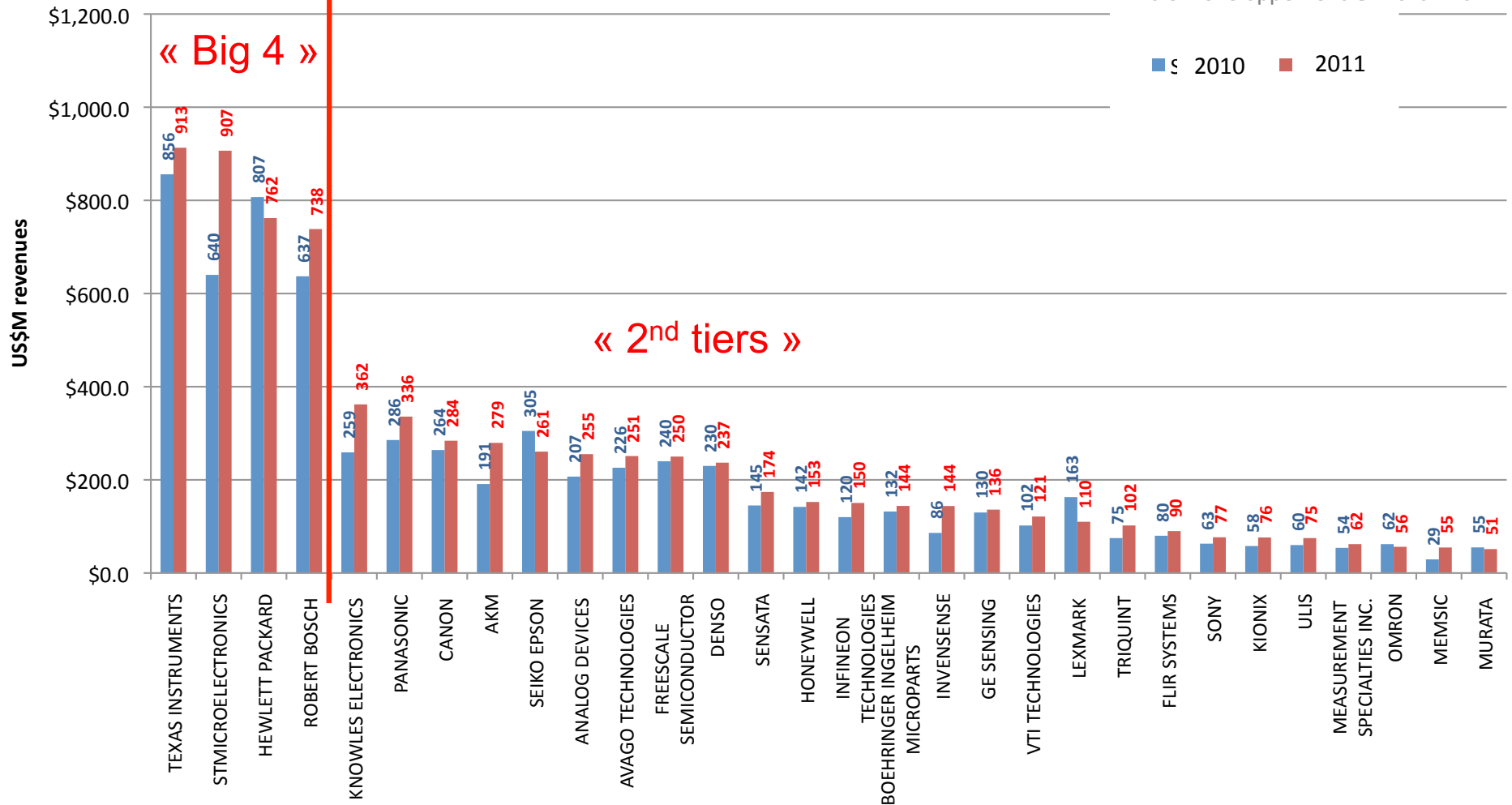
Evolution of the structure of the industry

2011 MEMS Ranking in \$M – TOP 30 players

2011 TOP 30 MEMS Players

Yole Développement March 2012

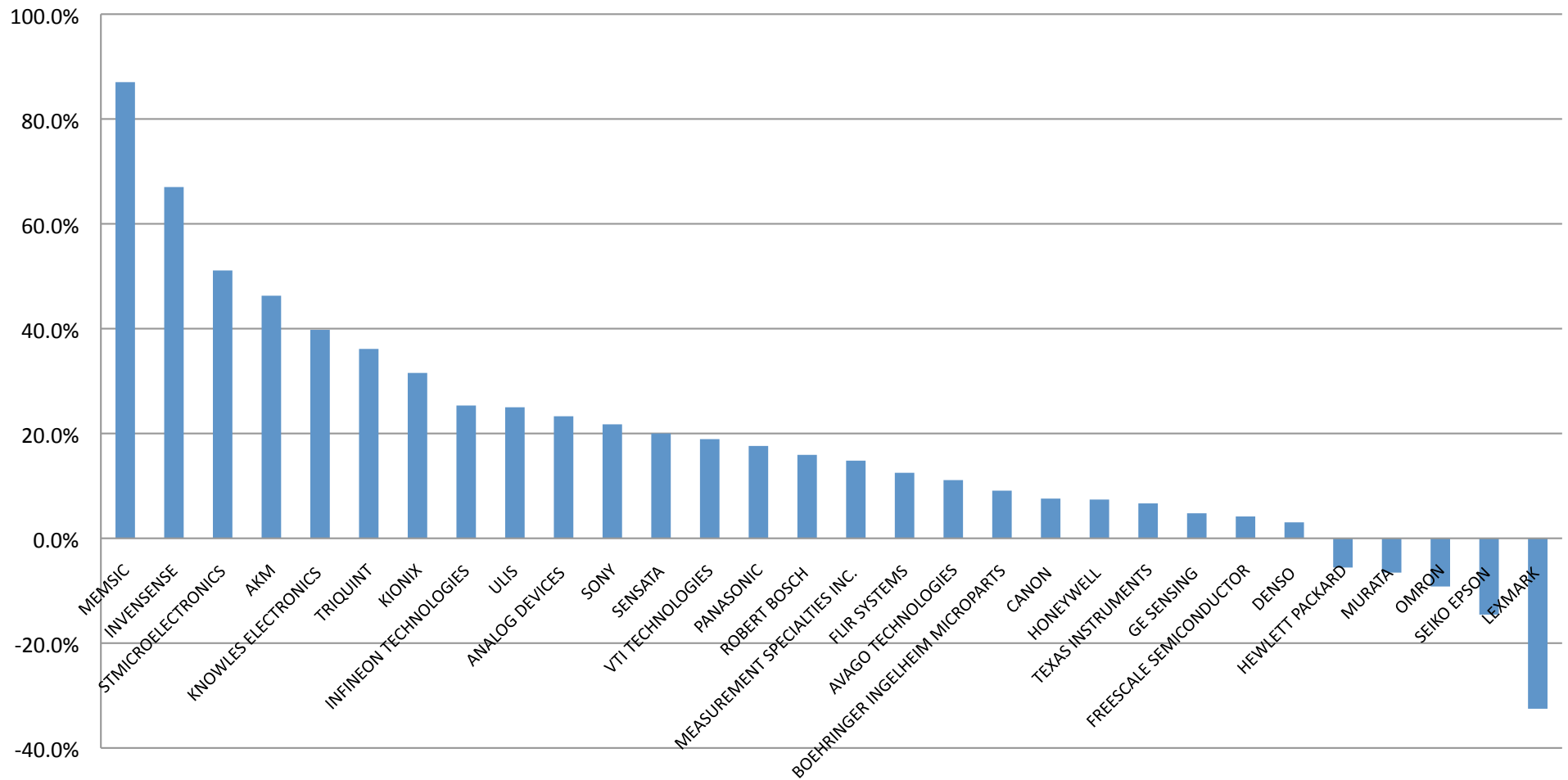
Yole Développement © March 2012



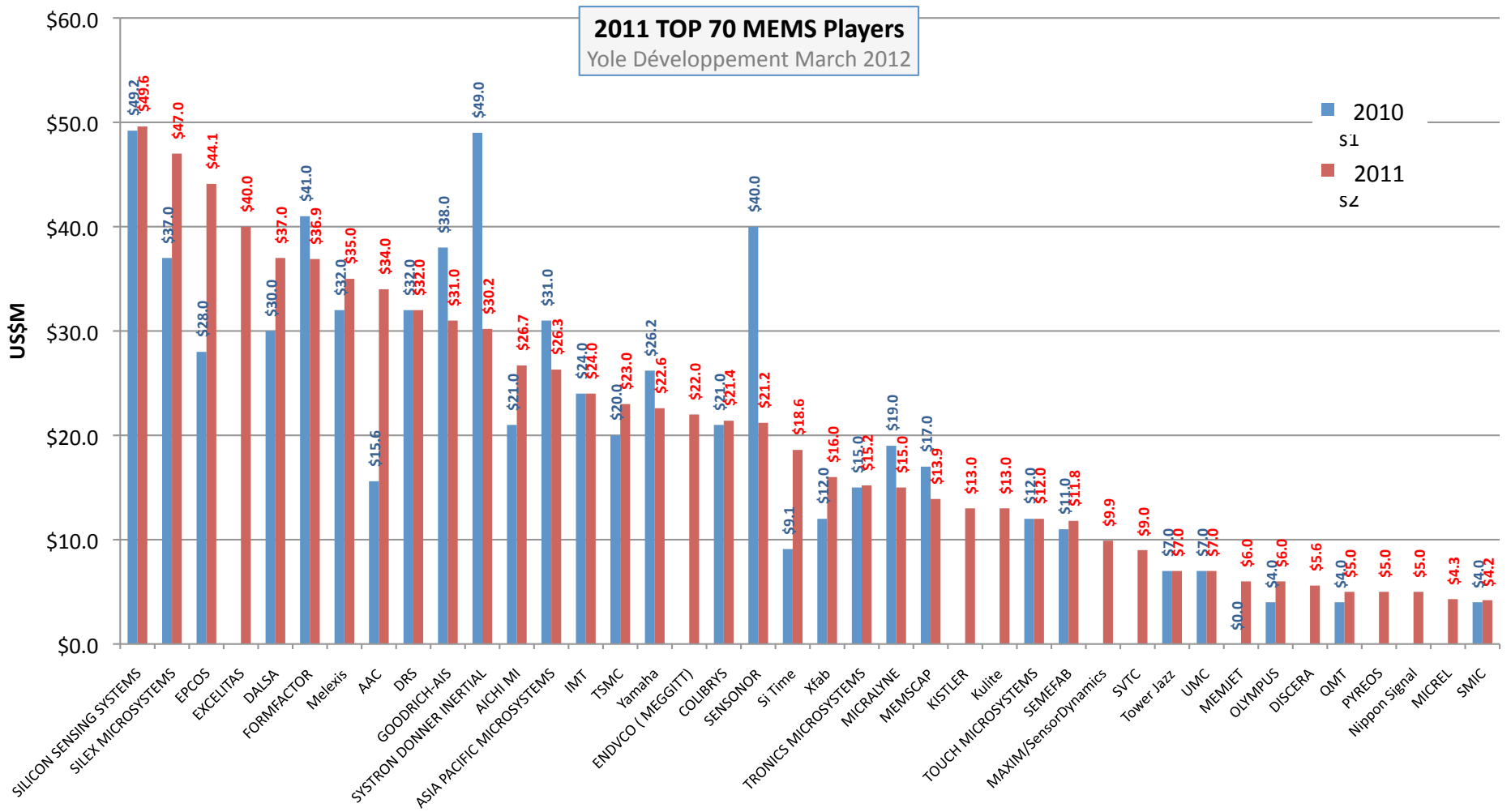
- TI, STMicro, HP and Bosch are the “Big 4” MEMS players with annual revenues > \$700M
- More than 25 “2nd tiers” players generate annual revenues from \$50M to \$300M

2011 MEMS Ranking – 2011/2010 CAGR TOP 30 Ranking

2011/2010 CAGR Ranking
TOP 30 MEMS Players

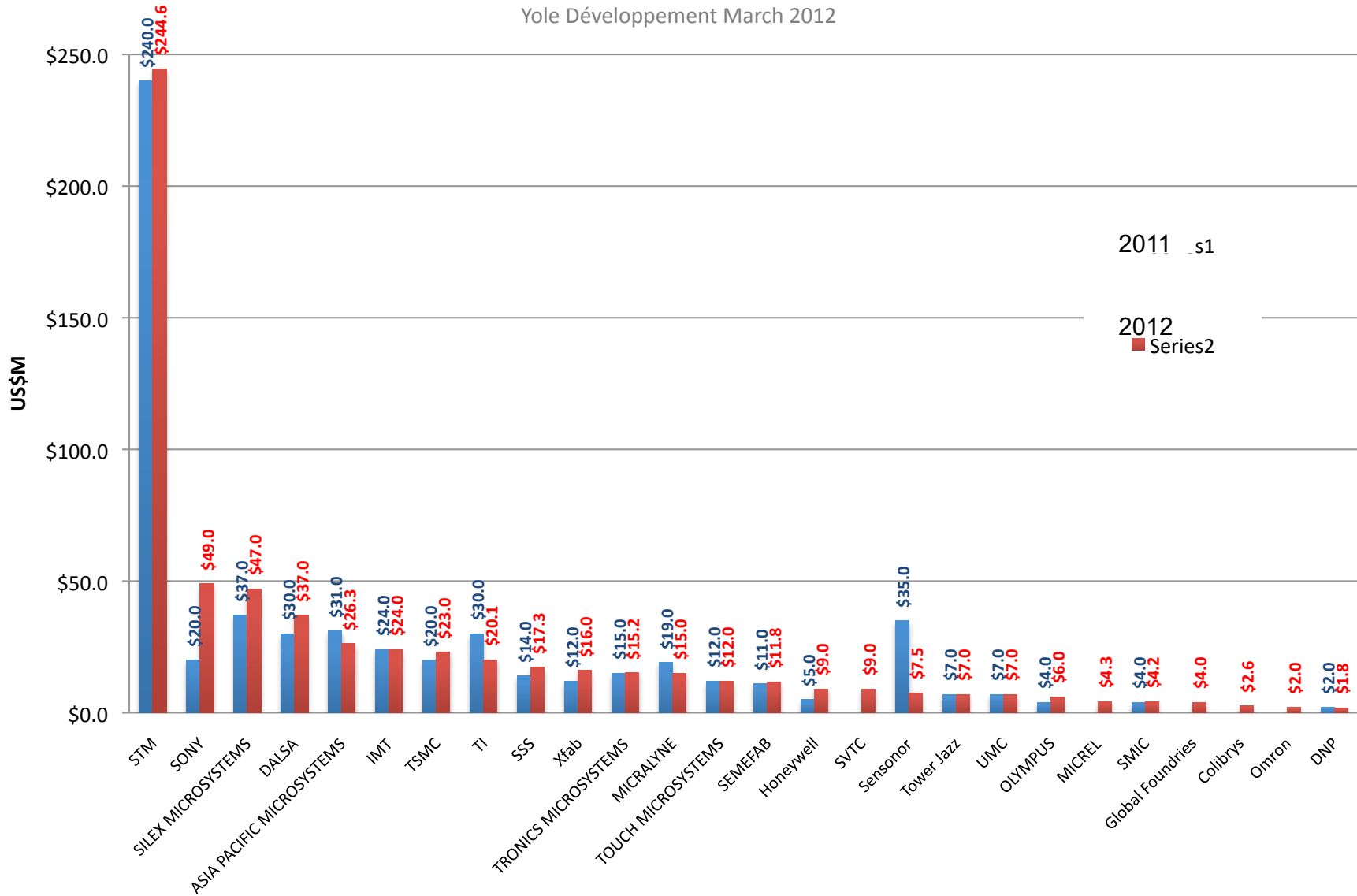


2011 MEMS Ranking in \$M – TOP 70



2011 MEMS Foundries Ranking

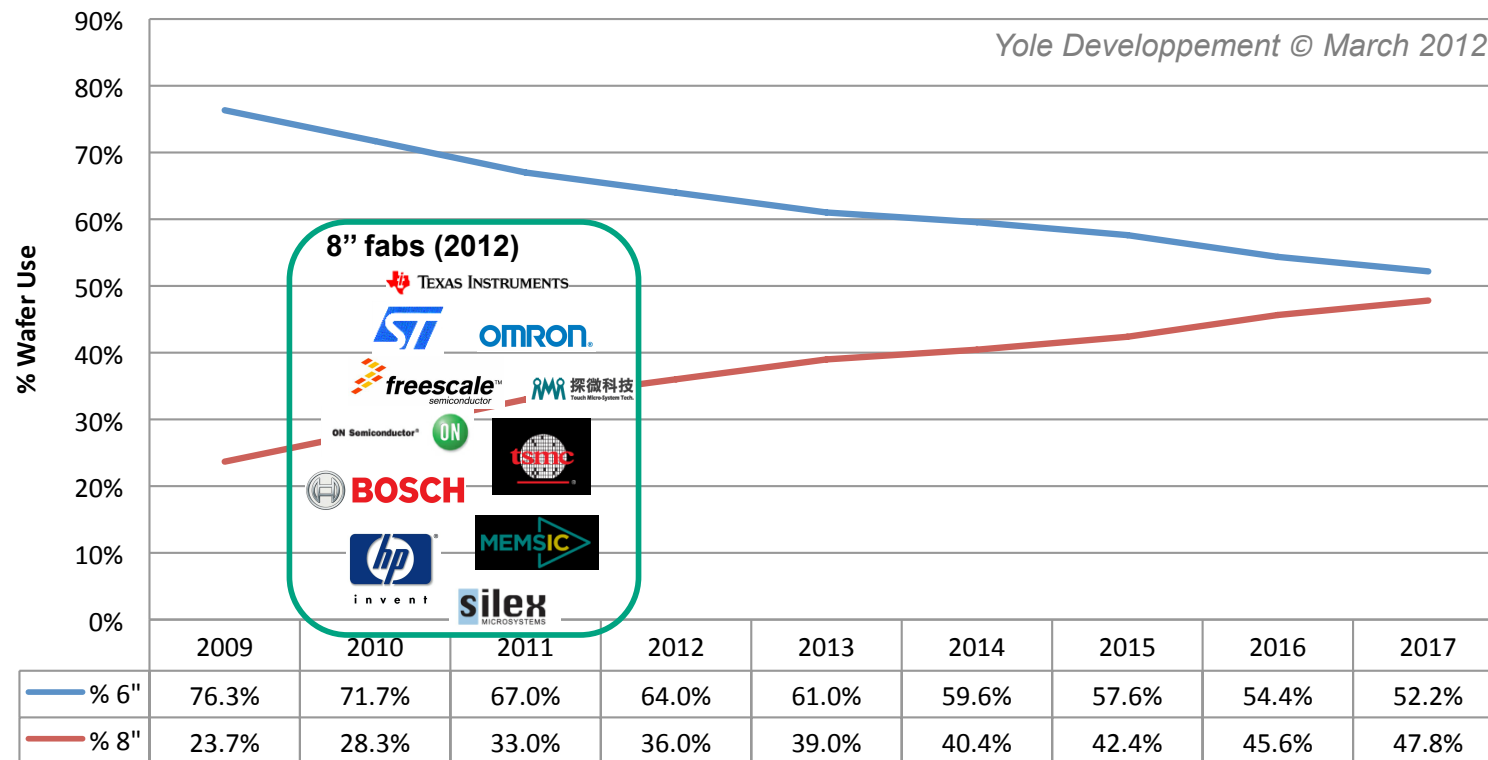
2011 MEMS Foundries Ranking
Yole Développement March 2012



6'' vs. 8'' wafer size breakdown

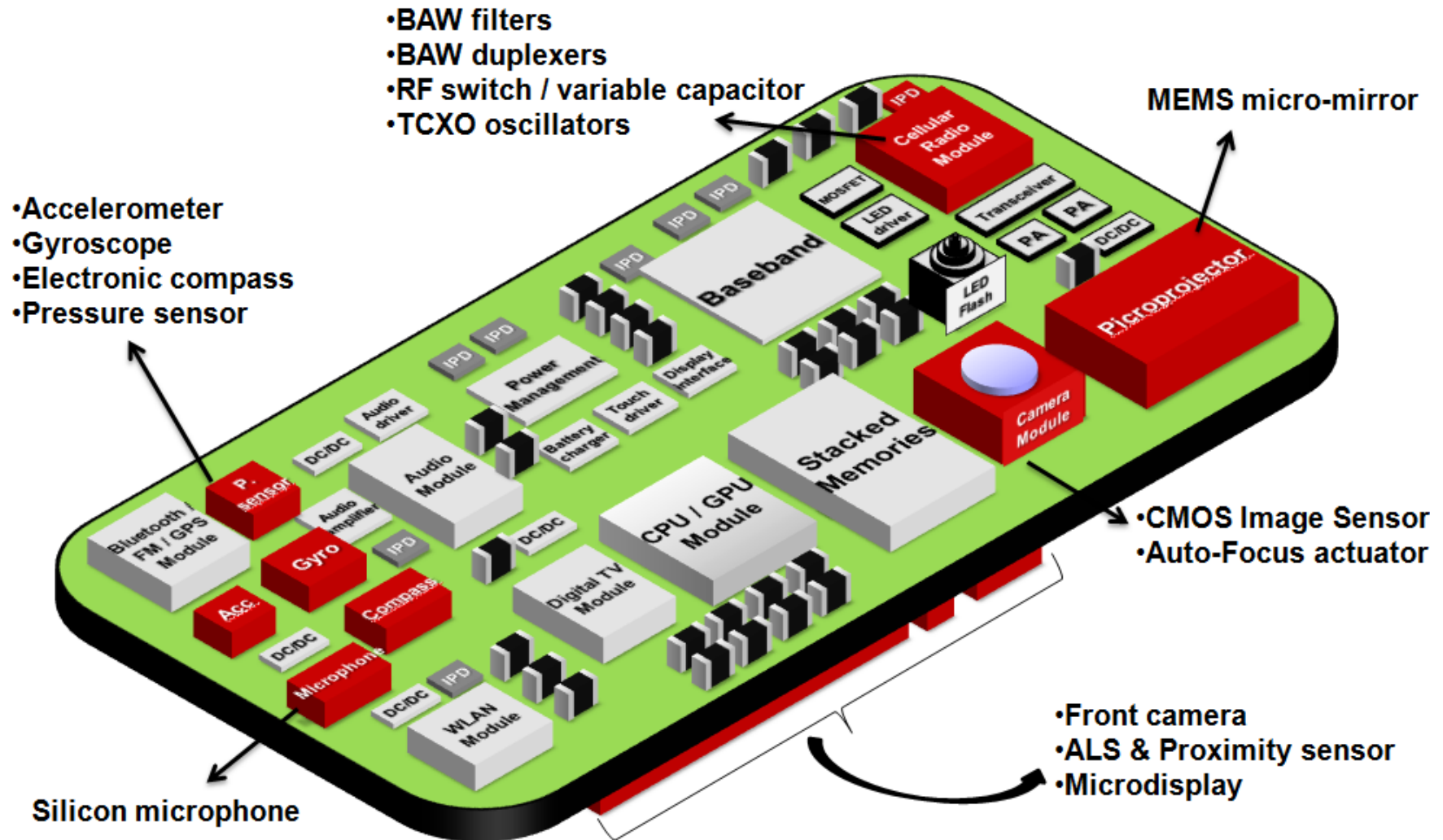
→ The total number of processed MEMS wafers will grow from 2.5M 8'' eq. in 2011 to 5.6M 8'' eq. In 2017.

6'' vs. 8'' MEMS wafer size evolution



**Mobile phone is becoming
really a big Mems business...**

MEMS & Sensors in mobile phones

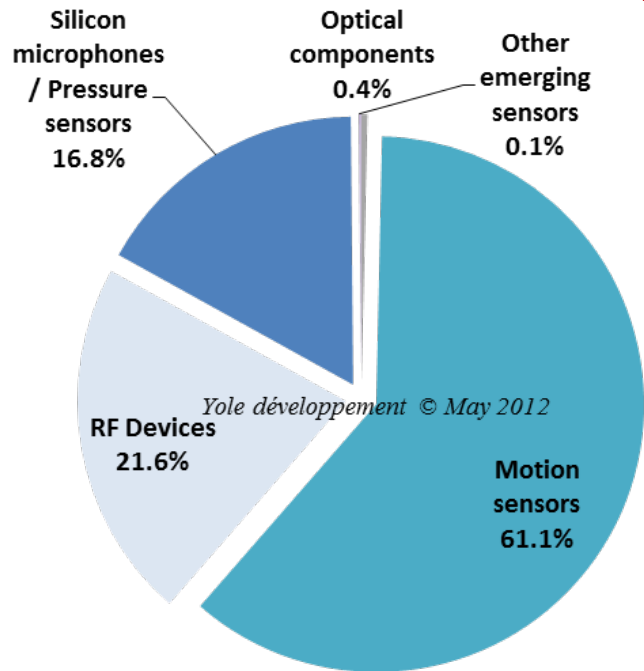


Global MEMS Market for Mobile Phones / Tablets

Breakdown by product category

MEMS in cell phones and tablets
Application segment breakdown

- 2011 - total = \$1.7B

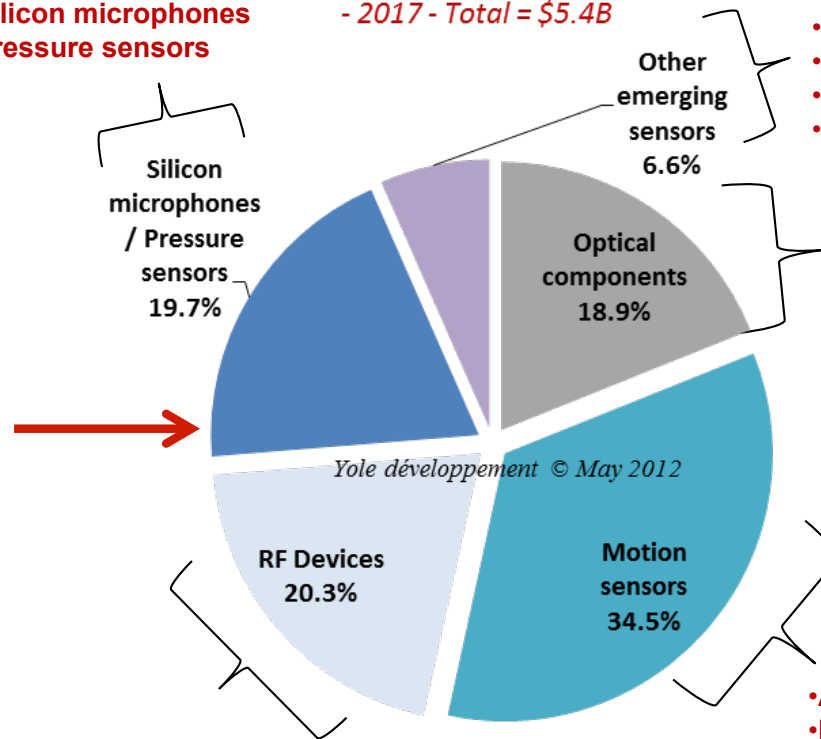


Yole développement © May 2012

MEMS in cell phones and tablets
Application segment breakdown

- 2017 - Total = \$5.4B

- Silicon microphones
- Pressure sensors



Yole développement © May 2012

- Energy harvesting
- Environmental sensors (temperature, humidity...)
- Micro fuel cells
- Microspeakers
- Touchscreen
- Joystick
- ...

- Auto-Focus
- Microdisplay
- Micro-mirror for microprojectors

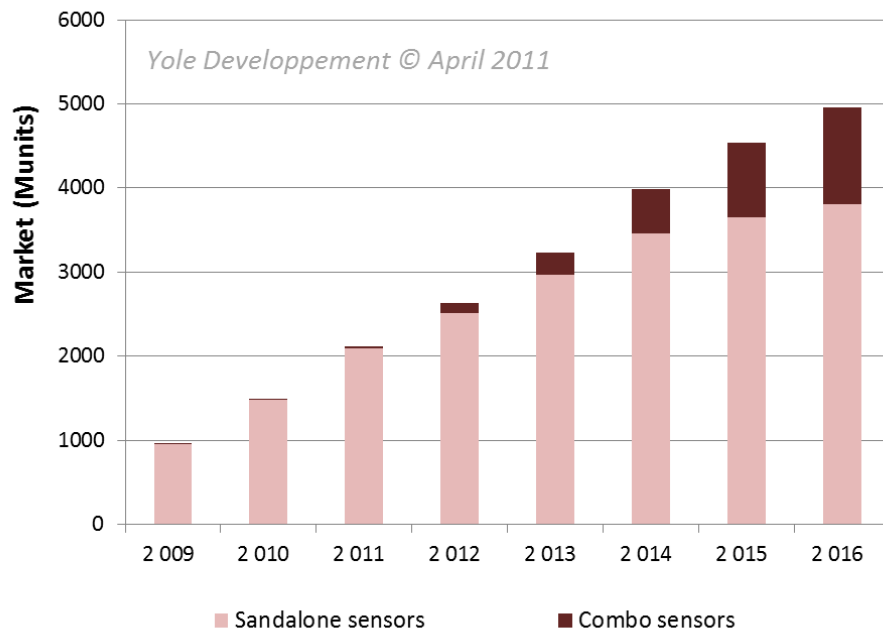
- MEMS timing devices
- MEMS switch / variable capacitors
- BAW filters
- BAW duplexers

- Accelerometers
- Magnetometers
- Gyroscopes
- 6 to 9DOF inertial combos

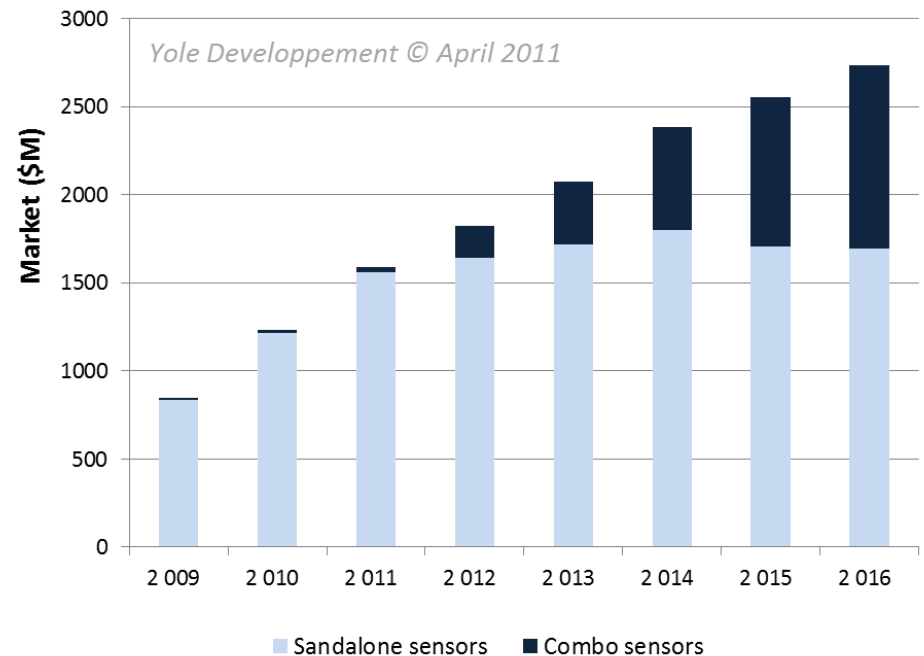
Emergence of combo sensors in consumer

- **Global consumer motion sensor market is still growing quickly**
 - 2011-2016 CAGR = 11,4% in value (18,6% in volume)
- **After few years of strong growth, the market for standalone motion sensors stabilizes**
- **Combo sensors are predicted to surge in the coming years**
 - Predicted to be \$1,04B in 2016 (1,15B units)

2009-2016 Consumer Inertial Sensor Market (M units)



2009-2016 Consumer Inertial Sensor Market (\$M)

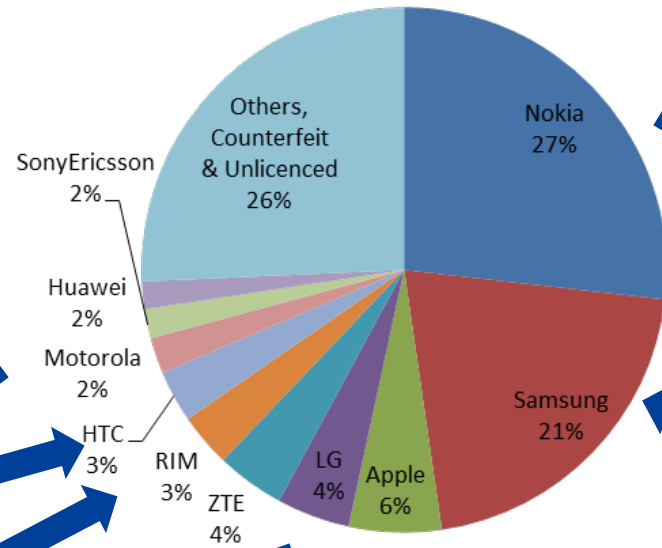


Key MEMS suppliers to cell phone makers (as of May 2012)

2011 Cell Phone Market Shares (in volume)

- Total = 1511M units -

Source Yole développement, IDC, Gartner © May 2012



For Motorola:

- Kionix, ST Micro (*MEMS acceleros*)
- InvenSense (*MEMS gyros*)
- AKM (*magnetos*) Knowles (*MEMS microphones*)
- TriQuint, Avago (*BAW filters*)

For Nokia:

- ST Micro, Analog Devices (*MEMS acceleros*)
- ST Micro (*MEMS gyros*)
- AKM, Aichi MI (*magnetos*)
- Knowles, ST Micro (*MEMS microphones*)

For HTC:

- InvenSense (*MEMS gyros*)
- Avago, TriQuint (*BAW filters*)

For Samsung:

- ST Micro, Bosch Sensortec, Kionix (*MEMS acceleros*)
- ST Micro, InvenSense (*MEMS gyros*)
- AKM (*magnetos*)
- Knowles (*MEMS microphones*)
- TriQuint, Avago (*BAW filters*)
- Wispry (*RF-MEMS antenna tuner*)
- TI (*micromirrors*)

For RIM:

- Bosch Sensortec, Freescale (*MEMS acceleros*)
- InvenSense (*MEMS gyros*)
- TriQuint (*BAW filters*)

For ZTE:

- Kionix, Freescale (*MEMS acceleros*)
- InvenSense (*MEMS gyros*)
- TriQuint, Avago (*BAW filters*)

For LG:

- Bosch Sensortec, Kionix, Freescale (*MEMS acceleros*)
- InvenSense (*MEMS gyros*)
- Knowles (*MEMS microphones*)
- TriQuint (*BAW filters*)

For Apple:

- ST Micro (*MEMS acceleros*)
- ST Micro (*MEMS gyros*)
- AKM (*magnetos*)
- Knowles, AAC Acoustics (*MEMS microphones*)
- TriQuint, Avago (*BAW filters*)

Key MEMS suppliers to tablet makers (as of May 2012)

For RIM:

- Bosch Sensortec, Freescale (MEMS acceleros)
- InvenSense (MEMS gyros)

For Acer:

- Kionix (MEMS acceleros)
- InvenSense (MEMS gyros)

For Motorola:

- Kionix, ST Micro (MEMS acceleros)
- InvenSense (MEMS gyros)

For LG:

- Kionix, ST Micro (MEMS acceleros)
- InvenSense (MEMS gyros)
- AKM (magnetos)
- Knowles (MEMS microphones)
- TriQuint, Avago (BAW filters)

For HP:

- Freescale (MEMS acceleros)
- ST Micro (Combo Accel Magneto)

For Asus:

- Kionix (MEMS acceleros)
- InvenSense (MEMS gyros)

For Barnes & Noble:

- Kionix (MEMS acceleros)

For Amazon:

- Freescale (MEMS acceleros)
- InvenSense (MEMS gyros)

For Samsung:

- ST Micro, Kionix (MEMS acceleros)
- ST Micro, InvenSense (MEMS gyros)
- AKM (magnetos)
- Knowles (MEMS microphones)

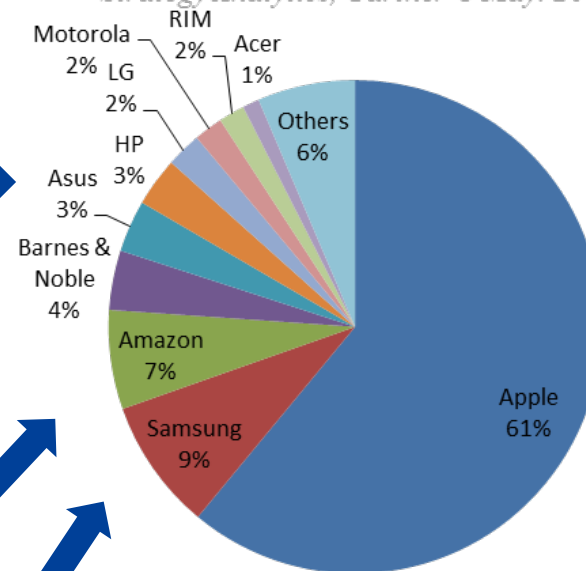
For Apple:

- ST Micro (MEMS acceleros)
- ST Micro (MEMS gyros)
- AKM (magnetos)
- Analog Devices, AAC Acoustics (MEMS microphones)

2011 Tablet Market Shares (in volume)

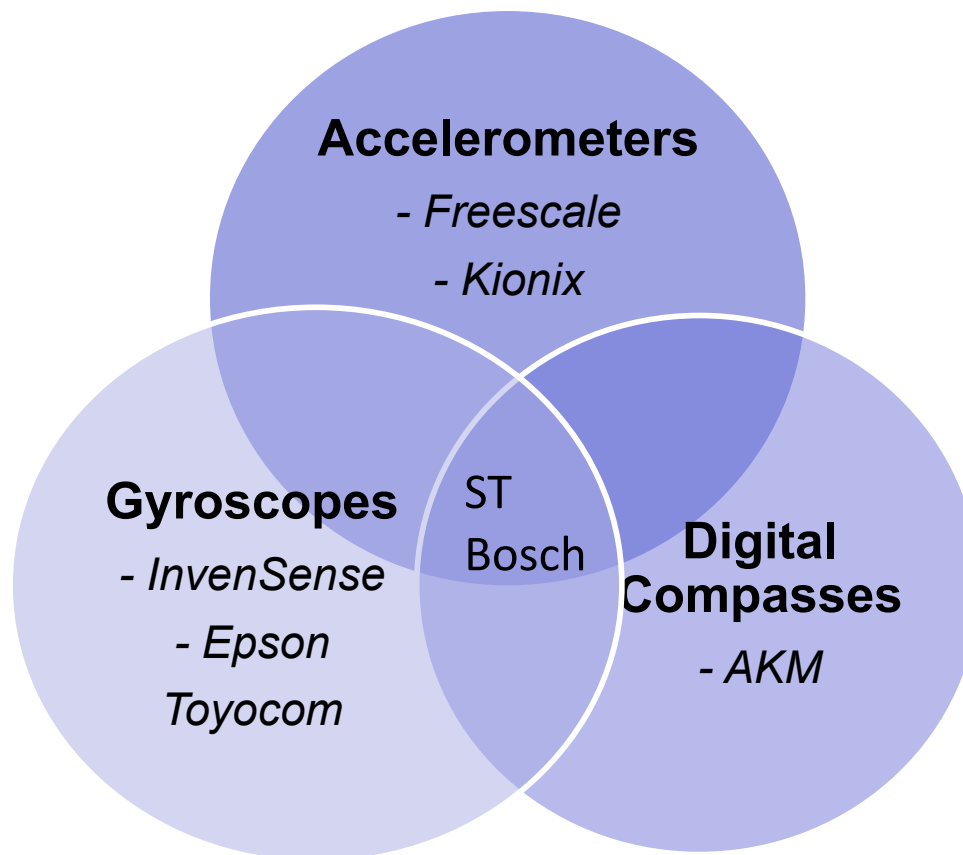
- Total = 66.4M units -

Source Yole développement, Canaccord Genuity, Strategy Analytics, Gartner © May. 2012



Motion Sensing Companies

- Although the number of competitors is high, only a few companies today really dominate the market:

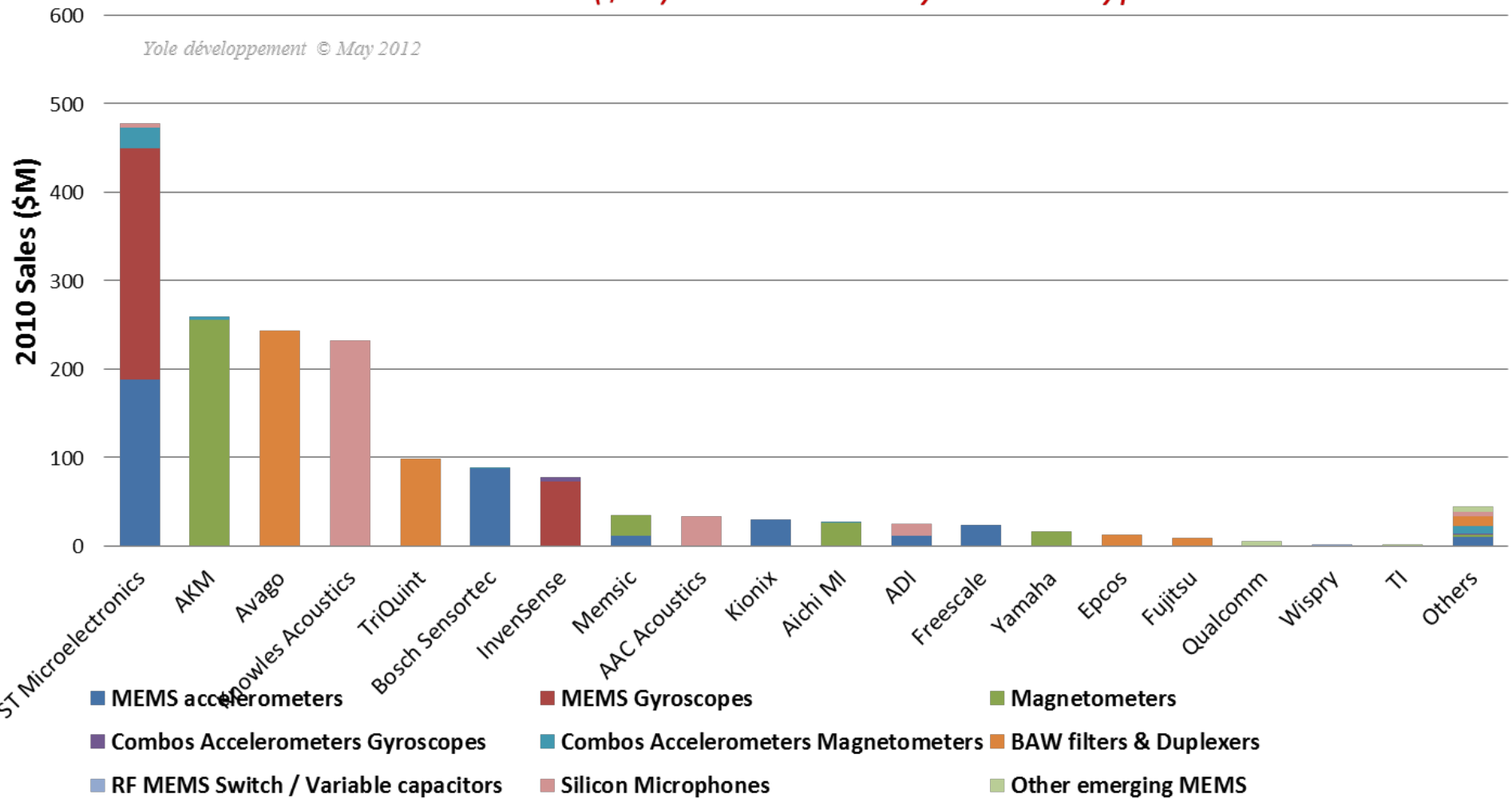


Sucessful companies are large leader in distinct MEMS categories

Top 4 players have >50% market shares on 5 different MEMS markets

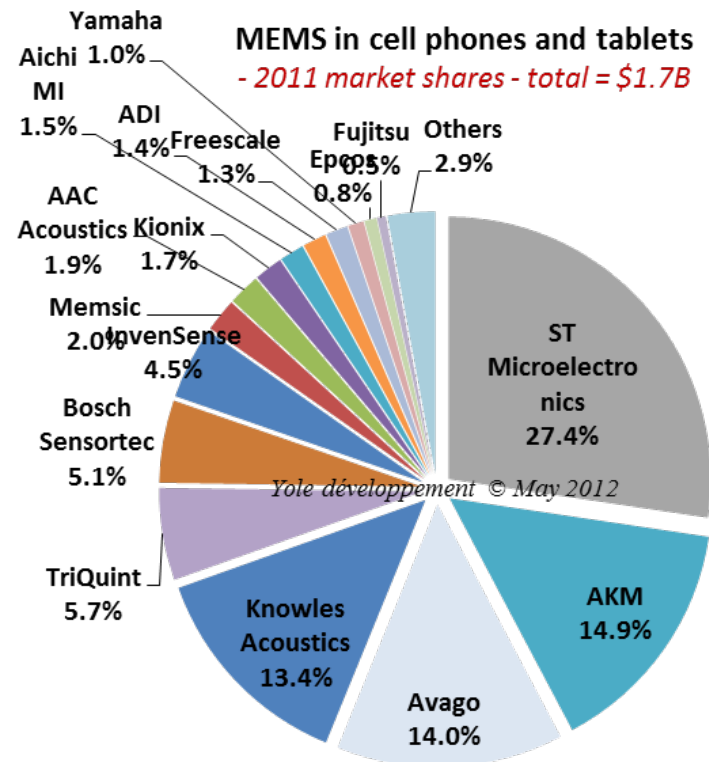
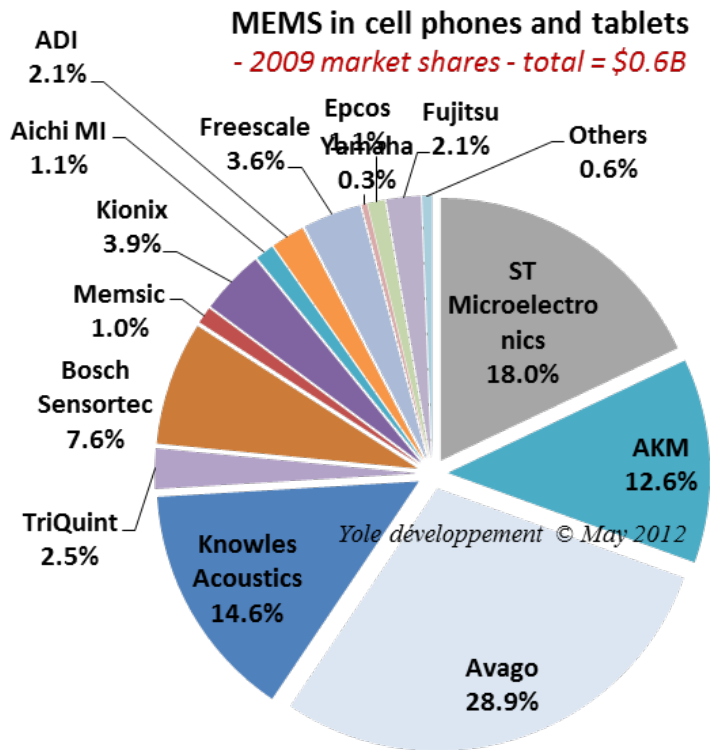
Top MEMS Suppliers in the Mobile Phone and Tablet Market

- 2011 Revenue (\$M) - Breakdown by Product Type -



2009-2011 market shares evolutions

ST is growing, Avago decrease InvenSense appears

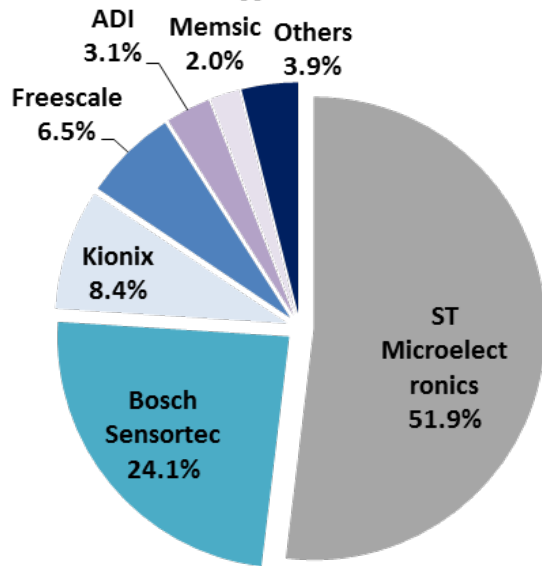


2011 market shares for discrete inertial sensors

3-axis accelerometer in mobile phones and tablets - 2011 market share

- Total = \$362.7M -

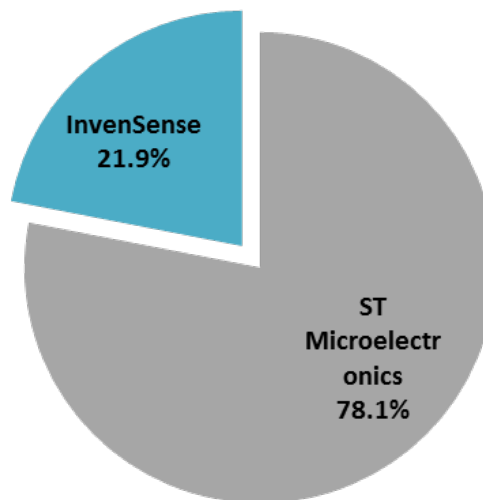
- Note: accelerometers in combos not counted -
Yole développement © March 2012



3-axis gyroscope in mobile phones and tablets - 2011 market share

- Total = \$334.6M -

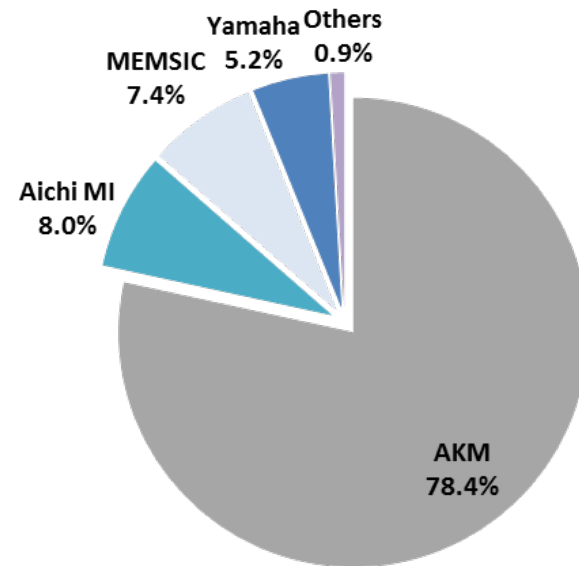
- Note: gyroscopes in combos not counted -
Yole développement © March 2012



3-axis magnetometer in mobile phones and tablets - 2011 market share

- Total = \$325.7M -

- Note: magnetometers in combos not counted -
Yole développement © March 2012



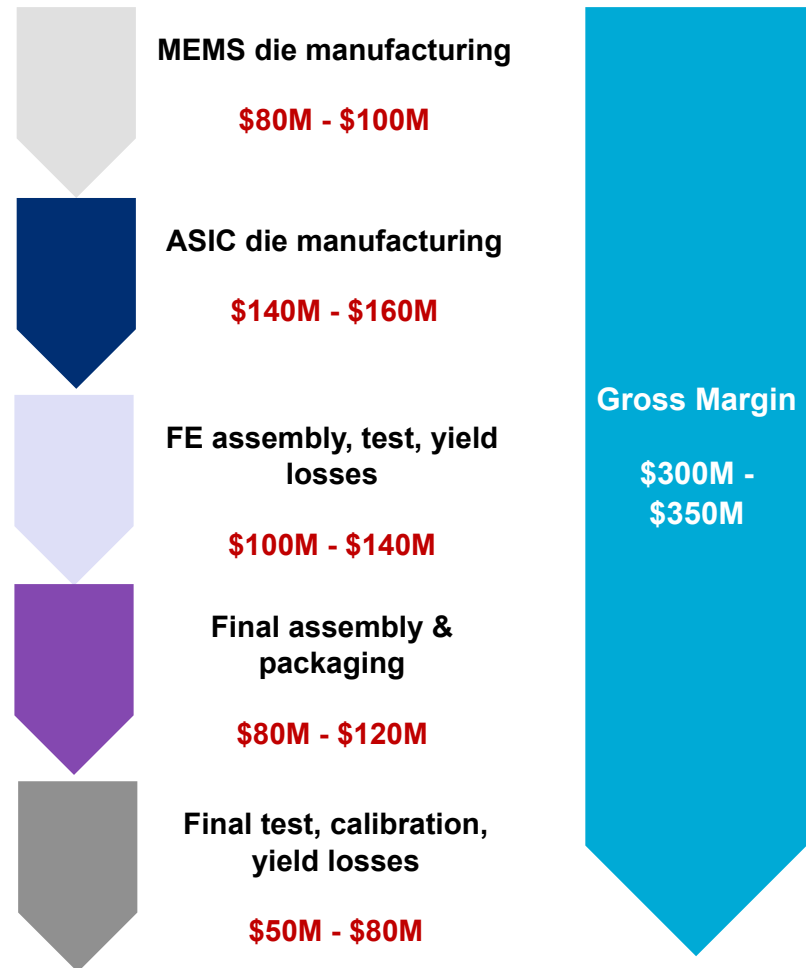
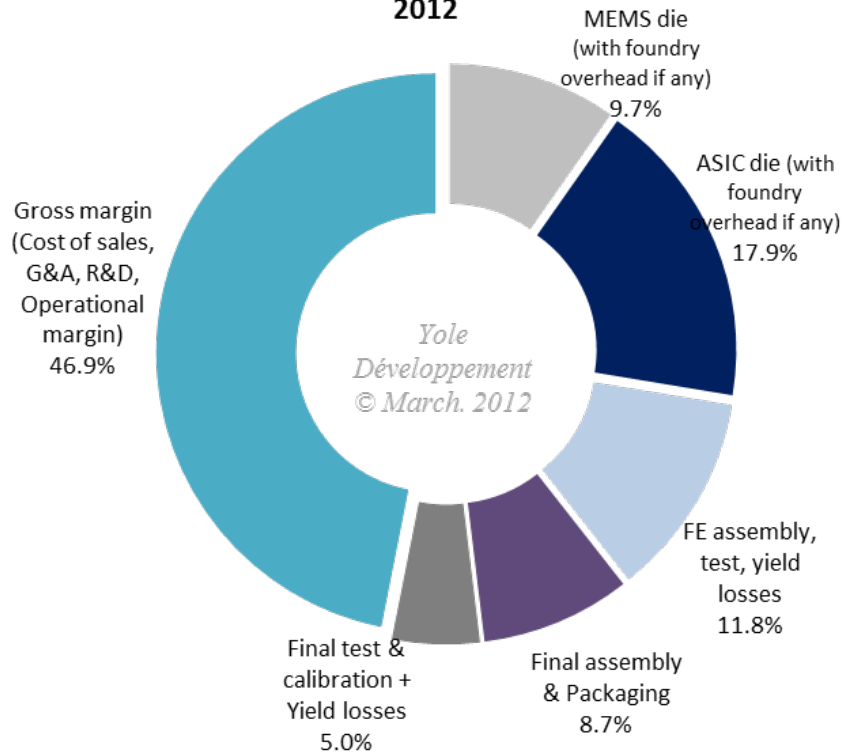
Accelero/Gyros 6DOF + 9/10DOF for mobile phones & tablets

Value chain estimation in 2015

2012 market: \$130M, 63 Munits

2015 market: \$824M, 726Munits

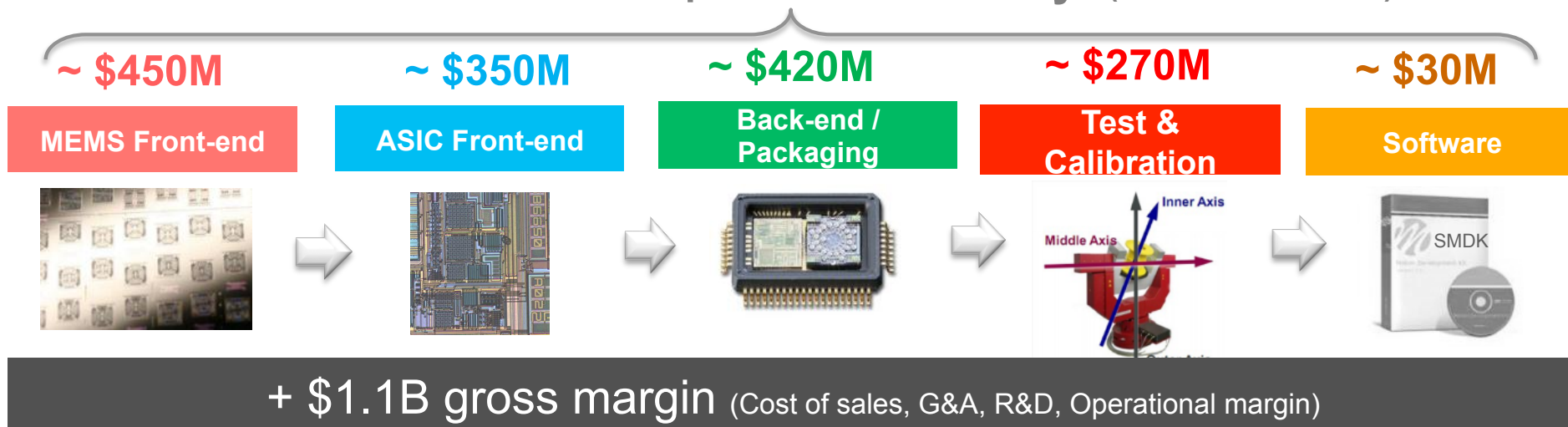
Typical Accel + Gyro Combo Cost Structure in 2011-2012



+ **Software sale** (typically 50 cents per component, for part of the market)
\$100M - \$140M

Inertial sensors value chain in 2011

~ \$2.6B industry! (consumer + auto)



- **In 2011, the inertial sensor industry is now a \$2.6 Billion business!**
 - ~ \$450M is related to the MEMS Front-end. This area is stable because the MEMS die cost is being strongly reduced
 - ~ \$350M is related to the ASIC Front-end. This is growing because although the technology nodes are more and more advanced, the need for larger processing capabilities (sometimes with MCUs) increase with combo sensors
 - ~ \$420M is related to the Back-end / Packaging. This area will grow a lot thanks to increasing expertise needed for combo sensors
 - ~ \$270M is linked to Test & Calibration. It is strongly growing, driven by 3-axis gyroscopes and combo sensors
 - ~ \$30M is linked to Software features. It is small today but definitively poised for important growth in the future, especially for combo sensors (for sensor fusion...)

A lot is happening...

Discussion...

- **Feel free to give your business card in order to get the electronic copy of this up-dated presentation;**
- **Please visit our booth in order to discuss our analysis**