Optical Solutions for Light Intensity Enhancement in Large Pixel Size SPAD Sensor

VisEra / Ken Wu

Outline

- VisEra introduction
- Planar Lens process
- Giant Micro lens process
- VisEra for SPAD development in future

VisEra Technologies

Location: Hsinchu Science Park in Taiwan

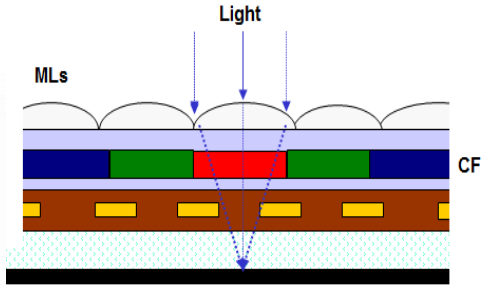
- Total Land Area 18,000 m^2
- Total Floor Area 65,700 m^2
- Total Clean Room Floor Area 13,500 m^2
  (including available space)

VisEra at a Glance

PROFESSIONAL FOUNDRY AND MANUFACTURING SERVICE

4 Major Service

- On-chip color filter and microlens
- Mask design and simulation
- Image sensor testing & WLQE /AR for engineering
- On-chip multi-film



10 Certification

- IECQ QC080000
- ISO/IEC 27001
- EICC VAP
- ISO 14064-1
- ISO 50001
- TS16949
- ISO 9001
- ISO 14001
- OHSAS 18001
- ISO/IEC 17025

2003

2004
3um CF

2005
Acquired CF equip. from TSMC.
Shipped over 100M Sensors.

2006
1.75 um CF

2007
12” CF/ML
Move to new Fab/HQ

2009
8” BSI CF MP Tech.

2012
12” CF/EBML& CVD Clear Pixel Sensor

2014
1 um CF

2015
Phase II Area Ready

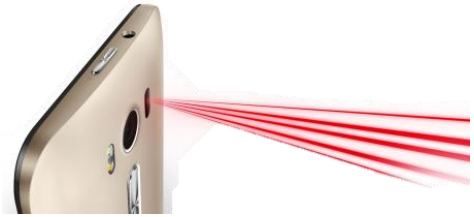
2016
On-Chip Multi-Film Develop

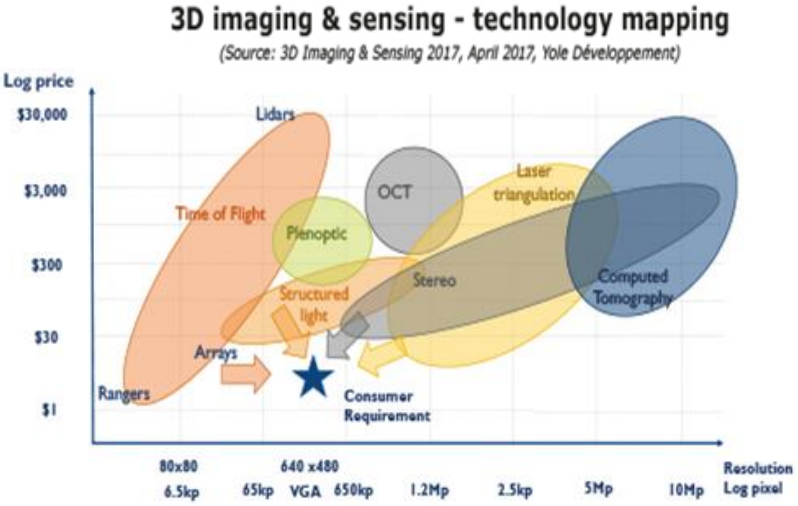
2017
On-Chip Multi-Film Mass Production

MILESTONE

ToF Sensor Application

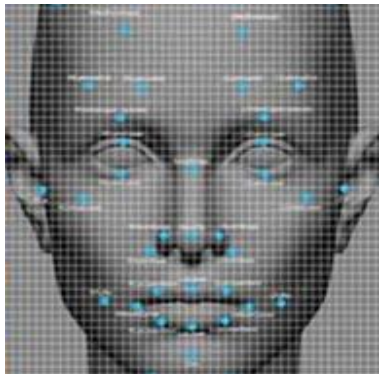
- **Rangers**
  - Laser focus, proximity sensor for mobile

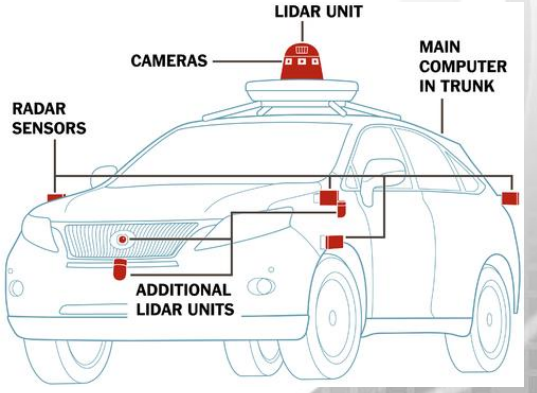




  - Human-machine interfaces and gaming

- **Lidar: Automotive application**
  - Pedestrian safety, pre-crash detection
  - Cabin driver monitoring & gesture
- **Arrays: Facial recognition**

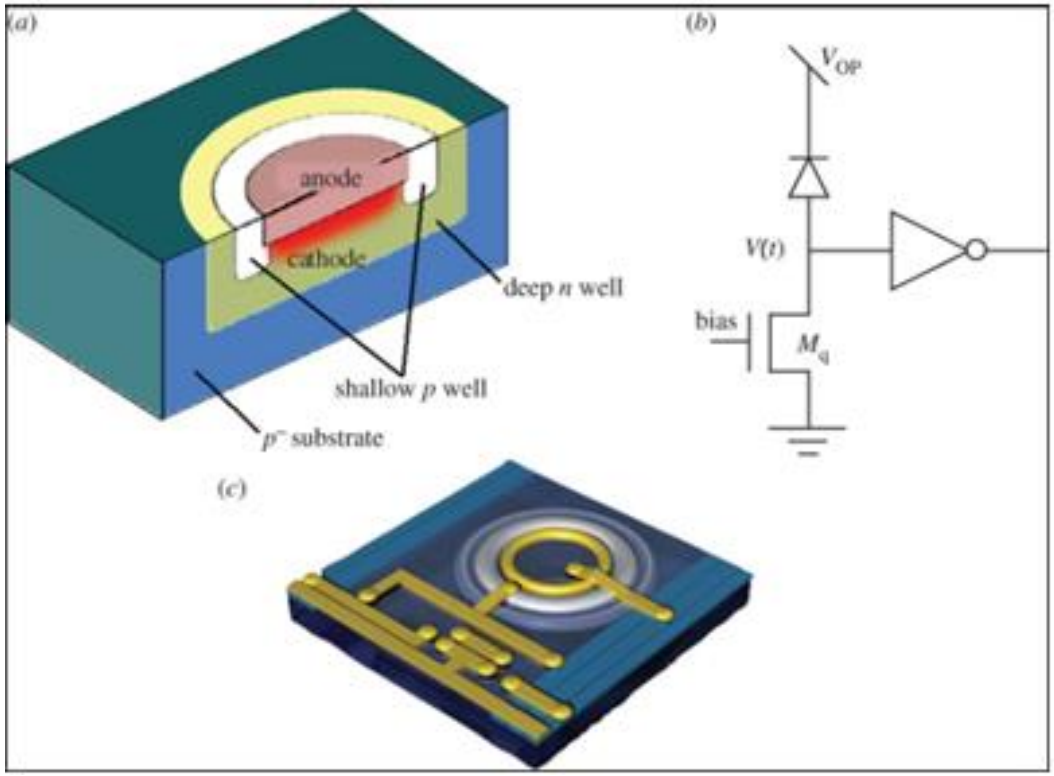


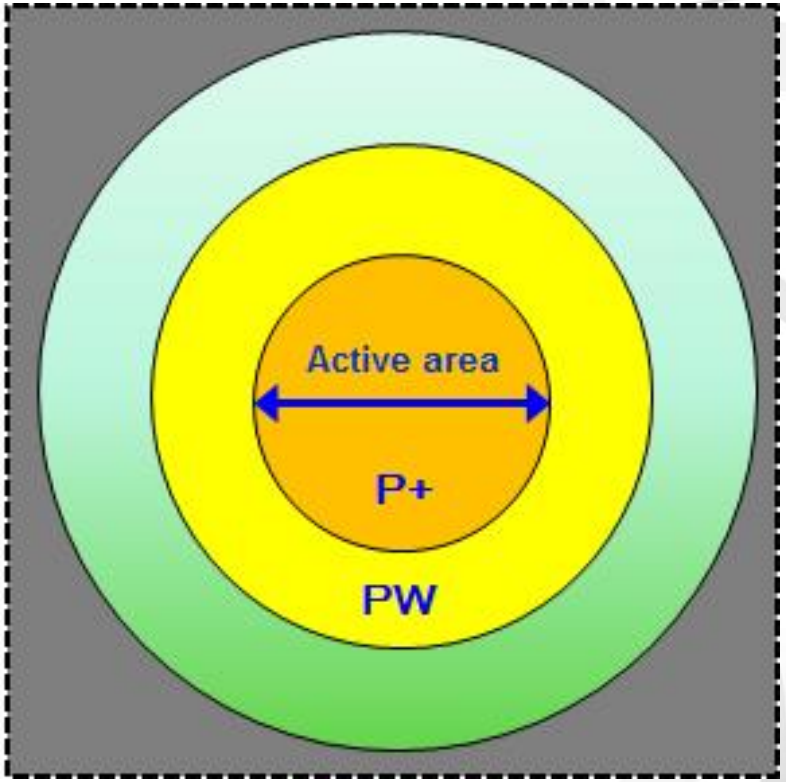


  - Machine vision

Limited Active Area of SPAD Sensor

- Electronic Layout

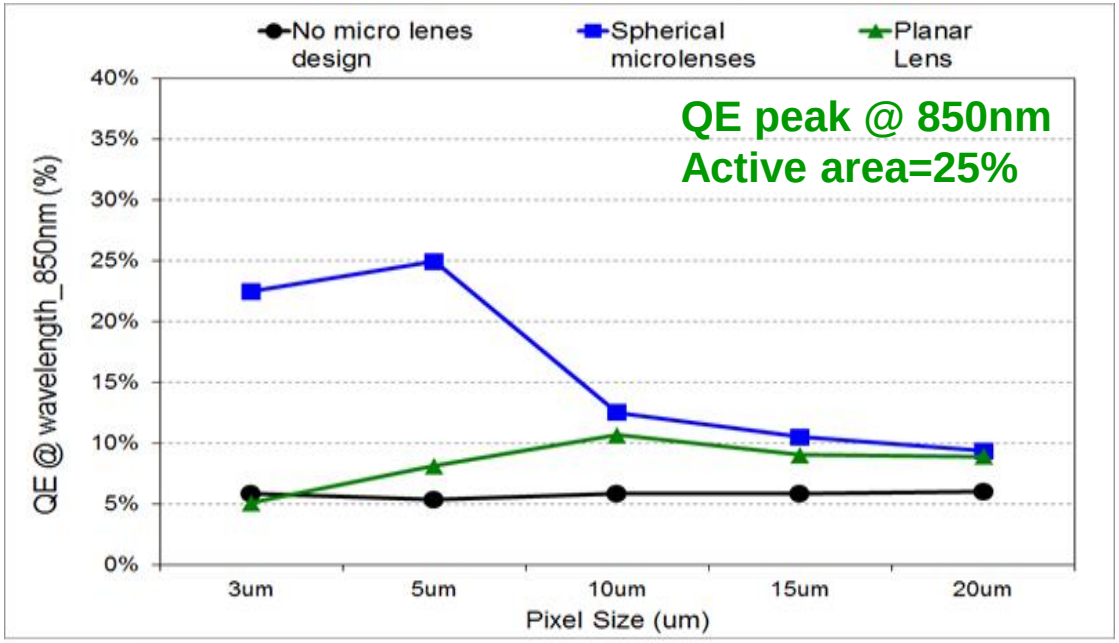




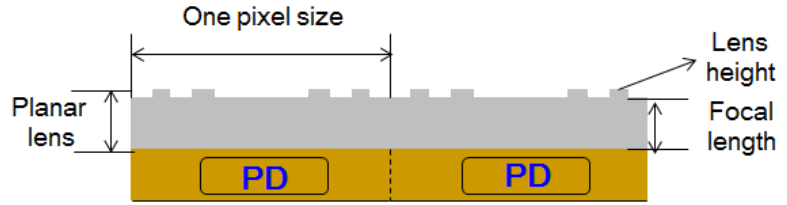
~30% for Active area

Should need Micro-optics component for SPAD enhancement !!!

Preliminary Optical Simulation for NIR Collection

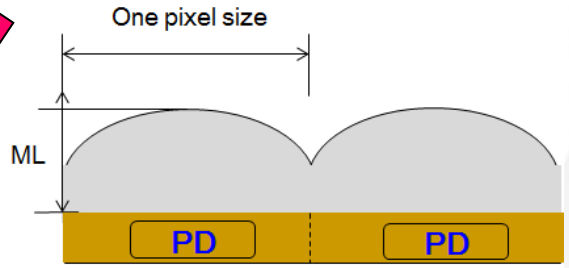


(1) Planar Lens with Binary



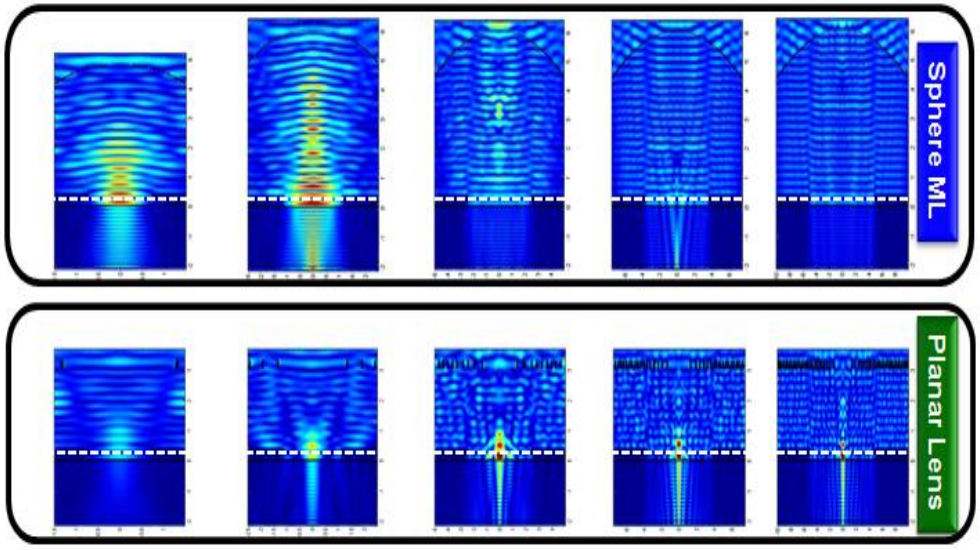
Focal length : 3.0um
Lens height : 0.3um

(2) Spherical ML



MLH: 3.0um
UL: 3.0um

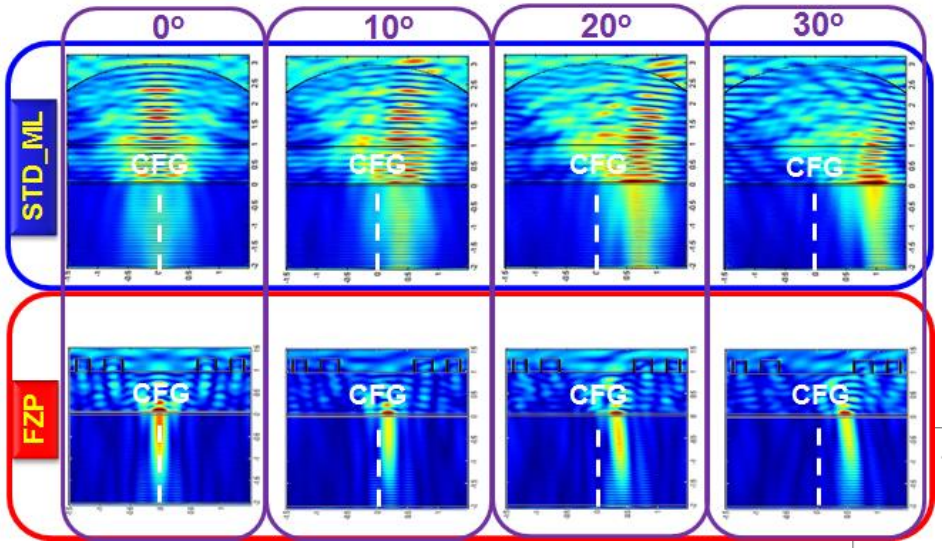
Electric field



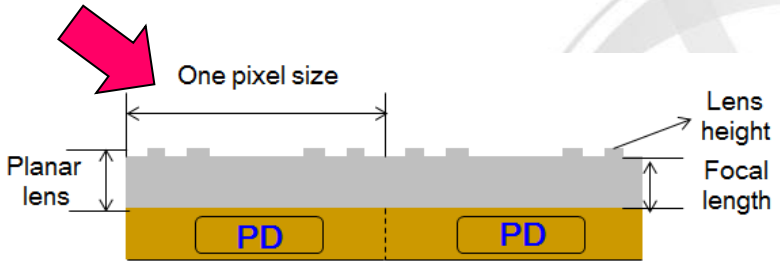
We are interested in Planar lens owing to its thinner structure height

Electrical Fields vs Incident Angle

- Planar lens got better angular response compared with STD-ML form analysis electrical fields.

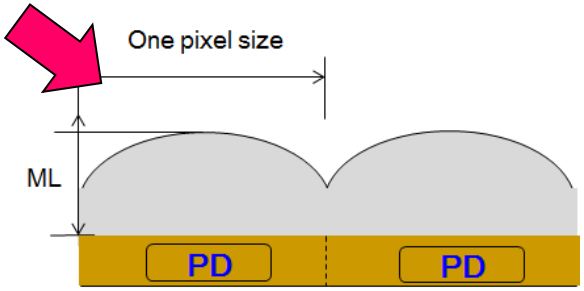


Incident light

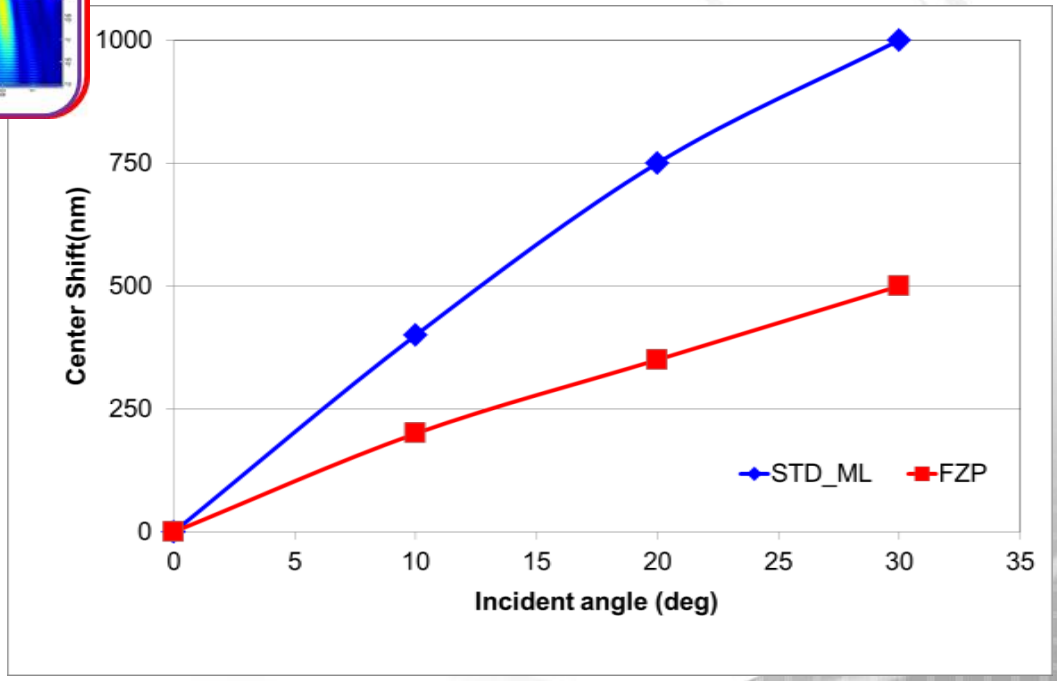


Focal length : 3.0um
Lens height : 0.3um

Incident light

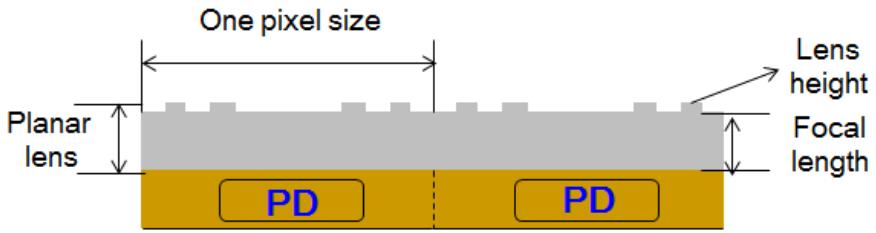


MLH: 3.0um
UL: 3.0um



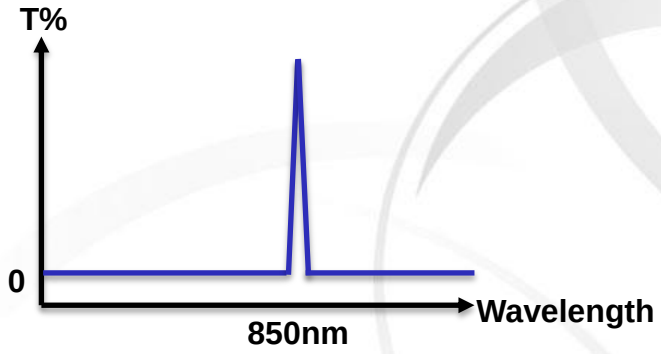
Planar Lens with Muti-film

Planar Lens scheme



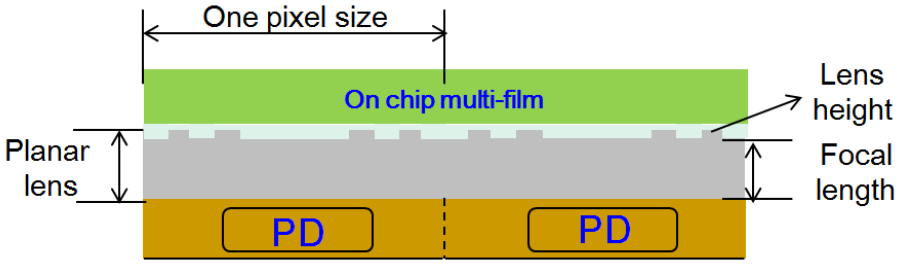
+

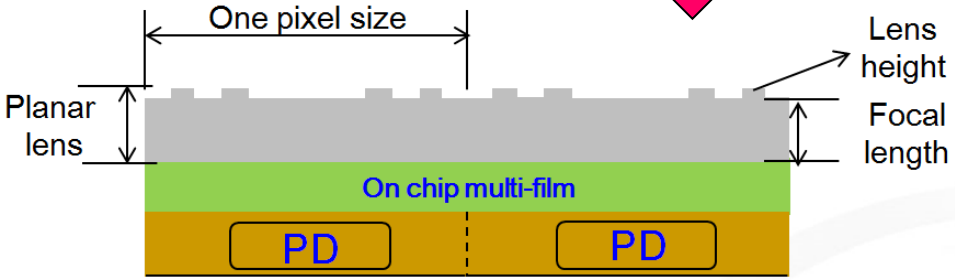
Multi-film



(1)

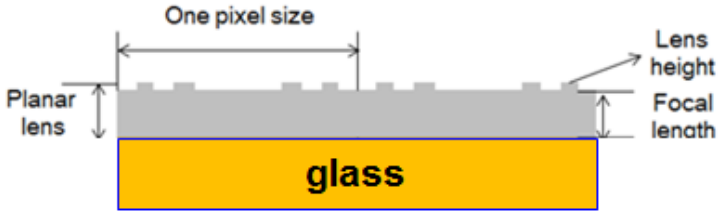
(2)



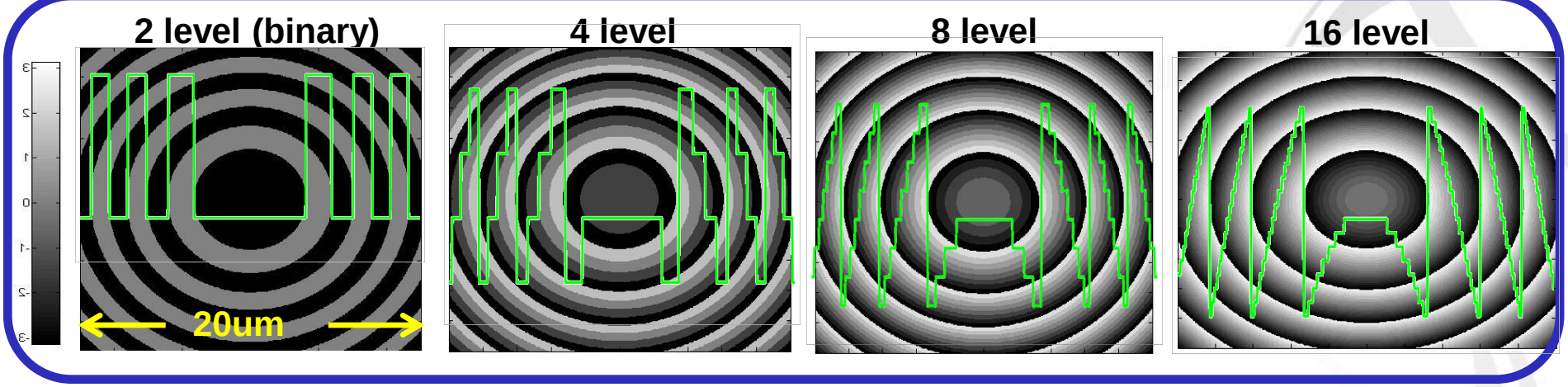


FZP (Shorter optical path) & Multi-film upon Si Wafer might be be good for angle shifting !!!

Efficiency Comparison vs. Phase Level

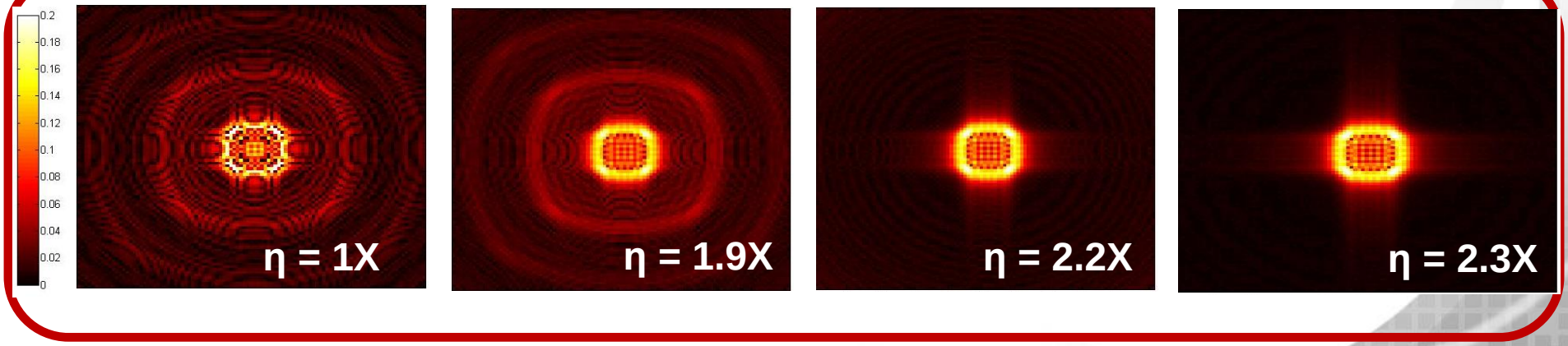


Spatial Domain



Fourier Domain

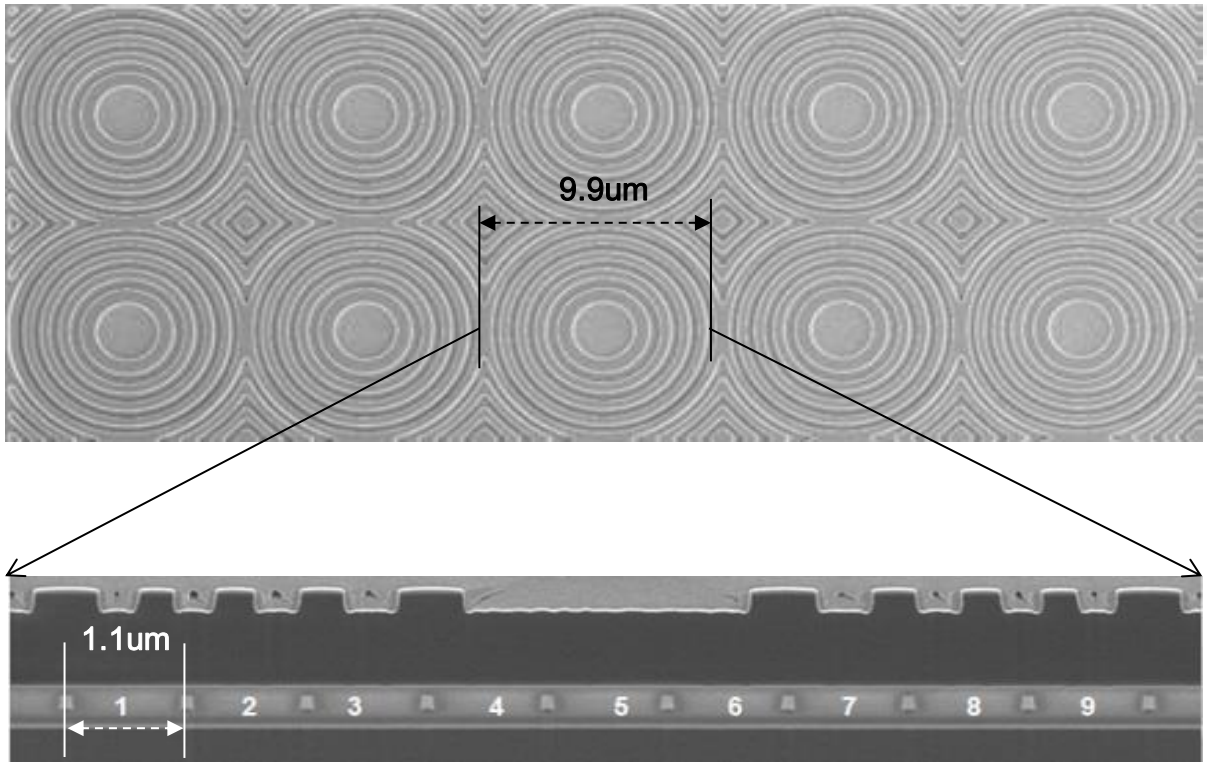
w/o Si response, 850nm, active area is 25%



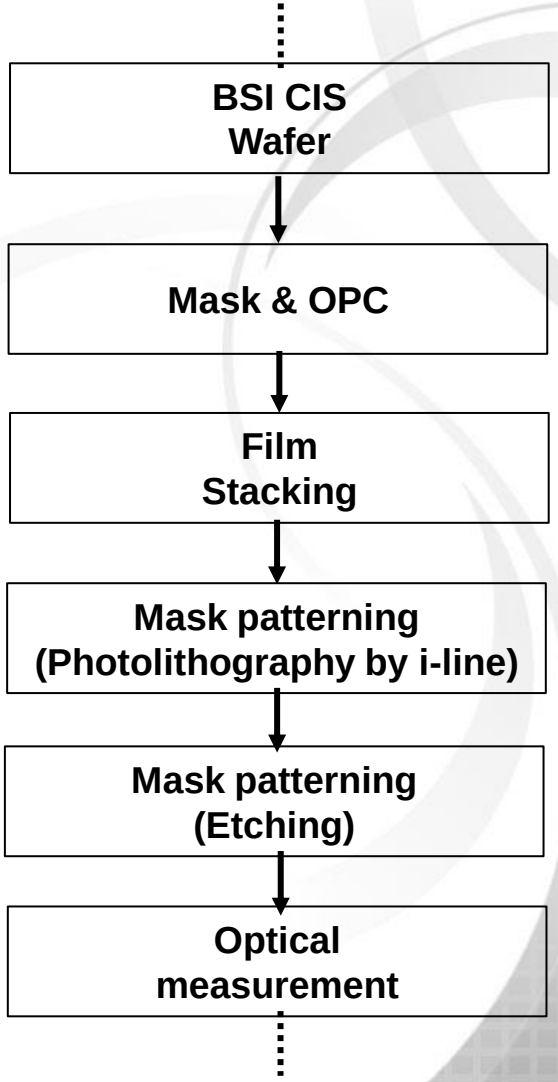
Process for Planar Lens

- Test Vehicle
  - BSI wafer with 1.1um pixel size
  - Emulate SPAD's pixel size=9.9um

Top view and cross-section



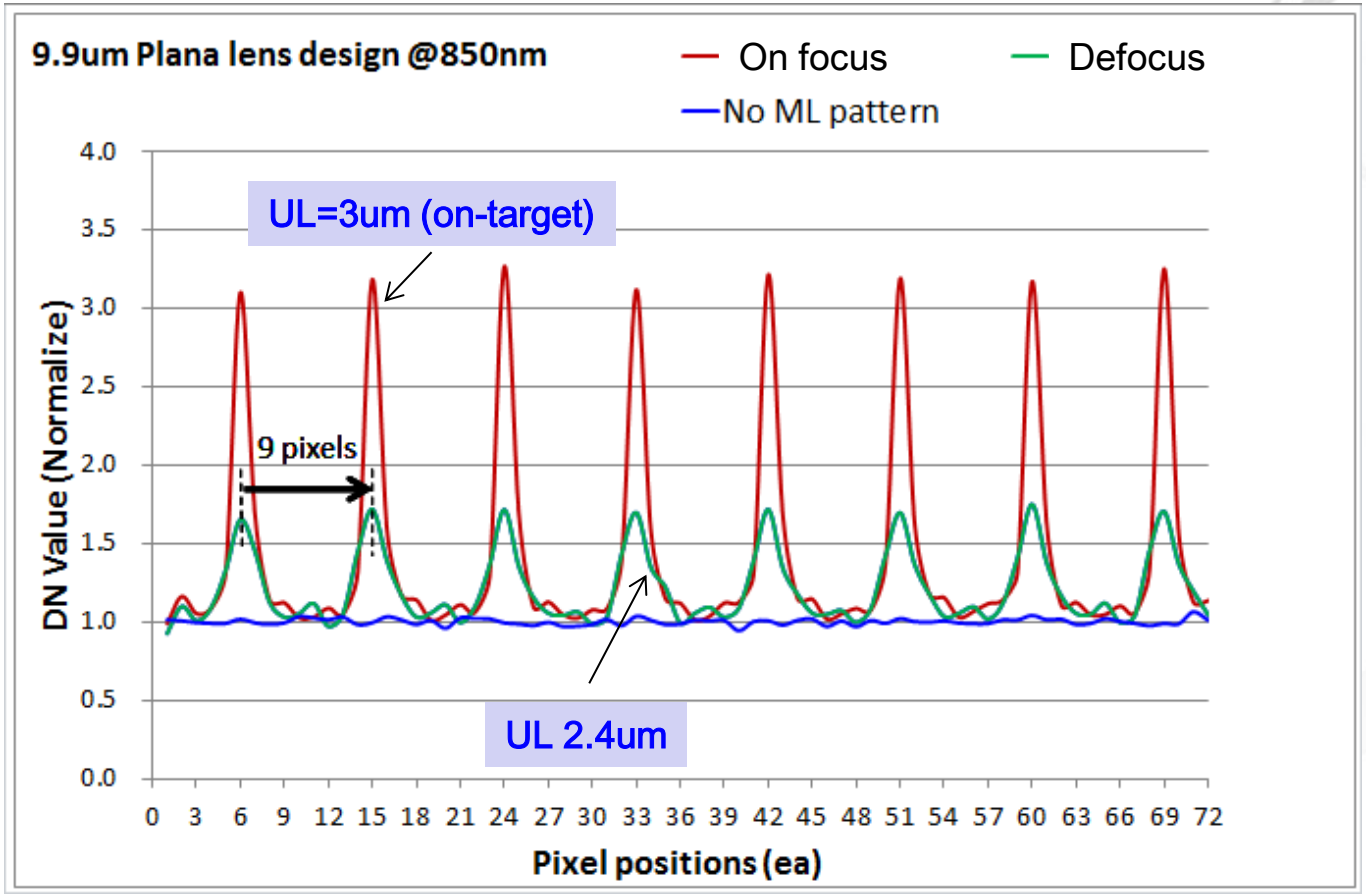
Min. design rule: ~0.3um



QE Result of Planar Lens

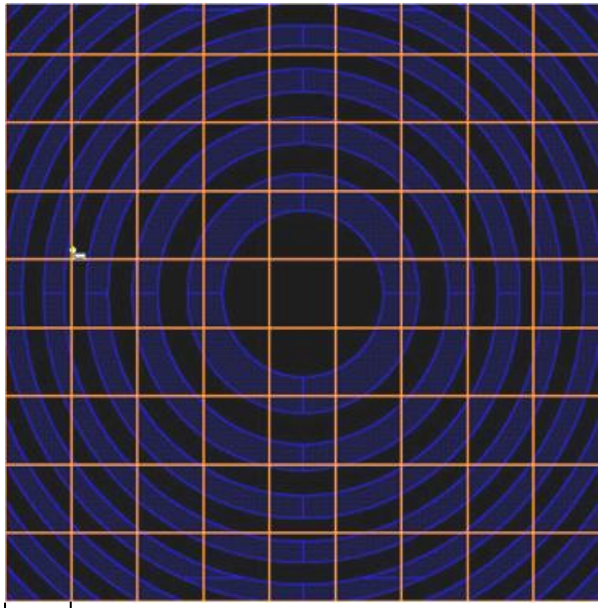
- 3.1~3.3 times DN (Digital number) was observed via on-target structure
- Sensitive for focus length

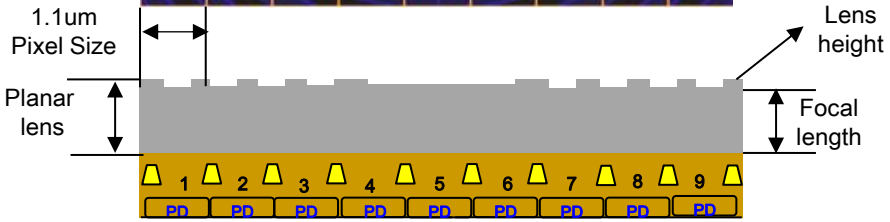
DN values (Before / After THK Adjustment ; Design @ 850nm)



New Test Vehicles for SPAD

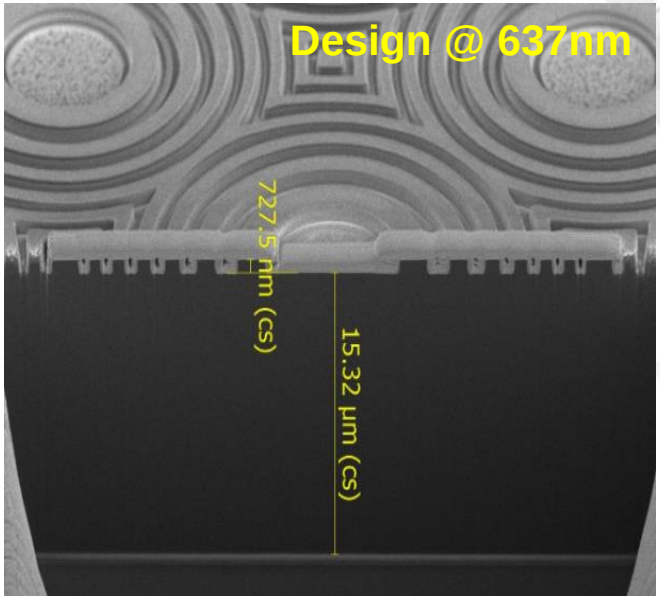
1.1um pixel size

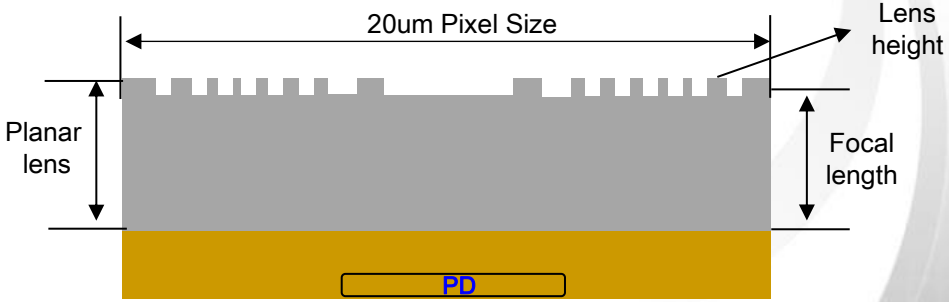




Planar lens: 0.5um
Focal length: 3.0um
Mini. Design rules: ~0.3um

20um pixel size

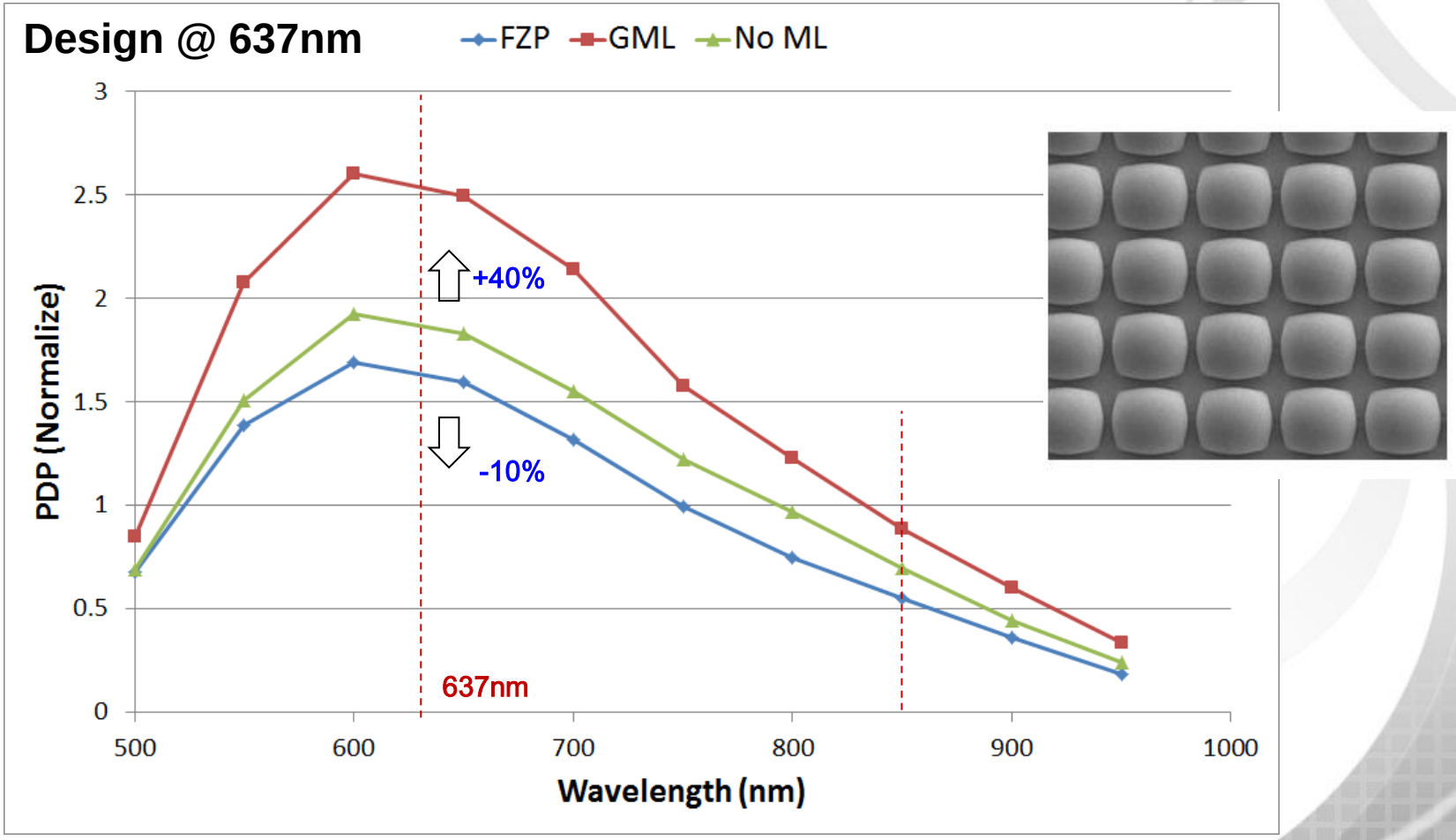




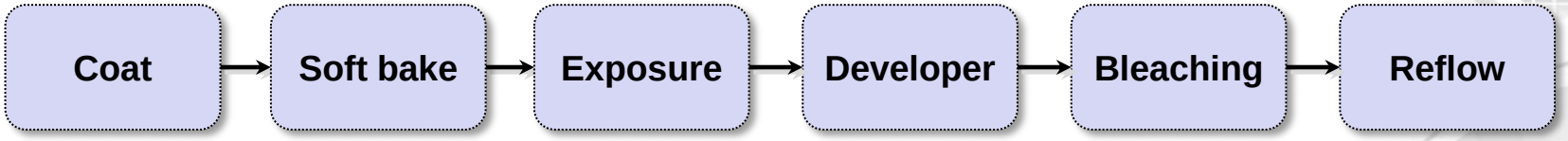
Planar lens: 0.7um
Focal length: 15um
Mini. Design rules: ~0.3um

Test Result by SPAD Test Vehicle

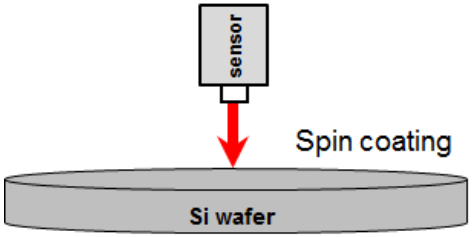
- Planar lens's testing result is out of expectation completely, we will revisit optical simulation and FZP design for large size pixel
- GML (Giant micro lens) get the 1.4 times improvement (MLH=10um)



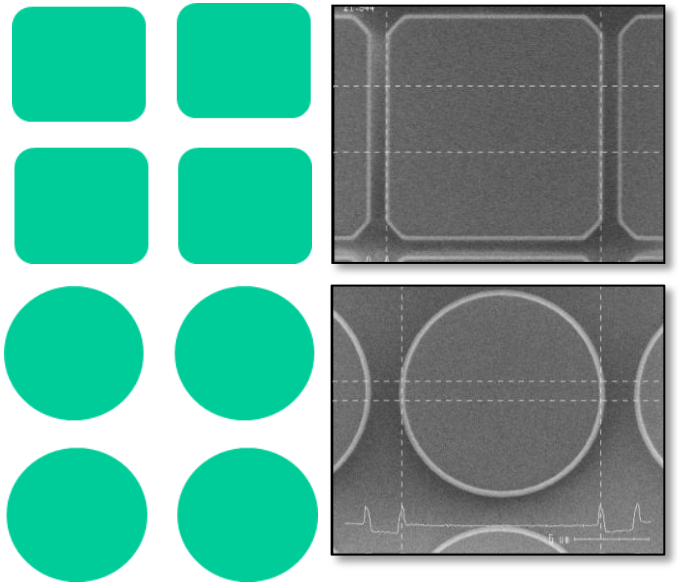
Process Flow for GML



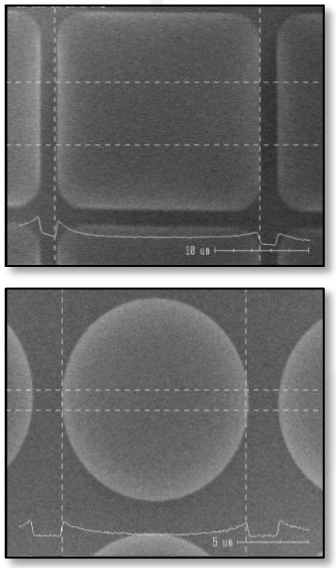
Coating



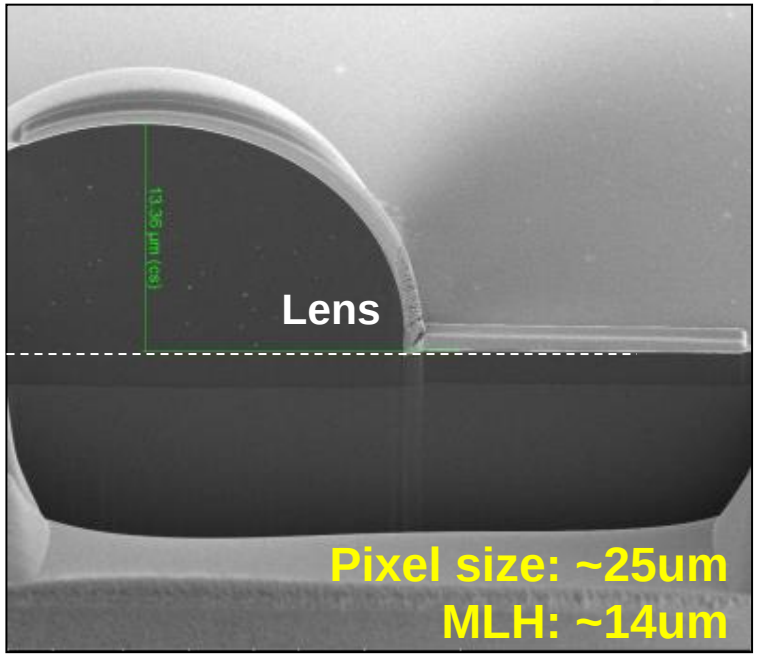
EXP / DEV

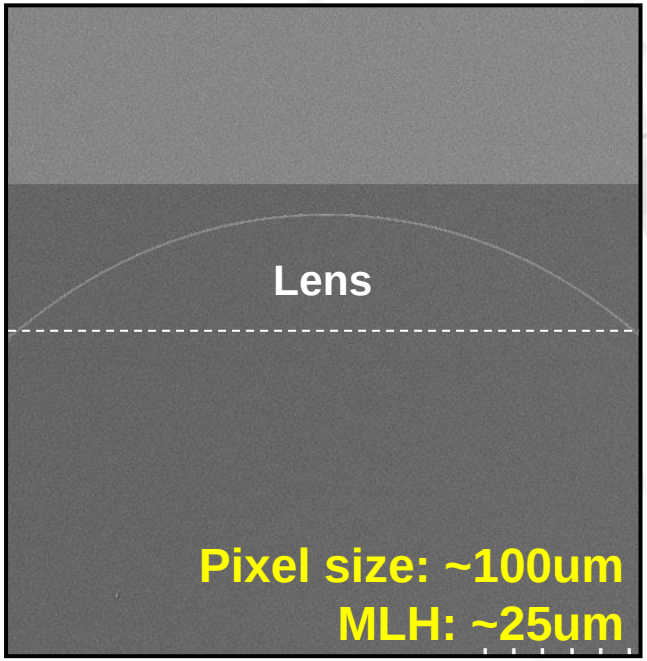


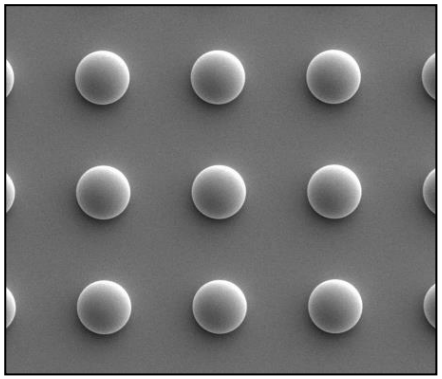
Reflow

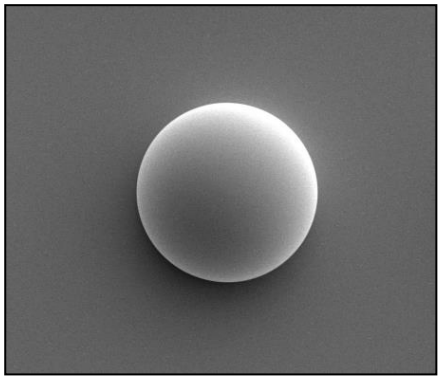


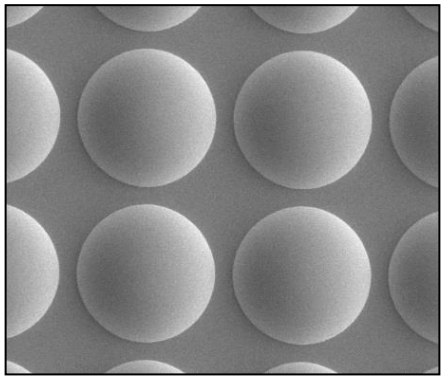
Cross-section for Achievable GML

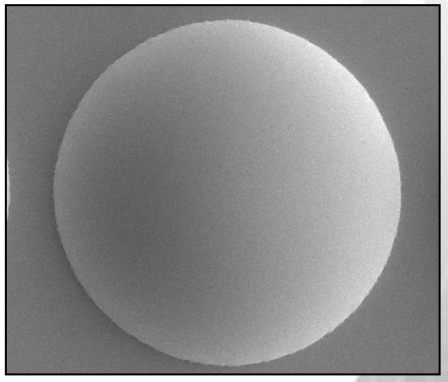




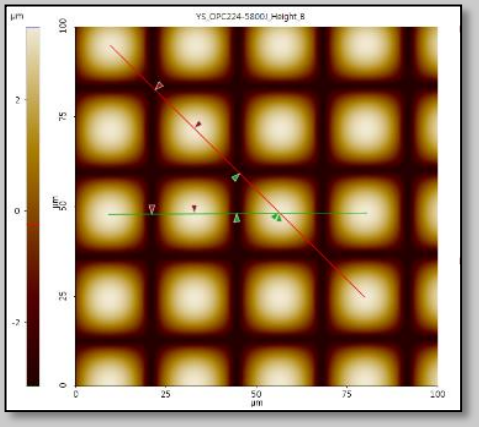
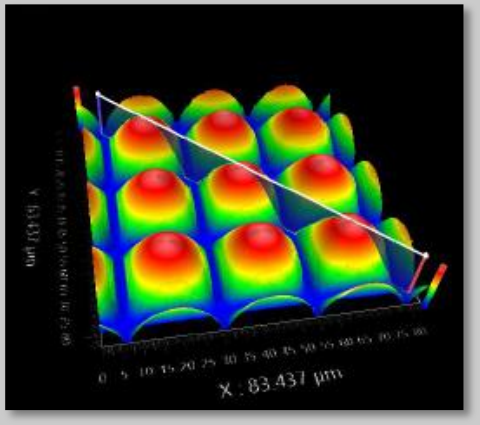






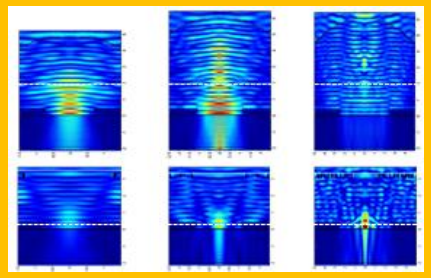


Metrology for GML

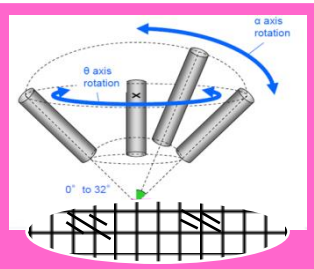
Type	AFM	White light interferometer	
Objective Magnification	---	50X	100X
Available Z distance	0~30um	No limit	No limit
Available X-Y distance	~100 x 100um	170x170um	85 x 85um
Slop limit (deg)	<90	<28	<42
Profile			
Constrain	1. Low WPH and high cost 2. Z distance limitation ≤ 30um 3. High accuracy measurement 4. Suitable for Eng. Study	1. High WPH and low cost 2. Limited Micro-lens slope angle 3. Suitable for in-line monitor	

VisEra For SPAD

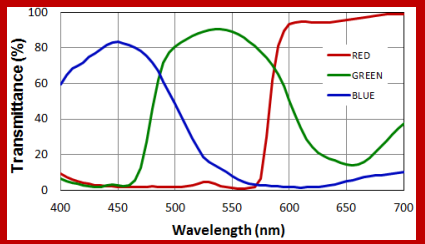
Optical



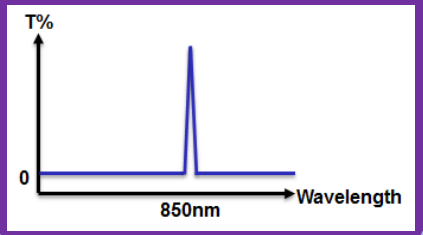
Wafer Level Characterization

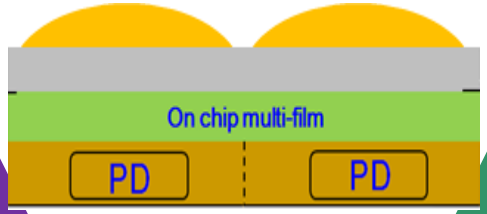


Material

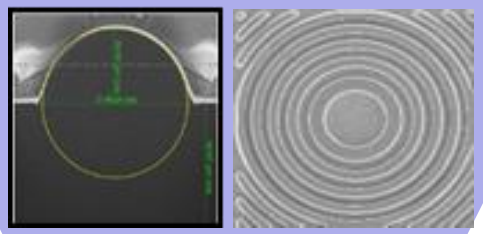


Multi-Film (IRC/NBP/AR)





Micro-optics



Process

(ASML)

(TEL)

Thanks for your attention !!!