

Charge Domain Type 2.2 μ m BSI Global Shutter Pixel with Dual Depth DTI Produced by Thick-film Epitaxial Process

***¹Toshifumi Yokoyama**

¹Yoshihiro Noguchi , ¹Masafumi Tsutsui , ¹Yoshiaki Nishi , ¹Masahiko Takeuchi ,
¹Masahiro Oda & ²Fenigstein Amos

1 Tower Partners Semiconductor Co,. Ltd.

2 Tower Semiconductor.



Background

Global Shutter (GS)

Image without distortion

Suitable for

**Machine vision,
Pro camera**

- Small pixel → High resolution, Small chip size
- BSI → High QE, High speed
- Charge Domain → Low Noise

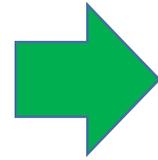
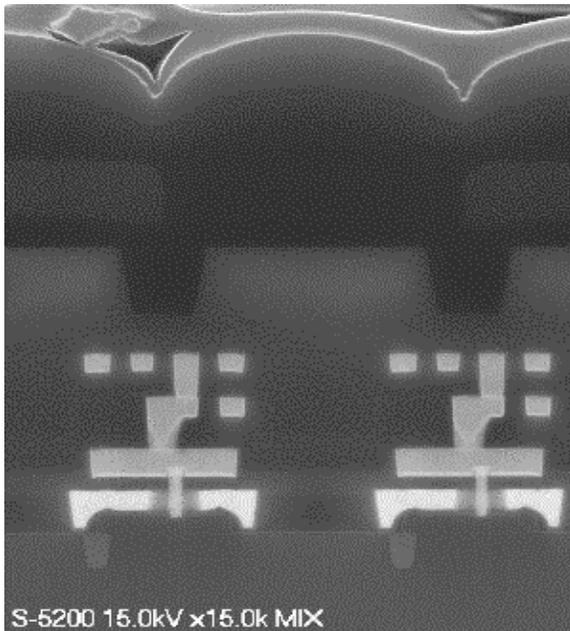


2.2 μ m BSI GS

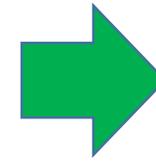
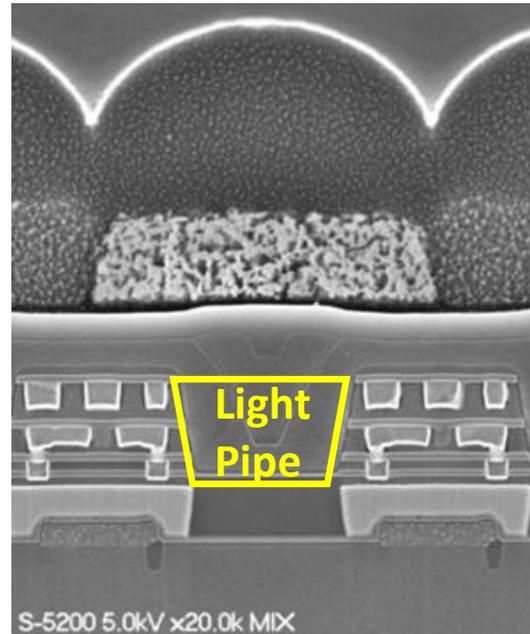
Challenge for Smaller GS Pixel

We possess extensive knowledge and experience in realizing 2.2 μm GS pixels.

2.8 μm FSI GS
(IISW2017)
Optical shield
on Memory



2.5 μm FSI GS
(IEDM2018,
IISW2019)
Light Pipe

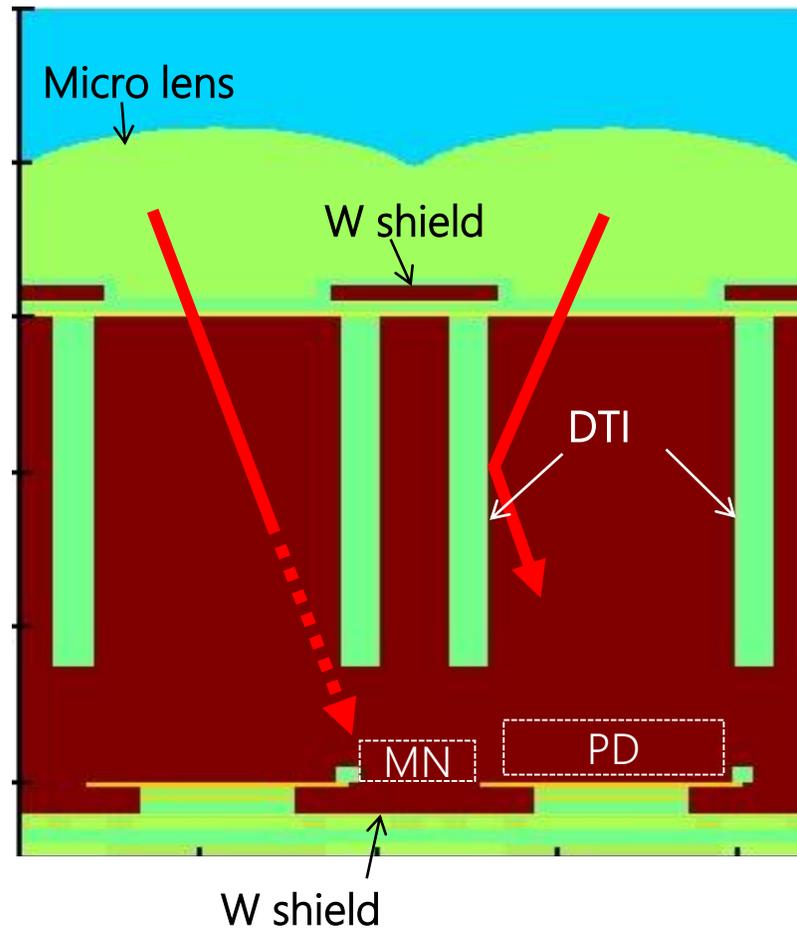


2.2 μm BSI GS
(IISW2025)

New challenge
to reduce
Parasitic Light
Sensitivity
(PLS)

Design Concept

Protect Memory Node(MN) from incident light → Deeper DTI
Reduce incident light reach to MN → Deeper photo diode

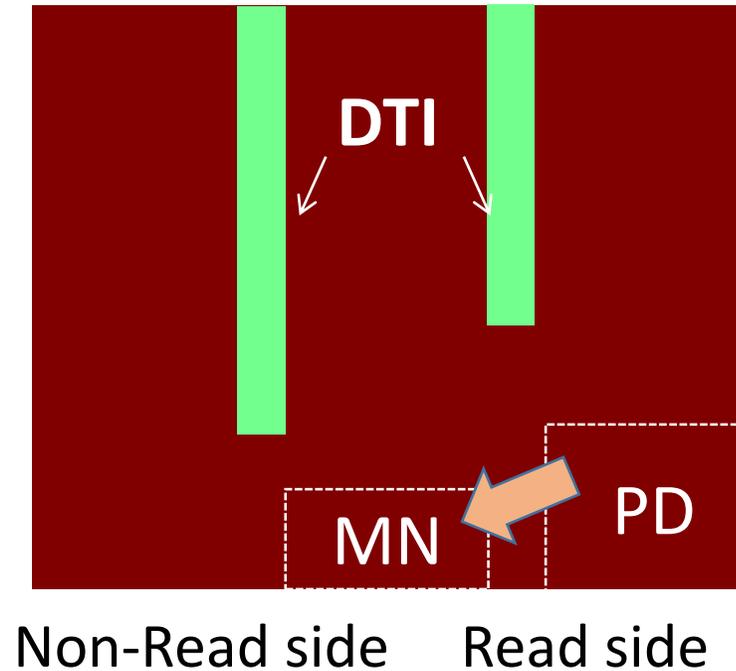


Dual Depth DTI

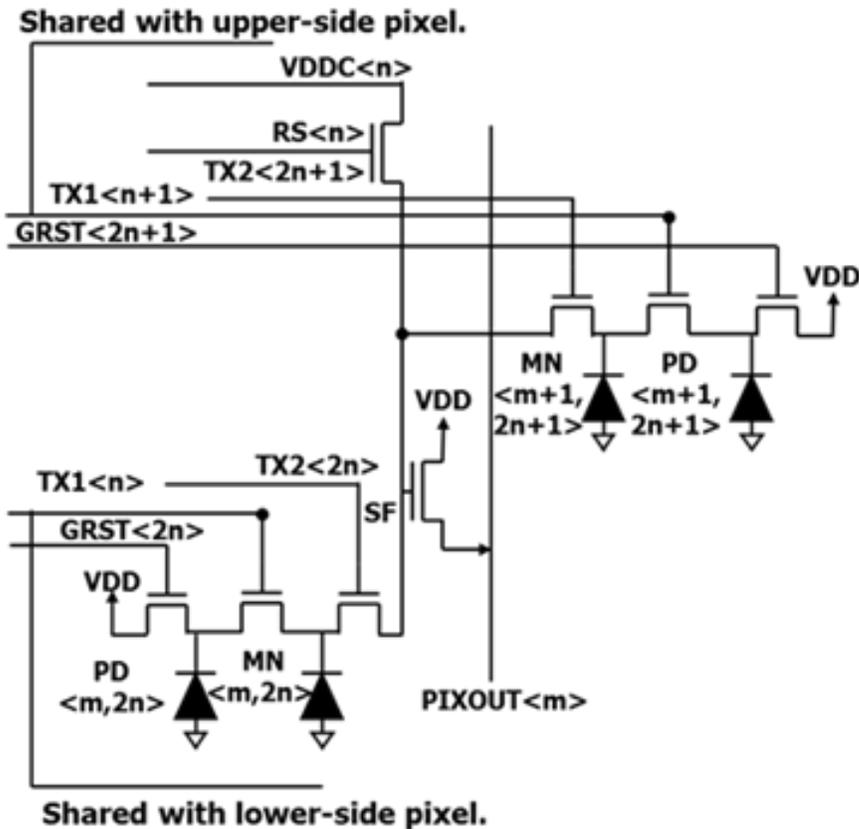
The DTI depth differs between the readout and non-readout sides.

Readout side: Not to impact on signal transfer

Non-readout side: Not to impact on PD/MN performance



Pixel Circuit for Larger Photodiode Area



Our pixel has two features.

◆ Shared Floating Diffusion (FD)

- RST and SF Transistor per pixel can be reduced.

◆ Row Select Transistor-less

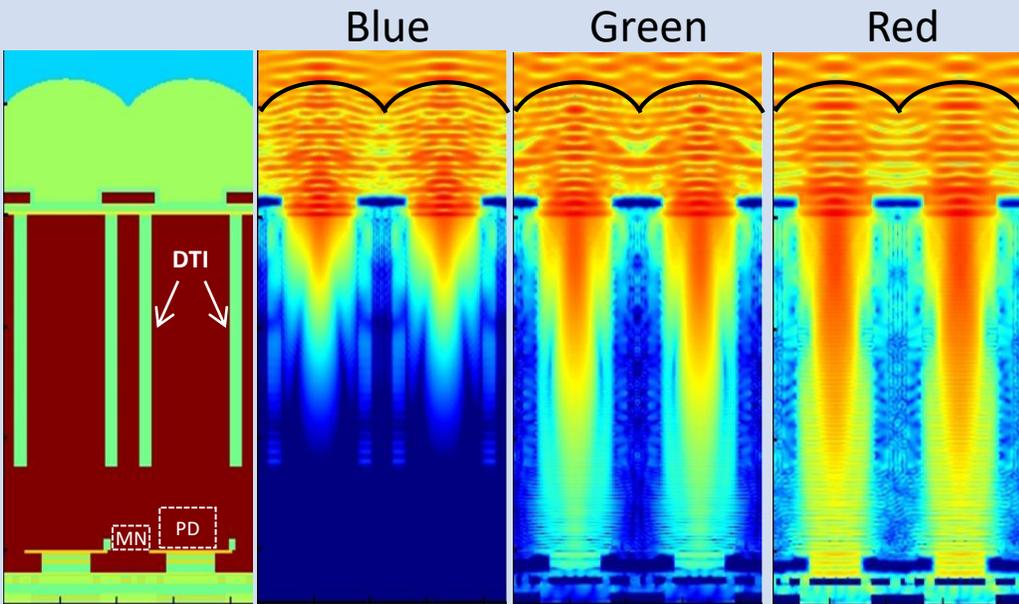
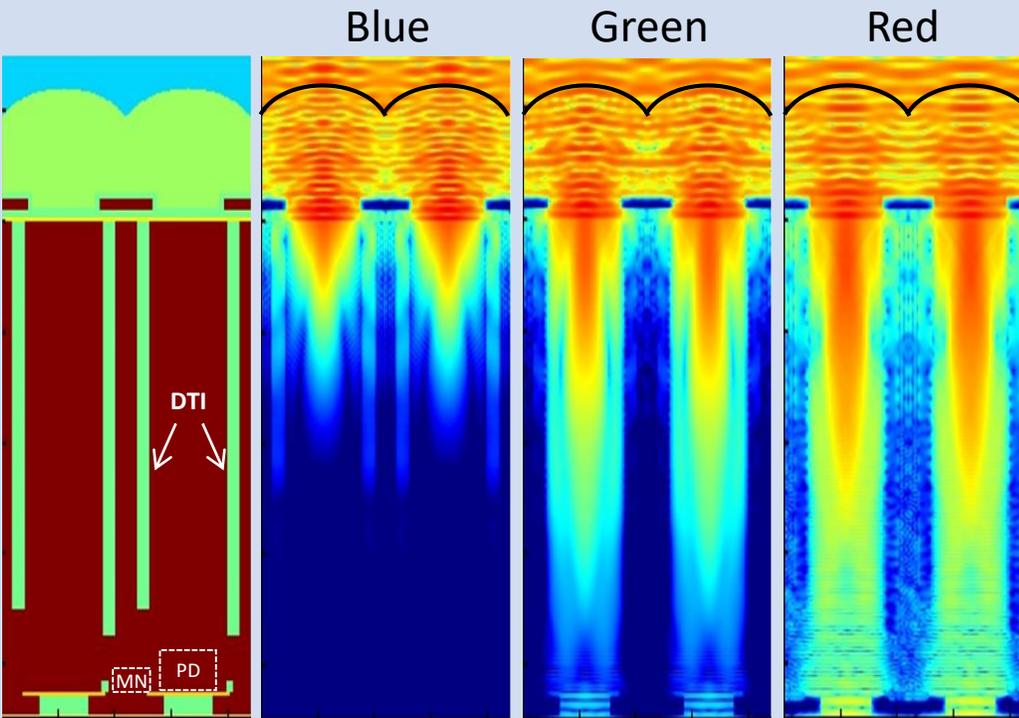
- Instead of Transistor, FD Drive is adopted.
(Low V_{FD_Drive} is written to FD for non-select row.)

The area of PD and MN can be increased.

➔ Large Full Well Capacitance.

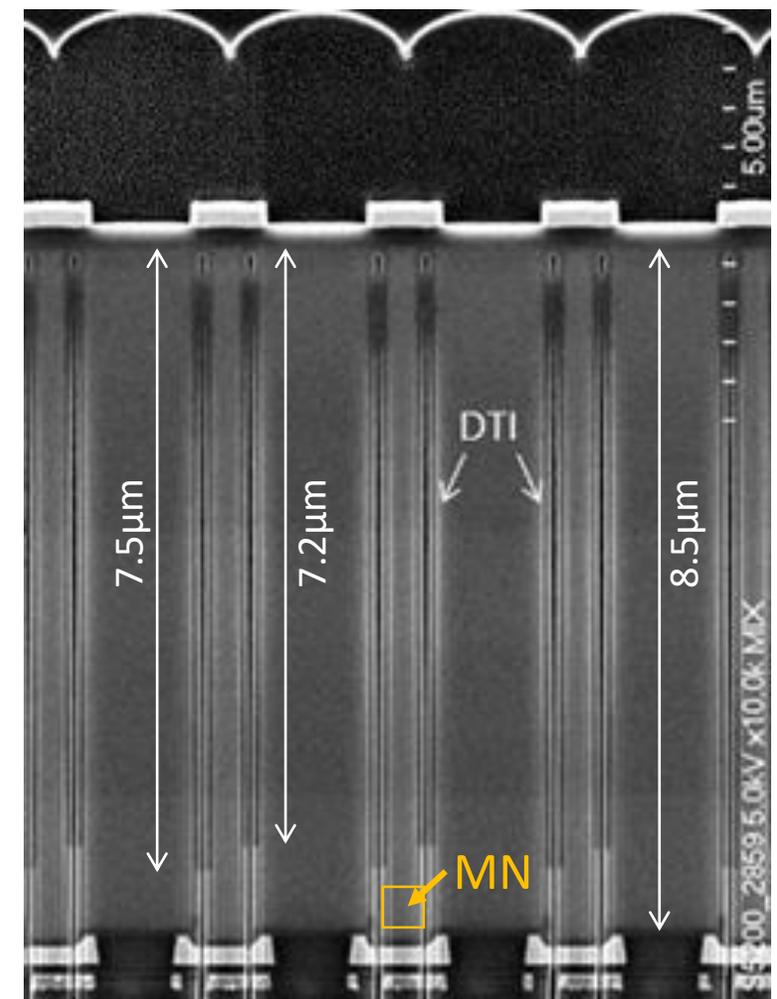
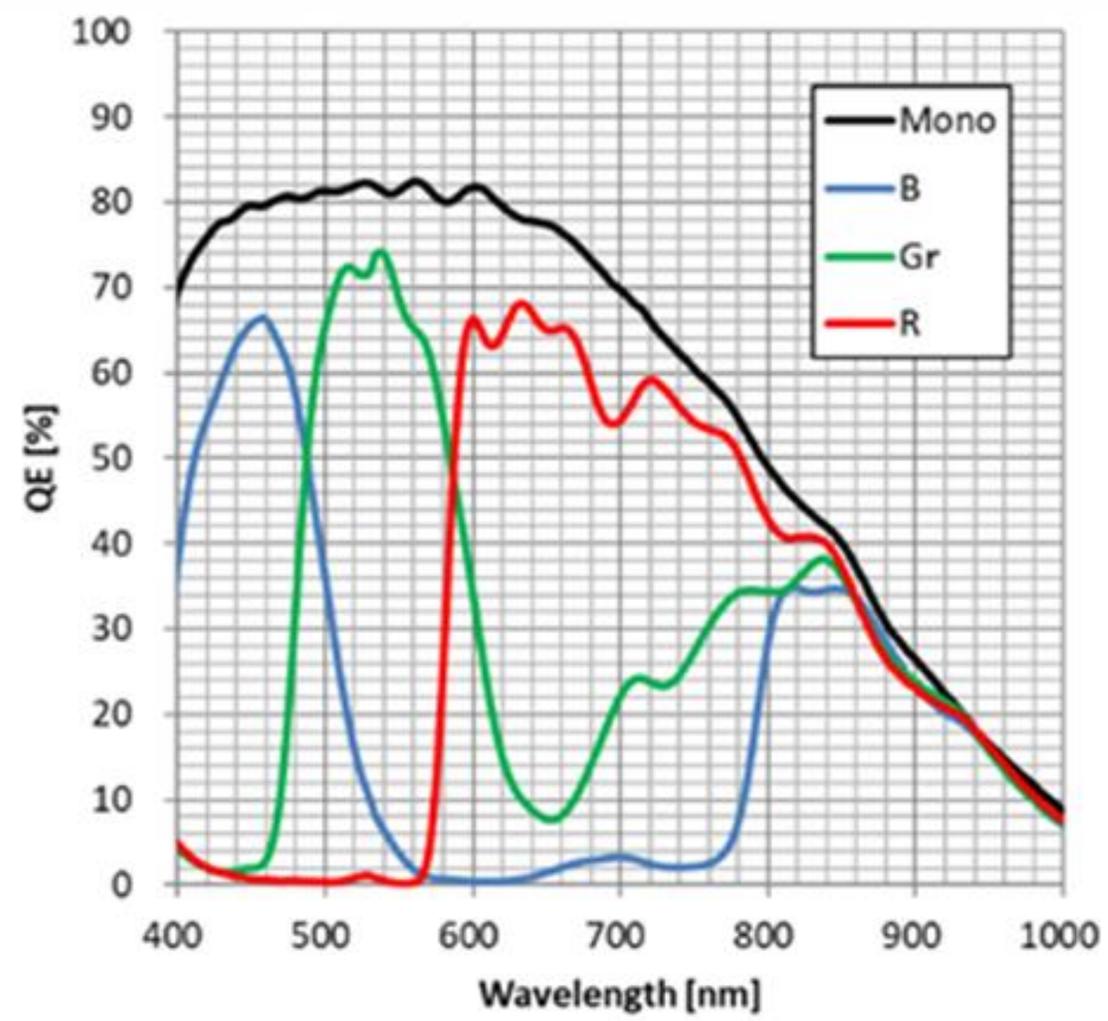
Optical Simulation

The combination of thick Epi and deep DTI is very effective.

| Structure | Ref | Epi 8.5 μm + dual depth DTI |
|-------------------------------------|---|--|
| Epi thickness | 6 μm | 8.5 μm |
| DTI depth | 4.5 μm | 7.2 μm + 7.5 μm |
| X-section $\lambda=600\text{nm}$ |  |  |
| 1/PLS (F#9) | 4425 | 10169 |

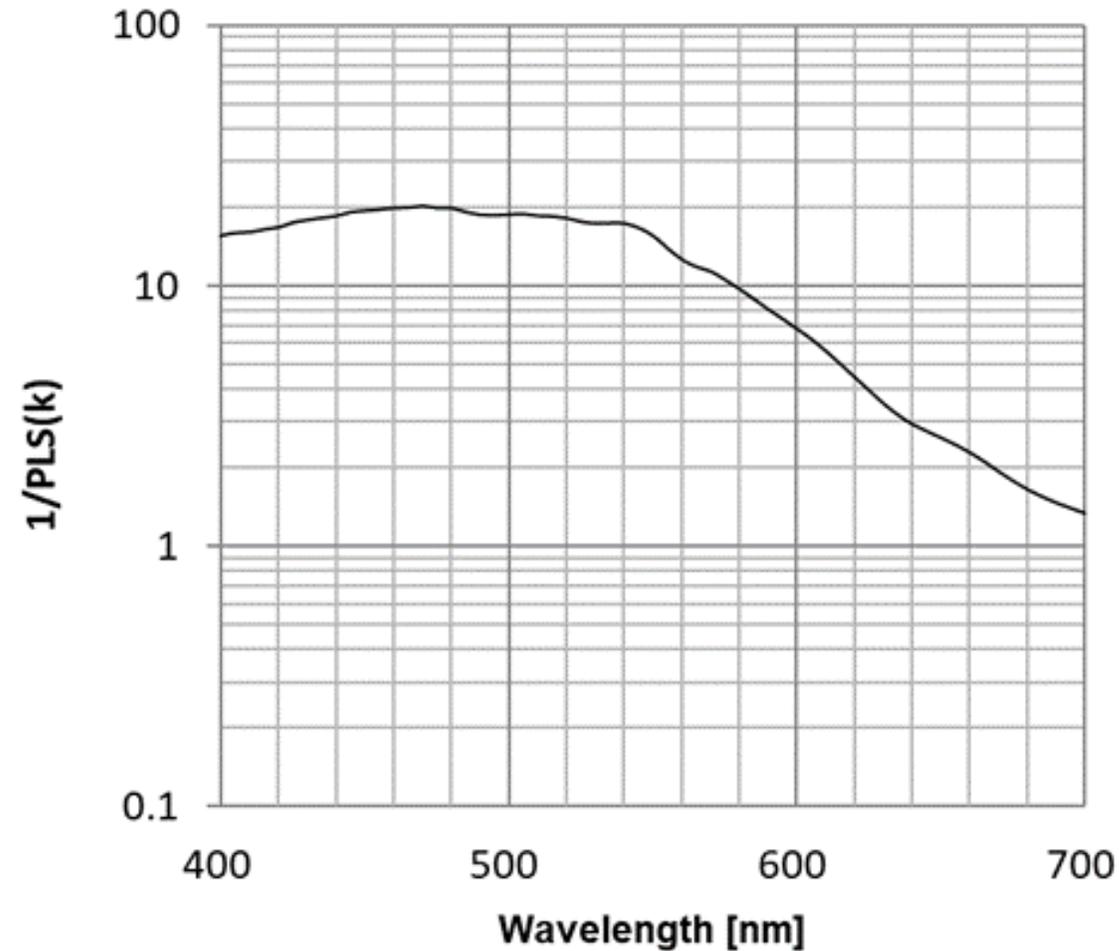
QE curve and Cross-section

QE is as good as Rolling Shutter product.



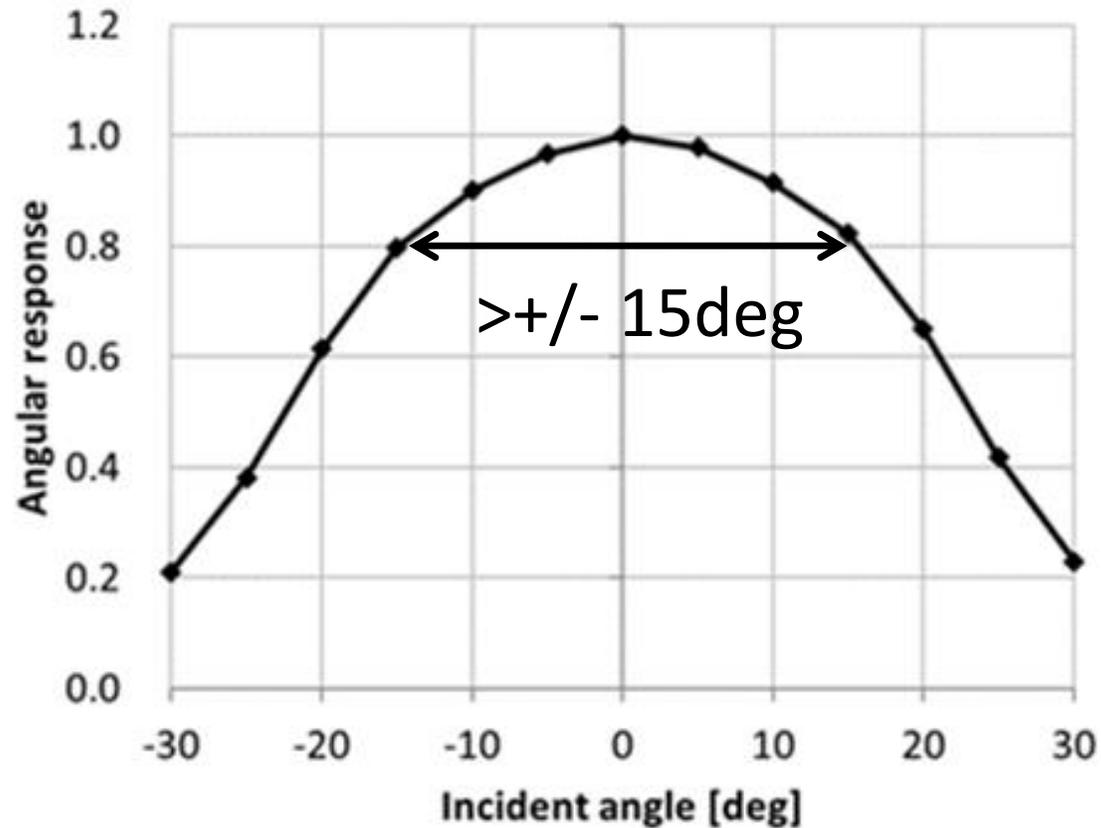
1/PLS vs Wavelength

At wavelengths less than 575 nm, 1/PLS is 10K or higher.



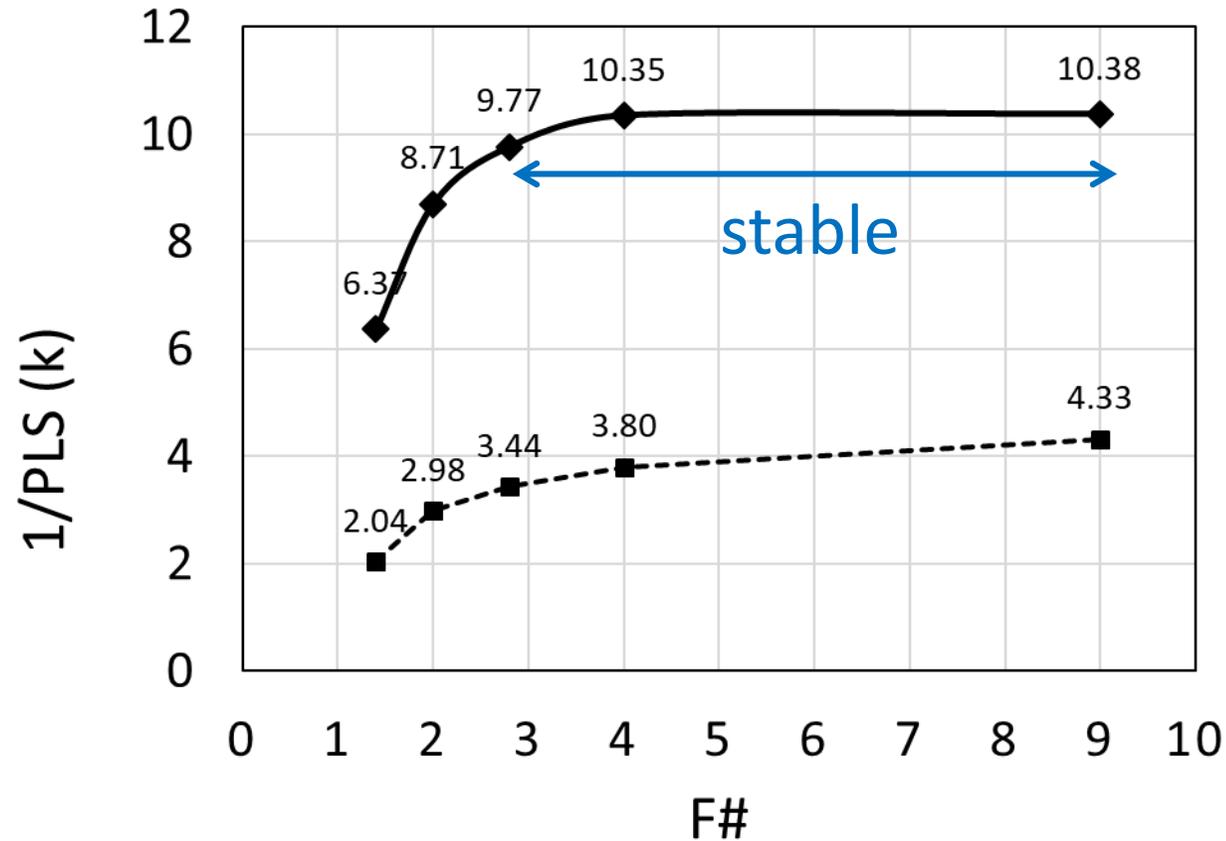
Angular Response

A wide Angular Response was realized in QE.
Our device can be used with F# 2.8 lens.
(F#2.8 \doteq 10.1deg)



F# Dependence of 1/PLS

1/PLS is very stable with F# 2.8 or larger.



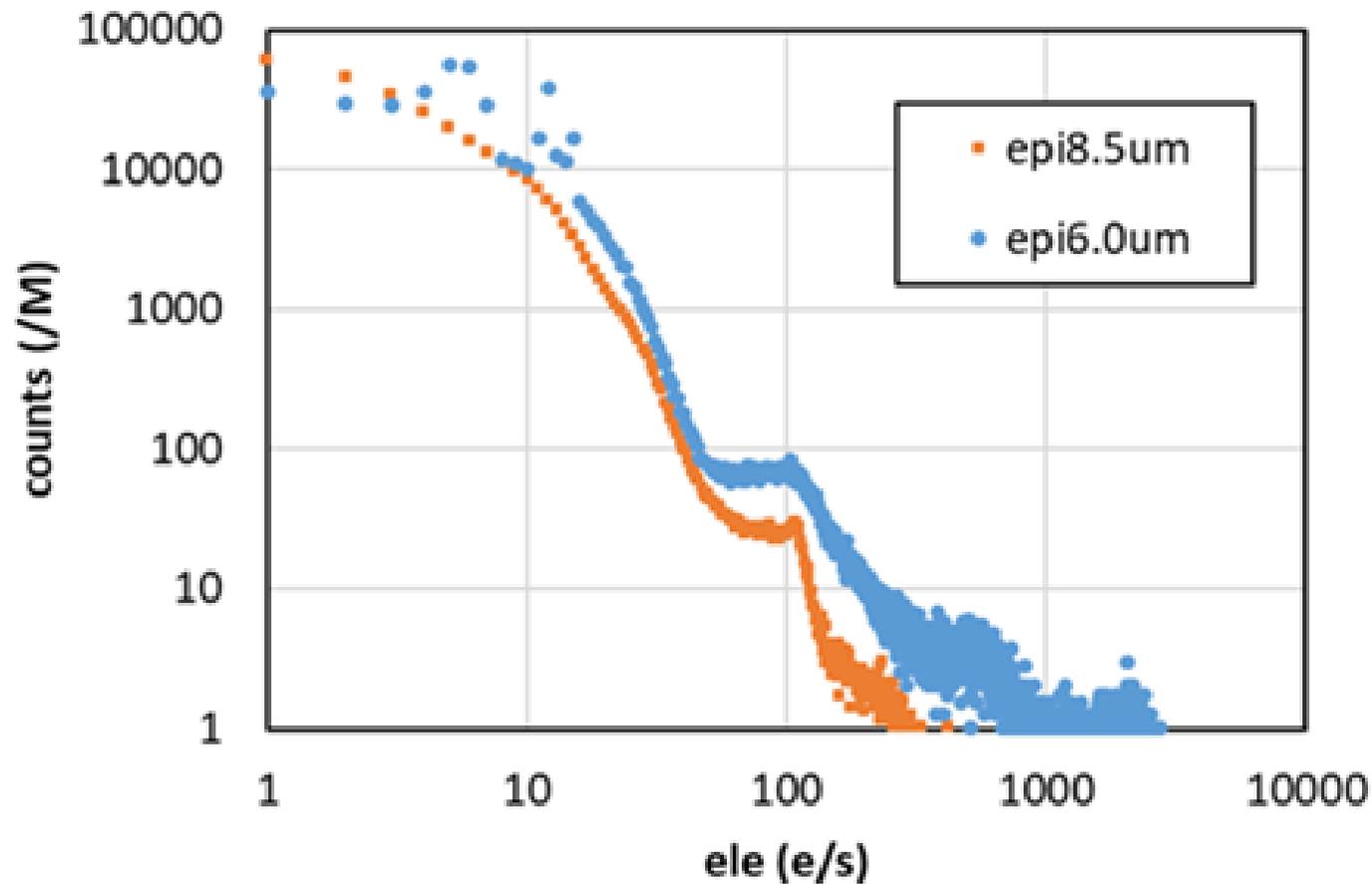
◆ Epi8.5um DTI7.5,7.2um ■ Epi6um DTI4.5um

* White light, Mono

Dark Current

Dark current was even better by optimizing DTI process, despite increased DTI depth.

PD Dark Current : epi 6.0um v.s. 8.5um



Conclusion

We developed the world's smallest 2.2 μ m BSI Charge Domain Global Shutter pixel with excellent characteristics.

| Pixel Performance | Value |
|--------------------------------|-----------------------------|
| Pixel Pitch | 2.2 μ m |
| Peak QE | 74 % (color) 83 % (mono) |
| 1/PLS (F#9, white light, mono) | 10380 |
| Angular response (80 %) | > 15 degrees |
| MTF @Nyquist frequency | > 40 % |
| Linear Full Well Capacity | 5400 ele |
| Pixel noise @SF out (25 deg.C) | 0.6 ele |

Thank you

<https://www.tpsemico.com/>

