ROHM GROUP
LAPIS
SEMICONDUCTOR

LAPIS's SOI Sensor Technology

Jan. 21, 2016

Masao Okihara[1], Hiroki Kasai[2], Takehiro Hirano[2],
Noriyuki Miura[2], Naoya Kuriyama[2], Hidenori Uehara[1],
Nobuo Ozawa[1], Yoshiki Nagatomo[1]

[1]LAPIS Semiconductor Co., Ltd.
[2]LAPIS Semiconductor Miyagi Co., Ltd.

ROHM
SEMICONDUCTOR

LAPIS Semiconductor's SOI Features

ROHM GROUP
LAPIS
SEMICONDUCTOR

LAPIS Semiconductor has developed and provided the fully depleted SOI devices for many years.

Basically focus on Low Power & Low Voltage operation Devices

Advantages of SOI to bulk-CMOS

Low parasitic capacitance	⇒	High Speed、Low Power
Easy isolation	⇒	High Density

Advantages of FD-SOI

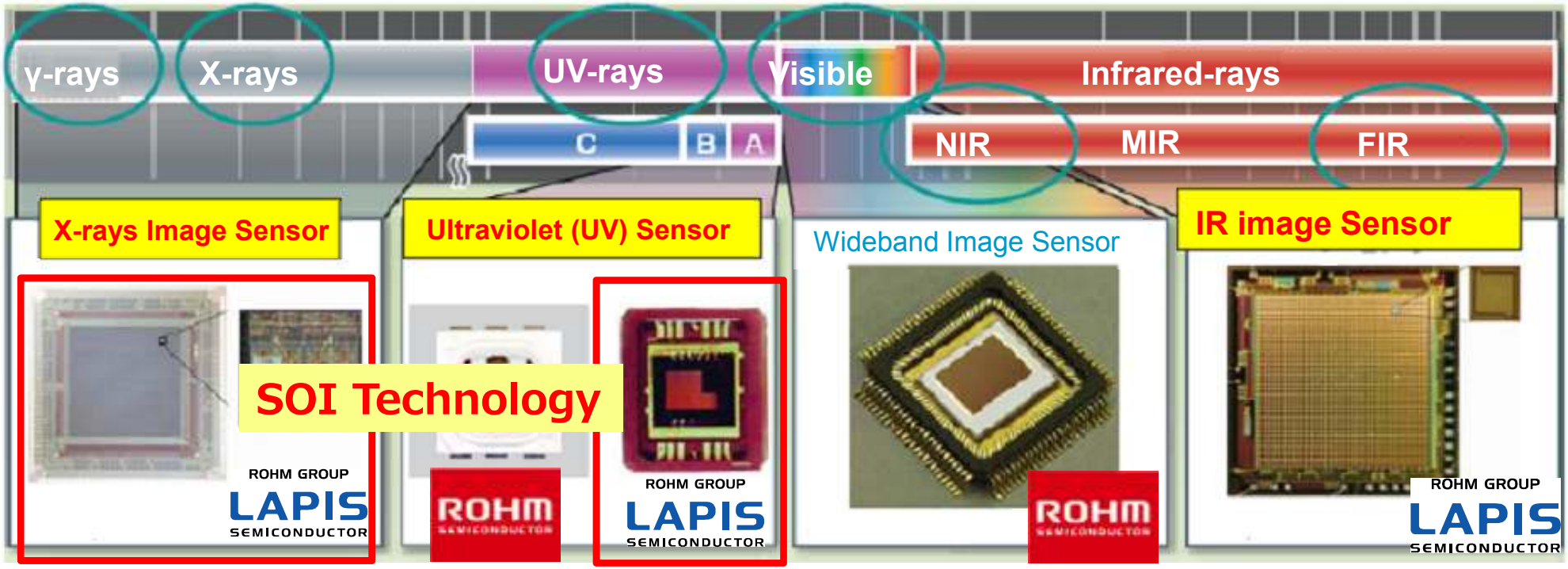
Low off-leakage with low Vt	⇒	Low voltage operation

Using experiences of FD-SOI device production, LAPIS Semiconductor is now expanding SOI technology to development of UV and X-ray sensors.

ROHM Group Light Sensing Technology

ROHM GROUP LAPIS SEMICONDUCTOR

ROHM/LAPIS sensors offer broad spectral range.



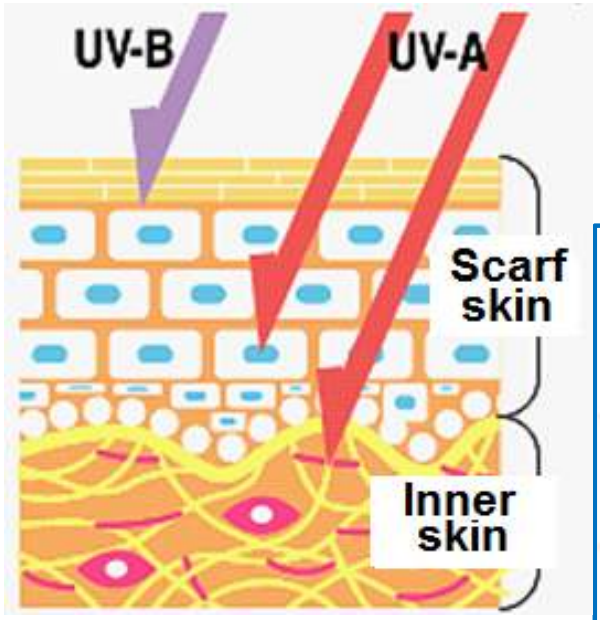
Market	-X-ray diagnosis Mammography -X-ray inspection 	-Smart phone -Watch -Suntan sensor -Weather station 	-Camera for medical use and FA use -Surveillance camera 	-Noncontact thermometer →Health care -Surveillance camera -Security sensor 
Asset	-Monolithic structure -Without scintillator -Small, High accuracy	-Embedded operational amplifier -High noise robustness	-Wideband detection range: Visible light to Near infrared-rays	-Mass production by semiconductor process - High vacuum package tech.

SOI UV Sensor

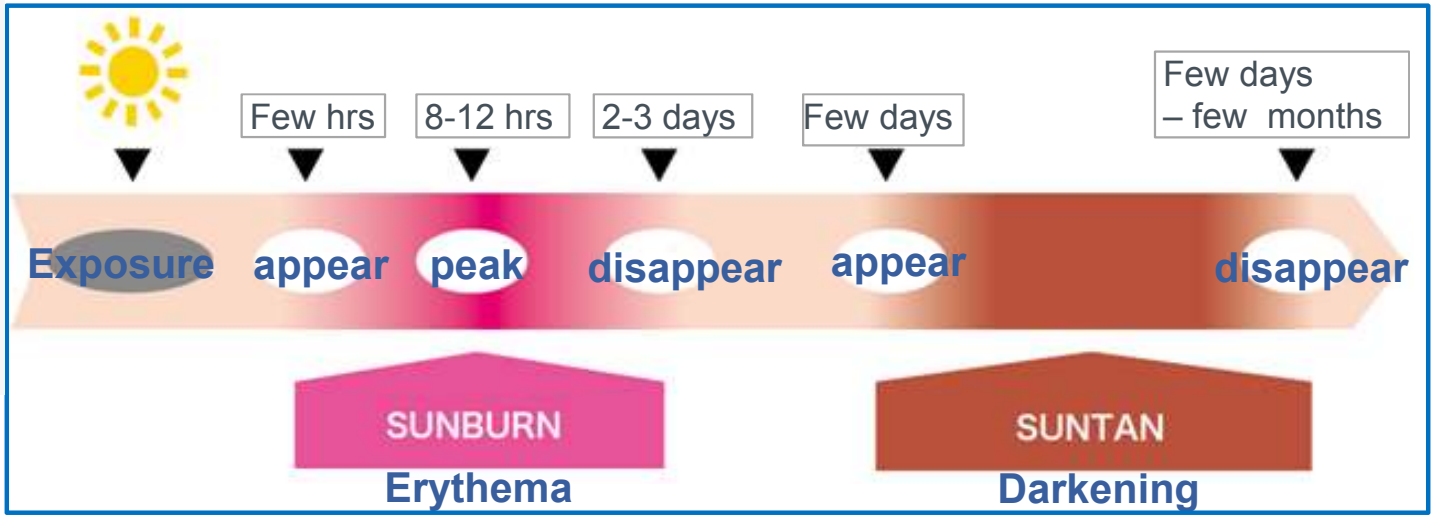
Influence of UV light

- UV-A penetrates into inner skin.
- UV-B is absorbed by scarfskin and not go farther.
- UV-A works to grow wrinkles, stains and freckles on face.
- UV radiation is though to be the major factor for most skin cancers.

Category	Characteristics
UV-A 315-400nm	- Skin aging (wrinkle, freckle) - Suntan
UV-B 280-315nm	- Sunburn - DNA damage
UV-C <280nm	- Cutting DNA chain - Skin cancers - Immunity damage

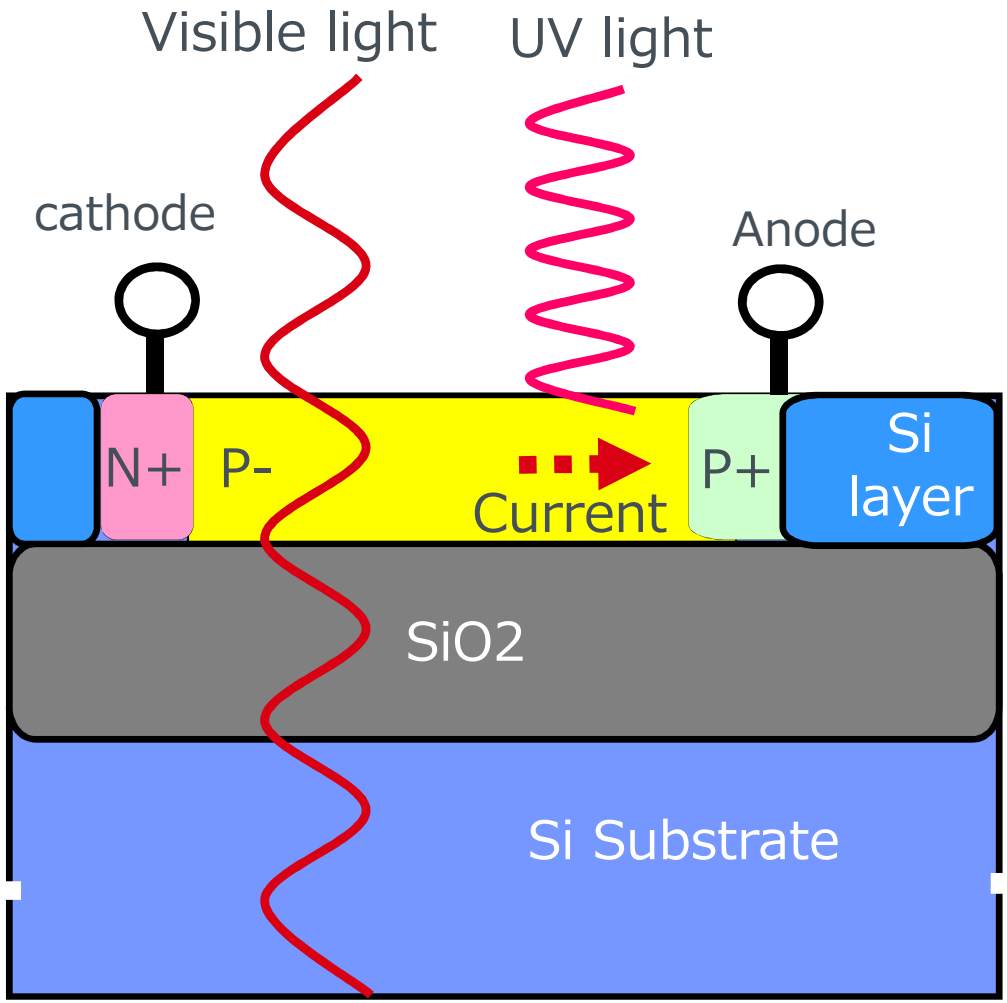


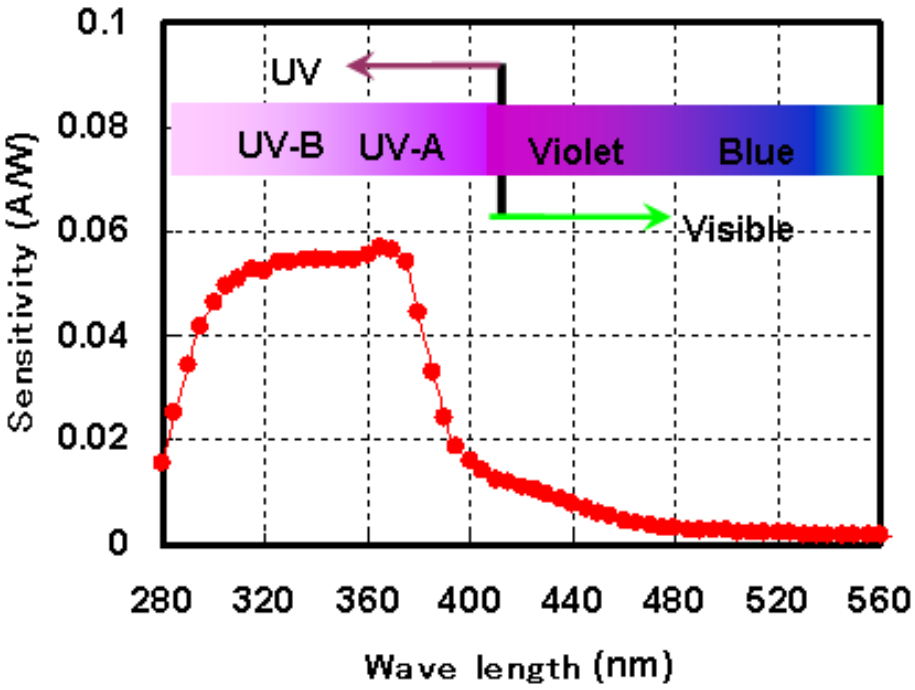
UV-A: 35-50% reach to inner skin



SOI UV Sensor Structure and Sensitivity

- LAPIS UV sensor is using SOI technology.
- Only UV light can be detected by the depleted thin Si layer.
- SOI UV sensor can detect UV-A and UV-B together.

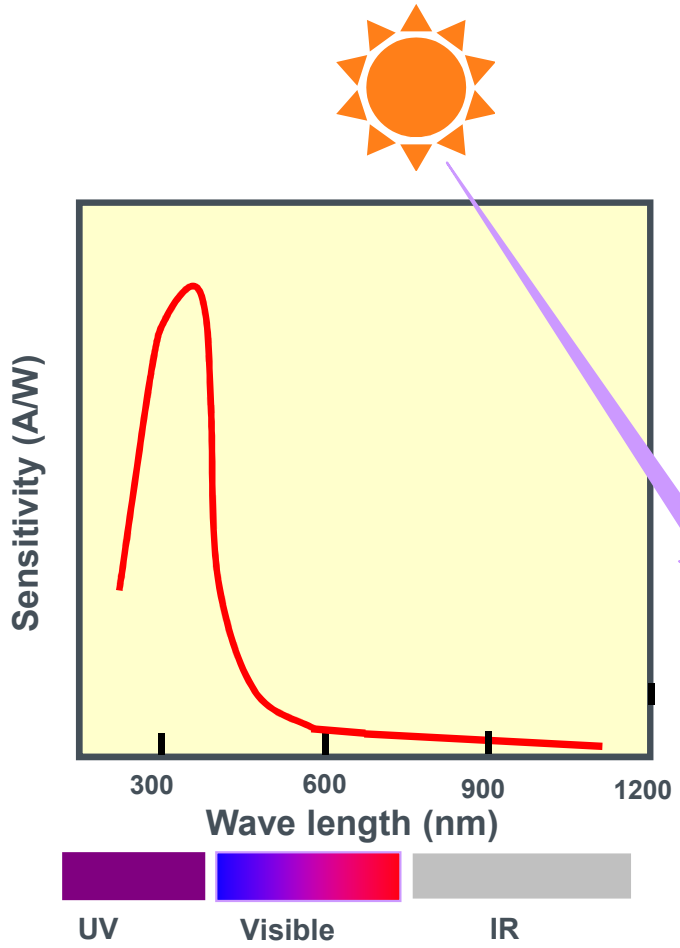


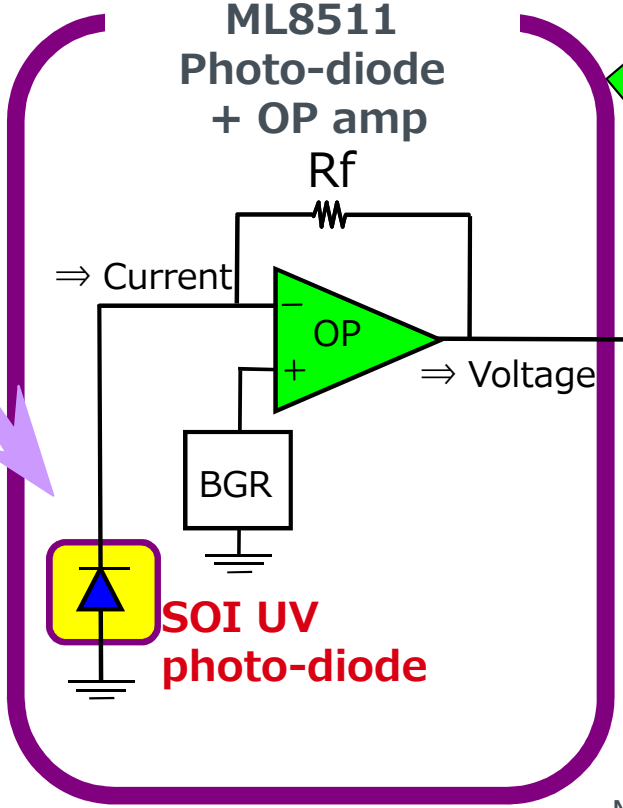


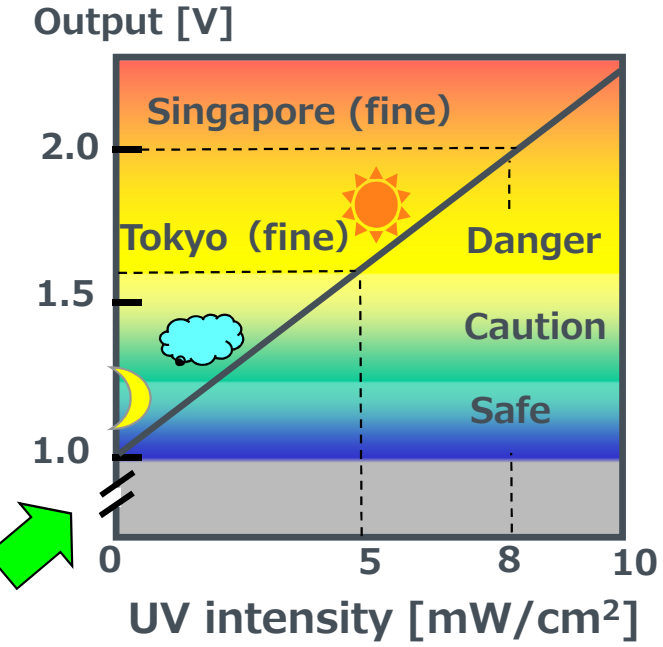
UV Diode Sensitivity Characteristics

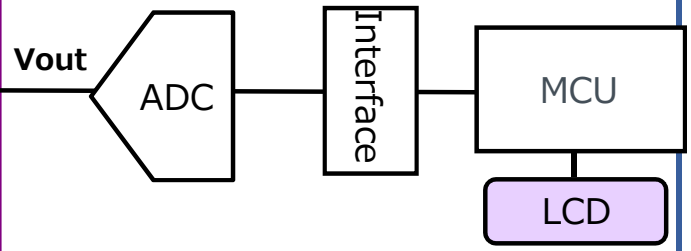
Features of UV sensor ML8511

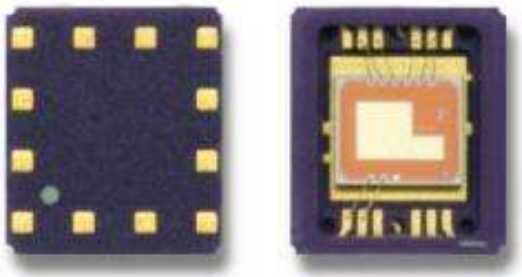
- UV Sensor for UV-A&UV-B Detection
- Convert of the detected photo-current to voltage
- High uniformity of sensitivity by the individual trimming process
- small current consumption 0.1uA (Standby)











ML8511 QFN 3.7 x 4.0 x 0.73 (mm)

LAPIS UV Sensor Development Roadmap

ROHM GROUP
LAPIS SEMICONDUCTOR

ML8511
- Voltage output
- Detecting UV-A and UV-B

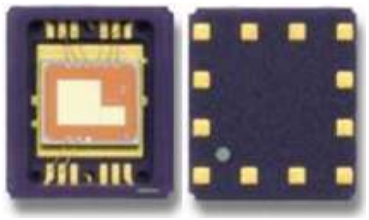
UV-A / UV-B separation

ML8523
- Digital output
- Detecting UV-A and UV-B separately

Embedded ALS

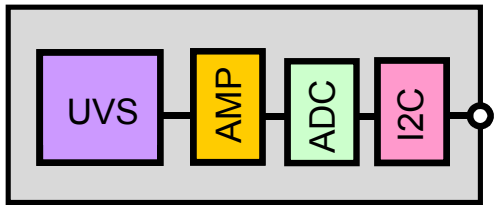
ML8524
- Ambient light sensing
- Detecting UV-A and UV-B separately

- Supply Voltage：2.7 to 3.6 V
- Low-power design
  Operating: 300uA
  Standby: 0.1uA
- UV Intensity Accuracy ±10%



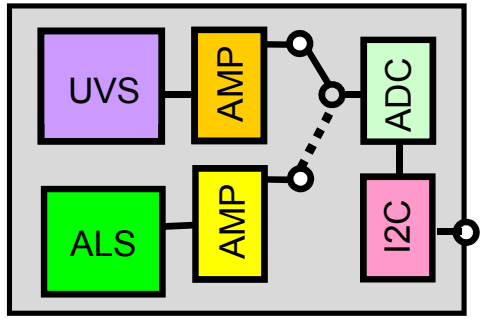
- Supply Voltage：1.65 to 3.6 V
- Low-power design
  Operating：500 uA
  Standby mode：1.4 uA
  Power down mode：0.1 uA
- UV Index accuracy: ±1
- I2C fast mode: 400 kHz
- 10-bit ADC

ES：Q1 / 2016
MP：Q3 / 2016



- Supply Voltage：1.65to3.6V
- Low-power design
- UV Index accuracy: ±1
- ALS :0.1-100,000 lx
- I2C fast mode: 400 kHz
- 16-bit ADC

ES：Q1 / 2017
MP：Q3 / 2017



CY 2014 ***CY 2015*** ***CY 2016*** ***CY 2017***

SOI X-ray Sensor

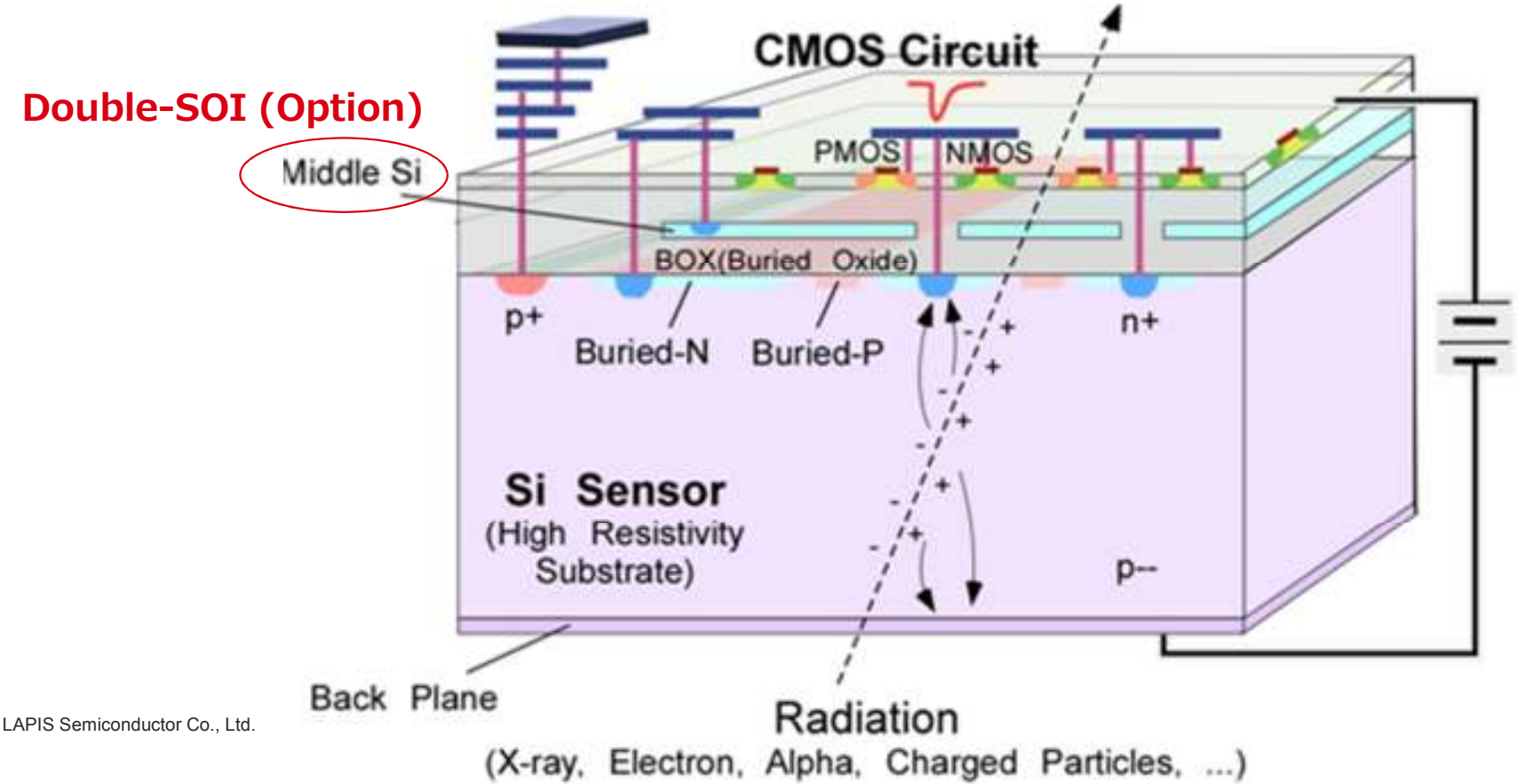
Features of SOI-Pixel Sensor

ROHM GROUP
LAPIS
SEMICONDUCTOR

Structural feature of FD-SOI Pixel Sensor

(1) one chip monolithic X-ray pixel sensor device can be obtained.
(2) high radiation hardness for SET can be obtained.
(3) wider depletion sensor to various X-ray energy can be embedded.

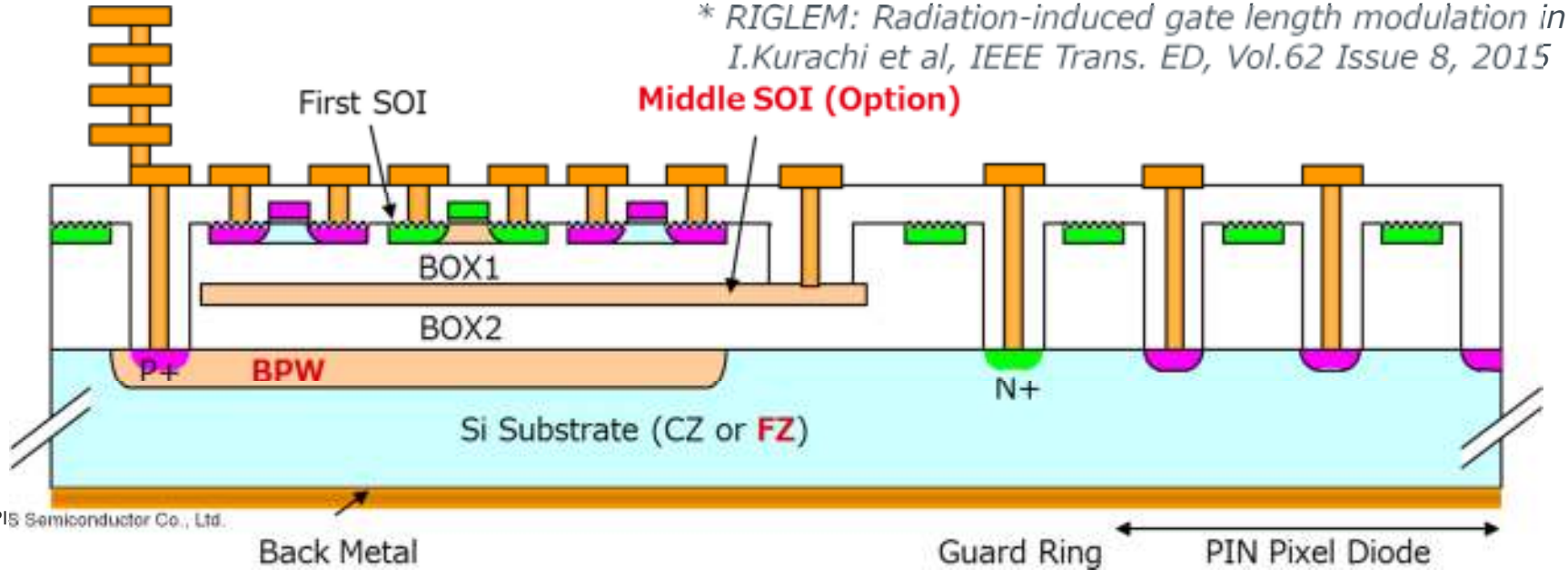
➡ FD-SOI is promising structure to realize high performance and reliable X-ray pixel sensors



Pixel Sensor Process and Improvement

ROHM GROUP
LAPIS
SEMICONDUCTOR

Process	0.2μm Low-Leakage Fully-Depleted SOI CMOS 1 Poly, 5 Metal, MIM Cap, DMOS option ⇒ Introduce the Buried P-well (BPW) under the Transistor ⇒ LDD Dose Optimization to reduce RIGLEM*(Under Development)
SOI wafer	Top Si : Cz, p-type, Low Resistivity Buried Oxide: 200 nm thick Handle wafer: High Resistivity Cz(700Ωcm) or FZ(≧2kΩcm) ⇒ Prevention of Slip line generation (with SOITEC) ⇒ Double SOI Wafer for Compensation of BOX charge (Under Development)
Backside	Thinned to 260 - 500 μm and Evaporated with Al (200 nm).



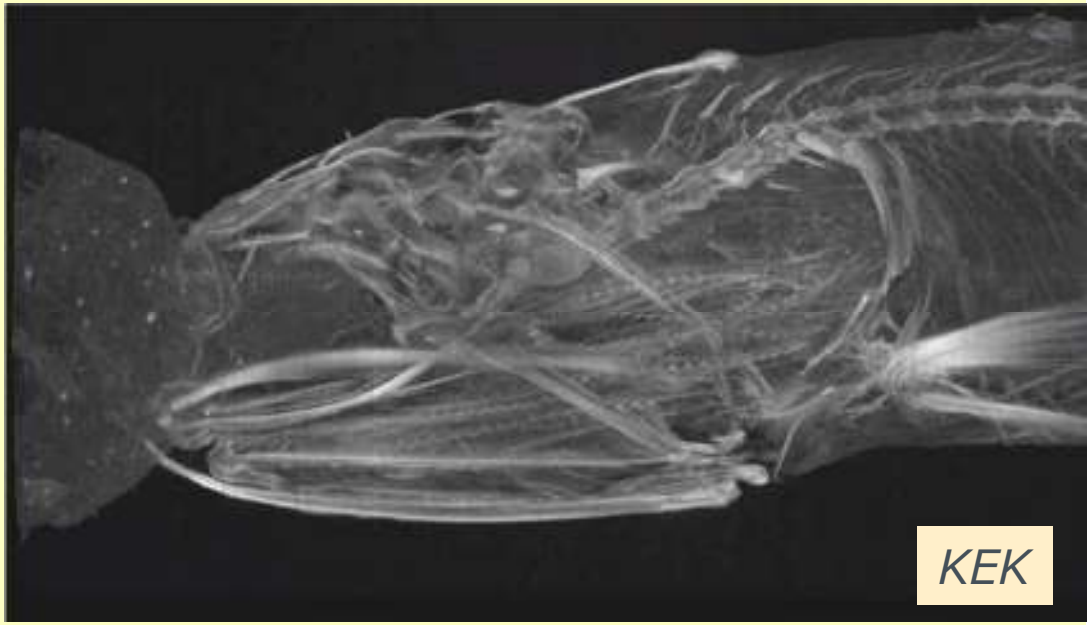
** RIGLEM: Radiation-induced gate length modulation in PMOS*
I.Kurachi et al, IEEE Trans. ED, Vol.62 Issue 8, 2015

X-ray Sensor Development

ROHM GROUP
LAPIS
SEMICONDUCTOR

Based on basic design of SOI pixel sensor technology by KEK, many kinds of sensors have been developed for variety of applications.

- Integration-type and Counting-type Pixel Sensor(KEK)
  - INTPIX: High Resolution X-ray Imaging with small Pixel Size (Min. 8um square)
  - CNTPIX: Photon Counting and energy dispersion, high S/N ratio
- Sensors for X-ray Free Electron Laser(Riken)
  - SOHPIAS: Large Dynamic Range Imaging Sensor
- X-ray Sensor for Astrophysics (Kyoto Univ.)
  - XRPIX: Low Noise, Trigger Driven Readout
- X-ray Sensor for Stress Analysis (Kanazawa Univ.)
  - INTPIX: High Speed, Portable Meas.
- TOF Sensors for Automotive (Shizuoka Univ.)
  - BPSPIX: High NIR Sensitivity TOF(Time of Flight) Sensor



An example of X-ray image (small fish) taken by the integration-type SOI sensor (INTPIX4).

SOPHIAS (SOI Photon Imaging Array Sensor)

ROHM GROUP
LAPIS SEMICONDUCTOR

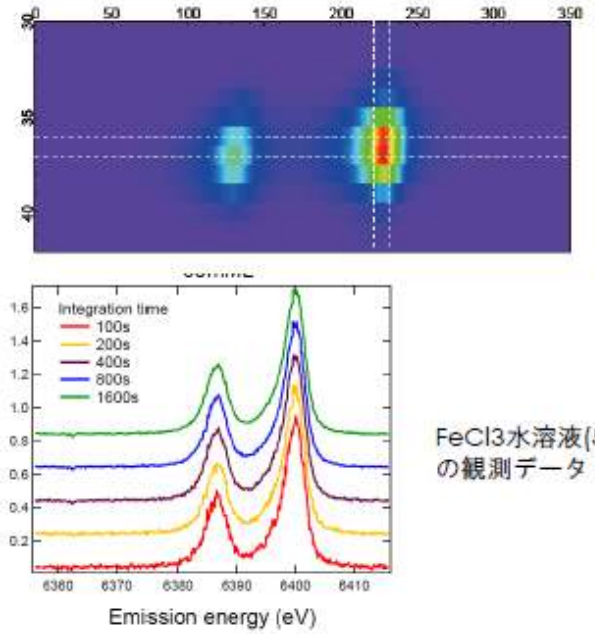
Utilization of SOPHIAS has been started for various experiments in SACLA@RIKEN.

- Dynamics of Atomic Structure
- Direct Observation of Chemical Reactions
- etc.

RIKEN's courtesy

Another Application of SOPHIAS

- Heavy Particle Radiotherapy for Cancer Treatment (Gunma Univ. and RIKEN)



FeCl3水溶液(50 ml)の観測データ

Results of the feasibility study.
Direct observation of electron transfer will be observed with SOPHIAS.
Current limitation: Observation is limited to the bond formation.
H. Ihee, S. Adachi et.al., Nature Vol. 518 (2015).

SOI X-ray Sensor for X-ray Astronomy

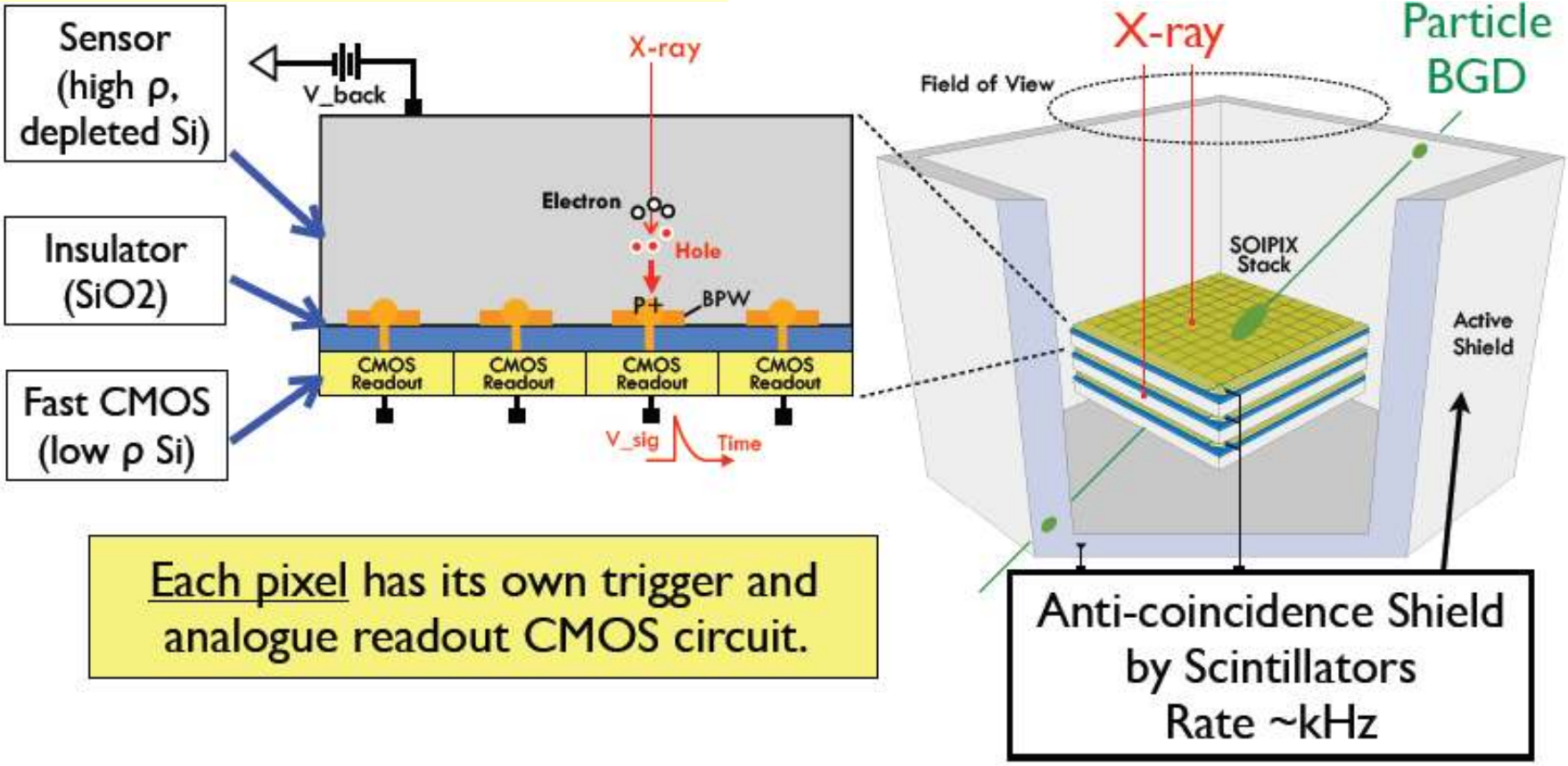
ROHM GROUP
LAPIS
SEMICONDUCTOR

XRPIX for X-ray astronomy is developing by Kyoto Univ.
It is intended to be equipped with next generation X-ray satellite.

XRPIX Features

- Event Driven Readout Mode
- Low Readout Noise
- High Energy Resolution

Kyoto Univ.



SOI X-ray Sensor for Stress Analysis

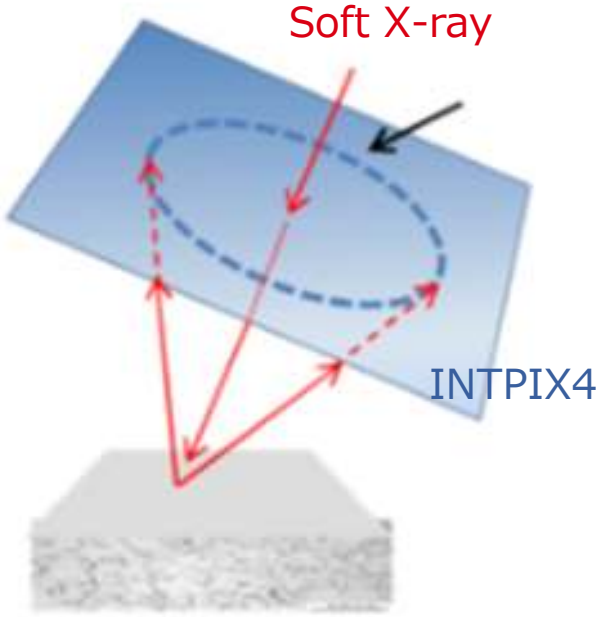
ROHM GROUP
LAPIS
SEMICONDUCTOR

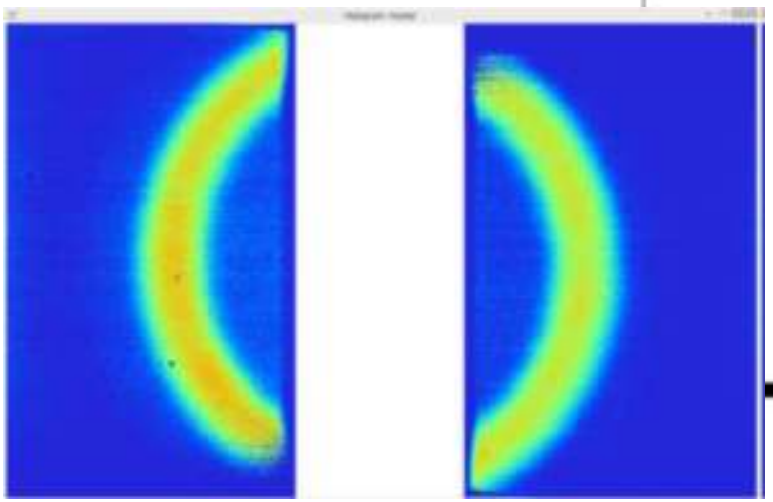
The X-ray stress measurement method is widely used for investigation of Residual stress and crystal grains of metallographic structure to evaluate their quality and durability.

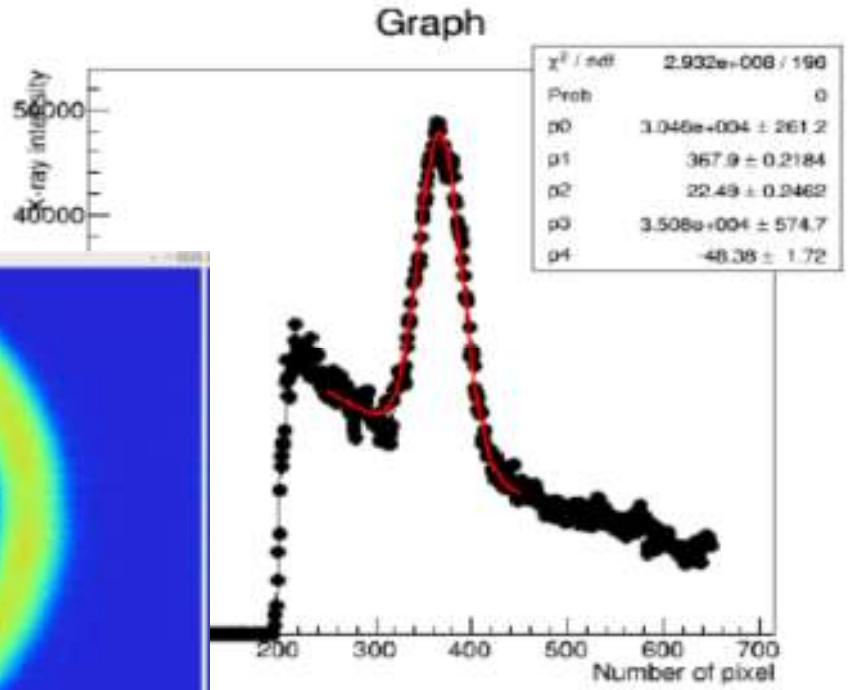
Kanazawa Univ.

Stress Measurement by INTPIX4

- High-speed measurement
- Portability of equipment







Back Reflection Debye-Ring Measurement of Industrial Materials by SOI Pixels Sensors.
S.Mitsui et al.,the 17th iWoRID, 2015.

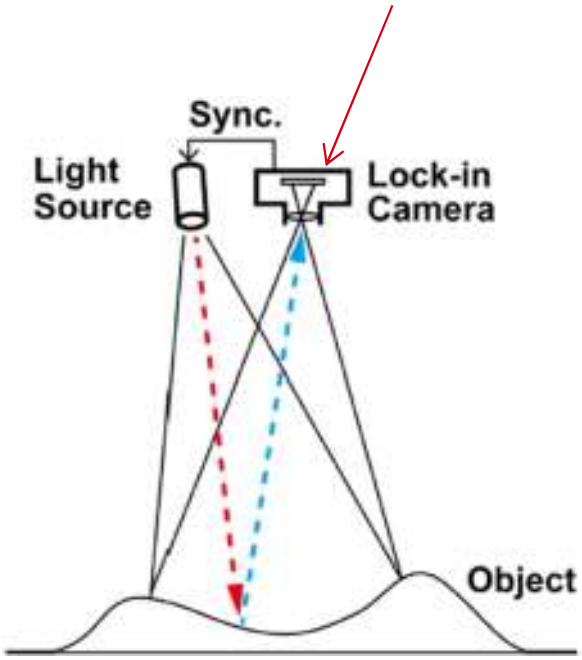
SOI X-ray Sensor for TOF Sensor

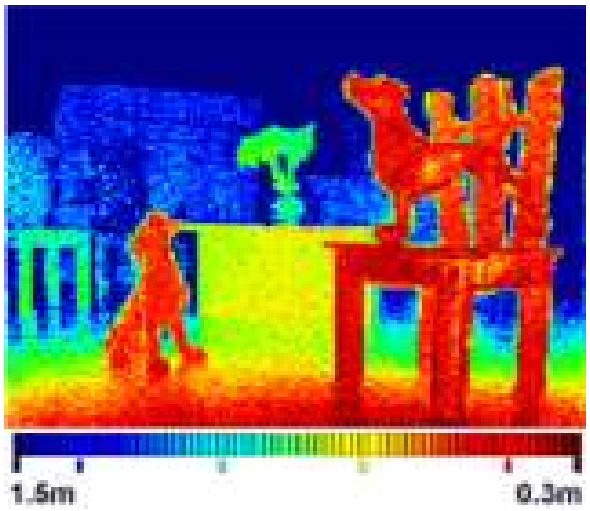
TOF (Time of Flight) sensor is developing by Shizuoka Univ.

Fully depleted Si more than 100um thickness can be obtained the high Q.E. around 950nm IR region.

Shizuoka Univ.

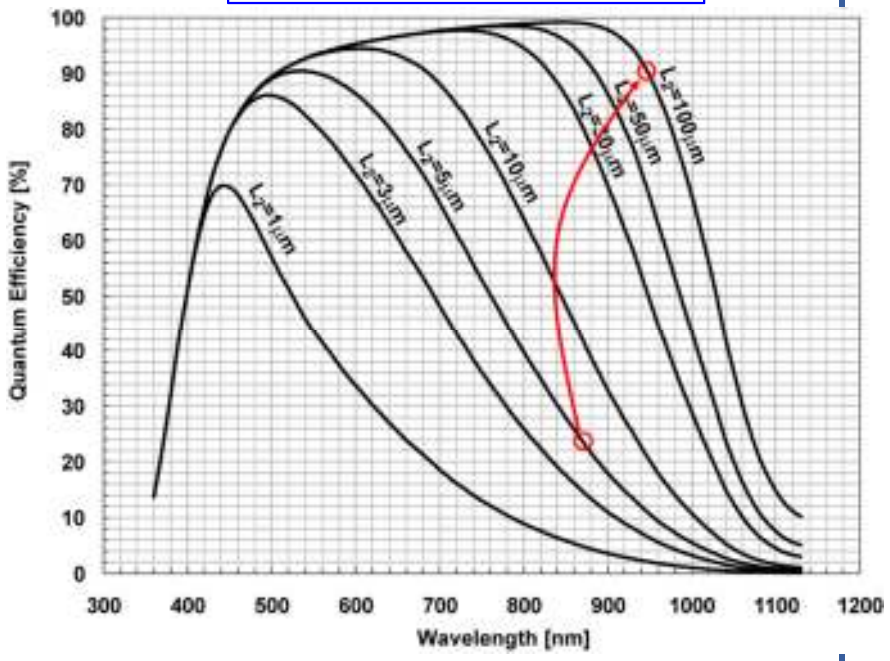
SOI X-ray Sensor





870nm Low Q.E.

950nm High Q. E.
Improved by 4



Summary

ROHM GROUP
LAPIS
SEMICONDUCTOR

- LAPIS has developed and provided the FD-SOI for low power and low Vcc operation application.

- LAPIS is now expanding FD-SOI to sensor technologies such as UV and X-ray Sensors.

- UV sensor ML8511 can be used for detection of UV intensity and next generation ML8523 is now under development for accurate UV index measurement.

- X-ray sensors have been developing with many collaborators (KEK, Riken, Shizuoka Univ., Kyoto Univ., Kanazawa Univ. etc.). It is starting to use for many application fields.

ROHM GROUP

LAPIS SEMICONDUCTOR

LAPIS Semiconductor Co.,Ltd.