CUDA를 활용한 실시간 IMAGE PROCESSING SYSTEM 구현

Chang Hee Lee

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Overview

- Thin film transistor(TFT) LCD : Inspection Object
  - Type of Defect
  - Type of Inspection
- Instrument Brief
  - Lighting / Focusing
  - Optic Magnification
  - Scanning
- Electrical System Component
  - Sensor / Camera
  - Grabber
- Processing
  - Inspection Spec.
  - Speed Obstacle
  - Algorithm / Implementation with CUDA

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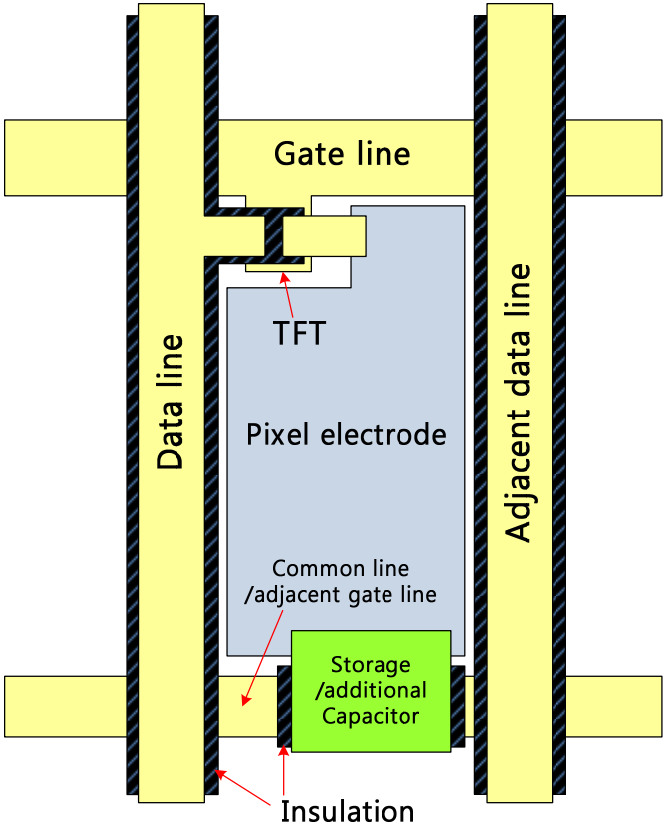
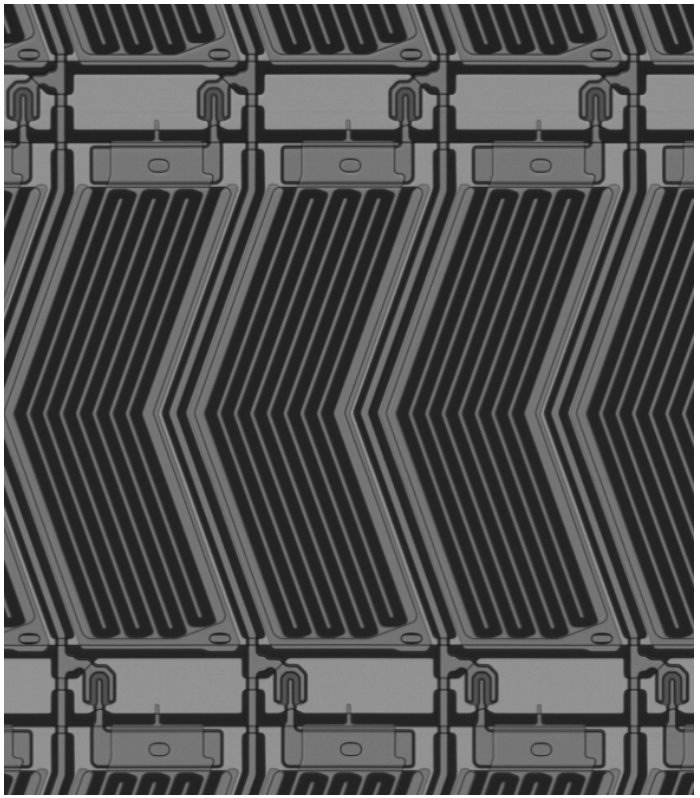
Schematic of TFT



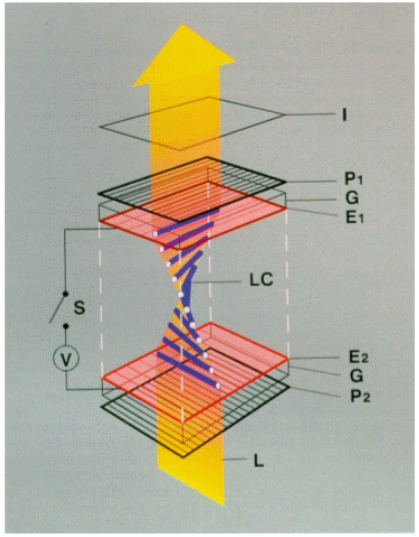


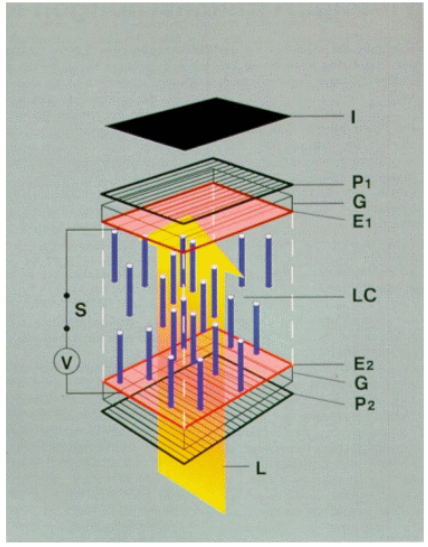
Types of TFTs

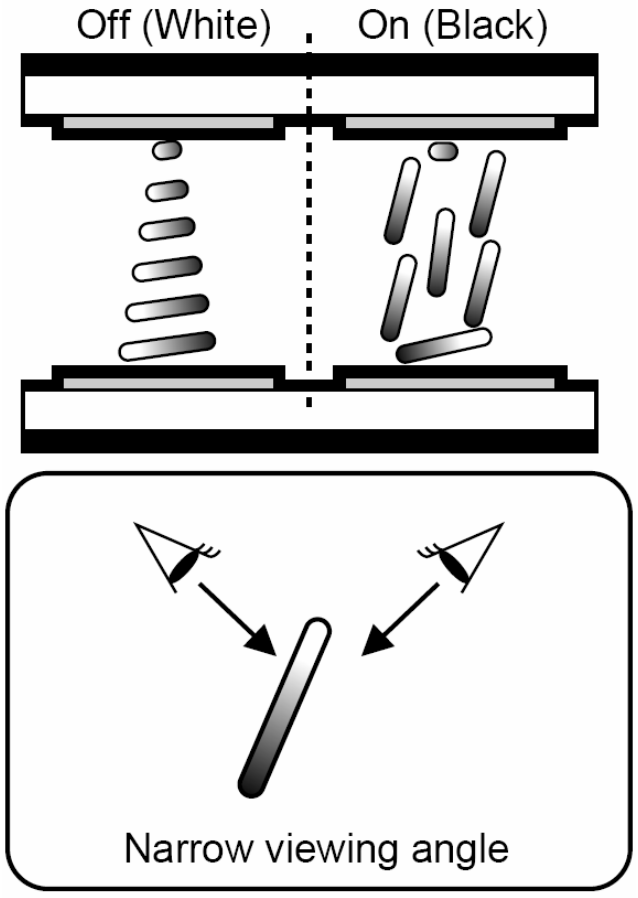
- TN + film (Twisted nematic)
- IPS (LG-Philips , Hitachi, 1996)
  - IPS (in-plane switching)
  - AS-IPS (Advanced Super-IPS) – LG-Philips
  - A-TW-IPS (Advance True White-IPS) – LG-Philips
- VA (Samsung, Fujitsu, 1998)
  - MVA (multi-domain vertical alignment)
  - PVA (patterned vertical alignment) - Samsung

TN

- Low Driving Voltage
- Narrow viewing angle

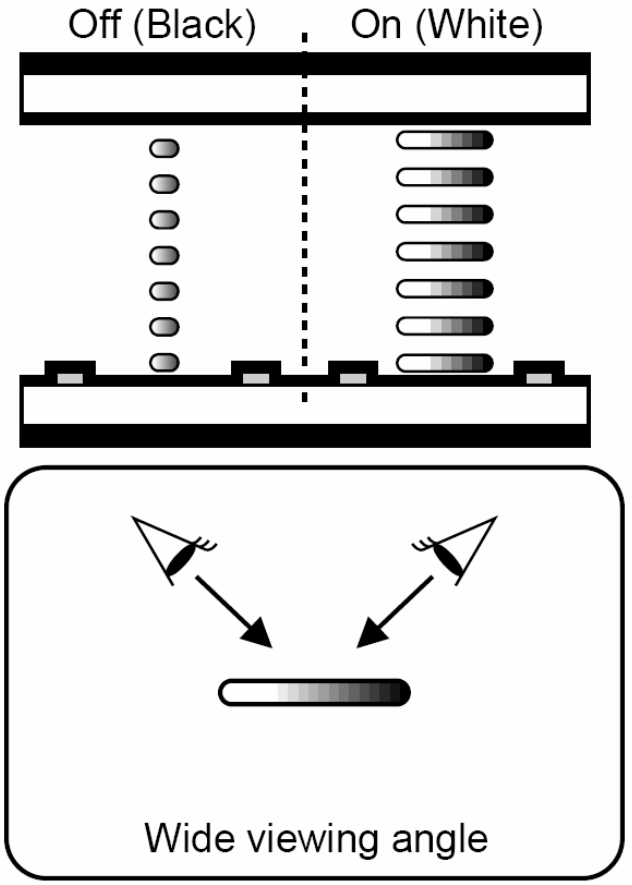






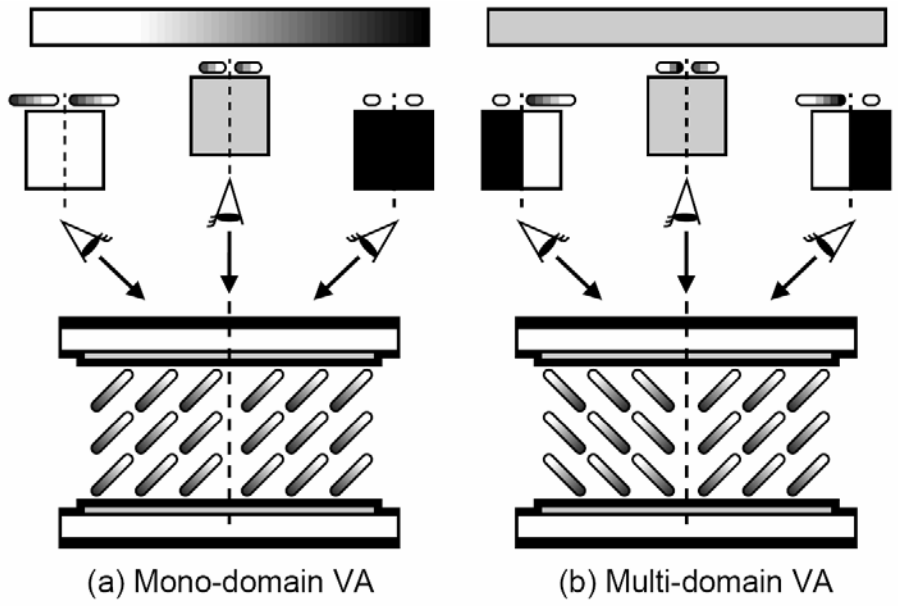
IPS

- **Very wide viewing angle**
- Slow Response speed
- Low brightness



VA

- **High Contrast Ratio**
- Wide viewing Angle
- **Fast Response speed**



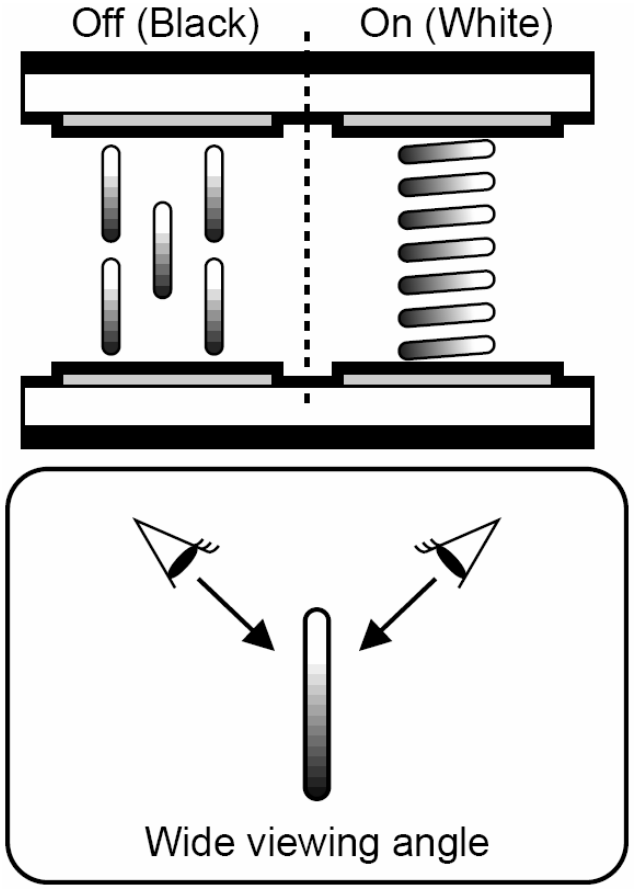


Figure: Koike, Y, Super high quality MVA-TFT liquid crystal displays 1999

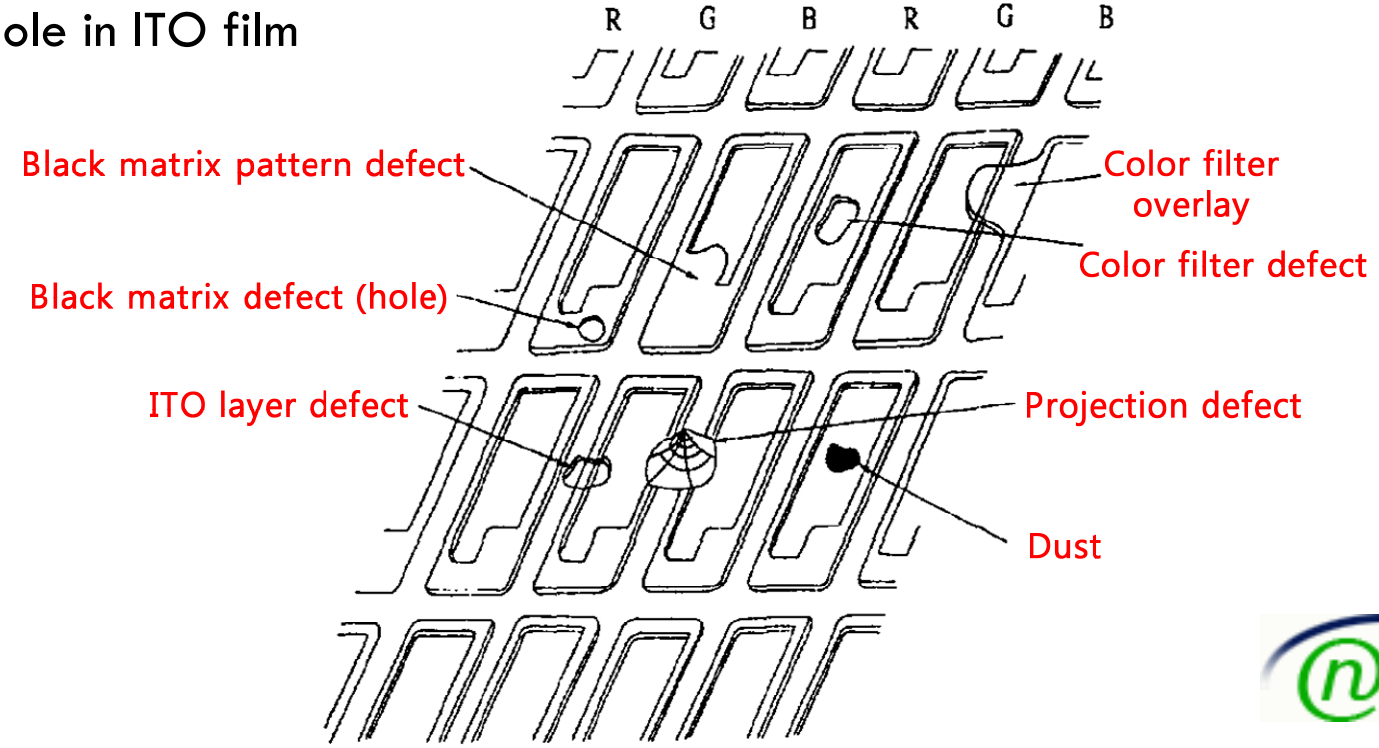
Types of Defects (Color Filter) (1/2)

- Macro-Defects (can be find by human eyes)
  - IRO-MURA : Unevenness of color
  - SIMI : Stain on a filter
  - IRO-ZURE : mis-alignmeant of color cells

Reference : K-NAKASHIMA, Hybrid Inspection System for LCD Color Filter Panels 1994

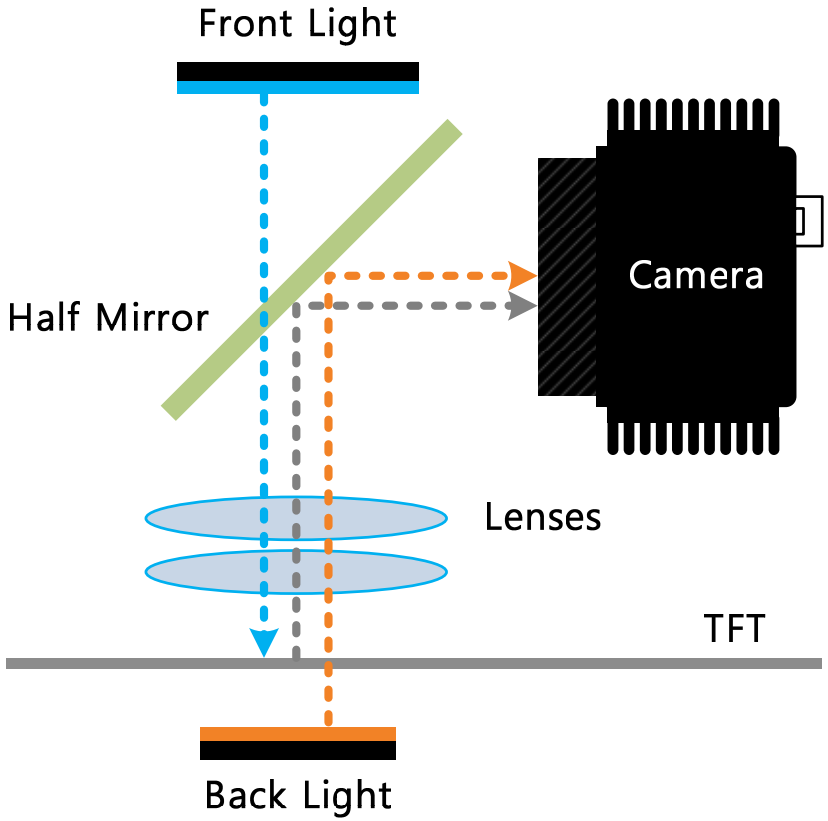
Types of Defects (Color Filter) (2/2)

- Micro-Defects
  - Black Matrix Hole
  - Black Matrix Pattern Defect
  - SIRO-NUKE (Color area shortage)
  - Particle /Grain / Dust
  - Hole in ITO film



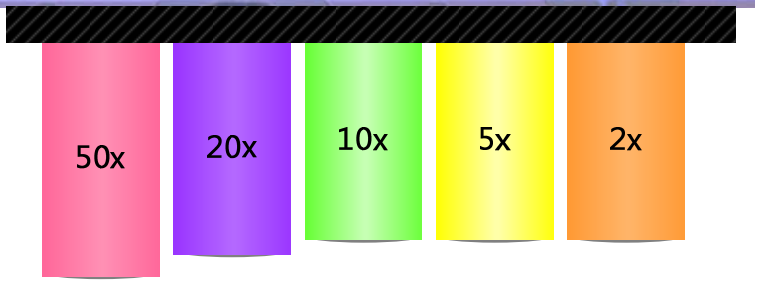
Lighting / Focusing

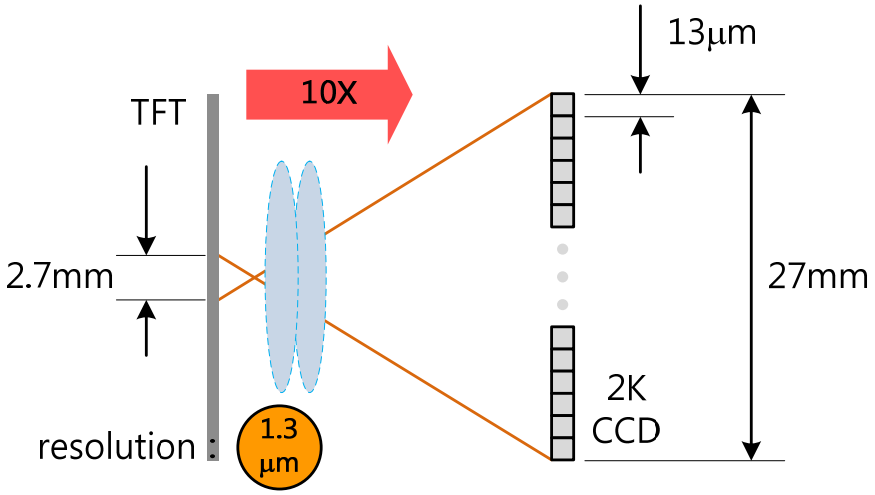
- LED Lighting
  - Co-axial
  - Front light
  - Back light
- Runtime Auto Focusing

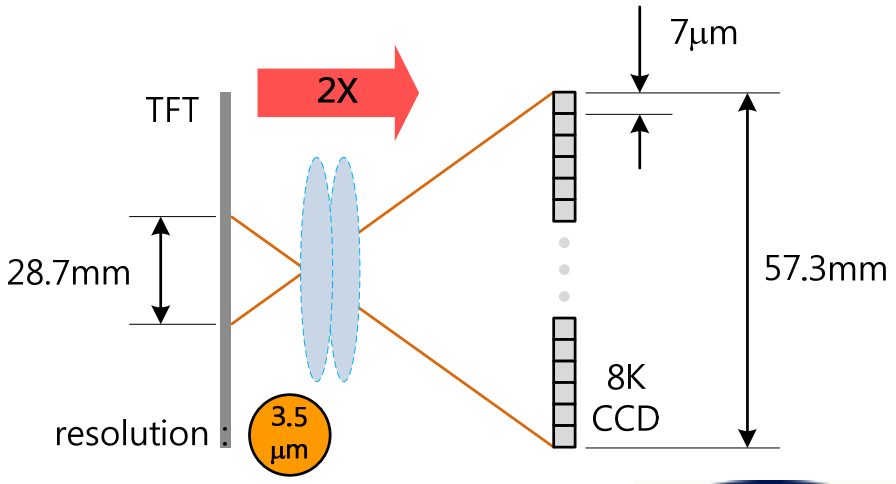


Optical Magnification

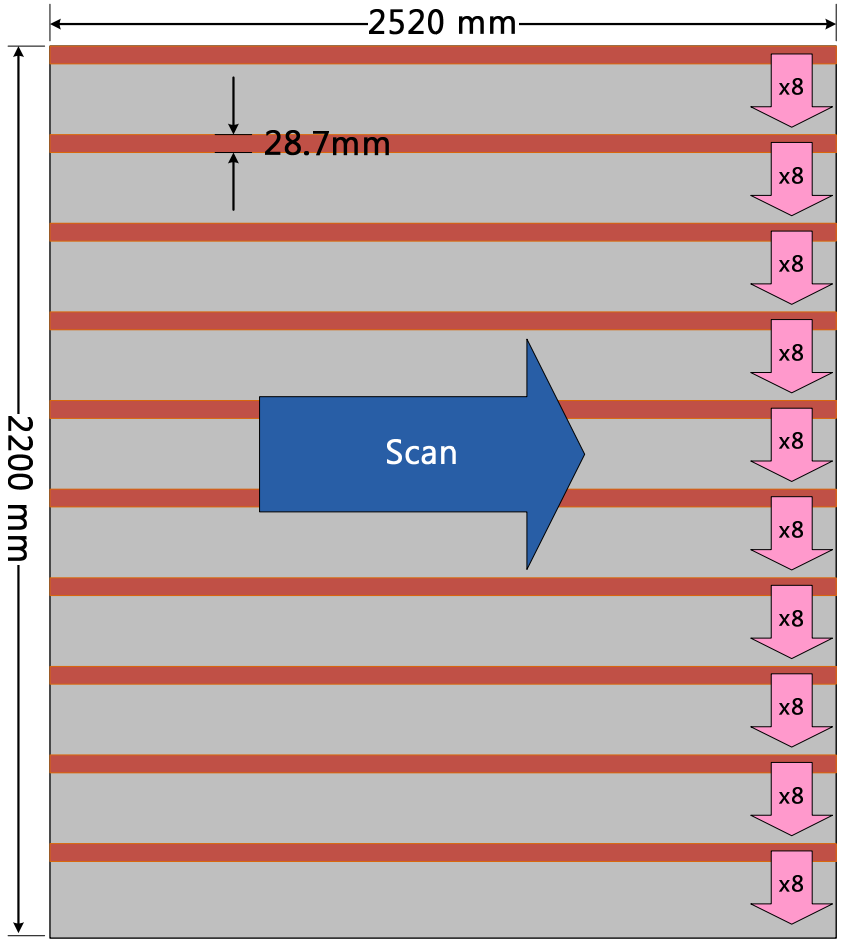
- 2x, 10x magnification



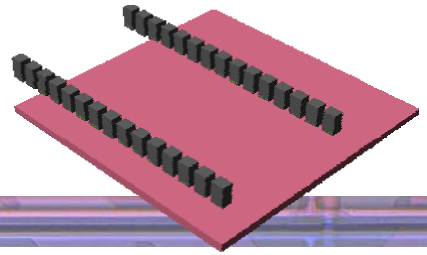




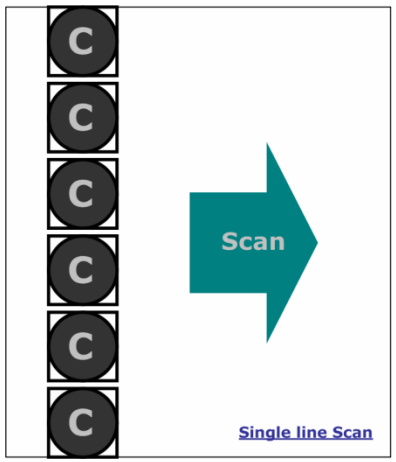
Scanning

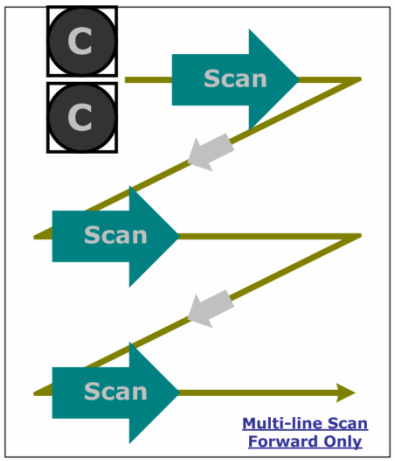


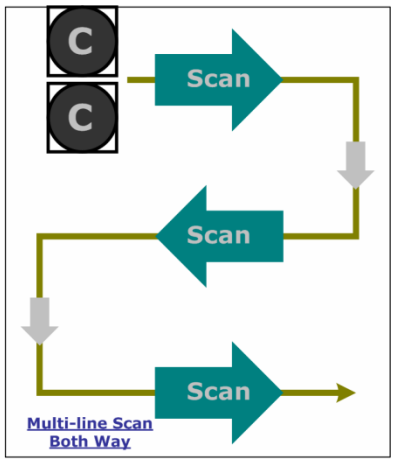
Array & Scanning



- Unidirectional Way
- Bidirectional Way
- Repetition (Multi Line Scan)
  - Related to magnification
  - Large No. of Repetition → Increase No. of Camera
  - 7 Gen. 2x, 10 Camera (7μm) : 8 times







Electrical System Components

- Sensor / Camera
  - 2K TDI Camera (13μm x 13μm, Max. 52KHz, 104MByte/s)
  - 8K Linear Sensor (7μm x 7μm, Max. 33KHz, 264MByte/s)
  - 8K TDI Camera (7μm x 7μm, Max. 68KHz, 640MByte/s)
- Grabber : Matrox's Solios eCL/XCL
- CPU : Intel's Dual Core, 2.4GHz
- GPU : nVidia's FX5600
- OS : Window XP Professional
- Soft Development Environment : MS Visual Studio 2005

Camera & Sensor

- Camera
  - 2048/8192, Gray
  - Time Delay and Integration (TDI), 64/96
  - Max. Line Rate
    - 52/68 KHz
  - Max. Data Rate
    - 120/ 640 Mbyte/s
  - 13x13 / 7x7µm²
  - 4/8 Taps
  - 8/10 bit
- Sensor
  - 8192, Gray
  - Line Rate
    - 33 KHz
  - Average Data Rate
    - < 304 MHz
  - 13x3 µm²
  - 8 Taps

Grabber

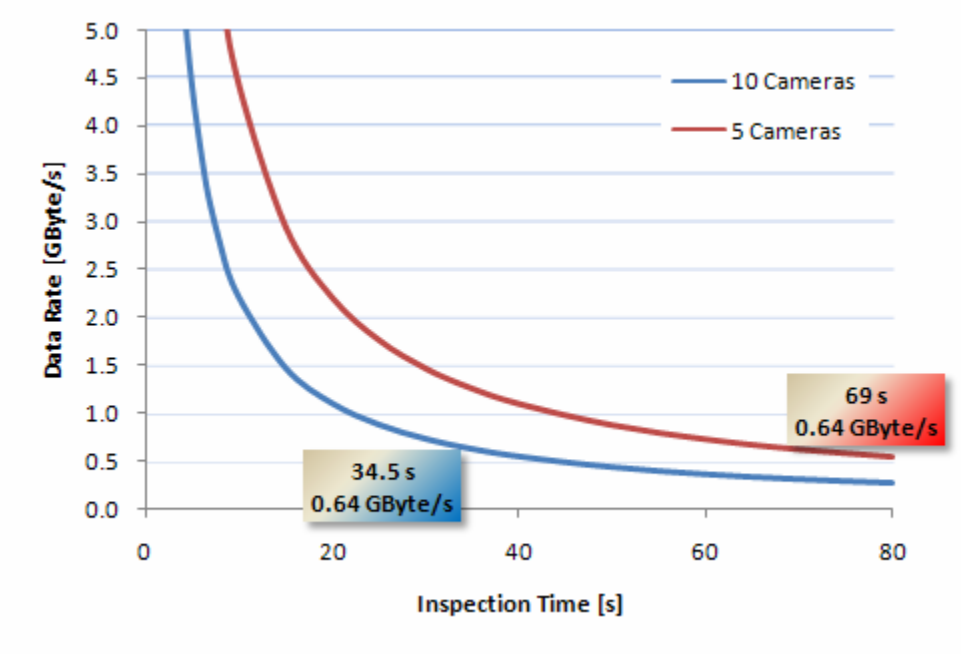
- Matrox's Solios eCL/XCL
  - Small amount of Preprocessing
- x4 PCI express/ PCI-X
  - PCI express : 1GByte/s for each direction
  - PCI-X (64bit, 133MHz) : 1GByte/s
- 64 MB acquisition buffer
  - Relatively Small buffer size - It's enough
  - Frame(number of line) Options
    - 2K x 500/1000/2000/4000 line
    - 1/2/4/8 MB per frame
- Camera Link
  - Dual Base/Medium Link
  - Full Link

Micro Inspection Specification

- Camera/Sensor : Area/Line
- Enlarge Defect Area after Macro Inspection
- Repair defects
- Resolution
  - Below 1μm x 1μm (About x10 optically magnified)
- Total Amount of Data
  - Proportion to no. of Areas where defects possibly exist
- Required Processing Power
  - Looser but *Real Time* *(large amount of data)*
  - Up to Camera maximum speed
  - **120 Mbyte/s**

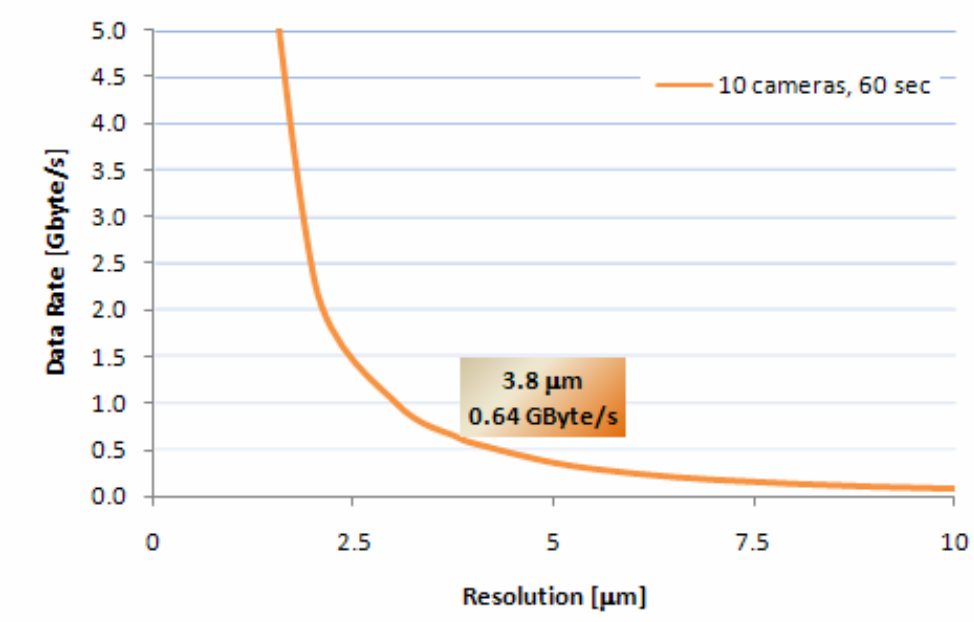
Macro Inspection Specification

- Scan Entire Area
- 7th Generation TFT
  - Size : 2200 x 2520mm
- Resolution : about 5μm x 5μm
- Total Amount of Data : 221.8GB per Panel



Data Rate

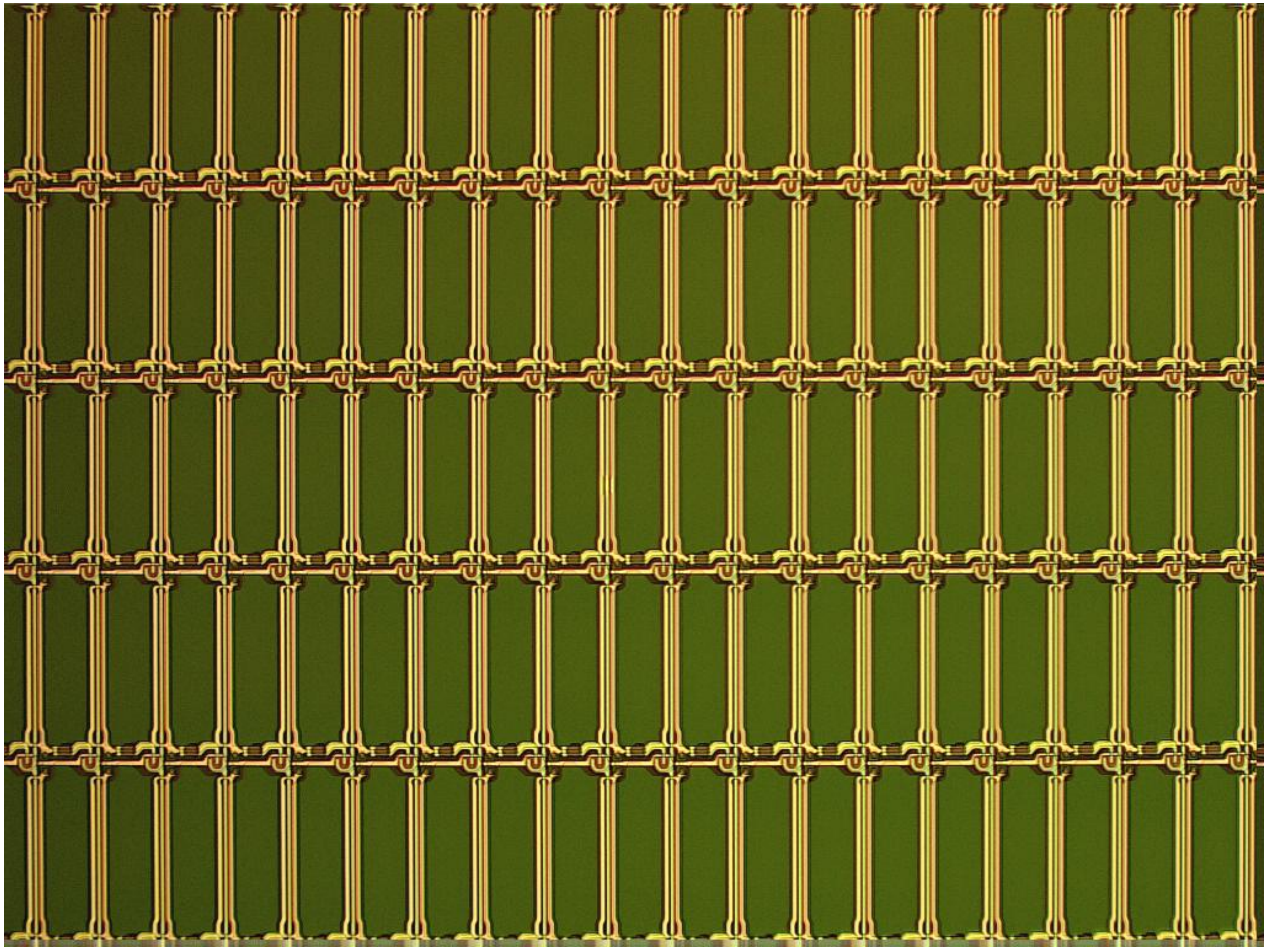
- No. of Cameras
- Inspection Time / Processing Speed
- Resolution
- Current Primary Target
  - ~640MByte/s



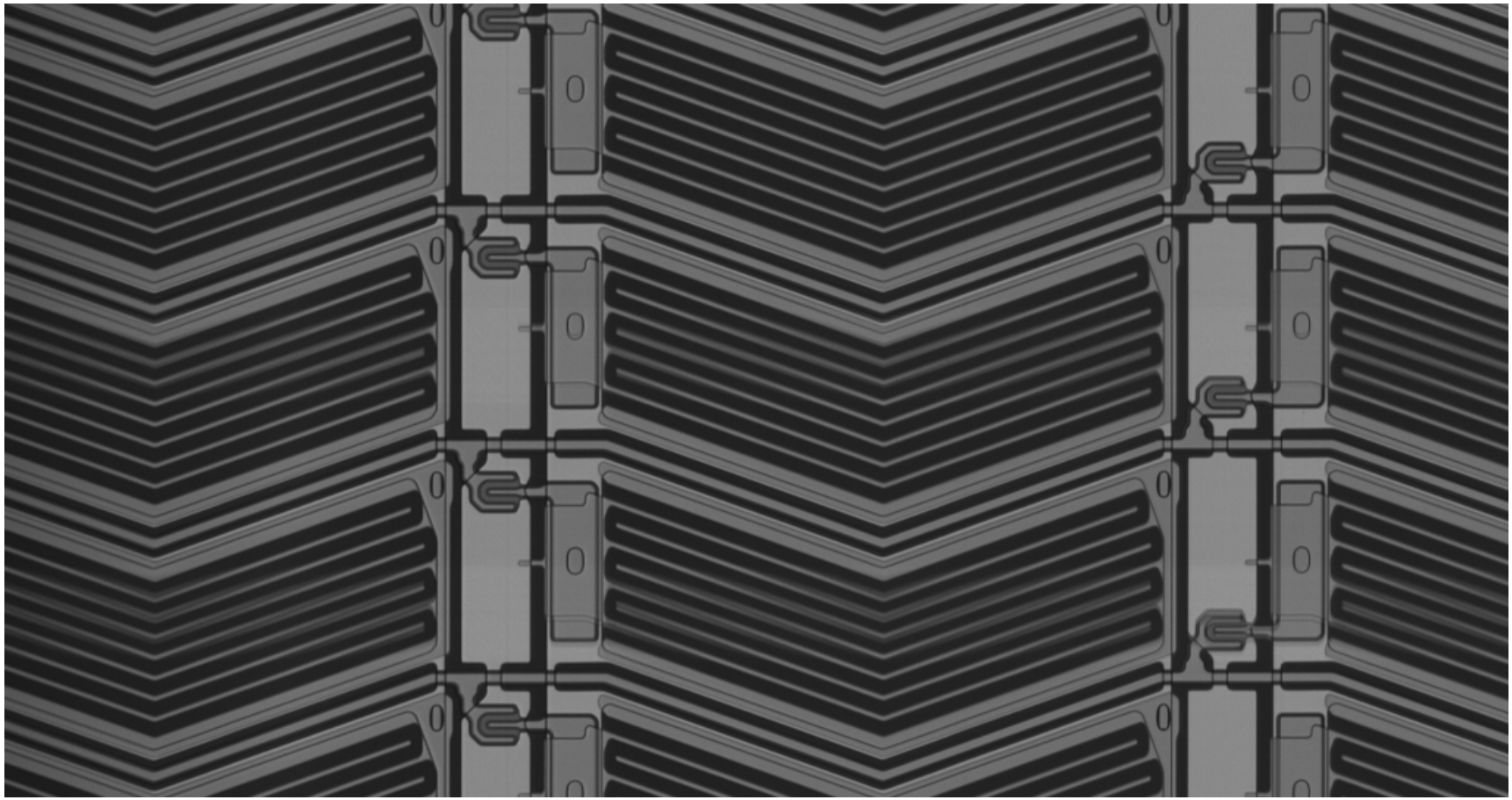
Speed Obstacles

- Image Quality (Simplifying Algorithm)
  - Unstabilized Focus
  - Scan speed perturbation
  - Unevenness of Light
  - Lens distortion
    - Reduce Camera Cell dimension / Enlarge lens diameter
  - Orientation
  - Large no. of defects
  - Sensor/Electrical Noise
- Algorithm Processing
  - Sensor/Camera Acquisition Speed
  - Data Transfer Bandwidth
  - Processing Speed

Light Unevenness & Lens distortion

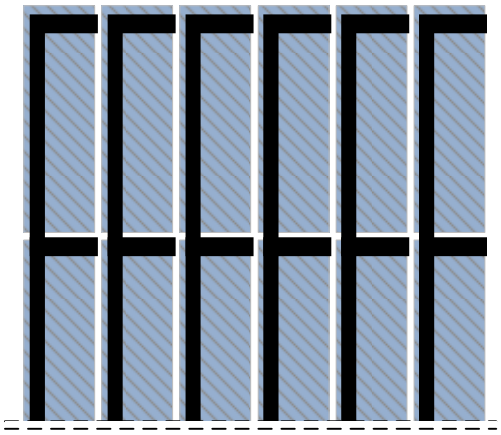


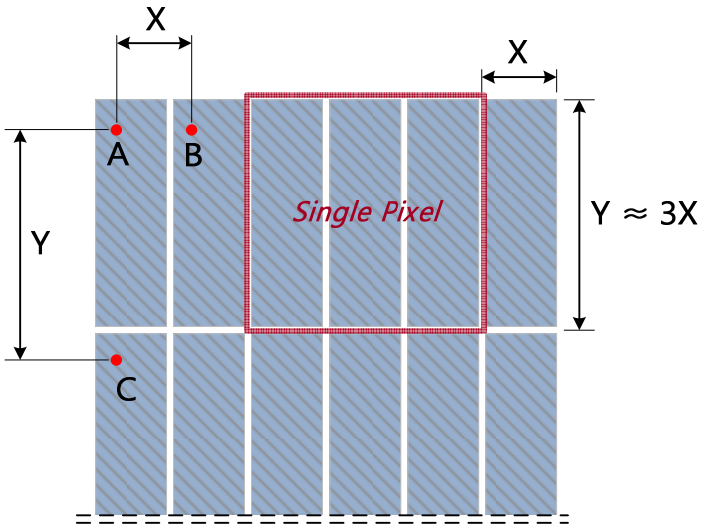
Scan Speed Perturbation

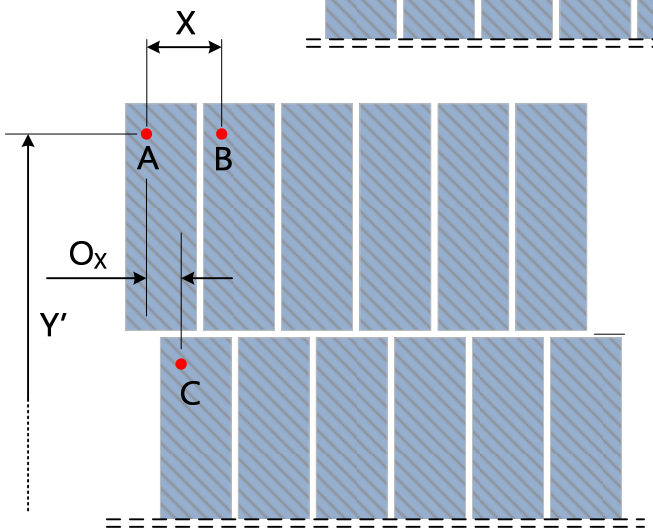


Basic Algorithms (1/4)

- Compare Neighbors
  - A, B and C
  - Constant distance X and Y
  - Shifted cell pattern
    - With Offset O_X
- Masking

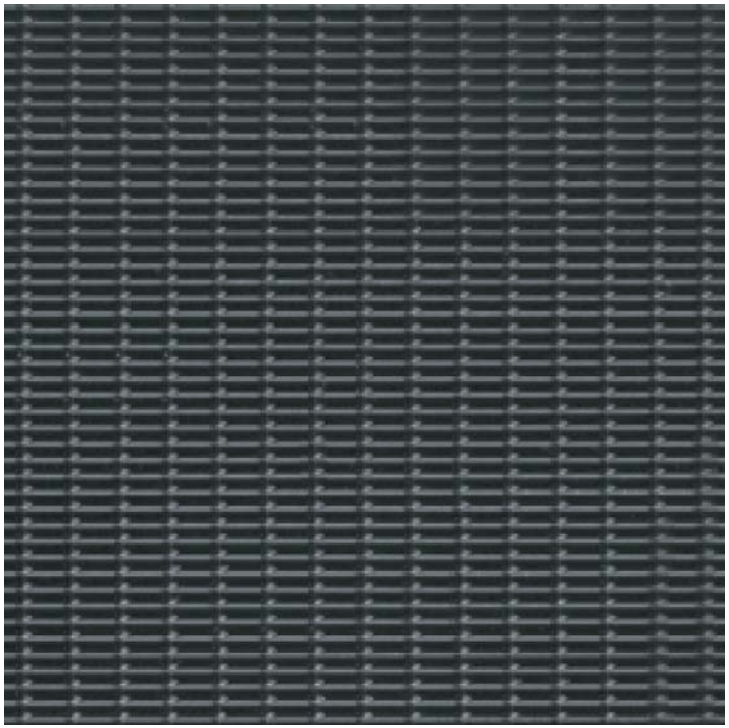


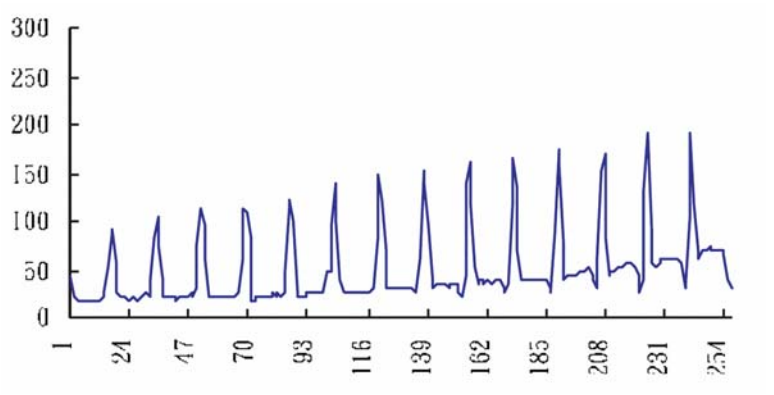


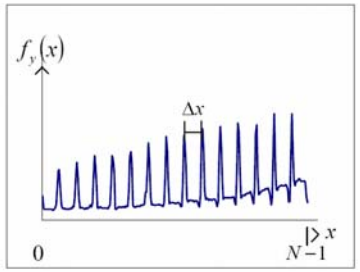


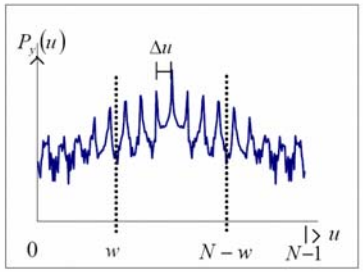
Basic Algorithm (2/4)

- 1D FFT (Macro Inspection)



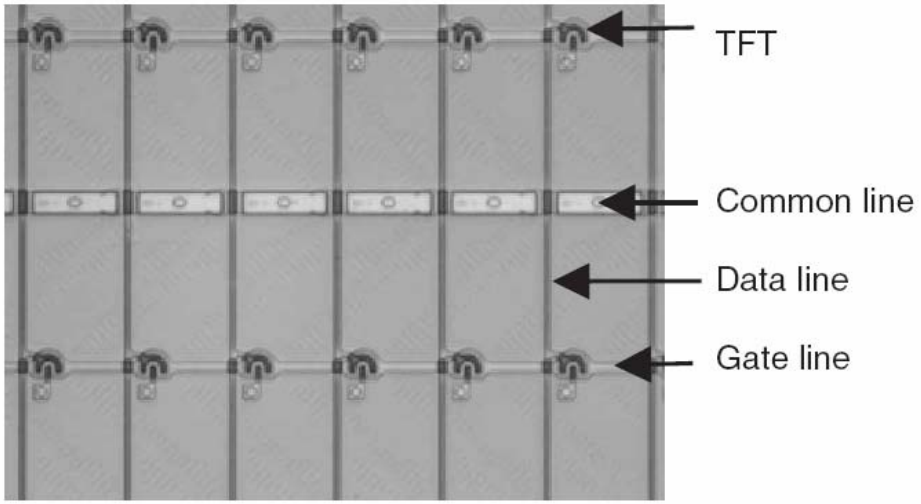


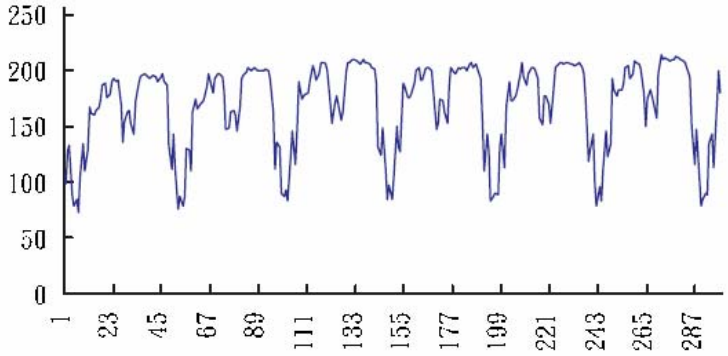




Basic Algorithm (3/4)

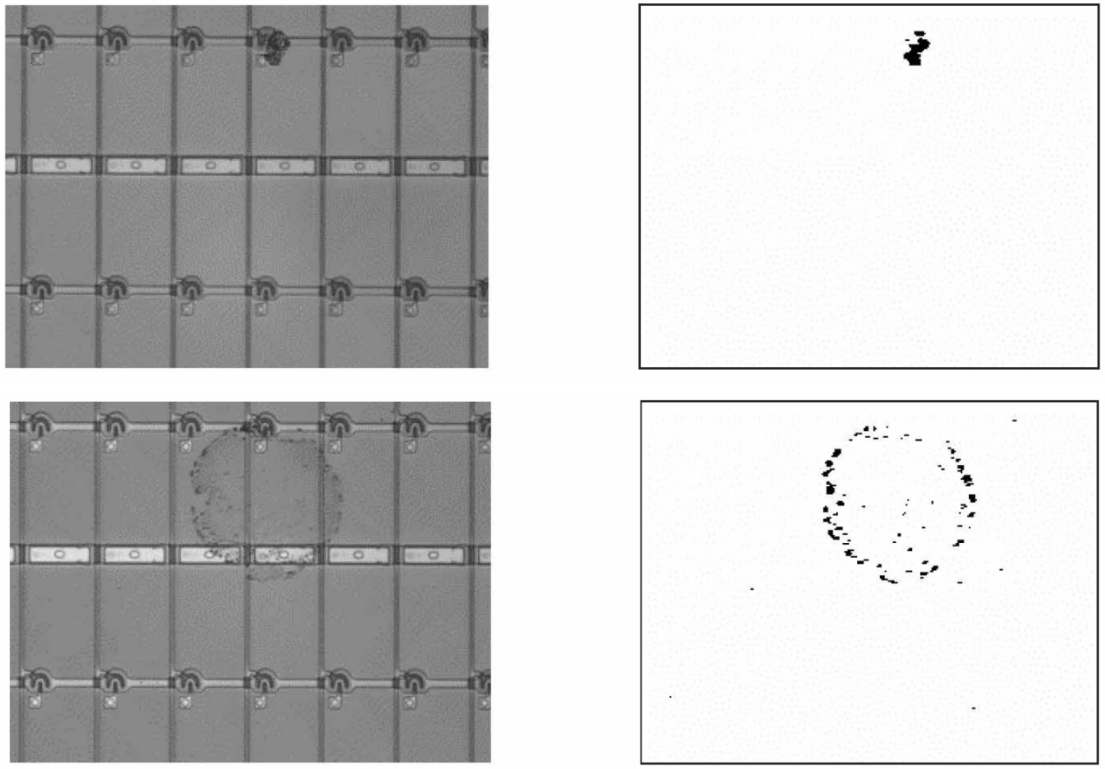
- 2D FFT (Micro Inspection)





Basic Algorithm (4/4)

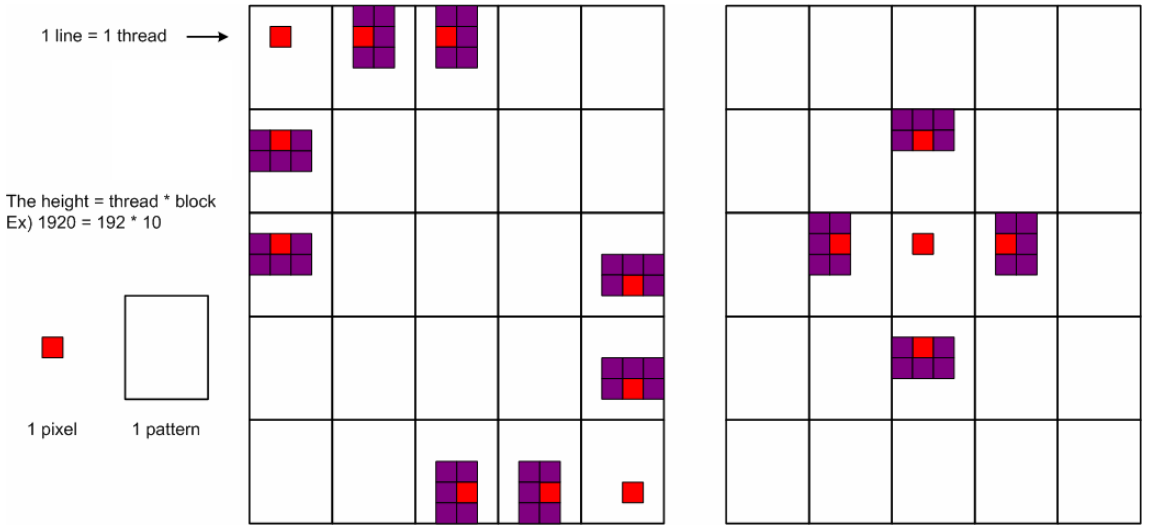
- Results



Reference : D.-M. TSAI, One-dimensional-based automatic defect inspection of multiple patterned TFT-LCD panels using Fourier image reconstruction 2007

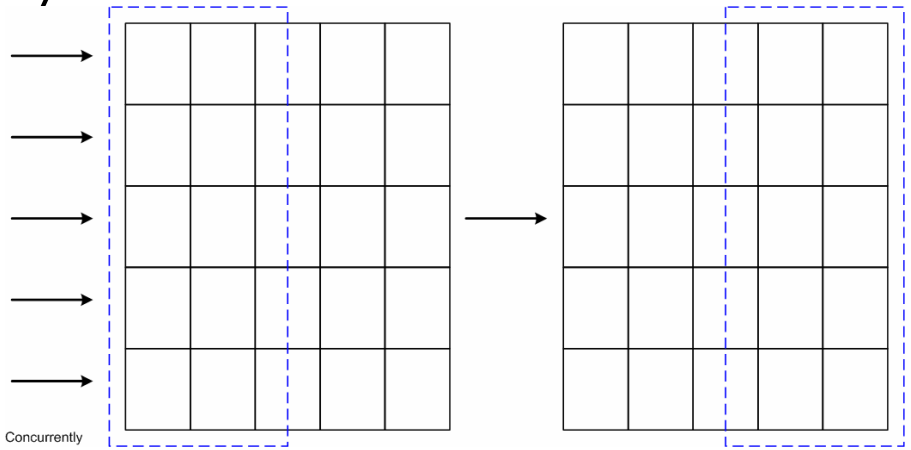
Implementation

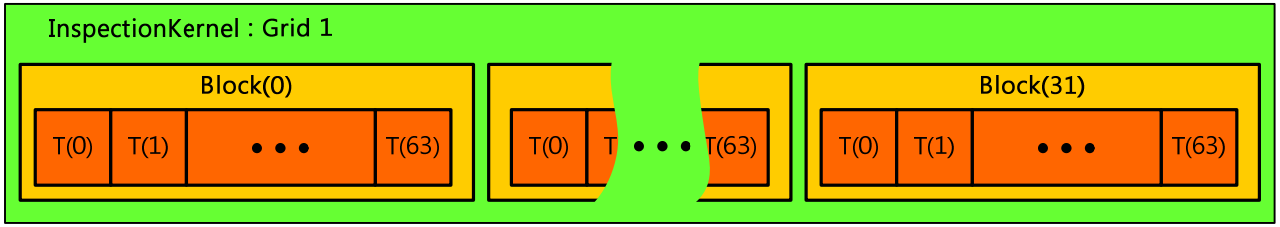
- Difference between patterns in neighbor
- Target pixel compared to 6 pixels in neighbor patterns :
  - Normal pixel should be below threshold



Implementation on GPU

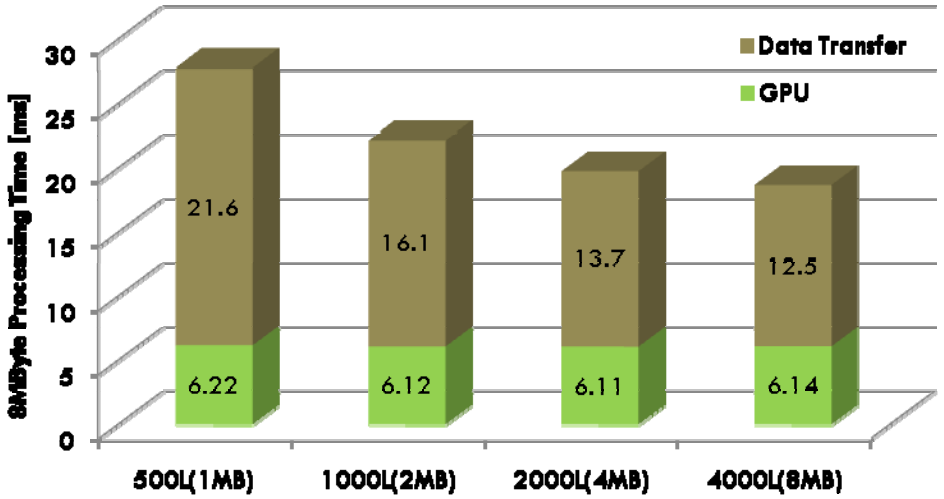
- 1 thread process through single line
- One Dimensional block/thread
  - 32 blocks in grid, 64 threads in a block (2048 thread)
  - Optimal : 32 threads in a warp
  - No. of threads can be increased by 32 times from 96 to 384
- Process from left to right





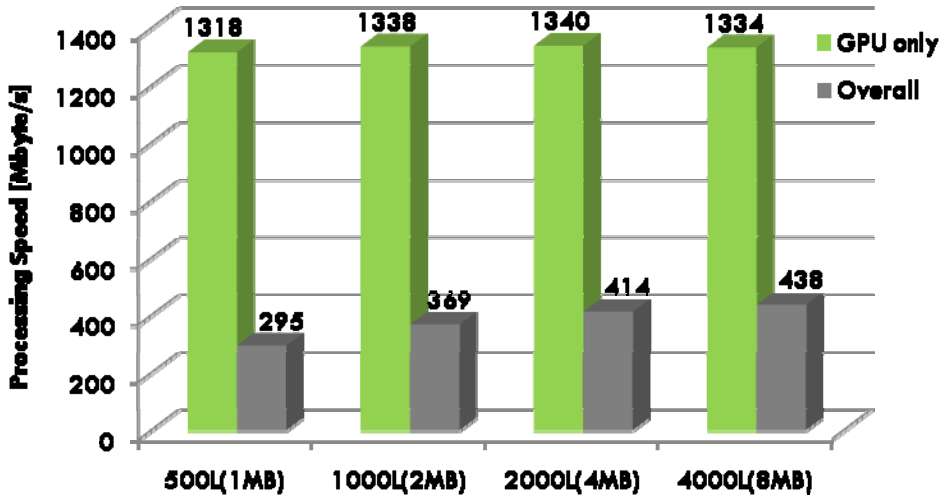
8MByte Processing Time (1/2)

- 2048x500 (≈1MByte) : Transfer ratio : 78 %
- 2048x1000 (≈2MByte) : Transfer ratio : 72 %
- 2048x2000 (≈4MByte) : Transfer ratio : 69 %
  - Best GPU efficiency
- 2048x4000 (≈8MByte) : Transfer ratio : 67 %
  - Best Transfer efficiency



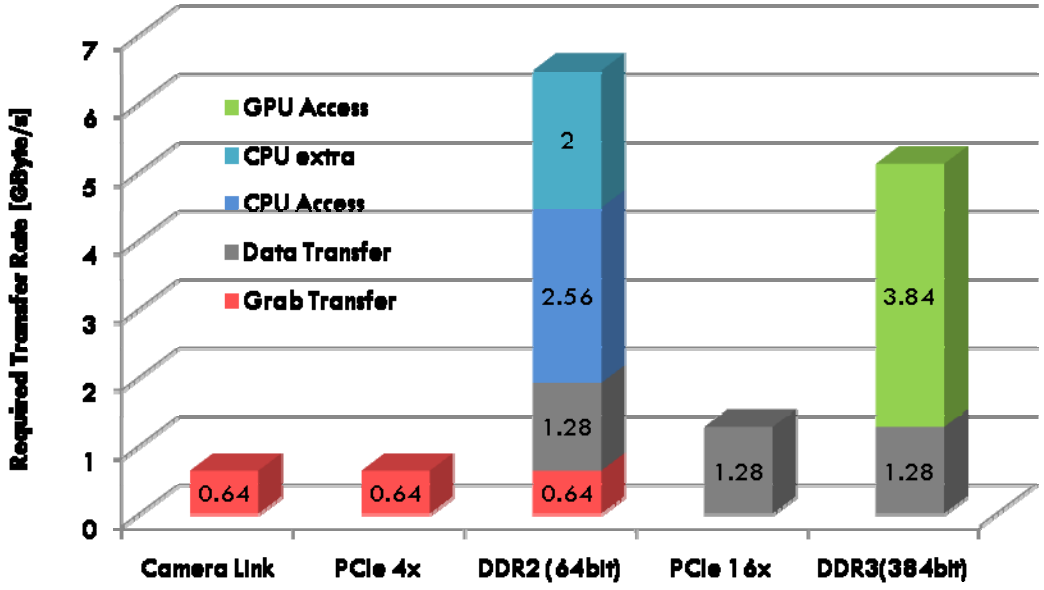
Processing Time (2/2)

- Reduce Data Transfer Time
  - Enlarge frame size
  - Reduce Result Data
  - Use streaming
  - Increase data Bandwidth (Host ←→ GPU)



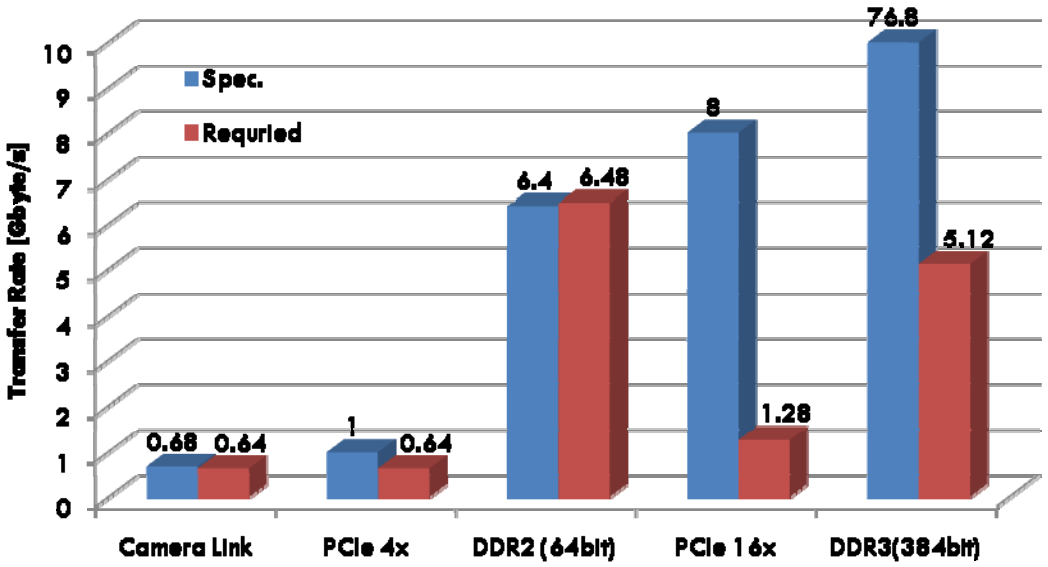
Required Bandwidth (1/2)

- Target Sensor/Camera Data Rate : 640MByte/s
- Extra CPU Main Memory (DDR2) Access
  - IO (Hard disk), DRAM Refresh / Phasing
  - Kernel/Application/Graphic
  - DMA Management



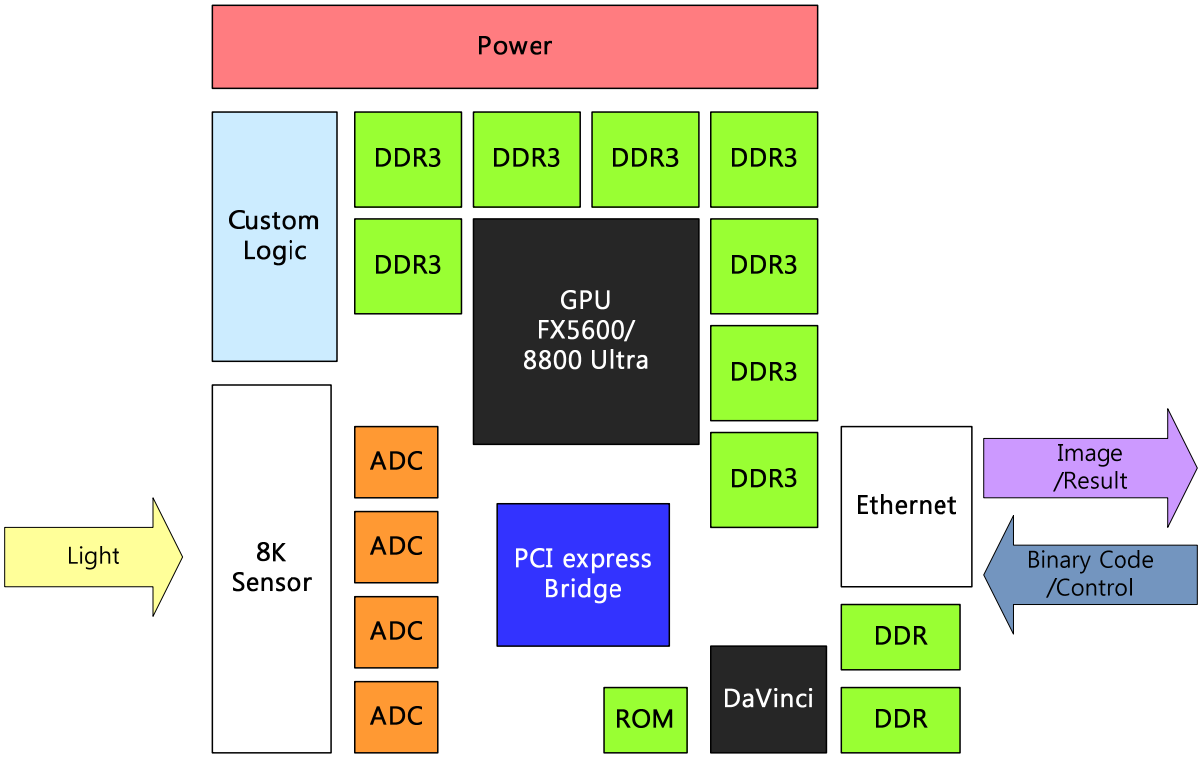
Required Bandwidth (2/2)

- **Actual Value**
  - **Host to Device (vice versa): 1.6 GByte/s**
  - **Device to Device : 62 GByte/s**



Embedded System

- Reduce No. of Computers
- Solve the bandwidth problem



Conclusion

- TFT Inspection System
  - Typical case of Single Instruction, Multiple Data (SIMD)
    - Relatively simple instruction/algorithm
    - Huge amount of data – Data Bandwidth important
- Currently 120MByte/s is achieved with CUDA
- 640Mbyte/s will be possible achieved with CUDA
  - Increase Data Bandwidth
    - Embedded system
    - Reduce extra transfer / Optimize Algorithm

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Thank You !