THAYER SCHOOL OF ENGINEERING AT DARTMOUTH

Early Research Progress on Quanta Image Sensors

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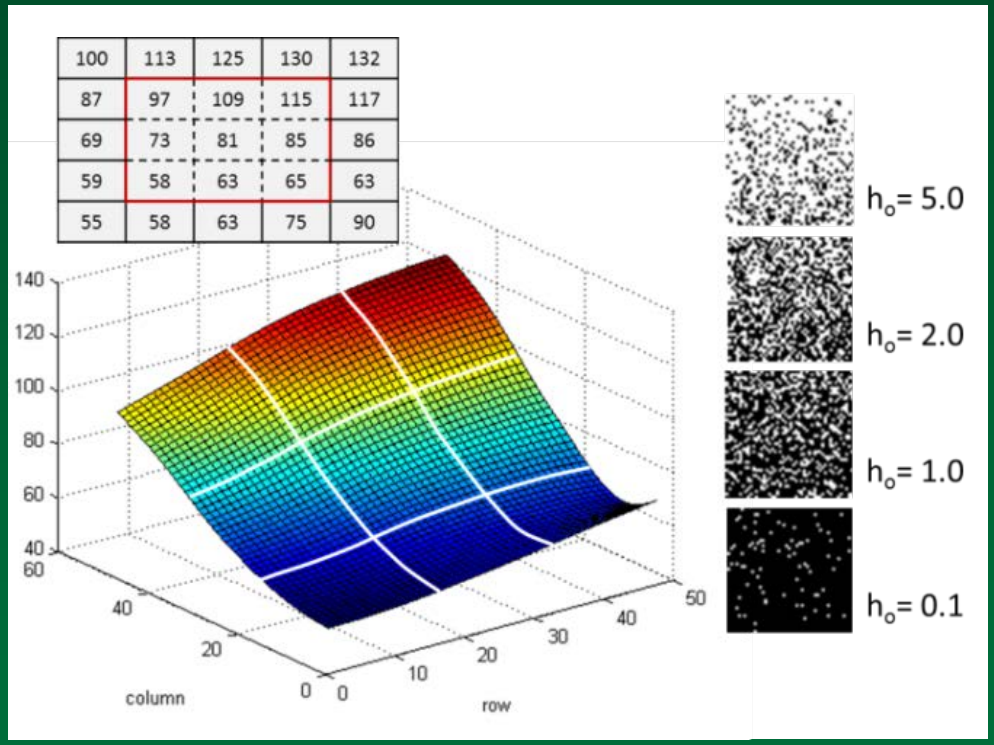
June 15, 2013

End to End System Simulation

Input Image
256x256 8b

→ 4096x4096 1b x 16 fields = 268 Mb



$$H = \frac{S_H h_o}{255}$$

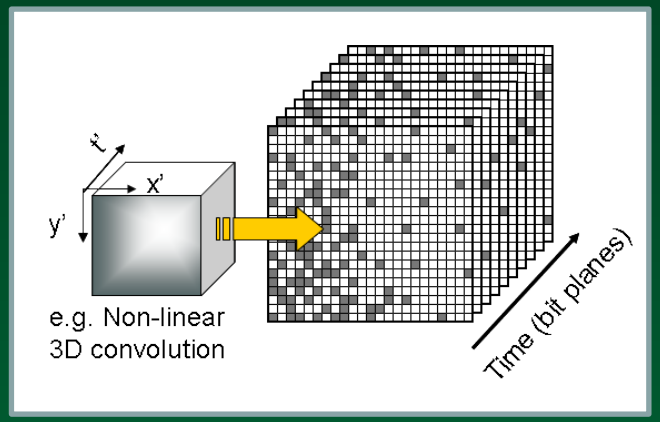
Output Image
1024x1024 8b

in this example

1 pixel = $\sum$ 4x4x16 jots

$SNR \leq \sqrt{256}$

Convolution

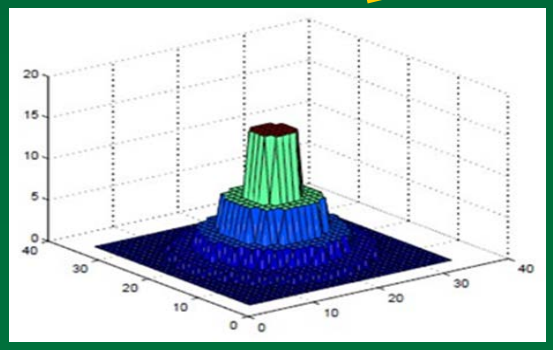


2D Examples:

Binary valued filter

1	1	1	1
1	1	1	1
1	1	1	1
1	1	1	1

Binary-weighted filter



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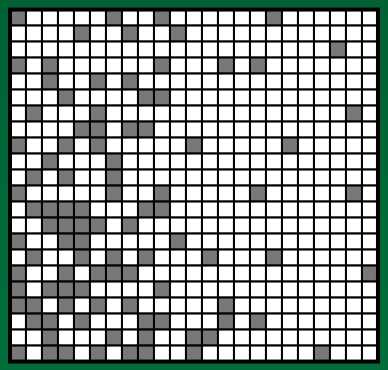
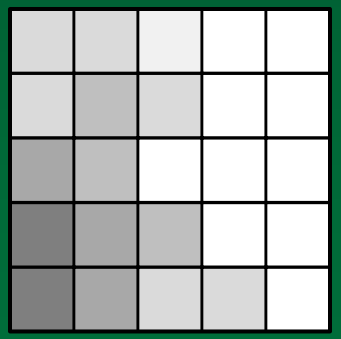


jot data

Down sample



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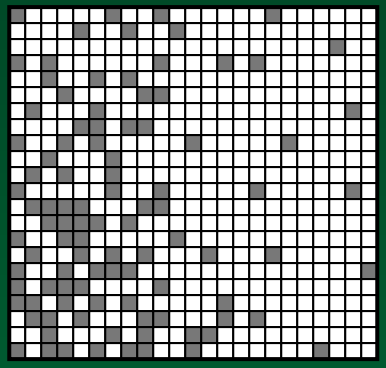
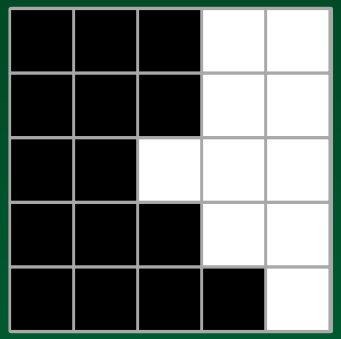
Digital Film Sensor Algorithm



Threshold
e.g. 3 hits
in 4x4

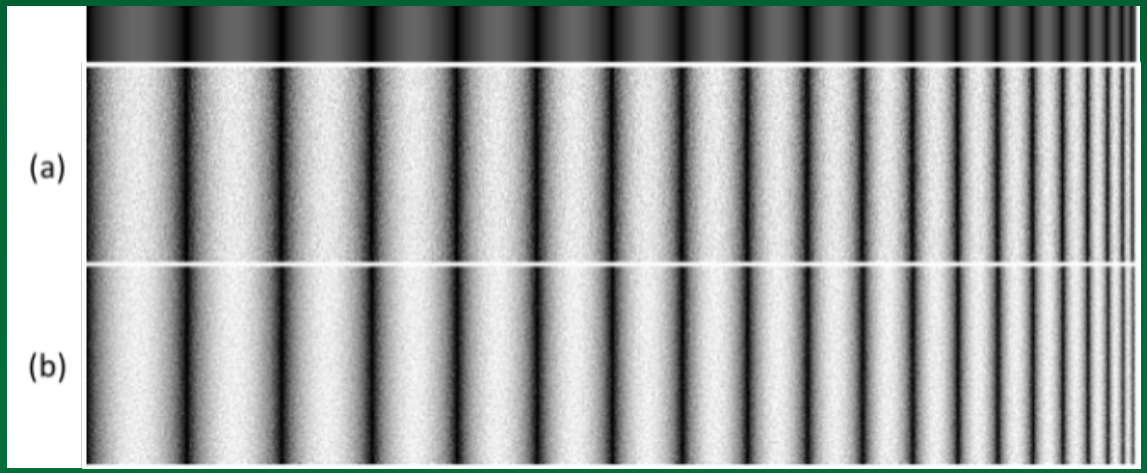


"gain"

Synthetic input image

After DFS development

Plus filter with dynamic kernel size



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Readout Signal Chain Strawman Design

General requirements:

- Need to scan 0.1-10 Gjots at 100-1000 fields per sec
- 8k – 80k jots per column → 0.8 – 80M jots/sec

Assumptions:

- 0.1 Gjot at 100 fps → 1Mjot/sec
- 1 mV/e- conversion gain
- 150 uV rms noise on column bus (0.15 e- rms)
- 0.18 um process
- Vdd = 1.8V

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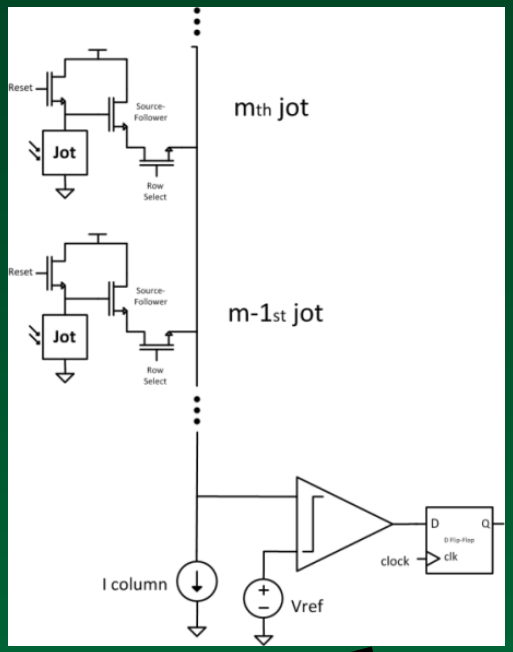
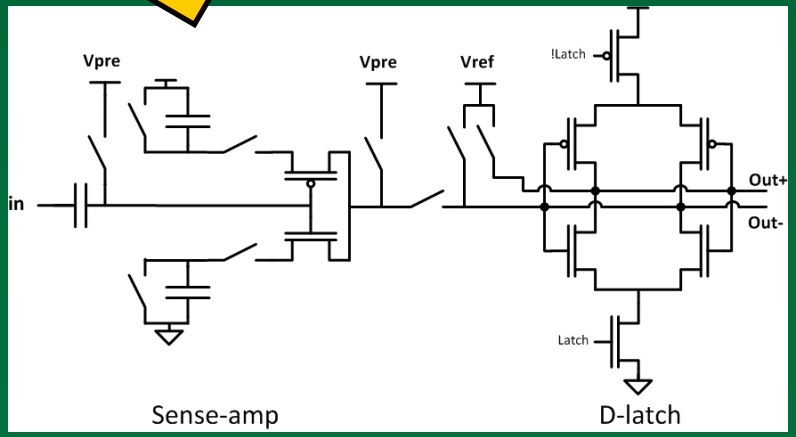
Readout Signal Chain



Generic column bus

Process	V_{DD}	Jot array	Column Speed	Column power	Comp power	Total	Array Power
CURRENT DESIGN							
0.18um	1.8V	0.001 Gjots (1k X 1k)	1MJ/s (1000fps)	0.71uW	1.28uW	1.99uW	1.99mW
0.18um	1.8V	0.1 Gjots (10k X 10k)	1MJ/s (100fps)	6.44uW	1.28uW	7.72uW	77.2mW
SCALED DESIGN							
0.18um	1.8V	0.1 Gjots (10k X 10k)	10MJ/s (1000fps)	64.4uW	12.8uW	77.2uW	772mW
45nm	1.1V	1 Gjots (24k X 42K)	24MJ/s (1000fps)	57uW	2.9uW	59.9uW	2.5W
22nm	0.8V	1 Gjots (24k X 42K)	24MJ/s (1000fps)	20uW	0.74uW	20.74uW	0.87W
45nm	1.1V	10 Gjots (75k X 133k)	75MJ/s (1000fps)	553uW	9uW	562uW	75W
22nm	0.8V	10 Gjots (75k X 133k)	75MJ/s (1000fps)	197uW	2.3uW	199.3uW	26.5W



Adapted from Kotani et al. 1998

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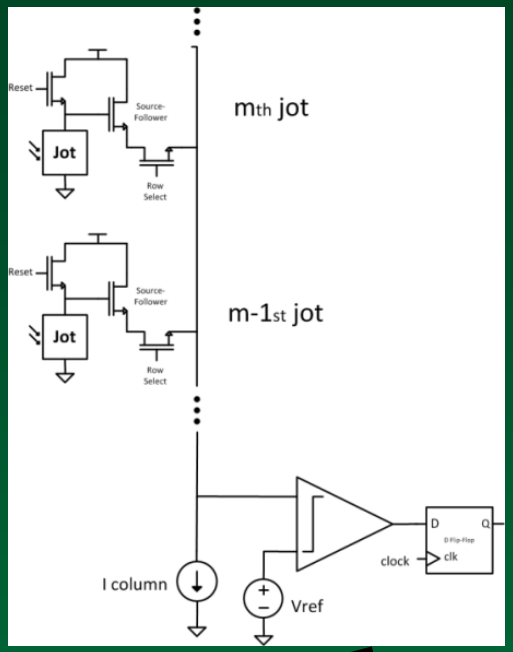
Readout Signal Chain



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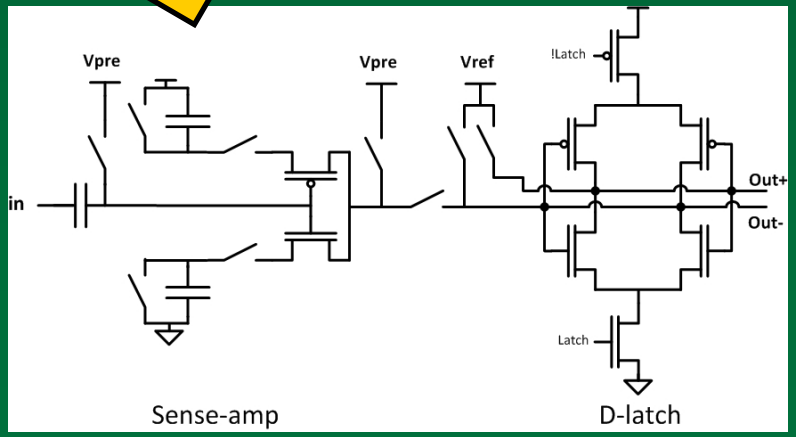

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Jot Device Considerations

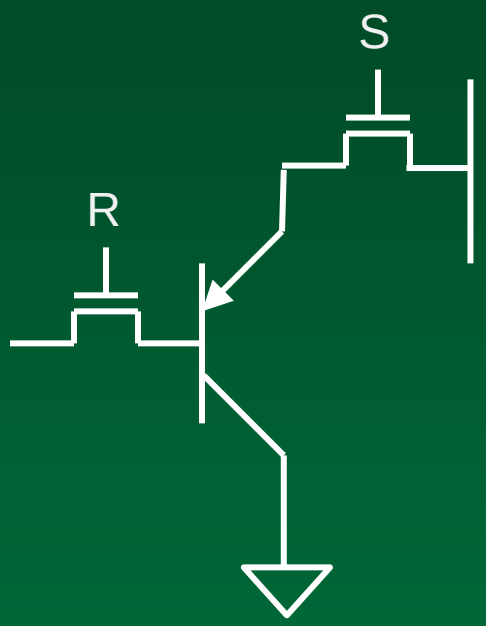
General requirements:

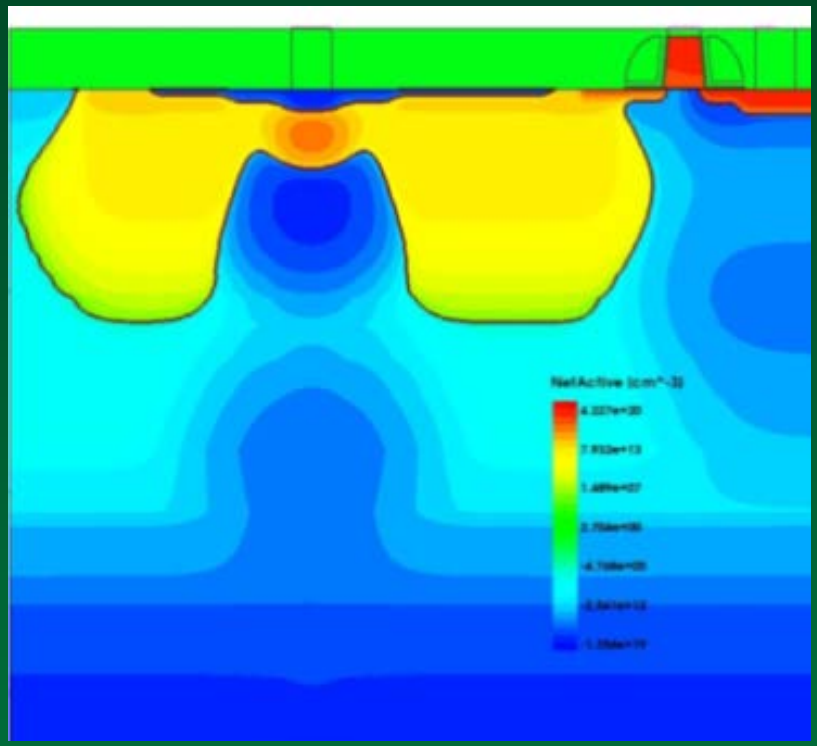
- 200 nm device in 22 nm process node (“10L”)
- High conversion gain > 1 mV/e- (per photoelectron)
- Small storage well capacity ~1-100 e-
- Complete reset for low noise
- Low active pixel transistor noise <150 uV rms
- Low dark current ~ 1 e-/s
- Not too difficult to fabricate in CIS line

For early investigation

- Cobbled together an imaginary 85 nm process
- Students learning to use TCAD tools etc.
- Anticipate that device principles can be migrated to real process

Bipolar Jot Concept





- CMOS APS but use pinning layer as emitter, storage well as base
- Complete reset of base using “TG”
- Emitter follower to reduce base-emitter cap

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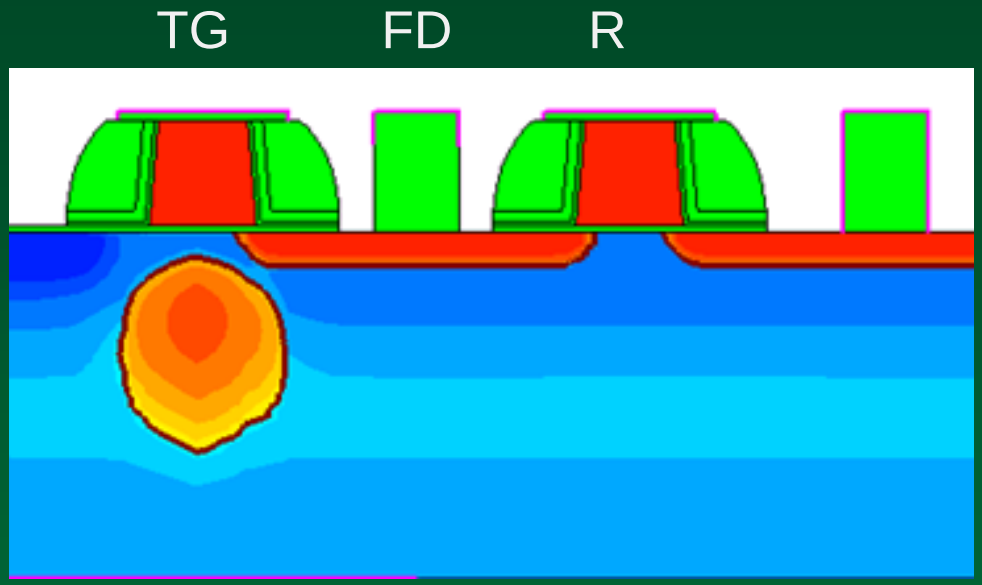
BSI CMOS APS Jot with Storage under Transfer Gate



- Low capacity storage gate makes barrier easier to overcome with low TG voltage
- Minimum FD size to increase conversion gain

Storage under transfer gate first proposed in
Back Illuminated Vertically Pinned Photodiode with in Depth Charge Storage, by J. Michelot, et al., 2011 IISW

Summary

- Early progress made on realizing Quanta Image Sensor
- >1 year support of Rambus (thanks Rambus!)
- Students up to speed and making headway
- Challenges don’t look as challenging
- Lots of work to do!