QUCAM

COURSE INFO

SCIENTIFIC DETECTORS IN THE VISIBLE AND INFRA-RED

Teacher: Dr. Simon Tulloch has worked for 20 years in observatory operations and scientific instrument development. He has built cryogenic cameras at the Isaac Newton Group, the European Southern Observatory and as a private contractor at the University Complutense.

Course Summary: The course begins with an introduction to the solid-state physics underlying the operation of modern scientific visible and near infra-red detectors. The basic principles of photo-diodes, CMOS and CCD detectors are then outlined. Visible wavelength detectors are then described in more detail. It is explained how CCD detectors have been progressively improved over the last 50 years and how their performance is now closely approaching that of an ideal detector. The current state of alternative CMOS design detectors and how they compare to CCDs is also described. Photon counting detectors such as the Electron Multiplying CCD and the Leonardo Saphira are also covered. The course then moves to longer wavelengths, covering the use of Teledyne Hawaii HxRG Near-Infra-Red (NIR) detectors and the Raytheon Aquarius Mid-Infra-Red (MIR) detectors. The various noise sources that degrade scientific observations with any detector and the way they combine statistically are examined in depth. The course finishes with a study of essential detector related topics such as characterisation, cryo-vacuum systems, thermal control and controller electronics.

At whom the course is oriented: The course is oriented at physicists, engineers and astronomers that have worked or are working in instrumental projects that involve the use of CCDs or IR imaging arrays, who feel that that they would benefit from a more in-depth knowledge of the detectors that play such a central role in the performance of their instruments. The course would also be a valuable introduction for those wishing to become scientific detector specialists.

Previous grounding: A basic grounding in physics is required. Some knowledge of electronics would be desirable but is not essential. The course contains very little mathematics.

At the end, the attendances will get:

- To gain an in-depth knowledge of the physics underlying modern scientific visible and infra-red detectors.

- An appreciation of the current advanced level of detector technology and the likely paths that further development will take in the near future.

- To be in a position to identify a suitable detector technology for their particular engineering application and to understand the various performance parameters described in manufacturers data sheets.

- A knowledge of the techniques of detector characterisation in practical camera systems.

SPECIFIC TOPICS COVERED

Underlying Physics:
- Semiconductors and the Periodic Table.
- The PN junction and its sensitivity to light.
- The electromagnetic spectrum and atmospheric transmission.
- Understanding detector performance data.
- Statistics of photons.

CCDs:
- Physical structure.
- CCD clock sequence design.
- Output amplifier variants.
- Noise sources: read noise, dark current, reset noise and photon noise.
- Boosting performance with backside illumination and thinning.
- Deep-depletion CCDs and Fringing.
- Anti-reflective coatings and Quantum Efficiency.
- Hi-Rho and Bulk-silicon CCDs.
- Electron-multiplying CCDs and their advantages/disadvantages.
- Traps.
- High-speed operation.
- Low-noise preamplifiers.
- Analogue and Digital video processor design.
- CCD mosaics.
- CCDs in Space.
- ESD precautions.

CMOS sensors:
- Physical structure.
- Global and Line Reset.
- Unit cell circuitry: 3T,4T and 5T designs.
- Boosting performance with microlenses and Silicon-on-Insulator fabrication.
- Hybrid CMOS.

Infra-red sensors:
- Mercury Cadmium Tellurium as a sensor material.
- The Teledyne HxRG detectors.
- The Saphira detector.
- Blocked Impurity Band detectors.
- Fowler Sampling.
- Persistence.
- Subtle image defects.

Cryo-vacuum systems:
- The Planck curve and the need for cooling.
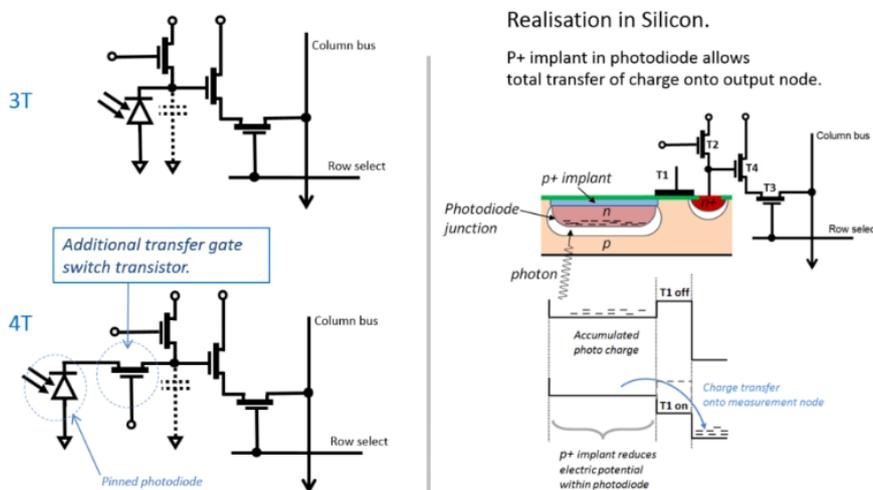- Cooling methods.
- Thermal sensing and control.

- Vacuum materials.

Detector Characterisation:
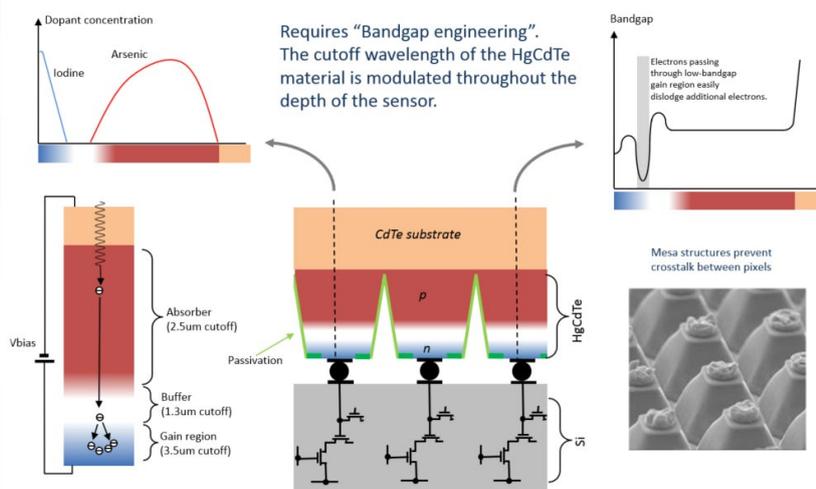
- Measuring Quantum Efficiency.
- Measuring gain and noise.
- Flat-fielding.
- Use of Iron-55 X-rays.
- Mosaic Coplanarity.

SAMPLE PRESENTATION MATERIAL

Low-noise CMOS: the 4T alternative

3T

Column bus

Row select

Additional transfer gate switch transistor.

4T

Column bus

Row select

Pinned photodiode

Realisation in Silicon.

P+ implant in photodiode allows total transfer of charge onto output node.

p+ implant

Photodiode junction

n

p

photon

Column bus

T2

T1

T4

T3

Row select

T1 off

Accumulated photo charge

Charge transfer onto measurement node

T1 on

p+ implant reduces electric potential within photodiode

Internal Structure of Saphira

Dopant concentration

Arsenic

Iodine

Bandgap

Electrons passing through low-bandgap gain region easily dislodge additional electrons.

Requires "Bandgap engineering".
The cutoff wavelength of the HgCdTe material is modulated throughout the depth of the sensor.

CdTe substrate

p

n

Passivation

Absorber (2.5um cutoff)

Buffer (1.3um cutoff)

Gain region (3.5um cutoff)

Vbias

HgCdTe

Si

Mesa structures prevent crosstalk between pixels

"eAPD" = electron multiplying avalanche photo-diode

VENUES

The course is normally given at premises in Sevilla in the south of Spain. Given the current COVID situation, however, the course is now only available on-line via Zoom. This format has proved very successful with over 50 clients served. Optimum class size appears to be around 6-8 clients.

COURSE FORMAT AND PRICE

The course consists of 3 days of power point presentations. English medium will be used although the teacher is fluent in Spanish also. Each day is divided into 4 1-hour sessions with breaks for coffee and lunch. Course times are totally flexible. Some reformatting may be required for clients in distant time zones.

Price for zoom-based course:

Per student : €850+VAT. Includes 80 page booklet of printed course material. 12 hours of presentations total.

Minimum class size 5 students. Discounts for groups greater than 10.

Shorter courses could be prepared for clients only interested in the fundamentals of detector technology.

smt@qucam.com

www.qucam.com