INTRODUCTION

Physical characterization of exoplanets is possible with the help of transit method of photometry. When the planet transits the star as seen from Earth, the starlight gets dimmer by the planet-to-star area ratio. If the size of the star is known, the planet size can be derived. The transit technique also makes it possible to characterize atmospheric constituents of exoplanets.

1. **IMAGE SENSORS**:

Image sensors are an essential part of the optical payload of a CubeSat. An image sensor is an electronic device that converts an optical image into an electronic signal. Sky survey applications require large format image sensors with high quantum efficiency, low read-out noise, fast read-out and a good inter- and cross-pixel stability and linearity. Following are the image sensors and their properties.

a. **Charge-Coupled Devices (CCD) sensors:**

- A charge-coupled device (CCD) is an integrated circuit containing an array of linked, or coupled, capacitors. Under the control of an external circuit, each capacitor can transfer its electric charge to a neighbouring capacitor.
- CCDs are linear sensors, with an output directly related to the number of photons received.
- CCD detectors transfer the photoelectrons in rows and then convert the charge to a voltage signal after the transfer.
- The CCD performs the photometry function, conducting relatively long integrations (up to 10 seconds) to collect as many photons as possible from the target star.

b. **Complementary Metal–Oxide–Semiconductor (CMOS) imaging sensors:**

- CMOS Image Sensors integrate amplification directly in the pixel. It provides a parallel readout architecture, where each pixel can be addressed individually or read out in parallel as a group
- The CMOS sensors are used to track the centroids of surrounding guide stars at a much faster update rate, serving as a star tracker for attitude determination.
- CMOS chips convert the charge to a voltage signal at each pixel. This parallel processing allows CMOS chips to read very quickly, but it also adds more read noise into the system

c. **Hyperspectral imaging sensors:**

- Hyperspectral imaging collects and processes information from across the electromagnetic spectrum.
- The goal of hyperspectral imaging is to obtain the spectrum for each pixel in the image of a scene, with the purpose of finding objects, identifying materials, or detecting processes.
- Recently, the United States government has sought to use CubeSats as low-cost platforms for advanced technology development, including hyperspectral sensors

CMOS image sensors and CCD detectors both offer low read-out noise, large sensitive area, and high frame rates. CMOS and CCD chips both harness the photoelectric effect to collect photons over an area and convert them into a signal, keeping spatial and intensity information.

ADVANTAGES AND DISADVANTAGES OF CMOS AND CCD SENSORS

- CCD detectors have outperformed other types of imagers which can be used for collecting astronomical data for decades. However, the CMOS technology is becoming comparable in its power to collect and transfer charges with low additional noise.
- CCDs lack only the read-out speeds which significantly lowers their performance for detecting and characterizing rapidly varying or moving celestial objects.
- CCD detectors usually have an advantage in collecting photons because they have higher quantum efficiency, a larger well capacity, and a better ratio of light-collection-area to electronics.
- CMOS imagers beat CCDs in settings where fast readouts are necessary or in environments with high radiation levels.
- The values for the dark current in the CMOS chip were higher than the CCD because exposure times for the CMOS were longer.
- CMOS sensors are much less expensive to manufacture than CCD sensors.

SOME TERMS RELATED TO IMAGE SENSORS

Dark current: Dark current in CMOS imaging sensor is a process of spurious electrons generation in the photodiode in the absence of incoming light, with many possible sources behind it, e.g., thermal generation, “diffusion” current, etc.

Jitter noise: The photometric signal is corrupted by jitter noise, which arises due to the combination of pixel response non-uniformity and spacecraft pointing error.

Read noise: Read noise or Johnson noise originates from the temperature dependent fluctuation in the load resistance R of the transimpedance detection circuit. The term "read noise" tends to be a catch-all for any noise that arises during the process of counting the electrons.

quantum efficiency: probability of generating of a photoelectron from an incident photon.

Piezo Stage: A Piezo Stage can be characterized as a mechanical device, driven by a piezoelectric actuator, which provides one or more axis of motion. Piezo stages are used in nano positioning applications since they can achieve that level of precision. It is the key element to reduce the spacecraft jitter to few ppm of noise.

Drawback: Piezo materials are influenced by environmental conditions like temperature and changes in moistness.

2. **IMAGE SENSOR MODELS:**

a. **Cypress HAS2 detector**

- HAS2 is a member in the STAR family of radiation-tolerant CMOS image sensors. The device has an array of 1024 x 1024 active pixels (18 µm pixel pitch) and supports on-chip Non-Destructive Readout and multiple windowing.
- Radiation hardened CMOS images play an important role in radiation environments where normal CMOS or CCD image sensors cannot survive, and where CRT image tubes are too expensive, too heavy or too large.
- The HAS temperature features are: dark current doubling for sensor temperature increment of 5.8 ◦C (average), and voltage-temperature variation of −4.64 mV/◦C.

b. **CIS2521F**

- The Fairchild Imaging CIS2521F has a large format, ultra-low-noise CMOS image sensor intended for scientific and industrial applications requiring high quality imaging under extremely low light conditions.
- The CIS2521F delivers extreme low-light sensitivity with a read noise less than 1.5 electrons RMS, Quantum Efficiency (QE) above 52% and very low dark current. These features, combined with 5.5-megapixel resolution and 100 fps imaging rates, makes the CIS2521F an imaging device ideally suited for a variety of high throughput, low light-level imaging applications.
- Andor Neo is one such camera that uses CIS2521F

c. **GSense400BSI**

- GSense400BSI is a scientific CMOS sensor with larger well depth, up to 120k electrons, and a back illuminated options having significantly better quantum efficiency (up to 95%). It is released by Gpixel.
- The GSENSE400BSI is ideal for scientific applications where both low noise and high dynamic range are critical requirements, utilizing an 11 µm pixel to deliver >93dB dynamic range in HDR mode, 1.6 e- read noise, a peak QE of 95% and achieving frame rates up to 48 fps.
- Andor Marana is a camera built around such back-illuminated chip, GSense400BSI.

OPTICAL PAYLOAD AND IMAGERS

a. **iSIM-90 VNIR SWIR**

iSIM-90 is the lightest and most compact optical payload of the iSIM family. It has been purposefully designed to fit 12U/16U CubeSat platforms, while keeping a high performance to mass ratio.

The payload includes the optical front-end as well as state-of-the-art CMOS matrix detectors and an electronics subsystem for payload management and control. With a total mass below 6kg, iSIM-90 can achieve ground resolution down to 1.65m from an altitude of 500km. It covers the Visible & Near Infrared (VNIR) spectral range, offering both panchromatic and multispectral imaging capabilities according to the user's needs.

b. **HyperScape100**

Simera Sense's HyperScape100 is a hyperspectral push-broom imager primarily designed for Earth Observation (EO) applications, as a payload for CubeSats. It is based on a CMOS image sensor and custom continuously variable optical filter in the visible and near-infrared (VNIR) spectral range.

c. **Caiman imager**

Dragonfly Aerospace's Caiman imager is a high-resolution, multispectral camera that is optimized for integration with 6U or larger CubeSat frames.

The main features and benefits include:

High-resolution, multispectral imaging, high-speed data storage, compact form factor that is optimized for integration with 6U or larger CubeSat frames customizable on-board storage and downlink options mechanical compatibility with standard CubeSat frames.

The Caiman imager offers imaging across 7 multispectral bands.

d. **Chameleon imager**

The Chameleon imager is a multispectral or hyperspectral camera suitable for integration with 3U or larger CubeSats. It builds upon the space qualified control electronics of the Gecko imager and combines this with high performance optics to maximize imaging capability in small form factor Cubesats. High capacity, high performance mass storage is integrated into the compact design.

The opto-mechanics have been optimized to fit within the available volume of CubeSat deployers, thus providing maximum volume to accommodate the functionality required for high performance CubeSat missions.