EDITION
AN-08

APPLICATION PRIMER · SPACE · ASTRONOMY

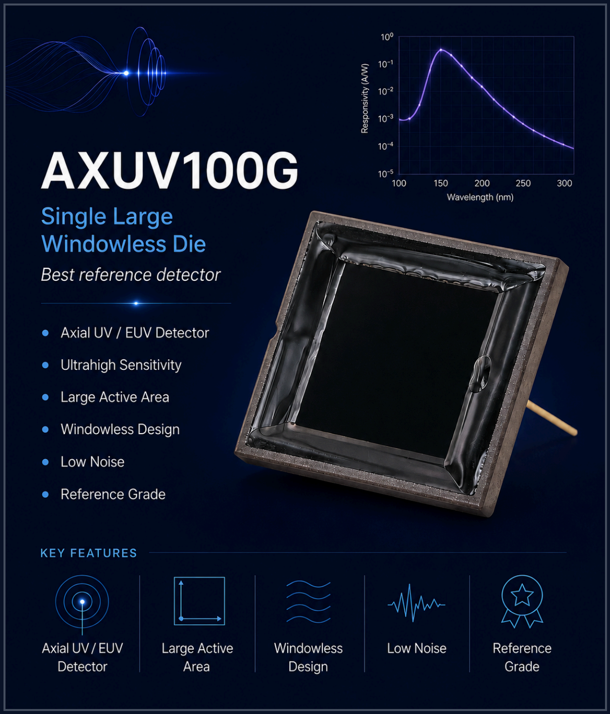
Seeing in Space: A Primer on Photodetection for Astronomy and Space Science

A technical introduction to photodetection beyond the atmosphere: the spectral bands accessible on orbit, the physical information each one carries, how solid-state point detectors complement imaging arrays, and the environmental factors that constrain detector selection. Written for engineers new to space photonics.

DETECTOR IN FOCUS

AXUV Series

UV-to-soft-X-ray stable silicon photodiode · radiation-tolerant · response calibratable to NIST traceability



λ	Soft X-ray – NIR
ANCHOR	AXUV / SXUV
RESPONSE	Stable, calibratable
ENVIRONMENT	Vacuum · radiation

WHAT YOU'LL LEARN

- L.01 Why astronomical information is distributed across the full spectrum
- L.02 The spectral reach and limits of silicon photodiodes on orbit
- L.03 How imaging detectors differ from measurement detectors
- L.04 How the space environment degrades a detector, and how it is mitigated

WHO IT'S FOR

- A.01 Engineers new to space photonics
- A.02 CubeSat and smallsat payload designers
- A.03 Solar physics and heliophysics instrument teams
- A.04 Students and early-career space-science engineers

OVERVIEW

Astronomy is fundamentally a photon-collection problem, and space science extends it above the atmosphere, where the optical path is unobstructed but the operating environment is severe. For an engineer arriving from another discipline, two facts reframe the work. First, most of the available information lies outside the visible band: a single source can present entirely different structure in X-ray, ultraviolet, infrared, and radio. Second, not every detector forms an image. A large fraction of space measurements are made by small, calibrated photodiodes that report incident flux within a defined band and hold that response, without measurable drift, across the mission lifetime. This primer outlines the territory: the spectrum, the detector families that span it, the environmental constraints they must tolerate, and where a stable reference photodiode is the appropriate choice on a spacecraft.

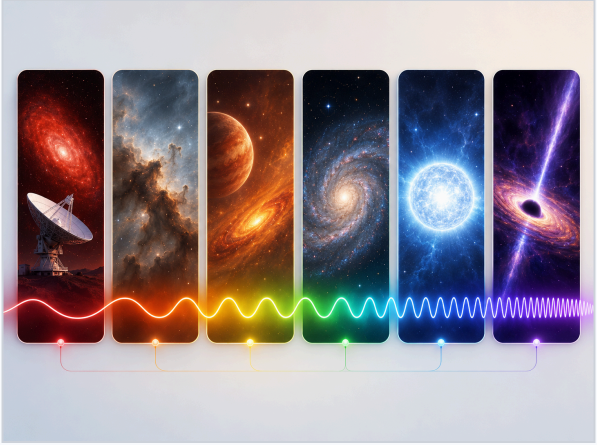
01

01 · THE OBSERVING PROBLEM

Orbit provides the full spectrum and very few photons.

Above the atmosphere, two conditions change simultaneously. The accessible passband widens: the atmosphere no longer absorbs ultraviolet, X-rays, and most infrared, so the full spectrum becomes observable. Everything else gets harder. Astronomical sources are faint, often delivering only a low photon flux that demands long integration times, while the same instrument may have to operate pointed near the Sun. The required dynamic range is large, the signal of interest is typically small, and no component can be serviced or replaced after launch. Combined with radiation exposure, hard vacuum, and wide thermal excursions, the detector becomes one of the most constrained choices in the instrument.

FIG.01 — THE ELECTROMAGNETIC SPECTRUM IN ASTRONOMY REFERENCE



02

02 · THE KEY IDEA

Each band corresponds to a distinct physical mechanism.

Space instruments are organized around the spectrum because wavelength maps almost directly onto physical mechanism. Radio traces cold neutral hydrogen and the magnetized remnants of dead stars. Infrared reveals dust, protoplanetary material, and light redshifted by cosmic expansion. Visible light shows stars and galaxies in their familiar form. Ultraviolet isolates the hottest young stars and the solar corona. X-ray and gamma-ray emission originates in the most energetic environments known: black holes, neutron stars, and plasma at millions of kelvin. Selecting a science target is effectively selecting a band, and selecting a band largely determines the detector.

WHY IT MATTERS

No single detector covers the full spectrum.

Silicon responds from the soft-X-ray and ultraviolet region through the visible to a cutoff near 1.1 µm. InGaAs extends coverage through the near-infrared to roughly 1.7 µm. Longer wavelengths require cooled compound semiconductors or bolometers, and the radio regime requires antennas and receivers rather than photodiodes. The first design question on any space instrument is therefore explicit: which segment of the spectrum is the mission required to measure?

TBL.01 — THE SPECTRUM IN ASTRONOMY: WHAT EACH BAND REVEALS

BAND	APPROX. WAVELENGTH	WHAT IT REVEALS	COMMON DETECTION
Gamma / X-ray	< 10 nm	Black holes, neutron stars, hot plasma	Scintillators, Si / CdTe, microchannel plates
EUV / UV	10 – 400 nm	Hot young stars, the solar corona	UV-stable silicon photodiodes
Visible	400 – 700 nm	Stars, planets, galaxies	Silicon CCD / CMOS, photodiodes
Near-infrared	0.7 – 2.5 µm	Cool stars, dust, redshifted light	Silicon (to ~1.1 µm), InGaAs
Mid / far-infrared	2.5 µm – 1 mm	Dust, forming planets, cold gas	Cooled HgCdTe, bolometers
Radio	> 1 mm	Cold hydrogen, pulsars, the CMB	Antennas, heterodyne receivers

03 · WHERE SOLID-STATE DETECTORS FIT

03 Silicon photodiodes handle the stable, non-imaging tasks.

It is tempting to assume every space detector is a camera, but much of space science is measurement rather than imaging. Many instruments require a small, stable point detector that reports incident flux within a band: total solar irradiance, the intensity of a single emission line tracked across a decade, the Sun vector for attitude determination, or a reference channel that maintains the calibration of a larger instrument. These functions are governed by stability, predictability, and radiation tolerance rather than pixel count.

A useful discipline for a new engineer is to separate two questions: is the requirement to form an image, or to make a measurement? Imaging drives the design toward arrays — CCD, CMOS, or cooled HgCdTe. Measurement, calibration, and monitoring drive it toward single photodiodes selected for minimal drift. Operational instruments use both together, and the reference diode is frequently the component that keeps the entire instrument calibrated across years on orbit.

BANDS	RESPONSE	STABILITY	ENVIRONMENT	RADIATION	CALIBRATION
Soft X-ray – NIR	DC – fast	Holds over years	Vacuum-rated	Tolerant designs	NIST-traceable

TBL.02 — DETECTOR TECHNOLOGIES USED ACROSS SPACE SCIENCE

TECHNOLOGY	SPECTRAL REACH	STRENGTH	TYPICAL ROLE
Silicon photodiode	Soft X-ray – 1.1 µm	Stable, simple, radiation-tolerant	Sun sensors, flux monitors, references
AXUV / SXUV silicon	Soft X-ray – NIR	Calibratable UV / EUV / X-ray response	Solar and EUV monitoring
Silicon CCD / CMOS	UV – 1.1 µm	High-resolution imaging	Star trackers, science cameras
InGaAs	0.9 – 1.7 µm	Room-temperature near-IR	NIR photometry, ranging
HgCdTe (cooled)	1 – 14 µm	Broad infrared imaging	Infrared science instruments
Microchannel plate	EUV / X-ray	Single-photon counting	High-energy imaging

TBL.03 — THE SPACE ENVIRONMENT AND HOW DETECTORS COPE

STRESSOR	EFFECT ON THE DETECTOR	HOW IT'S HANDLED
Radiation (protons, electrons)	Dark current rises, displacement damage	Radiation-tolerant silicon, shielding
UV / EUV exposure	Window solarization, response drift	Windowless or UV-stable silicon
Thermal cycling	Drift and mechanical stress	Hermetic packaging, stable mounts
Vacuum and outgassing	Contamination of nearby optics	Low-outgassing, bake-out materials

04

04 · WHERE OPTO DIODE FITS

A focused role: stable UV-to-X-ray reference detectors.

TBL.04 — WHERE PHOTODIODES APPEAR IN SPACE INSTRUMENTS

INSTRUMENT ROLE	WHAT IT MEASURES	DETECTOR APPROACH	WHERE OPTO DIODE FITS
Sun sensor / attitude	Direction to the Sun	Segmented silicon photodiode	Standard silicon
Solar EUV / X-ray monitor	Solar irradiance by band	UV-stable silicon photodiode	AXUV / SXUV
Radiometric reference	Absolute flux for calibration	Calibrated silicon photodiode	AXUV (NIST-traceable)
Particle / electron flux	Charged-particle counts	Silicon detector	AXUV (low-energy electrons)
Beam / laser monitor	Optical power on the bench	Silicon or InGaAs photodiode	Standard silicon / InGaAs

KEY TAKEAWAYS

- Define the spectral band before selecting a detector
- Distinguish imaging requirements from measurement requirements
- For monitoring channels, stability outweighs resolution
- Environmental constraints often drive the design more than the signal
- Reference diodes maintain instrument calibration over the mission

WHERE IT'S USED

- Solar EUV and X-ray monitoring
- Sun sensing and attitude control
- Radiometric calibration references
- Charged-particle and electron flux
- Optical power and beam monitoring

WHY SILICON

- Stable, predictable response
- Radiation-tolerant by design
- Calibratable to NIST traceability
- Simple, compact, and low-power
- Hermetic or windowless packaging

THE DETECTORS

AXUV and SXUV: silicon that holds its calibration.

Opto Diode's role in space science is narrow and well established. The AXUV family is a silicon photodiode with an unusually stable, predictable response that spans the near-infrared through the visible and ultraviolet into the soft-X-ray region, which is why these devices serve as reference and monitoring detectors and can be calibrated to NIST traceability. The SXUV family is the UV- and EUV-hardened variant, engineered to retain its response under intense exposure that would degrade a conventional silicon device. Neither is an imaging array; both are the stable reference detector that allows an instrument to trust its own radiometric output over years on orbit. Both are offered in hermetic and windowless packages, with custom active areas and geometries available.

NEXT STEPS

Evaluating a detector approach?

If you are scoping a space instrument and evaluating detector options, our applications engineering team can help map your spectral band, environment, and stability requirements to an approach — including where a calibrated AXUV or SXUV reference detector is the appropriate choice.

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