OPTO DIODE
An ITW Company

EDITION
AN-06

APPLICATION NOTE · MICROSCOPY · NANOPOSITIONING

Photodiodes for Microscopy Detection and Nanometer-Scale Position Feedback

How Opto Diode's silicon photodiodes, APDs, and segmented bi-cell and quad-cell detectors fit the everyday jobs on a microscopy and nanopositioning bench: fluorescence and confocal detection, AFM cantilever deflection, autofocus, beam centering, and optical alignment, from 190 nm to 1700 nm.

FEATURED COMPONENT

Quad-Cell Segmented

Common-substrate four-quadrant photodiode for AFM beam-deflection and beam-centering feedback · TO-8 hermetic

λ	190 nm – 1700 nm
FEATURED	Quad-Cell Detector
RESOLUTION	Sub-µm deflection
ELEMENTS	Bi-cell / Quad-cell

WHAT YOU'LL LEARN

- L.01 Why a quad-cell's matched quadrants beat a discrete array for AFM deflection
- L.02 How a bi-cell resolves single-axis focus error with a simple difference signal
- L.03 Where avalanche photodiodes win over PIN silicon in photon-starved confocal
- L.04 Which silicon family fits fluorescence emission bands from blue to NIR

WHO IT'S FOR

- A.01 Confocal, light-sheet, and super-resolution microscope designers
- A.02 AFM, SPM, and metrology instrument engineers
- A.03 Piezo-stage and nanopositioning control developers
- A.04 Autofocus and beam-alignment subsystem designers

OVERVIEW

Microscopy and nanopositioning ask a photodetector two different questions. Microscopy asks how few photons it can count before noise takes over. Nanopositioning asks how small a shift in a light spot it can resolve before drift takes over. Both answers come down to the same thing: a quiet, stable, well-characterized silicon or InGaAs junction. This note walks through how Opto Diode's current catalog fits the precision-instrument bench, with low-noise silicon and avalanche photodiodes handling fluorescence and confocal detection, and segmented bi-cell and quad-cell detectors handling AFM beam deflection, autofocus, and beam centering. In the end, an instrument is only as stable as the detector sitting under its beam.

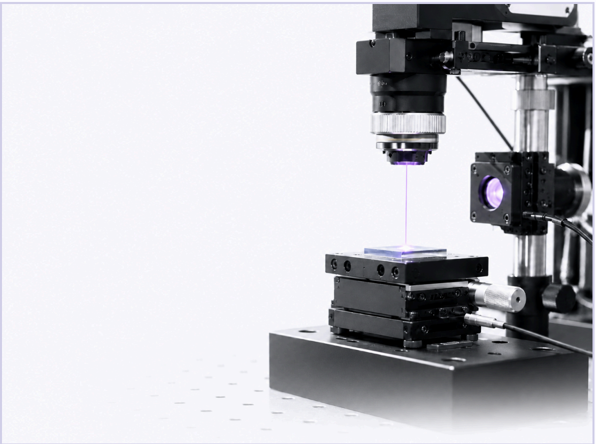
01

01 · APPLICATION CHALLENGE

Resolution lives below the noise floor.

A nanopositioning loop that has to hold a stage to a few nanometers is asking the detector to resolve a beam-spot shift far smaller than its own active area. A confocal pinhole hands it only a handful of photons per dwell. In both cases the signal you care about is a small wiggle riding on offsets, dark current, and thermal drift that are all larger than the thing you are trying to measure. Generic detectors get specified for peak responsivity on a datasheet plot, but precision instruments usually fail somewhere else: centering error, quadrant mismatch, dark-current drift, or a package that shifts dimensionally over a working day. The detector family, the element geometry, and the packaging matter far more than any single responsivity number.

FIG.01 — BEAM-DEFLECTION POSITION SENSING SCHEMATIC



02

02 · DESIGN PRINCIPLE

Match the geometry to the measurement.

Opto Diode's catalog splits the photodetector problem into two geometries. When you are measuring intensity (fluorescence, brightfield, or confocal), reach for a single large-area junction tuned to the emission band: Blue or Red Enhanced silicon for the visible, or an APD when photons are scarce. When you are measuring position (AFM deflection, autofocus, or beam centering), reach for a segmented geometry: a bi-cell for single-axis null-seeking, or a common-substrate quad-cell for two-axis beam centering. Because those segments share one die, they track over temperature far better than a discrete-diode array. Choosing a part number before you choose the geometry is the usual way to end up with a detector that works on the bench and drifts on the stage.

DESIGN PRINCIPLE · 02

Geometry and stability beat raw responsivity.

A quad-cell whose four quadrants are matched to a few tenths of a percent will null-seek more reliably than a higher-responsivity discrete array that drifts apart over a working day. For position work, specify quadrant matching, position linearity, and dimensional stability of the package first. For low-light detection, specify NEP and dark-current drift. Treat peak responsivity as tertiary.

TBL.00 — GENERIC vs. FIELD-ENGINEERED DETECTORS

PARAMETER	GENERIC DETECTOR	OPTO DIODE FAMILY	WHY IT MATTERS
MATCHED QUADRANTS	Discrete array, unmatched	Quad-cell segmented (common substrate)	Single-die quadrants track over temperature for stable nulling
SINGLE-AXIS NULL	Two separate diodes	Bi-cell segmented (common substrate)	Matched pair gives drift-free one-axis focus error
LOW-LIGHT GAIN	PIN silicon only	APD (Si / InGaAs, 400–1700 nm)	Internal gain lifts photon-starved confocal above noise
SPECTRAL MATCH	One generic window	Blue / Red Enhanced silicon	Responsivity tuned to the fluorescence emission band

03

03 · ENGINEERING SELECTION

A practical framework for choosing the right detector.

Start with what you are actually measuring: intensity or position. If it is intensity, work from the photons per dwell reaching the detector, then the SNR you need, then the active area and noise floor that follow, and finally whether PIN silicon is enough or you need APD gain. If it is position, start from the spot size and the resolution you are after, settle on a bi-cell or quad-cell, then pin down quadrant matching and gap width, and size the front-end bandwidth to suit. Package, window, and cooling come last.

WAVELENGTH	RESPONSE	RESOLUTION	GEOMETRY	WINDOW	CUSTOM
190 nm – 1700 nm	DC – high-speed	Sub-µm deflection	Bi-cell / Quad-cell	Quartz / sapphire	Active-area geometry

TBL.01 — OPTO DIODE FAMILIES FOR MICROSCOPY & NANOPOSITIONING

FAMILY	TECHNOLOGY	SPECTRAL RANGE	GEOMETRY	TYPICAL USE
Blue Enhanced Si	Silicon photodiode	190 – 1100 nm	Single element	UV/blue fluorescence, brightfield
Red Enhanced Si	Silicon photodiode	400 – 1100 nm	Single element	Red/NIR fluorescence, laser monitor
APD (Si)	Silicon avalanche	400 – 1100 nm	Single element	Photon-starved confocal, FLIM
APD (InGaAs)	InGaAs avalanche	900 – 1700 nm	Single element	NIR / SWIR spectroscopy
Bi-Cell Segmented	Si, common substrate	350 – 1100 nm	2-element	1-axis nulling, autofocus
Quad-Cell Segmented	Si, common substrate	350 – 1100 nm	4-quadrant	AFM deflection, beam centering

TBL.02 — DOMINANT FAILURE MODES IN PRECISION DETECTION

MODE	ROOT CAUSE	DESIGN RESPONSE
Centering error	Unmatched discrete diodes	Common-substrate bi-cell / quad-cell on a single die
Quadrant drift	Thermal mismatch between elements	Single-die quad-cell tracks over temperature
Dark-current drift	Thermal cycling, moisture ingress	Hermetic TO-5/TO-8; glass-to-metal seals
UV responsivity loss	Solarization of the window	UV-enhanced silicon with quartz window

04 · PRODUCT FIT

04 Recommended Opto Diode building blocks.

TBL.03 — RECOMMENDED OPTO DIODE PART NUMBERS BY APPLICATION

PART / FAMILY	APPLICATION	GEOMETRY / PACKAGE	WHY THIS PART
Quad-Cell Segmented	AFM cantilever deflection	4-quadrant, common substrate	Matched quadrants give stable, drift-free null sensing
Bi-Cell Segmented	Autofocus / single-axis tracking	2-element, common substrate	Matched pair gives a robust one-axis focus-error signal
APD (Si)	Photon-starved confocal / FLIM	Single element, hermetic	Internal gain raises weak signal above readout noise
APD (InGaAs)	NIR / SWIR microscopy	Single element, hermetic	Avalanche gain across the 900–1700 nm band
Blue Enhanced Si	UV / blue fluorescence, brightfield	Single element, low dark current	Silicon responsivity matched to short-λ emission
Red Enhanced Si	Red / NIR fluorescence, laser monitor	Single element, low dark current	Extended responsivity into the red and NIR

KEY FEATURES

- Common-substrate quad-cells with matched quadrants
- Bi-cells for single-axis null and focus error
- Low dark current, low capacitance silicon
- APD internal gain for photon-starved signals
- Custom active-area geometry and gap widths

APPLICATIONS

- AFM / SPM cantilever deflection
- Confocal and fluorescence detection
- Autofocus and focus tracking
- Beam centering and pointing
- Optical alignment and metrology

BUILT FOR PRECISION

- Hermetic TO-5 / TO-8 packages
- Glass-to-metal seals, no epoxy near die
- Matched-element centering accuracy
- Multi-element and array configurations
- ISO 9001:2015 certified

CUSTOM PROGRAMS

Engineered to your application.

Standard parts cover most instruments, but not all of them. Opto Diode designs custom active-area geometries, gap widths, and quadrant layouts for segmented detectors, along with multi-element and array detectors, integrated TIA amplifier hybrids, and hermetic, windowless, or filter-integrated packages for microscopy and nanopositioning instruments that have to hold calibration for years. Everything is designed and built in-house in class 1,000 to class 10,000 cleanrooms under ISO 9001:2015. Custom programs typically ship qualification samples in 8 to 12 weeks.

NEXT STEPS

Talk to Applications Engineering.

Bring your measurement geometry, beam profile, wavelength band, resolution target, and stability envelope, and we'll come back with a recommended standard family, or a custom path, within one engineering review cycle.

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