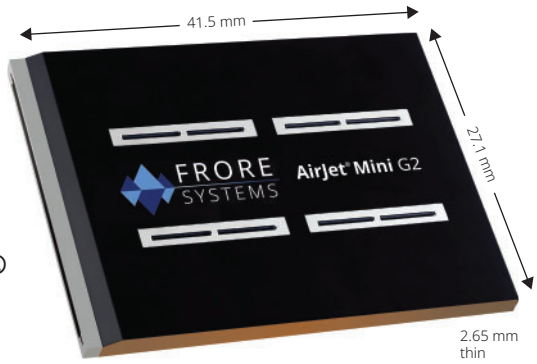
FRORE SYSTEMS



SWIR Cameras & AirJet®

Reducing Diffusion Dark Current in SWIR Cameras with AirJet Solid-State Active Cooling

SWIR (short-wave infrared) CMOS sensors are used in high-precision visual inspection, particularly in low-light and non-visible wavelengths. One of the most disruptive challenges they face is dark current—a thermally generated phantom signal that appears even in the absence of light, interfering with image accuracy and yield-critical inspection.

A study by Portland State University measured over 222,000 CCD pixels between 222 K and 291 K and concluded:

"Dark current is a thermally activated process that increases exponentially with temperature... [and] is strongly temperature dependent."

— Widenhorn et al., SPIE Proceedings Vol. 4669.

Types of Dark Current

1. **Depletion Dark Current** –
   Occurs at lower temperatures; showing up as isolated hot pixels (correctable).

2. **Diffusion Dark Current** –
   Dominates at higher temperatures as a smooth haze across sensors (difficult to subtract).

"A large dark current directly affects the CIS performance in terms of noise, pixel nonuniformity, and reduction in dynamic range. The dark current linearly increases with the exposure time and exponentially with the temperature. The dark current doubles every ~5–10 °C."

— Abarca et.al., Sensors-23-09109-v2.pdf, p. 2

Enter AirJet®

AirJet solid-state active cooling delivers 15°C of additional SWIR CMOS Sensor temperature reduction to supplement Thermal Electric Cooler (TEC) systems—without fans, or bulky heat sinks. This enables the sensors to capture cleaner images, achieve longer component life, and deliver faster AI performance.

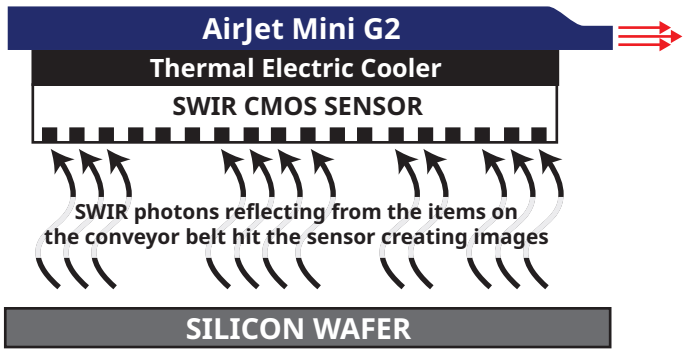
Using TEC helps reduce SWIR CMOS Sensor temperature down to 30°C and AirJet further reduces sensor temperature to a stable 15°C.

Why It Matters

- Software correction works best on patchy noise (depletion) but struggles with uniform thermal haze (diffusion).
- AI struggles with diffusion dark current because it can't distinguish noise from faint real signals. Lowering thermal noise improves model accuracy and inspection speed.
- A 15°C temperature reduction from 30°C can decrease diffusion dark current by 86%.

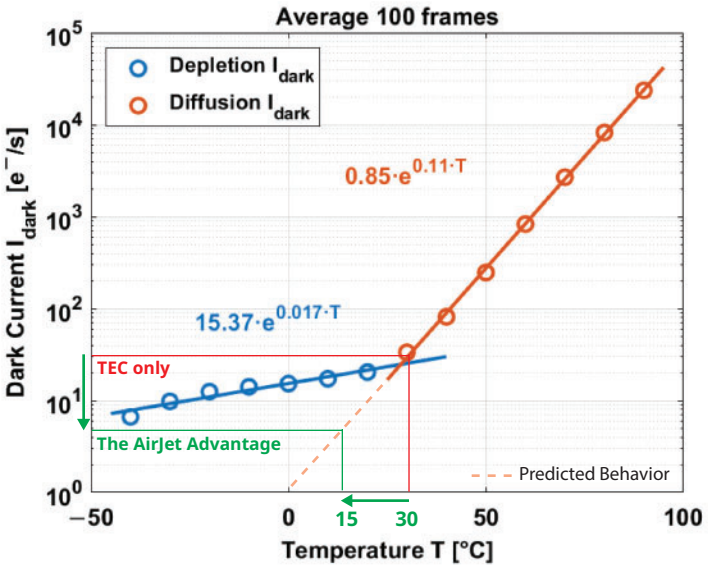
How It Works

AirJet removes heat from the TEC cooler, enabling the SWIR CMOS sensor to maintain much lower temperature compared to passive cooling only.



If the sensor gets hot, SWIR photons get 'excited' and move around irratically - creating image distortion that is difficult for AI to identify and remove effectively.

Dark current over temperature.



Bottom Line

If you care about yield accuracy, AI performance, or long-term reliability, cooling isn't optional—it's fundamental.

AirJet makes high-performance SWIR systems cooler, quieter, dustproof, accurate and more stable.

It's the difference between trusting every pixel—or second-guessing your data.

Download the AirJet Mini G2 product card for more information.

Sources:
1. SPIE Vol. 4669 – R. Widenhorn, Portland State University
2. Semiconductor Engineering, YieldHub, NIST CHIPS Report, arXiv ML noise studies.
3. A CMOS Image Sensor Dark Current Compensation Using In-Pixel Temperature Sensors, Sensors 2023, 23(22), 9109.

SWIR Cameras & AirJet®

Value Proposition: AirJet in Silicon Wafer Visual Inspection

Impact Area	Thermal Problems Without AirJet	How AirJet Helps	Potential Value
Yield & Defect Detection	Thermal noise hides micro-defects, lowering yield	Reduces diffusion dark current by 85%, improving contrast and accuracy.	1% yield boost = $5M–$10M/year in savings.
Inspection Throughput	Noisy images require re-scans and slow AI decisions.	Stable signal improves first-pass success and automation.	20% fewer re-inspections = faster, more efficient lines.
Equipment Longevity	Fans attract dust.	AirJet can operate in dustproof systems. No fans. No dust.	$100K+/year saved per line via fewer failures/repairs.
AI Performance	Diffusion noise confuses ML models.	AirJet lowers diffusion noise = cleaner inputs for AI.	More accurate classification, trend tracking, and predictions.
System Reliability	Heat causes drift, instability, and component degradation.	Reduces thermal stress and hot spot variation.	Fewer thermal surprises = longer-lasting systems.