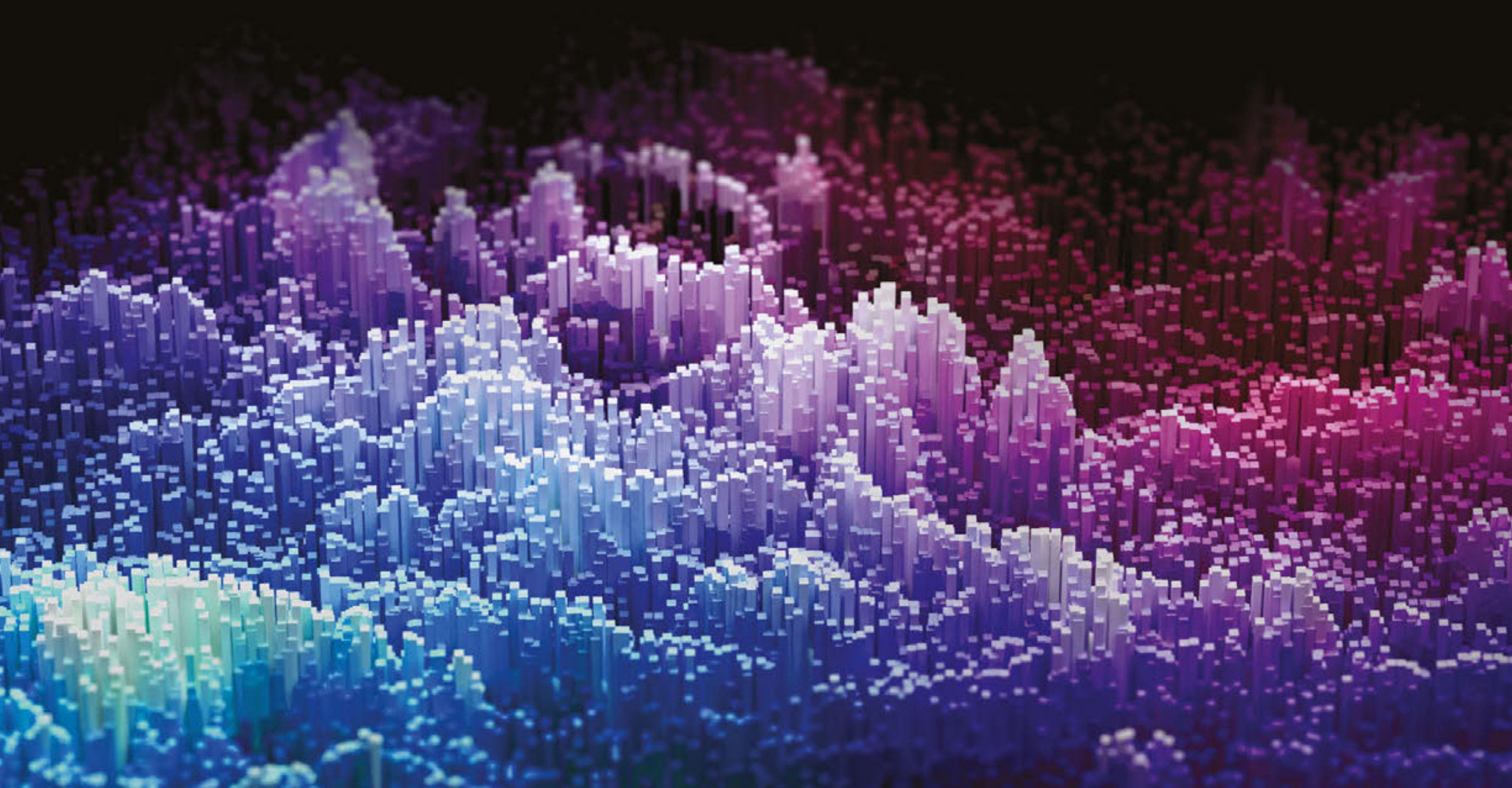
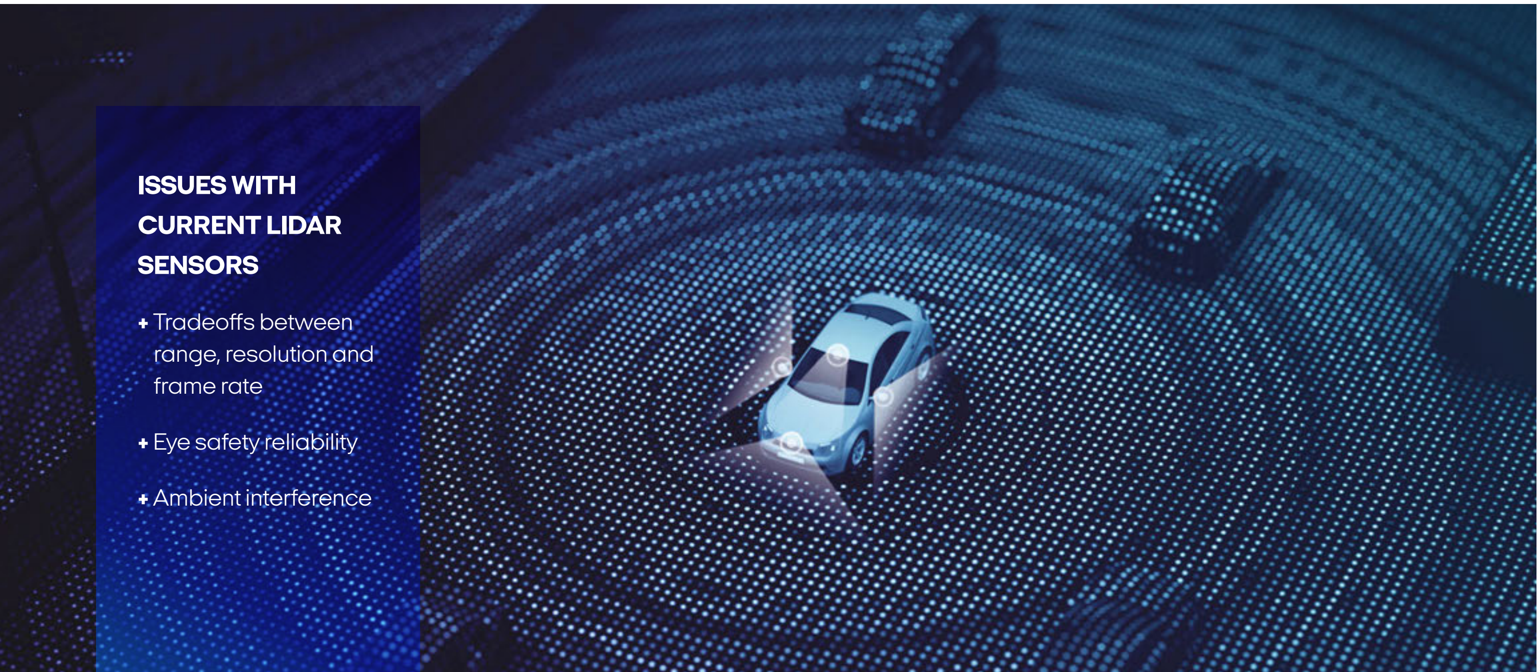
How TEC Advancements Can Mitigate LiDAR Application Tradeoffs





ISSUES WITH CURRENT LIDAR SENSORS

- Tradeoffs between range, resolution and frame rate
- Eye safety reliability
- Ambient interference

As the requirements for more powerful and reliable LiDAR grow in autonomous vehicles, so does the need for cooling

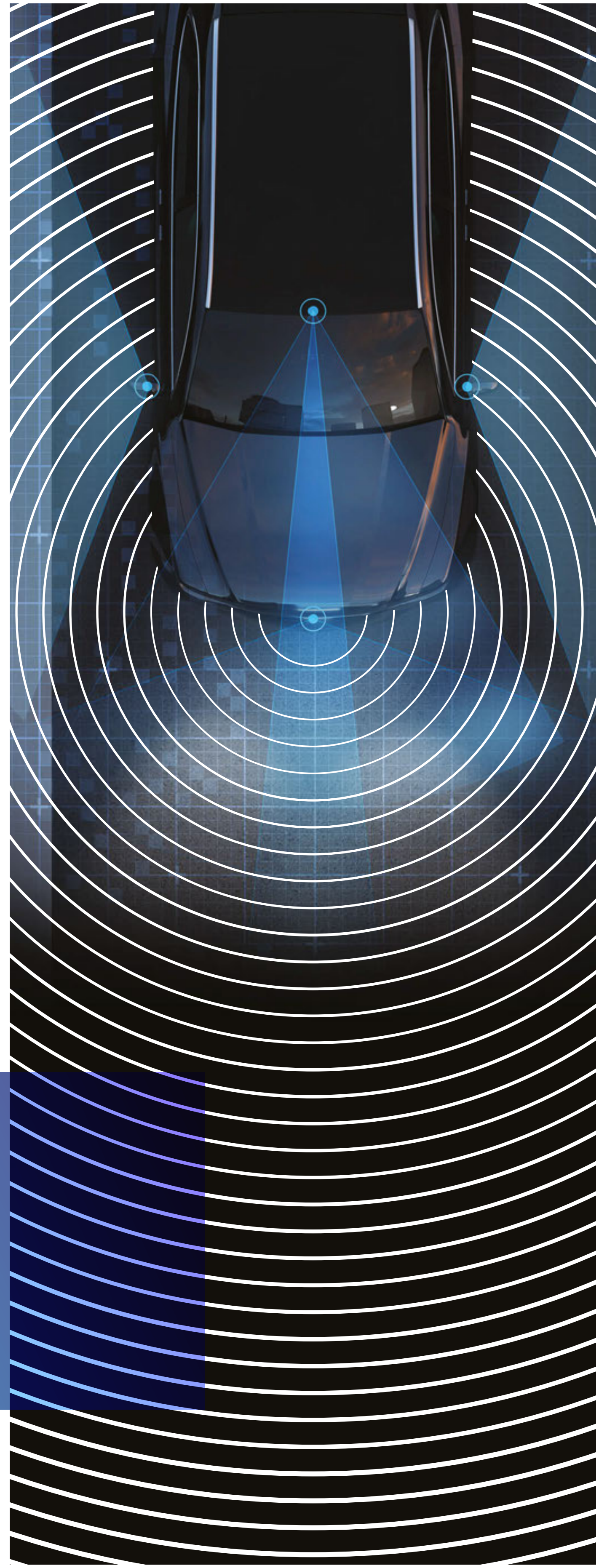
The world awaits the advent of the autonomous vehicle; more than just freeing us from the danger of human error, they will be a gift to people unable to drive themselves by improving traffic efficiency, creating a positive impact on the environment and more. But to facilitate customer (and manufacturer) adoption, we need assurances as to their safety, which is why the Light Detection and Ranging (LiDAR) sensors behind autonomous vehicle navigation systems must engender consumer trust in the cars' overall safety.

As we all know, LiDAR is the eyes of self-driving technology, reading the vehicle's surroundings through illumination, detection and imaging. A pulsed laser is emitted from the vehicle, which reflects from a surface, allowing the returning reflection to be measured by a sensor that creates a point cloud of the local environment. Ultimately, LiDAR works side by side with a camera and radar, creating a driving route and recognizing objects to avoid multiple times per second.

While LiDAR has come a long way since its inception, the limitations of our current technology are quickly coming into focus. In order to deliver unyielding safety to drivers and bystanders alike, we must achieve the highest levels of performance and reliability. To do that, we must mitigate the tradeoffs between critical requirements.

This is no easy task. With a closeup view, critical requirements such as range, resolution, frame rate and interference immunity can all be improved. Yet, when you step back to view how LiDAR operates as a whole, you quickly see that these requirements are all interconnected — an enhancement made to one often results in the deterioration of another.

By improving temperature stability, you can improve performance across all design corners. This can be accomplished by using powerful thermoelectric coolers, or TECs. Not only can TECs maximize the sensitivity of LiDAR sensors but they also eliminate temperature-dependent reliability tradeoffs created by LiDAR's critical environmental and power requirements.
By outfitting a LiDAR system with TECs designed to cool optical components, manufacturers can maximize their levels of stability and reliability.



NO REQUIREMENT LEFT BEHIND

How Phononic TECs enhance all critical requirements in LiDAR sensors

High-performance, high-range LiDAR sensors absolutely require a cooled laser source. Without it, there are constant performance tradeoffs between range, which delivers speed in decision making; resolution, which is important for perception; and frame rate, which is the frequency at which a new image can be created.

Phononic TECs deliver the wavelength stability and control needed for lasers and detectors that function at the desirable 1550nm operating wavelength. They can also be used to enhance the performance of shorter wavelength sources. What's more, by using our TECs to actively cool a detector, you can reduce their signal-to-noise ratio (SNR) by increasing the operating temperature range and ensuring more light is detected per pixel.

Active element cooling is especially important for long-range perception. To ensure a LiDAR sensor paints a target everywhere, high resolution is needed. At 1550nm Frequency Modulated Continuous Wave (FMCW), Phononic TECs can help manufacturers reach a range of 200m+ and accurately render images that onboard processors can easily evaluate. TECs allow designs to meet AEC-Q100, 102 and 104 reliability standards while achieving IATF 16949 certification.

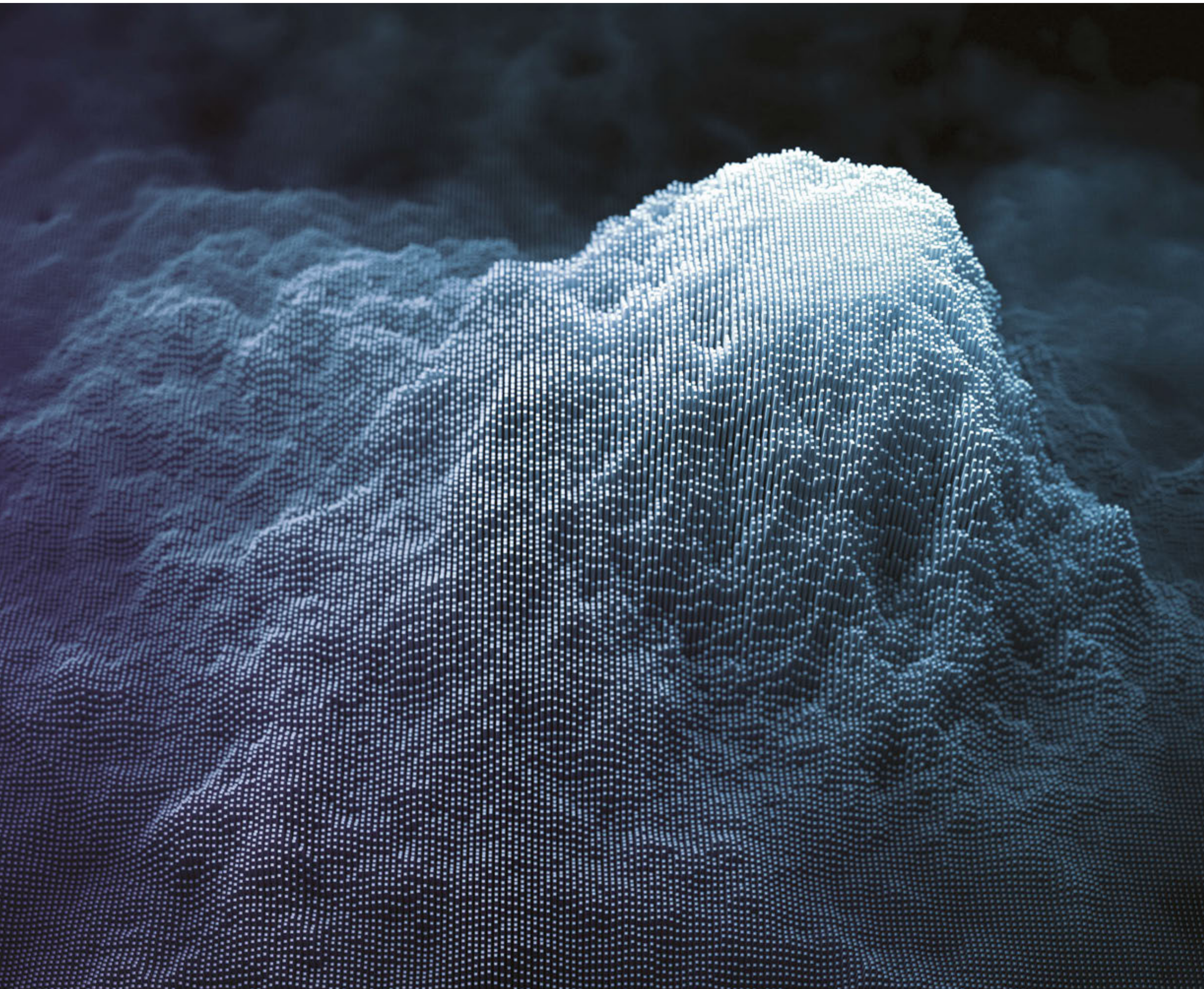
PHONONIC TEC BENEFITS

+ Enhanced LiDAR sensor performance
+ Low power consumption
+ High heat-pumping density
+ Enhanced sensor reliability

See the future safely with reliable eye safety

One of the biggest issues with moving LiDAR toward high performance and high range is eye safety. Shorter wavelengths present a significant danger to the eyes. But when the wavelength is longer, an optically safe 1550nm laser source is also capable of operating at a much higher optical power. Phononic TECs make this possible, giving LiDAR a substantially longer range without exposing passengers and pedestrians to dangerous light.

1550nm high-powered and fiber lasers require cooling; not only do TECs do this inexpensively, they also allow onboard systems to control operating temperatures, which can vary wildly in the different environments where autonomous vehicles operate. This feature is important for lower-power lasers and detection schemes, such as those found in FMCW-based sensors, which require strict control of wavelength and temperature control.



TECS FOR LIDAR REQUIREMENTS

- High heat load — 2–20 watts
- High voltage/ element count
- >100˚ C operating temperature
- High Δt
- Extreme reliability: AEC-Q10xs, 15-year lifetime
- Integrated electronics/optics
- Low $/watt

Immunity to ambient interference is just what the doctor ordered

Within the standard solar spectrum (~0.5 W/m2/nm at 905nm, ~0.25 W/m2/nm at 1550nm), there is a lot of opportunity for ambient interference. If an uncooled source wavelength drifts, input filtering must be relaxed to account for that effect within the LiDAR sensor, allowing for more ambient light to enter. This interference can lead to dangerous situations in autonomous vehicles.

Improper input filtering resulting from a drifting laser source allows ambient light to enter the sensor and interfere with detection circuitry.

And it doesn't take much wavelength drift to cause problems — an edge-emitting laser's wavelength will drift 0.3–0.5nm/˚C, resulting in a full 60nm of wavelength drift across the entire AEC-Q operating temperature spectrum.

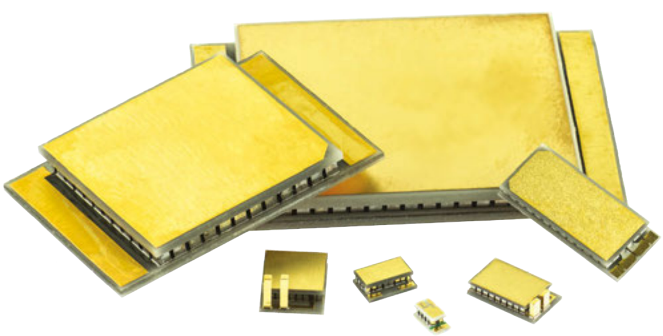
Cooling with Phononic TECs will stabilize the wavelength drift of the laser throughout the full operating temperature range. With this in place, narrow-band optical notch filters can be employed, ensuring very little ambient light will find its way into the LiDAR sensor.

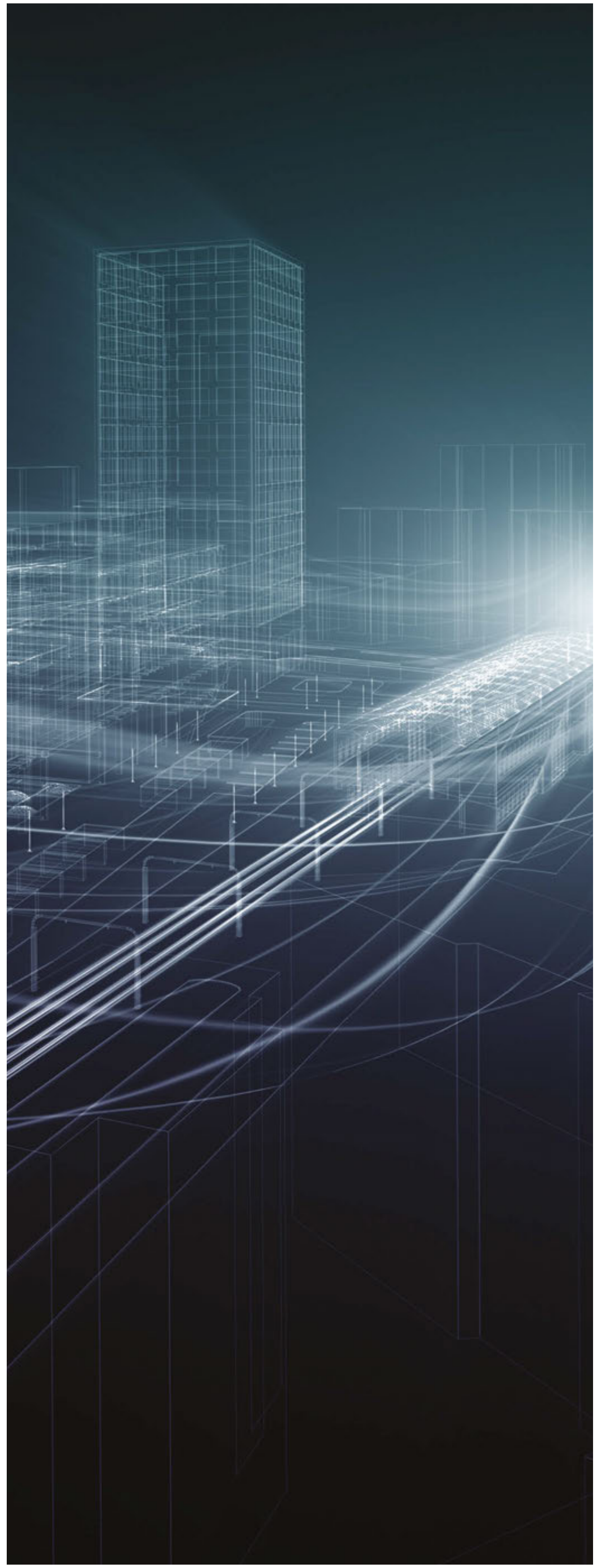
High-end, automotive-grade reliability

Not just any TEC will do when it comes to adding cooling to a LiDAR sensor; that's why Phononic TECs meet all AEC-Q10x reliability standards as well as IATF 16949 certification — to deliver the quality and reliability necessary to meet the high standard of automotive-grade quality.

Semiconductors have a maximum operating temperature of 150˚ C, which is a highly extreme environment. Plus, semiconductor TTFs decrease by ~50 percent for every 10˚ C in steady-state operating temperature; however, Phononic TECs enable high-precision temperature control to enable sensor components to operate at their preferred temperature, making extreme environments far less taxing for optical components.

To maintain automotive-grade quality, the demonstrated reliability of TECs becomes immensely important, and bulk-order TECs are not designed to meet the necessary automotive requirements.





Cooling is advancing the next generation of LiDAR: FMCW

Time of Flight LiDAR sensors have been used for quite some time, measuring the time between sending a signal and receiving it to deduce distance. This proven concept has a relatively simple design and a lower cost at 905nm, but the distance of its range is compromised by a weak return signal and ambient interference issues; it helped autonomous vehicle manufacturers get to where they are now, but its limitations are paving the way for better technology.

That's why Frequency Modulated Continuous Wave, or FMCW, is quickly establishing itself as the next big thing in LiDAR. A similar concept to coherent optical communications, FMCW works the same way most RADAR works — Δv, not Δ†. The availability of long, coherence-length lasers makes this technology possible.

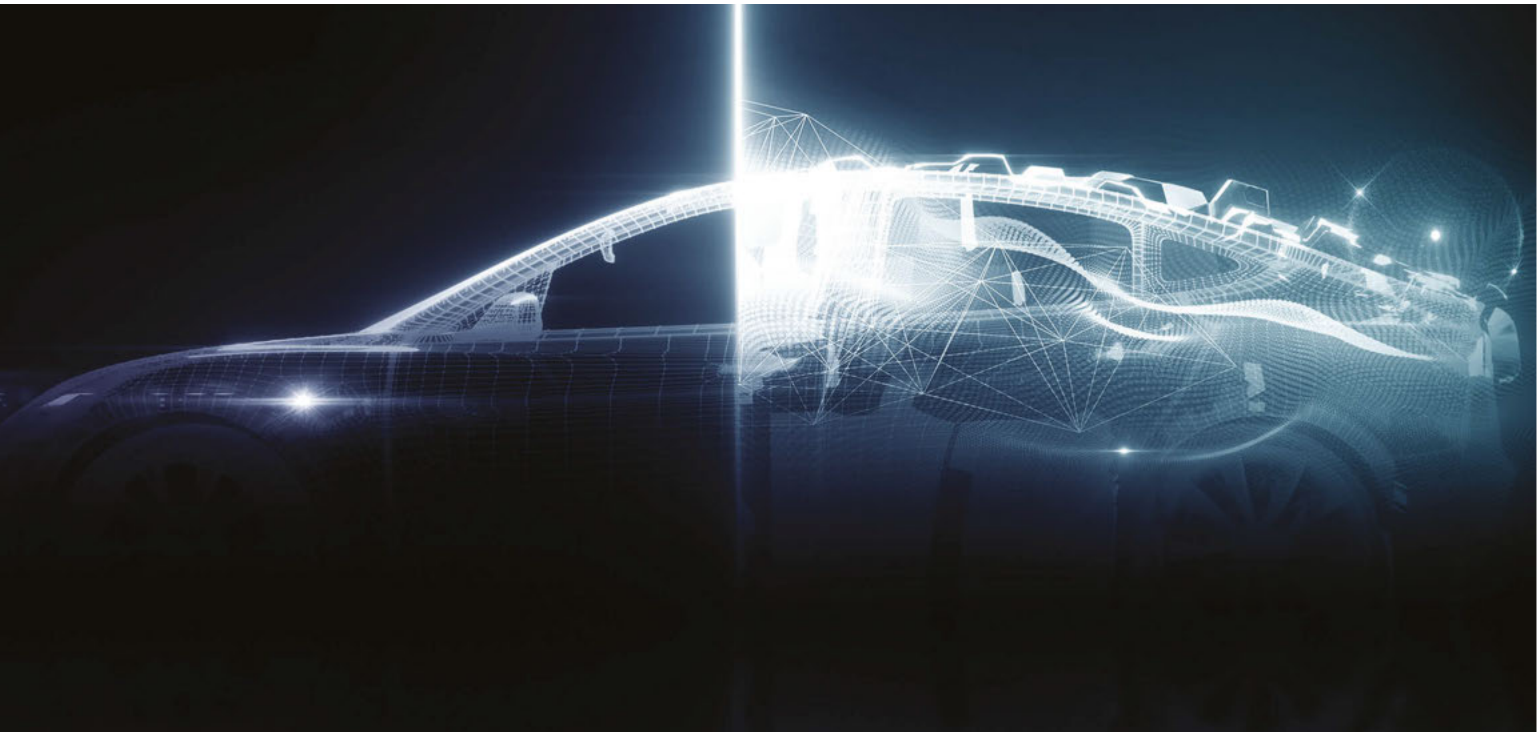
This high-performance, high-range method of distance detection essentially chirps the laser frequency. The beat between chirp and reception is used to measure the distance between the vehicle and the detected object.

Some of the biggest advantages of FMCW are its optical signal amplification, immunity to ambient noise and interference, and the ability to acquire distance and velocity readings simultaneously. But FMCW also faces some challenges, including its higher cost 1550nm fiber laser light source and manufacturers' difficulty in selecting the ideal beam-steering technology.

At 1550nm, the laser will generate a substantial amount of heat, so cooling is an absolute must. This is where Phononic TECs come in. TECs are employed with FMCW to cool the higher-power lasers, minimizing SNR and ensuring they can achieve a 200m+ range, as well as helping reduce the cost per watt.

It should be noted that there are hybrid technologies that blend ToF and FMCW, which are often seen in optical communications. And just like the separate technologies, these unique hybrids also need cooling to maximize their performance and range.

With TECs and FMCW, the autonomous vehicle revolution is closer to reality.



Are TEC costs too hot to handle? Bring performance and safety up while driving down the TEC price tag

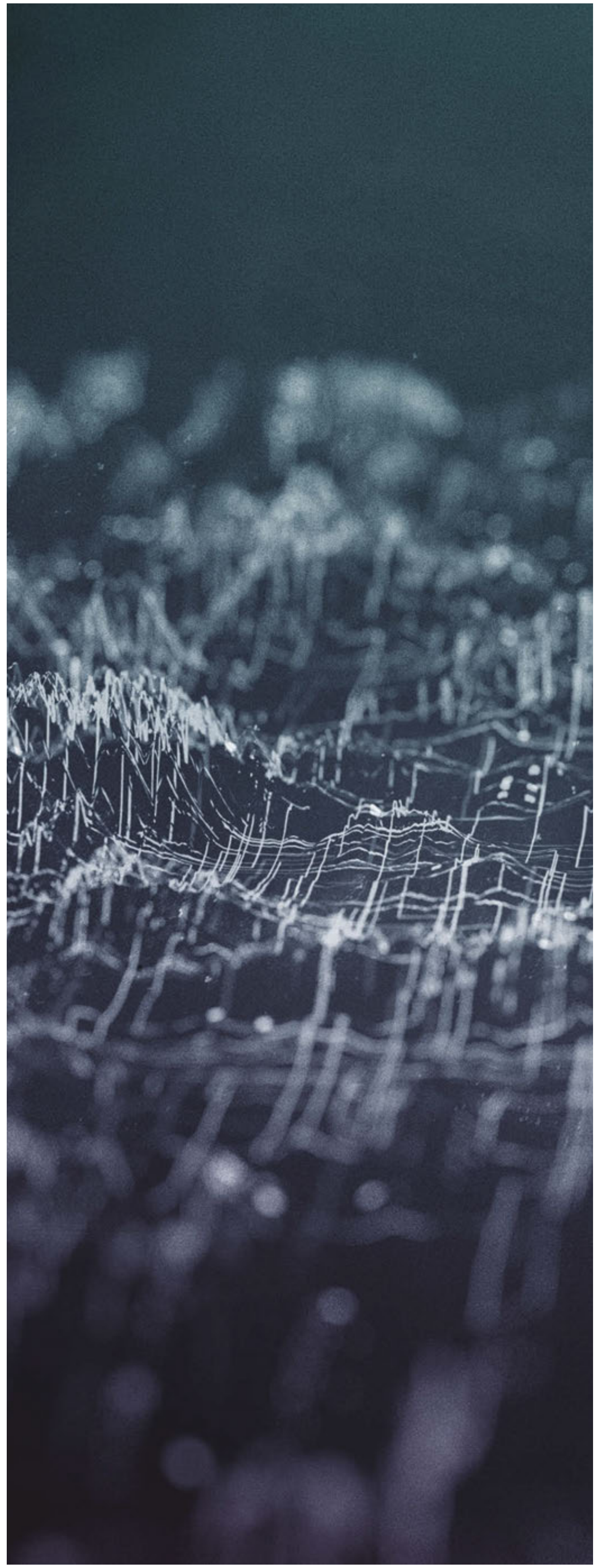
One of the biggest concerns about the introduction of cooling to LiDAR sensors is the price tag. Does their cost outweigh the benefits they deliver? It's a fair question to ask.

High-performance manufacturers already recognize that to achieve high-level autonomy, cooling is necessary. Mid-tier manufacturers have accepted the need for cooling, but they worry about the overall cost of implementation. On the lower-tier market, manufacturers are constantly experimenting with workarounds that they hope will eliminate the need for cooling. These R&D efforts are costly and highly application specific; they don't lend themselves to dynamic adjustments as required by nascent technologies.

It has been shown that cooling is the most price-efficient way for LiDAR to meet the ideal range and resolution needed to take autonomous vehicles to the next level. And as more cooling is introduced, the price has been driven down, much like the vast difference between the initial costs of solar power and LED technologies versus their current costs.

If manufacturers only focus on increasing the capability of low-cost approaches without introducing cooling technology, there will always be tradeoffs in critical LiDAR requirements that keep them from achieving the high performance and reliability necessary for mass consumer adoption of autonomous vehicles — the initial lower cost means nothing if consumers have reservations about safety.

The most practical approach to moving autonomous vehicles forward is a long-term investment in high-capacity architectures, which will continue to bring the overall cost down. In fact, trends show we're already seeing a 20x drop in $/watt in just 20 years for high-power 1550nm lasers. This is where the market is going, and TECs will fuel further drops in cost.



Phononic is already helping customers move toward the next generation of LiDAR

Phononic is already working with LiDAR manufacturers and developers in all corners of the world to help bring about the next generation of LiDAR systems. When our application-specific TECs are used to help increase power and stability in next-gen LiDAR sensors, they will consistently outperform the lower-power, uncooled LiDAR systems and the bulk TECs available on the market.

High-power LiDAR sensors, such as FMCW, already require cooling to achieve high standards of performance and reliability. And there are bulk TEC options available on the market that can help generate the desired performance results. But the problem with turning to bulk TECs to reach those standards is having to retrofit the LiDAR system to work with the TEC offered. For about the same cost, Phononic can provide an application-specific design that fits your system parameters instead of trying to design the system to fit the TEC.

Phononic sees and understands the inherent flaw in that development model, which is why we partner with manufacturers to develop custom TEC designs that are built for simple and immediate implementation into their LiDAR designs — no workarounds, no retrofitting.

The future of LiDAR is just around the bend, and Phononic is dedicated to creating the best cooling solutions to eliminate the barriers to innovation and the tradeoffs between LiDAR's critical requirements.

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About: Phononic is reimagining cooling and heating in ways never thought possible. Its breakthrough solid-state technology is transforming industries and creating new markets with innovative solutions that disrupt antiquated business models and incumbent technologies. Phononic is the critical element of innovation needed to radically change what it means to be efficient, effective and sustainable. The company has been named to the 2016, 2017 and 2019 CNBC Disruptor 50 lists, received the U.S. EPA's 2017 Emerging Tech Award, the R&D 100 Award and more.

Learn more at: **www.phononic.com**

Address: 800 Capitola Dr #7, Durham, NC 27713 **Website:** phononic.com **Twitter:** @phononic_inc