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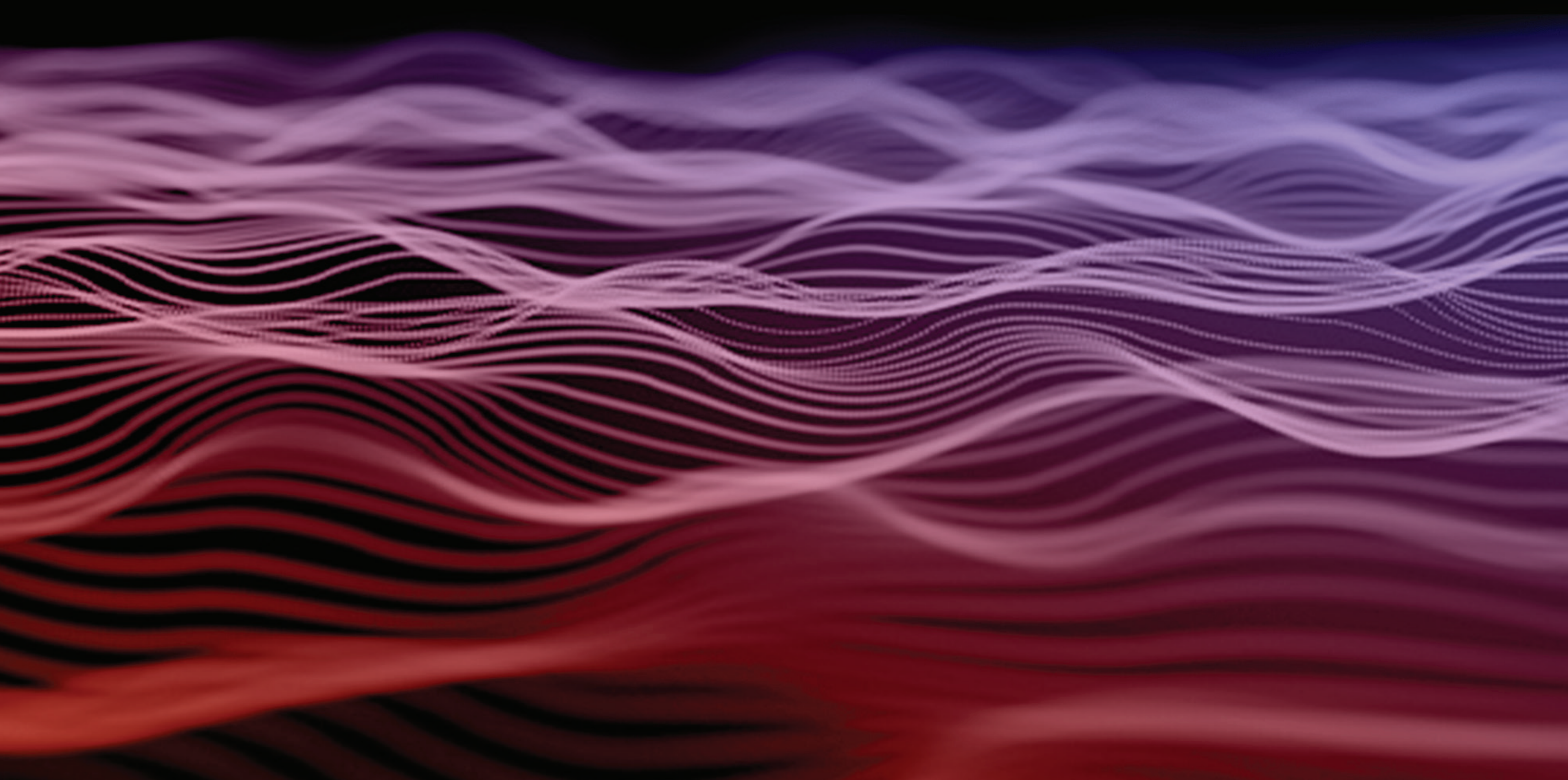
FMCW: The Next Generation of LiDAR Must Be Cooled



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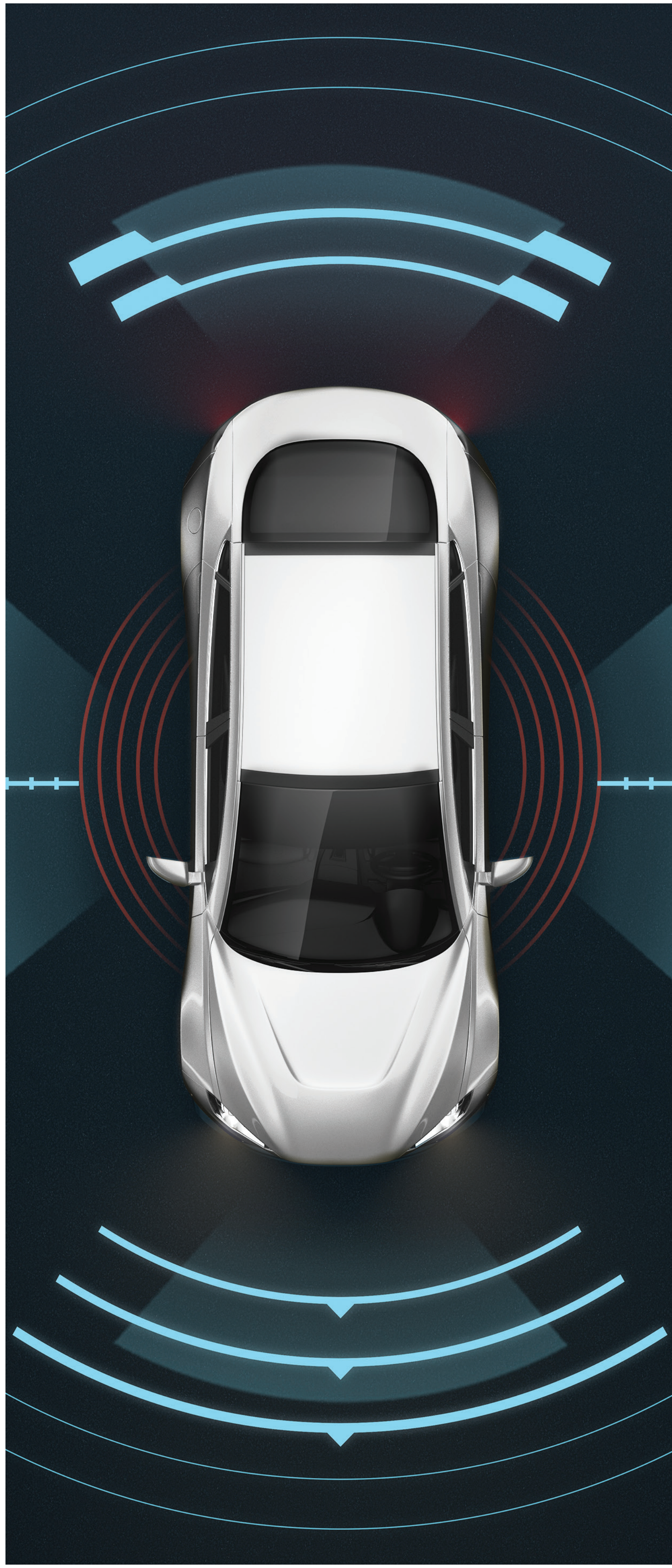
An Introduction to LiDAR

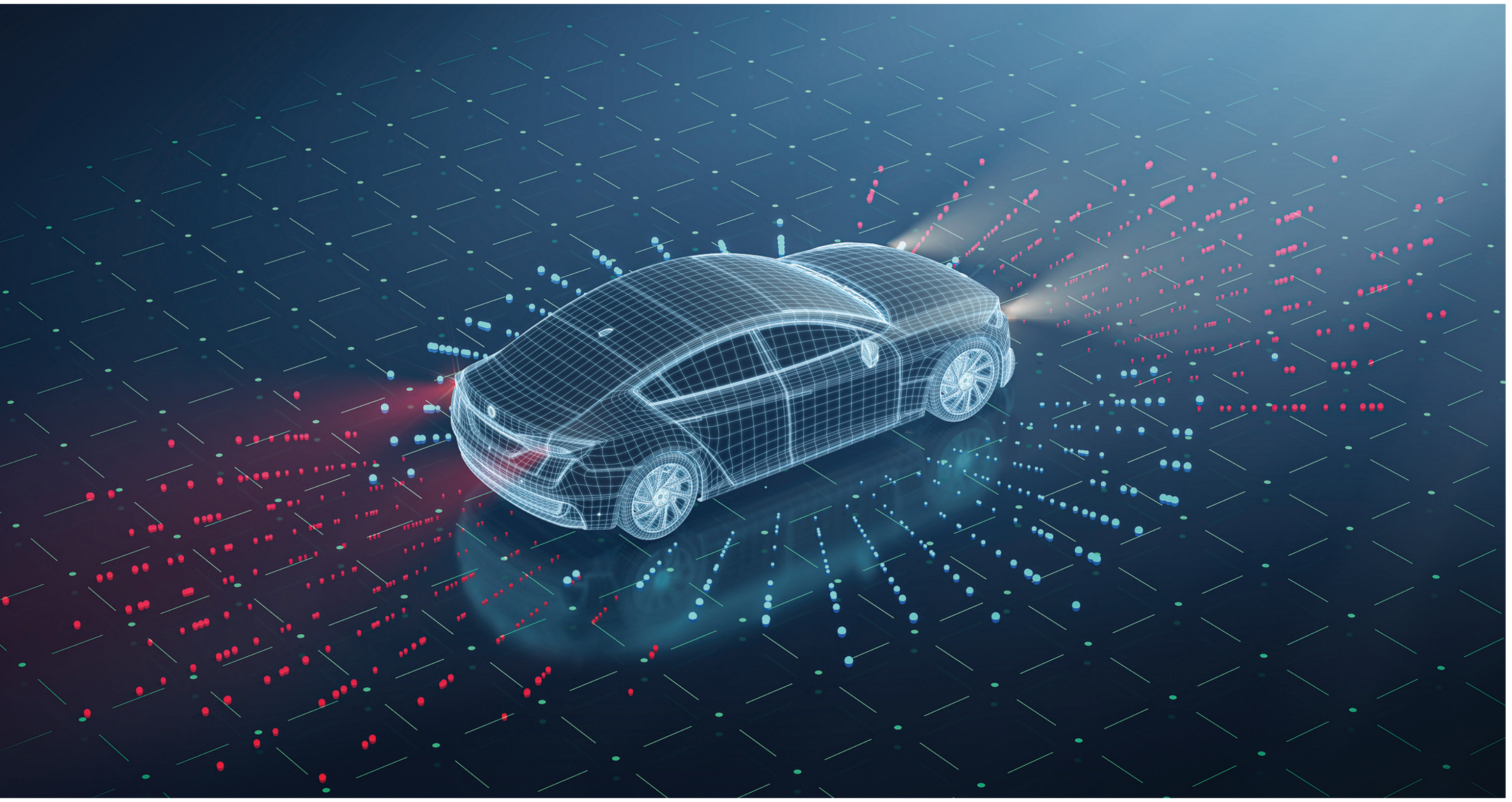
Light Detection and Ranging, or LiDAR, is a laser-based 3D-sensing technology used to generate high-resolution maps of different terrains. It's used in a variety of applications, from facial recognition in mobile devices to providing "vision" for industrial robots to general mapping and surveying and more. But its most prominent — and promising — application is to provide the "eyes" for autonomous vehicles.

In the field of driver-assisted and self-driving vehicles, LiDAR uses illumination, detection and imaging to, essentially, "see" a vehicle's surroundings. It works by having a pulsed or continuous wave (CW) laser sent from the vehicle, which bounces back from any surface it encounters. The returning reflection is then measured by a sensor. The reflected laser light is received and processed to create a 3D map of the local environment, also known as a point cloud. LiDAR gathers the critical information necessary to plot a safe and specific driving route, identifying objects in its field of view several times per second.

LiDAR sensors rely on three optical components to create their point clouds. The first, as previously mentioned, is a light source, which is typically a near-infrared (NIR) laser emitted at its targets along a 900nm to 1600nm wavelength. The second is a beam-steering mechanism that directs the beam as it scans the environment. Third, a detector collects the returning light a target has reflected; that information is then interpreted to measure the target's distance, velocity, shape and position.

With LiDAR sensors, there are several methods for detecting distance at each point. Time of Flight (ToF) is the tried-and-true method. However, ToF is compromised in several ways. Its limitations are driving the autonomous vehicle industry toward a next generation sensing approach: Frequency-Modulated Continuous Wave (FMCW).





The Evolution of LiDAR: Where It Is, and Where It's Going

LiDAR's go-to method for detecting distance at any point has been Time of Flight. Essentially, the time it takes for the laser light to be sent toward a target and return to the vehicle is used to determine that target's distance from the vehicle. This calculation is based on the speed of light. Since we know the velocity and the time it took for the light to emit, bounce and return, the distance can be reliably determined.

ToF boasts a significant number of advantages that make this method attractive to autonomous vehicle manufacturers. Measuring the time it takes for light to reflect back to the sensor only requires a relatively simple design, keeping the overall cost of the technology low. So why are manufacturers starting to move away from ToF?

The problem is several critical and interconnected LiDAR requirements are limited by the confines of ToF's design. ToF uses a lower-power, 905nm laser to eliminate danger to the eyes of other drivers and passersby, meaning its overall range is compromised by a weak return signal. Add persistent ambient interference issues to that, and you have a LiDAR system that only works well for short distances in good weather.

ToF is a proven technology, but in order for vehicles to move from "driver-assisted" to "fully autonomous," longer range and enhanced performance are required. As such, many manufacturers are turning toward Frequency-Modulated Continuous Wave (FMCW).

FMCW is quickly establishing itself as the next evolution of LiDAR. It is similar to radar in the way it functions, and cooling is an absolute must.

FMCW: High-Performance, High-Range Distance Detection Demands Cooling

FMCW is a high-performance, high-range method of detecting objects, where light from a frequency-swept laser is split into two. One-half (Tx) is transmitted directly to the target (a process known as chirping), while the second half (LO) stays local (meaning it doesn't go to the target). When the light from the target returns, it is recombined with the LO. The time delay and the beat difference between the LO and the received waveform are continuously calculated to yield distance and velocity information.

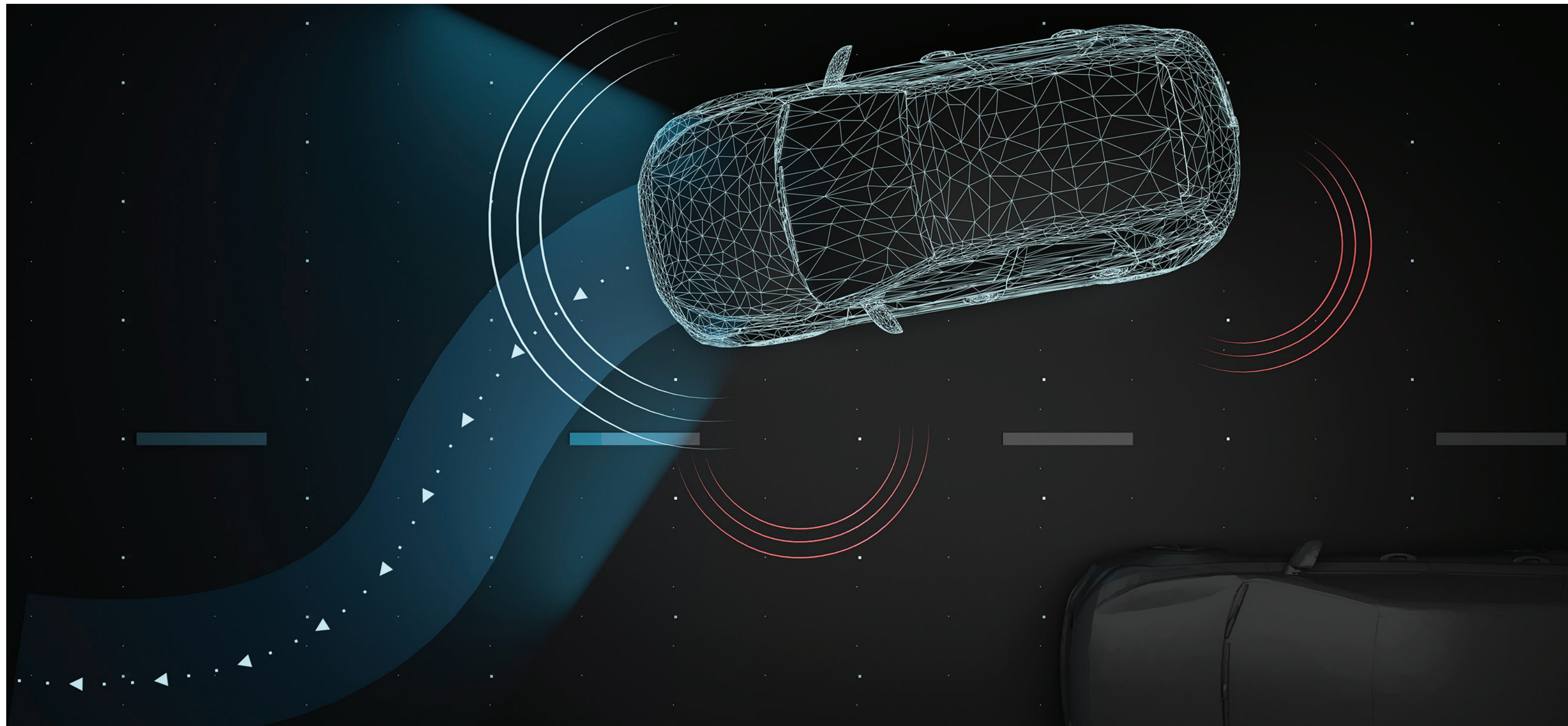
FMCW offers a host of advantages over ToF. First and foremost is higher optical power, which delivers improved range and resolution to autonomous vehicles. This allows for the separation and measurement of closely spaced objects at farther distances without confusing them for a single object — improving the system's overall reaction time. When coupled with cooling from Phononic TECs, FMCW sensors allow for very tight control of the laser and sensor component temperature. This provides a cost-effective way to maintain source wavelength stability and ensures immunity to ambient noise and interference, yielding more reliable and accurate imaging.

Another major benefit of FMCW, besides its resistance to interference, is its ability to determine an object's distance and velocity of motion concurrently — a critical requirement for autonomous navigation. Along with an improved range, this technology features greater distinction in the observed environment to enable earlier and more accurate readings and decisions. This lowers the incidence of false negatives and therefore increases overall safety as mandated by regulators and liability underwriters.

Several technological advancements help explain FMCW's adoption as the LiDAR system of choice. For one, the advent of highly stable, tunable lasers in combination with Phononic TECs ensures that very specific wavelengths can be achieved with lowered phase noise — this allows for long-distance sensing and measurement. Another important advancement is the integration of silicon photonic circuitry all in a single chip, which reduces scale and cost.

This combination of features, along with longer distances, makes cooled FMCW the solution for the next generation of LiDAR sensors. And though FMCW comes with some major benefits over ToF, there are some challenges that need to be addressed: namely, the 1550nm fiber laser light source comes at a higher cost. Add to that manufacturers' difficulty in selecting the proper beam-steering technology and there are still design tradeoffs that need to be considered.

One serious drawback that's easily addressed, however, is the generation of heat. An FMCW sensor generates a substantial amount of heat, which means cooling is an absolute must. This is where Phononic comes in.



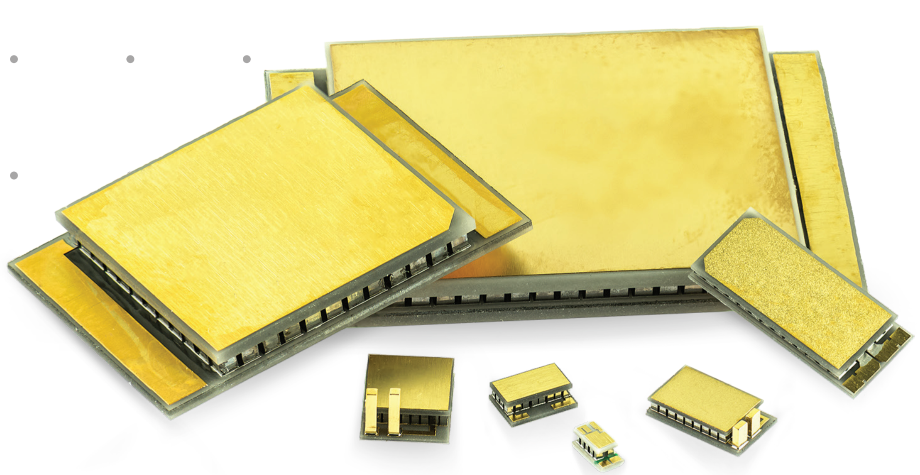
Maximize FMCW Capabilities With Phononic TECs

Cooling the critical LiDAR components is essential for both ToF and FMCW. It's what enables LiDAR to maintain peak performance throughout a wide variety of range applications and driving environments. Cooling is especially important for FMCW; in order to maintain wavelength stability, the laser must remain at a steady temperature to avoid drifting over a wide operating temperature range (up to 125˚C). Controlling laser operating temperature is imperative to ensure selectable and locked wavelengths that are reliable over time.

If cooling is not used with FMCW, it can lead to unpredictable variance in pulse width and modulation frequency stabilization, as well as a significantly lower operational lifetime. The light source in FMCW LiDAR applications must be cooled in order to maintain highly specific control over modulated wavelength, as well as to ensure the returned light is accurately detected alongside the reference signal.

When you partner with Phononic, you get application-specific TECs for your FMCW LiDAR that will cool temperature-sensitive components in the sensors. Our custom-built TECs will also help you improve performance, minimize the signal-to-noise ratio (SNR) and extend your range.

With an off-the-shelf TEC, you have to design — or redesign — around the TEC to get the most out of your LiDAR sensors. That's why so many industry leaders turn to Phononic. We work with you to build application-specific TECs for your specific FMCW LiDAR sensor designs, stabilizing the laser light source through active temperature control. Phononic TECs deliver best-in-class power consumption efficiency and the necesssary wavelength stability for FMCW systems, and are built to meet stringent automotive IATF standards.



Phononic TECs: Moving LiDAR Into the Future

Phononic is not new to the LiDAR industry. We've been working with LiDAR manufacturers and developers throughout the world to improve their sensors' capabilities and performance. The temptation to use low-cost bulk TECs should be avoided; they are designed for noncritical, inefficient, consumer-grade applications — situations where reliability is not a concern.

Phononic has long understood the flaw in turning to one-size-fits-all TECs, which is why our application-specific TECs are designed to work specifically with your system, and the cost is competitive with off-the-shelf solutions.

With the next evolution of LiDAR favoring FMCW systems, now is the time to turn to tailor-made TECs to deliver the performance, reliability and safety your self-driving vehicles need to reach the next tier of innovation. With Phononic, you have the ideal cooling solution for the next generation of LiDAR systems.

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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**

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