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SCANTINEL PHOTONICS
Scan | Detect | Navigate

Scantinel Technology Overview

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Content

FMCW LiDAR vs Time-of-Flight LiDAR

Autonomous vehicles, as well as any autonomous system, require a detailed 3D map of their environment to navigate safely. The capability to measure the distance to surrounding objects is essential to build accurate 3D mapping and is the key enabler for level 3-5 autonomous vehicles. The deep discussions we had with leading OEMs, Tier-1 suppliers, mobility service providers, and robotic vehicle companies confirmed this view and brought the unanimous feedback that LiDAR is essential for autonomous driving as another independent sensor modality, additional to cameras and Radar.

FMCW LiDAR advantages compared to Time-of-Flight:

There are two different range measurement principles currently used in LiDAR systems:

1. Time of Flight (ToF)
2. Frequency Modulated Continuous Wave (FMCW)

ToF LiDAR systems measure the time elapsed between an emitted short pulse of incoherent light and its reflection on the target. FMCW LiDAR, on the other hand, is based on a coherent measurement principle. A coherent superposition of the return light and of its local coherent copy, results in the signal that is then processed in the detection path. This process makes the system immune against interference from sunlight and other sources that are not coherent with the emitted light. The so-called coherent amplification effect in the detection path "amplifies" the return signal from the target, which is by nature very weak and consists only of a low number of photons. The coherent amplification effect significantly reduces the impact of the noise floor from other components in the system, such as the detectors. FMCW provides a so-called shot noise limited system, characterized by the best possible Signal-to-Noise Ratio (SNR) achievable by any physical system. This property of FMCW systems is the key enabler for long range (>300m) measurements required by autonomous vehicles.

In addition to these properties, FMCW enables direct velocity measurement in every pixel, which is not possible for ToF systems. Velocity measurement is a very important feature enabling significantly improved object detection in the final application of autonomous vehicles.

Most automotive LiDAR systems are currently based on the Time of Flight (ToF) principle, at wavelengths of 905nm or 1550nm. The big advantage of ToF systems at 905nm is the compatibility of the wavelength with CMOS silicon-based detectors, which are available at relatively low cost. However, 905nm systems cannot emit enough optical power for long range measurements due to human eye safety regulations. Consequently, experts expect 905 nm ToF to be ruled out as technology of choice for long range LiDAR due to very fundamental physiological reasons.

ToF systems at 1550nm can, in principle, achieve long range performance but require peak pulse power in the order of 1kW. This requirement mandates the use of short pulse fiber lasers, which are expensive and cannot be integrated on a photonic wafer platform. Furthermore, due to the short pulse-times used in the measurement, ToF systems at 1550nm require InGaAs avalanche photo diodes, which are very expensive and difficult to integrate on a wafer platform.

The required optical output power of FMCW LiDAR is below 100mW per FMCW channel of continuous transmission at a wavelength of 1500-1600nm. This has two important implications for the development of future low-cost automotive and robotic vehicle LiDAR sensors:

1. The chosen wavelength and the absence of high peak power pulses enable the design of Laser Class 1 eye safe long-range sensors.
2. The low power continuous wave operation enables the integration of the optical functionality, including lasers, optical amplifiers and low-cost detectors, in Photonic Integrated Circuits (PICs), which is in turn the enabler for low cost and high-volume optical sensors.

Summarizing, FMCW LiDAR systems at 1550nm show clear differentiating advantages, and are considered the key enabler for the next generation of autonomous mobility solutions.

Key competitive advantages of FMCW vs ToF:

Performance	Improvement vs ToF	Rationale
Range measurement	> 2x (200-300m @10% reflectivity with 90% detection probability)	▪ Narrow-linewidth laser and coherent detection principle enable superior photon detection probability. ▪ Eye-safe wavelength of 1550nm allows higher output power.
Direct velocity measurement	Not available in ToF	▪ FMCW technology uses the doppler effect to measure the direct velocity with 0,1m/s resolution in every pixel. ▪ Improves efficiency for perception algorithms and enables faster object identification, classification and tracking for better planning.
Output power/ Eye safety	10x output power with Laser Class 1 eye safety	▪ The laser source at 1550 nm permits to emit higher power within the eye-safe region with respect to the 905nm source used usually for ToF.
Robustness	8000x[1] Robustness against interference	▪ Coherent detection makes the system robust against interferences from other light sources like the sun or other LiDAR systems.
Cost	8x[2] Cost reduction via high-volume compatible solution	▪ FMCW technology and the laser wavelength enable the detection with low cost, CMOS compatible detectors (SiGe). ▪ Photonic integration, CMOS compatible technologies and high-volumes compatible photonic packaging allow the scalability to mass production.

1. Based on the principle of coherent detection that uses single mode coupling vs the multi-mode coupling of ToF.
2. Estimated cost reduction Compared to 1550nm ToF systems

Key FMCW LiDAR Challenges and Scantinel's Unique Value Proposition

Solid State Scanning

Long range FMCW LiDAR does not work in Flash-mode, therefore a beam steering (scanning) mechanism is mandatory. Long range LiDAR requires a minimum Field-of-View (FoV) of about 100°x20° (HxV), combined with a resolution of about 0,05°x0,05° (HxV, at least in the region of interest) and a frame rate of 10 Hz. At the same time, due to the long measurement range, a beam diameter of the scanning system in the range of 1-2 cm is required. The combined requirements are very tough to meet, and scanning is an even harder technical challenge than FMCW ranging itself.

Mechanical scanning in both axis is not feasible for a high pixel rate FMCW system, since an approach with 2 mechanical scan axes does not allow simultaneous output of multiple FMCW beams resulting in lower performance in terms of number of pixels per second. An approach with a single 2D mechanical scanning mirror will have the big drawback that the beam, on the fast-scanning axis, will also travel too fast on the objects. With this approach, the beam travel speed is very high and can cause phase decorrelation and a poor measurement performance. Therefore at least one fully solid state, multiplexing scan axis has to be provided.

One possible approach to solid state scanning is Optical Phased Arrays (OPAs), often claimed by some of the competitors in the FMCW space. Scantinel has investigated OPAs, considered the latest process technology options and developed very advanced patents pending OPA architectures in order to optimize the performance of this scanning principle. However, we came to the conclusion, that OPAs are not feasible as a high-volume product with foreseeable process technology limitations for the next 5-10 years. These process limitations are due to materials used in the process flow and the limitations of high-end lithography.

Optical Enhanced Array (OEA): Scantinel's unique approach to solid-state scanning

Scantinel has developed a unique solid-state beam steering technology, called Optical Enhanced Array (OEA). This is a unique combination of a photonic integrated chip and an advanced optical system.

A photonic integrated chip integrates a set of optical structures on silicon and processes light, in a similar way to what electronic chips do with electrical signals. The PIC, designed by Scantinel and manufactured at a standard CMOS foundry, enables the parallelization of multiple FMCW channels in a solid-state scan axis.

The PIC and the collimating lens system have unique optical and photonic design that requires the extensive expertise in the design and manufacture of PICs and lens systems that only an experienced engineering team, like the one of Scantinel, can provide. The technical challenge is the complex photonic design of the PIC, involving hundreds of photonic components, as well as the co-design of the collimating lens system and the light input/output waveguides for optimum coupling of the return light to the photonic IC.

Scantinel's OEA technology combines the best existing process technologies in a unique solution that enables solid-state, multi-channel scanning. This solution is quickly scalable to high volume with highly competitive price for performance.

Integration of the FMCW Engine

Scantinel's LiDAR on Chip architecture arranges FMCW Engine and photonic systems on Photonic Integrated Circuits (PICs) and electronic controls on ASICs. This approach offers a clear path to mass-production, cost reduction, product miniaturization and system reliability, which are the key enablers for successful commercialization.

A key role in cost optimization and miniaturization is the integration of the FMCW engine. The FMCW engine is the heart of the system that ensures a narrow laser linewidth (resulting in long coherence length), and linear modulation of the laser wavelength to generate the chirp signal. The integration of this module will reduce the number of components that need to be assembled in the final system, having a sensible impact on the total assembly cost. Moreover, the volume scalability of an integrated solution will further reduce the overall BOM, when compared to system using fiber-based lasers and discrete components.

Another fundamental discriminant for the integration of the FMCW engine, is played by the frequency modulation technique of the laser, key aspect for FMCW ranging. One common approach is to use Single Sideband Modulation (SSM) for this purpose. The main drawback of this approach is that it requires RF components that are difficult to integrate and expensive.

Hybrid-integrated tunable laser: Scantinel's solution for an integrated FMCW engine

Scantinel is developing a unique solution for the integration of the FMCW engine, based on a hybrid integration concept of III/V material on silicon. Our single chip laser provides very narrow linewidth and fast and linear tuneability. These laser properties are key to achieve the best possible Signal-to-Noise Ratio (SNR), which in turn enables long range measurements at low optical output power. The chirped laser design is developed by Scantinel based on in-depth know-how in laser physics and semiconductor laser integration technology. The integration approach leverages the most advanced photonics integration platforms and manufacturing processes. To amplify the light generated by the laser source, semiconductor optical amplifiers (SOAs) are used. Scantinel has developed a unique approach to hybrid integrate arrays of SOAs on the silicon photonics platform.

The laser tuning mechanism is based on direct wavelength modulation (or Carrier Mode Modulation, CMM), which allows a cost-efficient implementation of the swept laser source without the need for expensive high frequency RF components, as in case of single side band modulation (SSB) mentioned above.

Low-noise, Immune Detection

Sunlight or other LiDAR signal interference is a roadblock for most legacy LiDAR systems. By comparison, Scantinel's FMCW LiDAR system is inherently immune to such interference due to its working principle, only receiving the coherent copy of the transmitted signal.

High-volume manufacturability at competitive price for performance

Scantinel is developing a photonic integrated circuits based on standard CMOS technology, which relies on proven fabrication processes and highly automated manufacturing techniques, therefore, offers a cost competitive and high-scalable solution.

Modularity and silicon photonics: Scantinel's secret for a flexible high-volume solution

Scantinel's strategic approach towards PIC integration is to strictly utilize only fully CMOS compatible process flows for manufacturing. Even though some more exotic PIC platforms might lead to faster availability of samples, in our opinion they do not allow low-cost production in the long run since they are missing a straightforward path to high volume manufacturability. Therefore, we produce our PICs on a standard platform offered by a large CMOS foundry. This ensures a direct access to the latest CMOS-compatible PIC process technology and to future low-cost high volume manufacturing capability.

Scantinel's approach of the LiDAR system is a highly flexible modular concept. The Optoelectronics Core Module (OCM incl. OEA, laser system, photonic system, ASICs and collimator, etc.) can be integrated into any sensing platform (with different DSPs and horizontal scanning schemes). In addition, Scantinel is also able to offer a reference design for the complete LiDAR system solution, which can be quickly scaled up in production and is easy to implement in any desired applications.

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