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On-chip coherent LIDAR for imaging: progress and current limitations

Aude Martin[1], Patrick Feneyrou[1] and Jérôme Bourderionnet[1]

[1] Thales Research and Technology
1, avenue Augustin Fresnel
91120 Palaiseau, France
E-mail: aude.martin@thalesgroup.com

Abstract

In the context of unmanned vehicles, eye-safe, robust and compact sensors are required to analyze the environment. During this talk, the principle of a coherent LiDAR based on the frequency modulation of the laser will be described along with 3D measurements performed in degraded visual environments. Detection experiments of a moving target up to 50 m using a compact LiDAR based on silicon photonics are also highlighted. This photonic integrated circuit, without any moving part, allows emission and detection in 8 different collimated directions spread over the desired angle. Technological limitations preventing the full integration of LIDARs will also be discussed.

1. 3D imaging using Frequency Modulated Continuous Wave LIDAR

Multidimensional imaging systems either use an array of detectors such as gated viewing cameras [1]; single photons array [2], or use a single pixel technology such as laser ranging with a beam scanning technology [3] or a single pixel camera [4]. In this work, we have used the FMCW LiDAR technology with a scanning head for imaging through obscurants and used a non-mechanical scanning system with a LiDAR on-chip to detect a hard target.

The main idea for FMCW lidar is to obtain spatial resolution using a frequency modulation in a coherent detection scheme. Both local oscillator and emitted signal are frequency modulated. The backscattered signal is time-delayed due to the light propagation time from the lidar to the target and frequency shifted due to Doppler shift. Hence, the interference between local oscillator and backscattered light shows frequency plateaus, the average of which corresponds to the Doppler shift (speed measurement) and the difference of which corresponds to the range multiplied by the frequency modulation slope.

As illustrated in Figure 1, this type of detection also enables to distinguish a static target with two sharp peaks from a large signal backscattered by a cloud. Since the cloud presents a significant thickness, the power spectral density of the backscattered light is spread over a significant number of frequency bins. This clear signature of a hard target enables to reduce false alarms and, hence, increase the signal processing speed by removing peaks based on their spectral width prior to further signal processing. The signal processing used in the following experiments [5] also enables to process multiple targets within the collimated beam.

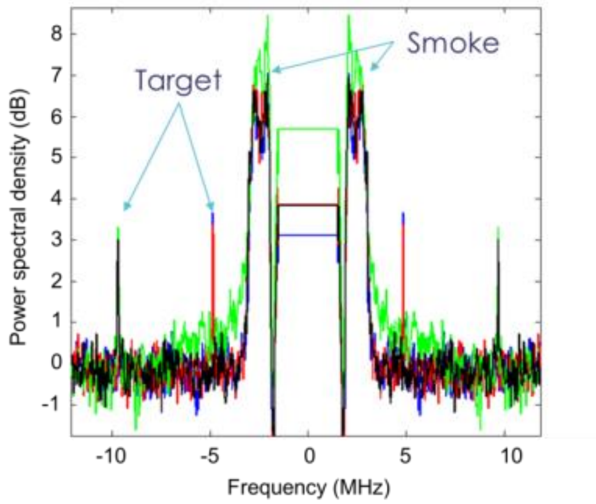

Fig. 1. Experimental power spectral density of a target behind a cloud.

2. A compact FMCW LIDAR using silicon integration

The use of Photonic integrated circuits (PIC) is considered a valuable option for the implementation of a compact 3-D LiDAR, able to measure simultaneously range and speed with no or few moving parts. Through monolithic integration, PICs are able to provide both electronic and optical devices on the same chip as well as thermal and mechanical stability. Besides the silicon technology is getting mature thanks to foundries, which supply parallel manufacturing paving the way for mass production. As high peak powers need to be handled with care with PIC and the transparency window of silicon imposes to use wavelength above 1100 nm, the implementation of the architecture of an FMCW LiDAR at 1.55 µm on-chip is particularly straightforward [7].

Except from the DFB and output circulators, the optical part of the LiDAR is fully implemented on a 3x3 mm silicon chip [8]. It consists of 8 emission channels and 8 collection channels addressed using phase modulators inserted in Mach Zehnder interferometers and a waveform calibration channel. In Figure 2, switches networks are highlighted in green (SN1) for the reception ports and red (SN2) for the emission ports. Emission channels are successively addressed and connected via optical fibered circulators (FC) to the corresponding Balanced PhotoDiodes (BPD) and the output collimator. Thus we avoid beam scanning and the PIC presents no moving parts by having each of the emission part covering the desired angle after passing through collimators. The waveform calibration is achieved with the delay line interferometer (DLI). The silicon chip is then bonded to a Printed Circuit Board to read the balanced photodiodes signals. Using this photonic integrated LIDAR, we have demonstrated up to 30 mW of output power for 200 mW input power and a homogeneous routing of the 8 channels and were able to detect a moving target at up to 50 m of range with less than 5 mW of output power [8].

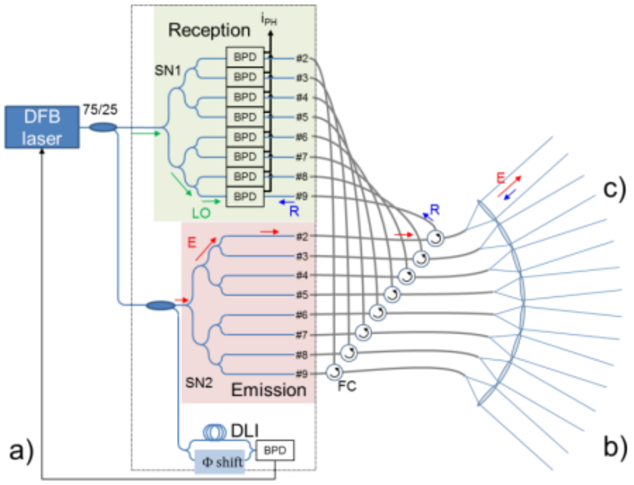

Fig. 2. Architecture of the FMCW Lidar system (the rectangle delimits the chip perimeter).

3. Conclusions

Detection and ranging on-chip using integrated photonics should definitely offer compactness and reduce costs but for longer ranges or wind measurements, the high power sustainability of the chip should be improved.

References

[1] Busck, J., and Heiselberg, H, Applied optics, 43(24), 4705-4710 (2004)

[2] Pawlikowska, A., Halimi, A., Lamb, R., and Buller, G., Opt. Express 25, 11919-11931 (2017)

[3] Aflatouni, F., Abiri, B., Rekhi, A., and Hajimiri, A. “Nanophotonic coherent imager”, Opt. Express 23, 5117-5125 (2015)

[4] Hardy, N., and Shapiro, J., Physical Review A, 87, 023820 (2013)

[5] Feneyrou, P., Leviandier, L., Minet, J., Pillet, G., Martin, A., Dolfi, D., ... & Midavaine, T., Applied Optics, 56(35), 9663-9675 (2017).

[6] Feneyrou, P., Leviandier, L., Minet, J., Pillet, G., Martin, A., Dolfi, D., ... & Midavaine, T., Applied optics, 56(35), 9676-9685 (2017).

[7] Poulton C. V. Yaacobi, A., Cole D., Byrd M., Raval M.,Vermeulen D. & Watts, M., Optics Letters, 42(20), 4091-4094 (2017)

[8] Martin, A., Dodane, D., Leviandier, L., Dolfi, D., Naughton, A., O’Brien, P., ... & De Heyn, P. (2018). Journal of Lightwave Technology, 36(19), 4640-4645.