EUROPEAN TRANSPORT CONFERENCE 2022

MULTISTATIC LiDAR SENSORS for ADVANCING SAFETY of AUTONOMOUS VEHICLES

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Zeina Nazer P.E. MSc. MBA PhD'23

University of Southampton, UK

Background

This research project is on “**IMPROVING MULTISTATIC LiDAR FOR AUTONOMOUS VEHICLES APPLICATIONS**” under the supervision of Prof. Otto Muskens and Dr. Ben Waterson.

The project is sponsored by DSTL and EPSRC.

Light Detection and Ranging (LiDAR) is a remote sensing technology widely used in many areas. In transportation, LiDAR combined with sensors suite, is applicable in Advanced Driver-Assistance Systems ADAS and autonomous vehicles to accurately detect and track pedestrians, vehicles and the surroundings.

The aim of this research is to improve implementation of LiDAR technology to provide a more accurate information of the presence and position of objects detected with the aim to improve pedestrian safety.

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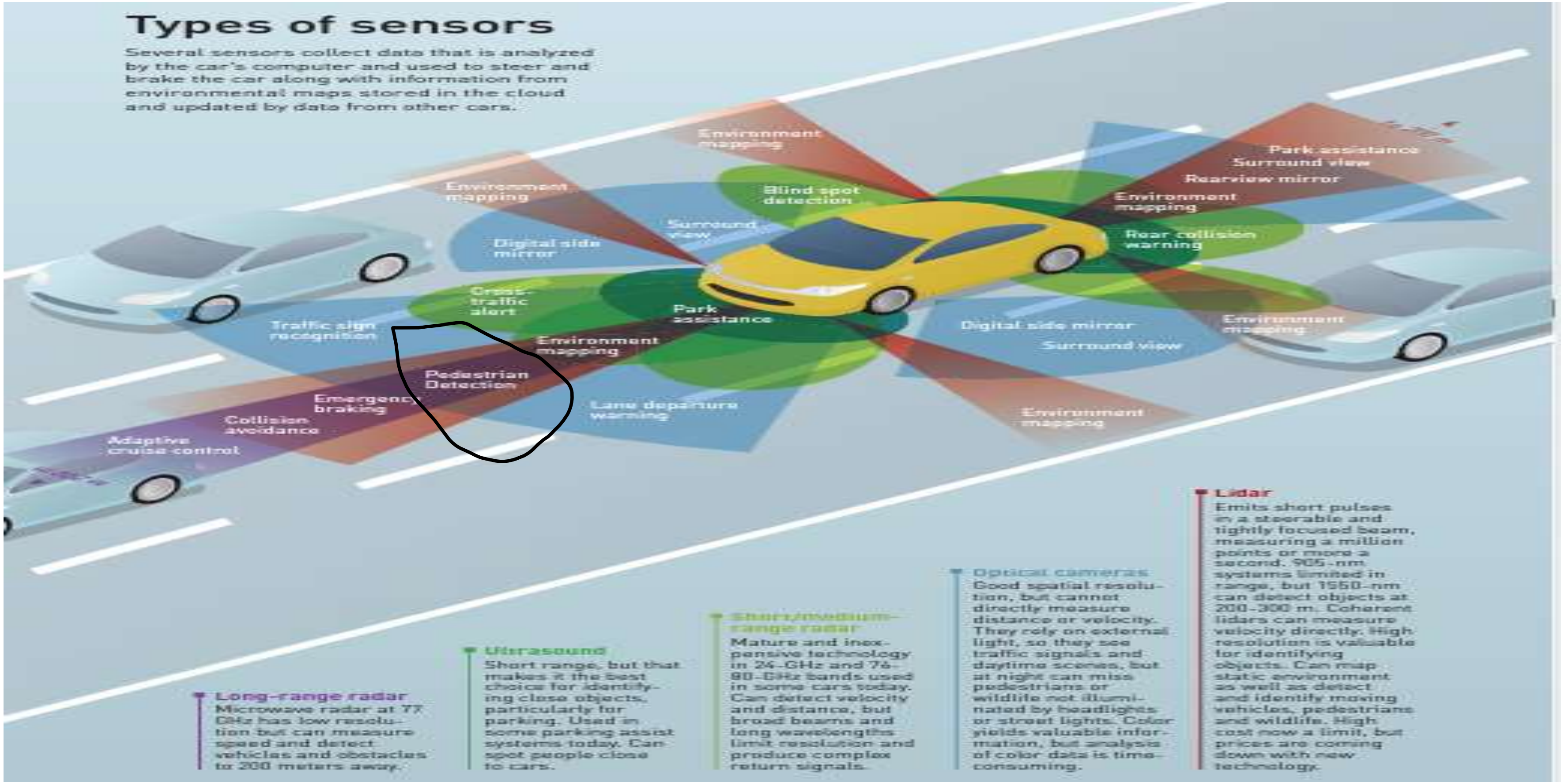
Autonomous Vehicle Sensors Suite



Overview of the sensing system for Autonomous Vehicles (Jeff Hecht 2018)

Definitions

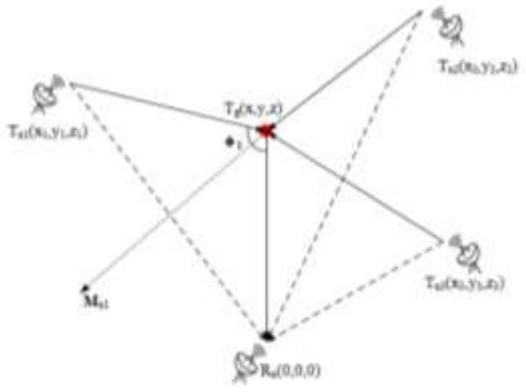
Monostatic or conventional LiDAR system comprises of a transmitter and receiver that are in same location.

Bistatic LiDAR system comprises of a transmitter and receiver that are separated by a distance.

Multistatic LiDAR system contains a combination of spatially diverse monostatic or Bistatic LiDAR components with a shared area of coverage.

A limited literature review was found on Multistatic LiDAR application for autonomous vehicles.

By using a diverging source instead of a single beam, the object can be seen at any point in space, rather than directly in front of the beam.



Geometric structure of Multistatic Radar system. Source: (Shao et al. 2021)

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Research Question

LiDAR and Radar are similar in techniques. Radar emits radio waves while LiDAR uses lasers with lower wavelength and higher accuracy allowing to detect smaller objects.

LiDAR sensors have several applications the focus of this research is on improving multistatic LiDAR sensors to better locate objects with the ultimate aim of the objects being pedestrians.

The novelty in this research is to explore how to improve object detection and position finding through using multistatic LiDAR hybrid solution combined with triangulation and deep learning. The research question is:

Can Multistatic LiDAR sensors improve the system performance which could lead to enhanced autonomous vehicle safety?

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Methodology

This study will investigate multistatic LiDAR systems in Physics lab using triangulation in the first phase and will take it to the real world in the second phase and experiment M16 Leddartech sensors combined with cameras for testing and validation.

The project runs experiments of LiDAR in the lab under different scenarios, starting with conventional LiDAR and looking into different scenarios of LiDAR combined with other sensors.

The emphasis in phase 1 is on the lab optics improvements through experiments and will be on using off-the-shelf LiDAR sensors in phase 2.

Tasks Completed To date

The tasks performed so far include:

1. Investigate the State-of-the-art of Automotive LiDAR sensors

2. Explore the different types of LiDAR sensors from literature review in academia and industry

3. Run lab experiments for conventional LiDAR using diverging lens

4. Introduce multistatic LiDAR and run lab experiments for Improved setup using triangulation

5. Run experiments of LeddarM16 with camera for single static object.

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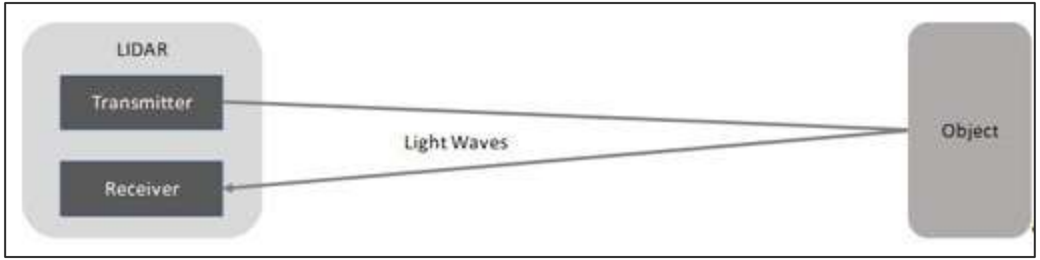
Conventional LiDAR Using One Detector

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = c$$

$$\Delta t = \frac{1}{c} \times [D1+D2]$$

A LIDAR set up is a Pulsed light shining onto an object of unknown distance. This light is then reflected by the object and measured by a detector.

Δt = the time of flight (seconds)
c = the speed of light ≈ 3×10^8 ms^{-1}
D1 = the distance of transmitter to object (m)
D2 = the distance of object to receiver (m)



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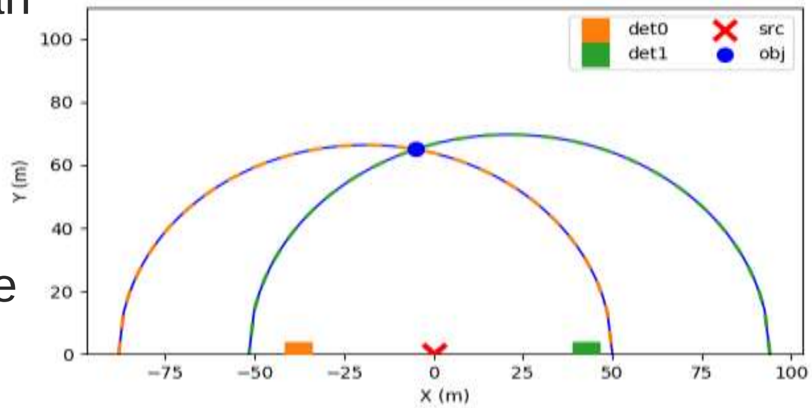
Ellipse Concept Using Two Detectors

From the set of graphs, we want to find the exact position of the object reflecting the light. Using the peaks, we can find the distance the light has travelled from source to object to detector. From this the position of the object can be determined as a point along an ellipse.



Using the ellipse equation
x2/a2 + y2/b2 =1
we can analytically calculate the position of one object from two detectors.

For more objects it is not always possible to find the location, can deep learning help?

LiDAR Experiments conducted in Lab 1035

Experiment 1: Monostatic (conventional) single beam LiDAR using Fianium pulsed laser with normal and diverging lens and 1 detector looking at a scattered object using DPC230

Experiment 2: Multistatic single beam LiDAR using Fianium pulsed laser with diverging lens and diffuser with 2 detectors with diffusers put close to receivers to extend the angle of view looking at a scattered object using DPC230

Experiment 3: Multistatic single beam LiDAR (improved version) using Fianium pulsed laser with diffuser and no lens with 2 detectors with diffusers looking for a scattered object using DPC230.

Experiment 4: Leddar M16 mounted with Camera using Labview looking at a scattered object

Experiment 5: (Future Work): we will use Deep Learning for Multistatic LiDAR to investigate how to interpret sensor data.

Will Deep Learning allow this setup to see multiple objects, which is not possible using theory only?

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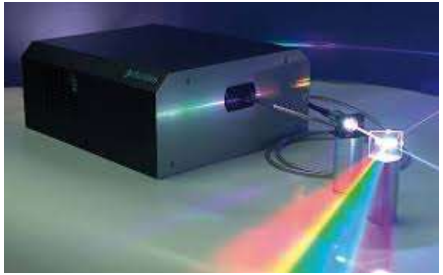
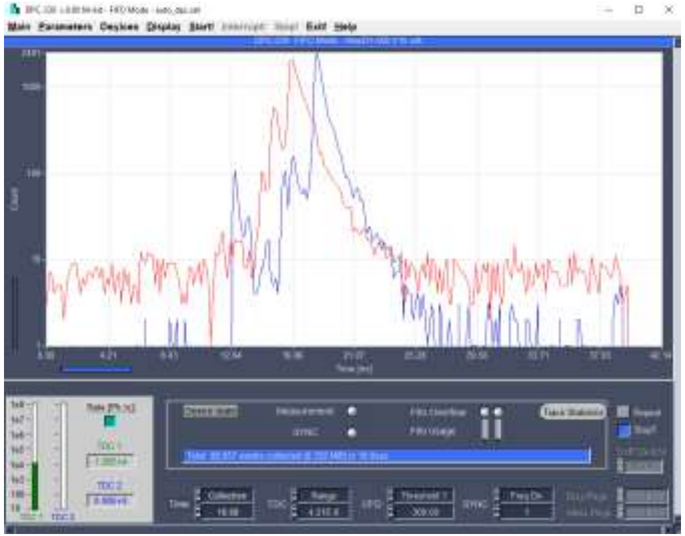
Experimental Setup

Fianium pulsed Laser (11 ps)



IDQ single-photon detector (50 ps)



Data collection program

Becker & Hickl DPC230 time-resolved counter (160ps)

Data analysis (Python)

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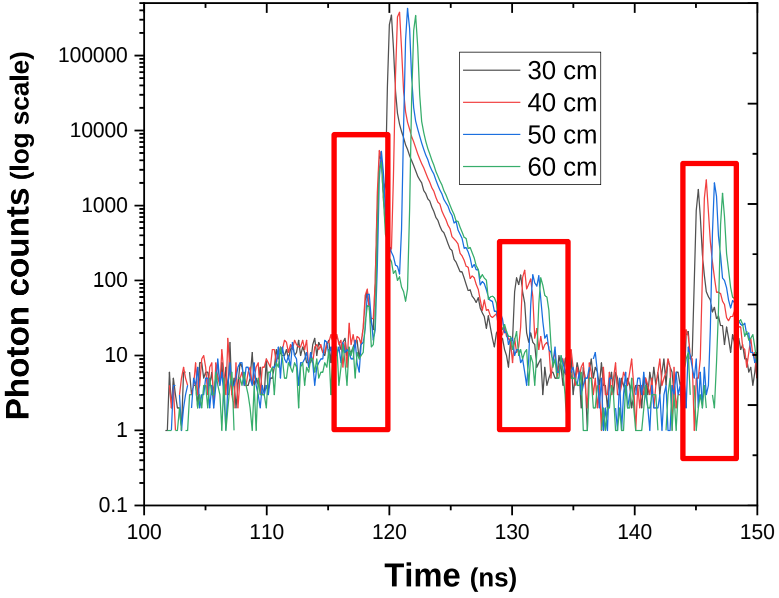
1. Single Beam LiDAR with One Detector

Photon counts over time for object distance 30-60cm



Extra reflections in setup

Trigger diode

2. Multistatic LiDAR: Single Beam LiDAR Experiment with Two Detectors Using Triangulation

2. Multistatic LiDAR: Single Beam LiDAR Experiment with Two Detectors Using Triangulation

- Step 1: measure the source power distribution
- Step 2: characterise the aperture angle of the receivers
- Step 3: determine the overlap area
- Step 4: find time delay for each object position

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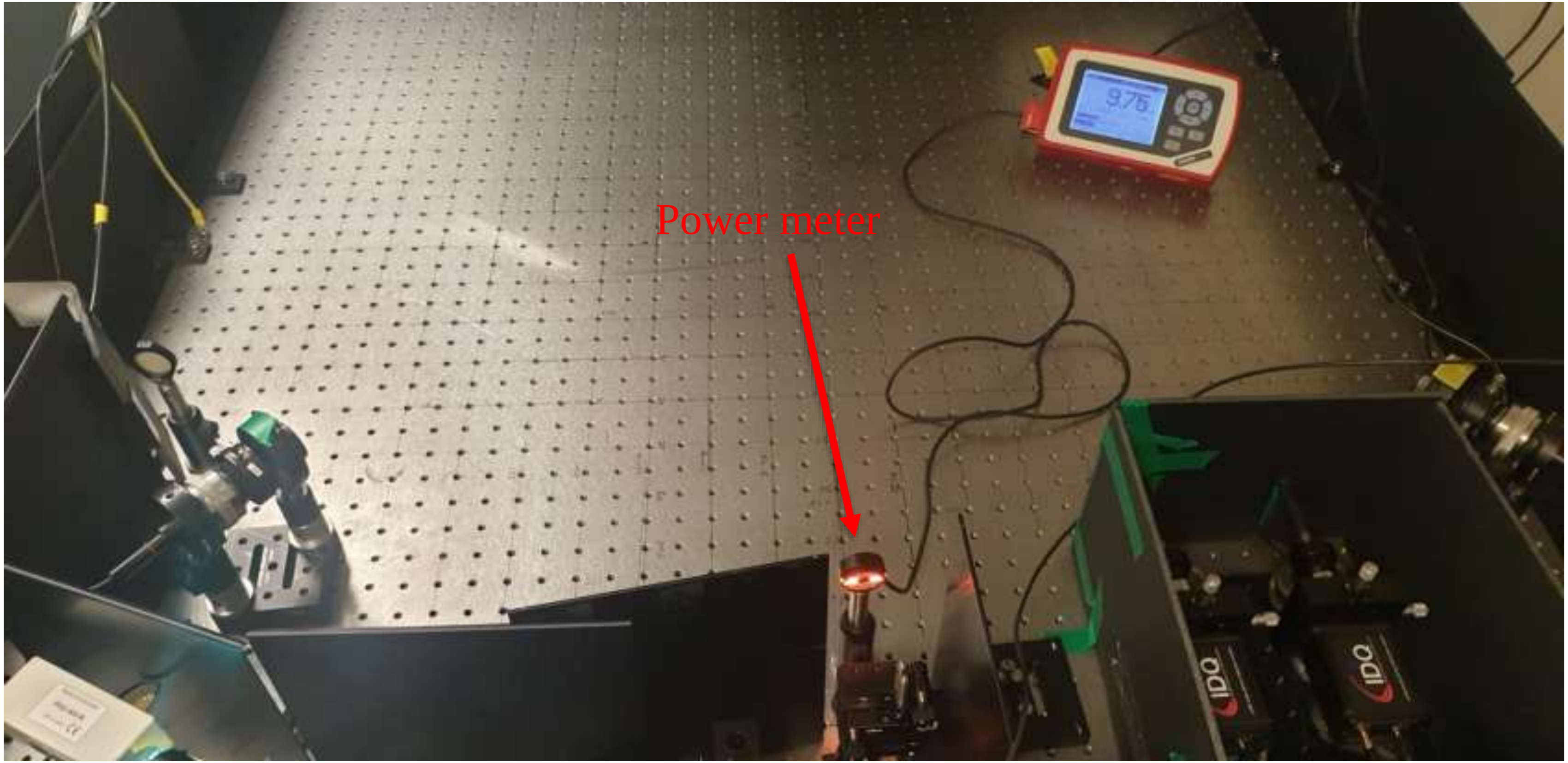
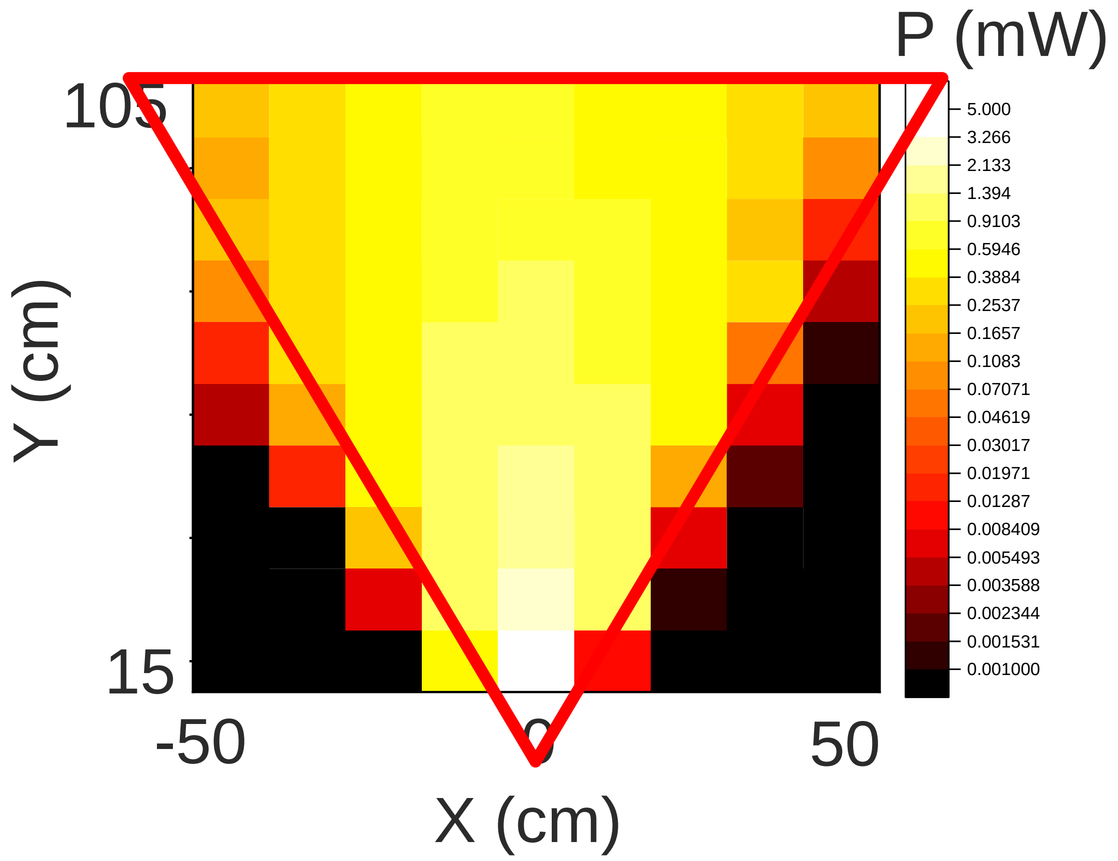
Step 1: Beam Intensity measure using Power Meter



Step 1: Beam Intensity measure using Power Meter



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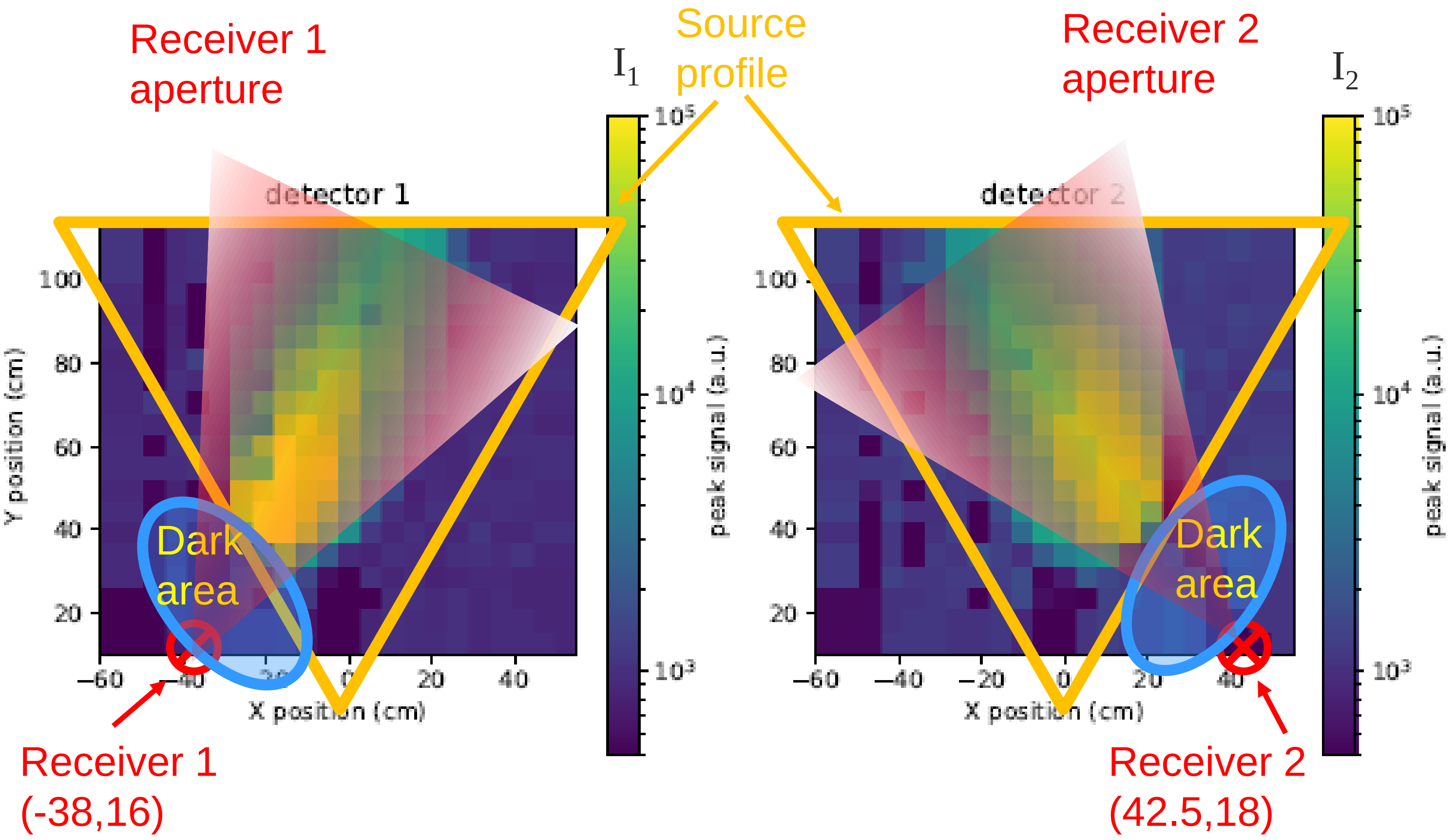
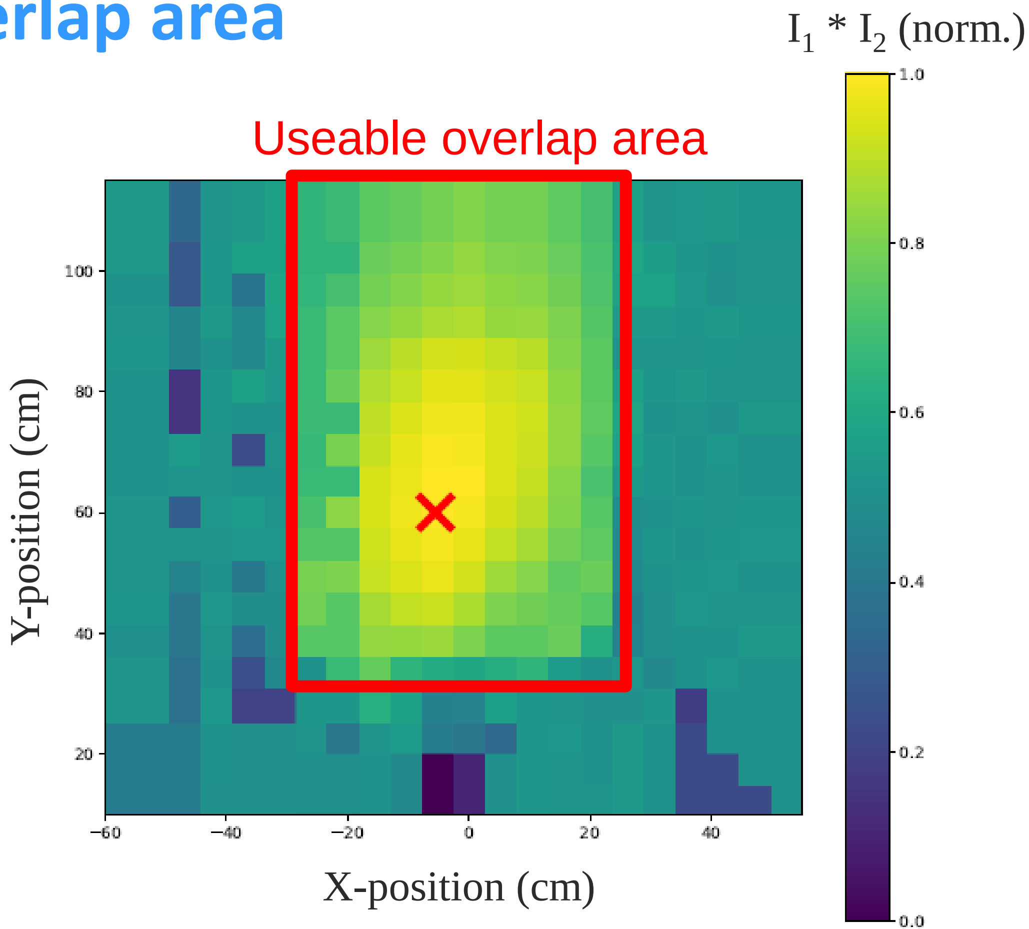
Step 2: Aperture angle of the receivers

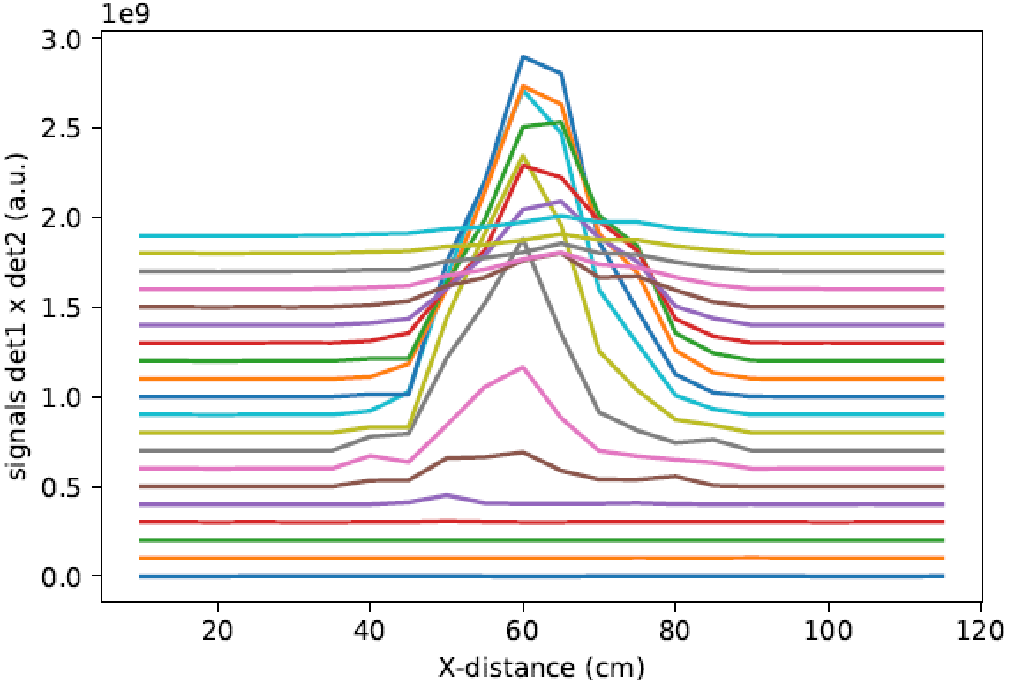


Step 3: Determine overlap area

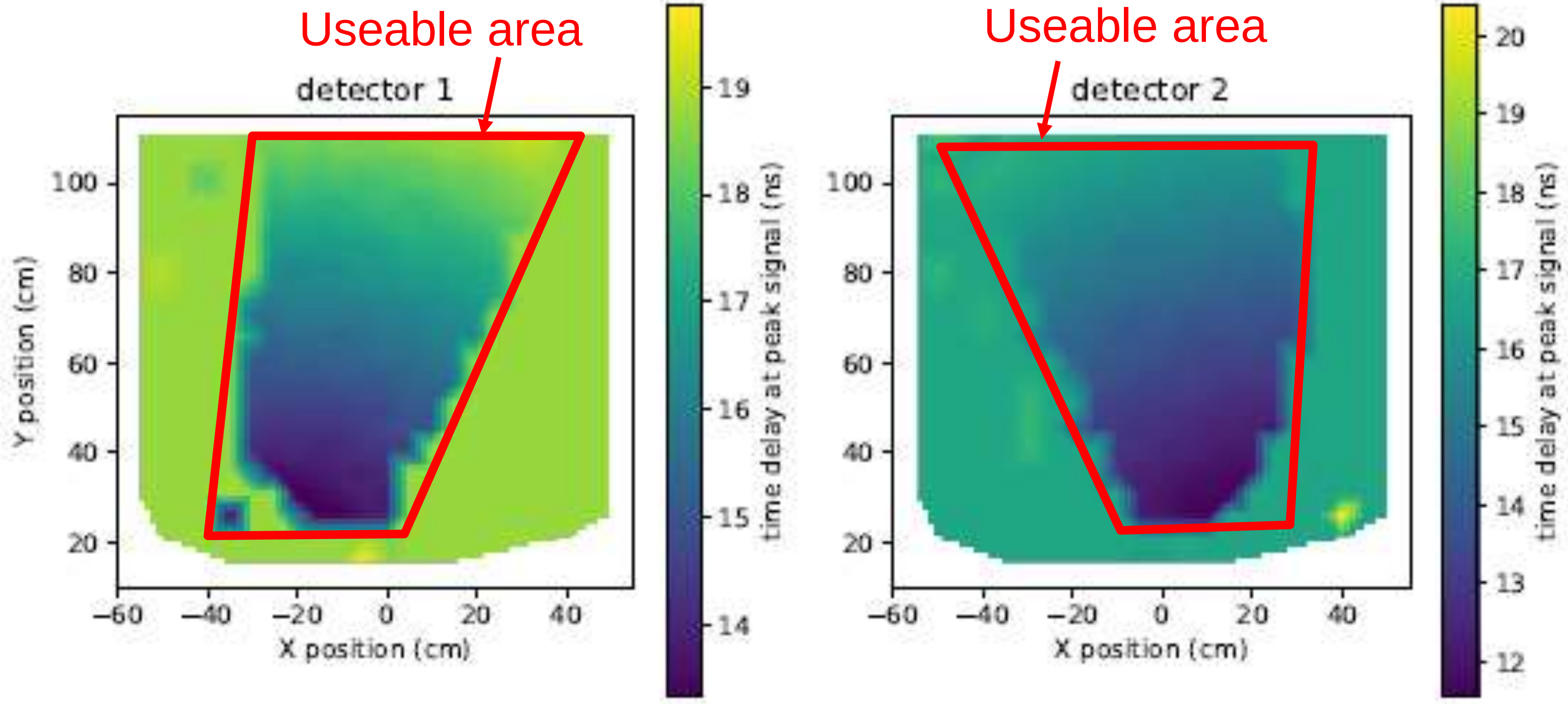


Peak point of both detectors overlapped found at (-5,60)

Step 3: Peak Point of overlap area



Step 4: Time Delay of Both Detectors



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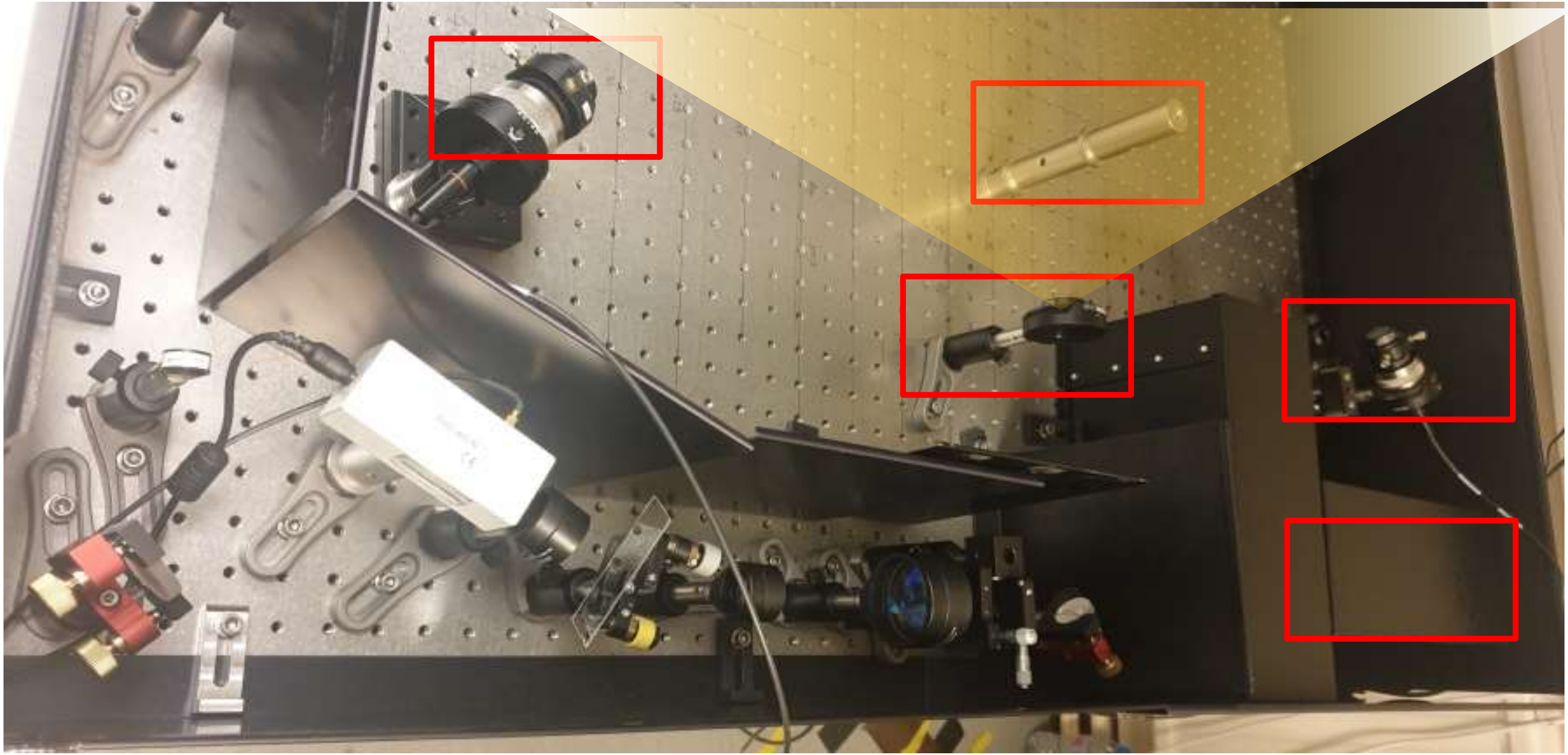
Conclusions from first trial of Multistatic LiDAR

- Achieved simultaneous data acquisition with two detectors
- Defined a shared coverage area of 50 x 80 cm^2
- Source angle is limiting the available area (dark areas)
- Aperture of receivers could be further improved

3. Multistatic LiDAR Version 2.0: Improvements on the setup



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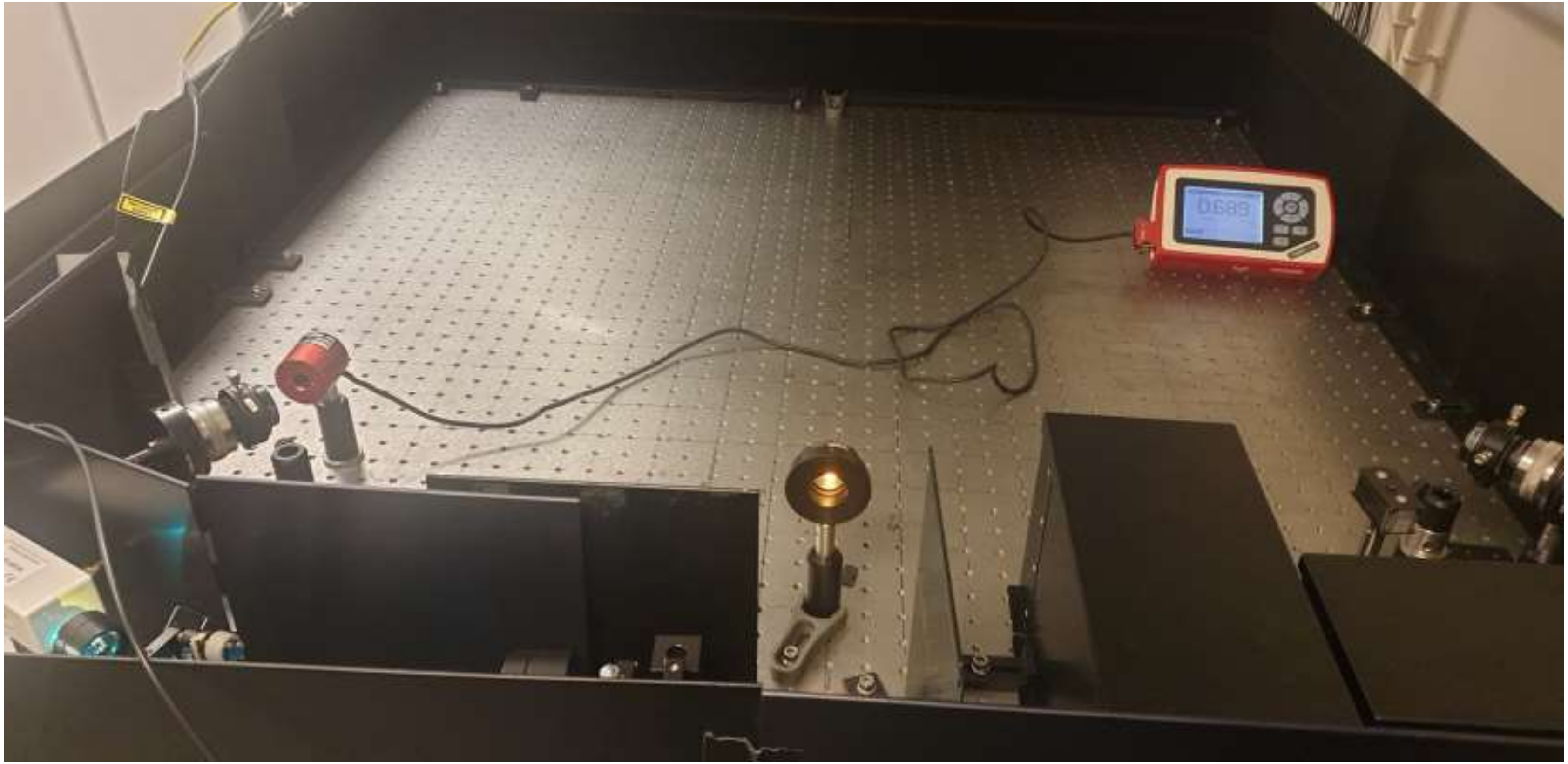
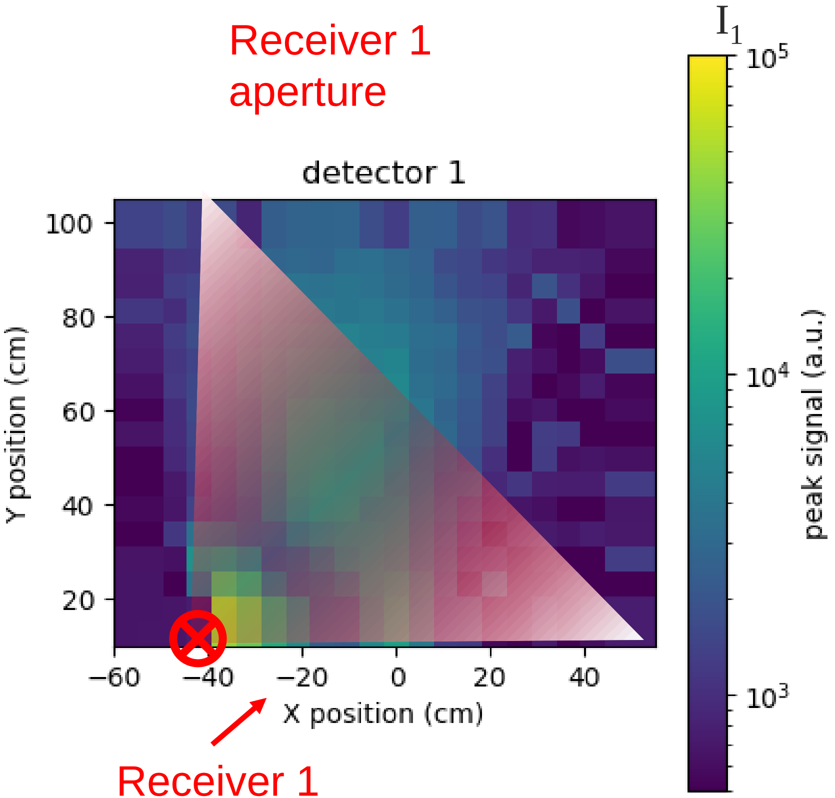
Step 1: Beam Intensity measure using Power Meter



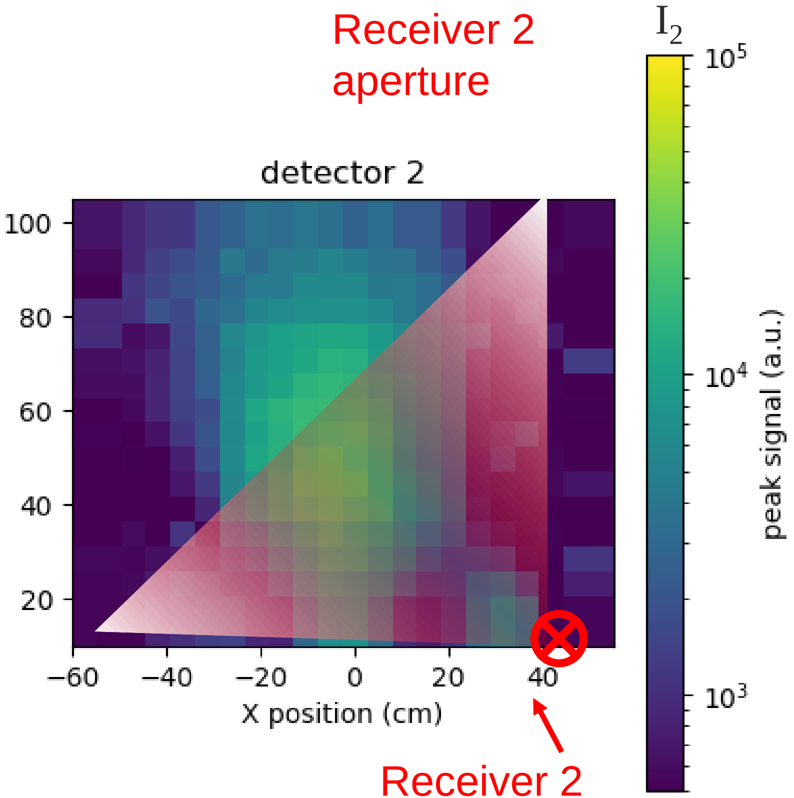
Step 2: Aperture angle of the receivers

Receiver 1 aperture



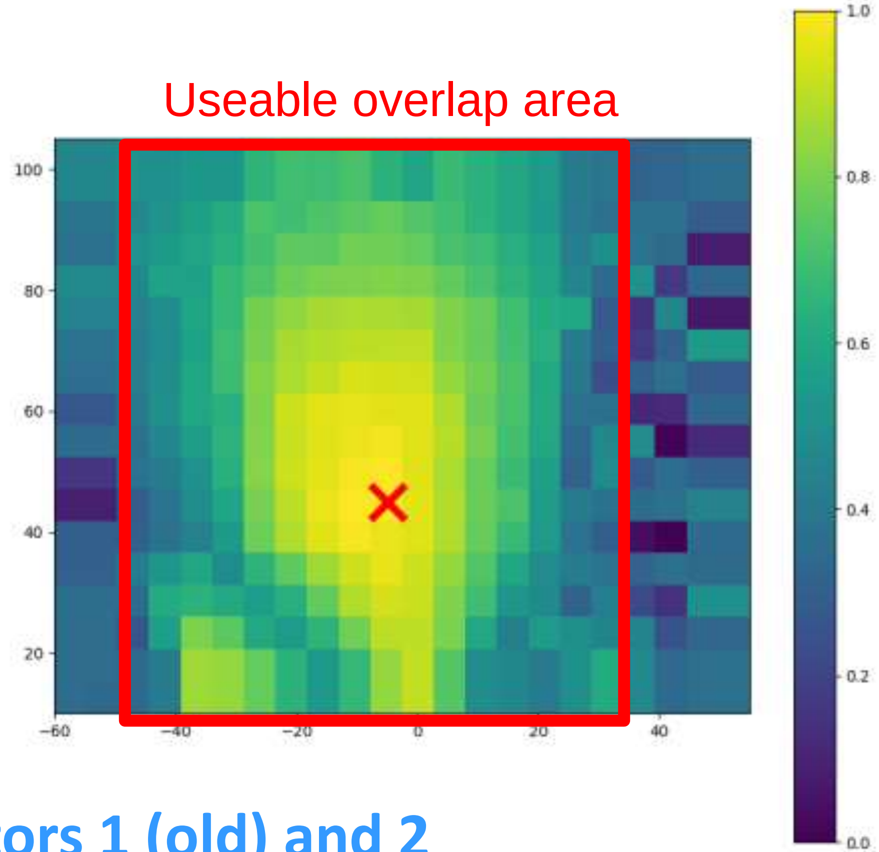
Receiver 1 (-38,16)

Receiver 2 aperture



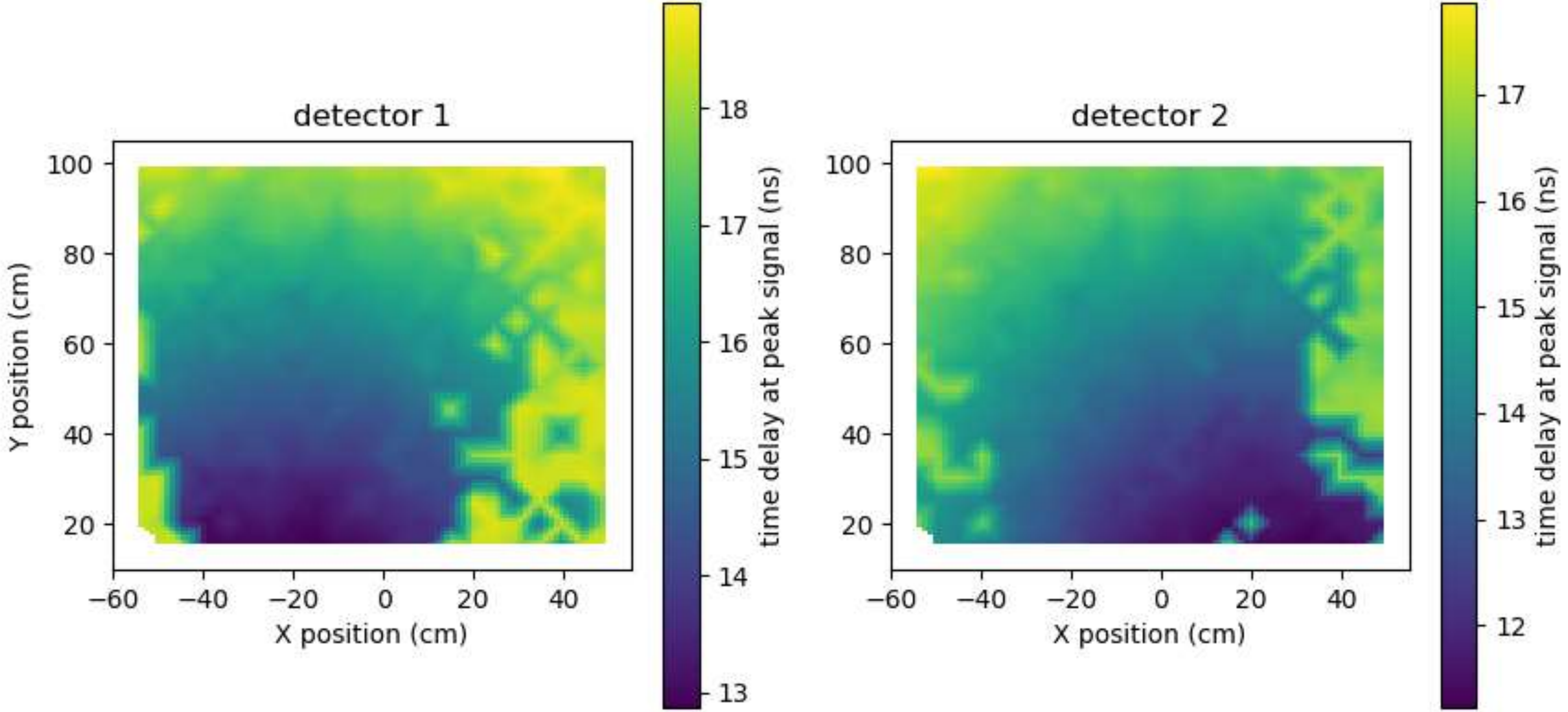
Receiver 2 (42.5,18)

Step 3: Determine overlap area



Overlap of Detectors 1 (old) and 2 (new) found at (-5,45)

Step 4: Time Delay of Detectors 1 (old) and 2 (new)



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Conclusions from Improved Multistatic LiDAR

- Achieved simultaneous data acquisition with two detectors
- Defined a shared coverage area of 100 x 80 cm^2
- Source angle is no longer limiting the available area (no dark areas)
- Aperture of receivers has improved

Future Work

Future work will include adding more complexity to the experiments including looking at multiple objects, static and moving objects and use deep learning in order to explore the potential performance improvement of multistatic LiDAR combined solutions.

Thank you

Zeina Nazer

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