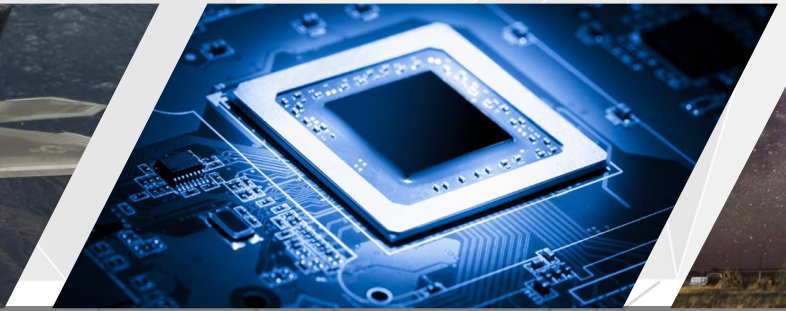
ALPHACORE

ROBUST HIGH-PERFORMANCE MICROELECTRONICS

Radiation Hard High Speed Camera System for Accelerator Beam Diagnostics

DOE SBIR/STTR Phase IIC (DE-SC0013232)



The Alphacore Team

- Alphacore's team is a combination of business and engineering professionals with long histories of delivering products and services to customers who demand state-of-the-art performance.

- Our team has had successful careers at companies ranging from start-ups to multinationals including **Raytheon, Texas Instruments, Analog Devices, Bell Labs, Intel, United Technologies,** and **Honeywell**.

- Current government contracts with DOD (Air Force, Navy, Army, DARPA, MDA, DMEA), DOE, NASA, and NIST. We have more and more commercial contracts as well.

Alphacore's Mission

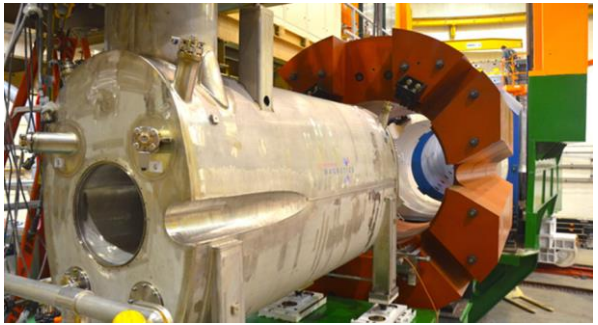
Alphacore is working to advance the community's knowledge of radiation effects and other harsh environmental effects on advanced electronics

Alphacore is simultaneously developing the rad-hard and rad-tolerant advanced electronics IP, ICs, and imaging systems needed to maintain and grow our technological advantages in this critical field

Alphacore's IP blocks are available today, augmented by engineering services to optimize and/or port for customers' applications

DOE SBIR Phase IIC (DE-SC0013232)

Radiation Hard High Speed Camera System for Accelerator Beam Diagnostics



Technical Objective: A radiation-tolerant, triggerable, high speed imaging chip and a complete camera system for investigating rapidly occurring phenomena in radiation environments. The primary applications are beam monitoring and scientific experiments at nuclear physics facilities.

Phase IIC Additional Goal: Work with a partner who will invest with the intention to commercialize the technology. We have a partner who is investing to commercialize the camera technology in the Autonomous Vehicles and Advanced Driver-Assistance Systems (ADAS) markets.

Accomplishments before Phase IIC

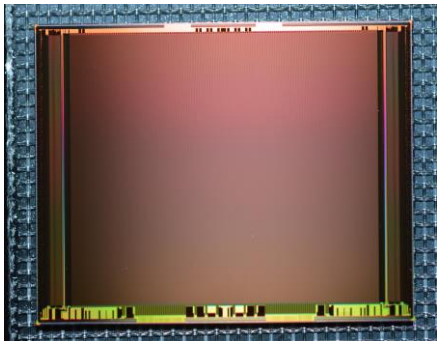
- 10,000-pixel, 20,000fps, scalable radiation-hardened CMOS image sensor and full camera system designed and tested.
- High Frame Rate Camera System capable of 1Mpix and 10,000fps (120Gb/s data rate) designed and tested.
  - 100% functional in pre-rad tests
  - Failed functioning at 11krad(Si) – 40krad(Si) at the intended harsh operation environment
- 1,024 x 768 radiation-hardened CMOS image sensor designed and tested.
  - Pre-radiation functionality not satisfactory
  - Passed 125krad(Si) TID test

Developed Items

10,000-pixel custom image sensor and camera operate up to 20,000 fps

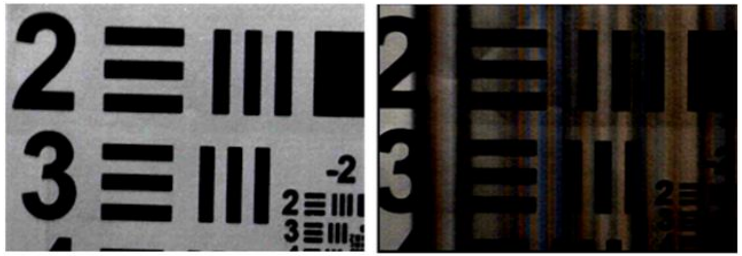
High Frame Rate Camera System capable of 1Mpix and 10,000fps (120Gb/s data rate)

1,024 x 768 radiation-hardened CMOS image sensor



Rad-Hard Image Sensor

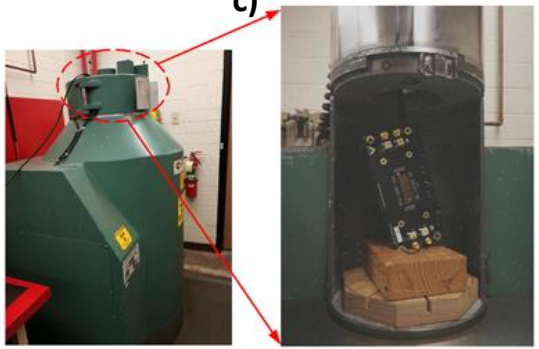
Radiation hardness of high-frame rate commercial cameras is poor



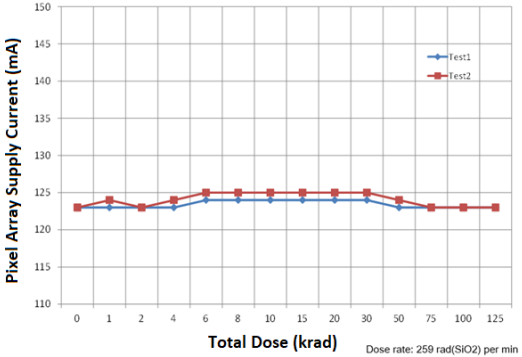
a) b)

- **Figure a)** COTS high-speed camera image at 0 krad(Si).
- **Figure b)** Same sensor, after 3.2 krad(Si). Image degradation was seen already at 900 rads(Si).
- Custom-hardened cameras are needed for imaging in radiation environments.

c)



d)



Alphacore's Rad-Hard Image Sensor

Figure c) shows Alphacore's high frame rate rad-hard image sensor prototype in the Gammacell Co60 radiation test chamber

- Figure d) shows no change in baseline pixel array current due to leakage during testing to 125 krad TID

Phase IIC Focus: Nuclear Physics

- Debugging the taped out 1,024 x 768, 10kfps CMOS Image Sensor
  - Decision was made to perform new tapeout with reduced specs (640 x 512, 5kfps)
  - Ultra-fast ROI capability was added, otherwise the architecture has been simplified
  - Capability to drive a long rad-hard cable was added
- Debugging the High Frame Rate Camera System capable of 1Mpix and 10,000fps
  - The developed and tested system contains >20 COTS ICs -> truly radiation-hard version very expensive
  - Decision was made to change architecture to “Rad-hard Image Sensor -> Rad-hard Cable (125 ft) -> Non-Rad-Hard Camera System”
  - Expected TID hardness: 300krad(Si) – 1Mrad(Si). Now our custom-hardened CMOS image sensor is the limiting factor.

Phase IIC Focus: Commercialization

- Completing a modified version of the CMOS Image Sensor Optimized for Autonomous Vehicles and Advanced Driver-Assistance Systems (ADAS) Markets.
  - Most of the Image Sensor is exactly the same.
  - Pixel Design is different. Sensing element is an APD.
  - Camera System is the same.
- Next tapeout for Nuclear Physics and Automotive sensors scheduled for October.

Array Resolution vs Frame Rate Programmability

One of the greatest benefits Alphacore's architecture provides is that the user can effectively increase the frame rate by selecting a smaller (square) region of pixels to be read out. This is enabled by the fact that Alphacore has designed high sampling speed ADCs and S/H circuits just for this specific purpose. Other companies' architectures using slower column ADCs do not have this benefit.

Selected Pixel Array	Frame rate [fps]
640 x 512	5,000
512 x 512	6,250
384 x 384	11,100
256 x 256	25,000

Modified Camera Configuration for Radiation Environments

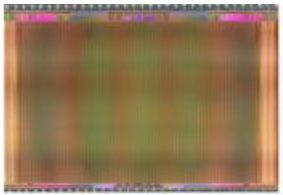


Image Sensor (CIS):

- Rad-hard up to 1Mrad
- 640 x 512
- 5kfps
- Built-in copper cable interface

Image Sensor enclosure:

- Very rad-hard, shielding can be added
- Can hold coolant
- Hosts Image sensor
- Has the right size window for rad-hard optics
- As small as possible

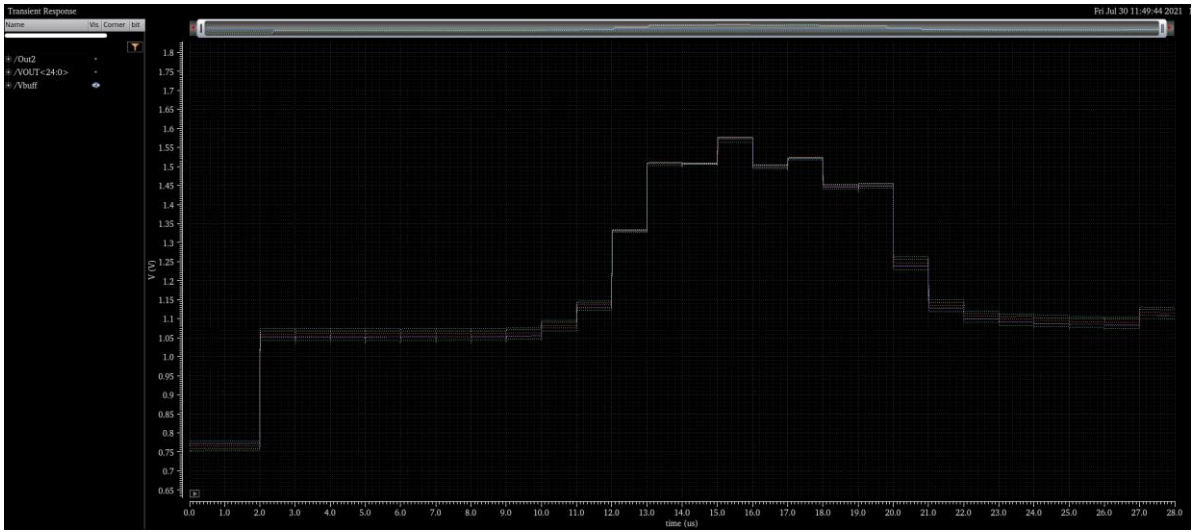
Cable from CIS to Camera Board

Rad-hard copper cable is needed.

Camera Board

- Receives data from CIS
- Interfaces with a PC
- Non-rad-hard

Modifications for the Commercial Version



The pixel design for the automotive sensor has been completed. Here are temperature variation simulation results (Cadence).

- Most of the Image Sensor Design is exactly the same (frame rate, the whole readout circuitry chain, I/Os).
- Pixel Design is different. Sensing element is an APD. Analog amplifier is needed in every pixel.
- Camera System is the same.

Status of the Development

- Both, the (improved) Nuclear Physics Image Sensor and the Commercial, Automotive Image Sensor are scheduled to be taped out in October 2021 in the same commercial 180nm CMOS process.
- The next step after receiving the chips is to integrate with Alphacore's Camera System and test.
- Considering the CMOS fabrication time, and the needed time for testing, we approximate that these objectives can be completed in April 2022.
- We have requested a No Cost Extension from DOE.

Summary

- Alphacore has been working on a DOE SBIR Phase IIC program to optimize for commercialization a DOE NP SBIR funded rad-hard camera.
- We are working with a partner who has invested into the program with the intention to commercialize the technology in the Autonomous Vehicles and Advanced Driver-Assistance Systems (ADAS) markets.
- We have also now optimized the camera design for the original Nuclear Physics application and are ready for the next tapeout.
- Both, the (improved) Nuclear Physics Image Sensor and the Commercial, Automotive Image Sensor are scheduled to be taped out in October 2021 in the same commercial 180nm CMOS process.
- We want to thank Dr. Michelle Shinn, Dr. Manouchehr Farkhondeh and Dr. Geoff Krafft.

Questions?