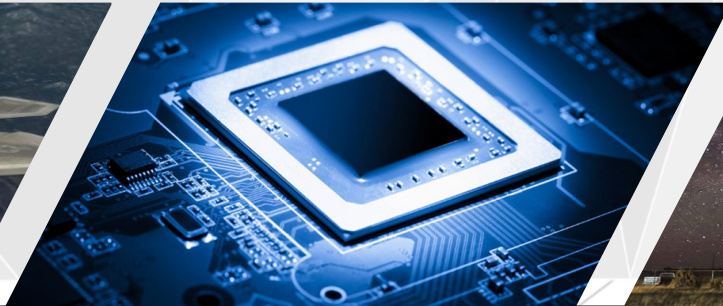




# Radiation Hard High Speed Camera System for Accelerator Beam Diagnostics

DOE SBIR/STTR Phase IIC (DE-SC0013232)





# About Alphacore

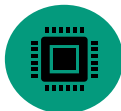


*Standard and customized IP*



*Global operation based in the U.S.*

Our focus areas are:



*Analog, Mixed Signal and RF Solutions*



*Imaging Solutions*

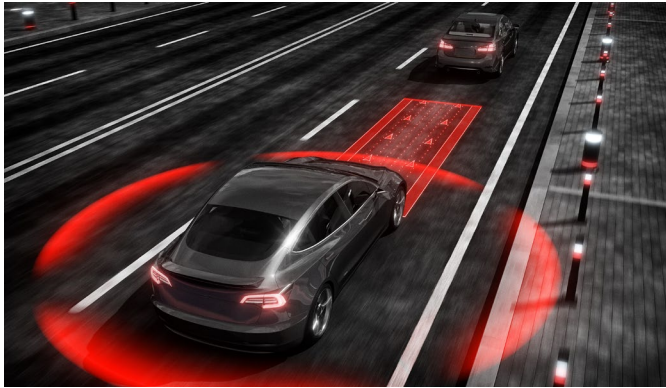
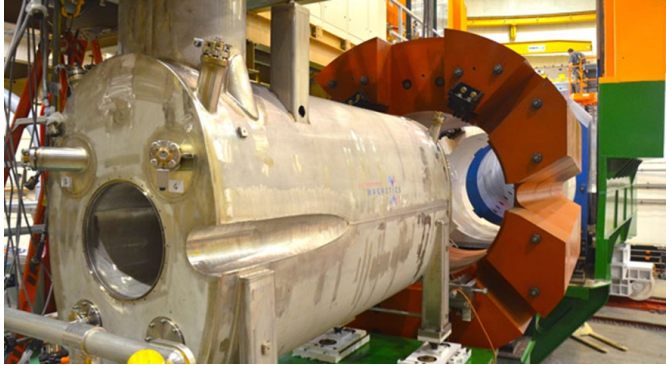


*Rugged, Radiation Hardened Electronics*



# 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 for **Autonomous Vehicles and Advanced Driver-Assistance Systems (ADAS)** markets.



# Accomplishments before Phase IIC

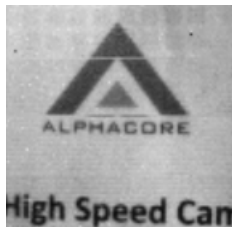
- 10,000-pixel, 20,000fps, scalable radiation-hardened CMOS image sensor and full camera system designed and tested.
- High Frame Rate Camera System capable of 1Mpix and 10,000fps (120Gb/s data rate) designed and tested.
  - 100% functional in pre-rad tests
  - Failed functioning at 11krad(Si) – 40krad(Si) in 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

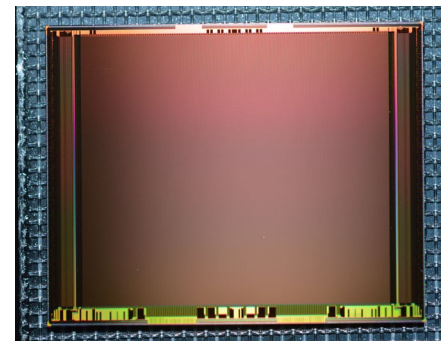
10,000-pixel custom image sensor and camera operate up to 20,000 fps



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

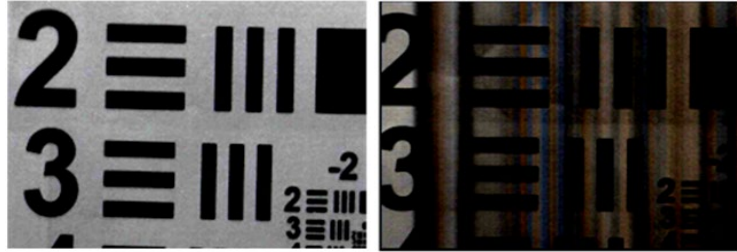


1,024 x 768 radiation-hardened CMOS image sensor



# Rad-Hard Image Sensor

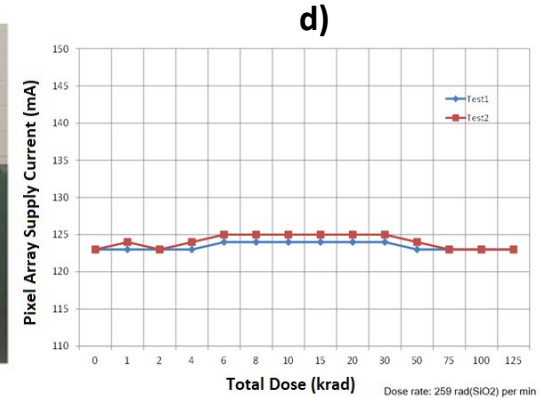
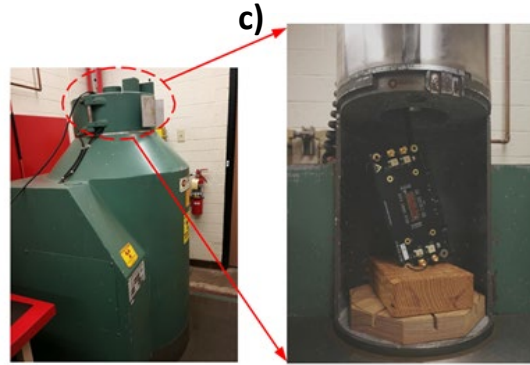
Radiation hardness of high-frame rate commercial cameras is poor



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.



## Alpacore's Rad-Hard Image Sensor

- Figure c) shows Alpacore'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: Commercialization

## Sensor optimization for Commercialization in Autonomous Vehicles and Advanced Driver-Assistance Systems (ADAS) Markets

A new test chip was designed, fabricated and tested.

- Sensing element is now an APD -> Pixel requires a high bandwidth amplifier.
- The new pixel was integrated with the rest of the camera CMOS circuitry on this chip.
- Good functionality was proven.
- Industry Sponsor is happy 😊

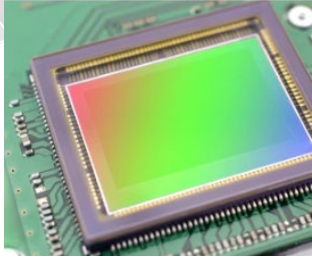


# Phase IIC Focus: Rad-Hard High-Speed Camera

- 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
  - Hardening against single event effects (space and defense applications) 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. Sourcing the IC components not possible in today's situation.
  - 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). Now our custom-hardened CMOS image sensor is the limiting factor.



# Modified Camera Configuration for Radiation Environments



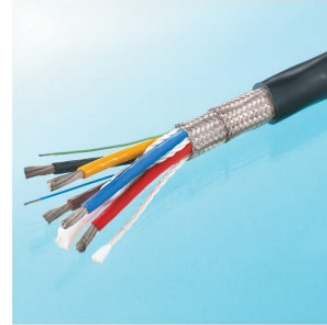
## Image Sensor (CIS)

- 640 x 512 pixels
- 5kfps frame rate
- Radiation hardened to 300krad
- Single event hardening added
- Resolution Vs Frame Rate programmability
- Debugging interface
- Built-in drivers for 28Gb/s data over 100ft of cable



## 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



COMPOSITE ROUND CABLE

## Cable from CIS to Camera Board

Rad-hard cable used.



## Camera Board

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



# 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           |



# Rad-Hard High-Speed Camera Status

- The chip design has been completed
- The sensor is scheduled for tapeout in September 2022.



# 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.
- The commercial, Automotive Market's Optimized, Image Sensor design has been taped out and tested.
- We have also now optimized the camera design for the original Nuclear Physics application and are ready for the next tapeout.
- The (improved) High Frame Rate Rad-Hard Image Sensor is scheduled to be taped out in September 2022.
- We want to thank Dr. Michelle Shinn, Dr. Manouchehr Farkhondeh and Dr. Geoff Krafft.

# Questions?

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Business: [Rusafa.Shahreen@alphacoreinc.com](mailto:Rusafa.Shahreen@alphacoreinc.com)

# Thank You !