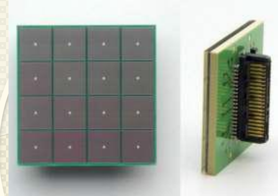
Imaging Camera Electronics

- Desired Design specifications
- GAPD sensor
- Design Considerations
- Overall Camera Electronics
- Camera FE prototype
  - Pixel Cluster Module - Current status

Desired Design Specifications

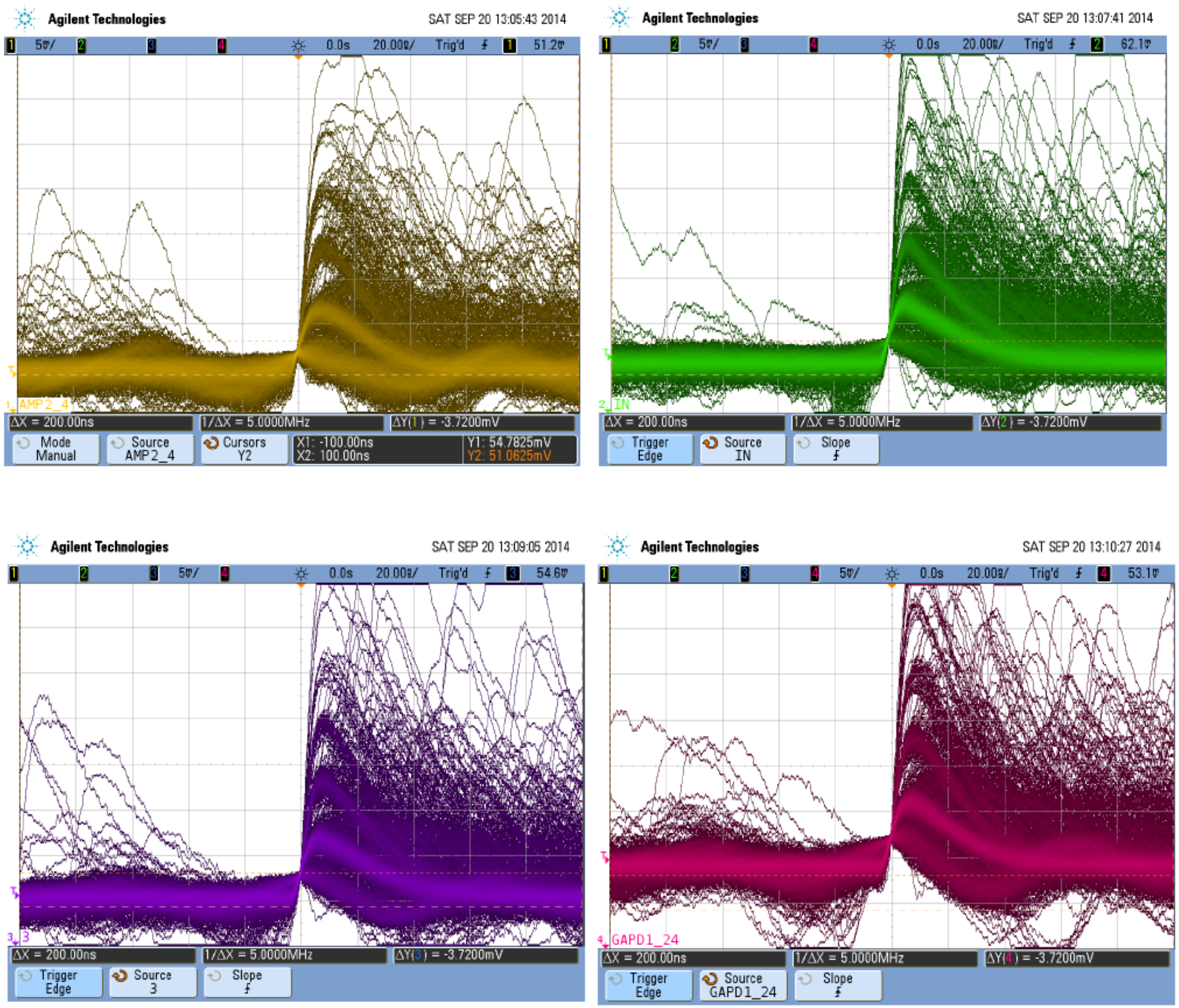
- Imaging of Cerenkov flashes (290 to 600nm) of few nsec duration against the large NSB(above 550nm) background
- Imaging Camera at focal point of 4m TACTIC telescope
  - 256(16x16) pixels of 0.3° each with total FOV 4.8x4.8°
  - Dynamic range upto 2000 pe/pixel with a resolution of 0.5 pe (for <10pe)
- Operational site is Hanle :
  - Temp variation of ~10 C over the night observation and seasonal night variation + 20C to -20C.
- NSB at Hanle: pe seen by electronics 100MHz/pixel(dark sky)
- 4x4 array GAPD (16 sub pixel of 3x3mm^2) is used as a pixel sensor. Hamamatsu S 12642 -050C or better
- sensor pulse profile digitization is required
- In-situ Single photo electron calibration
- Expected Trigger rate is upto 500 Hz



GAPD sensor

- 4x4 array of 3mmx3 mm size as a pixel
- 320 to 900nm(P-500nm),3600ucell, OV=BdV+10V, PDE =35%,
- Dark count rate 1MHz /sub pixel at 25C
- BdV is increases with temperature OV= Bias-BdV, So gain decreases
  - BdV variation with temp is 47.9 mV/ ° C
- Variation of BdV in 4x4 array is around 200mV (Manufacture data)
  - Typical Breakdown voltage at Room Temperature (25° C) = 69.71V

2x2 array with in-house amplifier



Rise time 6-7ns
Fall time 30-35ns

Figure-1: Typical pulse pattern of GAPD four channels recorded with oscilloscope. Bias voltage=71.0V. Four panels represent CH1 (Yellow), CH2(Green), CH3(Purple) and CH4(Magenta) of 2x2 array GAPD

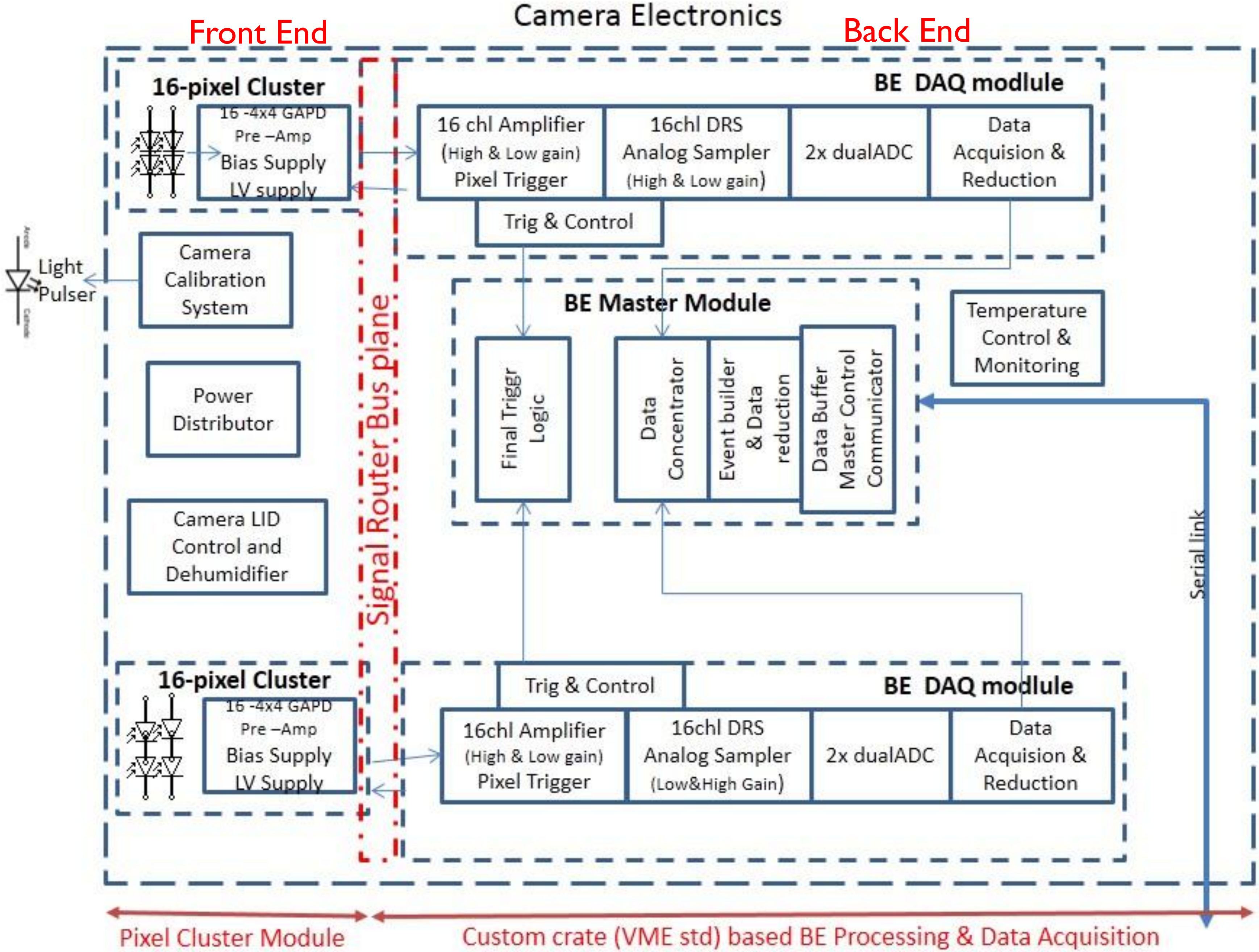
Design Considerations

- 256 pixel Imaging Camera will be housed at focal point with acquisition and control electronics and a down link for data transfer , command interface
- 4x4 array of $3x3mm^2$ GAPD per 0.3° pixel is planned to use
  - Each element is referred as sub-pixel
  - Light guide per pixel is used to optimize the sensor area from $21x21mm^2$ entry window to 12mm x 12mm of sensor area
  - To reduce number of electronic channels
    - Tying sensor output deteriorates the shape of pulse due to large capacitance. So planned to sum the sub pixel pulses in electronics
- Retain and record the Pulse profile
  - GAPD : Rise time ~6ns Fall time 30-35ns (wide BW amplifiers are used)
  - Sampling @1GHz, ROI of 100ns recorded using DRS Analog Sampler of range 1000 samples
  - NSB pe/pixel is 100MHz. Attempt to reduce fall time before summing to avoid pile up effect
- Dynamic range : up to 2000 pe/pixel assuming 7.5uA/avalanche at 1.5V OV
  - Amplifier with trans-impedence stage per sub pixel and summed, amplified to get Low and High gain outputs per pixel. HG covers upto 125pe
- Expected Trigger rate is few hundred. Consider upto 500Hz for design
  - With 99% Efficiency & 500 Hz rate, Event dead time < 20us
  - With 95% Efficiency & 100 Hz rate, Event dead time < 105us

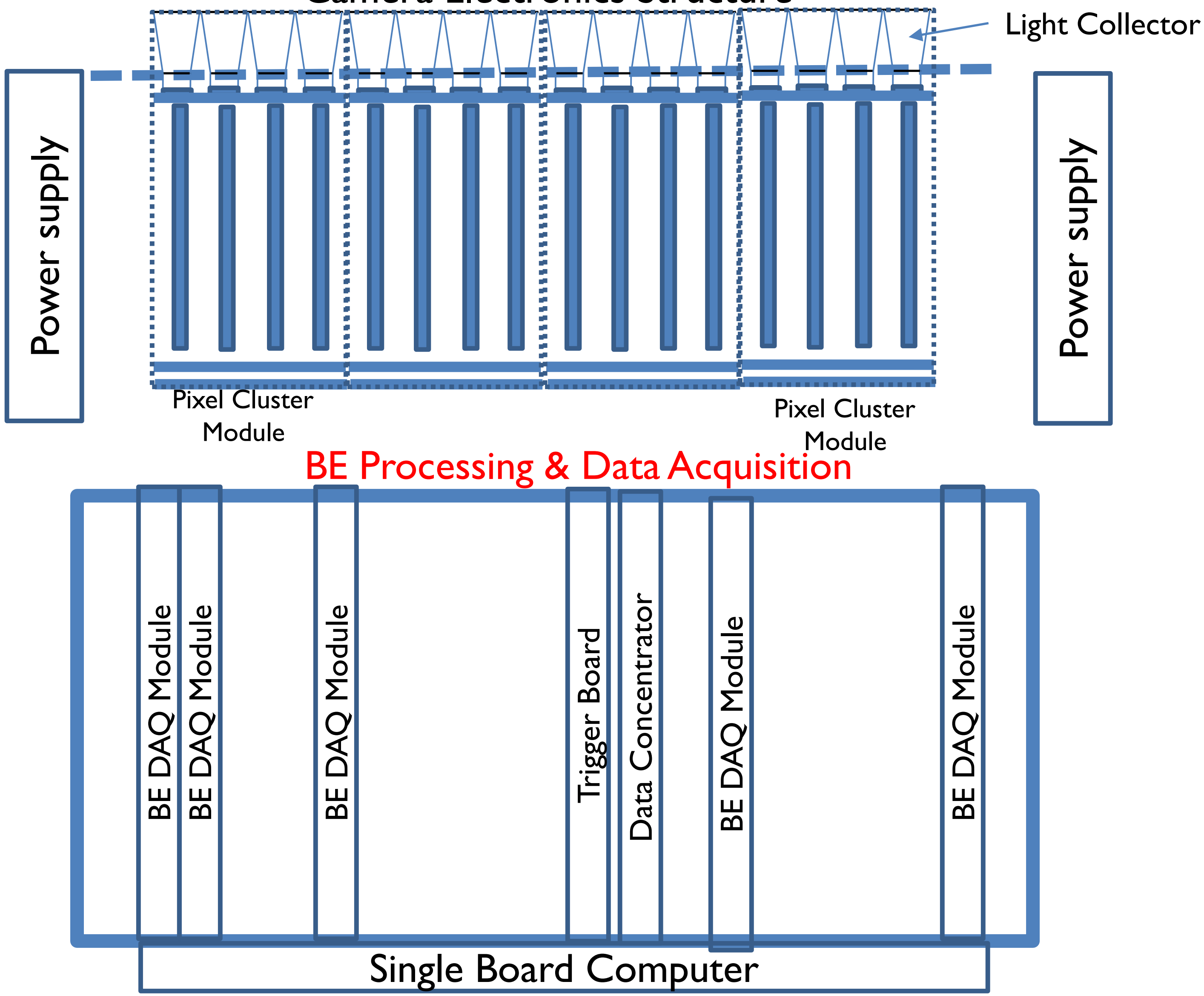
Design Considerations (continued)

- Single Bias Voltage for each Pixel and programmable
  - BdV variation of 200mV across 16 sub pixels in 4x4 array GAPD results in Gain variation of 8%, So Single bias voltage for 4x4 array is used
  - Bias voltage range :0 to 80V
  - 10s of uA BIAS load upto 100MHz NSB pe (dark sky)/pixel , near 10mA required for moon light observation (NSB-25GHz pe)
  - Design is considered for 2 to 4 mA satisfying twilight observation
- Thermal regulation near sensor
  - GAPD BD voltage increases with temp by 48mV/°C
  - So temperature near sensor need to be regulated within few degree or need to be compensated by tuning the bias voltage. 4 temperature sensors are mounted near GAPD surface
  - Thermal insulation between sensor and Electronics is preferred.
  - Also it is better to operate GAPD at low temperature for low dark count (May need heating in most nights in Hanle)
  - Keep Electronics in positive temperature (it may need cooling/heating arrangement)
- Online Gain calibration, and correction by tuning Bias voltage.
  - Frequent monitoring of sensor output by Calibration using a pulsed Laser source beam on imaging Camera may be used and Variation in gain may be monitored and corrected for all pixels for uniformity and stability
- Auxiliary monitoring of Temperature, Humidity, voltages, rates
  - At many points in the camera for stability and reliability.

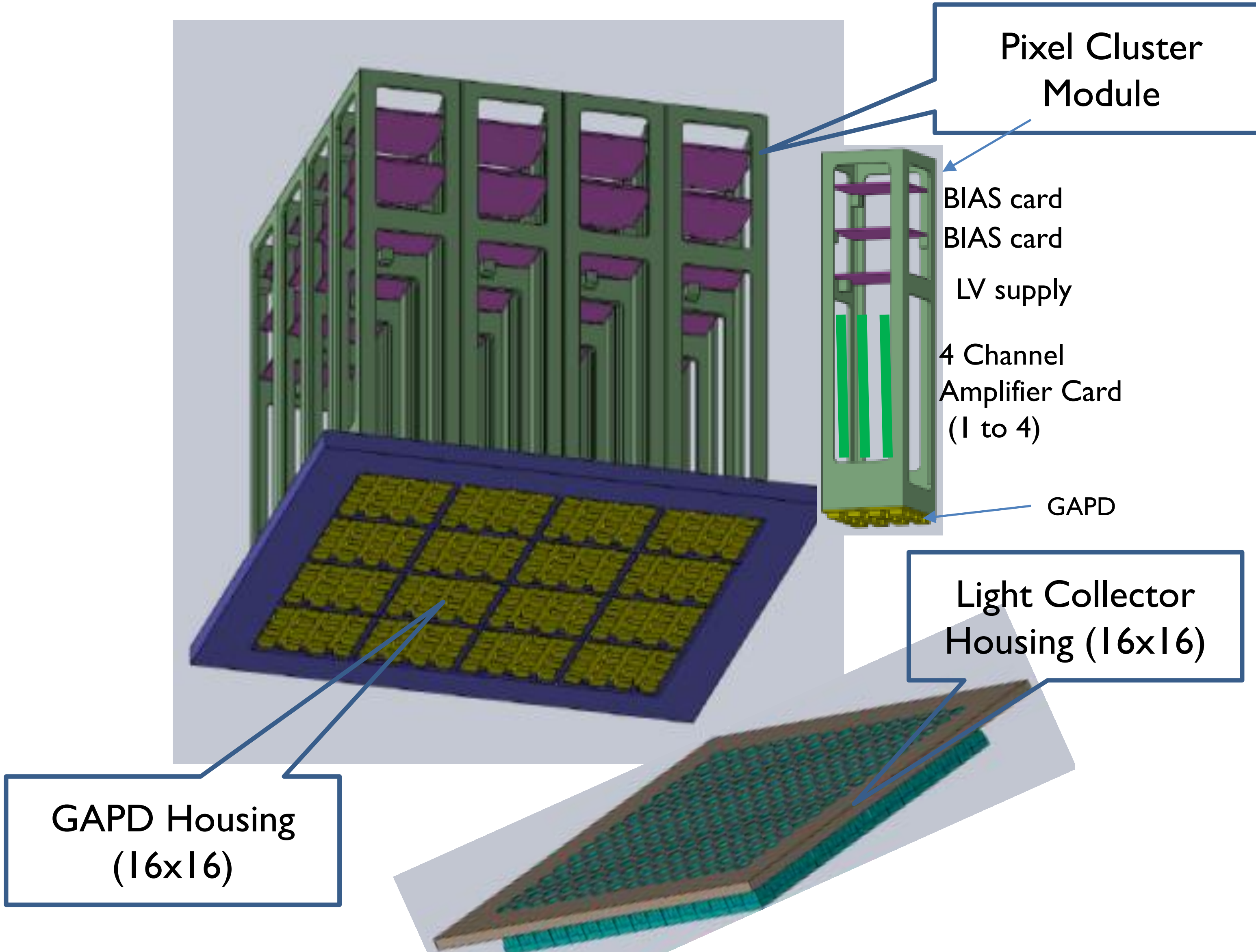
Camera Electronics



Camera Electronics Structure



Camera Electronics Front End

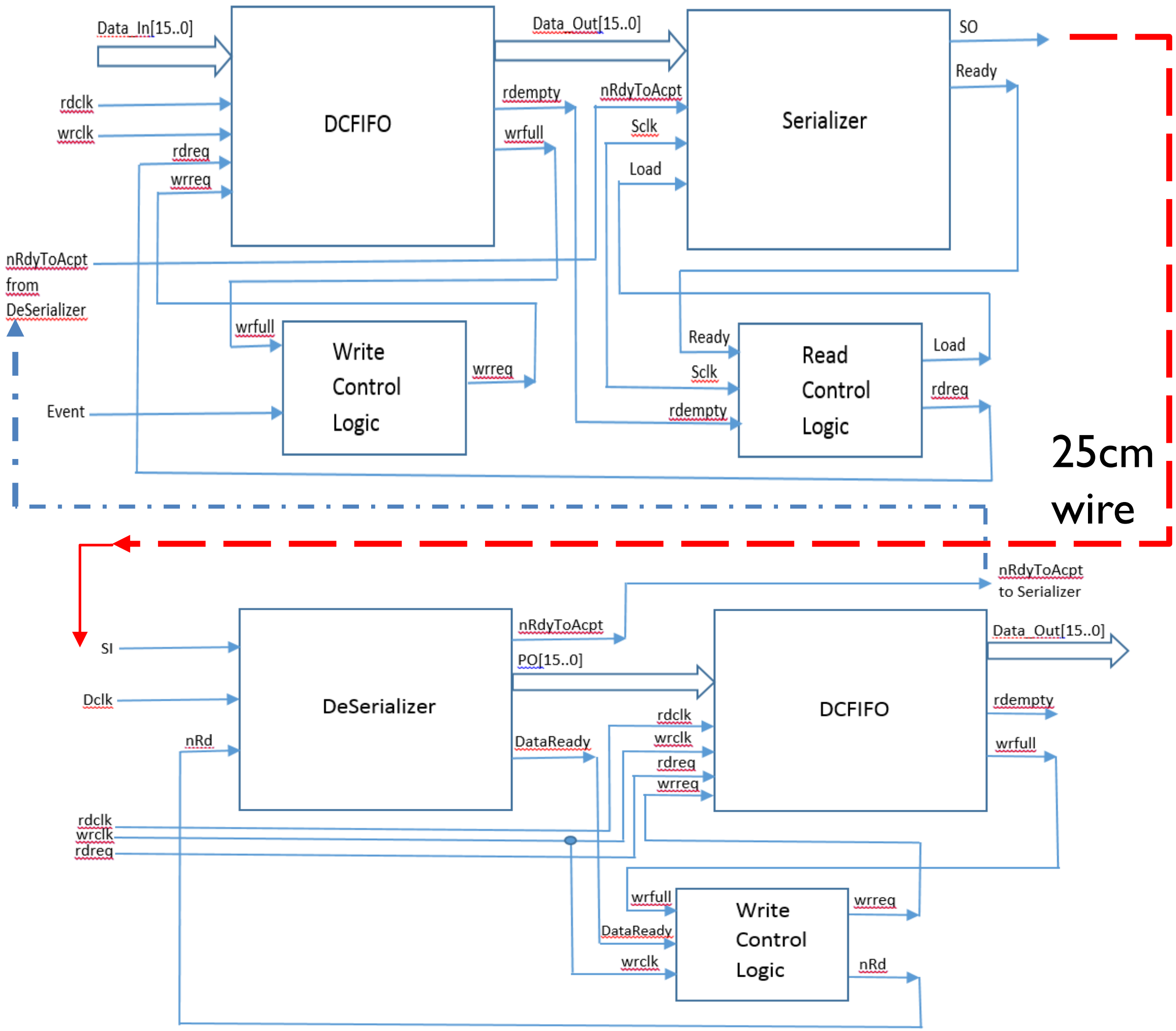


Camera Electronics Components

- Pixel Cluster Module – 16no.s
  - in the front end for signal conditioning of 256 pixels outputs
- Back end Processing & Data Acquisition
  - BE DAQ Module – 16no.s
    - 16 pixels signal digitizing, data processing, acquisition
    - Generates full trigger and partial trigger
    - 100ns, 1GSPS, 16 bit ADC – 200x8x2ch = 3.2Kb/pixel or 51.2kb/module(16pixels)
    - For 500Hz Trigger, data throuput/module = 25.6 Mbps
  - Trigger Board: Generate final trigger from full and partial triggers
  - Data Concentrator & Event Builder
    - Data concentrator (1 channel) Throuput rate 25.6Mbps
    - Event builder : 256 pixel (16 PCM) – 409.6 Mbps/camera (worst case)
- Single Board Computer
  - Processing, Control and data transfer via downlink

BE DAQ module to Data Concentrator

(Serializer – Deserializer)



- Asynchronous
- Reuirement is 25Mbps throughput
- Upto 50MHz baud rate is tested
- Two Altera FPGA kits are used to test

Pixel Cluster Module

(87.5x87.5x320mm)

- GAPD Board (87.5x87.5mm) – 1no.
  - houses 16 pixels of 4x4 GAPD
  - 4 temperature sensors (2 each monitored by one BIAS board via 1wire communication)
  - A common Bias voltage for 16 sub-pixels of, 4x4 array GAPD, Supplied from two BIAS boards
- 8 Channel Bias Board(78x72mm)- 2no.s
  - Micro controller based mother board houses 8 Bias module of 80V
  - Bias module is designed on two approaches
    - High gain high voltage opamp
    - DC to DC converters
      - ✓ LT3482 (from Linear Technology)
      - ✓ RT8541A (from Richtek Technology)
      - ✓ HV80 (from AiT Instruments)

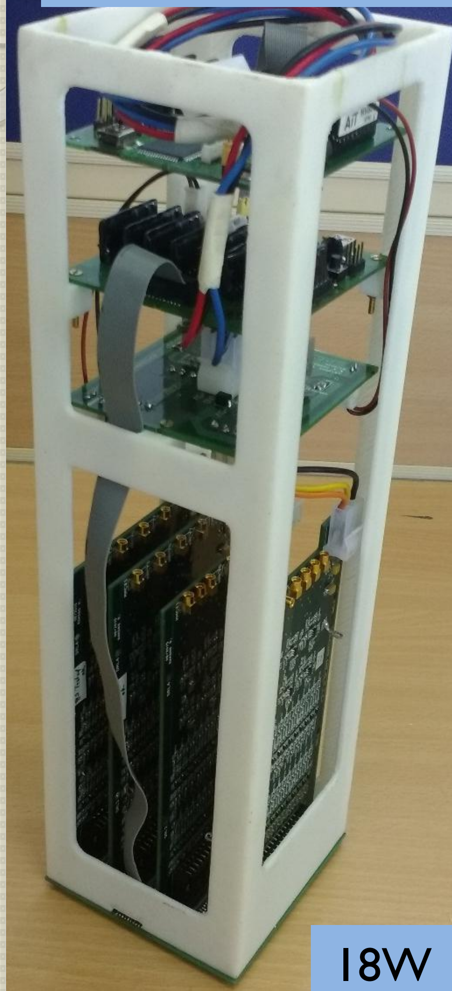
  Power consumption : 5V @1.12A
- Supply Distributor Board 78x72mm- 1no.
  - Input is +- 5V
  - Output is +2.5 @600mA (4 output) and -2.5V @ 1A (2 ouput)

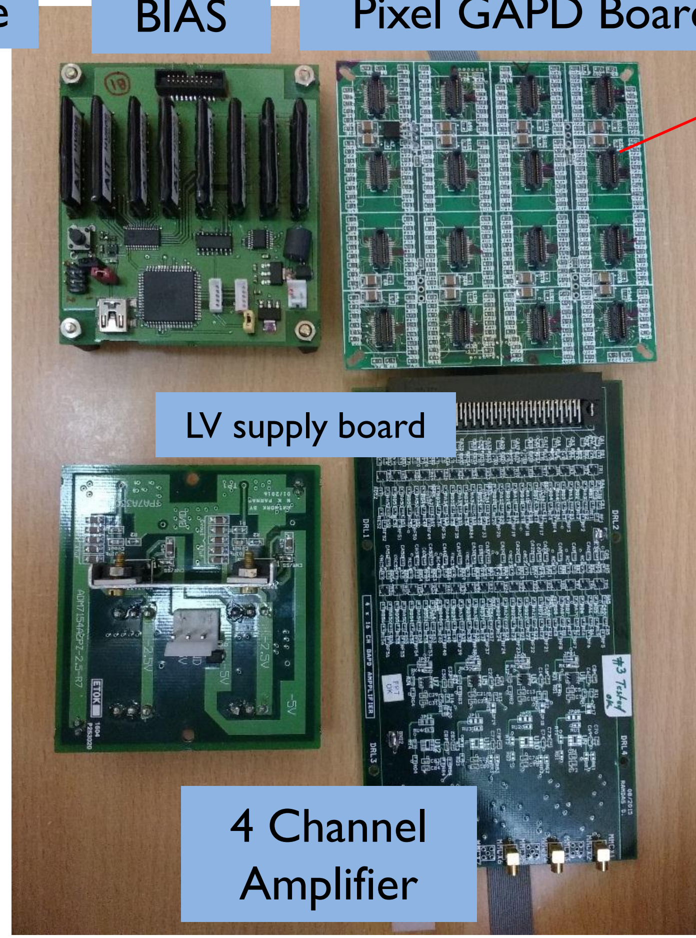
Pixel Cluster Module(continued)

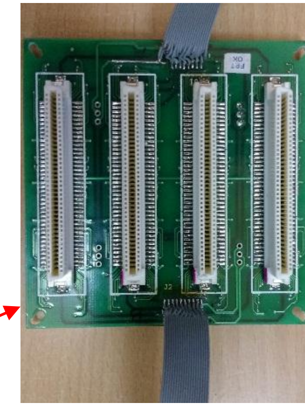
- 4 Channel Amplifier card(150x80mm)- 4no.s
  - Need to amplify the signals from 16 GAPDs contained in a single pixel
  - Wide BW amplifier due to fast rise time and fall time (6/35ns)
  - Large detector capacitance of ~320pF and varying output impedance of GAPD
    - Need to have very low input impedance amplifier ..Trans-impedence amplifier (TAI) using common base configuration is the option
  - Adding the signal right after the 16 GAPDs by shorting their anodes is ruled out due to the large terminal capacitance . Therefore the signals are added after the front end TIA stages.
  - Large night sky background (NSB pe) : <100MHz at pixel. during dark night at Hanle
    - May need pulse shaping to avoid pile up.
  - Wide Dynamic range to be covered: up to 2000 photoelectrons
    - Two parallel amplification stages after adding signals from 16 GAPDs(sub pixels) low gain and high gain with overlap of 125pe
- Each channel consumes 300mA @ +2.5V and 450mA @ -2.5V

Pixel Cluster Module

Current Status







- Amplifier cards are tested
- Multiple Bias Cards with firmware is interfaced with Rasberry Pi via SPI.
- The Rasbery Pi is accessed remotely via Ethernet
- Bias board is tested
- LV Supply card is tested at full load
- Pixel Cluster Module is integrated using one Amplifier card and one GAPD and is ready for testing for its full performance

Back end Processing and Data Acquisition for prototype testing

- Using Commercial NIM/ VME modules, we want to develop BE data acquisition to study the prototype of Pixel Cluster Module
- 1-GSPS 16 channel Aqiris Digizer module with optical interface for data transfer, is used and tested for its functionaliyty
- Basic functionality is tested
- Ordered NIM/VME crate for integration and testing

Thanks all Colleagues of HAGAR team