Progress on IsCMOS

XIOPM

2021-02-23

Outline

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- Customization of key devices
- The Special Image Intensifier
- Customized sCMOS
- Progress on IsCMOS Camera

Customization of key devices

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- **Customized Special image intensifier.(Work has actually started)**

  with integrates the front taper and the rear rapper,

  Long lifetime ALD MCP,

  P24 Phosphor or some better one.

- **Customized sCMOS sensor. (Reach cooperation intention)**

  with Global Reset exposure mode, lower readout noise,

  Big Pixel,

  Greatly reduce the original data rate,

  Greatly reduce the power consumption of the IsCMOS.

Customized Special image intensifier

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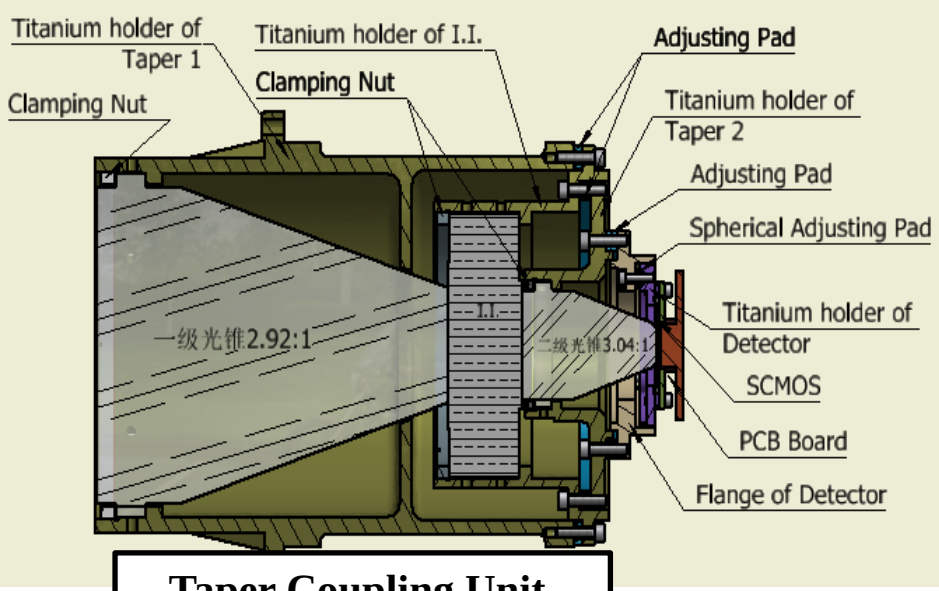
- The front taper is used to replace the photocathode.
- The rear taper is used to replace the phosphor screen.
- Compared with discrete devices, two fiber optic panels are reduced and two coupling interfaces are reduced. It may halve optical transmission loss and double the light sensitivity.



Taper Coupling Unit.

Customized Special image intensifier

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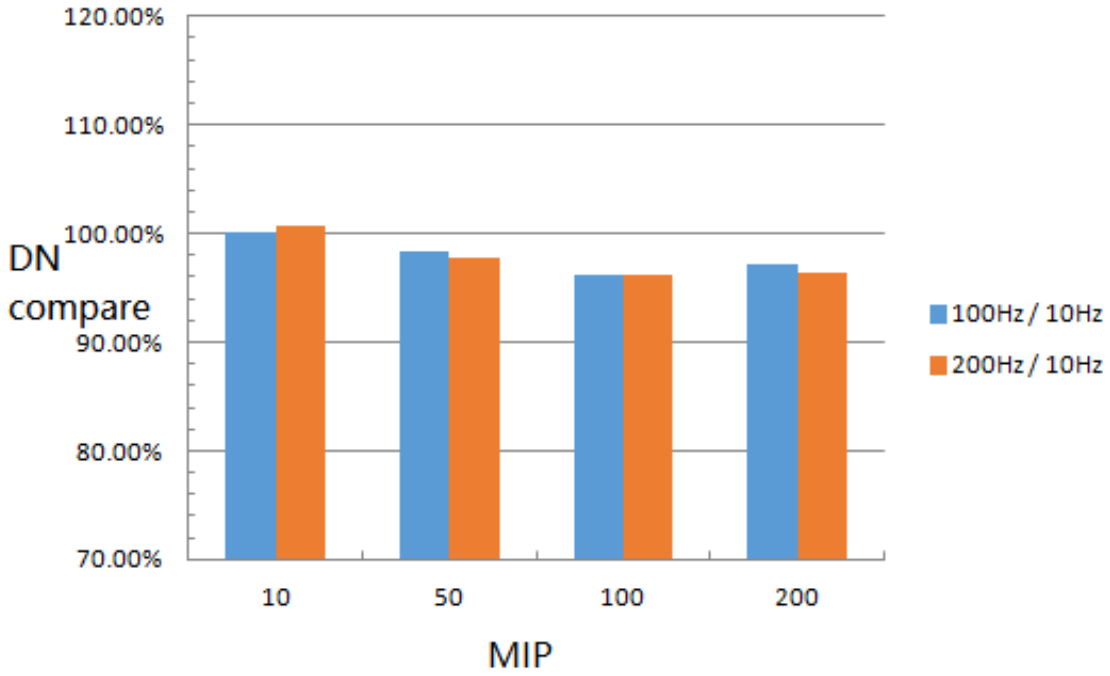
- P24 phosphor is very stable at different frequencies.
- Under four kinds of light intensity, the response of the P24 tuber is tested as below.
- The slight difference mainly comes from the setting deviation of the light source.



Afterglow test system

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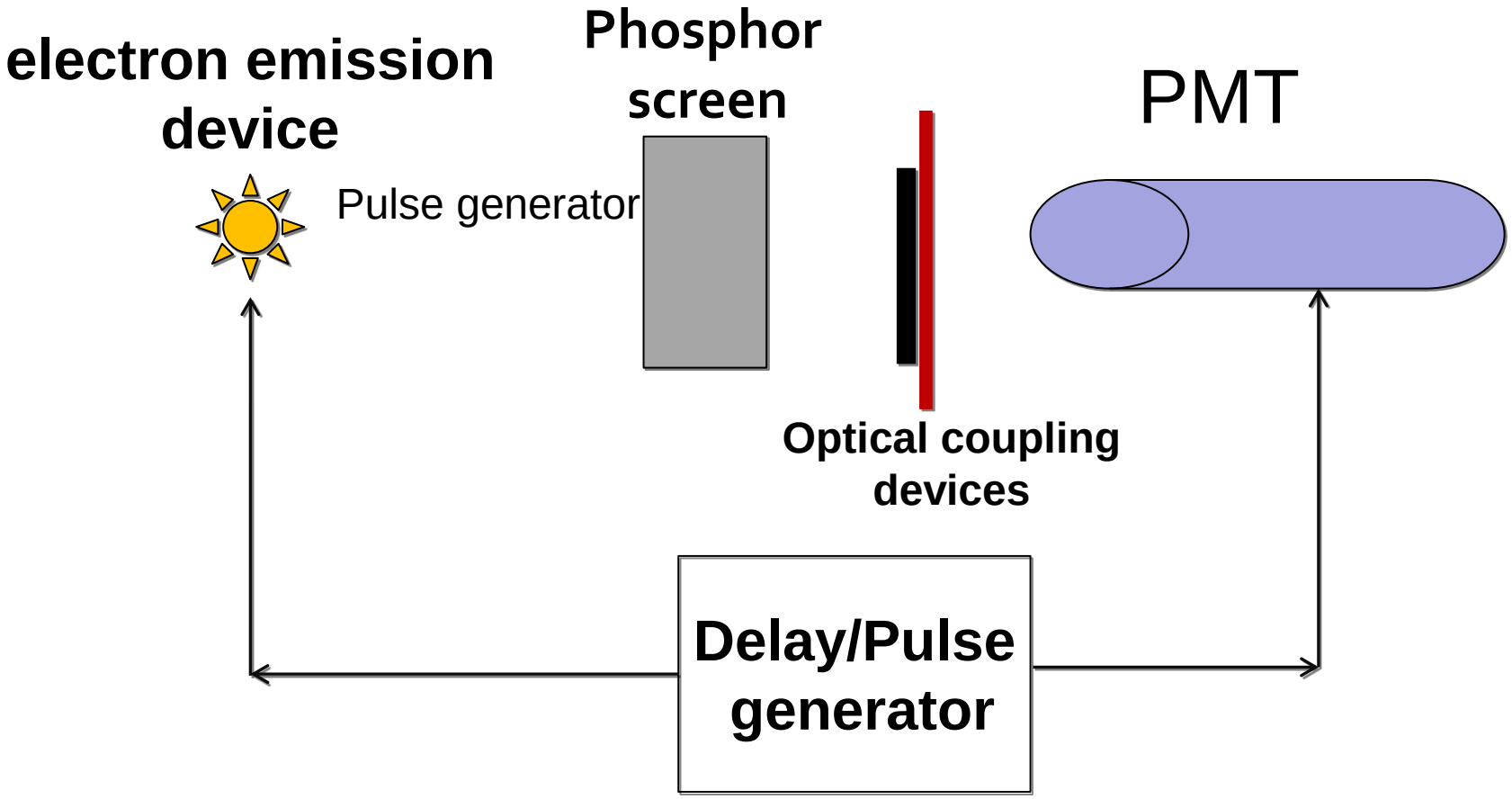
- **In order to obtain accurate afterglow curves of various phosphors, we built an afterglow test system.**



Customized Special image intensifier

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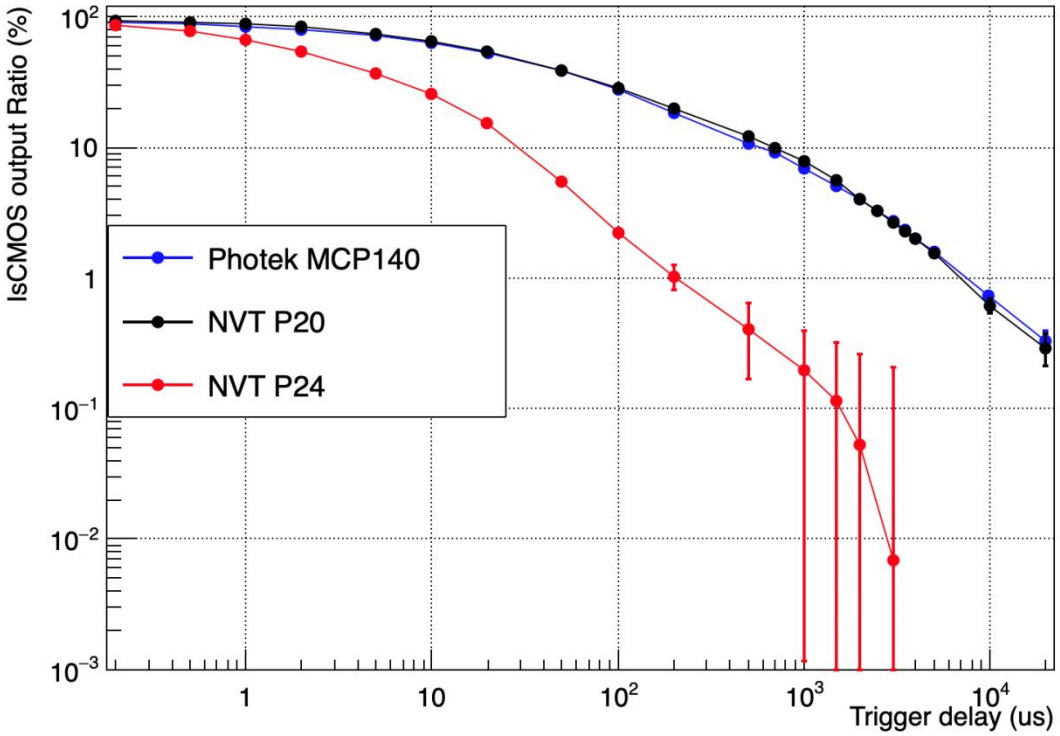
- P24 phosphor is very fast. It is reduced to 1% of the event energy at 200us.
- P20 phosphor reduced to 1% of the event energy at 900us.
- Compared with P20, P24 can save 700us of exposure time per event.



Customized sCMOS sensor

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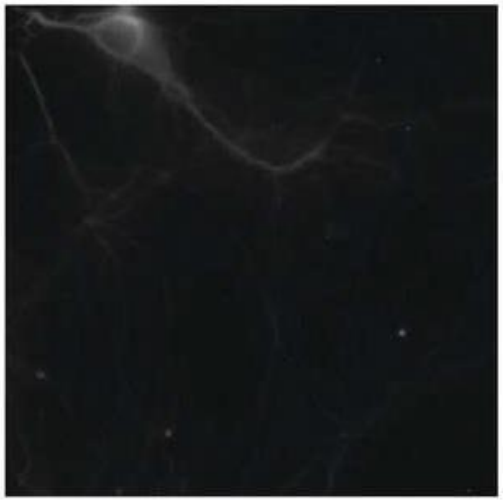
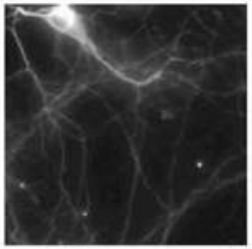
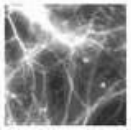
- **Why we need big pixel?**



A



B



C

$$\frac{SNR_1}{SNR_2} = \frac{\sqrt{\text{Sig } 1 * QE}}{\sqrt{\text{Sig } 2 * QE}} = \frac{\sqrt{15^2}}{\sqrt{5.5^2}} = 2.73$$

1. For higher sensitivity. The larger the pixel, the stronger the sensitivity. Large pixel is very beneficial to weak light detection.
2. Reduce data rate while keeping large area of photosensitive.

Customized sCMOS sensor

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- **Big pixel, also enough thickness pixel**

$$QE = (1 - \mathrm{R}) \cdot \zeta \cdot (1 - e^{-\alpha \cdot d})$$

with:

$(1 - \mathrm{R})$	Reflection at the surface, which can be minimized by appropriate coatings
ζ	Part of the electron-hole-pairs (charge carriers), which contribute to the photo current, and which did not recombine at the surface.
$(1 - e^{-\alpha \cdot d})$	Part of the photon flux, which is absorbed in the semiconductor. Therefore the thickness d should be sufficiently large, to increase that part.

QE(Quantum efficiency) describes the ratio of incident photons to converted charge carriers in the sensor.
When photons fall onto a semiconductor, there are 3 mainly loss mechanisms.

Customized sCMOS sensor

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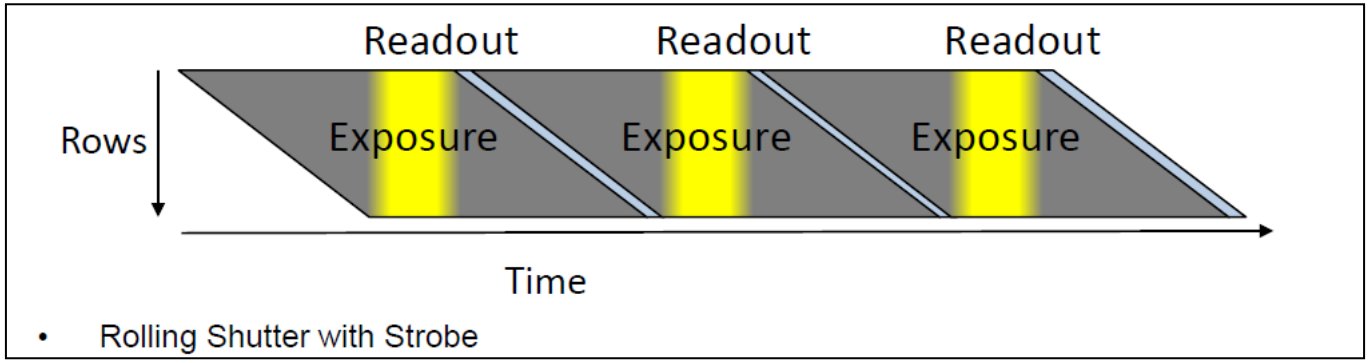
- **Three Exposure mode**

There may three exposure mode of sCMOS: RS, GS, GR.



First one is rolling shutter,it has low readout noise, and high speed. In this mode, although the exposure time of each line is the same, the exposure start time and end time are different. This mode isnot suitable for high speed motion. There is always image distortion for high speed motion.

Customized sCMOS sensor

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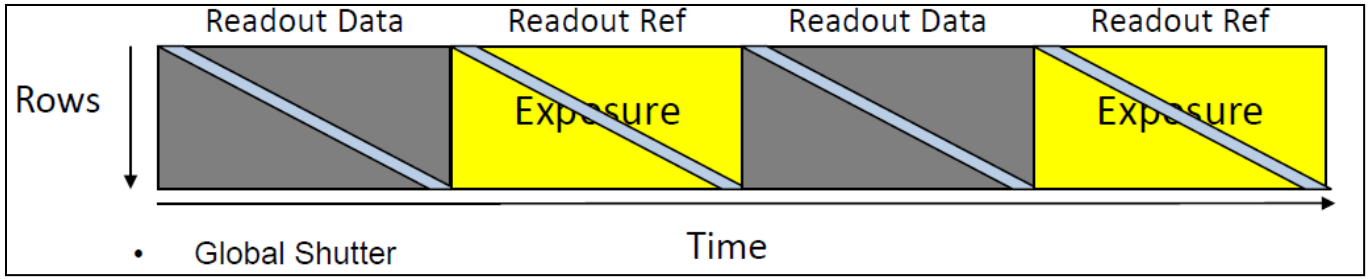
- **Three Exposure mode**

There may three exposure mode of sCMOS: RS, GS, GR.



Second one is Global shutter, compared to RS and GR, it has higher readout noise (3 times), and lower speed (half).

In this mode, the exposure time of each line is the same, the exposure start time and end time are also the same. This mode is suitable for high speed motion. At 2017 and 2018 Beam test, IsCMOS worked on this mode.

Customized sCMOS sensor

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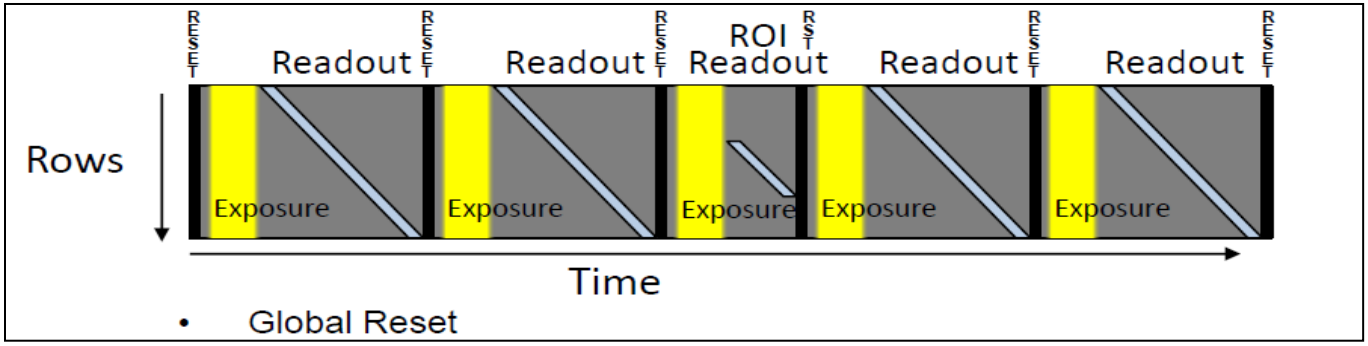
- **Three Exposure mode**

There may three exposure mode of sCMOS: RS, GS, GR.



The 3rd one is Global Reset, compared to RS and GS, it has lower readout noise, and higher speed . More importantly, this exposure mode does not cause image distortions.

In this mode, the exposure start time is the same, but the end time is not same for each line. This mode is suitable for fast decay phosphor.

Customized sCMOS sensor

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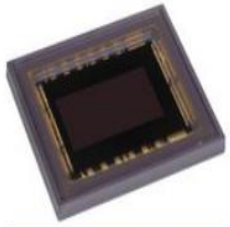
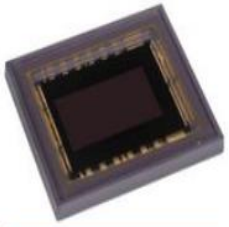
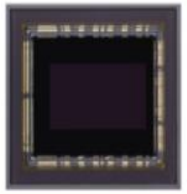
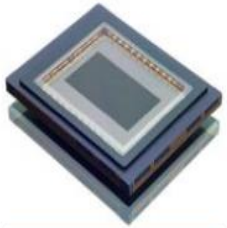
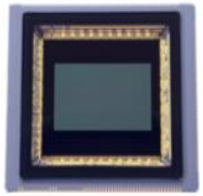
- **High preformance exposure mode: GR.**
- **It may doubles the frame rate, and the readout noise is one third of the GS. This mode may be verifyed in this year's beam test. After some supplementary tests and analysis of P24 recently.**

Sensors	MST4323	LTN4323	HWK4123	MST4625A	LTN4625A	C
	 Explore Product	 Explore Product	 Explore Product	 Explore Product	 Explore Product	 Explo
PIXEL						
Pixel Size	4.6 µm x 4.6 µm	4.6 µm x 4.6 µm	4.6 µm x 4.6 µm	5.5 µm x 5.5 µm	5.5 µm x 5.5 µm	6.5µ
Shutter Type	Rolling Shutter or Global Reset	Rolling Shutter and Global Reset	Rolling Shutter (RS) and Global Reset (GR)	Rolling Shutter (RS)	Rolling Shutter (RS), Global Reset (GR), Global Shutter (GS)	Rolling S S
Read Noise	1.0 e- RMS @ 120 fps	0.7 e- RMS @ 5 fps	0.5 e-RMS @ 120 fps	<1.5 e- RMS at 240 fps (RS/GR), <5e- RMS at 120 fps (GS)	<1.5 e- RMS at 240 fps (RS/GR), <5e- RMS at 120 fps (GS)	<2 e- RMS
Dynamic Range	86 dB	89 dB	83dB	>88 dB Single Frame (RS/GR), >77 dB Single Frame (GS)	>88 dB Single Frame (RS/GR), >77 dB Single Frame (GS)	>
Peak QE			>85%			CIS252 CIS252
Full Well Capacity			7,000e-	>40,000 e- (RS/GR)	>40,000 e- (RS/GR)	>3

Customized sCMOS sensor

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- **The customization of key devices will greatly improves the frame rate and greatly reduces the power consumption and transmission bandwidth.**
- **The table below indicates what improved.**

parameters on single IsCMOS for flight	Two years ago with Commercial sensor	NOW with the customized sensor
Frame rate	400fps	≥800fps
Readout noise	5e-	1.5e-
Power consumption	280Watts	About 40Watts
Mem Storage	64Gbits	8Gbits
sensor data rate	≥60Gbps	about 3Gbps
Main processors	FPGA V7-690t，x5	FPGA K7-325t, x3
Data compression	Needed at the front, and risky.	Original data may go to the CSS storage module directly.

Progress on IsCMOS Camera

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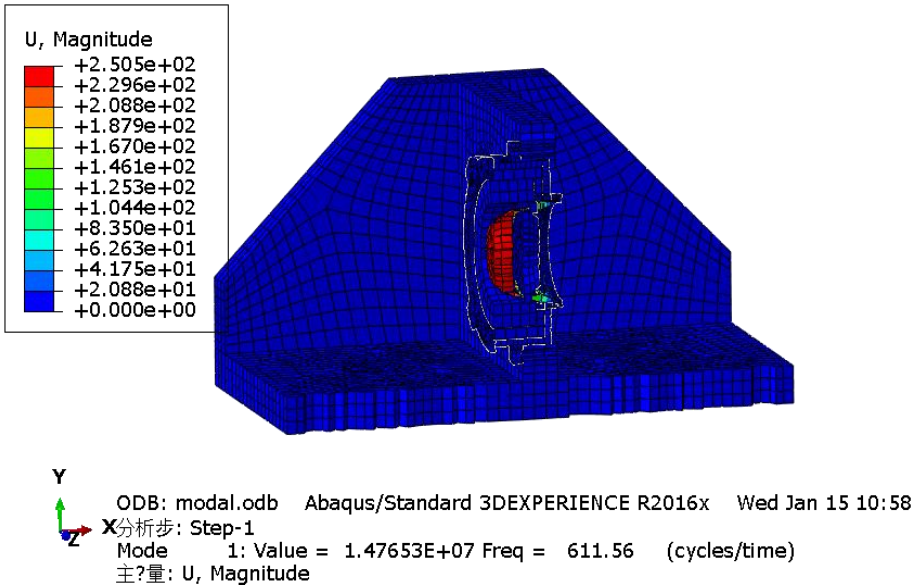

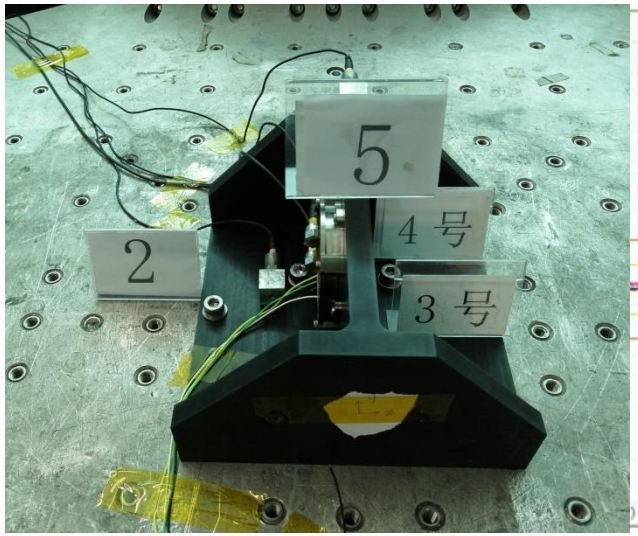

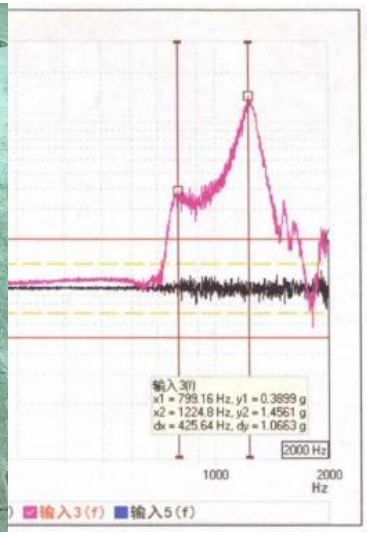

- Numerical simulation and environmental testing have been completed at this stage.
- The first eigenfrequency is much more than 100Hz. Have a good foundation in flight.

Progress on IsCMOS Camera

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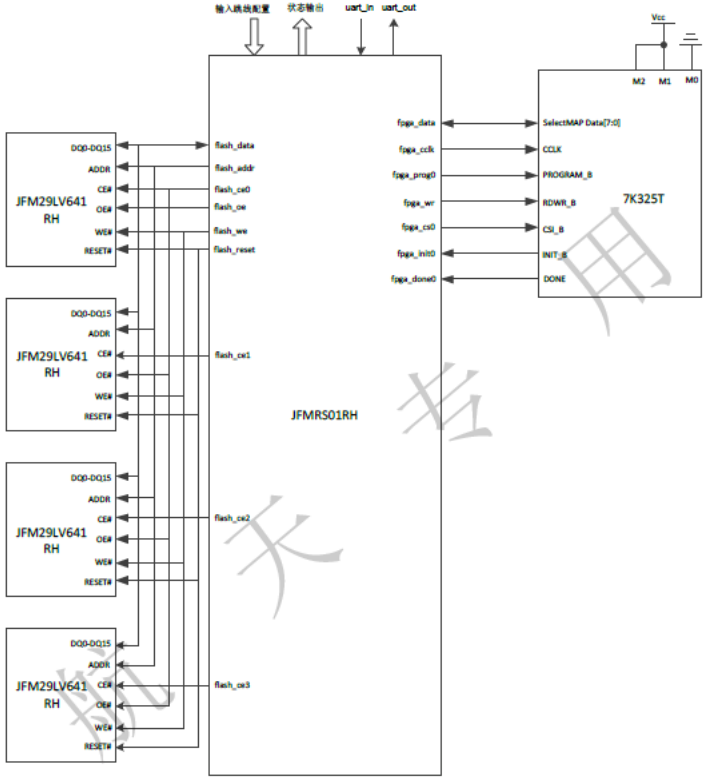
- The service life of HERD in orbit is long, In response to possible device degradation, it may need to update of the algorithm in orbit.
- The software update method has been solved by XIOPM HERD team.



Progress on IsCMOS Camera

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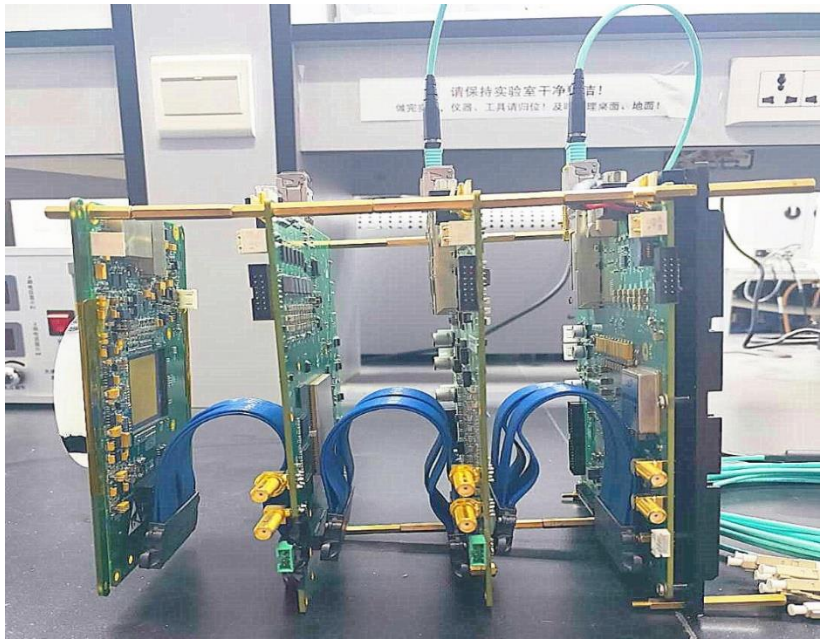
- **Based on V7 FPGA which aerospace compatibility, we overcomes 288Gbps transmission bandwidth of FPGA board, and has high performance expansion of 36 nodes.**
- **The hardware platform is developed for HERD. It is ready for the on orbit data processing of HERD.**



Progress on IsCMOS Camera

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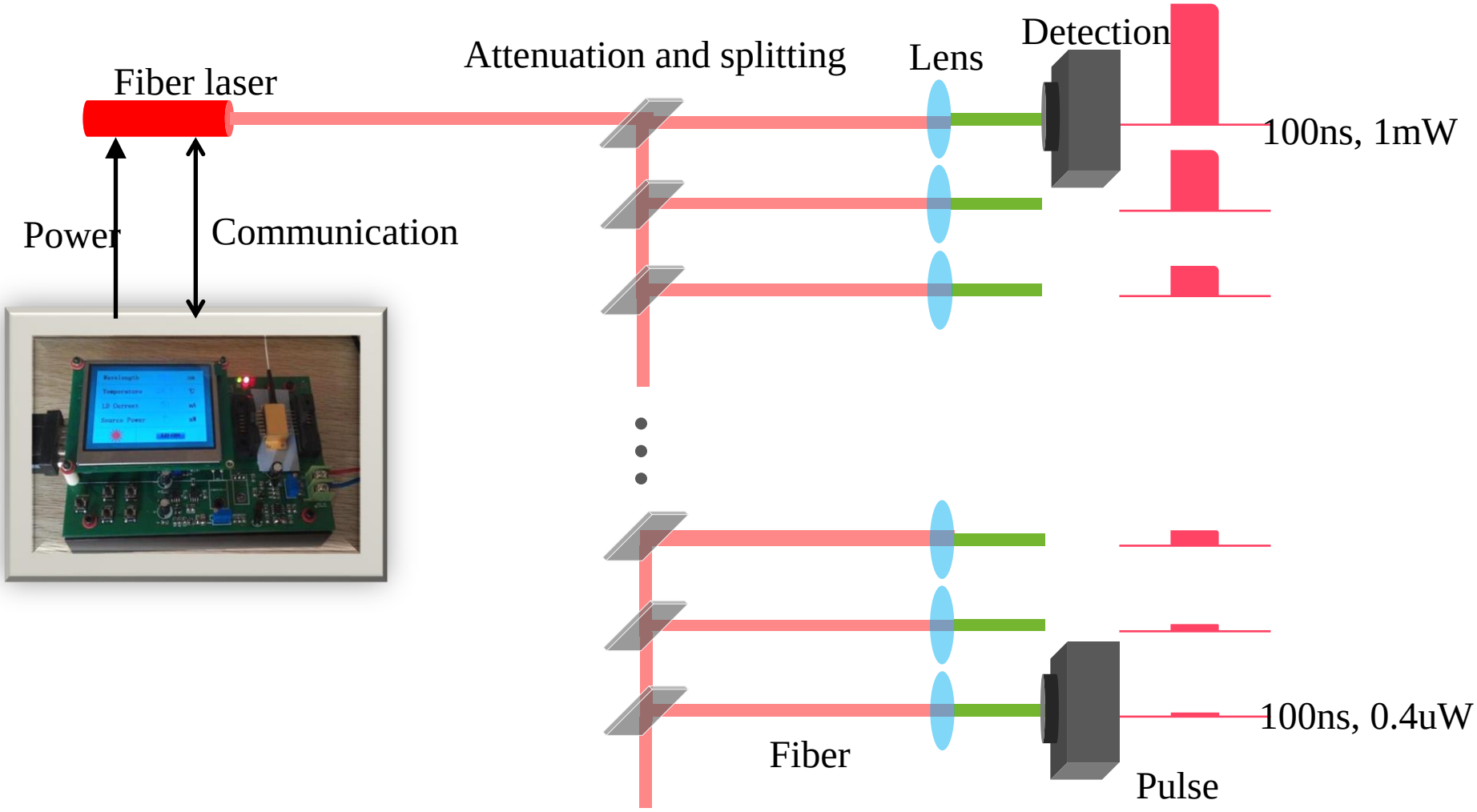

The light source of the dynamic range test for image intensifier

Next to do

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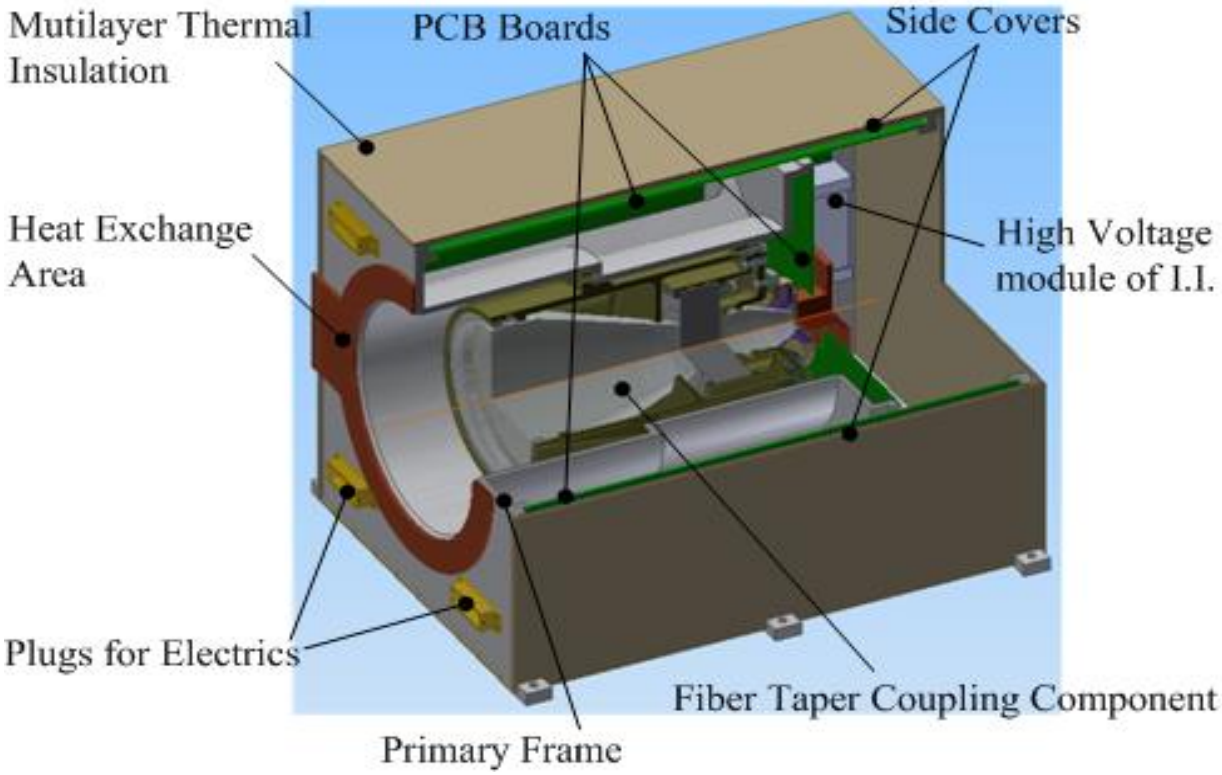
- IsCMOS with the Special Image Intensifier and Customized sCMOS.
- Start detailed design of on orbit re-coupling.



Conclusion

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Thanks for your attention