Preliminary Scheme of the CALO ICCD Readout (Upgrading)

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Contents

I. Introduction of TEAM

Introduction of XIOPM

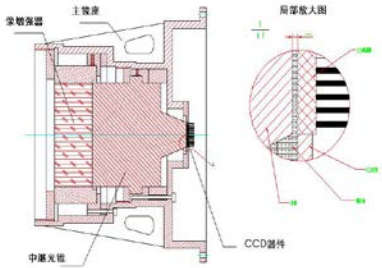
Xi'an Institute of Optics and Precision Mechanics , CAS,

Founded in 1962,

One of the largest institutes of CAS in Northwestern China.

A comprehensive scientific research base

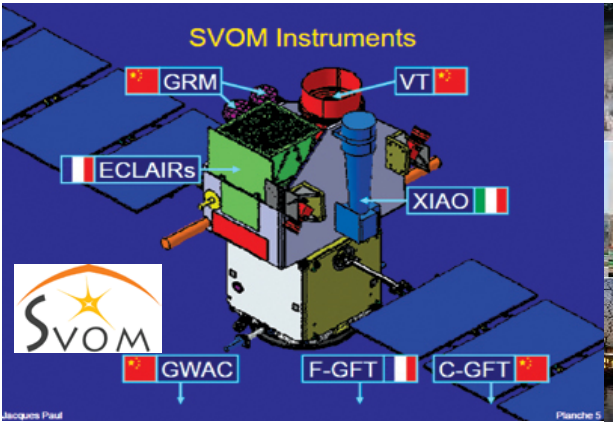
State key laboratory of transient optics and photonics



Key Laboratory of Spectral Imaging Technology, CAS

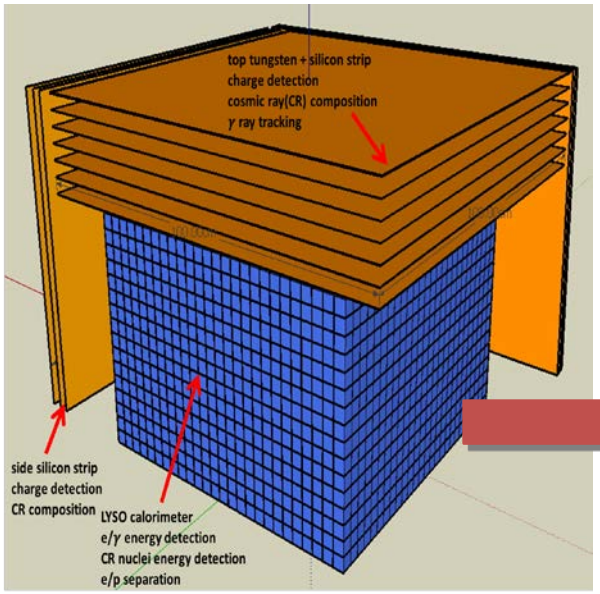
SVOM mission

Chinese Lunar Exploration Program (CLEP)



II. Brief introduction on the CALO ICCD

Brief Introduction



CsI light transmission and collection

Direct Coupling

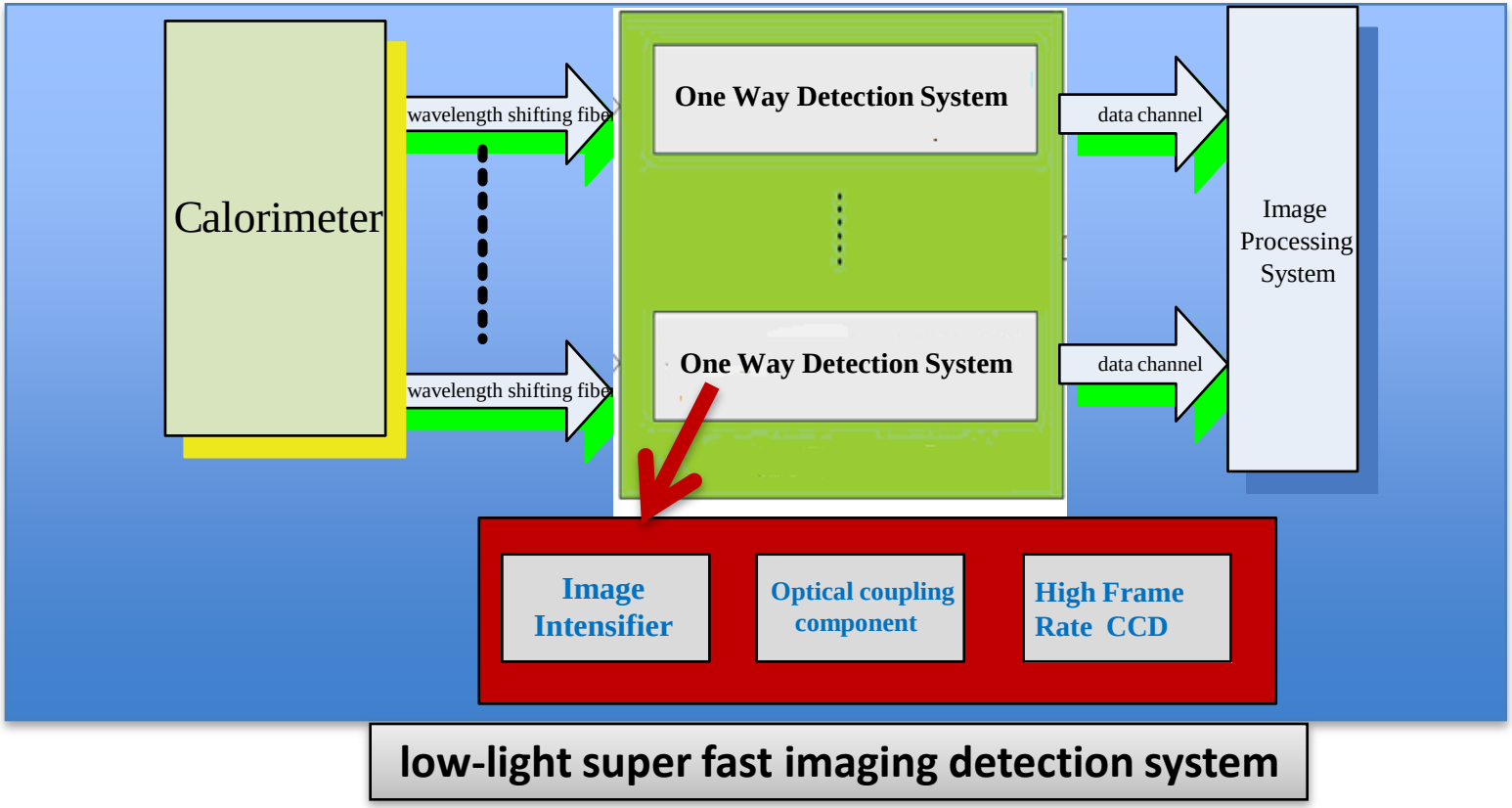
PD, APD, SiPM: Complicated system, high power consumption

MAPMT, SiPM:high power consumption
CCD: No single photon detection
EMCCD, EBCCD: no ns gate control
ICCD: no above problems, but premature

Wavelength Shifter Fiber

Performances of Digital 3D imaging detector contrast with the traditional scheme	
Semi-Digitalized 3D imaging detector	**The traditional scheme**
larger field of view	**smaller field of view**
lower power consumption	**higher power consumption**
imaging detection	**not imaging detection**

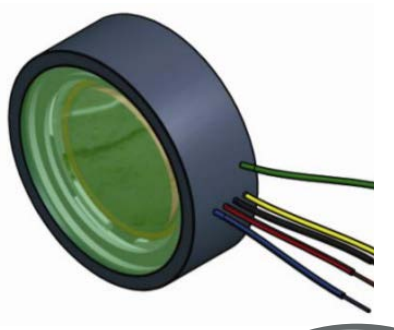
Brief Introduction



low-light super fast imaging detection system

One Way Detection System can obtain the signal from 30~40 thousands of wavelength shifting fibers, the Low-Light super Fast Imaging Detection System is consisted of four ways.

Brief Introduction

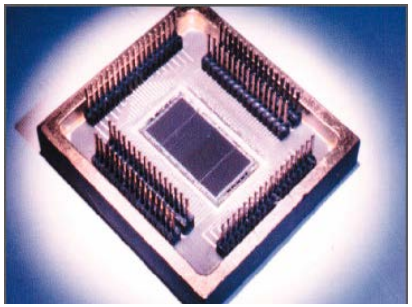


Image Intensifier +CCD

- **15,000 PMT**
- **Semi-digital**
- **Smaller Lighter**
- **Low-light super fast**

low-light super fast imaging detection system

Advantages:

Larger field of view ,
3D imaging detector ,
5 usable surface,
More detection way,
Larger energy range

III. Requirements

Requirements

Requirements of low-light super fast imaging detection system	
Spectral response range	450nm-600nm
Weak light detection requirements	≤ 160 photon/100ns/fiber
Dynamic range	≥5000
Image intensifier time delay	24μs
The quantum efficiency of image intensifier	the second-generation products＞10%
The clear aperture of image intensifier	the second-generation products Φ75mm
The shutter time of image intensifier	100～120ns
CCD format	1024×1024
CCD detector frame frequency	500～1000fps
Integration time of CCD	72μs
The quantum efficiency of CCD	50%

Analyses of System Requirement

According to the requirements of system technology, it has to be compli mented by the critical partials to meet all requirements as following:

CCD:

- High frame rate and large format CCD

Image Intensifier:

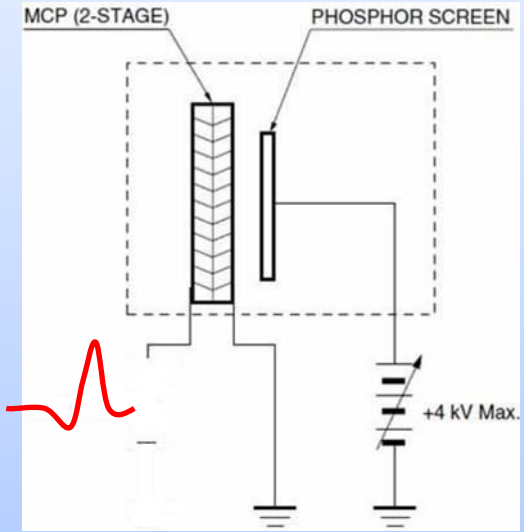
- Photocathode switching ------ shutter
- Fluorescence time ------ time delay
- Micro channel plates------- weak light enhanced

Aerospace Environment :

- Mechanics and heat in the space environment

IV. Preliminary Scheme

Preliminary Scheme



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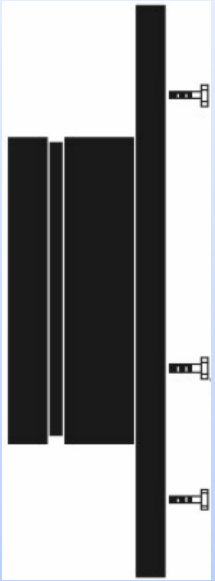

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Cathode Triggered Intensifier

Optical Coupler

High frame rate and large format CCD

Concept of ICCD readout system

high-speed gating image intensifier with single cathode manages to satisfy and realize the requirement of 160 photons/100ns “low-light detection” according to the overall indicator;

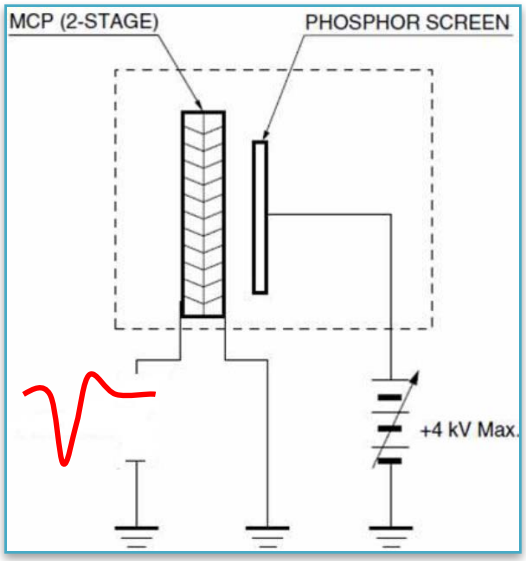
One Image Intensifier = Multi-Channel PMT

15,000 PMT

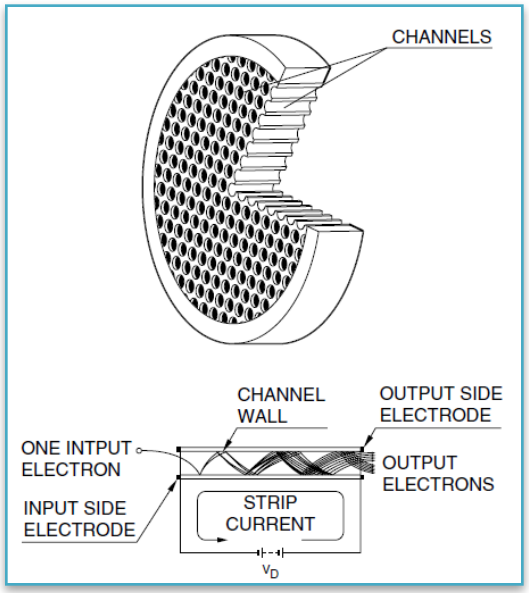
Preliminary Scheme

XIOPM

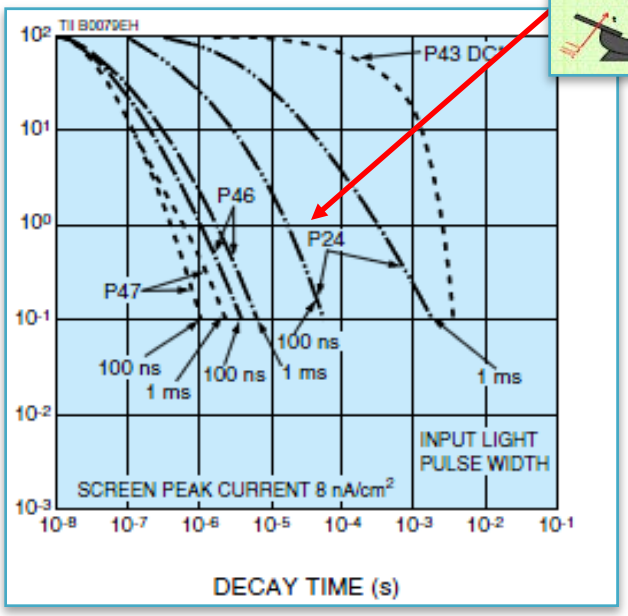
Why Image Intensifier ?



photocahode switching



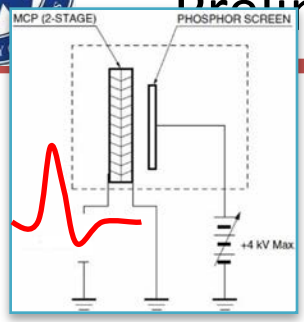
weak light enhanced

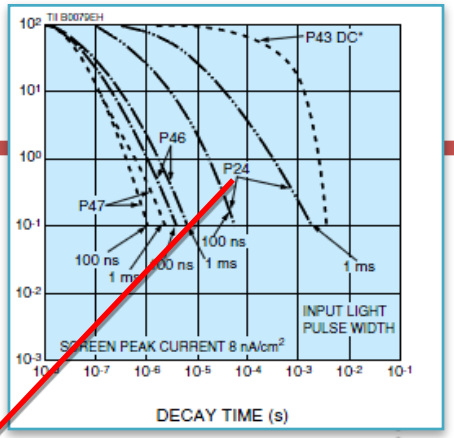


time delay

- photocathode switching------ shutter
- fluorescence time------ time delay
- micro channel plates------- weak light enhanced

Preliminary Scheme





Time diagram

PMT_Tri

Freedom

Photocathode_Tri

On

100nS

Off

1 ms

Screen time delay

24uS

CCD_Tri

CCD_Work

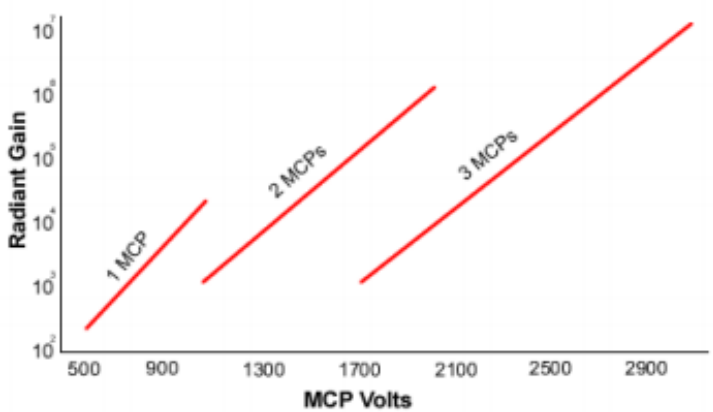
Charge

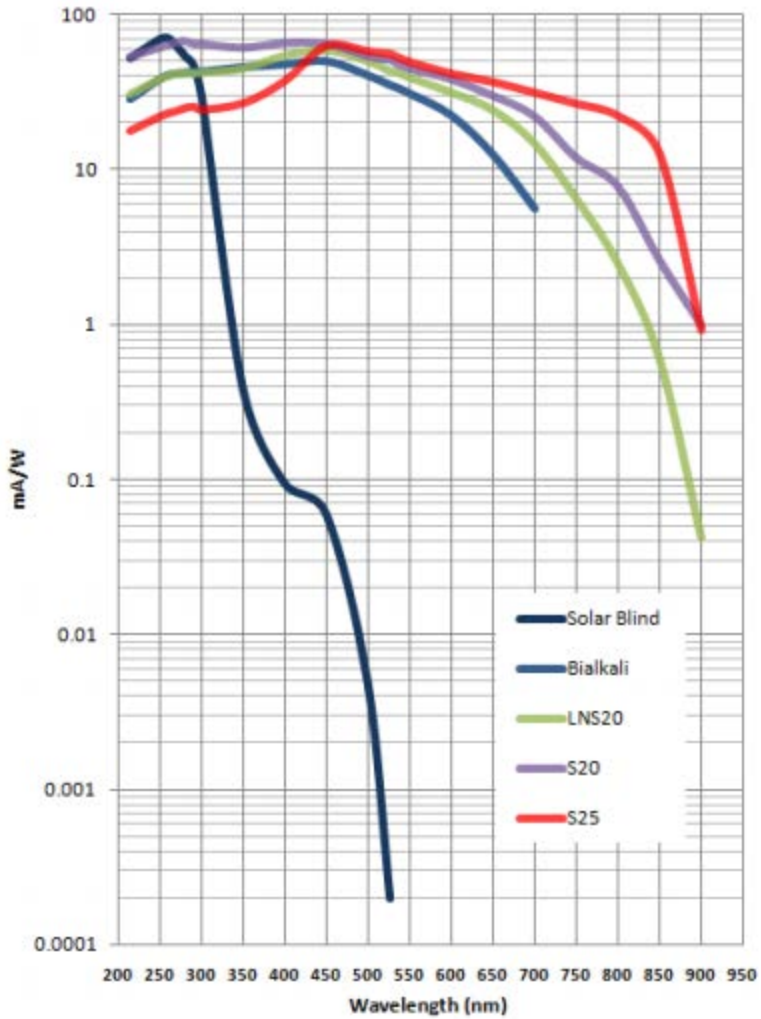
Transfer

72uS

Preliminary Scheme

Parts Selection

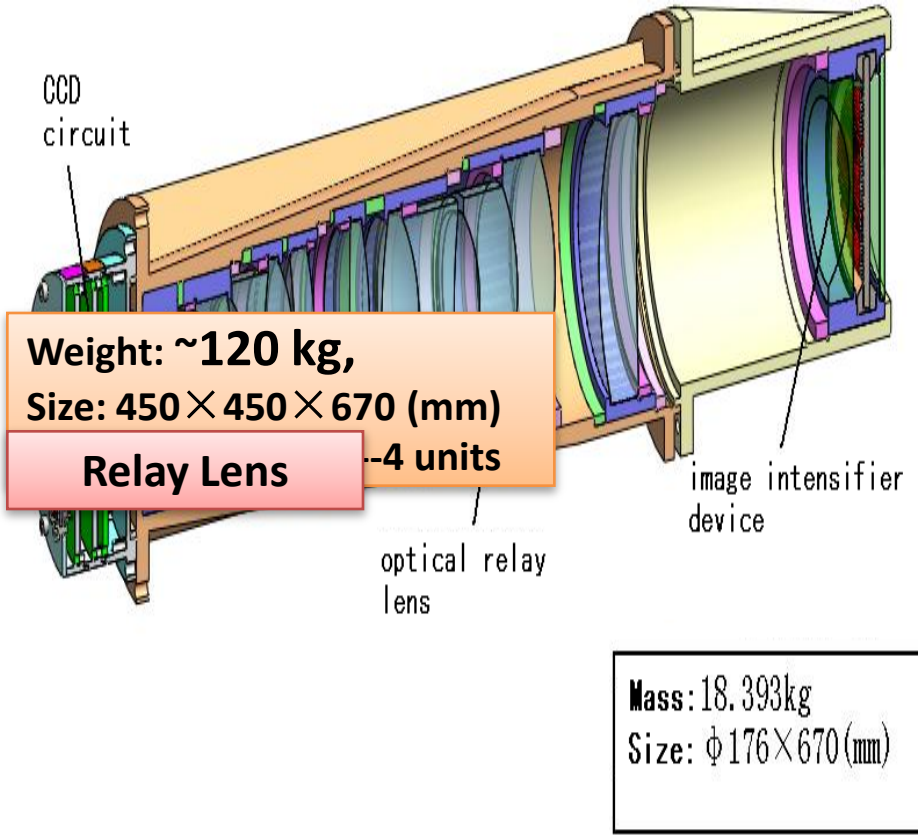




Parameters: 75mm, P24, MCP, S20, fiber faceplate I/O

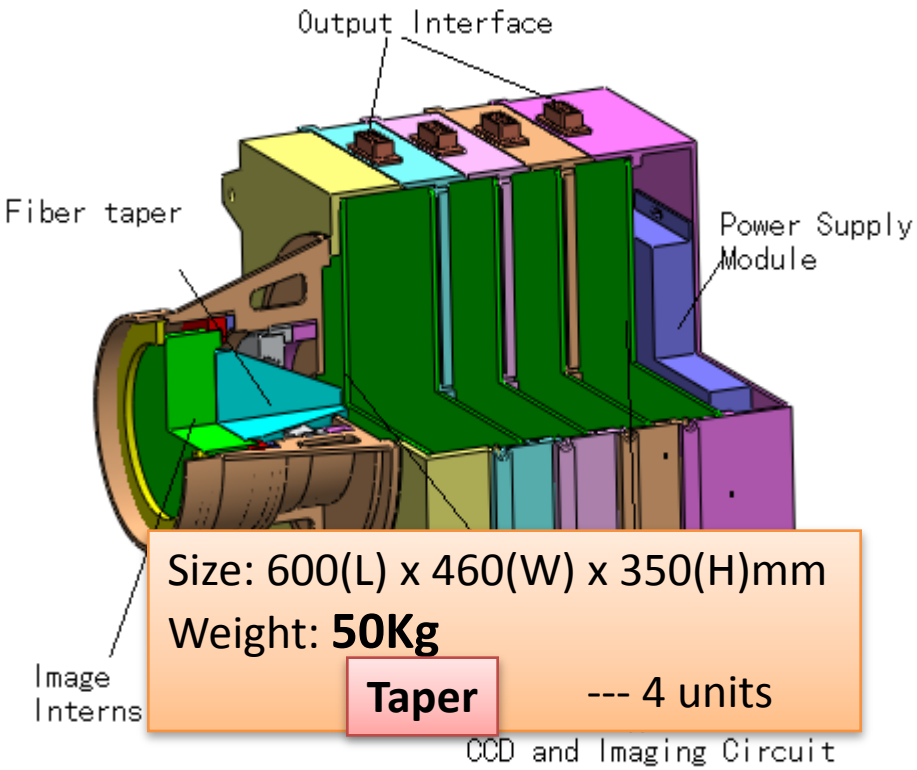
Preliminary Scheme

Two types of coupling



Weight: ~120 kg,
Size: 450×450×670 (mm)
--4 units

Relay Lens



Size: 600(L) x 460(W) x 350(H)mm
Weight: **50Kg**

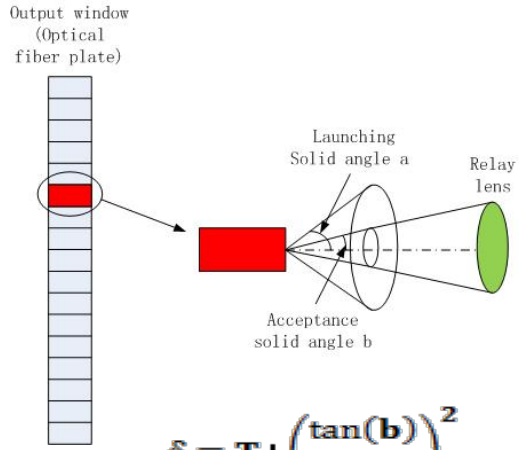
Taper --- 4 units

Preliminary Scheme

Relay Lens Coupling

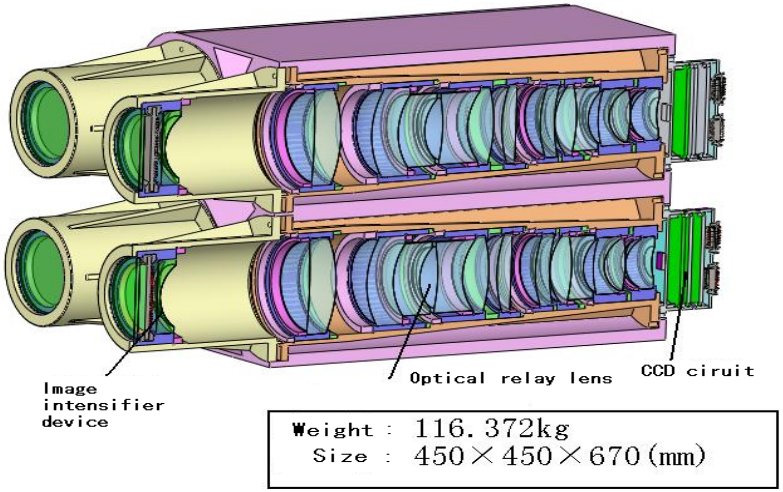
The fundamental considerations of the optical design are listed as below:

1. Telecentric in the object space;
2. Telecentric in the image space;
3. The distortion of the relay lens shall be designed to be less of 0.5% (relatively), or compensate the distortion brought by the image intensifier(if it is determinable);
4. The magnification of the relay lens is -0.25;
5. The uniformity of RMS is required, the RMS radius of each FOV shall be no larger than 90 micrometer.



$$\delta = T \cdot \left(\frac{\tan(b)}{\tan(a)}\right)^2$$

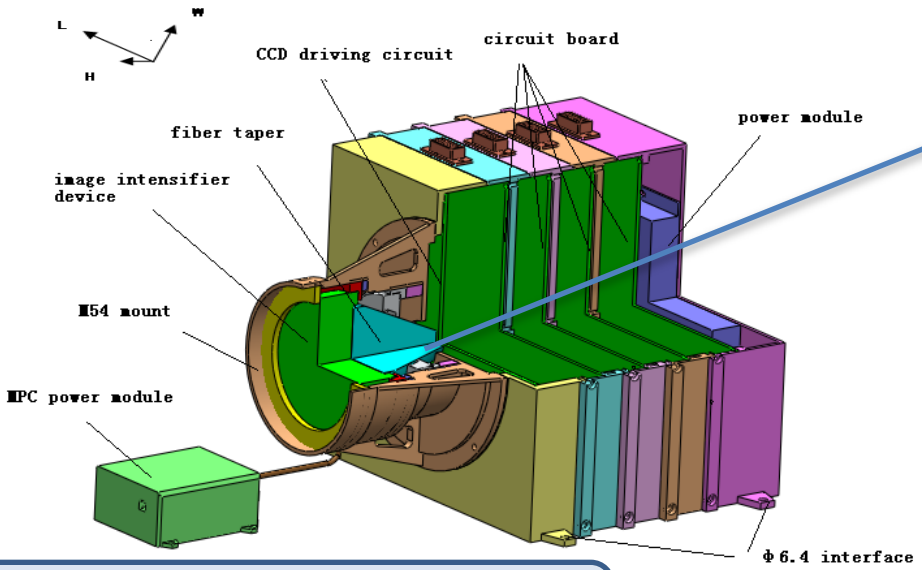
One problem bothers us is the coupling efficiency of the relay lens. From the schematic shows left, we can see that the object space NA determines the amount of light to be collected.

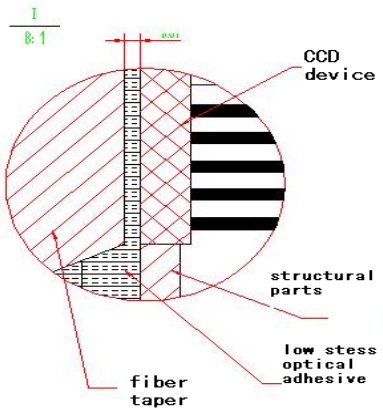


In the relay lens coupling scheme, the 75mm 2th generation image intensifier provided by Photek will be used to accomplish the light signal collection.

Preliminary Scheme

Taper Coupling

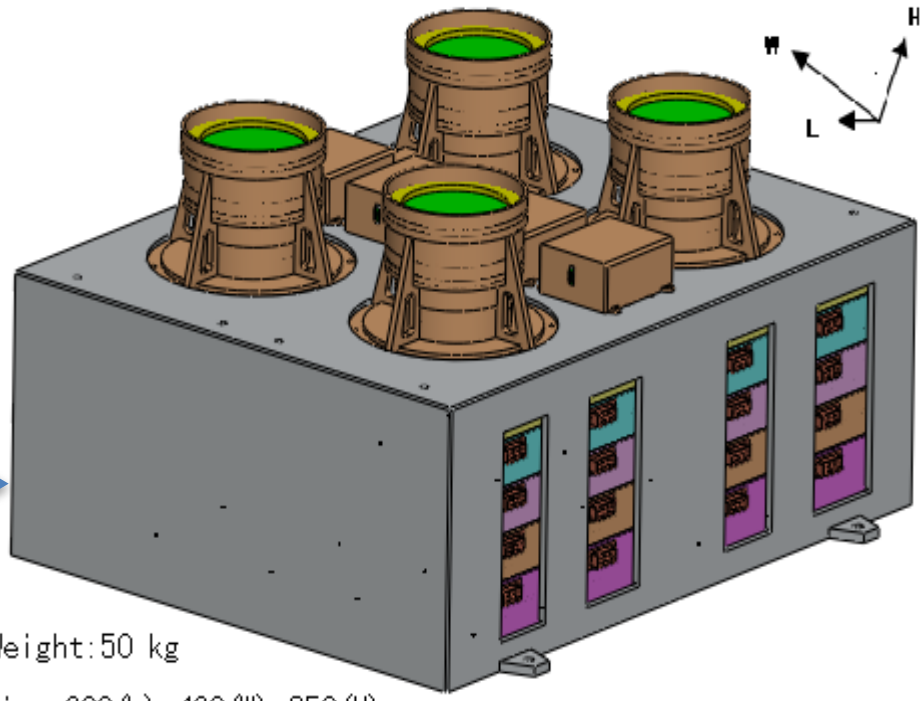




Weight: ~11Kg
Size: 286 (L)× 236 (W) ×320 (H)mm

Structure of Single Unit

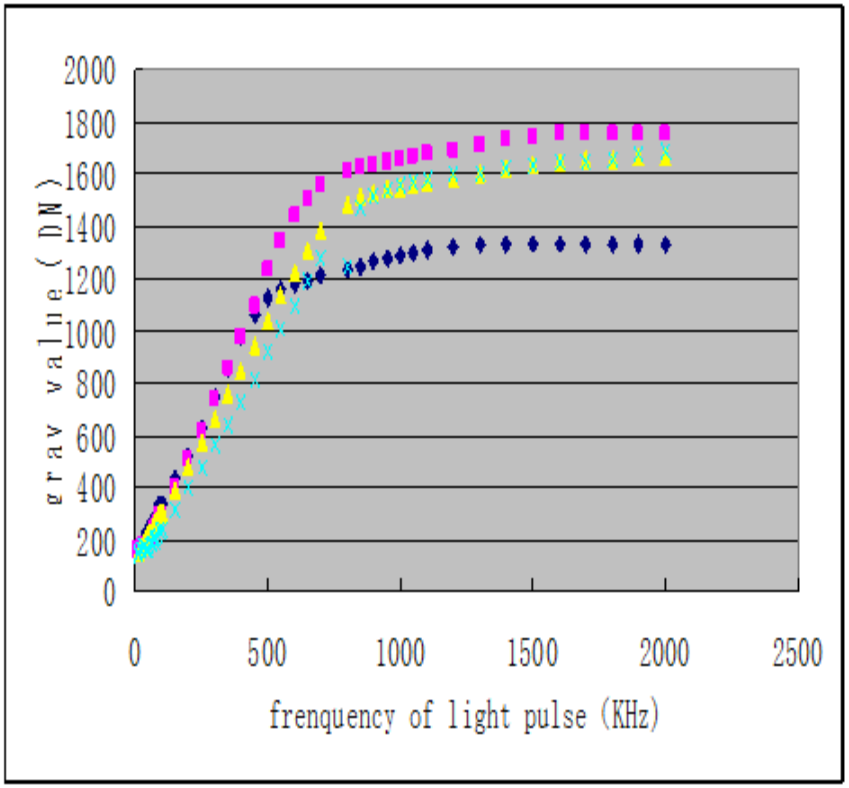
Structure of the System



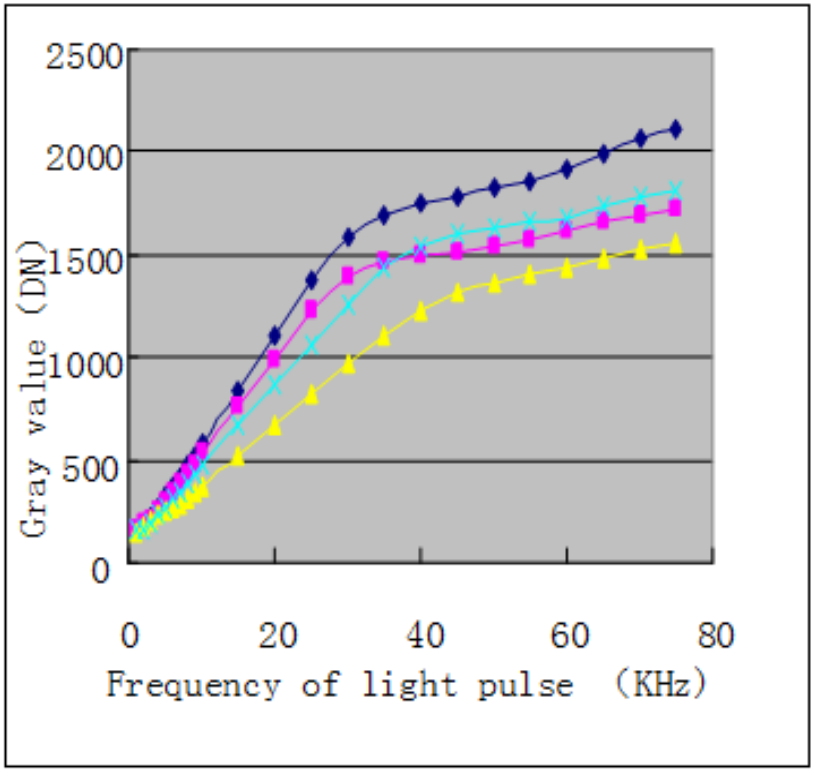
Weight:50 kg

Size:600(L)×460(W)×350(H)mm

Preliminary Scheme



Detection capability of relay lens coupling (MCP gain is 5000)

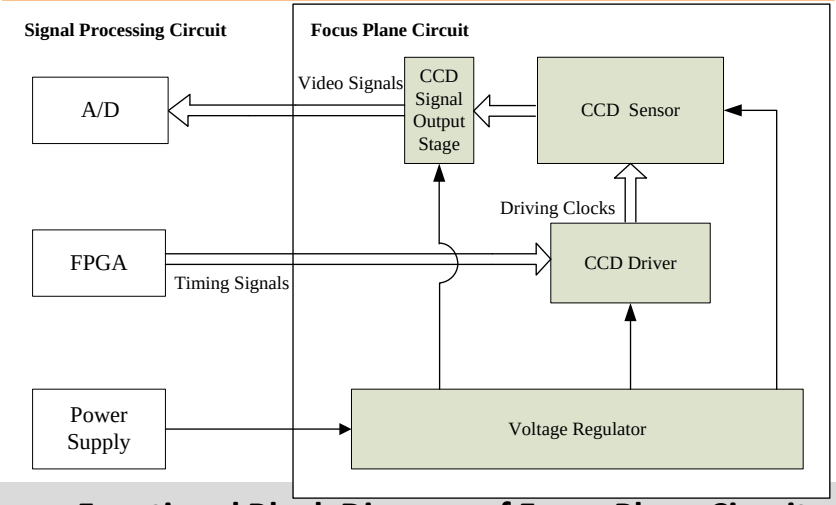


Detection capability of taper coupling (MCP gain is 600)

The coupling efficiency of taper is much higher than relay lens.

Preliminary Scheme

CCD Performance Description



Functional Block Diagram of Focus Plane Circuit

The focus plane circuit is composed of four modules:

→ Voltage Regulator

Several low dropout linear regulators are used to supply the power for different voltage requirements of CCD sensor and CCD drivers.

→ CCD Driver

CMOS drivers with high speed and high capacitive drive capability are used to convert the TTL timing signals to level-shifting driving clocks.

→ CCD sensor

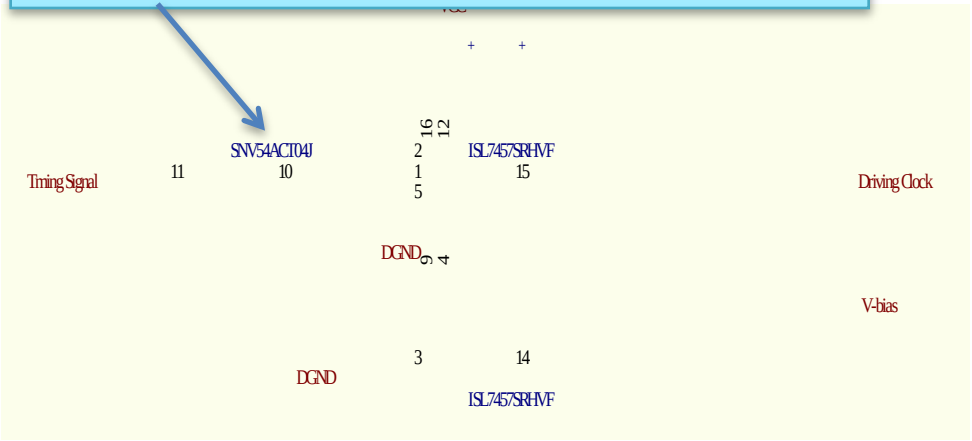
The custom designed CCD sensor is the core component of focus plane circuit, which converts the light signal to electric video signal.

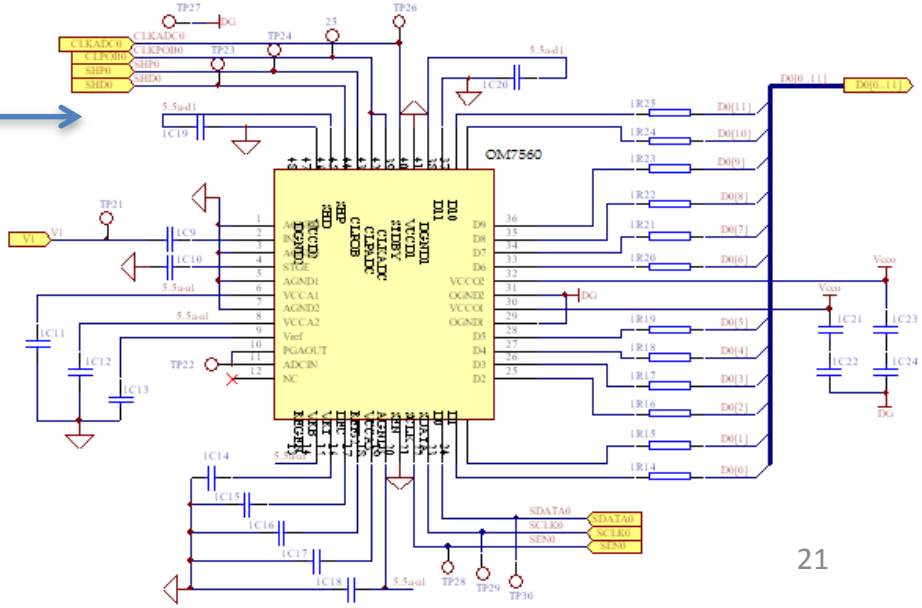
→ CCD Signal Output Stage

For insulating and protecting CCD sensor, a triode emitter-follower circuit is applied as the output stage to Signal Processing Circuit Unit.

Successful Experience--- in satellite for CAST

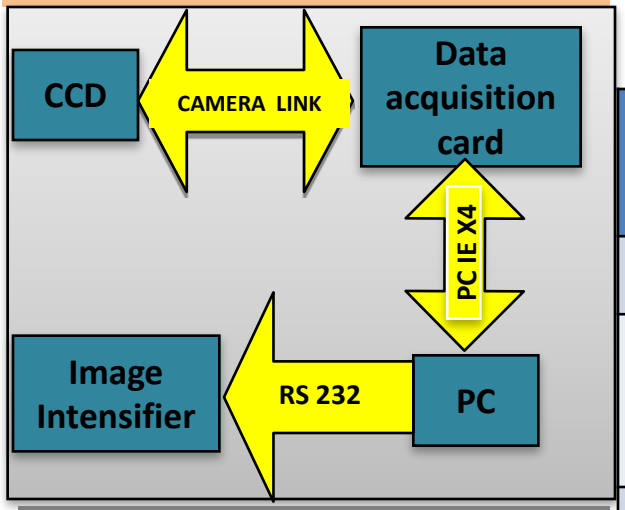
- 1024 x 256 pixels and up to 720fps;
- OM7560 is applied as CCD signal processor;
- ISL7457 is used as CCD driver





Preliminary Scheme

Ground Test Module



Interface Requirements

Data rate: > 7.8GbPS

Transmitting frequency: 119200bps

	Image Data Acquisition	Control Signal Part
Signal Properties	Digital signal	Digital signal
Signal Name	Video signal, Stored signal, Mode selection	Image intensifier gain adjusting signal , image intensifier timing delay signal
Transmission Mode	CAMERA LINK	RS232 & CAMERA LINK

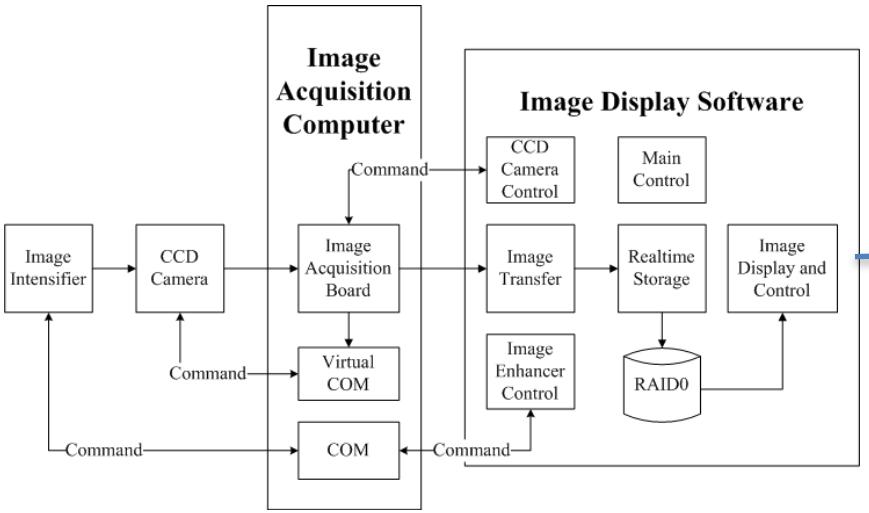
Performance

Camera interface	CCD Format	Pixel clock	Bits per pixel	BUS	SoftWare
2 Base or 1 Medium	Base or Medium Camera Link	MAX 85 MHz	8、10、12、14、16	PCIe x4	Sapera LT, 32/64-bit

Functional requirement

1. Receiving the vidio signal from the CCD Camera and stored in the PC disk ;
2. Through the RS232 interface to send to the image intensifier gain adjustment and delay adjustment signal ;
3. Communication and CCD Camera ; 4. The video signal is displayed in the PC .

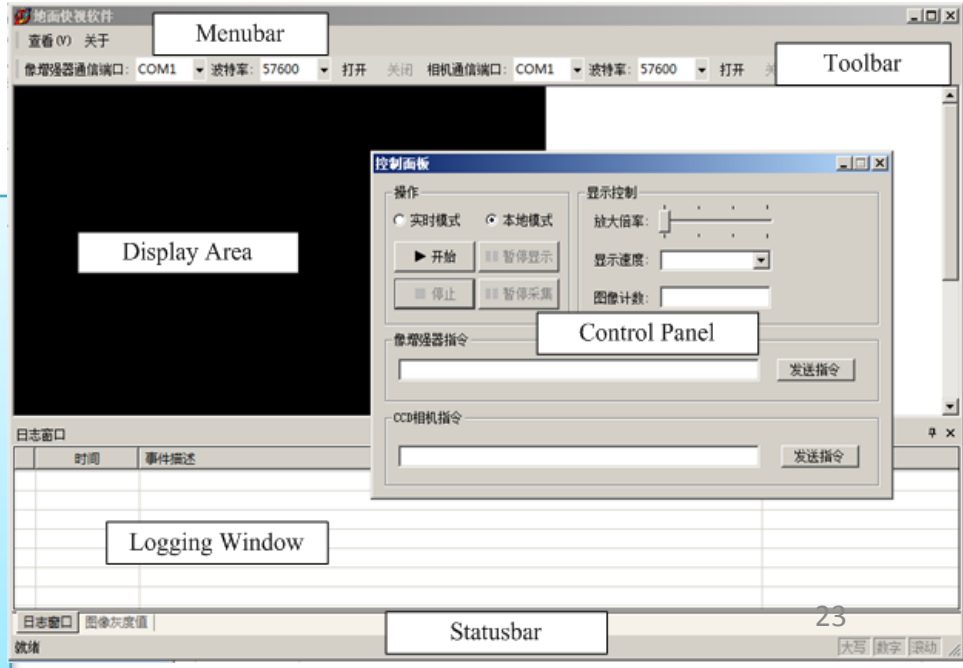
Image Display Software's Role in System



The software receives images by accessing the acquisition card on computer, then stores the images to high-speed disk array. The software access images stored on disk and displays them on the screen. In addition, the software controls image intensifier and CCD camera through COM port.

Image Display Software UI

UI contains a menu bar, toolbar, status bar, logging window, control panel and display area.
Toolbar contains COM port settings.
Status bar is used to display image info.
Logging window is used to show running state and info.
Control panel is used to control image display, CCD camera and image intensifier.
Display area is used to show images and pixel values.

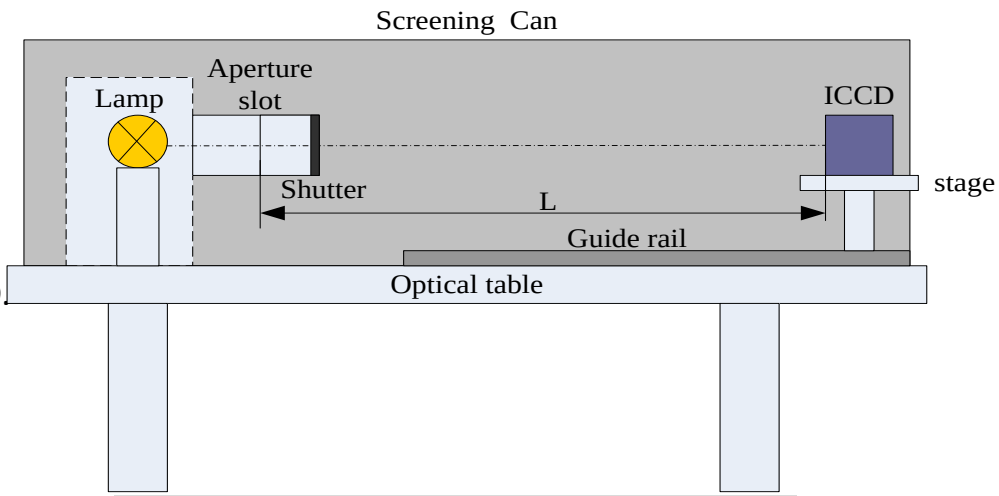


Preliminary Scheme

ICCD Calibration Program

3 Steps:

- Sensitivity calibration、Imaging quality test of the CCD
- Sensitivity calibration、Imaging quality test of the Image Intensifier tubes;
- Sensitivity calibration、Imaging quality test of the ICCD.



Schematic Diagram of ICCD Calibration

Imaging quality Parameters：

1. Limiting Resolution
2. Modulation Transfer Function (MTF)
3. Signal To Noise Ratio (S/N)
4. Blemishes (dark spots, white spots, chicken wire)
5. Output Brightness Uniformity
7. Useful cathode diameter
8. Image Alignment
9. Distortion
12. Magnification
14. Fixed pattern noise

Sensitivity calibration Parameter：

1. Luminous Sensitivity
2. Radiant Sensitivity
3. Saturation Level
4. Equivalent Background Input
5. Gain

Purpose: Establish the quantitative relation between the input illumination and the output DN of the ICCD.
Key devices: Standard light source, MTF tester, Illuminometer

V. Critical technologies

Critical Technologies

System for Coupling Optical-taper with CCD

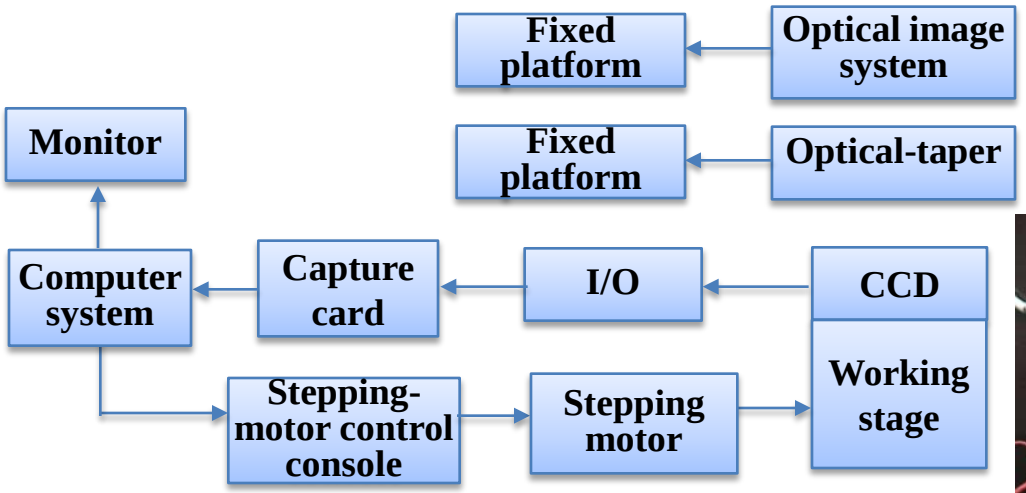
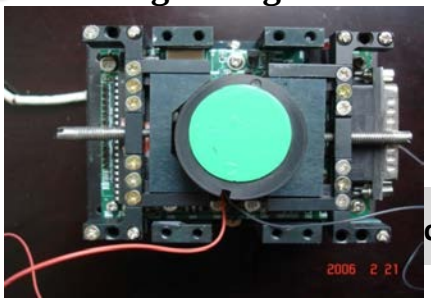


Fig . Original



coupled with CCD object picture

- The system for coupling optical fiber-taper with CCD is based on image processing technique by using image-evaluation function .
- By experiments, it is proved that a higher accuracy is achieved. This method successfully resolves the problem how to obtain the best efficiency of coupling during the coupling process.
- At present, we have completed CCD coupled with the fiber taper which applies in the laboratory, and we are optimizing the system to meet the mechanical shock, heat shock and other space environment.

XIOPM

Aerospace Environment

Analyses :

- The finite element analyses(FEA) of the mechanical structure and Heat in the space environment;
- The analyses of magnetic in the space environment;
- The choice of the materials.

Test :

- Mechanics and heat in the space environment;
- Magnetic in the space environment

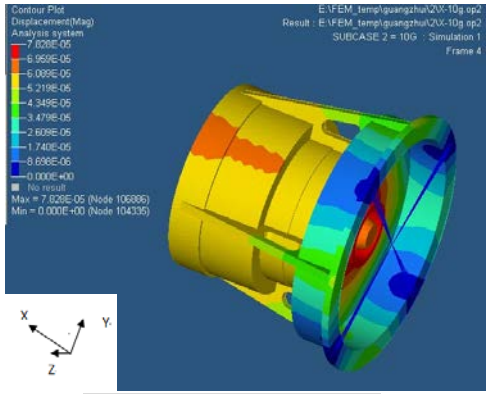


Fig. X direction

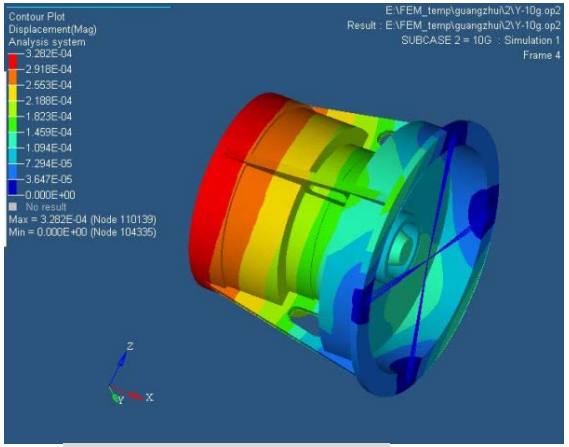


Fig. Y direction

VI. Principle prototype

Principle prototype

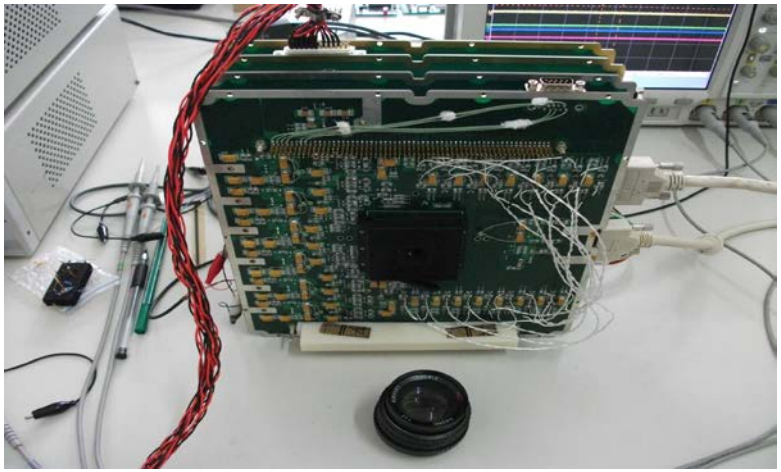
Requirements of Principle prototype	
Spectral response range	450nm-600nm
CCD detector frame frequency	>400fps
Weak light detection requirements	30photon/μs/fiber
Strong light detection requirements	2000 photon/μs/fiber
Image intensifier time delay	≤5ms
The quantum efficiency of image intensifier	the second-generation products＞15%
The clear aperture of image intensifier	the second-generation products≥Φ25mm
The shutter time of image intensifier	≤1μs
The precisely synchronous delayer	ns to μs delay implementation， ns scale delay accuracy

Manufacture and Test

Relay Lens Coupling

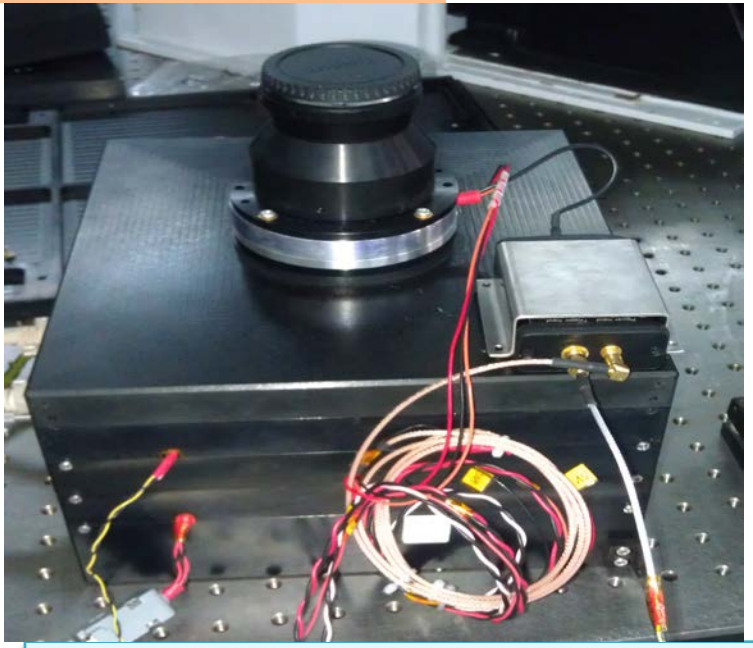
Performance Characteristics of Principle Prototype :

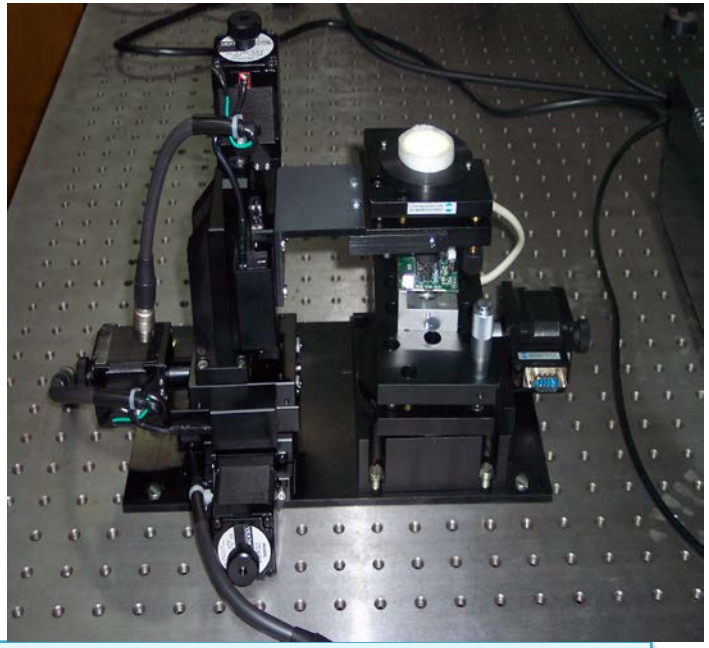
- 512×512 back illuminated CCD;
- Adjustable CCD gain and MCP gain ;
- Fame rate : 280 frame/second;
- External trigger mode



Manufacture and Test

Taper Coupling

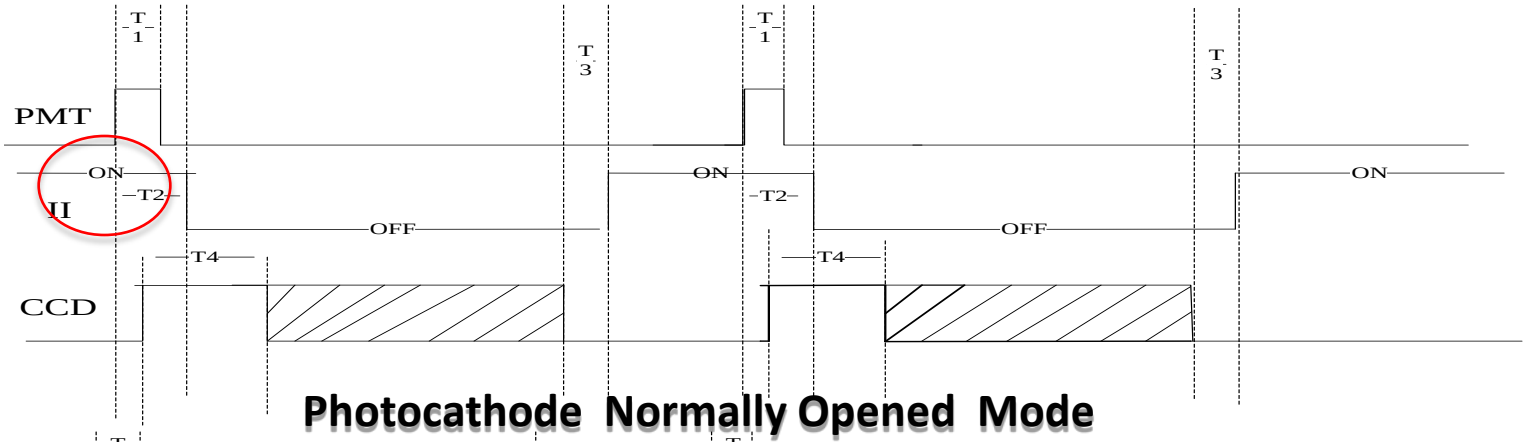




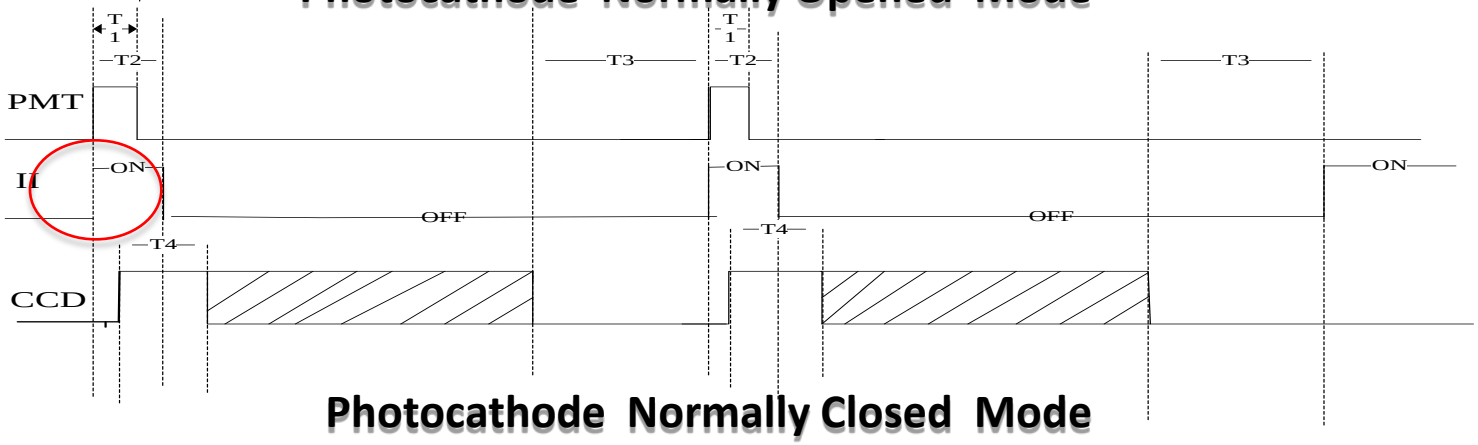
Performance Characteristics :

- 512×512 back illuminated CCD;
- Fame rate : 280 frame/second;
- Adjustable CCD gain and MCP gain ;
- **High performance of weak light detection : 10 photons;**
- External trigger mode

Manufacture and Test



Photocathode Normally Opened Mode



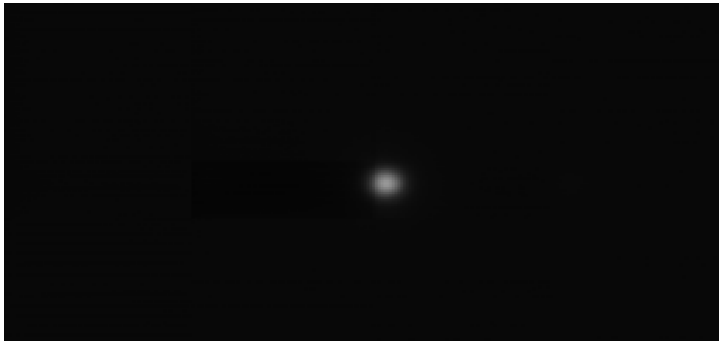
Photocathode Normally Closed Mode

The principle prototype has two work patterns. The normally opened mode is favor to acquire super-fast phenomenon. The normally closed mode would reduce the noise of photocathode.

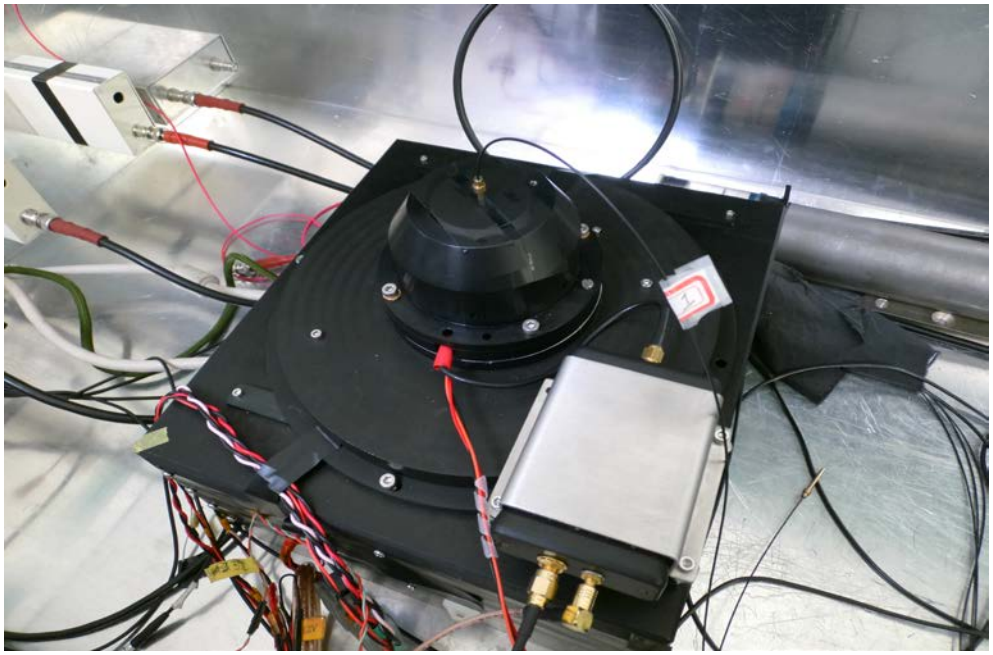
Manufacture and Test

Performance Test

Fiber and LED



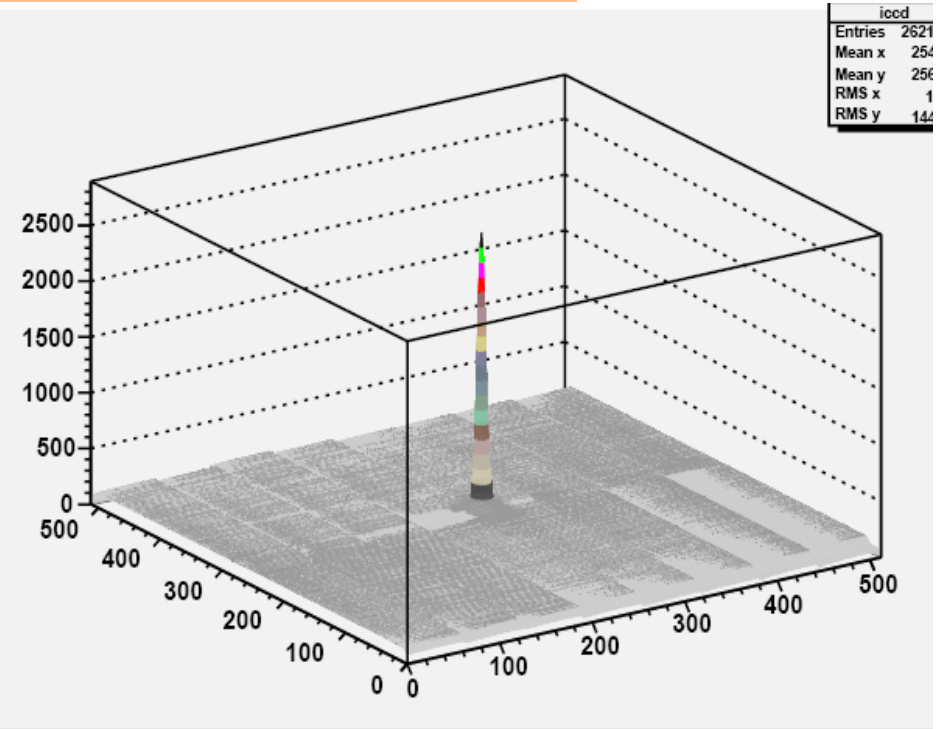
Fiber Signal acquired by principle prototype



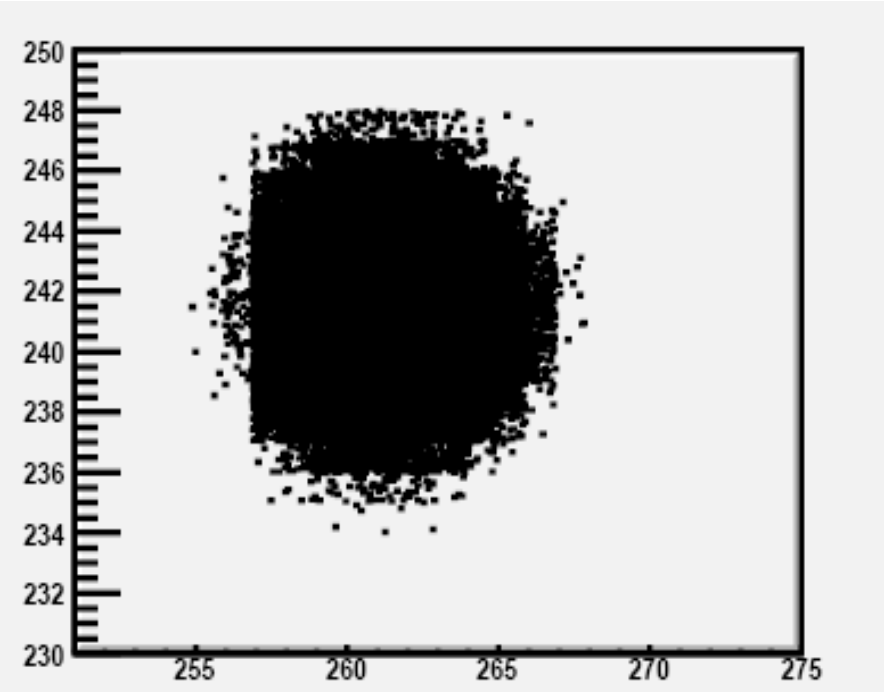
Fiber and ICCD

The principle prototype is testing in IHEP now .

Performance Test



Three-Dimension distribution of Fiber Signal



Two-Dimension distribution of Fiber Signal

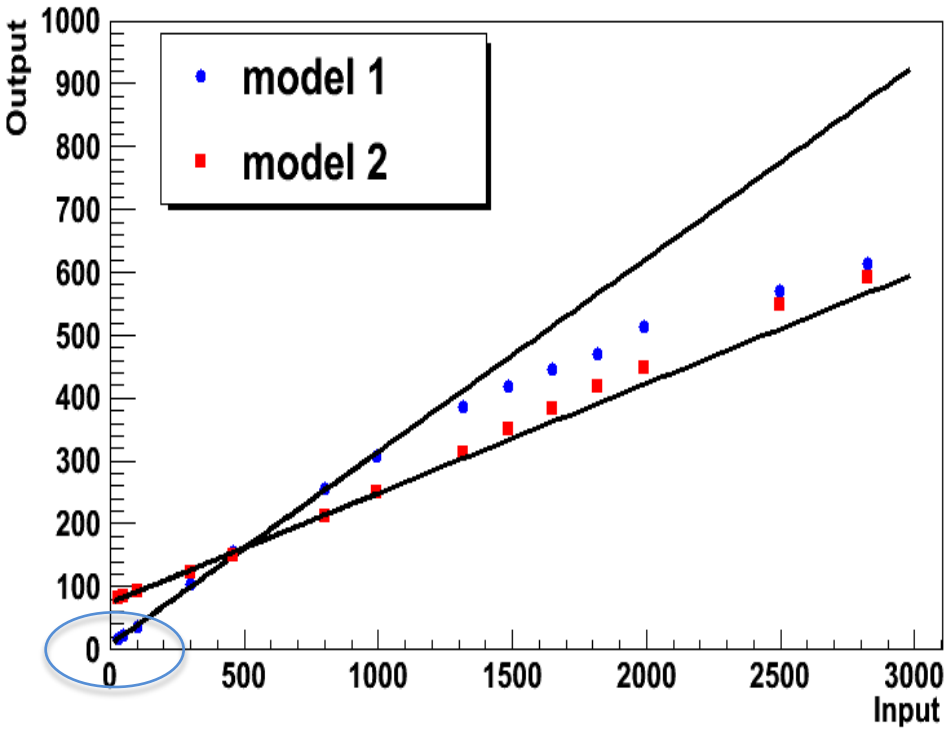
Measurement of Diffused Facula :

- The ratio of diffusion is about 1.25 when 10 photons enter the prototype.

Manufacture and Test

Performance Test

Dynamic Range
Mode1: 10-1500 photons
Mode2: 10-3000 photons



Dynamic Range of Taper Coupling Prototype
Mode 1: CCD gain is 2, MCP gain is 1.5e5
Mode 2: CCD gain is 8, MCP gain is 1e4

Proposal for improvement

- Increase the frame rate up to 400 fame/second .
- Enhance the experimental method to achieve more precision result .
- Optimize the design of prototype to extend dynamic range and shrink the facula .

Photocathode Normally Opened Mode

VII. International cooperation

International cooperation

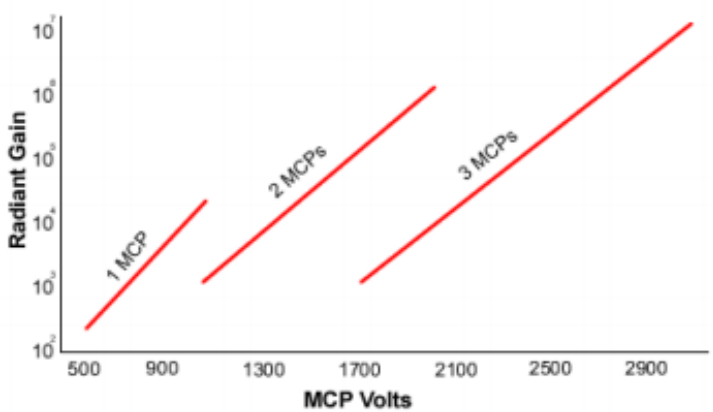
Our project has been supported by the "National Natural Science Foundation of China" and "Open Foundation of XIOPM ".

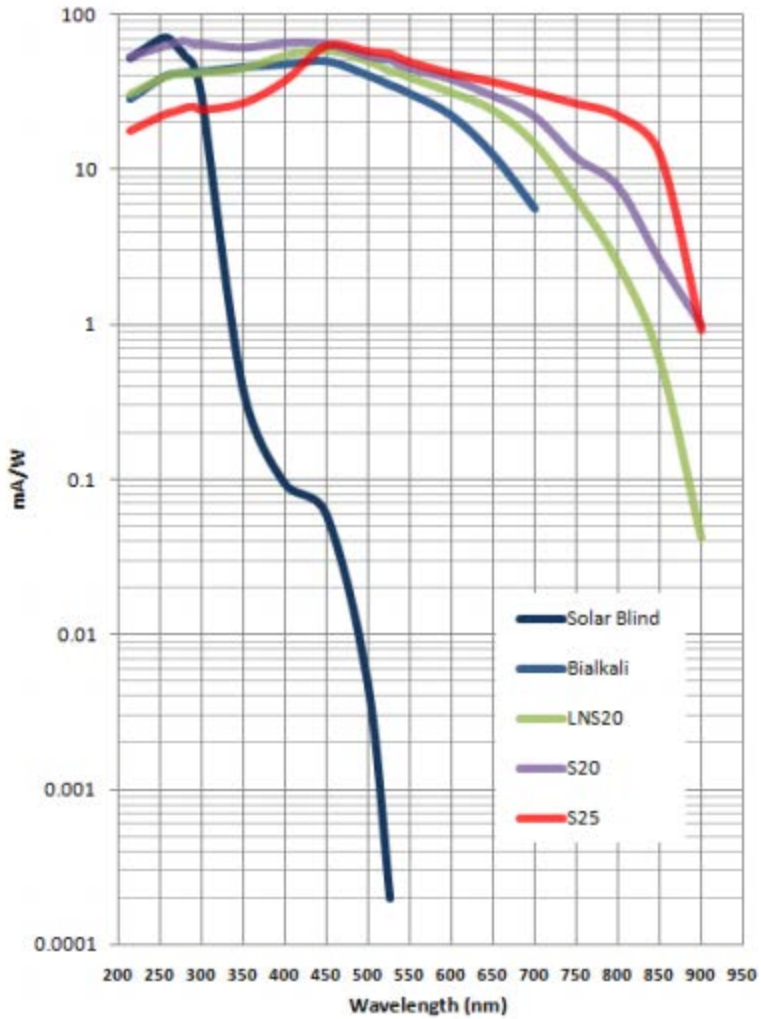
We also need technological and financial support from other institutes and corporations. Our cooperation can cover these aspect:

1. High grade image intensifier
2. Technology of taper coupling

Welcome to join us

International Cooperation

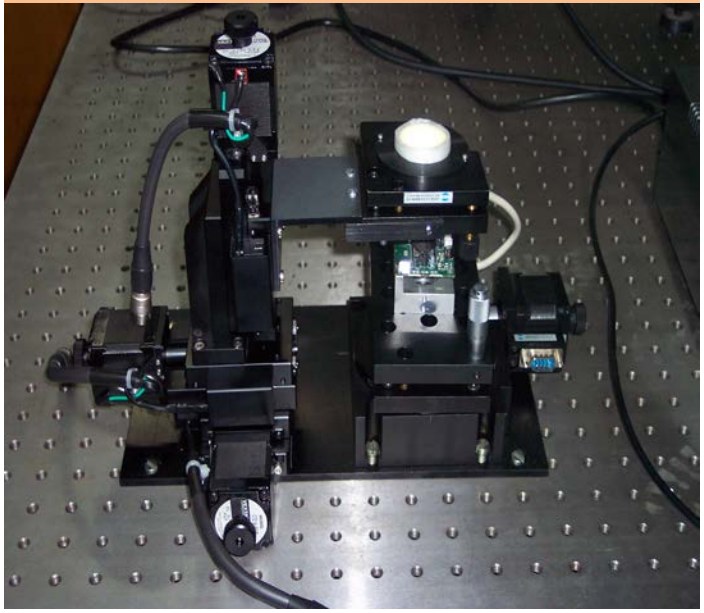


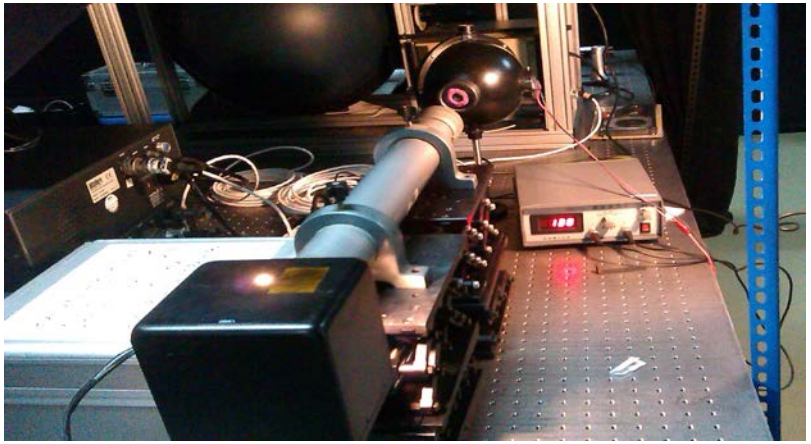


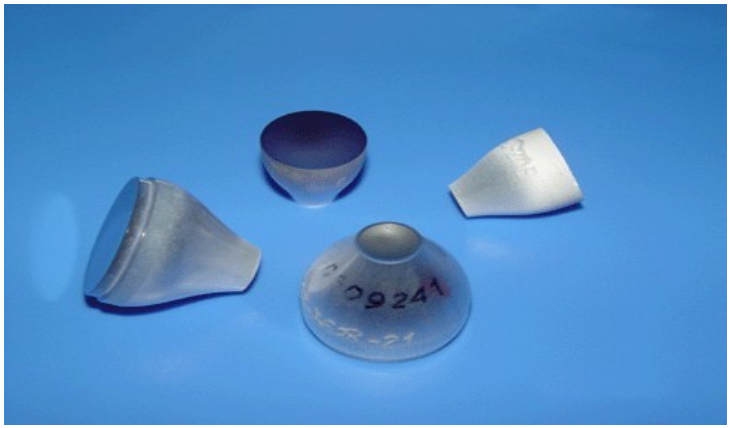
Parameters: 75mm, P24, MCP, S20, fiber faceplate I/O

International Cooperation

Taper Coupling







Thanks!