

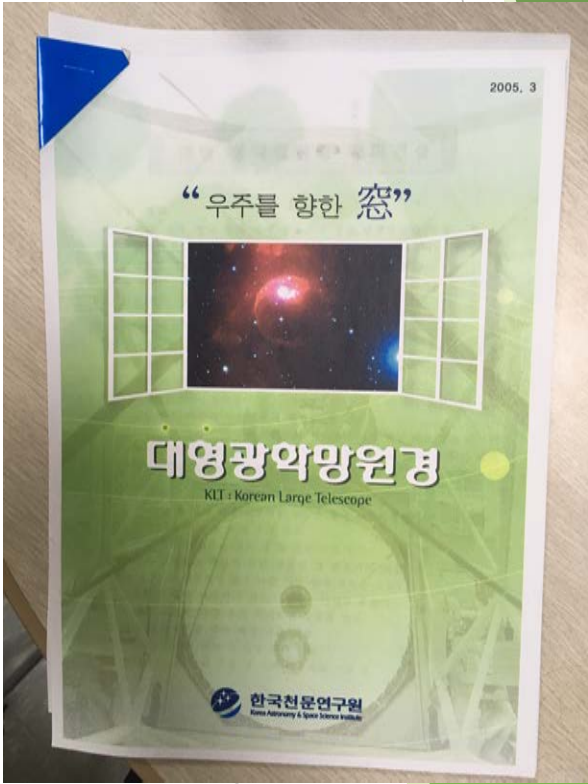
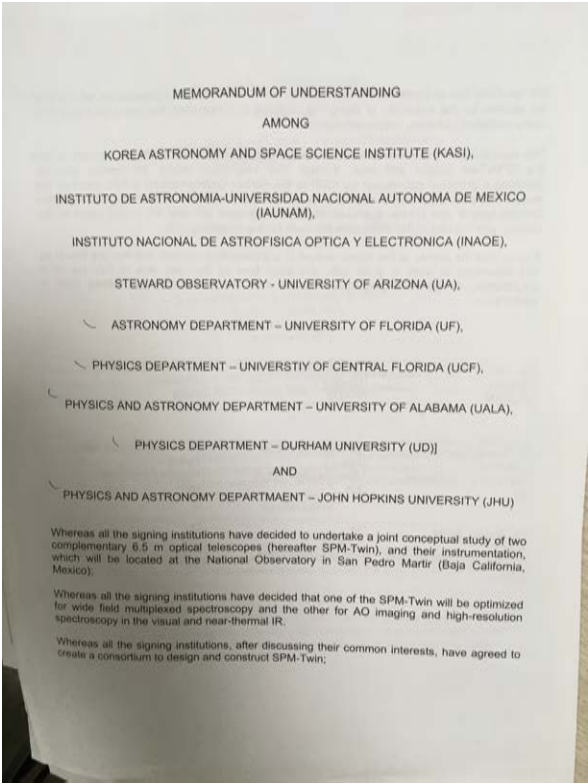
The subsystems of K-SPEC in my charge

Moo-Young Chun
SSG workshop
2022. 2. 14. ~ 16.

MOS 관련 추억

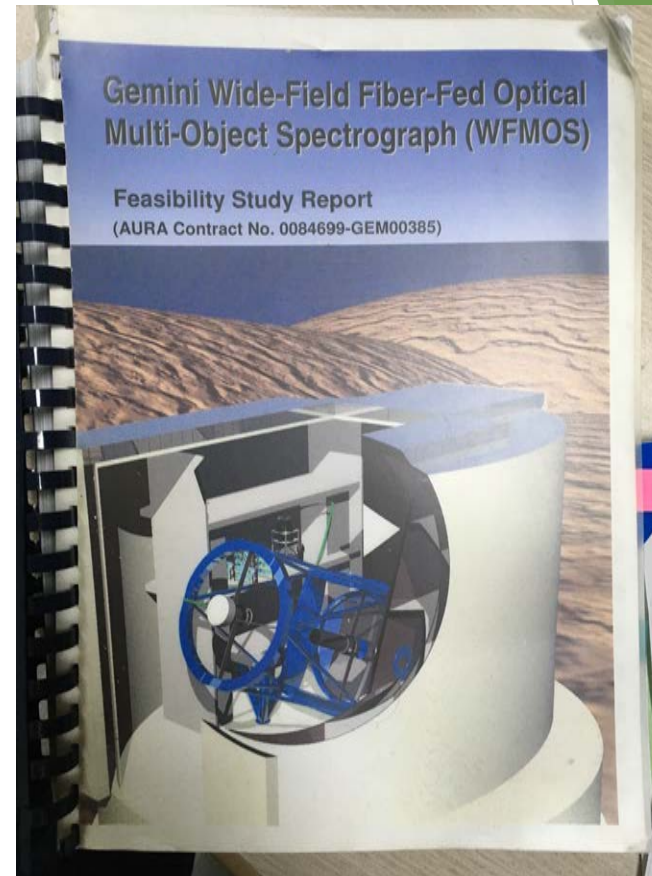
- ▶ 90년대 중반 : BOES vs MOS : Science/경험에서 밀림 (형식박사)
- ▶ 00년대 중반 : 6.5m TWIN with Mexico(UNAM), 1대는 분광전용
 - ▶ LOI, MOU, (MOA)
 - ▶ Brochure
 - ▶ WFMOS Feasibility Study Report 읽기 & AAO 방문 (2005. 12.)
 - ▶ 예산 확보 실패 => GMT 참여로 계획 변경, 예산 확보 성공

KLT - 6.5m TWIN Telescope



WF MOS

- Gemini 용 다천체 분광기
 - 제미니 펀드 받아 Feasibility Study
- Aspen meeting 에서 원점
- Echidna (Fiber Positioner) 기술 사용
- 523pages



Subsystems of K-SPEC in my charge

- ▶ K-SPEC Focal plate & GFA Camera
(Guide, Focus, and Alignment)
- ▶ K-SPEC Electronics
- ▶ K-SPEC ADC motion & Bezel design
(Atmospheric Dispersion Corrector)



K-SPEC Focal plate & GFA Camera



Components of focal plate

- ▶ ~~L4 lens & its cell - interface with KMTnet Telescope & Cage 김윤중/오희영~~
- ▶ ~~Plate - interface with Fiber Positioners & Fiducial fibers, base of GFA 오희영~~
- ▶ GFA - Guide, Focus & Alignment Camera 천무영, 이용석, S/W Engineer
- ▶ ~~Cage - Heat exchanger, Fan, (Fiber connector, positioner connector) 이승복~~
- ▶ Ref : [KMTNet Camera to Telescope Interface Control Document \(ICD\)](#)

See the Next presentation by HSHwang

Selection of GFA detector

- ▶ DESI : e2v CCD230-42, frame transfer CCD, 4 readout, 15um/pix, 2048x2048
=> **Operating at Room Temp.**
- ▶ KMTNet : e2V CCD47-20, frame transfer CCD, 13um/pix, 1024x1024
=> **imaging aera : 13.3 x 13.3 mm (177mm²)**
- ▶ K-SPEC : Sony IMX540, CMOS, 2.74um/pix, 5320x4600
=> **image area : 14.6 x 12.6mm (184mm² , 9.7 x 8.4 arcmin²)**

Sony IMX540

- ▶ Web page : <https://www.sony-semicon.co.jp/e/products/IS/industry/product.html>
- ▶ imaging area : 14.6mm x 12.6mm (9.7 x 8.4 arcmin²)
- ▶ pixel size & FOV : 2.74um => 4 x 4 binning (10.96um) => 0.44arcsec/pix if focal length is 5152mm
- ▶ **12 bit ADC**, QE peak ~ 67%, QE at SDSS r filter(623.1nm) ~55%, , **dark noise : 0.351 e-/pix/s**
- ▶ Basler Camera (GigE) : a2A5328-4gmPRO - Basler ace 2 pro
 - ▶ Foot print : 29mm x 29mm
 - ▶ <https://www.baslerweb.com/ko/products/cameras/area-scan-cameras/ace2/a2a5328-4gmpro/>

- Procurement of GFA cameras



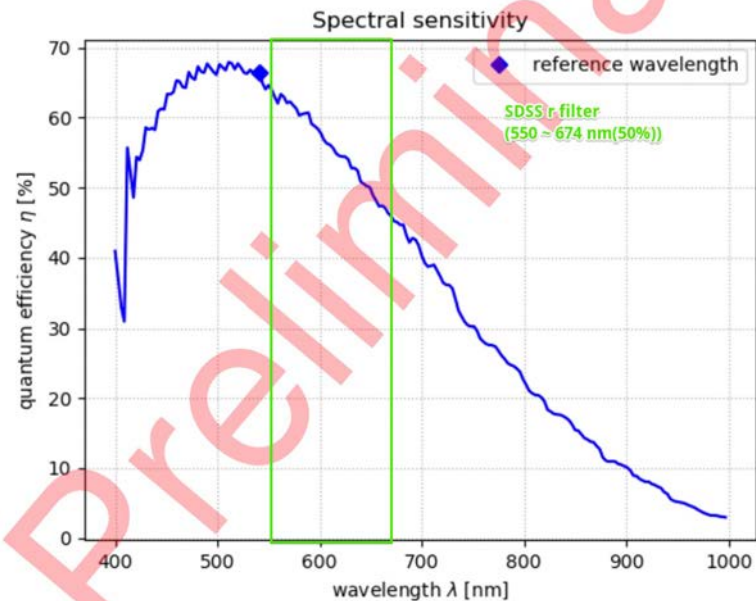
- ▶ GFA cameras arrived
- ▶ 7 set of GFA camera
- ▶ SDSS r filter ordered : 3mm(6ea), 2mm(1ea), 4mm(1ea)
- ▶ C-mount ring & camera tripod adapter are ready

The measured performance of Basler Camera

Item of measured performance		Results
Readout noise		$2.1 e^-$
Conversion gain		$2.44 e^- / \text{ADU}$
linearity		99 %
Full well capacity		$8660 e^-$
Defects	Dead pixel	0 개
	White pixel (95%)	6 개
	Warm pixel	4500 개
	Cold pixel	5189 개

(백마인턴 2인, 유영삼 지도 - 자세한 내용 backup slides)

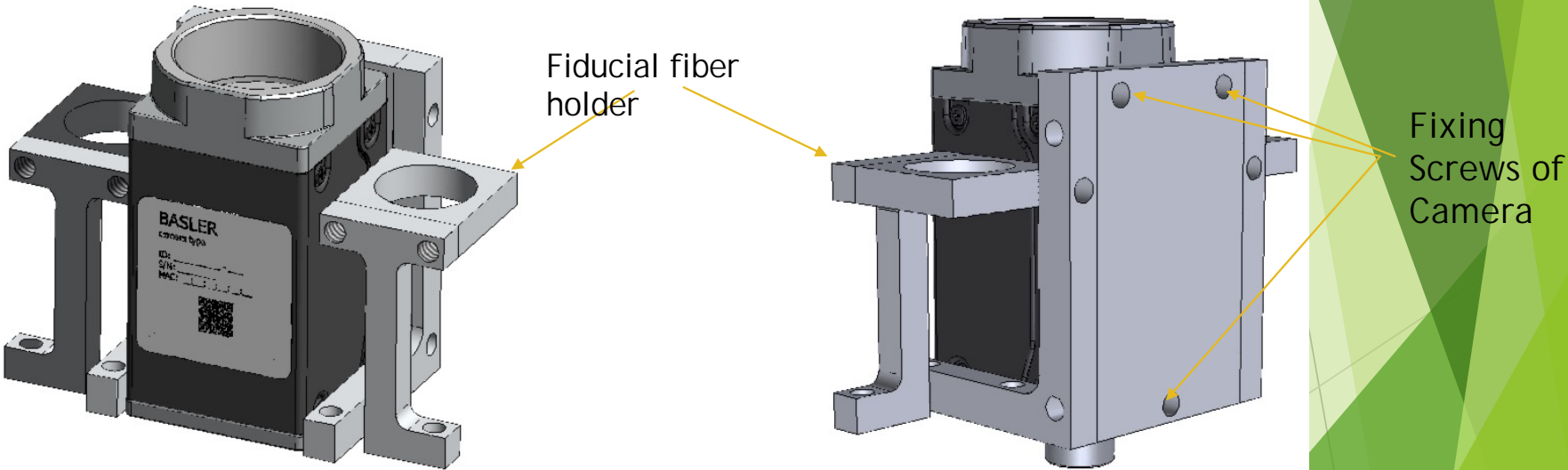
QE -from EMVA 1288 Standard



► EMVA 1288 Standard

EMVA1288 is an electronic measurement standard developed by the European Machine Vision Association. Its purpose is to define the methods to measure and characterize image sensors and cameras that are used in machine vision. [Wikipedia](#)

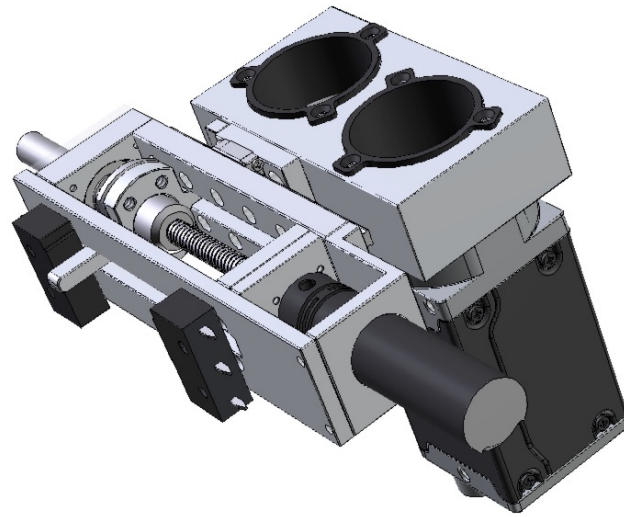
Draft of GFA mount



When the error budget of optical design & mechanical assembly, image shift by gravitation direction change are fixed, we will reinforce the GFA mount through Finite Element Analysis(FEA).

GFA Filter changer

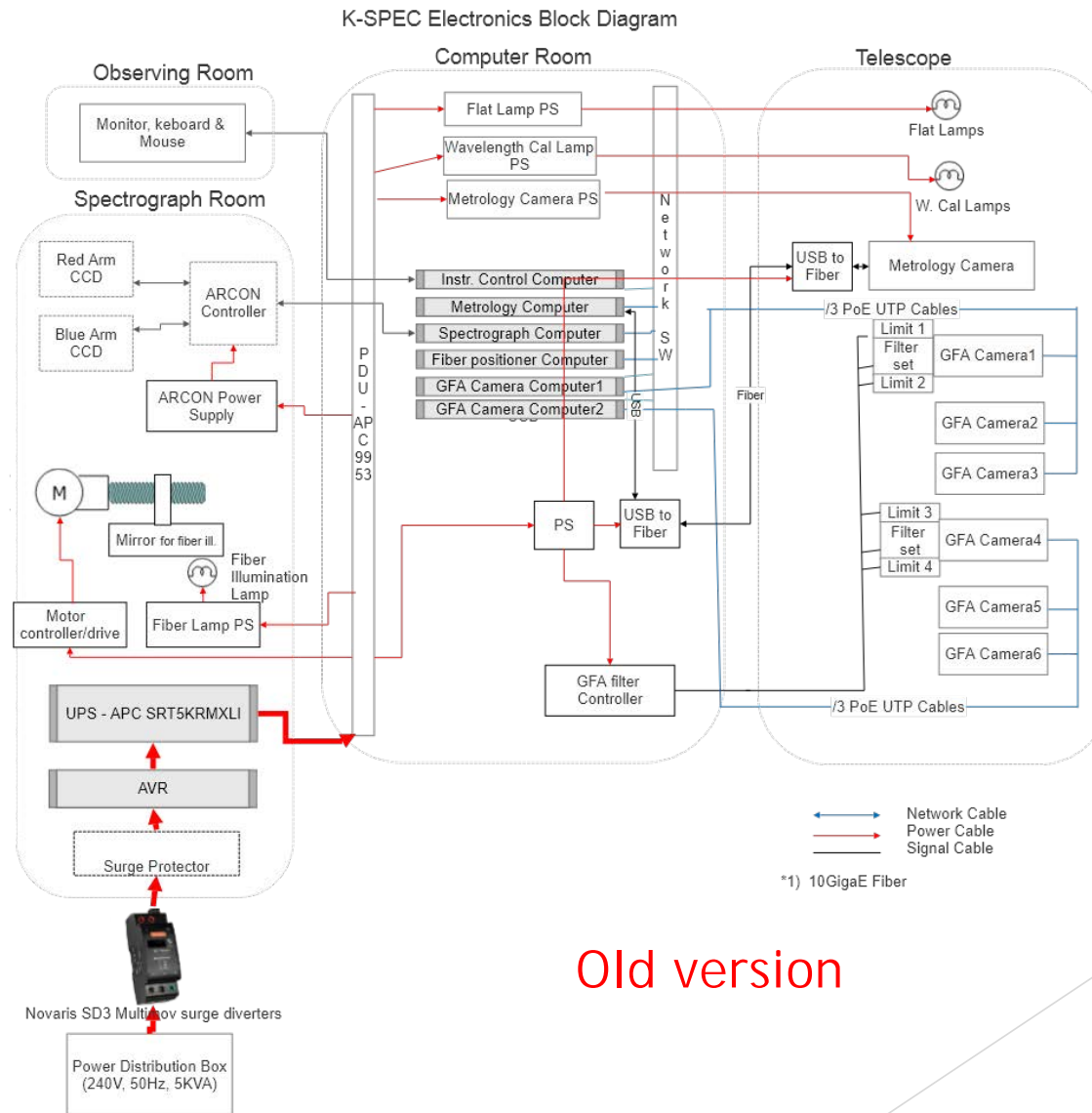
- ▶ Using filter changer, GFA camera is in guiding mode at most time with SDSS r filter 3mm thickness. When focus or alignment mode are required, 2mm and 4mm filter are setted at the front of camera. (Idea from Chung-Uk Lee, Designed by Yongseok Lee)



K-SPEC Electronics



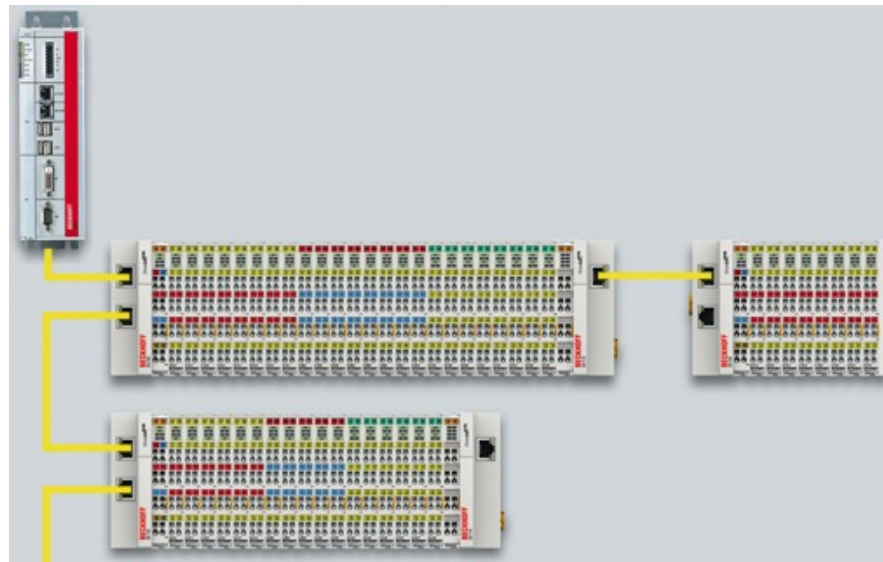
K-SPEC Electronics Block Diagram



Old version

EtherCAT mater is needed

- ▶ We should use EtherCAT for fiber positioner
- ▶ EtherCAT stack or RS485+PDU
 - ▶ Beckhoff module as base
 - ▶ several I/O module - GFA filter changer motor & limit SW, Lamps ON/OFF?
 - ▶ Motor & motor drive for ADC



K-SPEC network

- ▶ KMTnet Network
 - ▶ SSO network → Cisco Router at KMTnet dome → Network Switch
 - ▶ No PoE → new Network switch required
 - ▶ BMC for IPMI
- ▶ K-SPEC network
 - ▶ Min. 16 ports : ICC, Metrology Comp., SP comp., Fiber comp., GFA comp., PDU & 6 GFA camera, 4 Fiber positioner controller
 - ▶ Candidate network sw : Aruba 1930



Aruba Instant On 1930 24G Class4 PoE 4SFP/SFP+ 370W Switch

☆☆☆☆☆ (0) | 7WA512

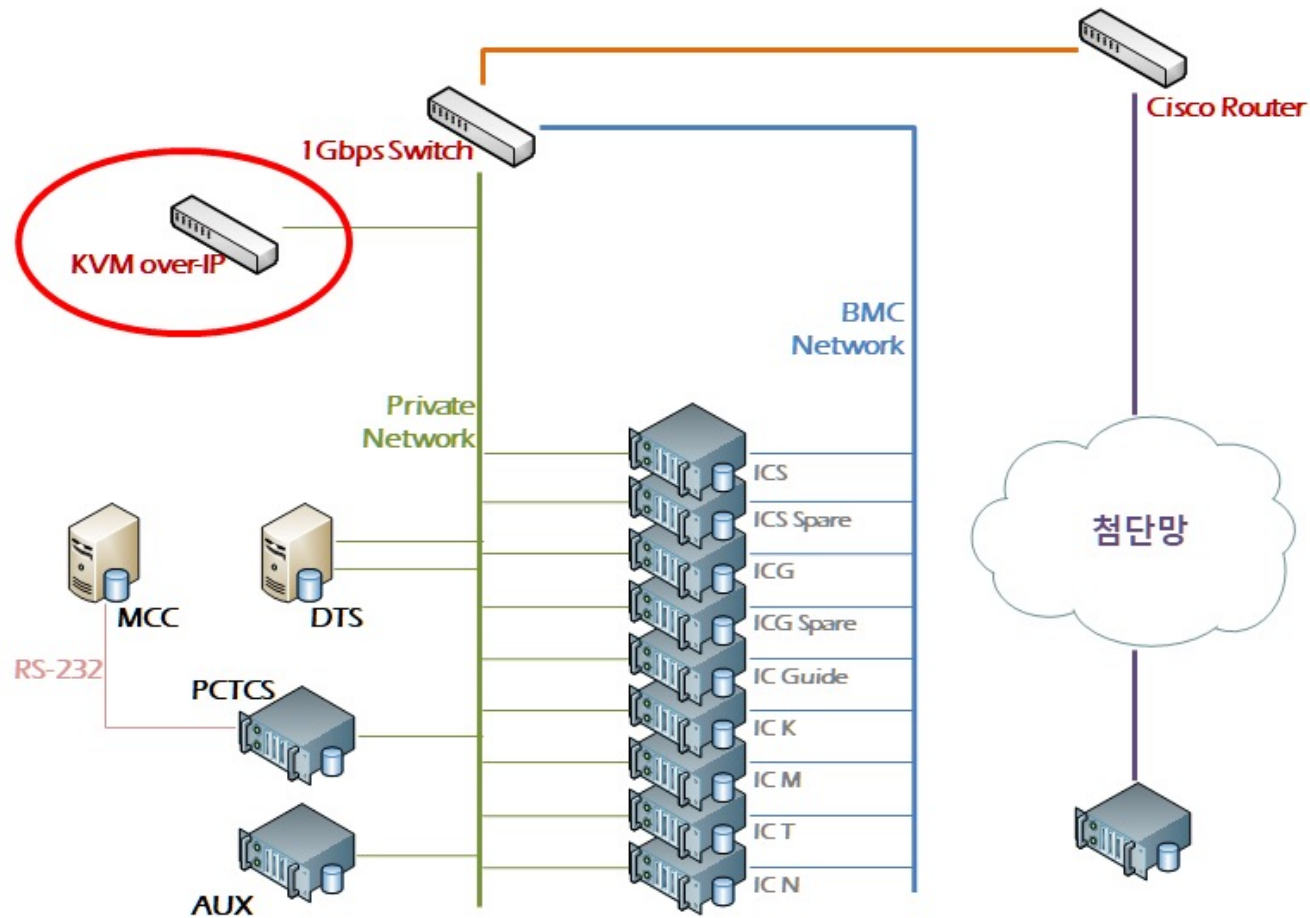
- Aruba Instant On 1930 24G Class4 PoE 4SFP/SF...
- 28 Ports - Manageable - 3 Layer Supported - Mo...

[Tech spec](#) |

\$599.99

Ships within 1 business day

Network Diagram of KMTnet SSO

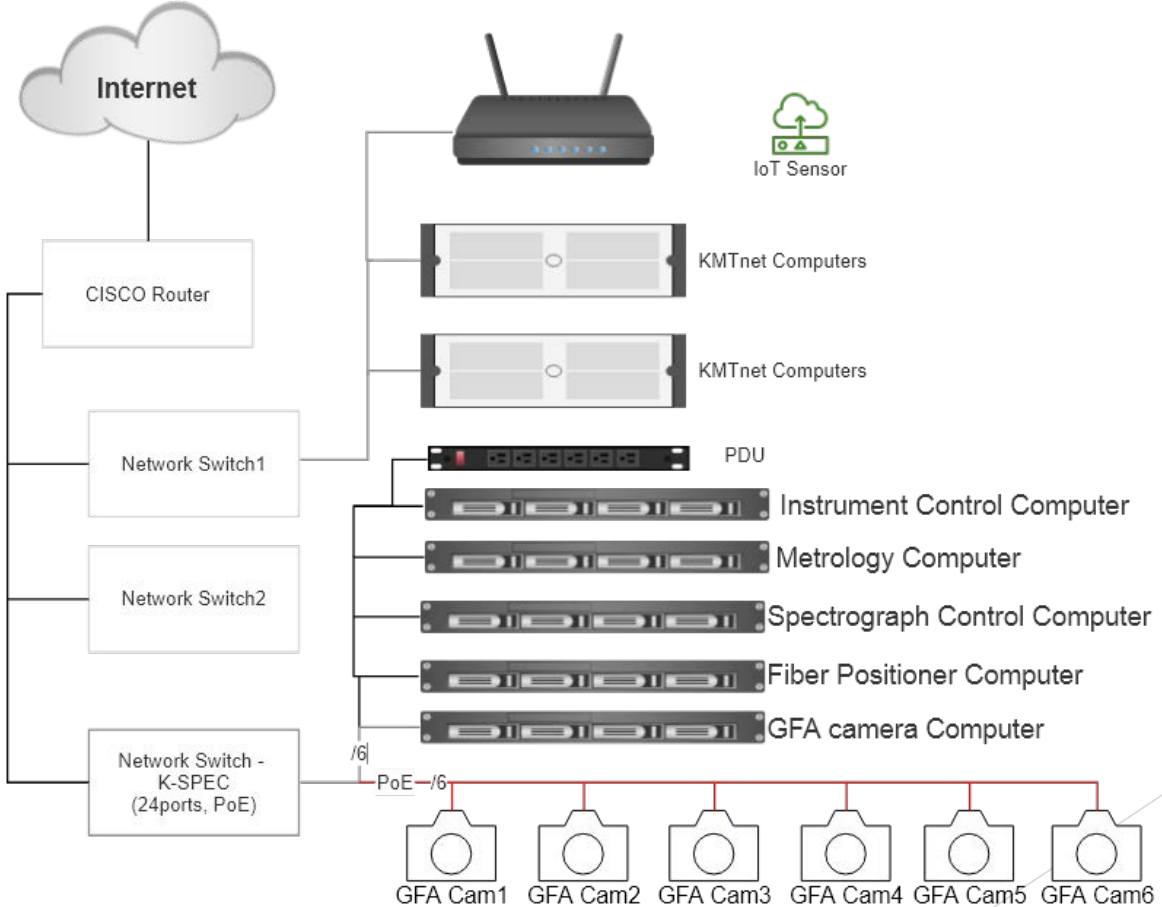


김동진 제공

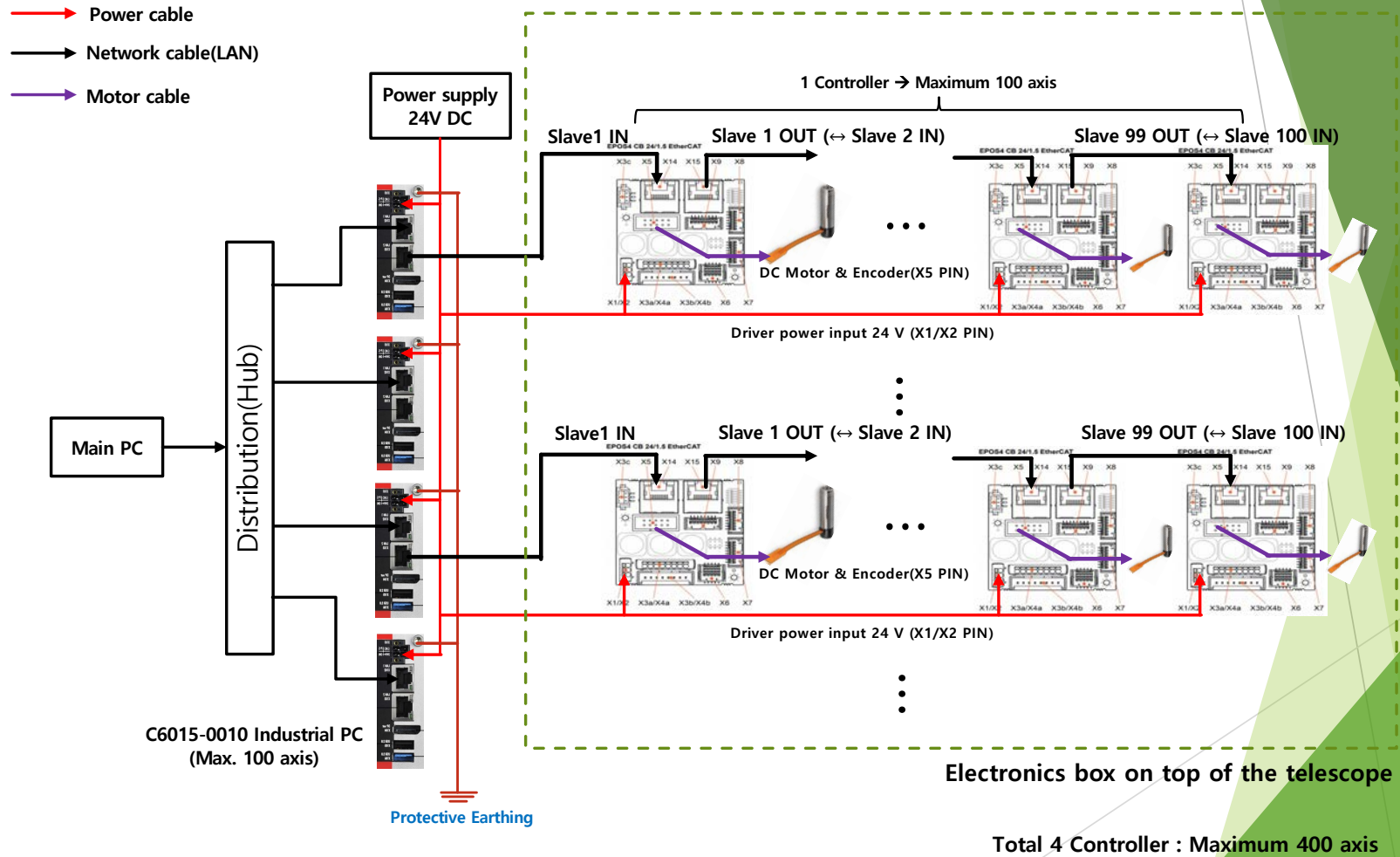
설치방안1

- ▶ 모든 파워서플라이와 네트워크 스위치를 컴퓨터실에 장착
- ▶ 장점 : 열원을 컴퓨터룸 에어컨등으로 해결
- ▶ 단점 : 컴퓨터실에서 망원경으로 가는 선들이 많아짐
 - ▶ 광섬유
 - ▶ 네트워크(Cat 6, UTP) 선 : GFA(6), Fiber Position Controller(4)
 - ▶ 전원선 : 메인전원선(230V), 램프전원선(2), PS cable for fiber drive

Network Diagram for K-SPEC



2차 FPU Prototype 설계 : Communication Scheme



설치방안2

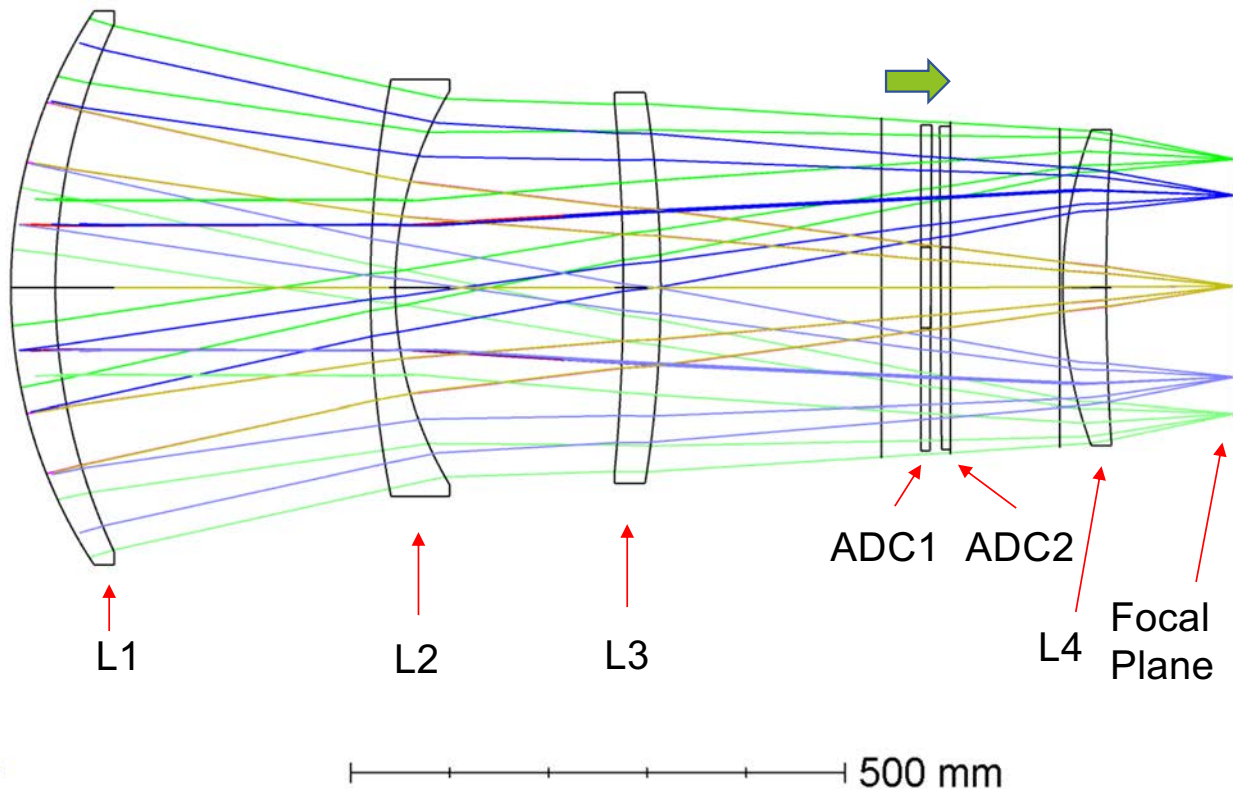
- ▶ 모든 파워서플라이와 네트워크 스위치를 필터박스(?)에 장착
- ▶ 장점 : 컴퓨터실에서 망원경으로 가는 선들이 줄어듦
 - ▶ 광섬유
 - ▶ 네트워크 (광섬유) : 1개 (컴퓨터룸의 네트워크스위치와 필터박스내 12포트 PoE 네트워크 스위치 연결)
 - ▶ 전원선 : 메인전원선(230V)
- ▶ 단점 :
 - ▶ 공간문제 : 설치부품이 많아짐(positioner drive, controller & PS, Network SW, PSs for lamps)
 - ▶ 열관리
- ▶ => 해결책은 중간 어디쯤

To be decide (TBD)

- ▶ Location of Network & power supply
 - ▶ KMTnet computer rack
- ▶ Computer : same model of all computers?
 - ▶ If possible, the same model
- ▶ Power Supply : Switch power supply or Linear power supply
 - ▶ Almost Switching power supply
- ▶ One or Two computer for GFA camera
 - ▶ Test the frame rate of network switch vs network card(4 port x 2)

K-SPEC ADC Bezel & motion



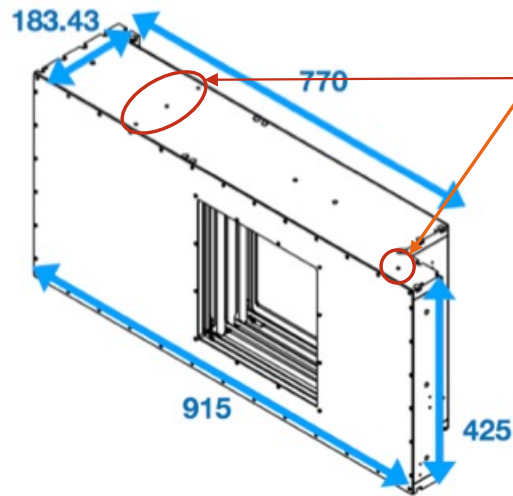
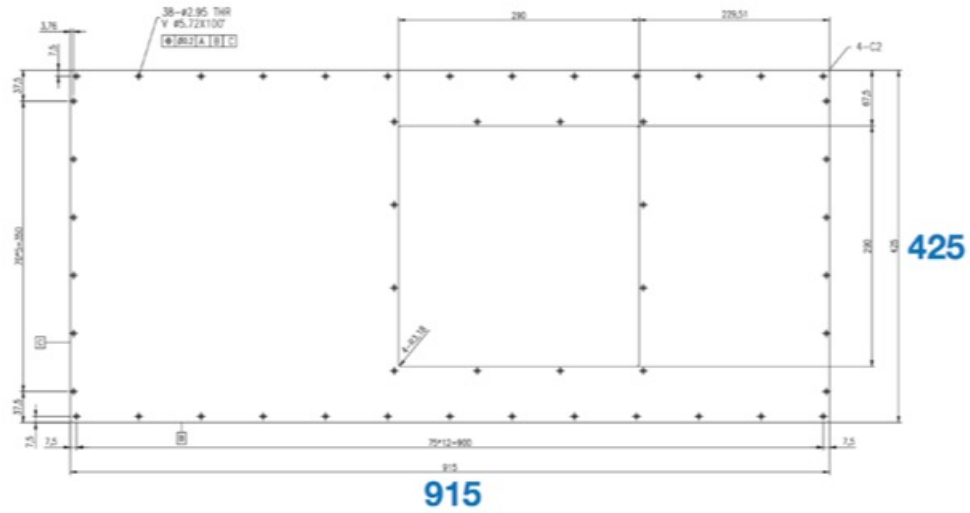


- Constraint
ADC CA Diameter: less than 340 mm
ADC1 to ADC2 Distance: 10 mm
- Variable
L4 Position
ADC Wedge Angle
L4 to Focal Plane Distance
- Design Check
ADC Thickness

	Initial	Modified
ADC Wedge Angle(°)	0.326947	(V)
L3 to ADC1(mm)	223.3	263.3
ADC1 to ADC2(mm)	5	10
ADC2 to L4(mm)	155.7	110.7 + (V)
L4 to FP(mm)	132.273	130.082
ADC CA(mm)	344.2	339.2

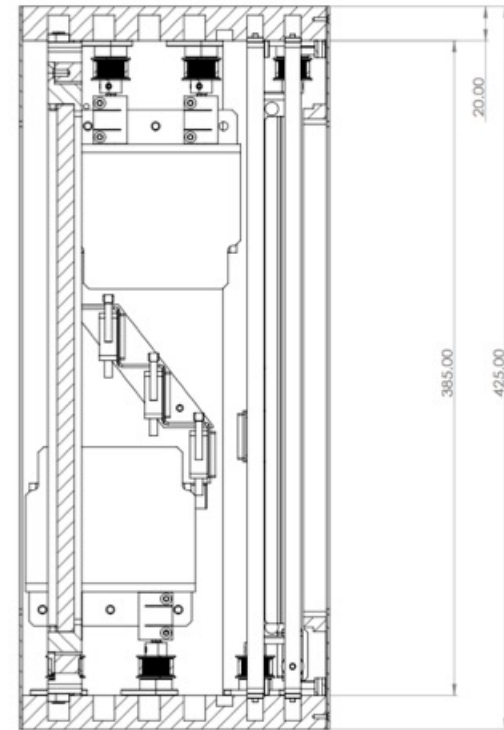
From YJ Kim's slide

KMTNet FSA & ADC



Taps to fix the box at Telescope

From YS Lee's slide



Athermal lens mount

From Gabor Furesz's Thesis (p.82)

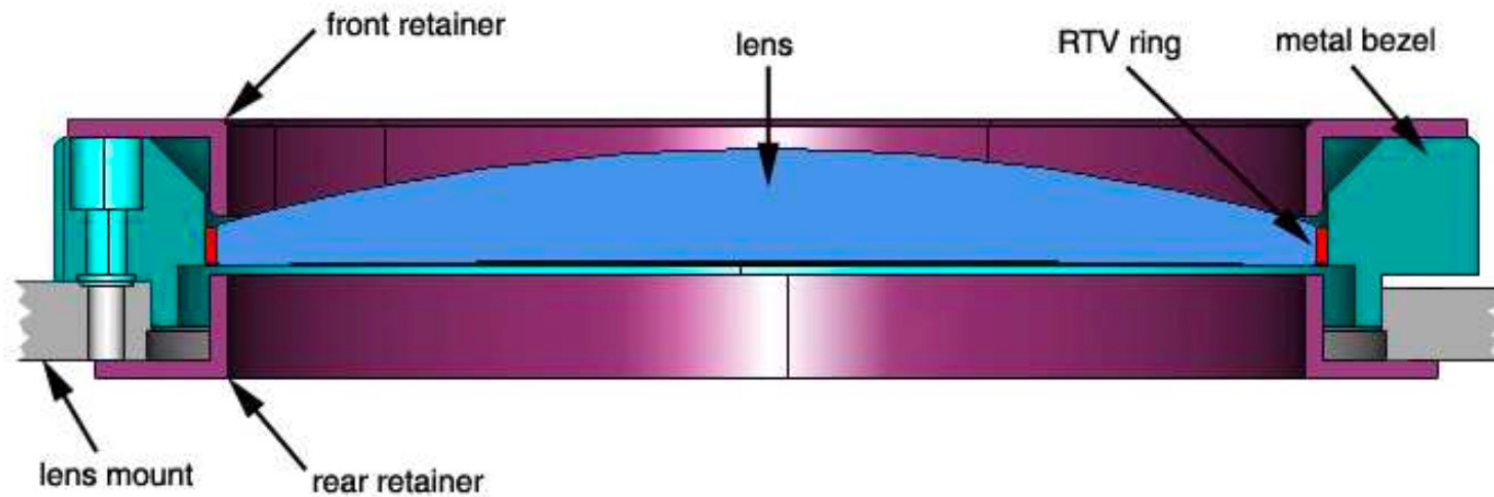


Figure 2.33: *Cross section of a continuous RTV bonded lens mount. The lens is bonded to a bezel (green), while the bezel is supported by the lens mount (gray). The retainers (purple) are attached to the bezel and do not touch the glass. Their role is only safety, to prevent the lens falling out of the mount in case the RTV bonding fails.*

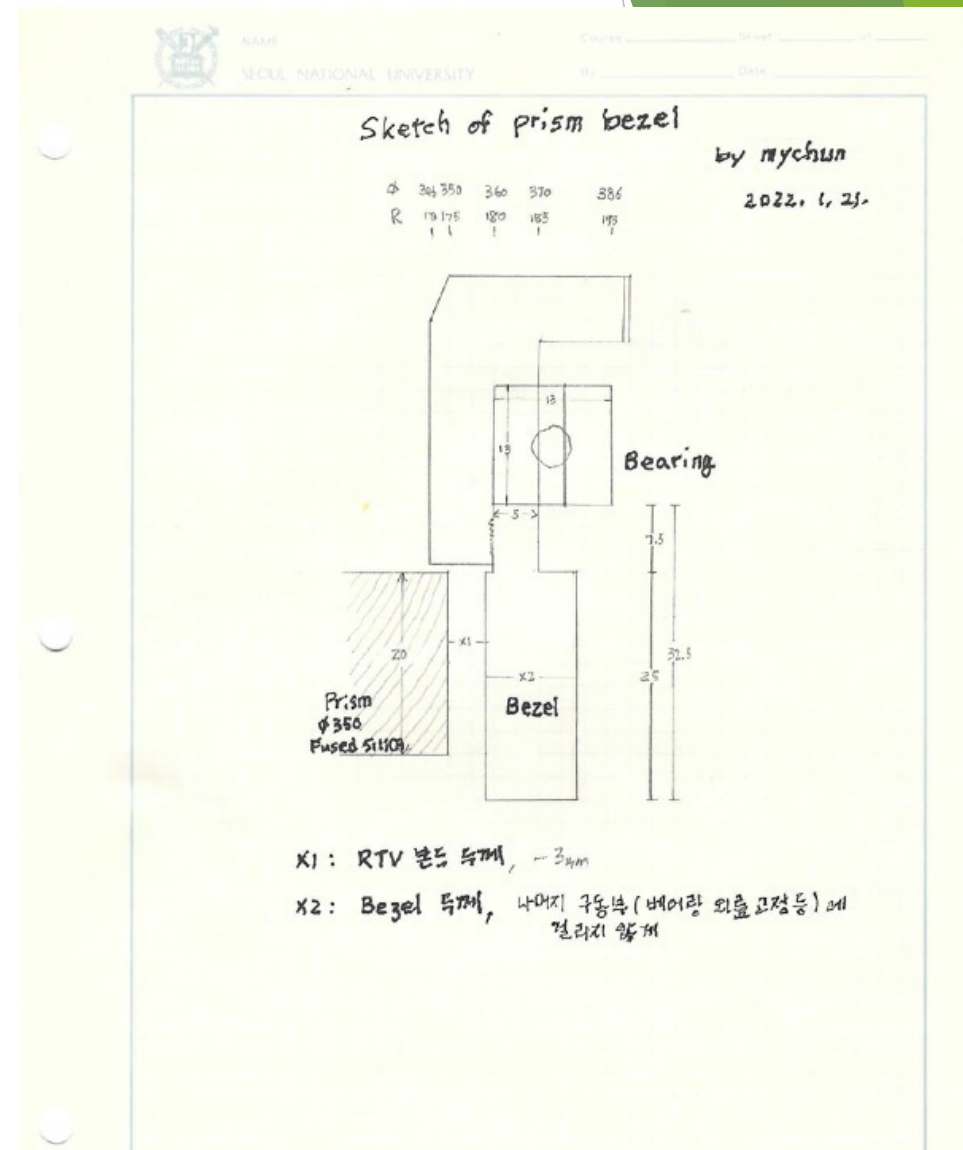
Sketch of Prism bezel

Material of Bezel : AL60 series

Thickness of RTV bond : 3mm (Cal. By HY Oh)

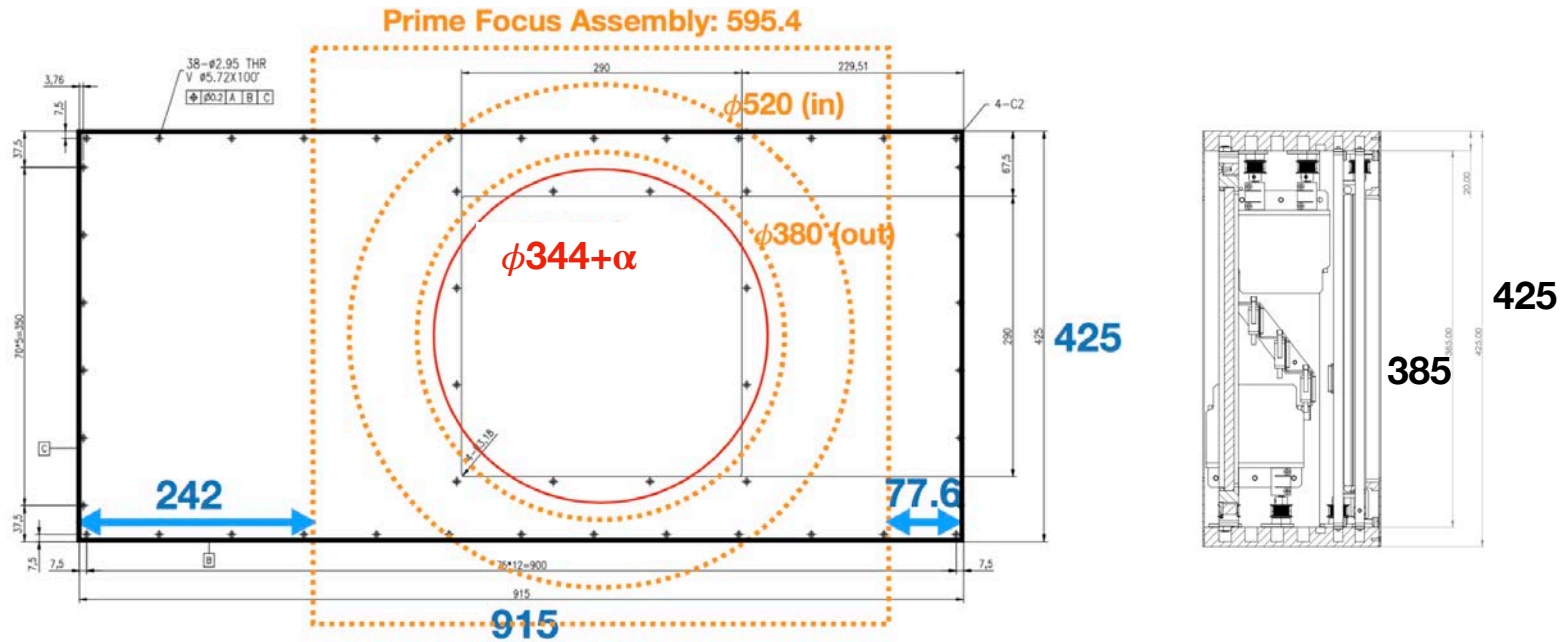
Bearing : Kaydon metric 4 point, bore 360, **outer 386**

Fixing of inner rim of bearing : nut(tap at Bezel) and bolt(tap at mount & gear part)



KMTNet FSA & ADC

From YS Lee's slide



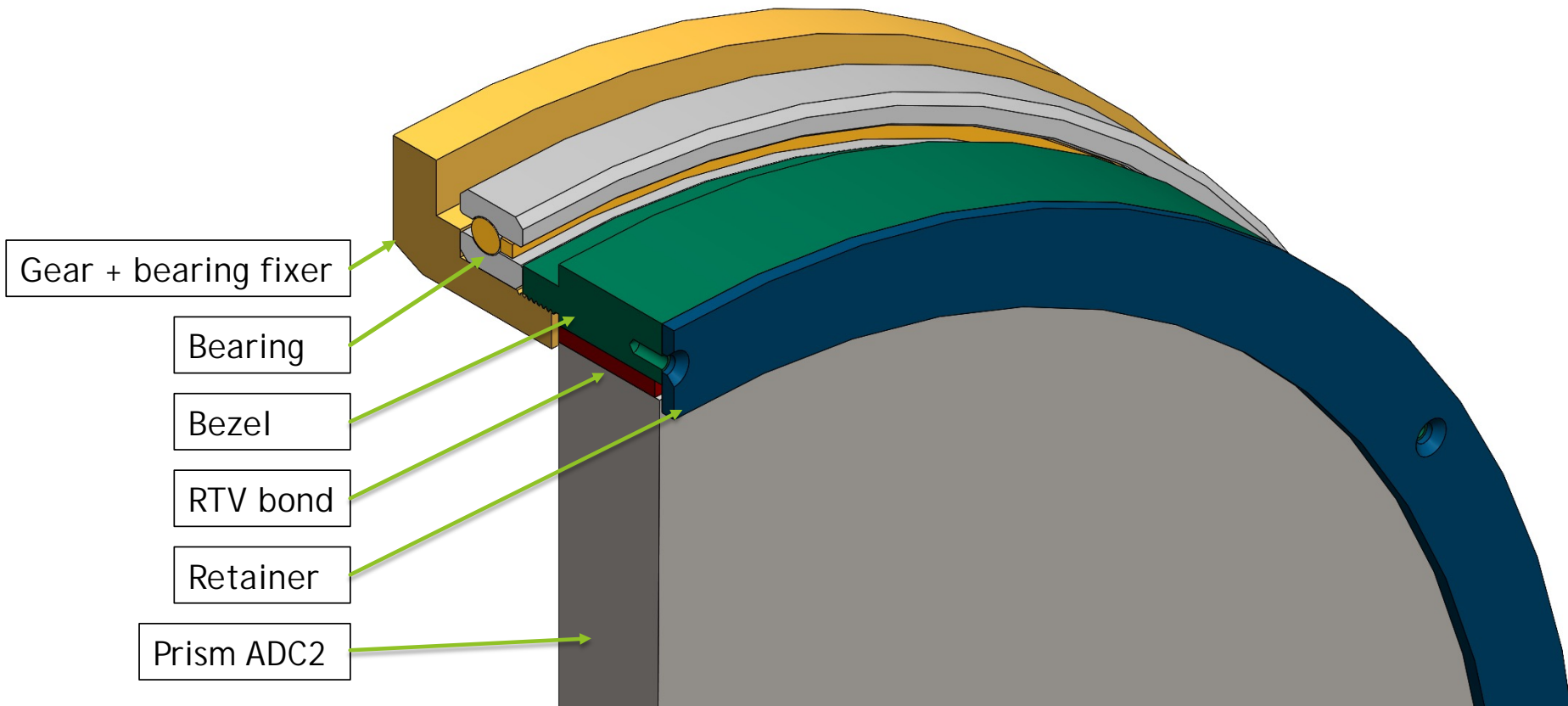
ADC: $\phi 344$ clear aperture + α

ADC + moving/holding part < 385 mm

ADC 회전 제어는 옆에서...

3D design of Bezel & mount

Designed by HY Oh



Lens/prism bonding technique

From Gabor Furesz's Thesis

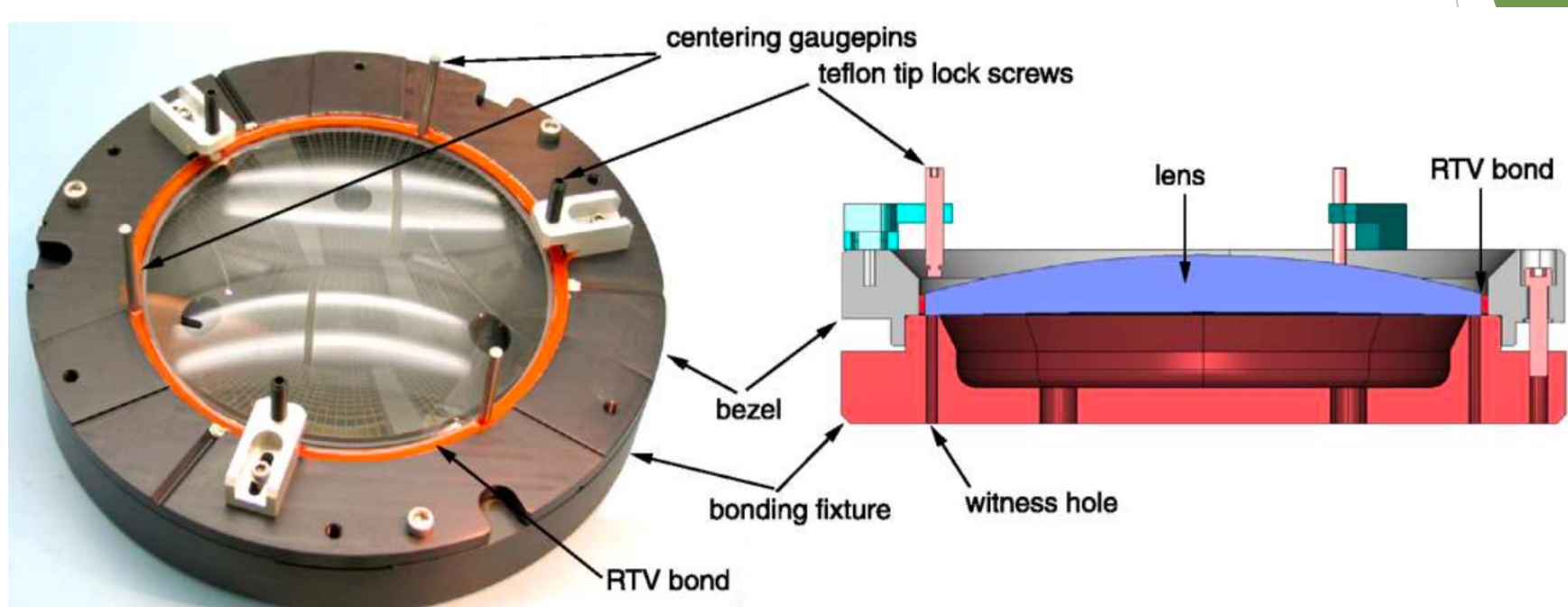


Figure 2.73: *Lens bonding technique*

KMTNet team has some knowhow of bonding RTV. They recorded these detail procedure on KASI technical report.

감사합니다



Backup Slides



Basler 카메라 성능 측정 결과 및 셋팅 방법

박예찬 신가은 (백마인턴학생), 유영삼(지도)
2021/07/26

1. Basler 카메라 성능 측정 결과

성능 측정 list		결과
Readout noise		$2.1 e^-$
Conversion gain		$2.44 e^- / \text{ADU}$
linearity		99 %
Full well capacity		$8660 e^-$
Defects	Dead pixel	0 개
	White pixel (95%)	6 개
	Warm pixel	4500 개
	Cold pixel	5189 개

2. Basler 카메라 성능

Resolution (H x V Pixels)	5328 x 4608
Sensor Type	CMOS
Sensor Format	1.2"(3.048cm)
Pixel Size (H x V)	2.74 μm x 2.74 μm
Frame Rate	4.2 fps
Mono / Color	Mono
operating temperature	0–50 °C (32–122 °F)

3. Basler 카메라 구성

전원 케이블



Basler 카메라

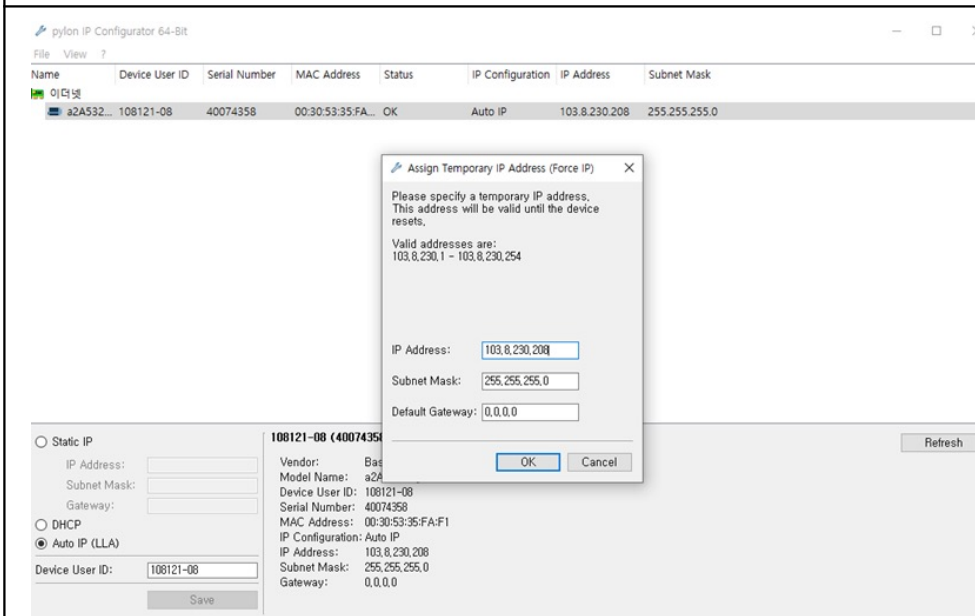
랜 케이블

✓ Manual website) <https://www.baslerweb.com/ko/products/cameras/area-scan-cameras/ace2/a2a5328-4gmpro/>

4. 실험 세팅

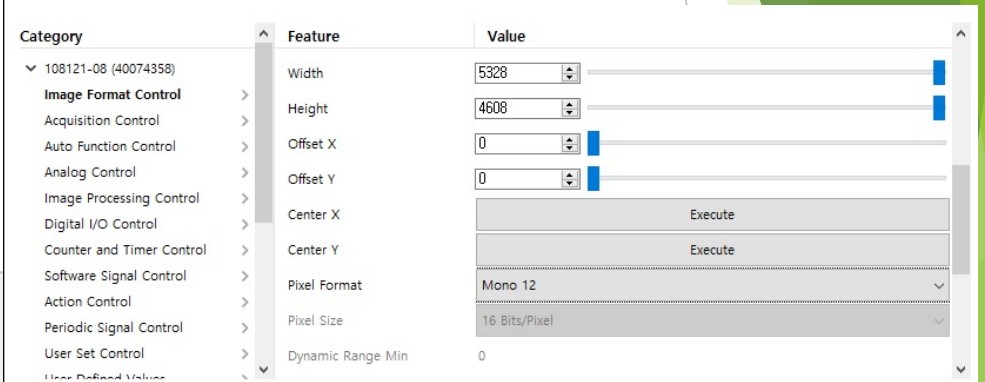
4.1 pylon viewer

① Ip configurator를 이용한 ip 연결 (tool - ipconfigurator)



- ✓ Pylon ip configure를 사용하여 ip address 값 설정 (Basler 카메라와 연결된 랜 케이블의 ip address를 사용 -> error 메시지에서 추천하는 address 설정)

② Image format control



- ✓ number of pixels(width & height)
- ✓ pixel format (Bit/pixel - Mono12 : 16Bit/pixel)

4. 실험 세팅

4.1 pylon viewer

③ offset (=black level) 설정

The screenshot shows the 'Features - All' window in Pylon Viewer. The 'Common Tasks' tab is active, and a search bar is present. The 'Category' list on the left includes '108121-08 (40074358)', 'Image Format Control', 'Acquisition Control', 'Auto Function Control', 'Analog Control', 'Image Processing Control', 'Digital I/O Control', 'Counter and Timer Control', 'Software Signal Control', 'Action Control', 'Periodic Signal Control', 'User Set Control', and 'User Defined Values'. The 'Feature' list on the right shows 'Gain [dB]' (0.0), 'Gain Auto' (Off), 'Black Level [DN]' (4095.0), 'Black Level Compensation ...' (Off), 'Gamma' (1.0), and 'Digital Shift' (0). The 'Value' column shows the current settings for each feature.

Category	Feature	Value
108121-08 (40074358)	Gain [dB]	0.0
Image Format Control	Gain Auto	Off
Acquisition Control	Black Level [DN]	4095.0
Auto Function Control	Black Level Compensation ...	Off
Analog Control	Gamma	1.0
Image Processing Control	Digital Shift	0

④ exposure time 설정

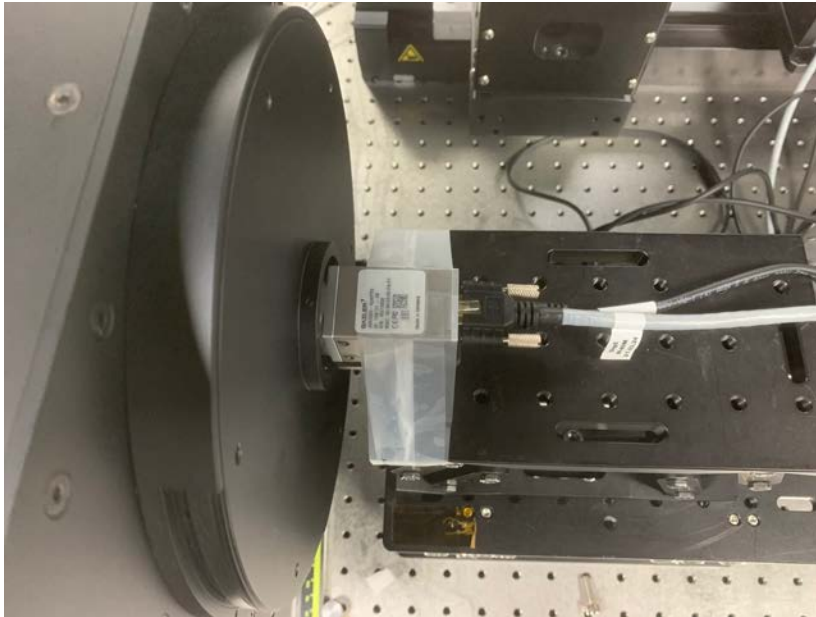
The screenshot shows the 'Common Tasks' window in Pylon Viewer. The 'Category' list on the left includes '108121-08 (40074358)', 'Image Format Control', 'Acquisition Control', 'Auto Function Control', 'Analog Control', 'Image Processing Control', 'Digital I/O Control', 'Counter and Timer Control', 'Software Signal Control', 'Action Control', 'Periodic Signal Control', 'User Set Control', and 'User Defined Values'. The 'Feature' list on the right shows 'Acquisition Stop Mode' (Abort Exposure), 'Exposure Time [us]' (18.0), 'Exposure Auto' (Off), 'Exposure Mode' (Timed), 'Sensor Bit Depth Mode' (Auto), 'Sensor Bit Depth' (Bpp12), 'Acquisition Frame Rate [Hz]' (100.0), 'Enable Acquisition Frame R...' (unchecked), and 'Sensor Readout Time [us]' (67657.0). The 'Value' column shows the current settings for each feature.

Category	Feature	Value
108121-08 (40074358)	Acquisition Stop Mode	Abort Exposure
Image Format Control	Exposure Time [us]	18.0
Acquisition Control	Exposure Auto	Off
Auto Function Control	Exposure Mode	Timed
Analog Control	Sensor Bit Depth Mode	Auto
Image Processing Control	Sensor Bit Depth	Bpp12
Digital I/O Control	Acquisition Frame Rate [Hz]	100.0
Counter and Timer Control	Enable Acquisition Frame R...	<input type="checkbox"/>
Software Signal Control	Sensor Readout Time [us]	67657.0

4. 실험 세팅

4.2 실험실 카메라 세팅

카메라 세팅 사진



랜선 연결 상태



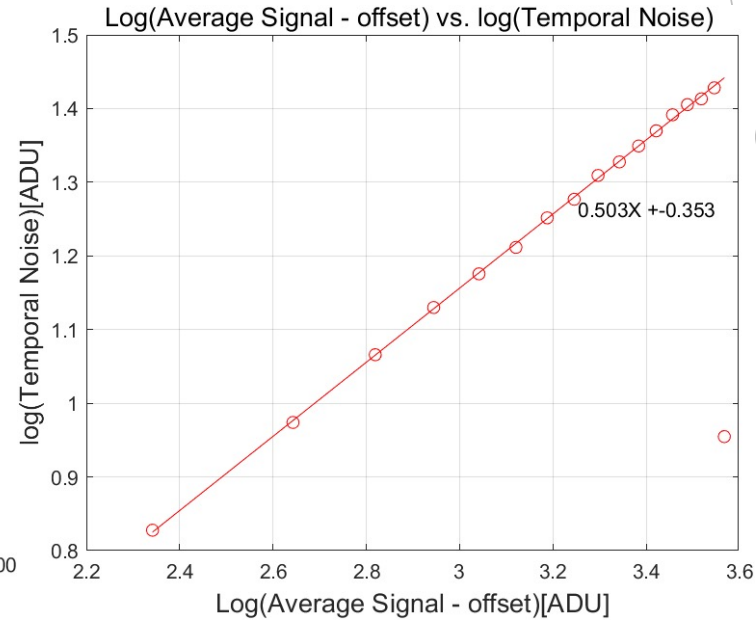
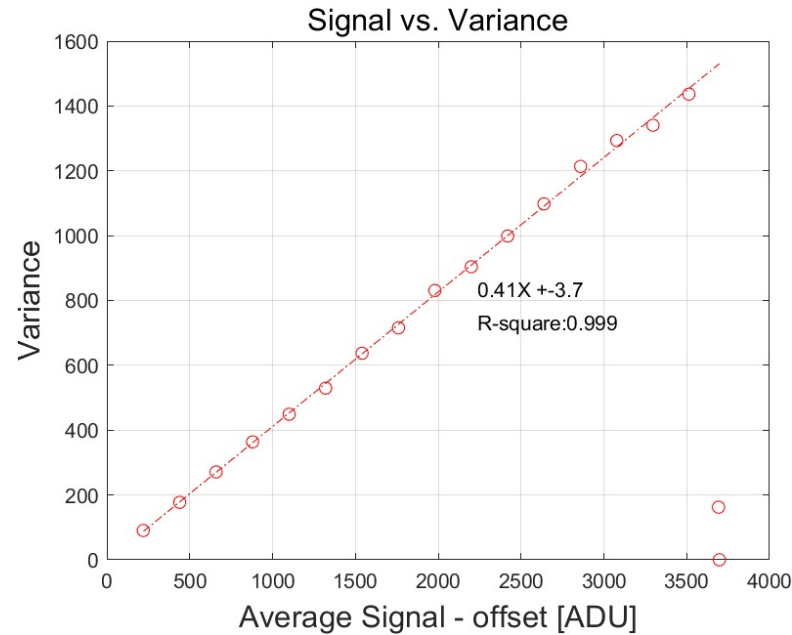
4. 실험 세팅

4.3 실험 세팅

<ul style="list-style-type: none">• 광원 Setting<ul style="list-style-type: none">- Lamp : 8 W- Monochromator : Grating 4 (백색광)• 카메라 Setting (Pylon viewer setting)<ul style="list-style-type: none">- Black Level : 400- Bit/pixel : mono 12 (12bit/pixel)	Exposure time	
	Conversion gain	0s~10s 까지 0.5s 간격으로 측정
	Readout noise	18us
	Full well capacity	0s~10s 까지 0.5s 간격으로 측정
	linearity	0s~10s 까지 0.5s 간격으로 측정
	Defects	4s

5. 실험 결과

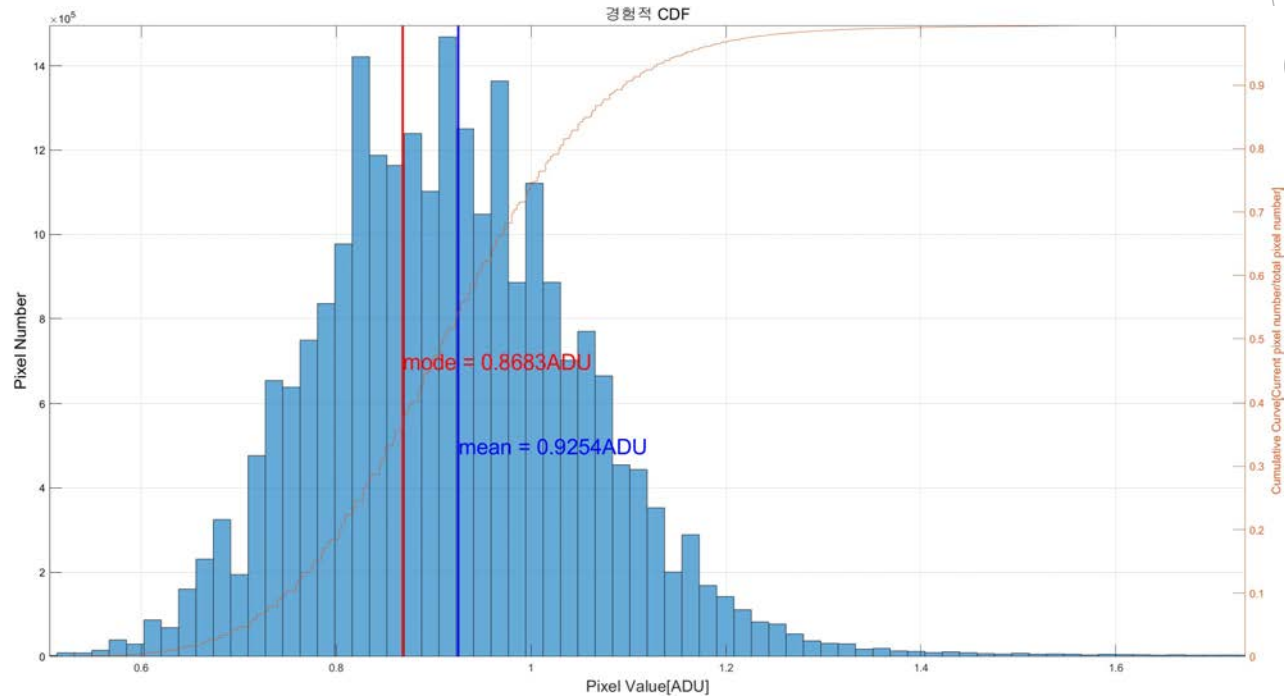
5.1 Conversion gain



- ✓ Conversion gain은 출력 신호에 대한 분산값을 그래프로 그릴 경우 그 기울기의 역수이다.
- ✓ Conversion gain = $\frac{1}{0.41} = 2.44 [e^-/ADU]$
- ✓ 신호와 노이즈를 로그 스케일로 그려 fitting한 결과가 0.5에 수렴되는가를 기준으로 시스템 변환이득 계산의 정확성을 판별할 수 있다.

5. 실험 결과

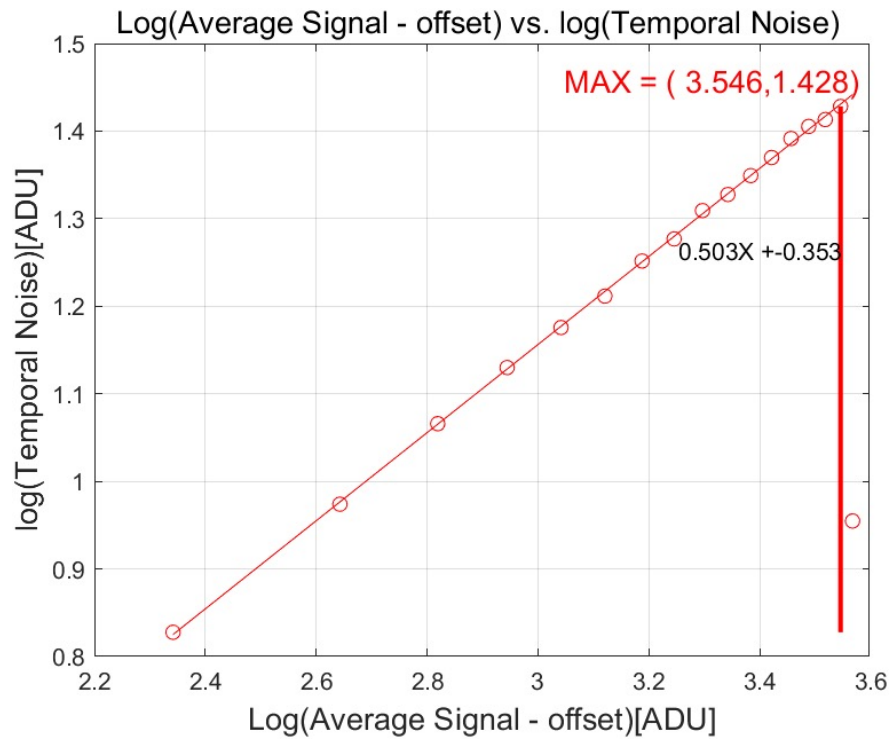
5.2 Readout noise



- ✓ Black level이 400 일 때, 각 픽셀의 표준 편차 및 최빈값(mode)을 이용하여 측정
- ✓ $Readout\ noise : 2.44[e^-/ADU] \cdot 0.87[ADU] = 2.1[e^-]$

5. 실험 결과

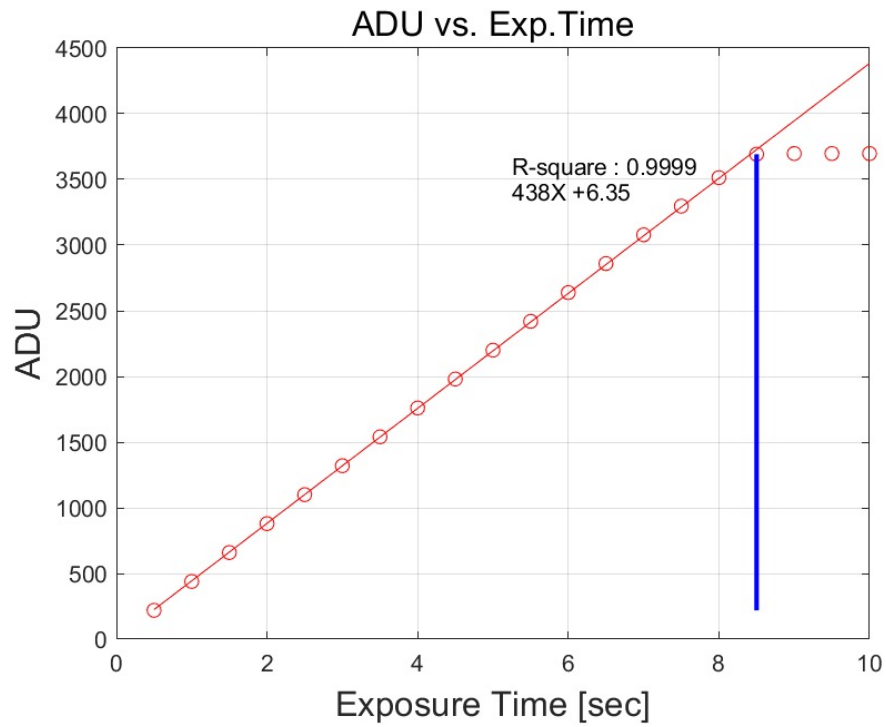
5.3 Full well capacity



- ✓ 노이즈와 신호의 관계를 통해, 포화 직전 상태를 판별 한다.
- ✓ 최대 포화 전자 개수 (*Full well capacity*)
: $2.44[e^-/ADU] \cdot 3548.13[ADU] = 8660[e^-]$

5. 실험 결과

5.4 Non linearity



- ✓ 노출 시간에 따른 pixel value[ADU]값의 상관관계를 통해 비선형성 평가
- ✓ pixel value[ADU] 측정값으로 fitting한 추세선과 실제 관측치의 R square(결정계수)를 사용
- ✓ linearity = 99%

5. 실험 결과

5.5 Defects

✓ *Dead pixel*

❖ 최대포화의 중간수준 노출시 (1946ADU 수준) 최대 포화수준 (4096) 의 10, 5, 2%를 초과하는 픽셀들

	2%	5%	10%
Number of dead pixel	0	0	0

✓ *white pixel*

❖ 최대포화의 중간수준 노출시 (1946ADU 수준) 최대 포화수준 (4096) 의 90, 95, 98%를 초과하는 픽셀들

	98%	95%	90%
Number of white pixel	5	6	12

98%		
NO.	row	col
1	685	4226
2	836	3457
3	982	1755
4	3359	4248
5	4669	2665

95%		
NO.	row	col
1	685	4226
2	836	3457
3	982	1755
4	1867	2948
5	3359	4248
6	4669	2665

90%		
NO.	row	col
1	57	3925
2	464	3207
3	541	1170
4	685	4226
5	751	1101
6	836	3457
7	982	1755
8	1867	2948
9	2649	3394
10	3359	4248
11	3694	1572
12	4669	2665

5. 실험 결과

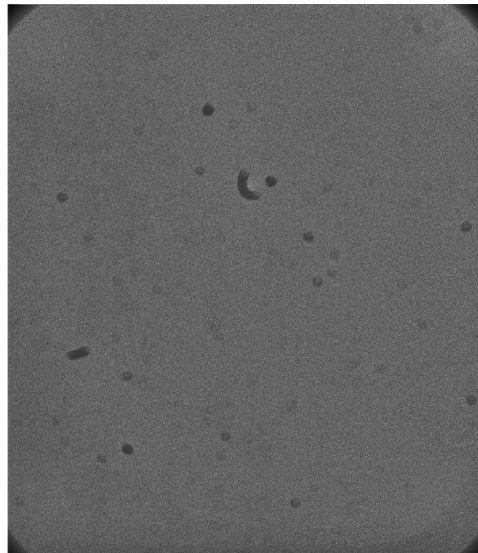
5.5 Defects

✓ warm pixel (평균 대비 3σ 이상 픽셀 개수)

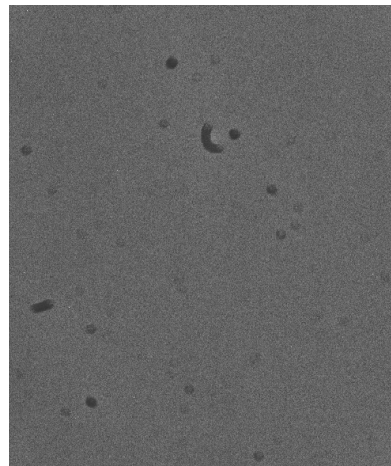
	warm
Number of pixel	4500

✓ cold pixel (평균 대비 3σ 이하 픽셀 개수)

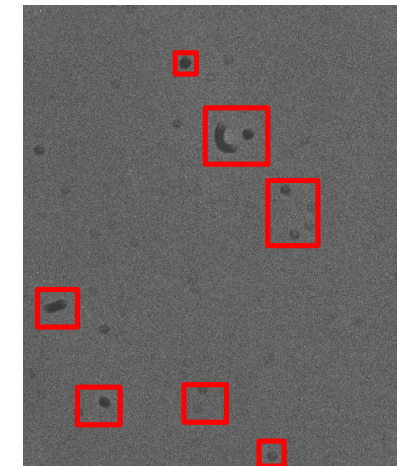
	①	②	③
Number of cold pixel	58258	24012	5189



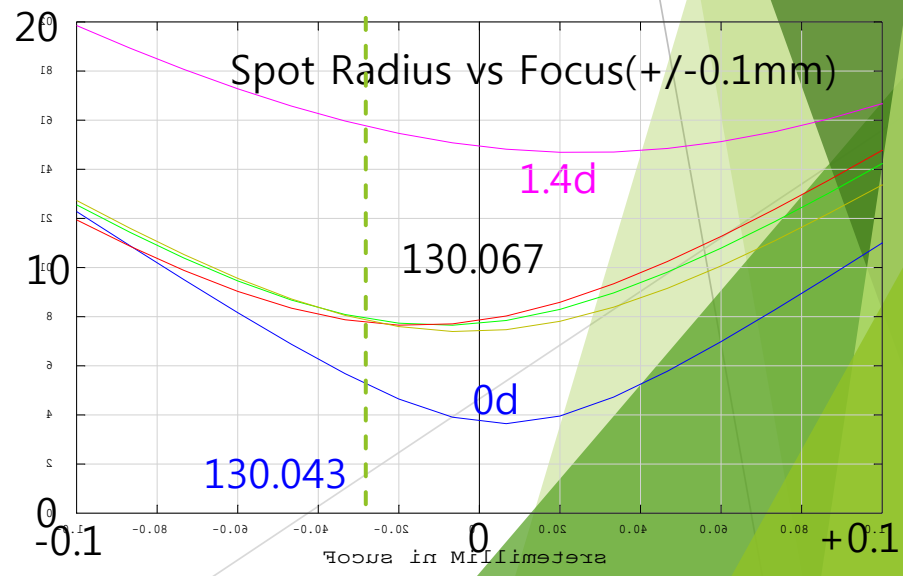
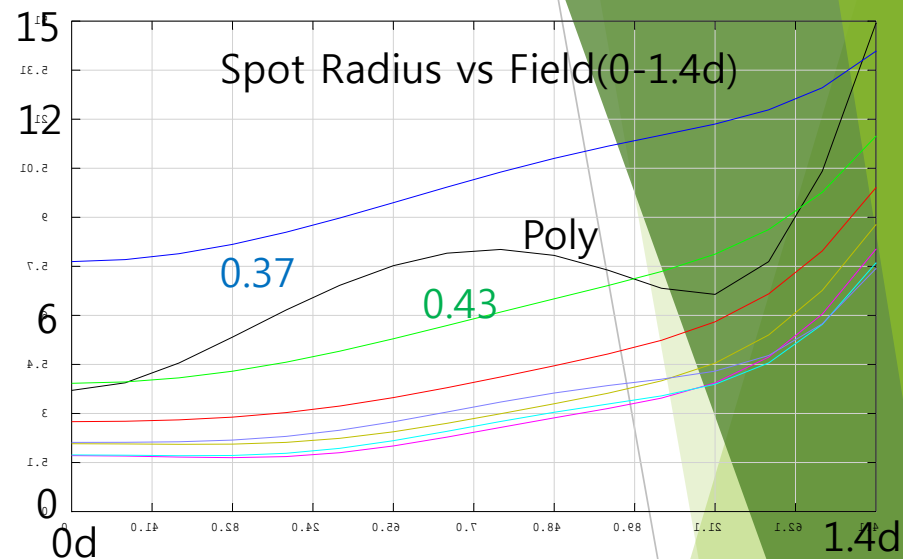
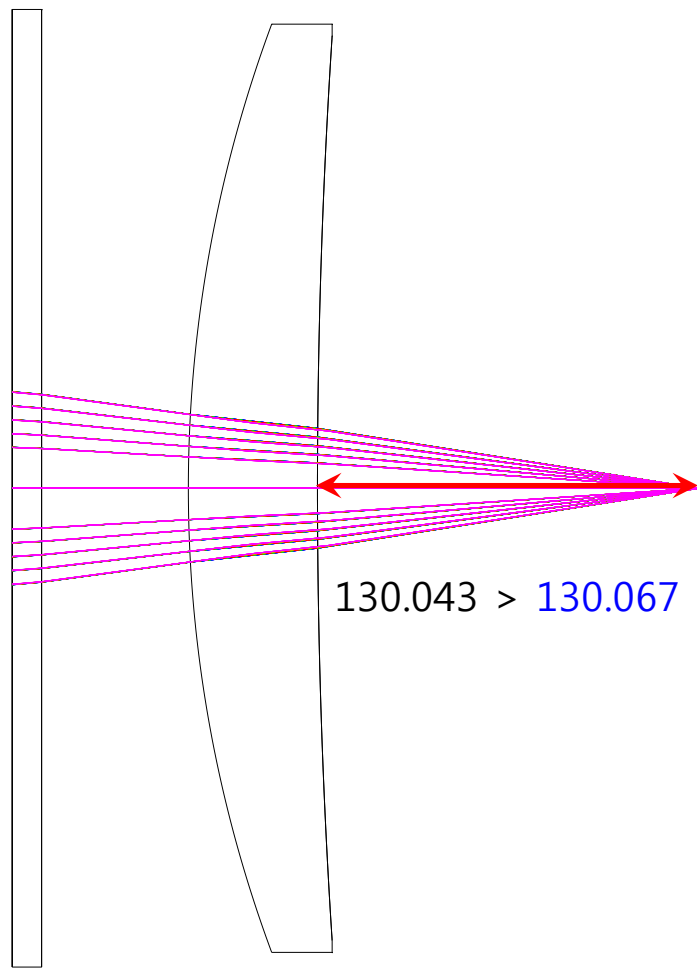
① 전체 이미지에 대해 측정



② 모퉁이 영역 제거



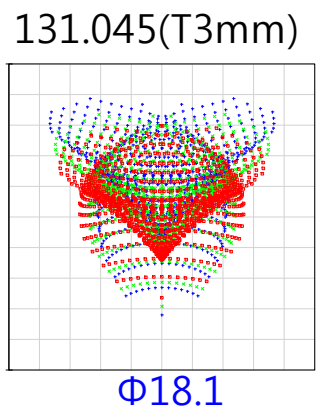
③ dust로 인해 발생한 어두운 영역 제거
(표시 영역을 모두 mean 값으로 변경)



130.067 @1.4d
(λ 582/612/642)
[filter@7.82](#) from CCD

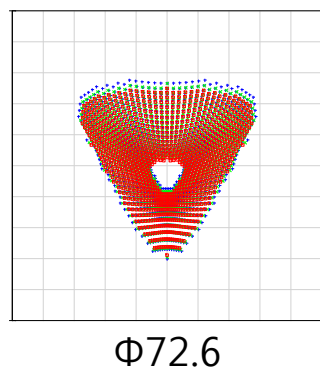
T3mm

44



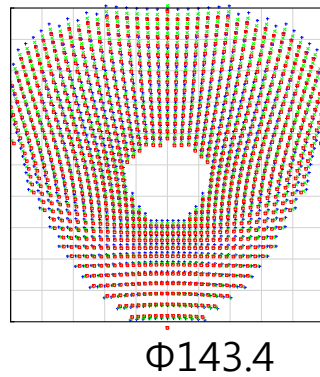
T4mm

200

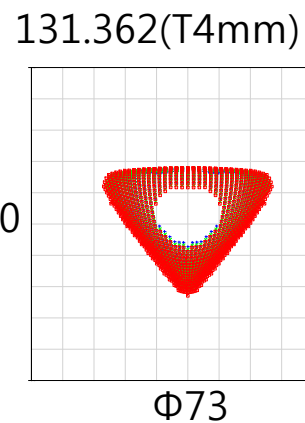


T5mm

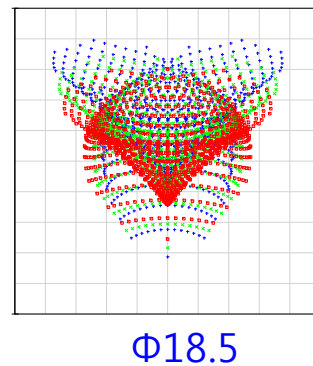
200



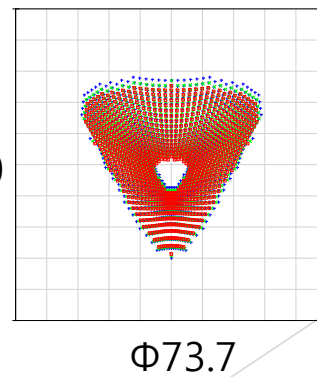
200



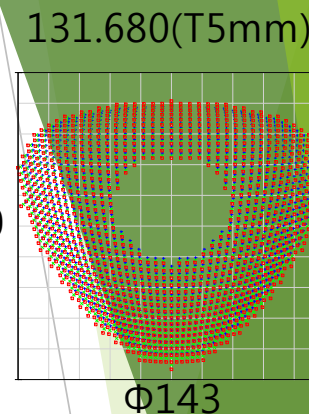
44



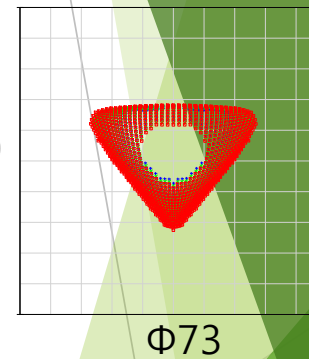
200



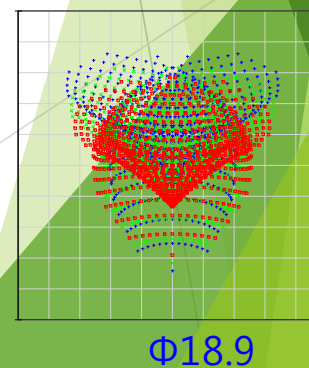
200



200



44



Baseline models of Electric components



Baseline Model of Surge Protector

Novaris SD3 Multimov Surge Diverters

Model : SD3-100-275-N

MULTIMOV Surge Diverters

Use SD3 - MULTIMOV high energy surge diverters for three phase point of entry protection at main switchboards. Models are available for all wiring systems worldwide.

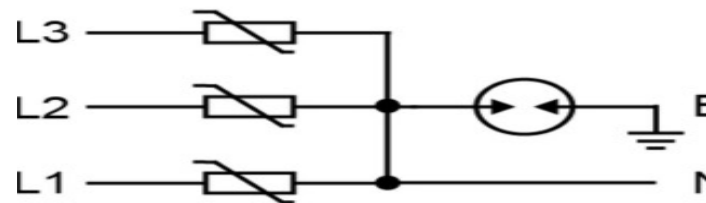
All Mode Protection

Models containing N-E protection (-N versions) feature all mode protection. Protection is provided for all combinations of lines (L-L, L-N, L-E, N-E) ensuring the maximum level of protection is achieved at all times

Heritage from KMTnet SSO



Wiring



Baseline Model of UPS

APC Smart-UPS SRT 5000VA RM 230V

Model : SRT5KRMXLI

High density, double-conversion on-line power protection with scalable runtime.

Includes: Documentation CD, Installation guide, Rack mounting brackets, Rack mounting hardware, Rack mounting support rails, Temperature probe, Warranty card, Web/SNMP ...

Heights : 3U

Heritage from KMTnet SSO



Baseline Model of PDU

APC Rack PDU 9000 Switched, ZeroU, 32A, 230V,
(21) C13 & (3) C19

Model : APDU9953

With Industry leading reliability, manageability, and security, APC Switched Rack PDU's provide advanced load management plus on/off outlet level power cycling and sequencing control.

Includes: Installation guide, Rack mounting brackets, Safety guide, Serial configuration cable

Dimension (mm) : 1829 x 56 x 46

Heritage from KMTnet SSO

