Alpha-particle Events and the Blocker Window by Asahi Bunkou (summary)

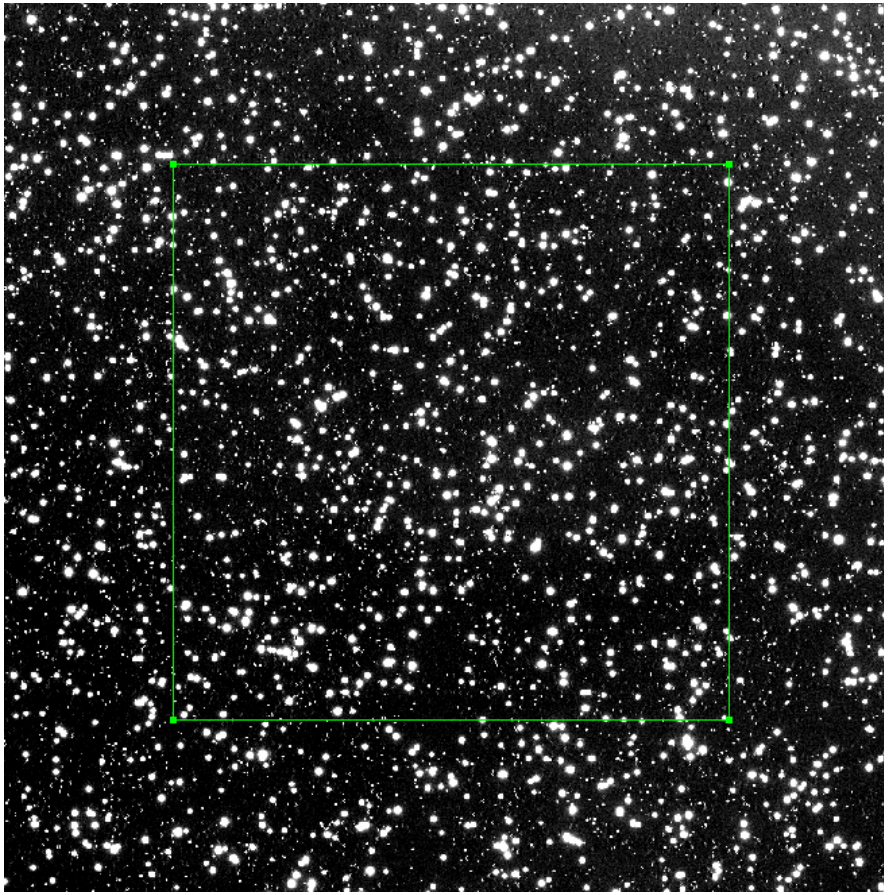
July 2016

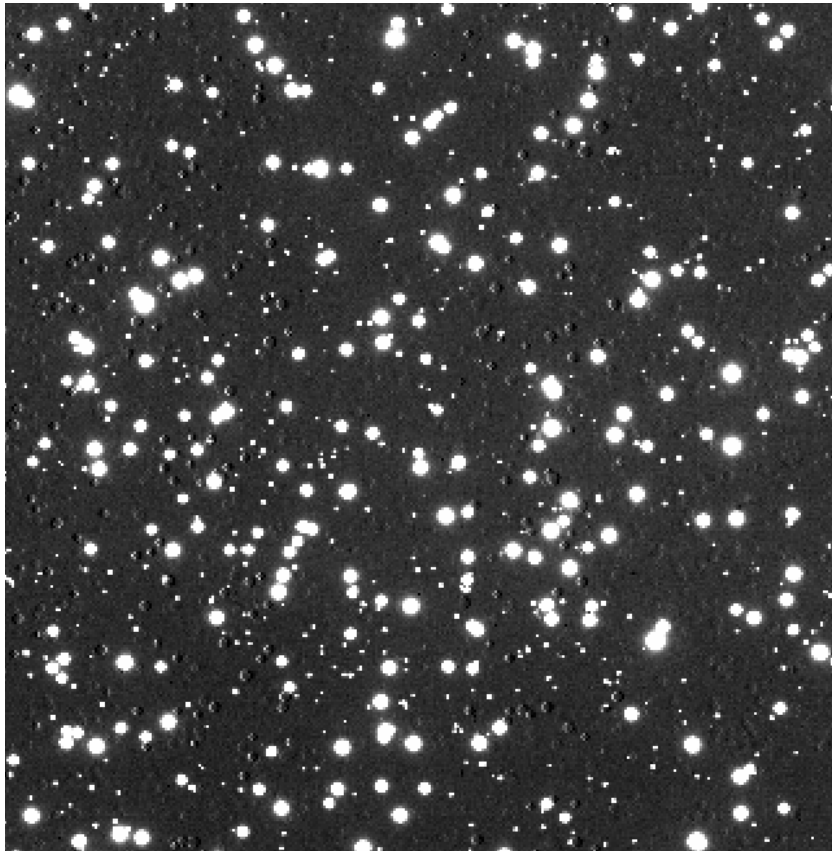
Ichi Tanaka

Background

- After we replaced the old Hawaii2 detector to Hawaii2RG, we observed significant radiation event.
- IRTF Staff informed us that they also experienced similar events (though the event rate is smaller than us). They think that the event is caused by the alpha-particle radiation from the AR coat in the last lens where the radio-active Th is used.
- We confirmed that our case is the same. Geiger Counter recorded significant radiation from the last lens.
- The original MOIRCS Builder are recognizing that they did not specify prohibiting the use of Th on the AR coat.

600-sec Dark Frame

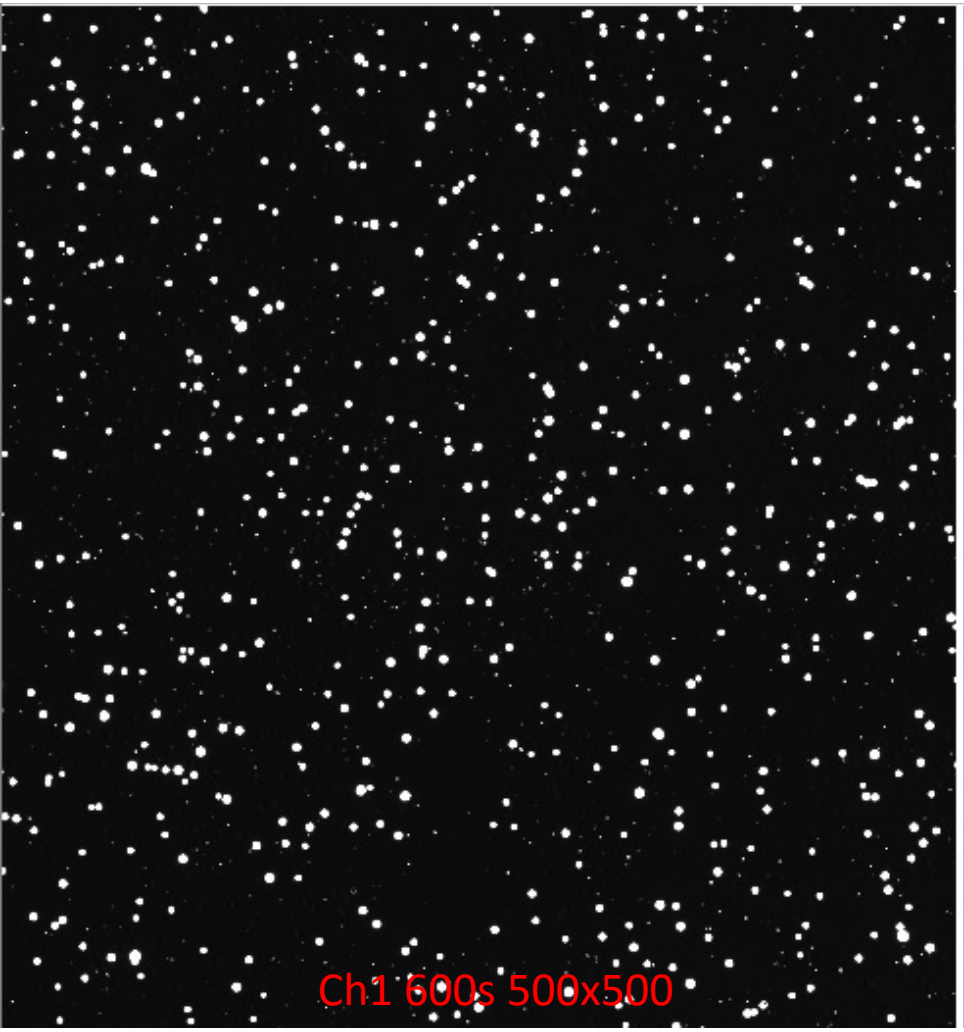


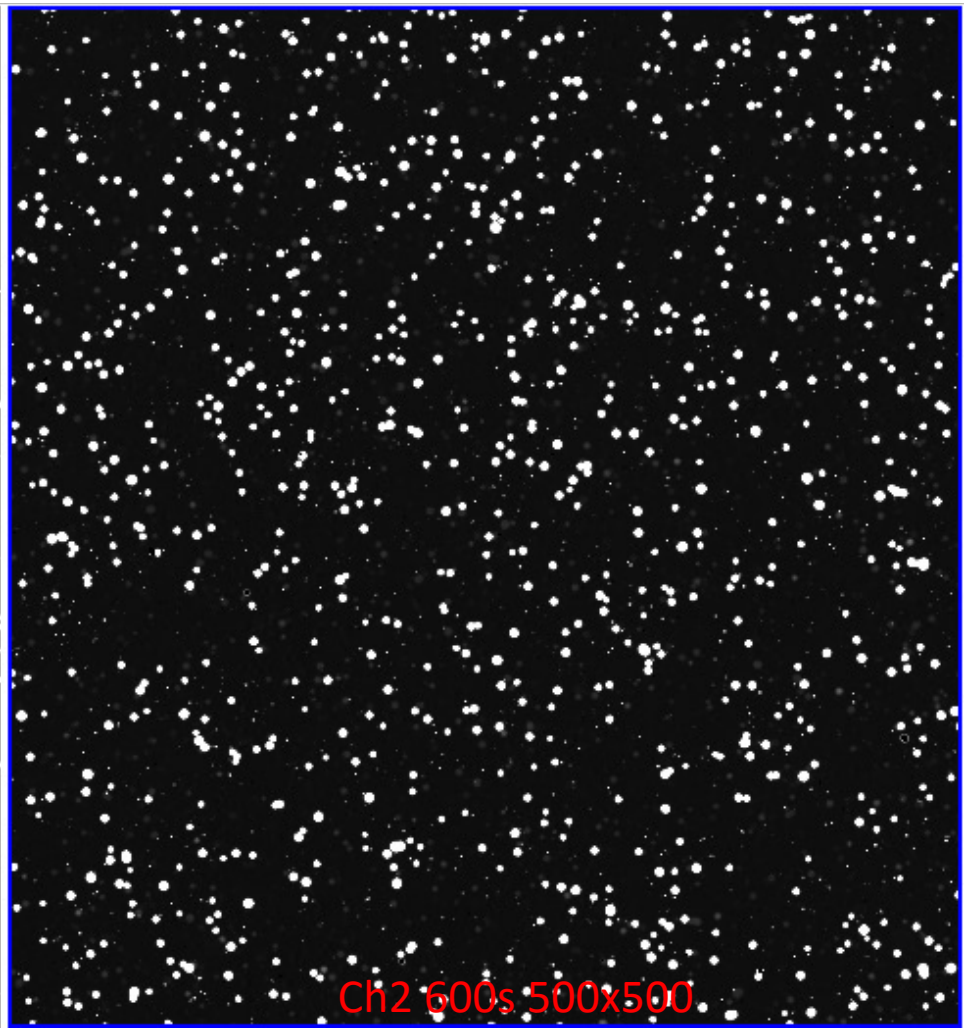


Green area~500x500 pixels

600-sec Dark Frame

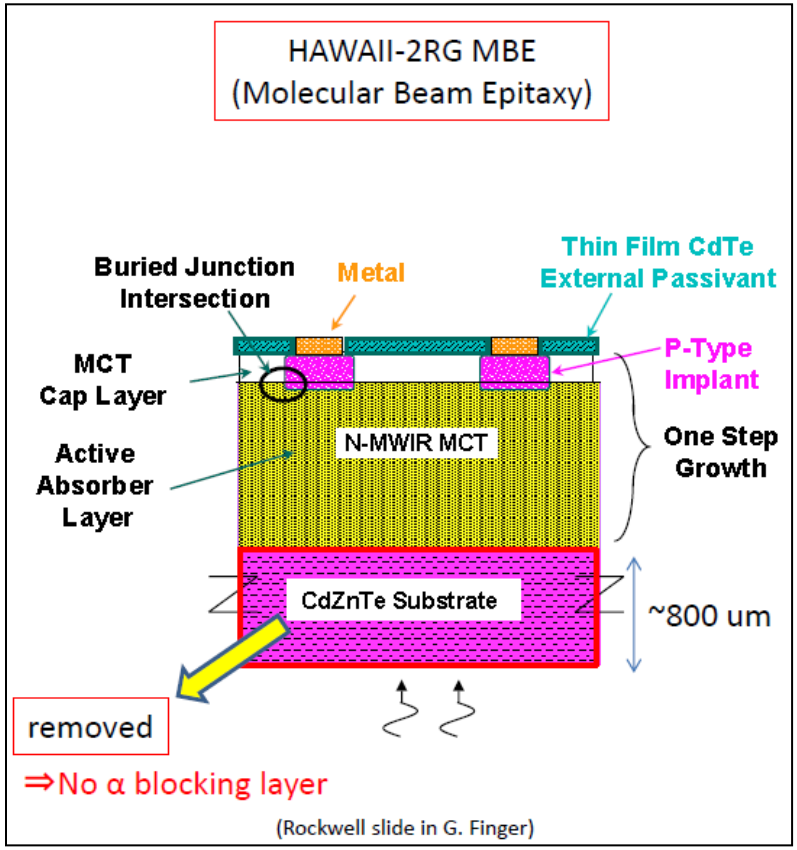
Ch2 has slightly more radiation than ch1





Why the old detector did not see it?

- The old Hawaii2 was with Sapphire (ZnCdTe) ubstrate
  → worked as efficient alpha particle blocker.



Performance of the WFC3 Replacement IR Filters
S.Baggett (STScI), R.Boucarut (GSFC), R.Telfer (OSC/GSFC),
J. Kim Quijano (STScI), M. Quijada (GSFC)
February 15, 2007

Introduction

The original IR filters procured for WFC3 fully satisfied the requirements at the time of their installation in the filter wheel (Lupie et al. 2003) and the filters performed as expected during instrument-level ground testing. However, instrument-level ground testing revealed that the HgCdTe IR detector suffered from particle-induced luminescence. Subsequent radiation testing of non-flight parts determined that the luminescence arises within the detector's CdZnTe substrate and that the problem can be effectively eliminated by removing the substrate (Waczynski et al. 2005). As a consequence, a new substrate-removed IR detector for WFC3 is under development. But, in addition to reducing the luminescence, removal of the substrate also results in a significant increase in the quantum efficiency blueward of 800nm (Kimble et al. 2006), which is an issue for two of the original IR filters. Due to schedule constraints at the time of their manufacture, the IR filters

Takato-San's Note on the issue.

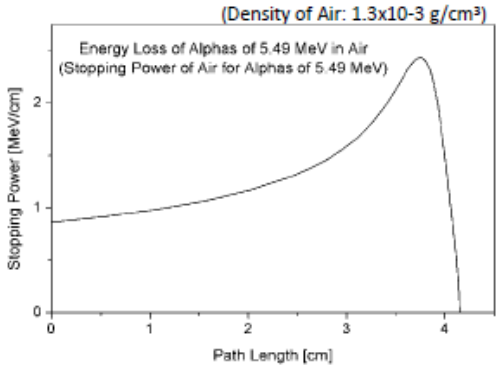
Efforts for Fixing this…

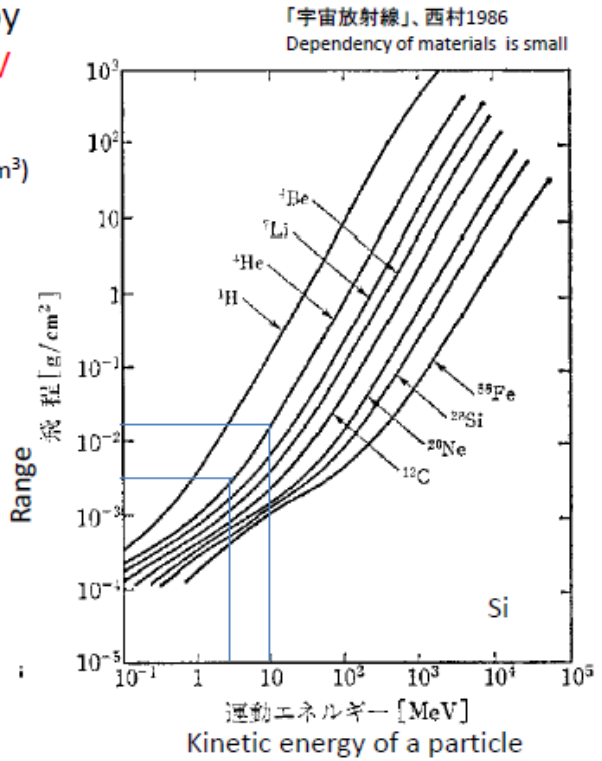
- Contacted to the original vender. They said removing the old AR coat would change the optical parameter. It is also costy. Remaking the same lens might be the option.
- Adding the alpha-particle blocker is the easiest and cheapest option.
- Issue…material? Thickness? Ghosts? Affection to the imaging quality? Where to put? How? Space available? Vendor? Cost?
- Additional issue is that the BaF2 would emit the broad (but weak) blue fluorescent light (peak ~400nm) if exposed in the high radiation environment. We decided to add the (loose) blocking of the optical wavelength regime (<~0.8um) on the filter Specification.

Takato-San's (great) Note about the explanation of the radiation event and on the thickness of the Window

Range of α particle

- Energy of α-particle created by radioactive nuclide: 4 ~ 9 MeV
- Range ~ 10^{-2} g/cm^2
  ~ 40 um in glass (~2.3 g/cm^3)
- Glass plate of t〜0.1 mm would be sufficient to block alpha-particles



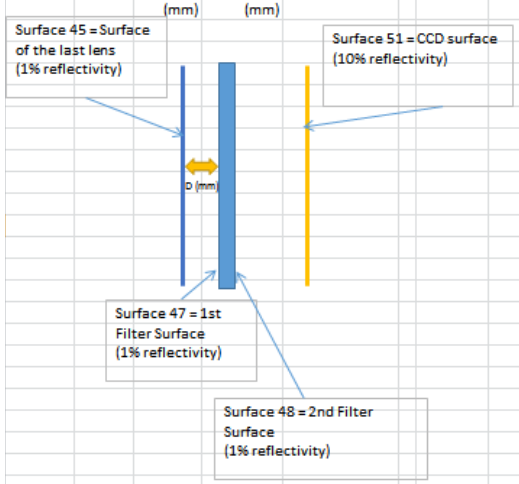


He concluded that adding ~0.1 mm thin glass will be enough.
In order to keep the strength of the filter for the AR coating, we choose ~1mm.

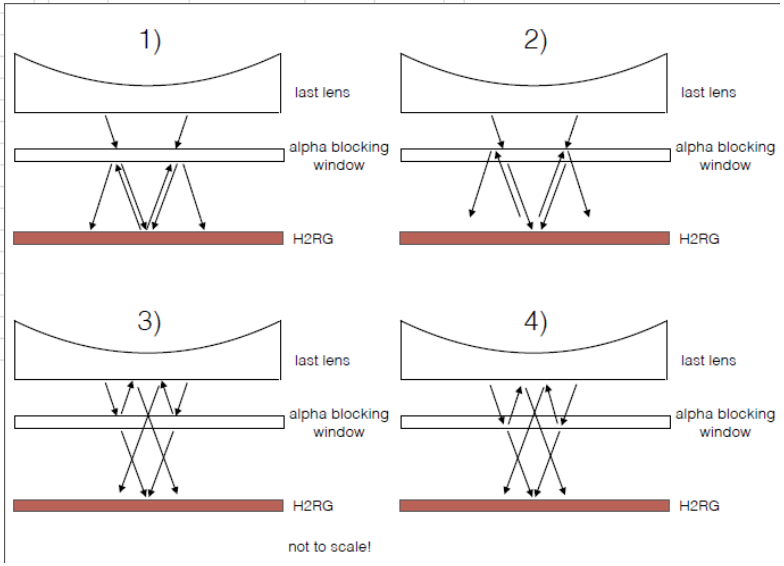
Ghost Analysis by Y.Tanaka and M.Fabricius

MOIRCS Ghosts by Thin Filter: Spot Analysis — 2015-10-16 Y.T. (Translate by IT)

	Filter Thickness 2.5mm						Filter Thickness 1mm						
	D=1mm		Relative Intensity	D=5mm		Relative Intensity	D=1mm		Relative Intensity	D=5mm		Relative Intensity	Max's figure
Surface	marginal	RMS Radius		marginal	RMS Radius		marginal	RMS Radius		marginal	RMS Radius		
51-45	2.7989	1.9718	1.44676E-08	2.7989	1.9718	1.44676E-08	2.7989	1.9748	1.44237E-08	2.7989	1.9748	1.44237E-08	---
51-47	2.5447	1.7929	1.74989E-08	1.5278	1.077	4.84943E-08	2.5447	1.7959	1.74405E-08	1.5278	1.0803	4.81985E-08	2)
51-48	2.104	1.4861	2.54699E-08	1.087	0.77	9.48727E-08	2.3684	1.6732	2.00922E-08	1.3515	0.95756	6.13466E-08	1)
48-47	0.4407	0.3123	5.76738E-08	0.4407	0.3123	5.76738E-08	0.1763	0.12924	3.36766E-07	0.1763	0.12924	3.36766E-07	---
48-45	0.6949	0.4912	2.33134E-08	1.7118	1.2068	3.86235E-09	0.4305	0.30812	5.92492E-08	1.4474	1.0237	5.36756E-09	4)
47-45	0.254	0.184	1.66145E-07	1.2711	0.899	6.9599E-09	0.2542	0.1854	1.63645E-07	1.2711	0.90098	6.92935E-09	3)
	(mm)	(mm)											



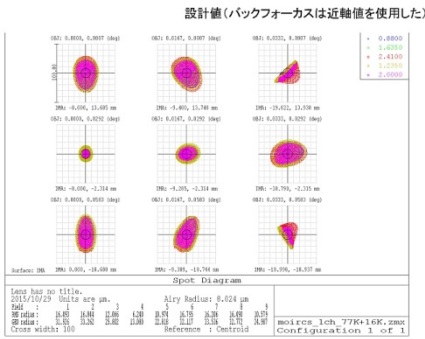
MOIRCS	(mm)	Intensity
RMS radius of Central Spot	0.0075	1



It is concluded that the ghost would confine within the PSF of the bright Star. Affection would be smallest if the window is away from the detector. Suppressing the reflection to ~1% level would be important.

Y.Tanaka's Simulation on Image degradation by the distortion of the shape of the Window.

Original Design Spots

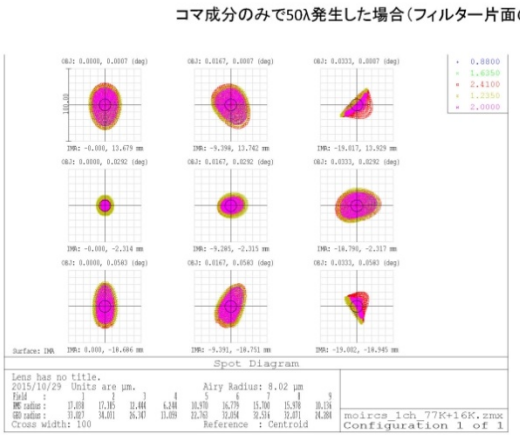


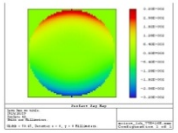
スポットのRMS半径(um)

16.493
16.844
12.066
6.240
10.974
16.795
16.206
16.490
10.579

She concluded that there is no affection of the shape distortion of the window, even after ~50um distortion.
As some level of bend or distortion of the filter is expected by the AR coating, the conclusion here helped much for the directionl.

50λ for Comatic Aberration

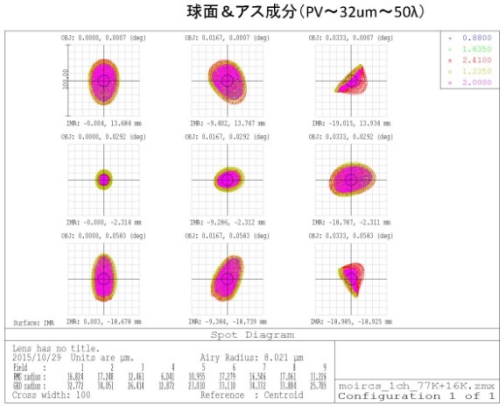


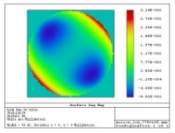


スポットのRMS半径(um)

17.038
17.385
12.444
6.244
10.970
16.779
15.700
15.978
10.136

50λ for Spherical + Astigmatic Aberration





スポットのRMS半径(um)

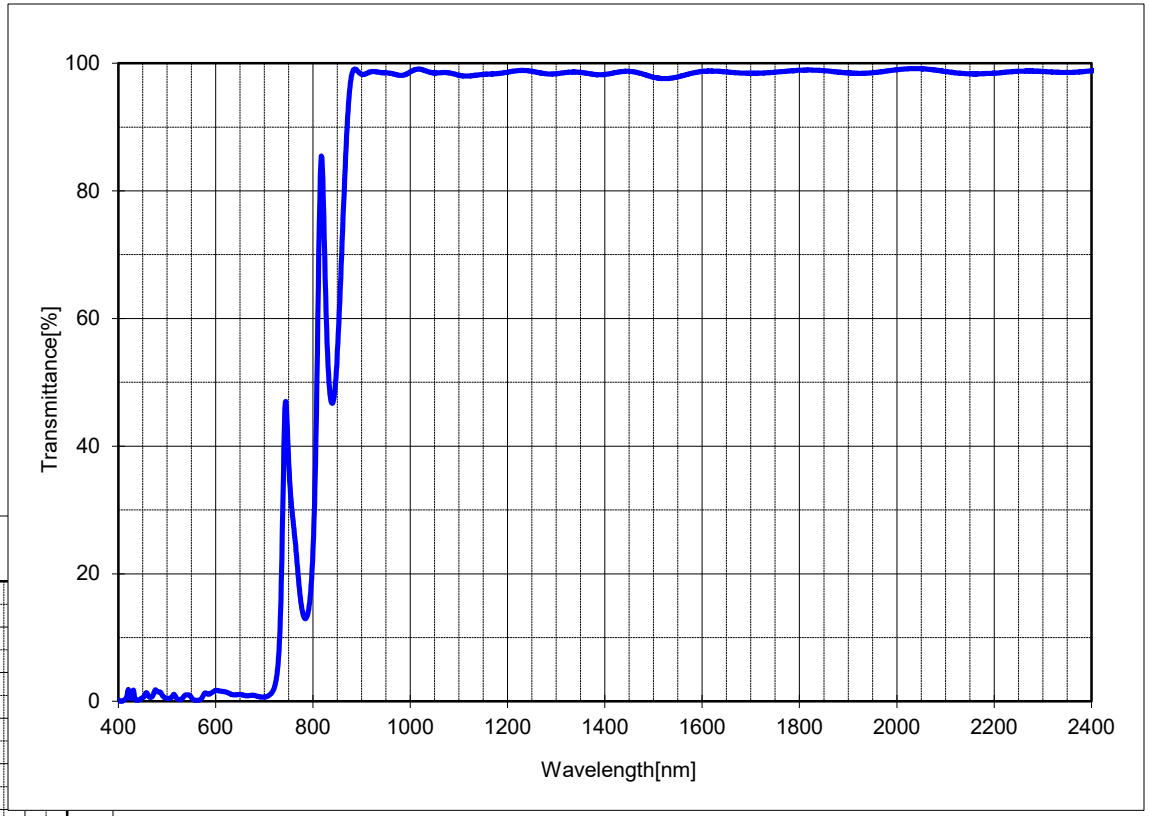
16.824
17.248
12.461
6.041
10.955
17.279
16.546
17.061

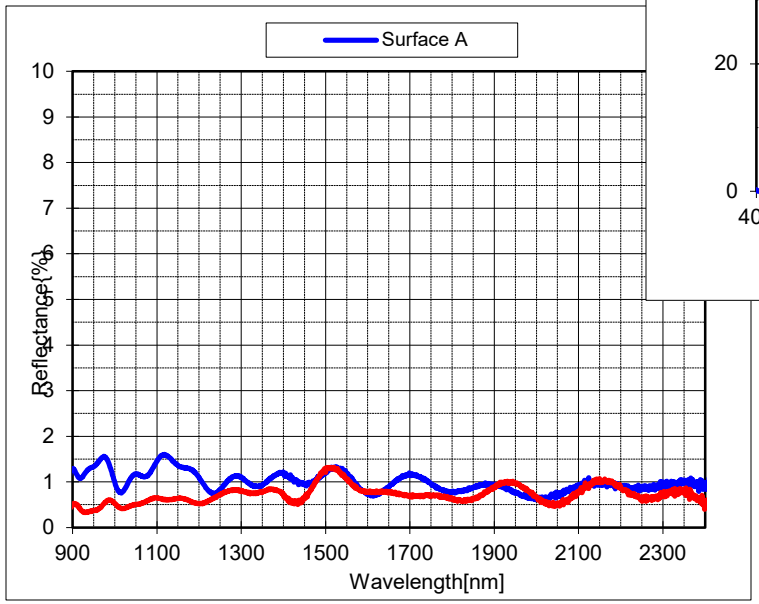
- At the same time, the efforts to seek for the way to replace the old AR coat or re-fabricate the last lens was taken in parallel.
- We have confirmed that it is costy, more risk by the change of lens parameter, errors in alignment, and all the work related to the replacement.
- Lens material (BaF2) is difficult to get in Japan. Polishing it in aspherical shape is also not an easy task.
- The delivery time is the ultimate limiation.

Purchase

- After asking some companies for the quote with quite tight delivery date constraint, we choose Asahi Bunkou, CO. for purchase. The estimate from them is cheapest, though the expected quality simulated is as great as other USA-based M company (they requested much much more money for fabrication).
- The efforts by Kimura san (Asahi) in the company helped much for on-time delivery.

Asahi Bunkou Alpha-Particle Blocker Window

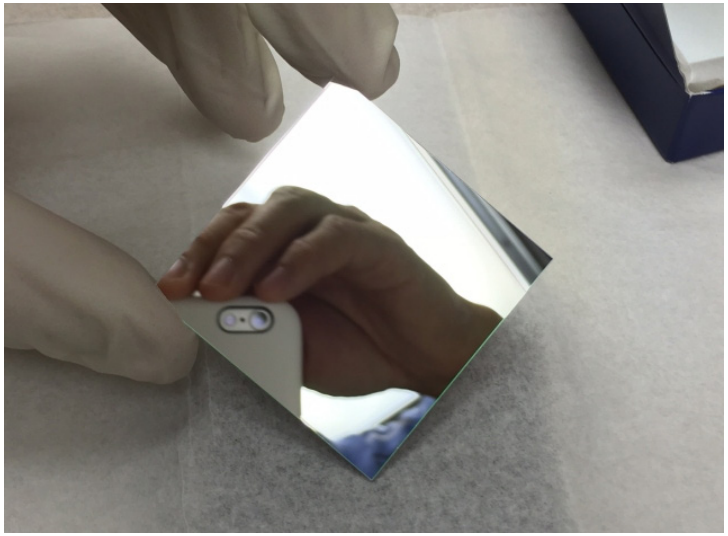


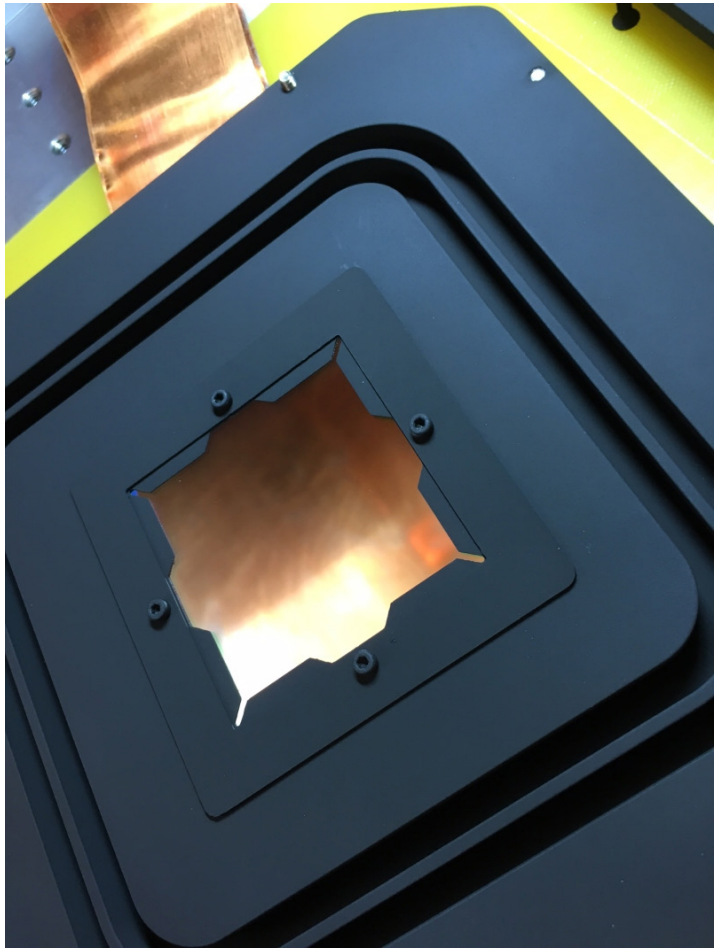


Just Great Performance!
Average NIR transmittance >98% across 09-2.4um(!), with reflectivity ~<1% on average(!!).
Optical Blocking is also as good as <1%!

Installation

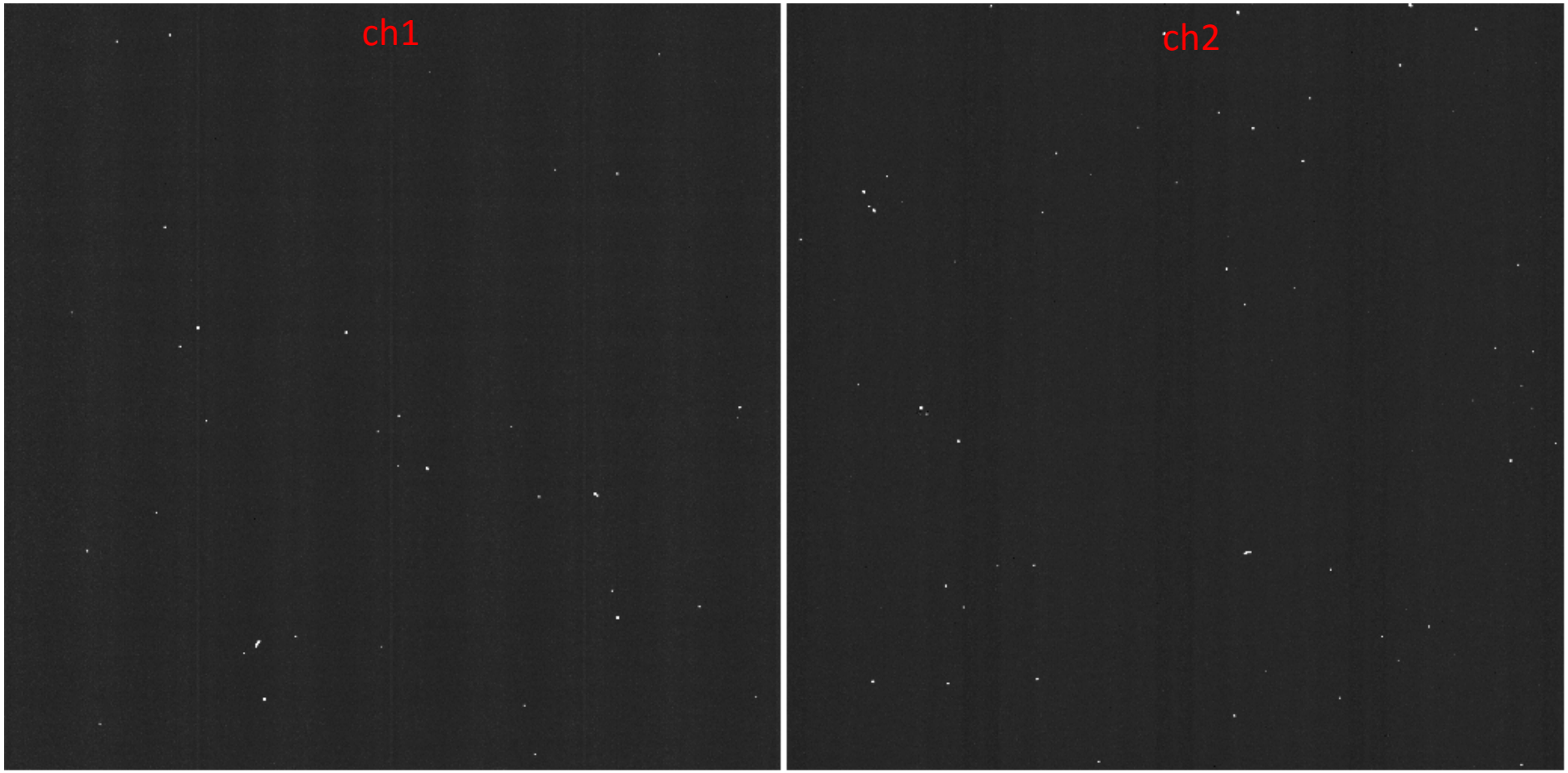
by M. Fabricius and IGTech





Result

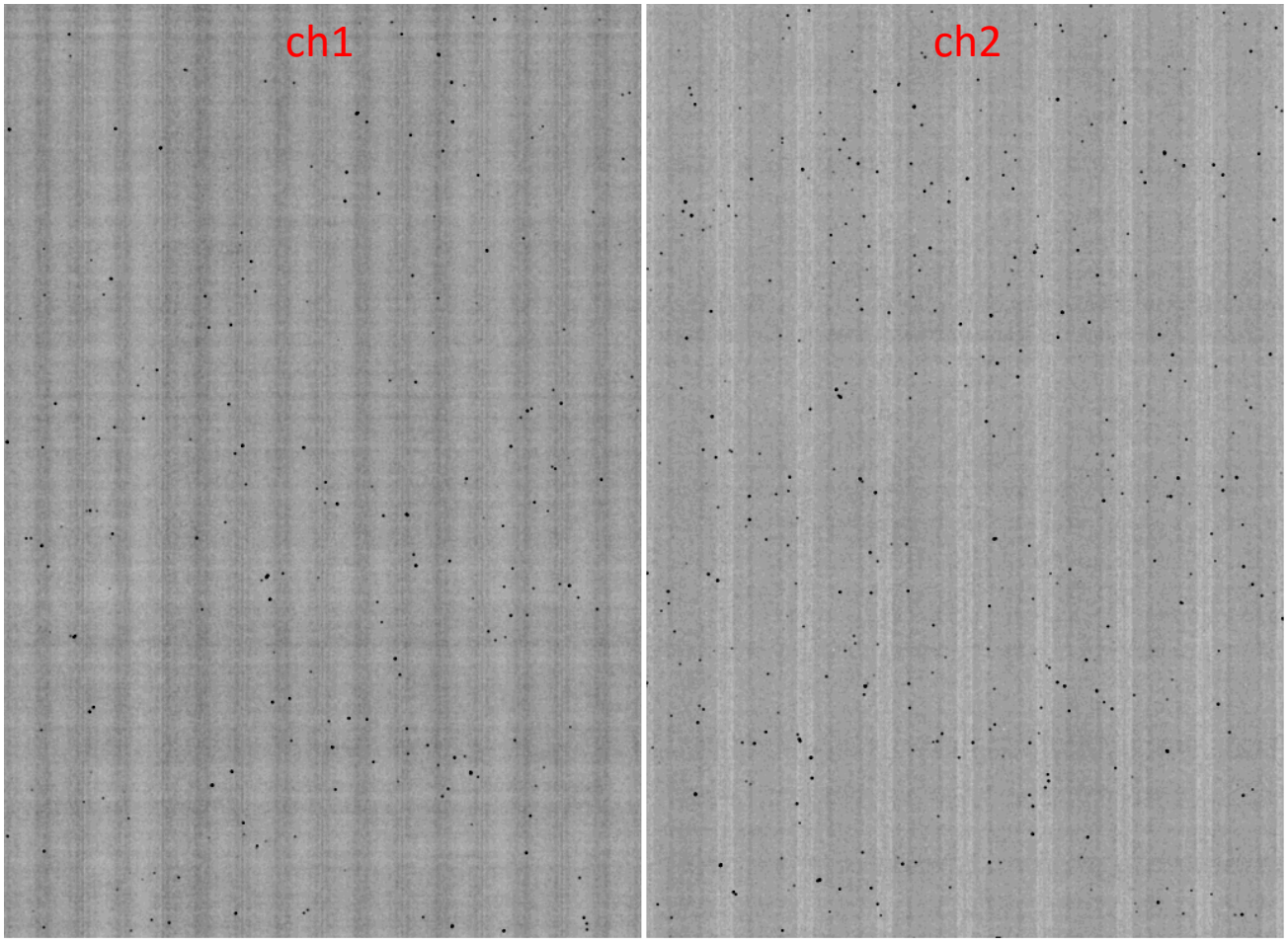
As expected, all the alpha-particle events have gone!



40 sec x 8 dark frames (=320sec equivalent). 500x500 pixel zoomed Image
Only some cosmic-ray hit events are seen.

1000x1500 pix2 area comparison

(level Inversed for better view)



Slightly more for channel-2?

Result

- Overall, the alpha-particle event has effectively eliminated.
- More CR event for ch2 than ch1 is observed.
- If this is the CR event, both channel should have similar number of events.
- The alpha particle hit event was more for channel-2 than ch1. Do they related?
- It might just be due to the sensitivity difference of the detector on the high-energy radiation.
- The effect on the science observation is negligible.

For more detail, see

M. Fabricius et al. (2016) SPIE Proceedings

“Detector Upgrade of Subaru's Multi-Object Infrared Camera and Spectrograph (MOIRCS)”