Flagship Subcommittee Report and Next Steps

June 26, 2015

Segmented Mirror Technology

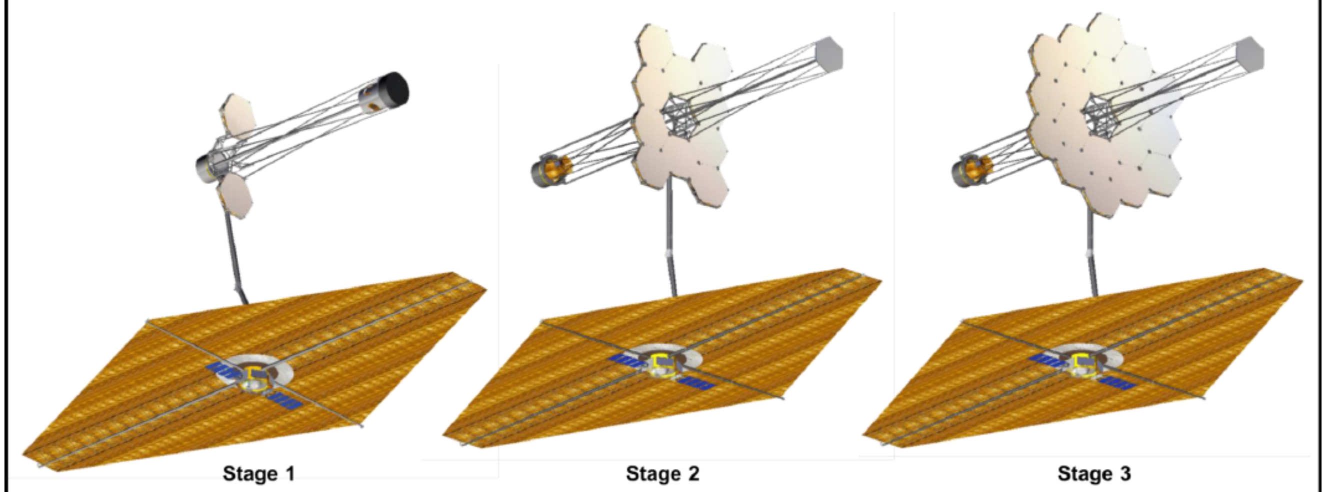
- A Flagship-class mission will need to have a segmented primary mirror
- Based on thermal expansion properties and expected operation at room temperature, either ULE or SiC are the best choices
- Glass will be machined mirrors or thin active face sheets with open back
- Mirror stability critical – 20 pm over 10 minutes – trade between CTE and conductivity
- Trade between 5nm RMS surface figure and production rate needs to be traded
- Segment size likely to be between 1.3 and 2.x m – larger than that will require a new infrastructure (100's $M)
- Goal is 3nm RMS – can this be done with 5nm RMS plus a DM? Trade to see if you can accept the extra bounce in the UV

Segmented Mirror Technology

- SiC a viable alternative – sectional stiffness can be tuned to meet requirements for weight and stability
- Areal density below 8 kg/m^2
- Mirrors can be active or passive
- Segments can be produced on 6-week centers

Evolvable Space Telescope Concept

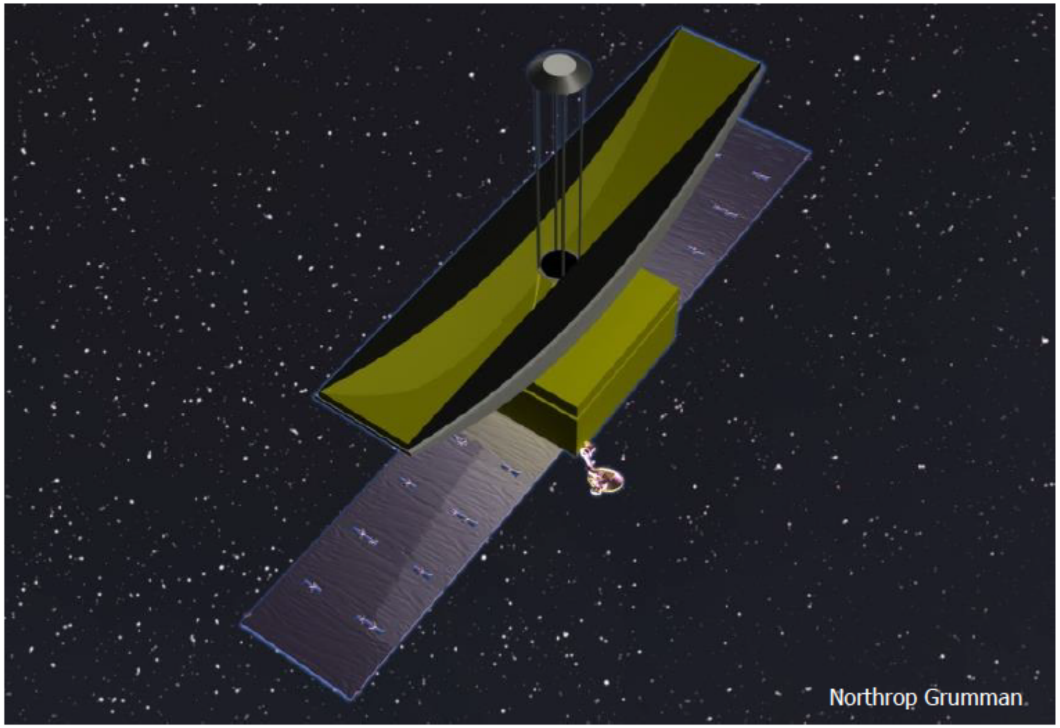
- To mitigate cost load by spacing the demand over time
- Launch a simple 2-mirror configuration and then add to it over time robotically
- Allows addition of newer technology
- Adds adaptability and serviceability
- Possible introduction of instrument payload at the Prime Focus to improve throughput



Evolvable Space Telescope Observatory Stages

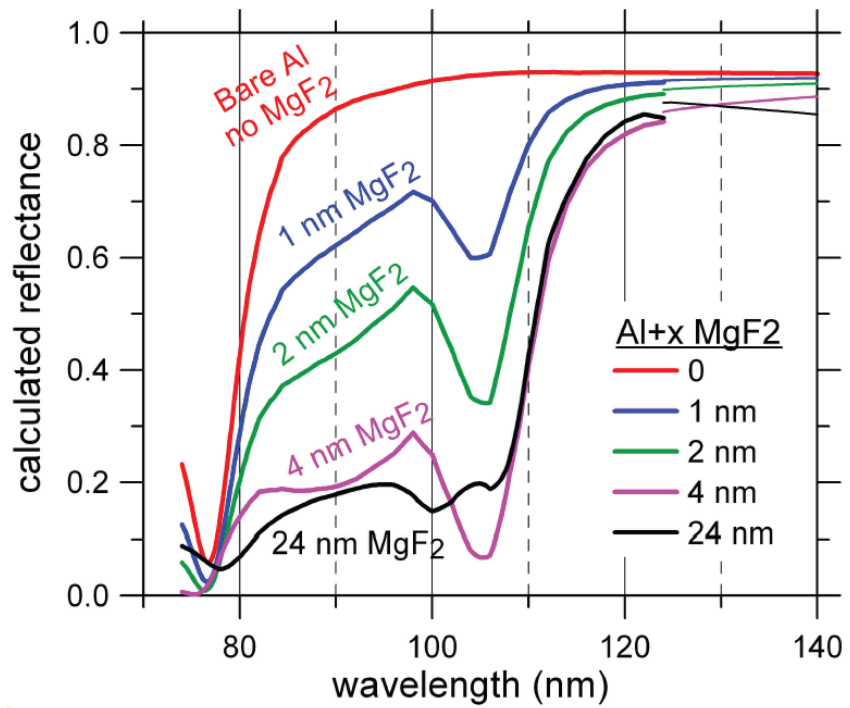
Rotating Synthetic Aperture Concept

- Developed by other government agencies
- Allows trades in collecting area, angular resolution and integration times
- Uncertain rotation rate compared to integration times
- An 18m 6:1 ratio RSA design weighs only 22% of a conventional design



Coatings for the FUV

- The conventional solution of Al overcoated with MgF_2 is still the simplest and most effective solution
- Optimum deposition technique involves heating the whole surface to 220 °C – can this be done uniformly enough for a large piece of glass? Similarly for LiF.
- MgF_2 has a cutoff in reflectivity at 115nm – if deposited by ALD at the right thickness this can be extended into the FUV
- Roughness of MgF_2 coatings appears to be of order or less than UV wavelengths -> absorption and some scatter



Detector Technologies for a Flagship Mission

"Heritage" MCP detectors

Strengths	*Weaknesses*
Good FUV QE	NUV/optical QE
Photon counting	Limited lifetime
Large area	Limited count rate
Rad hard	Non-uniform response
Solar blind	Spatial distortions
Curved focal planes	High voltage
Temporal resolution	Vacuum operation

"Heritage" CCD detectors

Strengths	*Weaknesses*
Superb optical QE	Readout Noise
Dynamic Range	Radiation ageing
Uniform response	Cyrogenic contamination
Small pixels	Red response (for UV)
Geometric stability	Cosmic ray sensitivity
	Focal plane tiling

MCP detector progress

Atomic layer deposition (ALD) to functionalize micropore surface

- *Larger plates*
- *Longer lifetime*
- *Lower background*
- *Opaque photocathodes*

Better readout anodes and electronics

- *Higher count rates*
- *Lower gain (longer life)*
- *Lower HV*
- *Less distortion*

Better MCPs

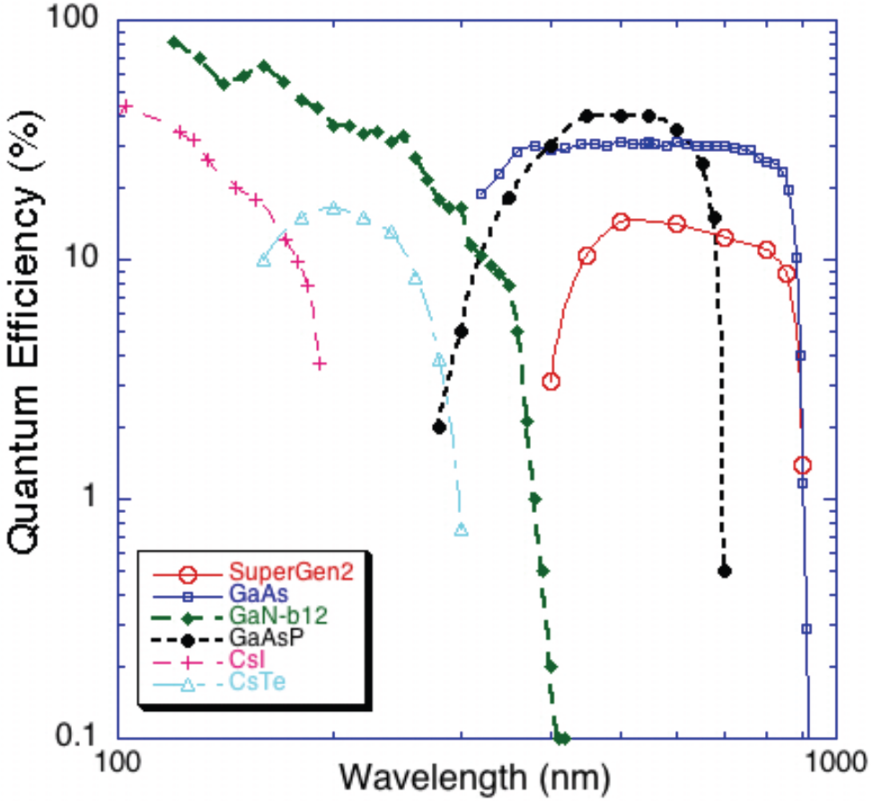
- *More uniform*
- *Smaller pores*

CCD detector progress

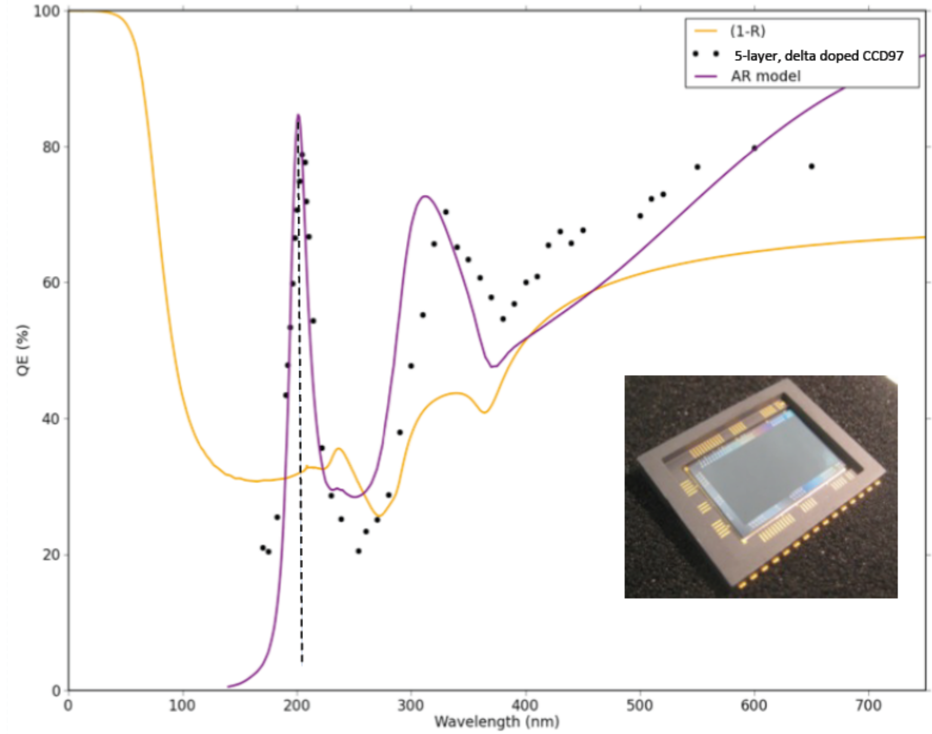
Surface engineering via MBE Delta Doping and ALD coatings

- *High (> 50%!), stable QE in FUV/NUV*
- *Anti-reflection coatings over defined bandpasses*
- *Diminished red response for specialized bandpasses*

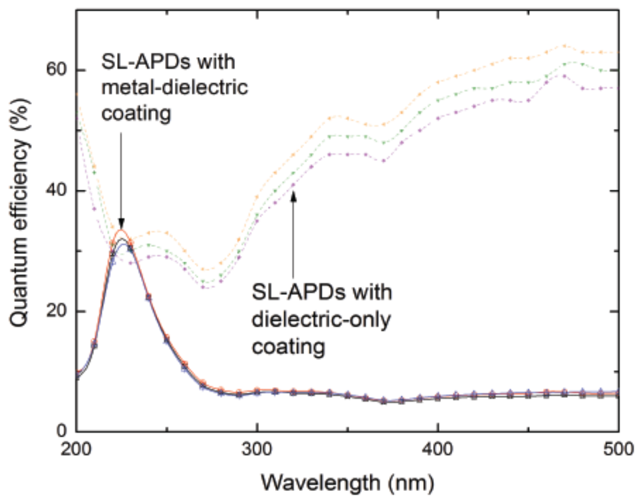
Can be applied to all back-illuminated Silicon devices: CMOS, APDs, EM-CCDs, p-CCDs, PIN Arrays

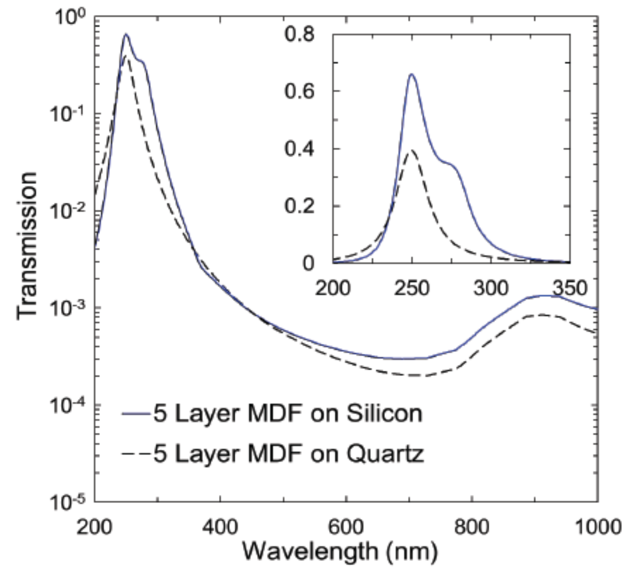


QE Results on AR Coated (5-Layer) designed for FIREBall Delta Doped EMCCD (0.5 Megapixel, CCD97)



Breakthrough: Visible-blind Silicon Detectors!





Superlattice-doped avalanche photodiode with integrated 3-layer metal-dielectric filter. Diodes were not depleted for these measurements

Nikzad et al, IEDM, 2014

Calculated performance of a 5-layer metal-dielectric filter on silicon or quartz substrate showing in-band efficiency of ~ 60% and out of band rejection approaching 10^4

Hennessy et al., Applied Optics, 2015

Detector Technologies for a Flagship Mission

- Given the recent progress made in the "standard" heritage detector types, most likely large, modern MCP detectors will be chosen for Flagship FUV instruments, CCDs for the optical instruments, and there will be a battle for the NUV crossover.
- Photocathode improvements can still have a significant impact in overall instrument performance
- Optical/NIR photon counters need their TRL increased significantly before becoming a Flagship detector

Lessons Learned in Promoting Flagship Missions

- Must have a compelling science case (appeals to community, public, decision makers)
- Mission provides a significant advance
- Mission provides broad involvement for the community
- Focus on cost control
- Invest early in technology
- For large missions: complexity >> ∑ technologies
- Leverage existing technology investments
- Requirements must be clearly written
- Insist on common instrument architectures