2015 Dec 15 B mode from Space @ Kavli IPMU (WPI)

Optics design for LiteBIRD and realization plan

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Optics design for LiteBIRD and realization plan

1. Background

1.1. Status of LiteBIRD

1.2. Joint Study Group

2. Design approach

2.1. Ray tracing

2.2. Physical optics

2.3. Consistency level between ray tracing and physical optics

2.4. 1/3 scale model, including baffle/hood testing

3. Basic design

4. Recent studies

4.1. Estimates of effects of mirror surface dimpling

4.2. Preliminary design for high frequency telescope

4.3. Feasibility studies of modifying aperture size

5. Realization plan

- JAXA Chamber

- CGH for 10um interferometer

6. Summary

1.1. Status of LiteBIRD

2015 June (2015 Feb submission)

Passed initial down-selection 50-320GHz

through Mission Definition Review by JAXA/ISAS,

→ in transition to ISAS phase-A1, targeting SRR

2015 July (2014 Dec submission) 35-450GHz

US participation proposal for NASA MO

passed initial down-selection

→ US phase-A

1.2. Joint Study Group

Joint Study Groups (JSD)

Detailed study/simulation on each key issue.

Including external collaborators.

- Foreground
- Systematics

→ Face-to-face meeting held on 2015 Dec 12.

Close interactions on inputs for System Requirements.

2. Design approach

2.1. Ray tracing
- Code V with or without Beam Synthesis Propagation
- LightTools for stray light

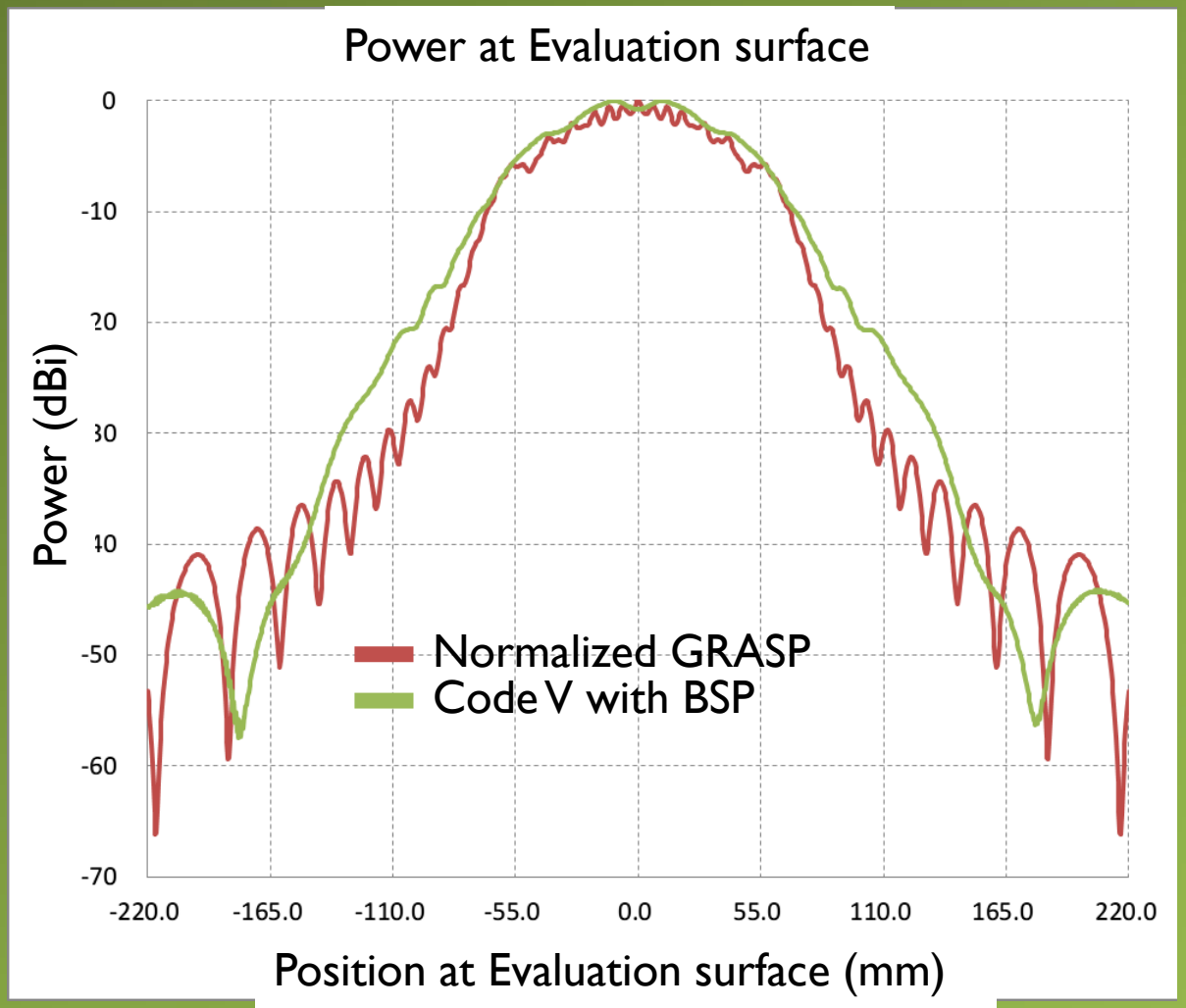
2.2. Physical optics
- GRASP

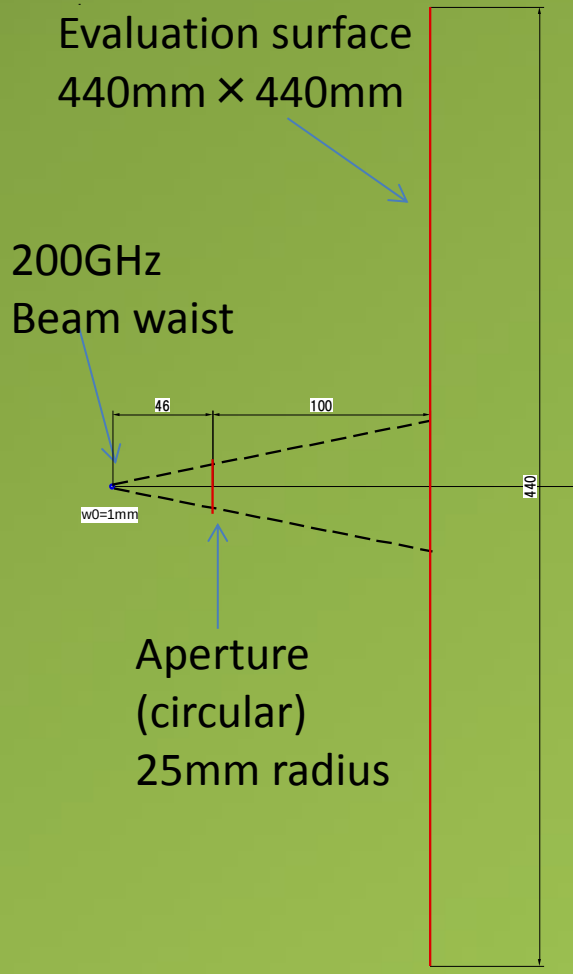
2.3. Consistency level between ray tracing and physical optics

2.4. 1/3 scale model, including baffle/hood testing

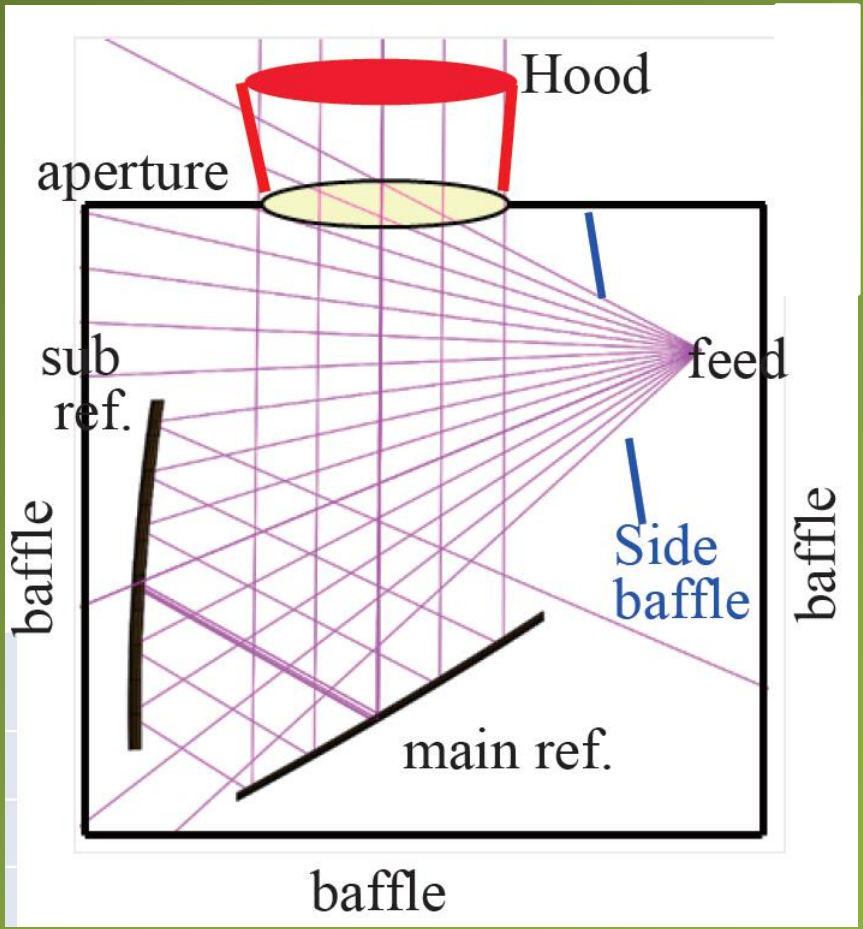
For physical optics, see:
- Kimura et al.'s talk; P11. Inoue et al.
  "Characterization of the LiteBIRD telescope using Physical Optics simulation"
- P12. Ito et al.
  "Measurement and Evaluation of the 1/3 Scale Model of LiteBIRD Using Phase Retrieval method"

2.3. Consistency level between ray tracing and physical optics

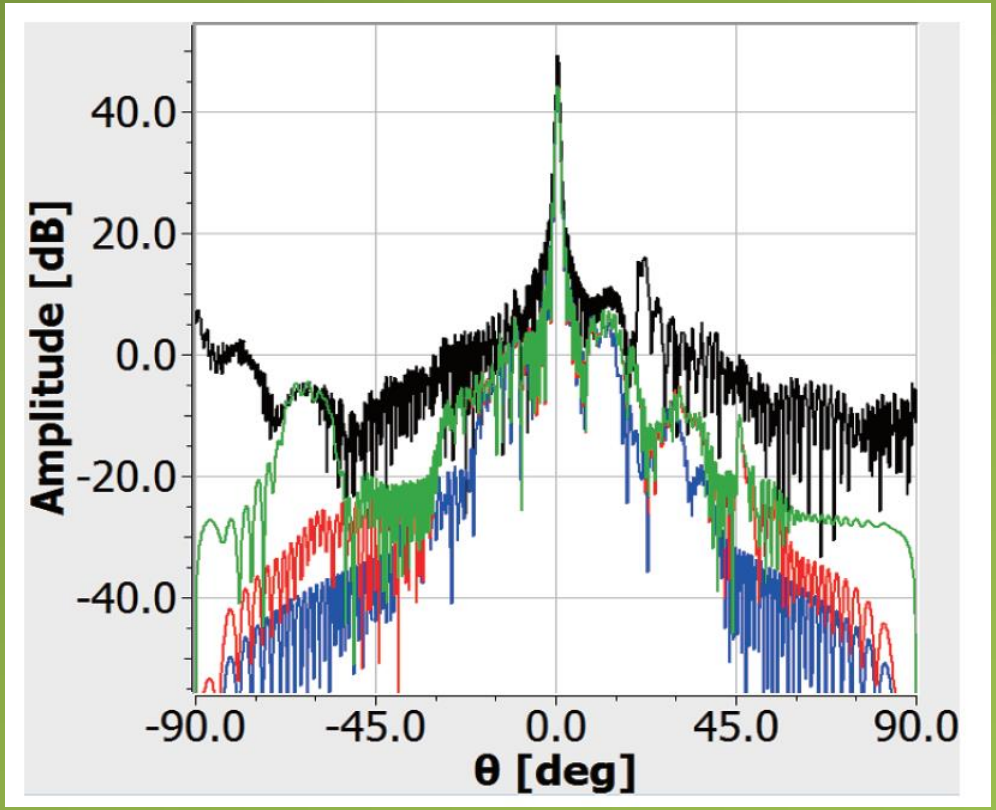




2.4. 1/3 scale model, including baffle/hood testing

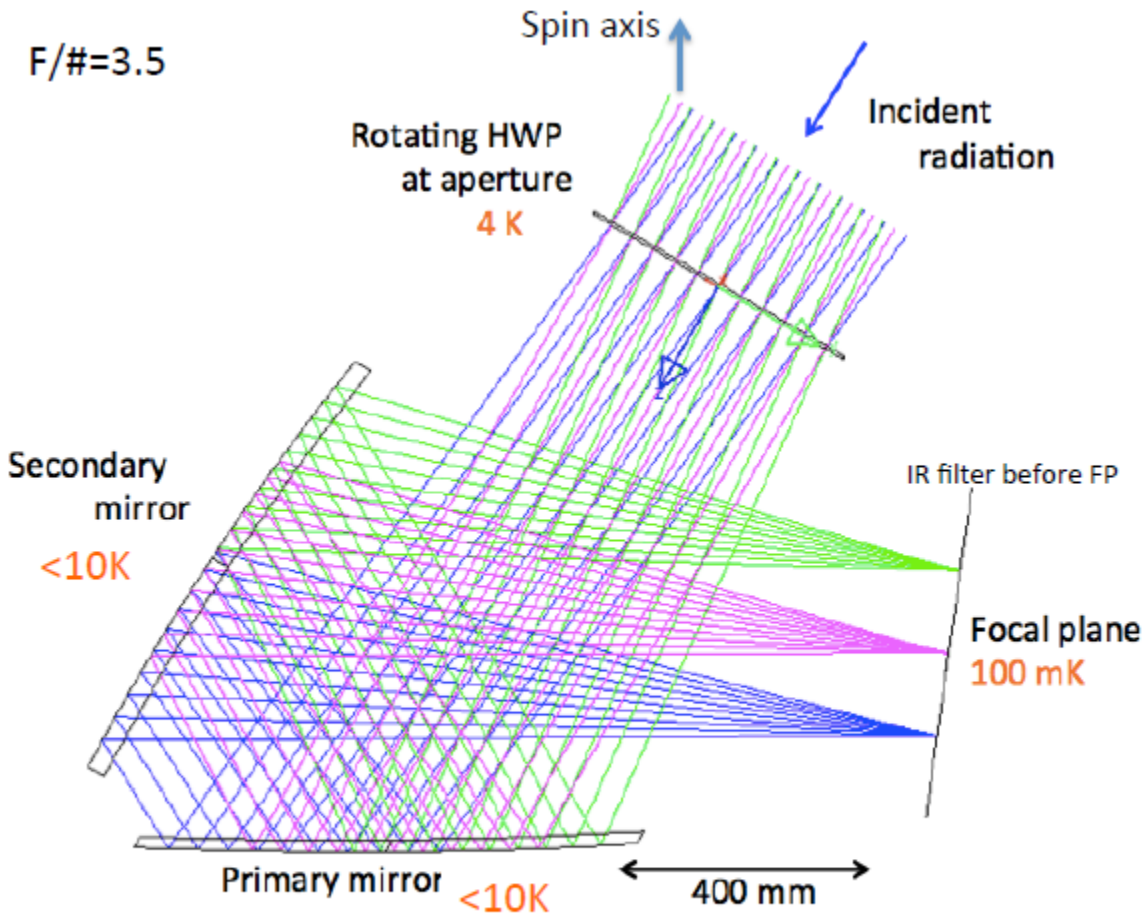


Design by using GRASP



Taken from P11. Inoue et al.
"Characterization of the LiteBIRD telescope using Physical Optics simulation"

3. Basic design – Crossed Dragone



- In the ongoing/upcoming CMB experiments, QUIET, ABS, LSPE employ the similar optical system.
- Two 800 mm reflectors are in anamorphic aspherical shape.
- The cryogenically cooled entrance aperture to control the sidelobe of the feed.
- the telecentric field-of-view of 10x20 degrees^2 with the Strehl ratio above 99% for all the observing bands.
- The chief ray does not cross at 90 degrees to minimize the multi-reflection.
- Fit within a rocket envelop.

Matsumura et al. 36th ESA antenna workshop

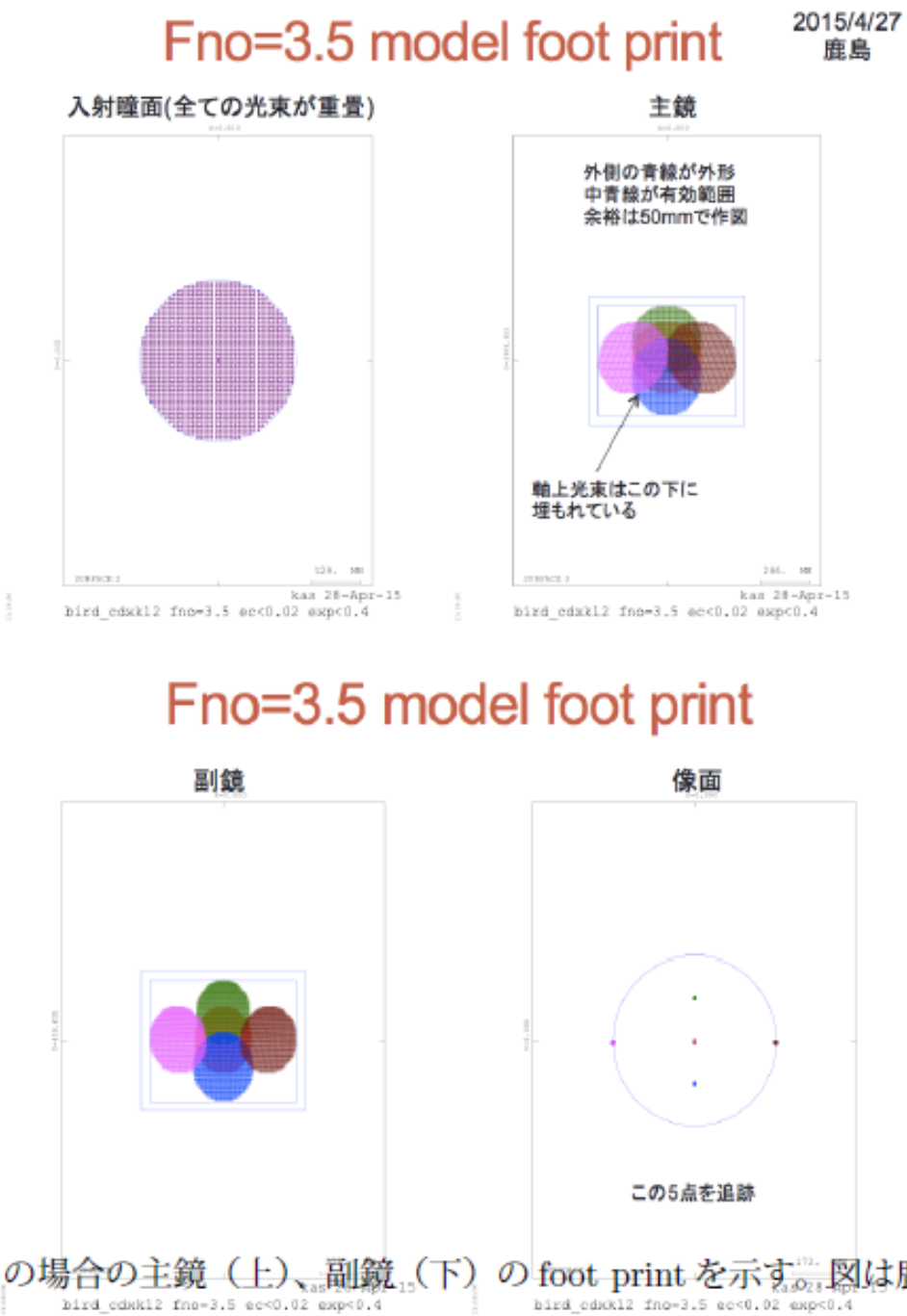
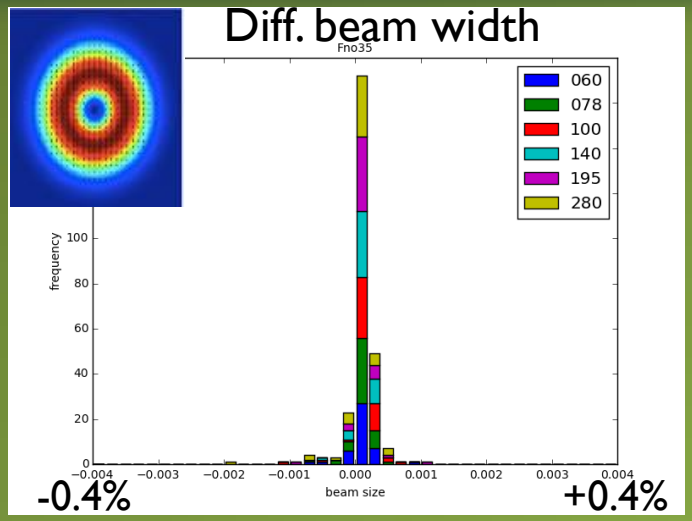
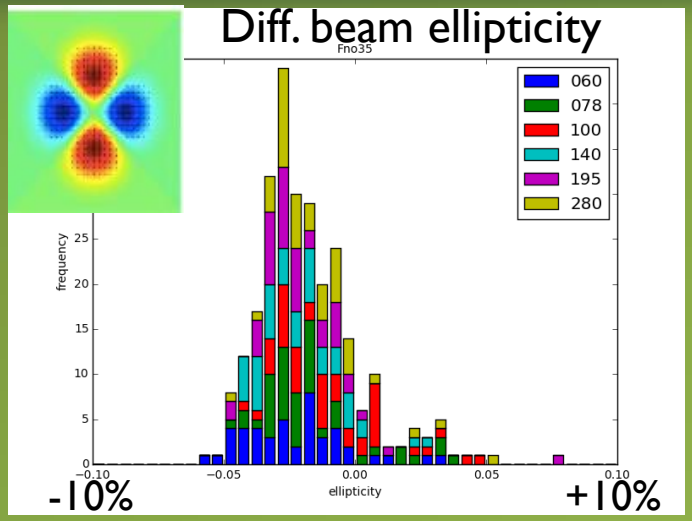


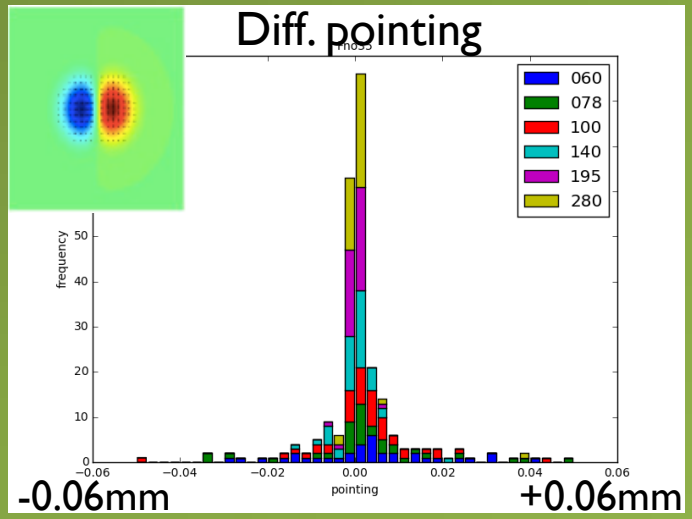
図 4: F 値 3.5 の場合の主鏡（上）、副鏡（下）の foot print を示す。図は鹿島さんより。

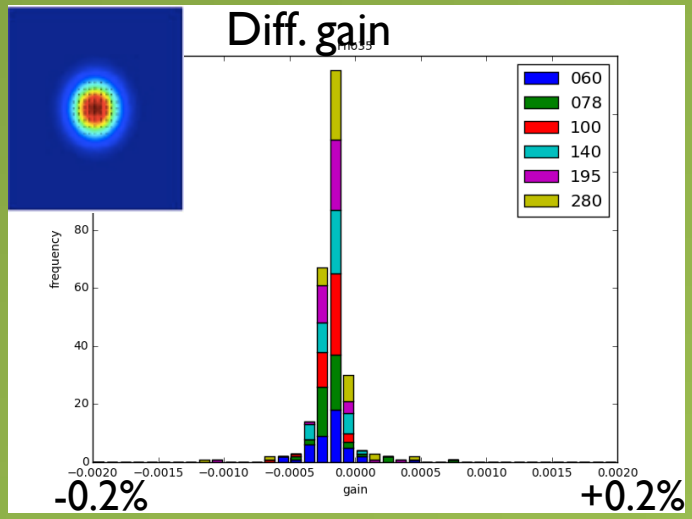
Differential PSF (pol 0° vs pol 90°)





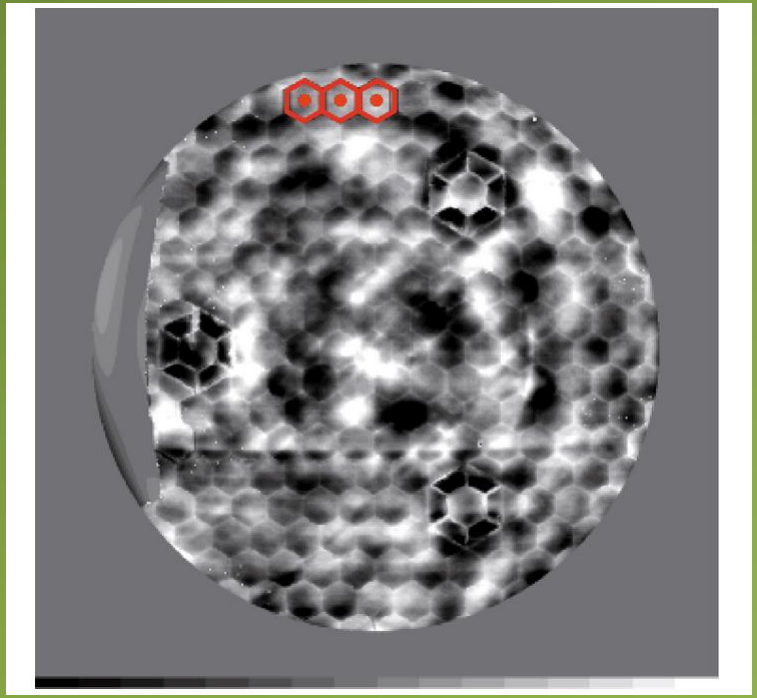
F/#=3.5





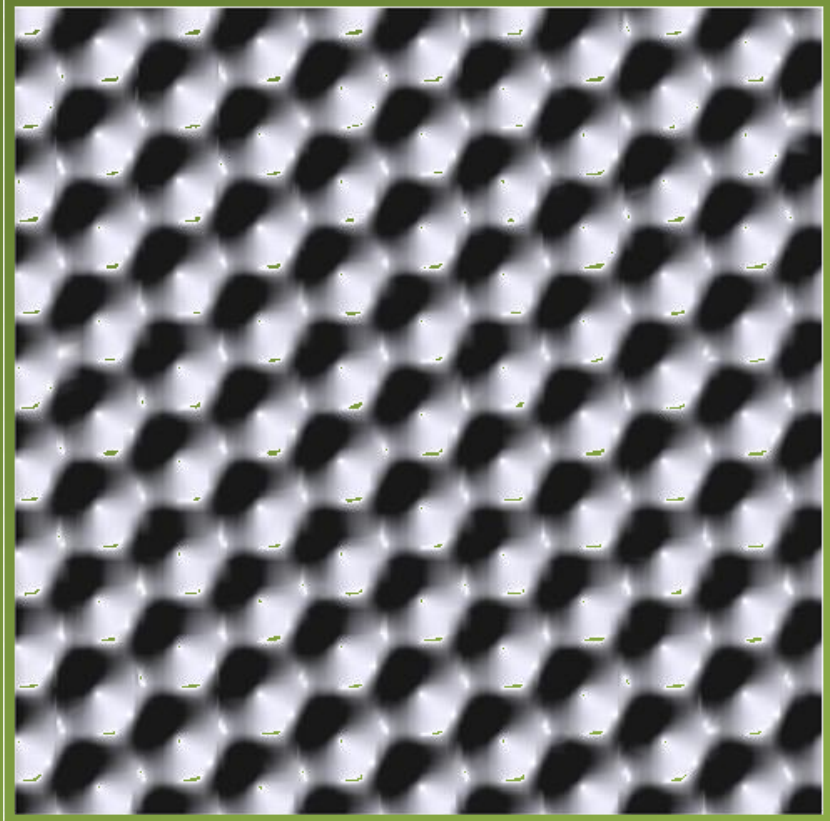
4. Recent studies

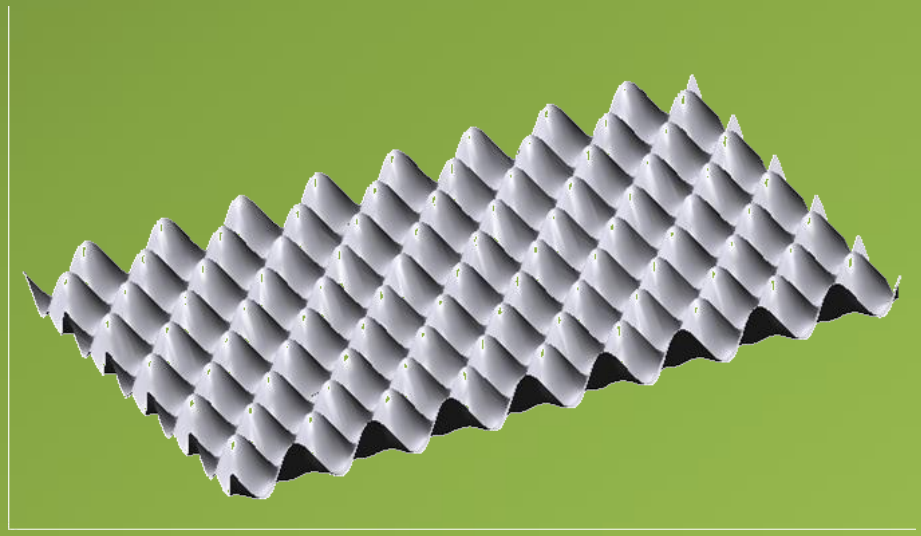
4.1. Estimates of effects of mirror surface dimpling



Deformations of Planck off-axis ellipsoid Secondary Reflector
measured by using 10um interferometer
(Tauber et al., A&A 520, A2, 2010)

Developed to produce honeycomb-type dimpling pattern on Code V

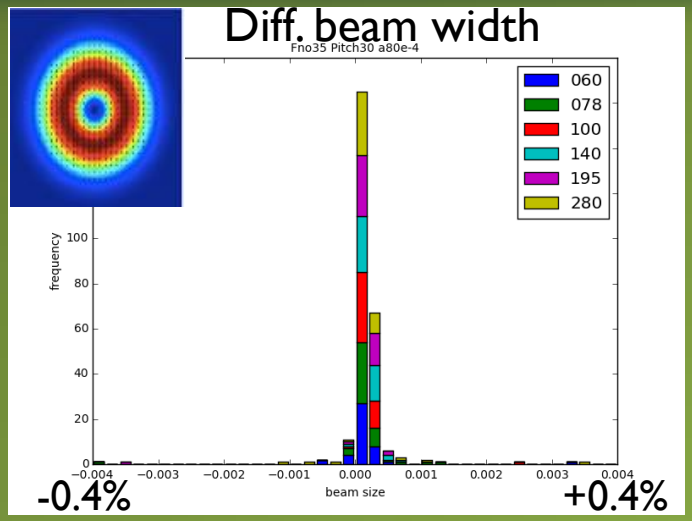


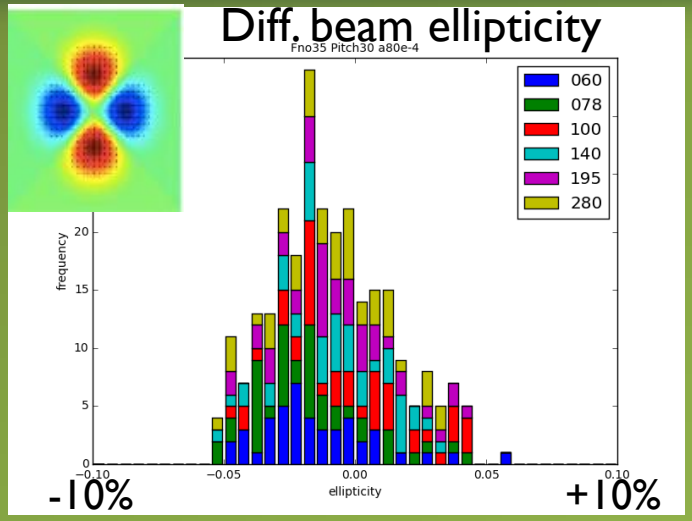


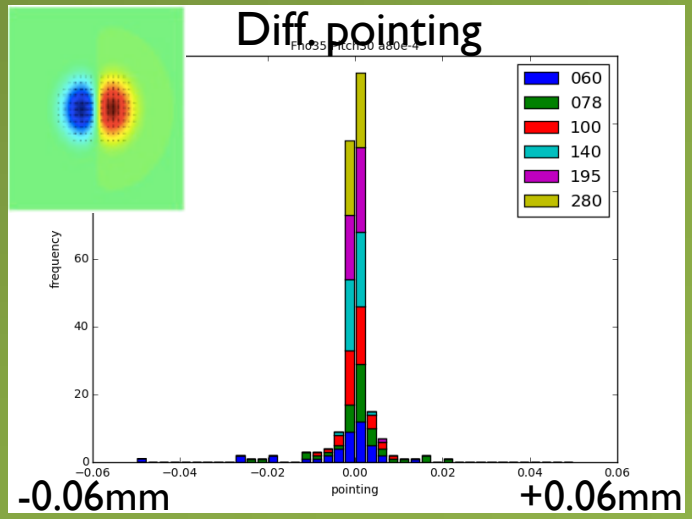
$\cos^2\theta$ shape (exaggerated) as an example

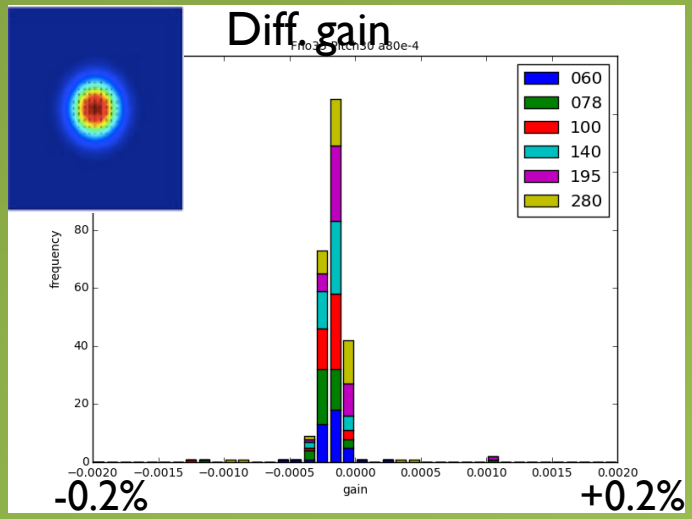
Differential PSF (with 8um dimpling (30mm pitch))

F/#=3.5

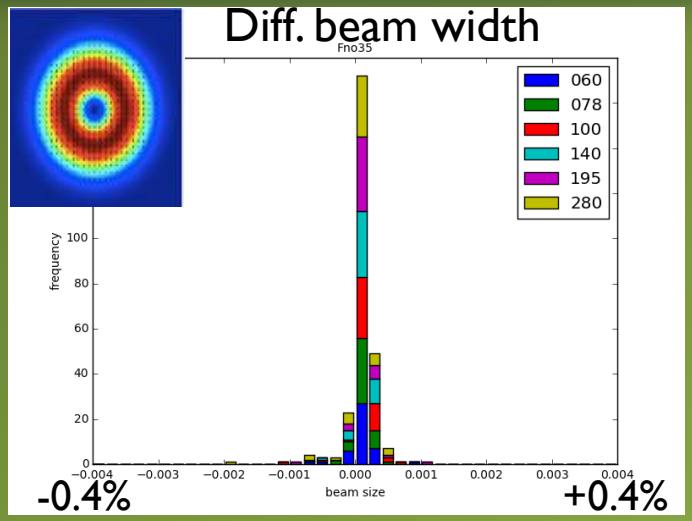


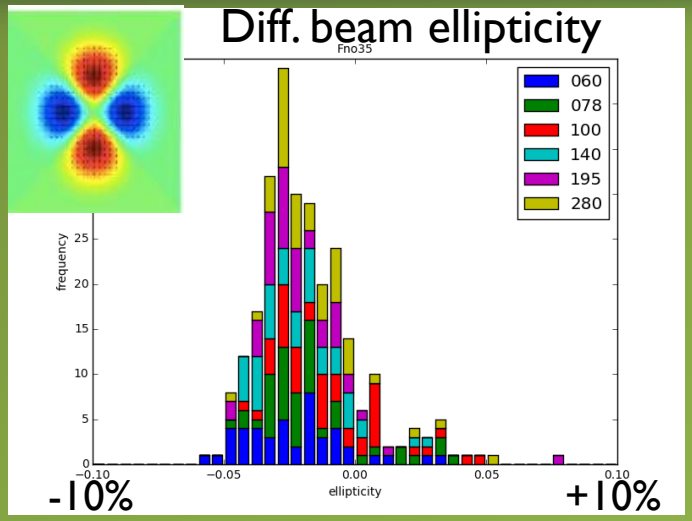




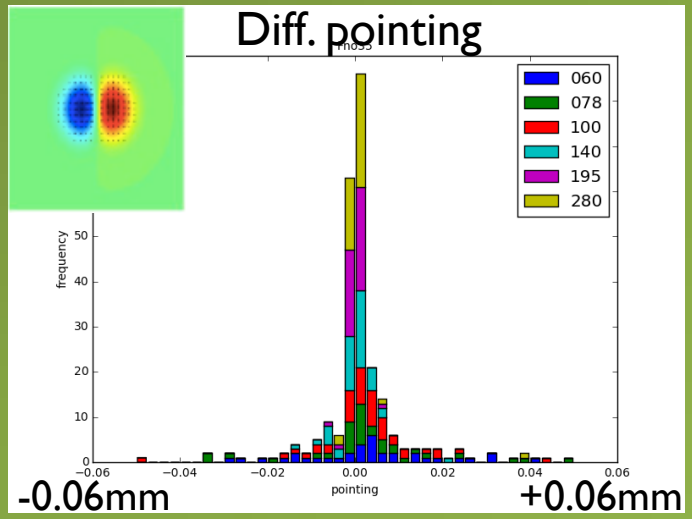


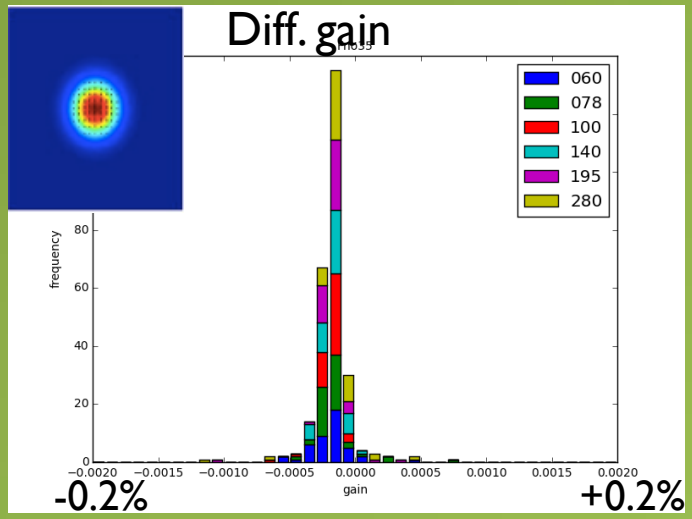
Differential PSF (pol 0° vs pol 90°)





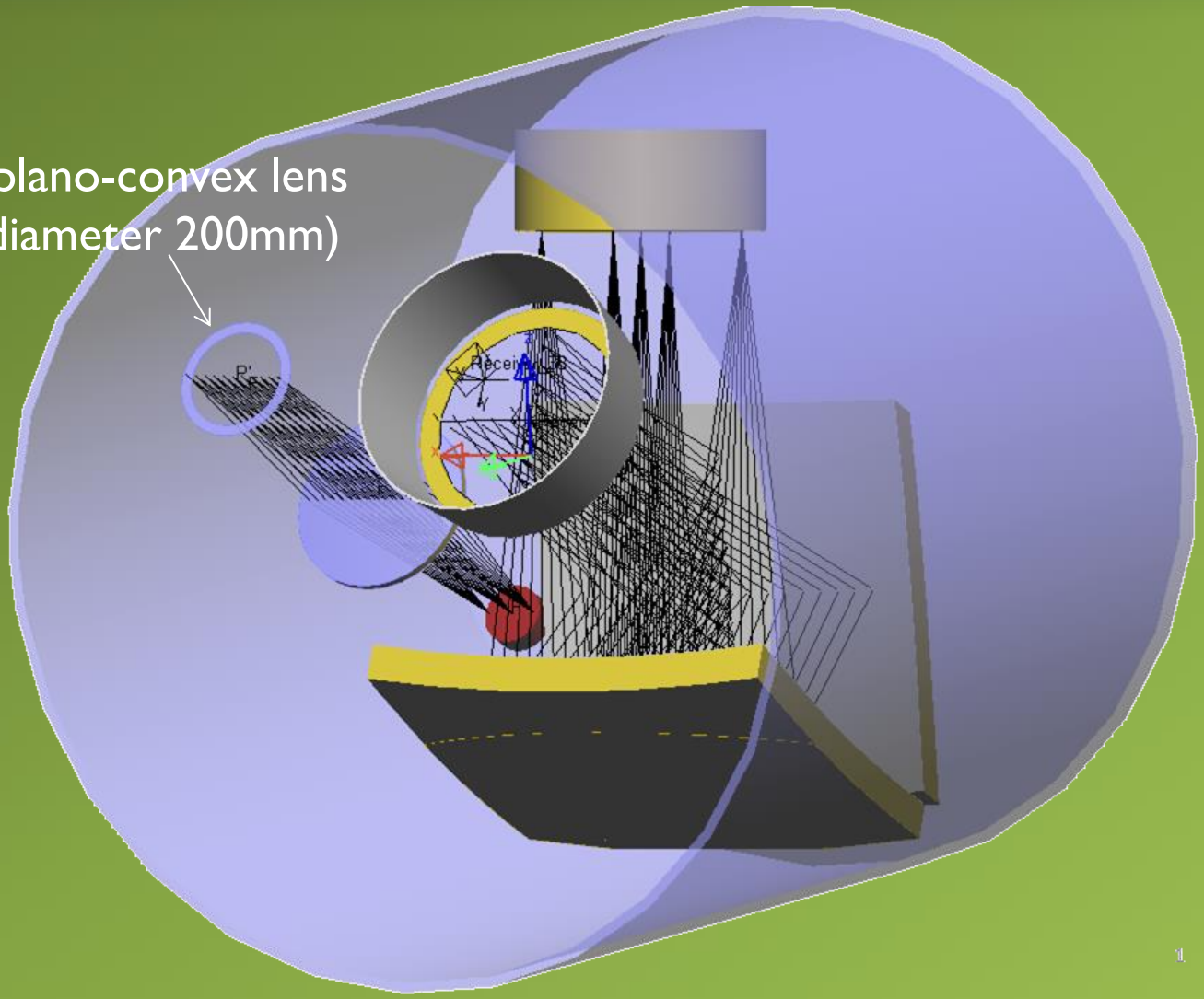
F/#=3.5





4.2. Preliminary design for high frequency telescope

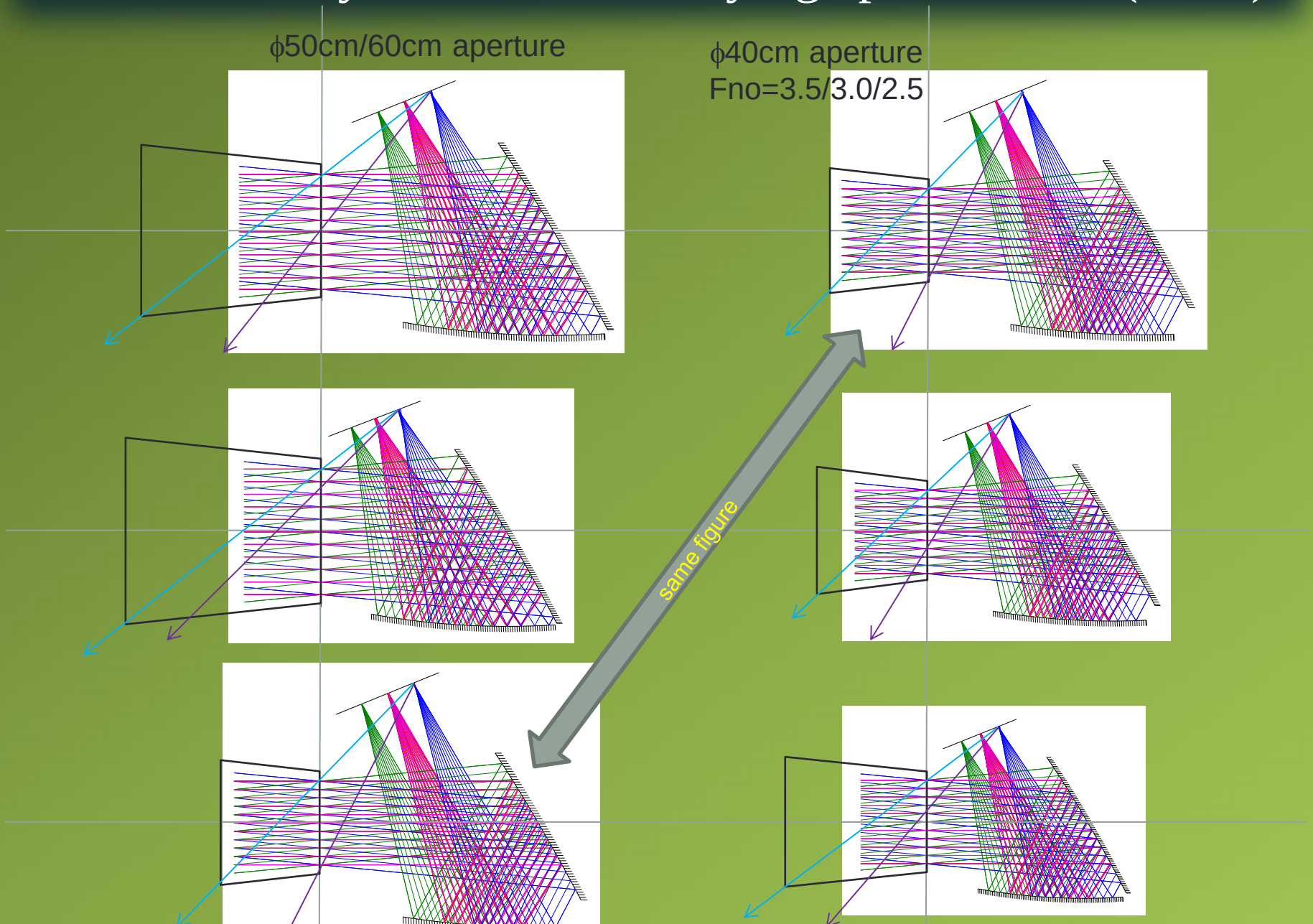
HFT:
360mm Si plano-convex lens
(aperture diameter 200mm)



4.3. Feasibility studies of modifying aperture size (&F/#)

ϕ50cm/60cm aperture

ϕ40cm aperture
Fno=3.5/3.0/2.5



5. Realization plan

Validation method candidates	Warm (Room temp)	77K (or 4K)
Surface roughness (PM/SM) ~2um level	- 10um CGH interferometer - 3D-CMM on small regions	- 10um CGH interferometer - (No measurements?)
Surface shape error (PM/SM) ~30um level	- 10um CGH interferometer - Photogrammetry on larger-scale structure - 3D-CMM	- 10um CGH interferometer - Photogrammetry on larger-scale structure
Alignment	- Photogrammetry	- Photogrammetry
Radio freq. properties (Main)	- Beam map	- Beam map
Radio freq. properties (Side)	- Beam map	- Beam map

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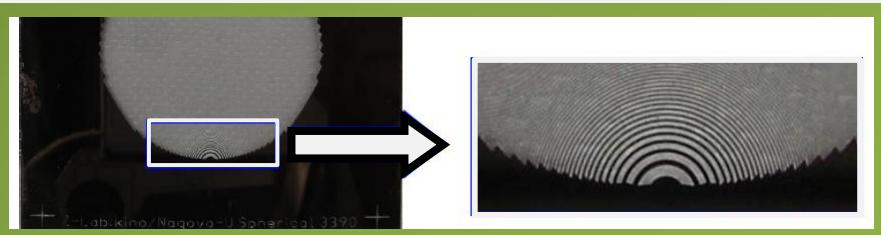
- Develop Computer Generated Hologram (CGH) for 10um interferometer?

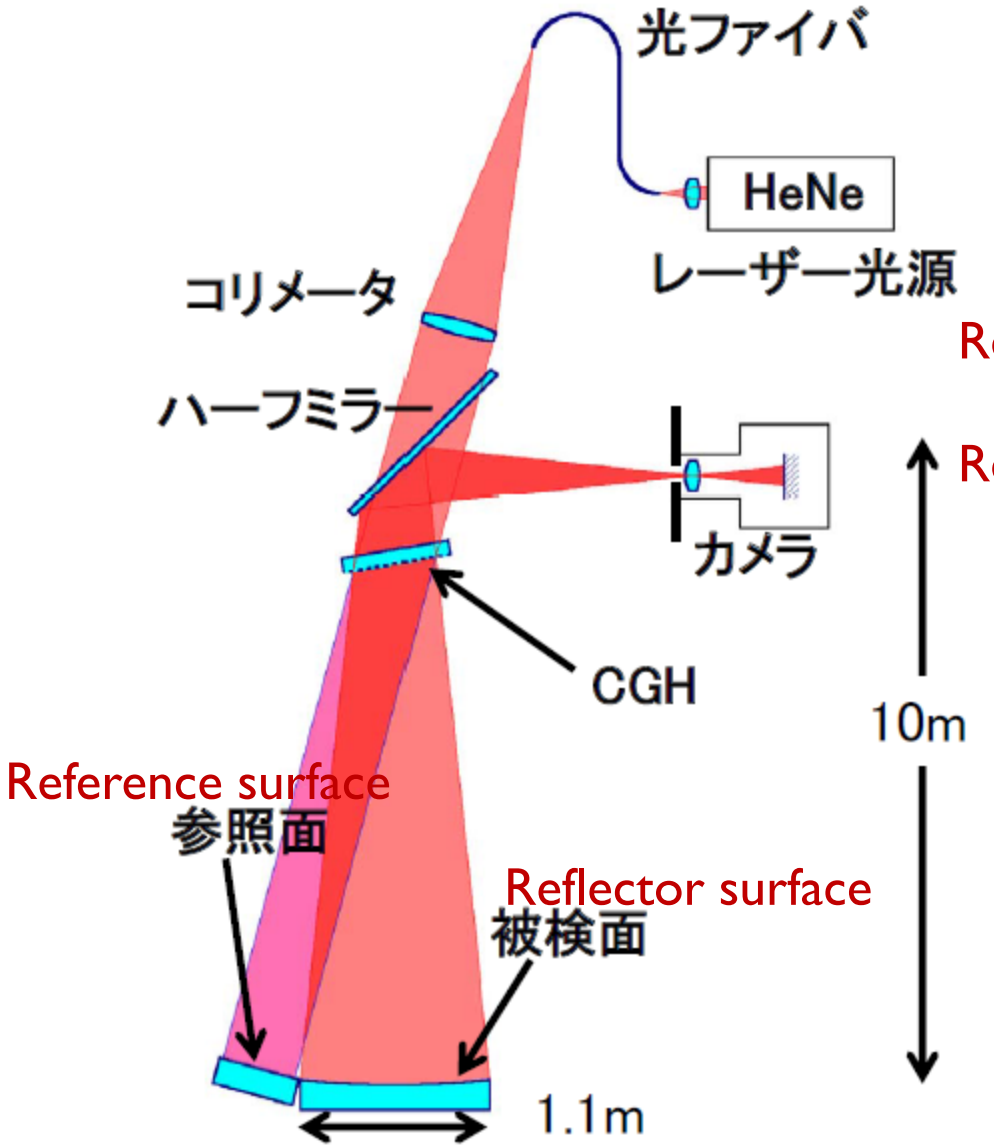


cf. CGH for 3.39um interferometer
(Miyazaki 2009)

- Use JAXA **13mφ (or 8mφ)** Space Chamber on Alignment & RF prop. at **low temperature**?

- Down to -170℃
- Small windows
- Parallel beam incident horizontally (or vertically)

CGH interferometer optics



Reference light (enter) 0th order
参照光(往路) 0次光

Reference light (return) 1st order
(復路) 1次光

Reflector measurement light (enter) 1st or
被検光(往路) 1次光

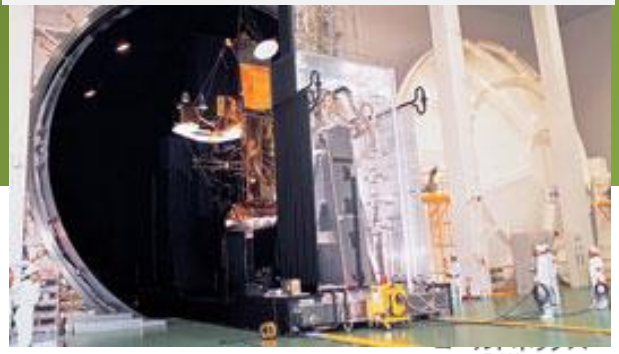
Reflector measurement light (return) 0st o
(復路) 0次光

- 回折効率が等しい
  Common diffraction efficiency
- 高い横解像度を実現
  High lateral resolution

Kino (2009: in Japanese) for Okayama 3.8m optical/NIR telescope segment m

Alignment & RF properties
at **low temperature**?

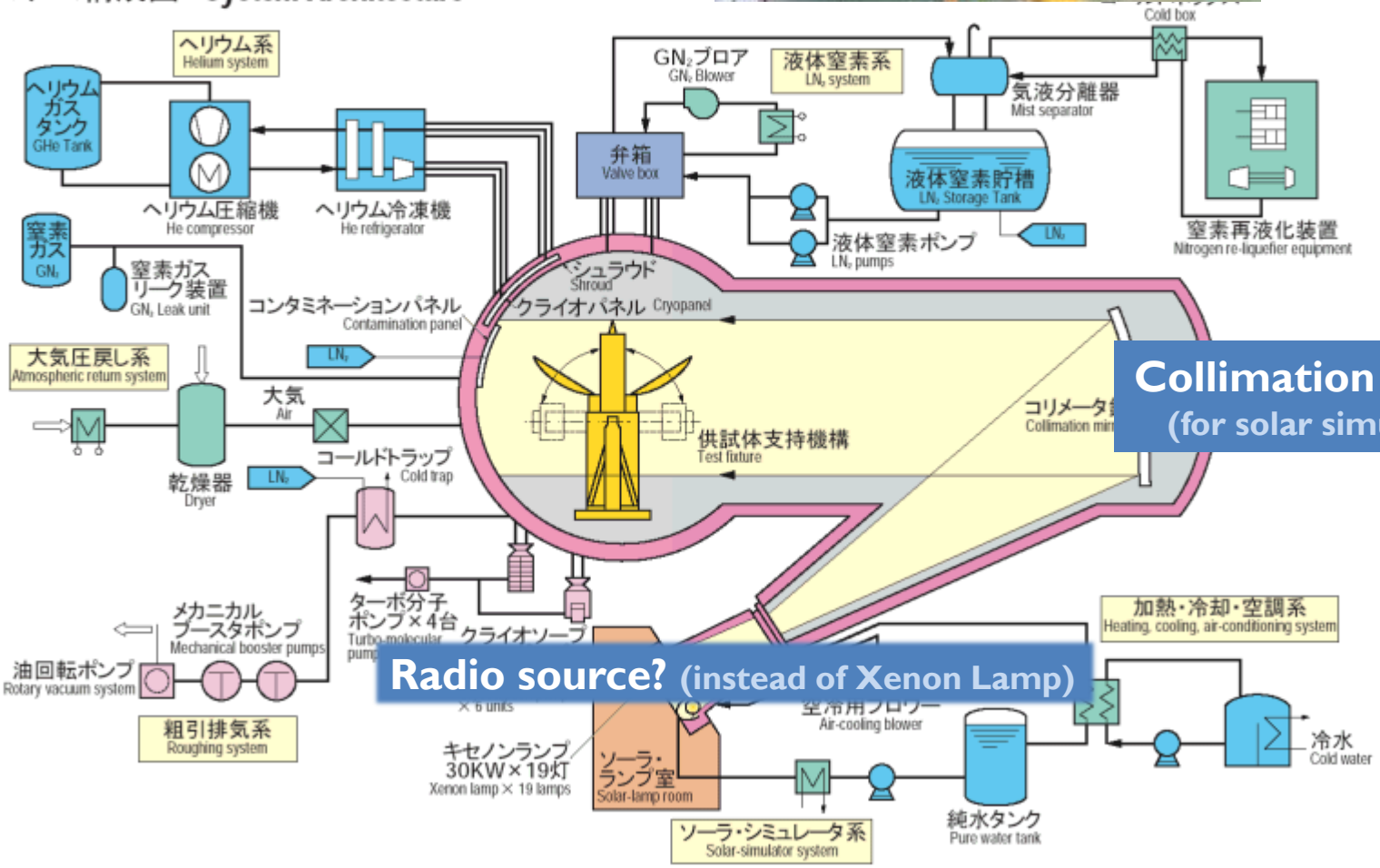
http://aerospacebiz.jaxa.jp/jp/facilities/list/facility11.html



JAXA

13mø Space Chamber

システム構成図 System Architecture



Collimation Mirror
(for solar simulator)

Radio source? (instead of Xenon Lamp)

Original figure from http://aerospacebiz.jaxa.jp/jp/images/facilities/13m_space_chamber.gif

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