9904-170

SPIE Conference "Space Telescopes and Instrumentation 2016: Optical, Infrared, and Millimeter Wave" 2016 Jun 26 @ Edinburgh International Conference Centre, UK

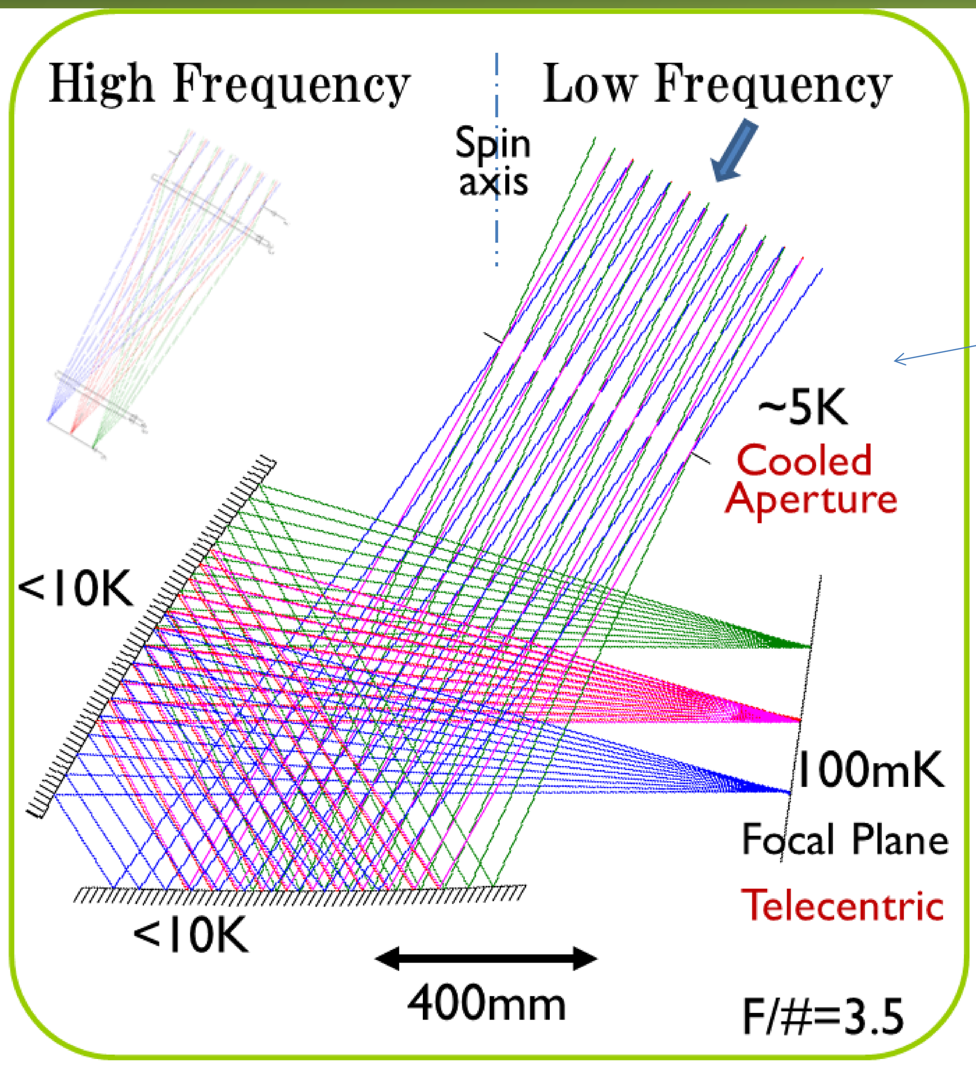
Optical Designing of LiteBIRD

Hajime Sugai (Univ of Tokyo), Shingo Kashima (NAOJ), Kimihiro Kimura (Osaka Pref Univ), Tomotake Matsumura (JAXA), Masanori Inoue (Osaka Pref Univ), Makoto Ito (Osaka Pref Univ), Toshiyuki Nishibori (JAXA), Yutaro Sekimoto (NAOJ), Hirokazu Ishino (Okayama Univ), Yuki Sakurai (Univ of Tokyo), Hiroaki Imada (JAXA), LiteBIRD Working Group

ABSTRACT

LiteBIRD (Lite (Light) satellite for the studies of B-mode polarization and Inflation from cosmic background Radiation Detection) aims to detect the footprint of the primordial gravitational wave on the Cosmic Microwave Background (CMB) in a form of polarization pattern called B mode. In order to separate CMB from the Galactic emission, our measurements cover 35 GHz to 450 GHz. The optics of the main telescope of LiteBIRD consists of crossed Dragone type, which provides a compact configuration with a wide field of view. The whole optical system is cooled down to around 5K to minimize the thermal emission. We use two kinds of approaches of designing calculation, as well as the experimental confirmation.

1. Basic design of Main Telescope – Crossed Dragone

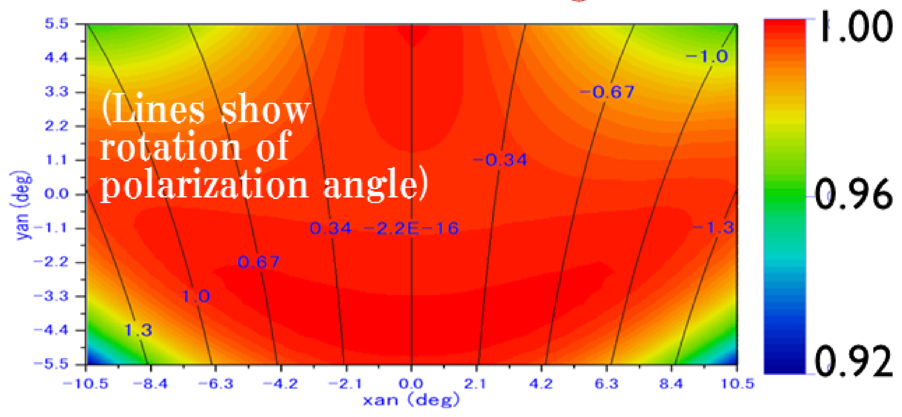


Rotating Half Wave Plate for polarization modulator will be placed at cooled aperture (see Matsumura et al. on this conference).

Low Frequency telescope – Crossed Dragone.
Compact configuration with wide FOV.
Two 800mm reflectors – anamorphic aspherical.

Cryogenically cooled entrance aperture to control sidelobe of feed.
Chief ray does not cross at 90 degs to minimize multi-reflection.

Strehl ratio @150GHz over wide (10x20deg^2) FOV on LFT



In order to cover a wide frequency range, we have adopted to have two separate frequency-range telescopes: a low frequency telescope (LFT: main telescope covering around CMB peak) for 35-270 GHz and a high frequency telescope (HFT) for 240 to 450 GHz. This eases anti-reflection coating designs of optical components, including half wave plates. The LFT tends to give us more difficulties in terms of designing and fabrication aspects since the size of the whole optics as well as detectors are scaled with wavelengths, i.e., reciprocals of the corresponding frequencies. For the LFT we have selected and designed crossed-Dragone type, taking advantages of its low side lobe levels (off-axis optics) and its large field of view.

Design approach

①Ray tracing

searching proper design candidates with the ray tracing, which requires relatively short simulation timescale.

- Code V (Synopsys, Inc.)
- LightTools (Synopsys, Inc.) on stray light

②Physical optics

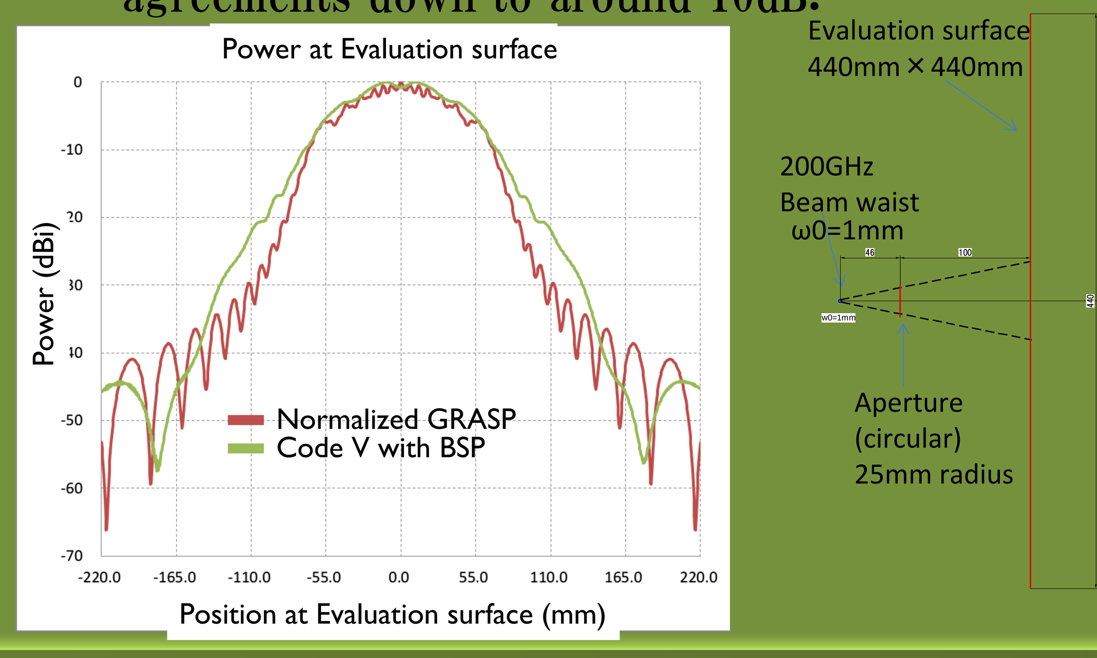
obtaining the strict design solution by using the physical optics around candidates found in the ray tracing method.

- GRASP (TICRA) for precise modelling of reflector antennas

Consistency level between ray tracing and physical optics

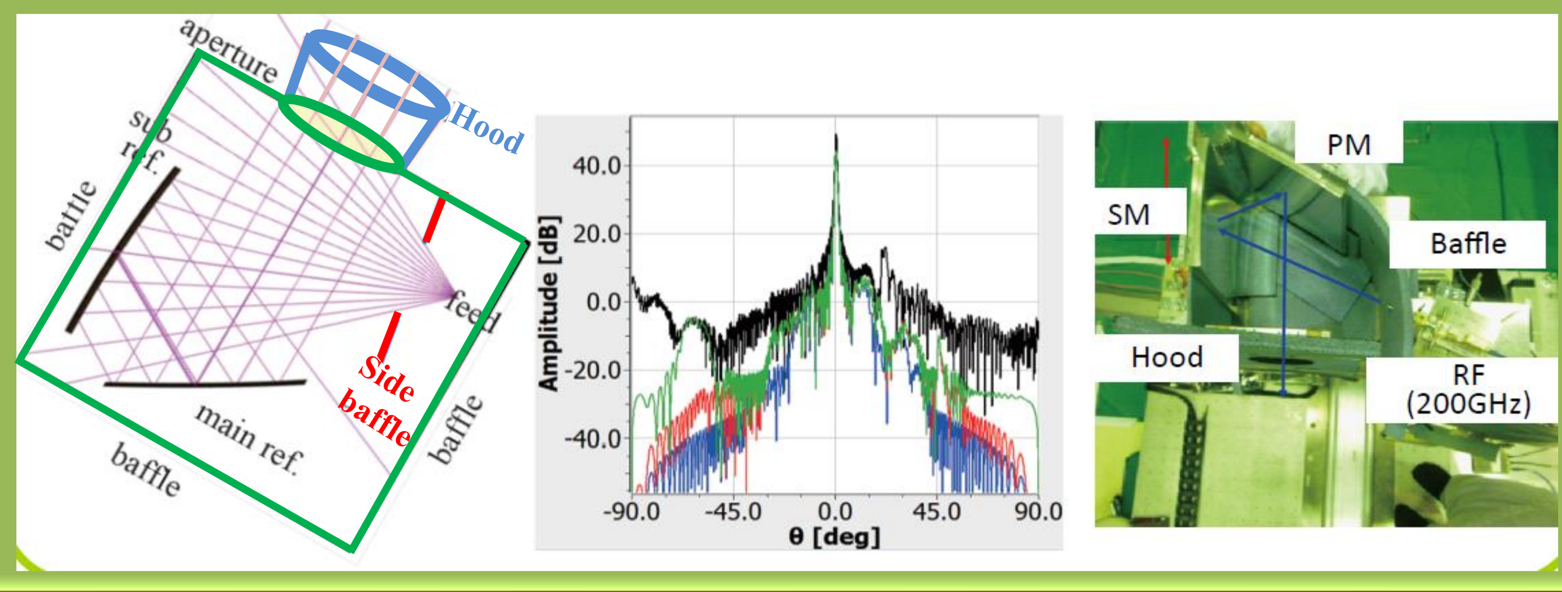
validity of approach of ①→② flow

→Comparison between Code V (including Beam Synthesis Propagation) and GRASP by using a simple configuration with Gaussian feed + circular aperture shows relatively good agreements down to around 10dB.

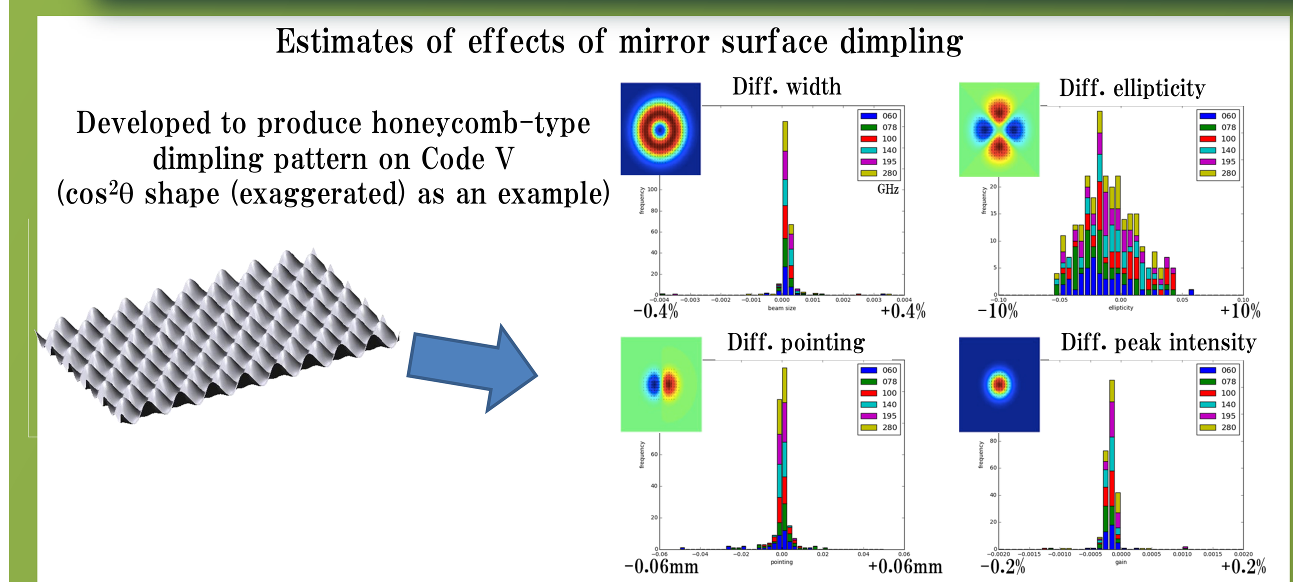


Verification of GRASP simulation using 1/3 scale model, including baffle/hood

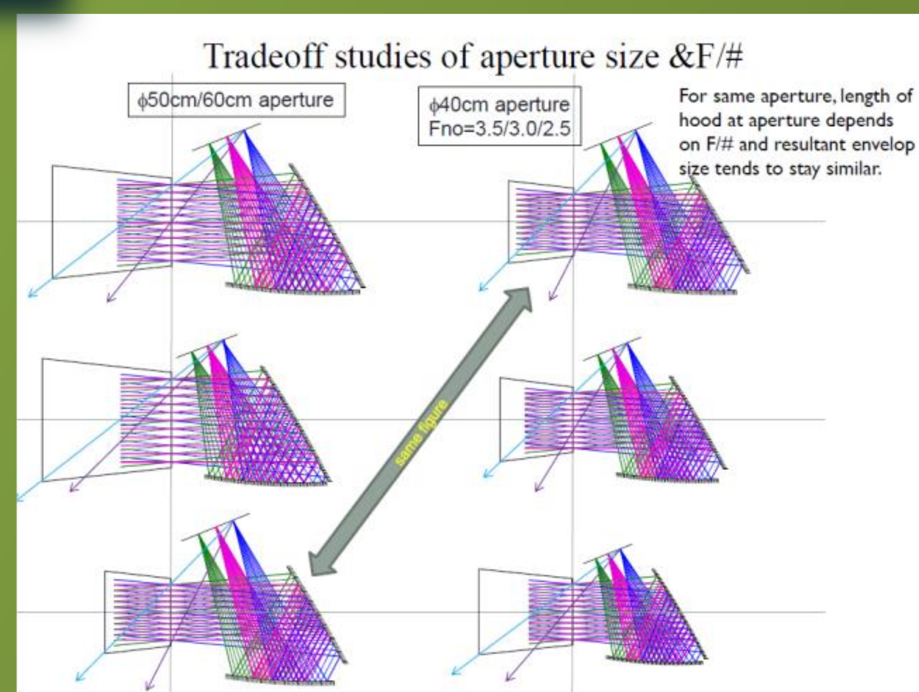
In order to confirm the accuracy of the GRASP calculation, particularly in terms of detailed baffle/hood designs, we have produced a 1/3 scale model aluminum mirror and are pursuing radio property measurements at 200GHz. This corresponds to 60GHz in a full model.



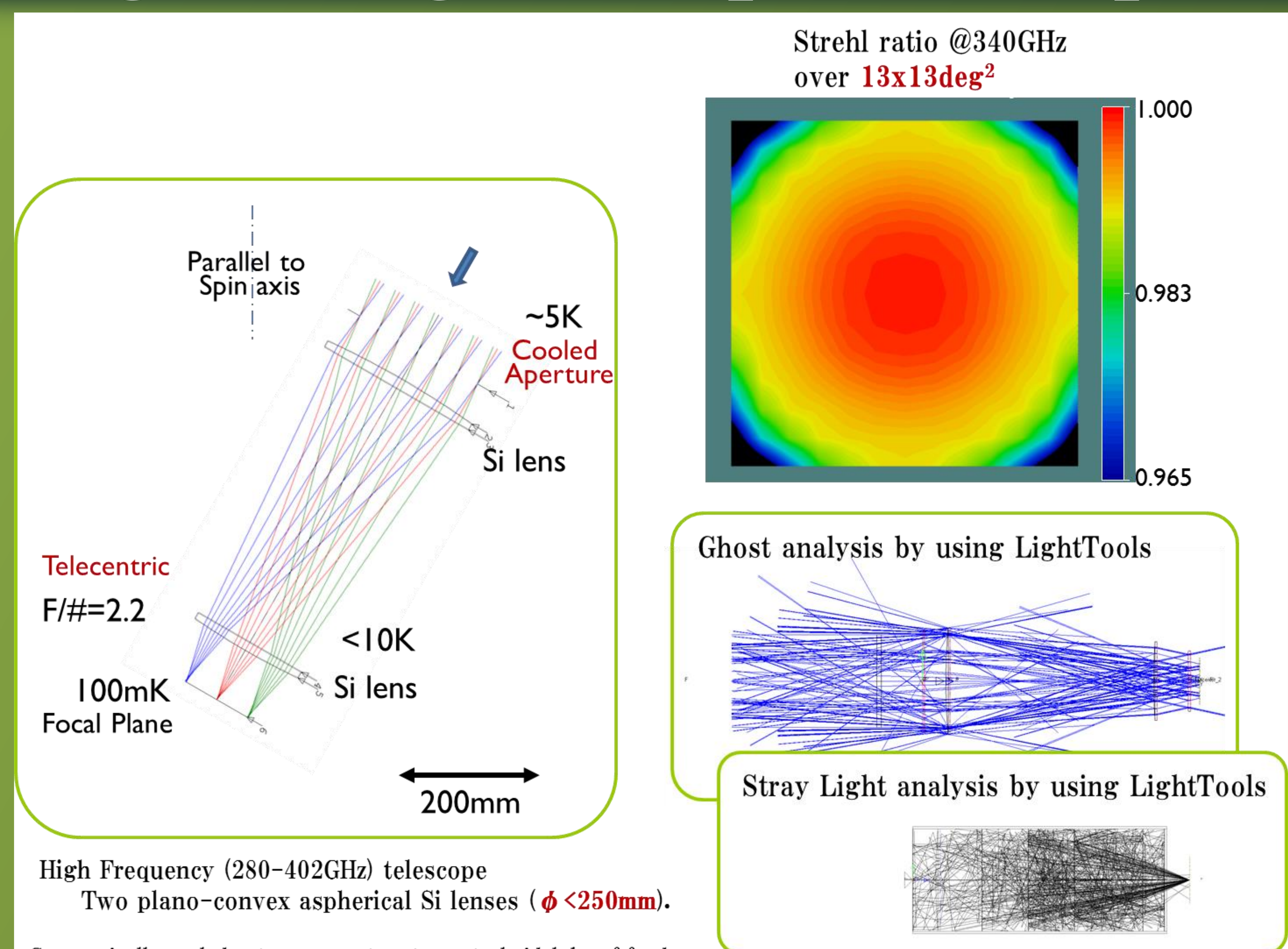
Detailed studies



Example of Statistics for Differential Point Spread Function (PSF) in the whole FOV: between 0° polarized and 90° polarized lights for case with 8um dimpling at 30mm pitch. Each entry corresponds to one grid point at FOV.



2. Designing of High Freq Telescope – Refractors



High Frequency (280–402GHz) telescope
Two plano-convex aspherical Si lenses (ϕ <250mm).

Cryogenically cooled entrance aperture to control sidelobe of feed.