Estimating the rotational energy loss of a superconducting magnetic bearing for LiteBIRD

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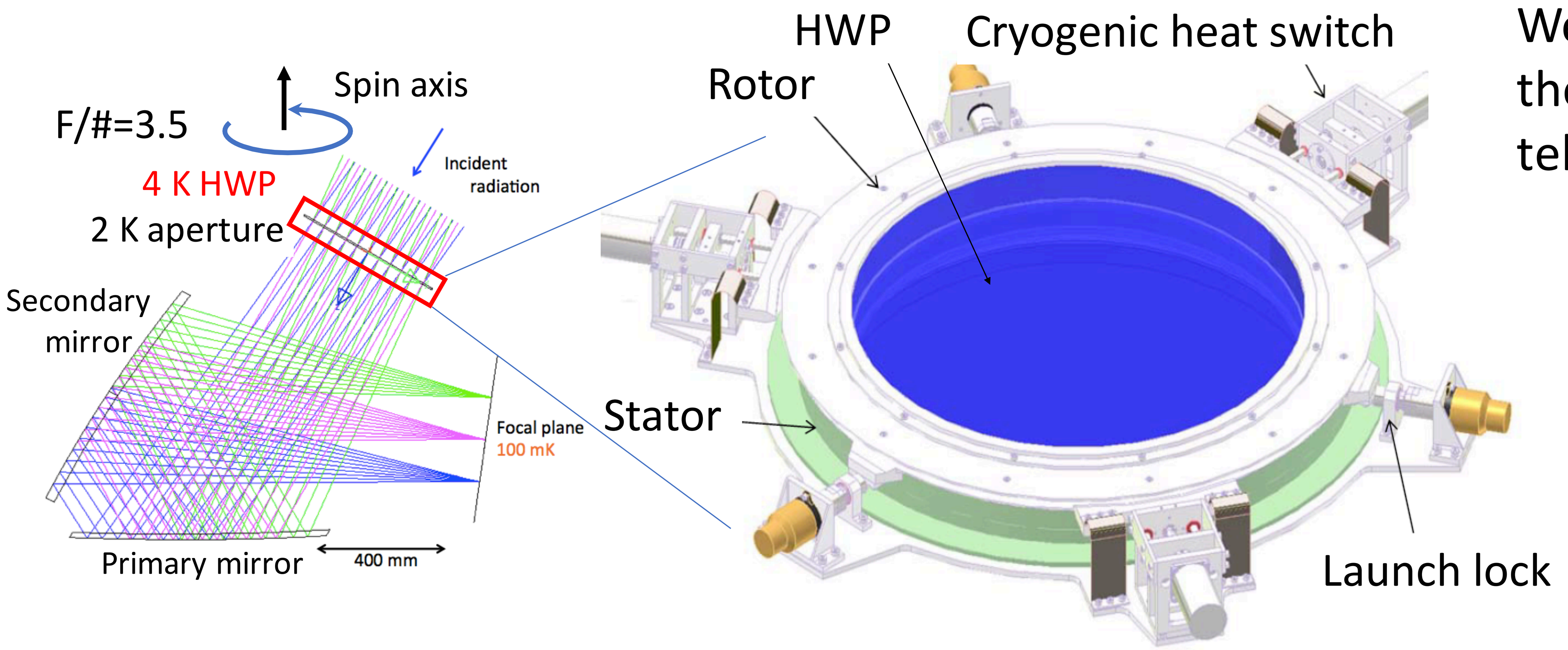
Introduction

- The inflation signal in the B-mode power spectrum appears at low ℓ, i.e. large angular scale, and thus the it is essential to be able to make a distinction between the signal and the 1/f noise from the observational system including the detector and readout.
- Introducing a polarization modulator is one of the standard techniques to overcome this problem. The baseline design of LiteBIRD employs a continuously rotating half-wave plate (HWP) based polarization modulator. LiteBIRD is in PhaseA1, and we focus on some of the key development items.
- We present the dynamical characteristics of the rotational mechanism using our prototype system.

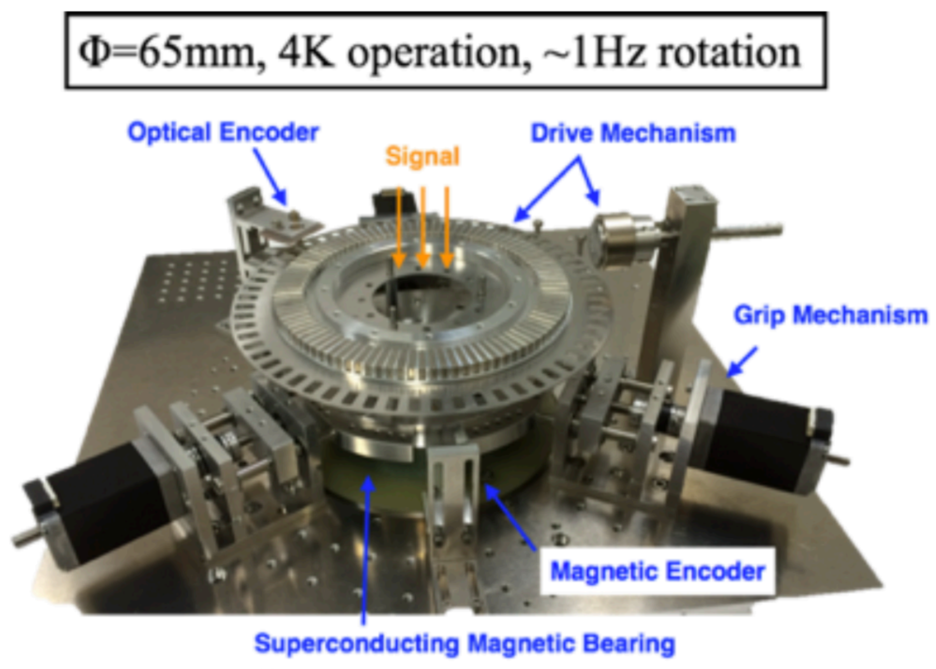
Overview of Polarization Modulator for Low Frequency Telescope



We focus the development that is specifically for the polarization modulator of the low frequency telescope (LFT) of LiteBIRD.

- A HWP is placed at the aperture and as a first optical element.
- The HWP is cooled **below 10 K**.
- The frequency coverage of the LFT is **34-270 GHz** (edge-to-edge).
- The aperture diameter is 400 mm, and correspondingly the HWP diameter is **450 mm**.
- The HWP rotates at about **1 Hz**.

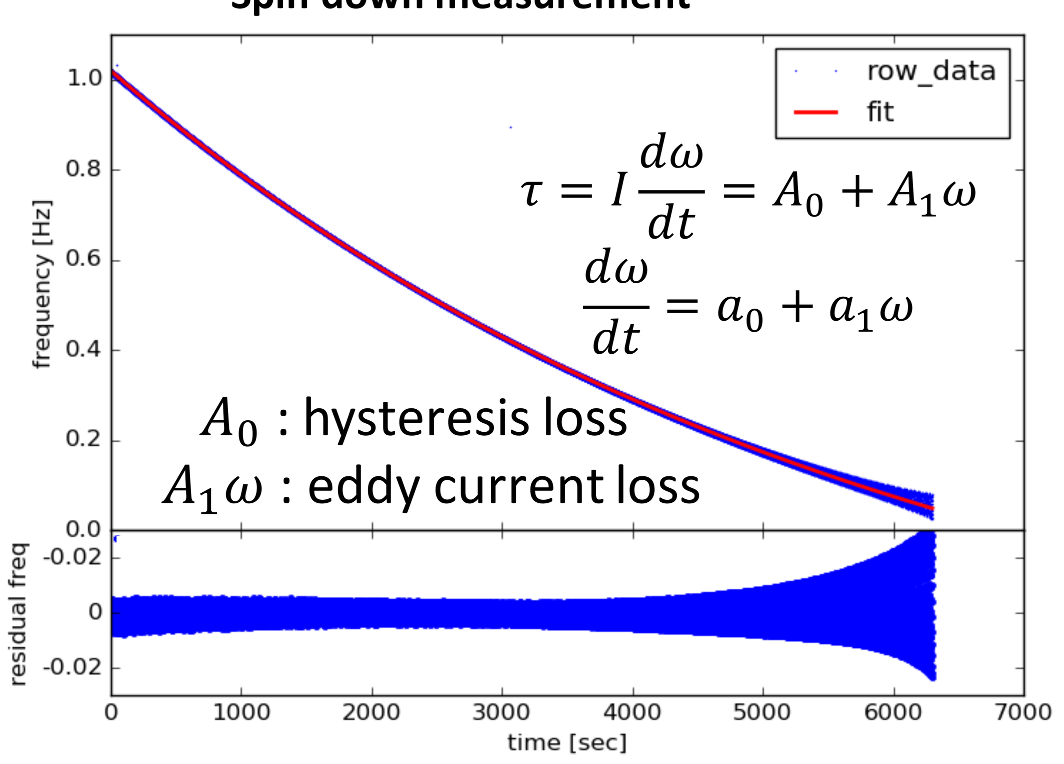
Dynamical characteristics using our prototype system



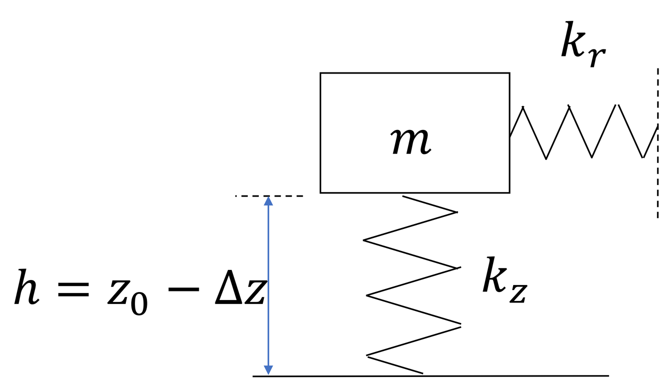
Prototype

We employ the superconducting magnetic bearing (SMB) to achieve the minimal heat dissipation from the mechanical rotation. While it is a levitation based bearing, it has electromagnetic friction. We carried out the spin down measurement and the stiffness characterizations with various rotor masses in order to establish the SMB model. From these data set, we can simulate the SMB dynamics under gravity.

Spin down measurement

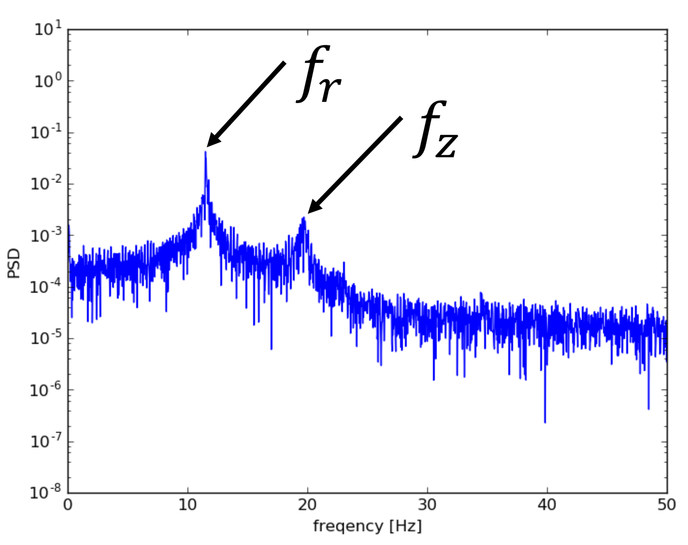


SMB spring model

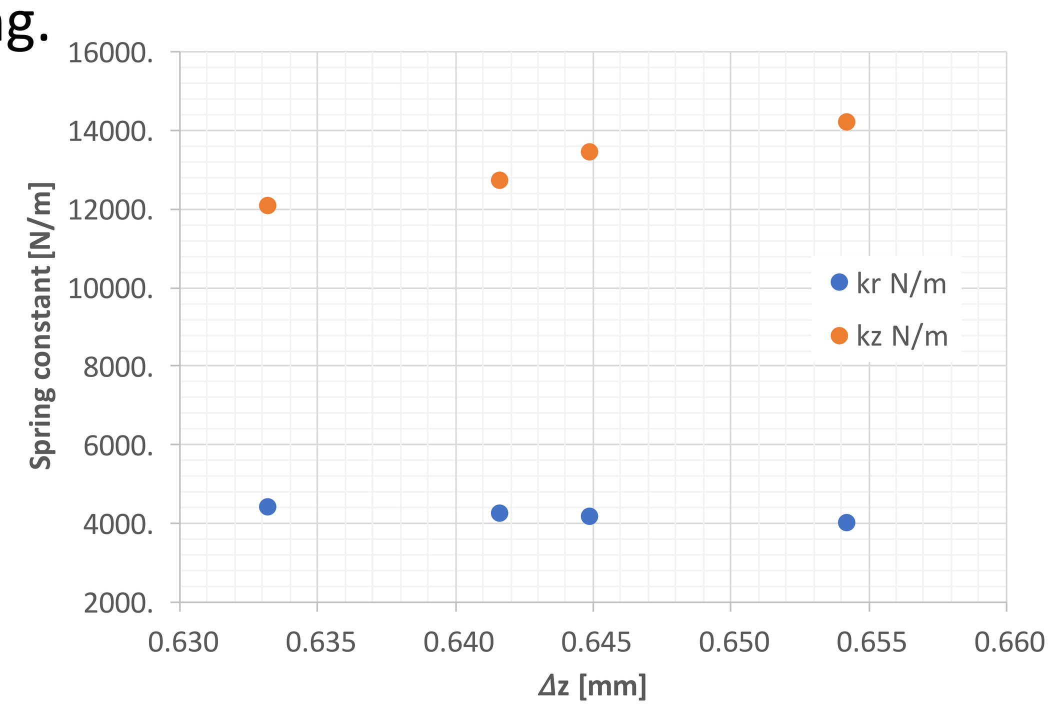


In space, there is no gravity. In order to understand the dynamical characteristics of the SMB, the experimental results on the ground have to be extrapolated. We conducted the measurement of a spring constant with 4 different rotor masses when the rotor is levitating. Correspondingly, the levitation height varies due to the extra mass after the field cooling.

The spring constant given each mass is estimated from the resonance frequency. The spring constant of the SMB is purely determined by the magnetic field configurations, and thus the spring constant is different with and without the presence of the gravity. Due to the non-linear nature in the estimation of the spring constant, the spring constant with no gravity has to be estimated by the simulation, and it's in progress.



Resonance frequency



Levitation height	rotor mass [kg]	a_0 $[1/s^2]$	a_1 $[1/s]$	A_0 $[1/s^2\text{gcm}^2]$	A_1 $[1/\text{sgcm}^2]$	f_r [Hz]	f_z [Hz]	$k_r [N/m]$	$k_z [N/m]$	Δz [mm]
5 mm @ 10-16 K	0.783	-1.3×10^{-3}	-2.2×10^{-4}	-3.31	-5.58					
6 mm @ < 10 K	0.783	-6.60×10^{-4}	-1.98×10^{-4}	-1.68×10	-5.03	12.00	19.80	4.451×10^3	1.212×10^4	0.633
6 mm @ < 10 K	0.835	-4.85×10^{-4}	-1.74×10^{-4}	-1.24×10	-4.45	11.44	19.67	4.314×10^3	1.275×10^4	0.642
6 mm @ < 10 K	0.888	-1.43×10^{-4}	-1.05×10^{-4}	-3.69×10^2	-2.72	10.98	19.62	4.226×10^3	1.350×10^4	0.645
6 mm @ < 10 K	0.951	-1.16×10^{-4}	-9.75×10^{-5}	-3.02×10^2	-2.53	10.19	19.48	3.898×10^3	1.425×10^4	0.654

Summary

We measure the stiffness and the energy loss of the SMB with various rotor masses. These properties depend on the rotor mass due to the distance between the rotor permanent magnet and the YBCO. From these data set, we can simulate the SMB dynamics under no gravity. The modeling and its extrapolation is in progress.