Design and evaluation of a cryogenic continuous rotation stage for CMB polarization modulation on POLARBEAR-2

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SPIE.





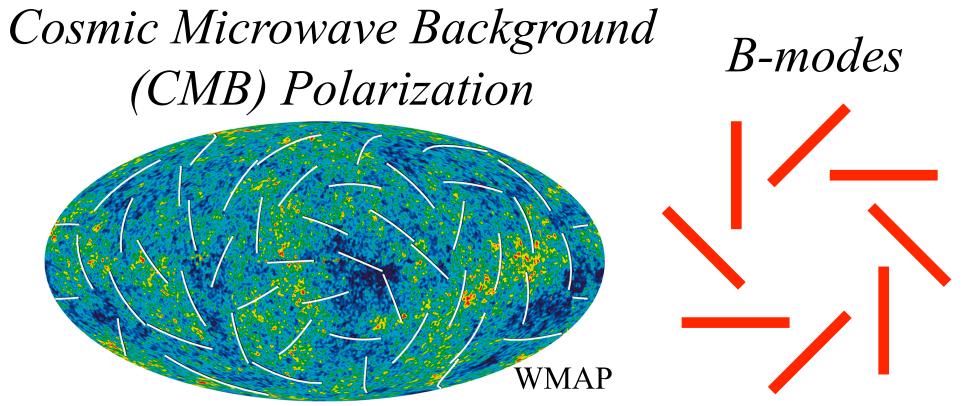
SIMONS FOUNDATION

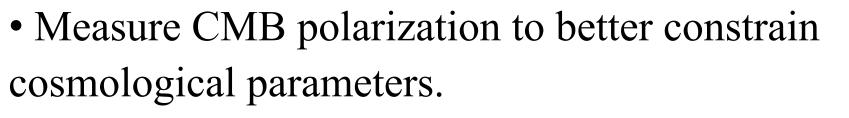






Science Motivation



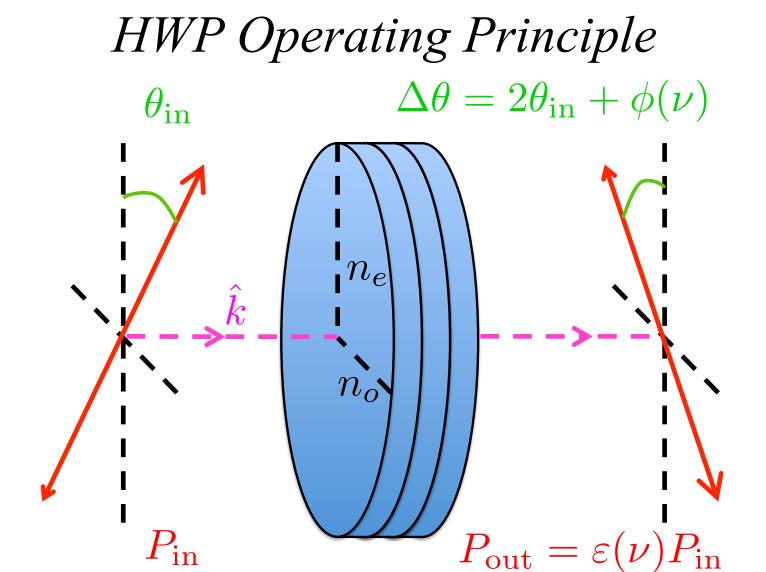


• Detect B-modes created by inflationary gravitational waves to confirm and characterize inflation.

Huan Tran Telescope



Half-wave Plate (HWP) Concept



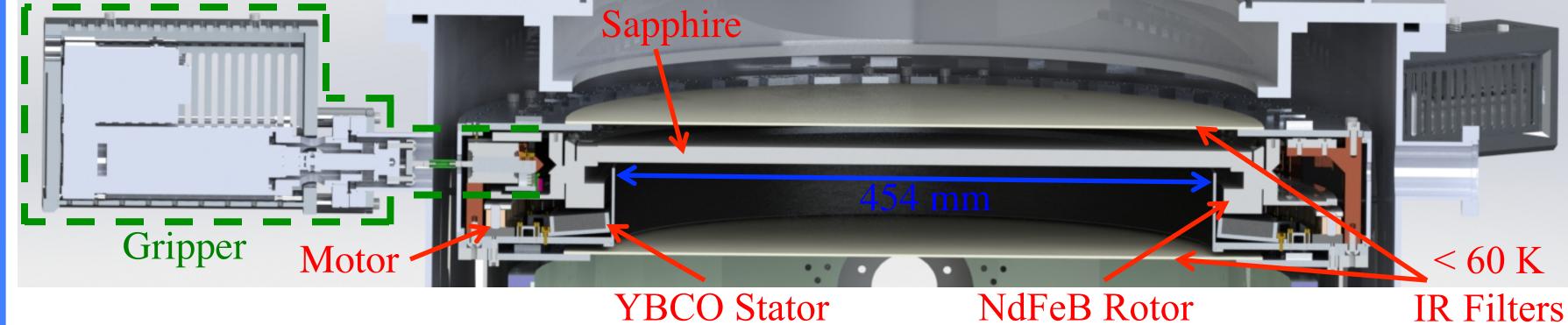
- A HWP rotates linear polarization while preserving input polarization fraction.
- The HWP can be made broadband by stacking multiple birefringent plates in an optimized orientation.

HWP Polarization Efficiency*					
1.0					
	90GHz		150GHz		
50.9					
Modulation Efficiency $\varepsilon(\nu)$					
n Eff					
oj 0.7				-	
[oqn]					
≥ 0.6	/ [-	1 pl			
0.5		1	ates	100	
Frequency [GHz]					

Config	ε (90 GHz)	ε (150 GHz)
1 Plate	0.721	0.780
3 Plates	0.99 ± 0.01	0.99 ± 0.01

*C. A. Hill et al, SPIE 2016, <u>10.1117/12.2232280</u>

CHWP Rotation Stage (CRS) Design



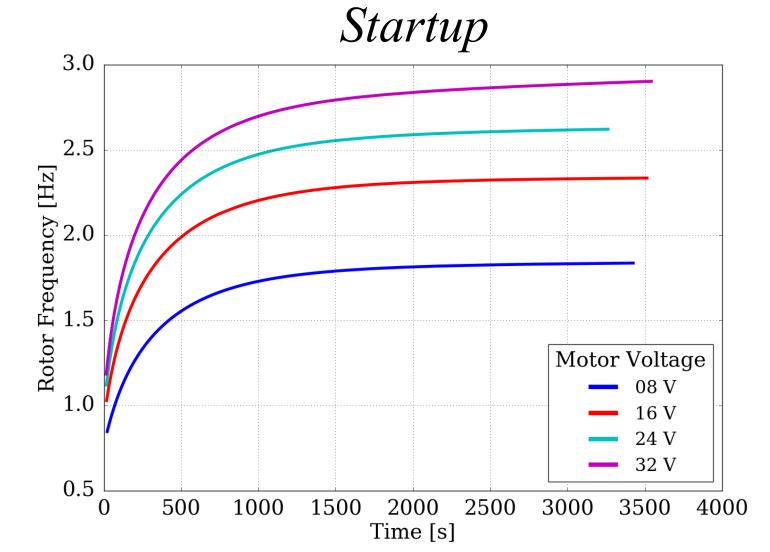
Motor Driver Design CRS Assembly (< 60 K) PD Sprocket Slotted Plate Half-H Driver Half-H Driver

• A custom motor driver uses an optical encoder to generate a three-phase AC input to an array of electromagnets on the stator stage.

Standalone Testing 454 mm

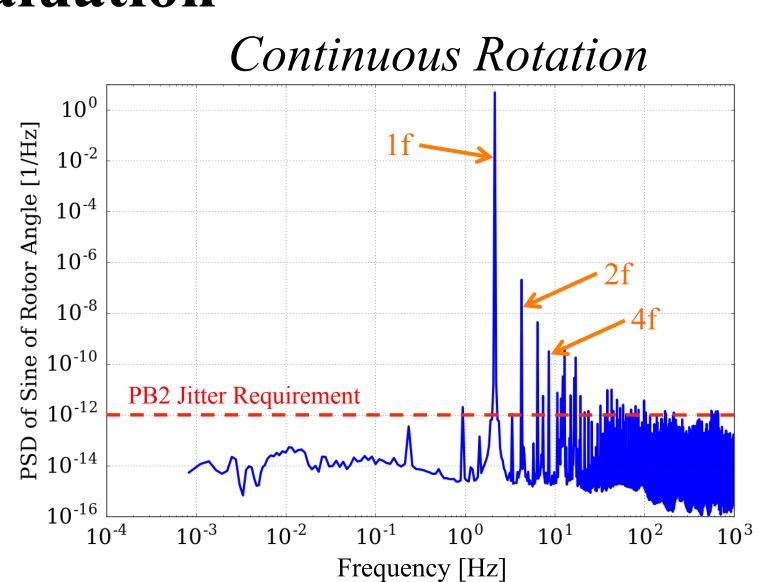
• CRS testing is performed at LBNL prior to integration with PB2 using a Gifford McMahon (GM) cooler in a dark test cryostat.

CRS Evaluation



- The rotation frequency is tuned by setting the voltage supply to the motor driver.
- The startup time is ~5 minutes, which can be improved with PID control.

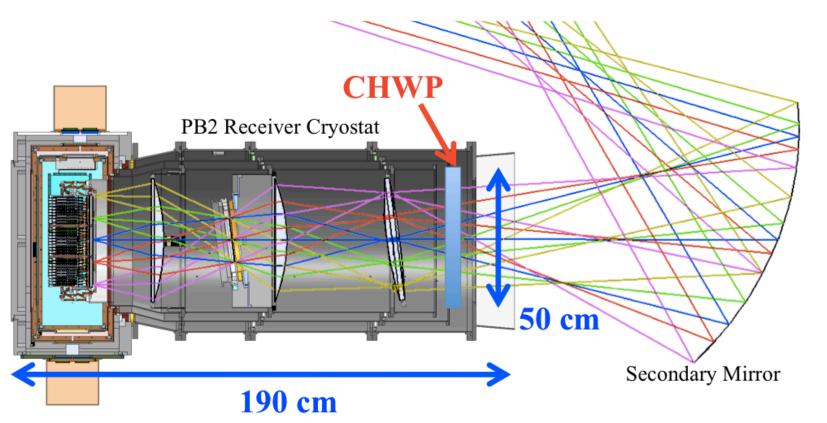
Power Dissipation



• Continuous rotation and data acquisition for one hour shows a clean sine wave with suppressed harmonics, good low-frequency performance, and a low noise floor.

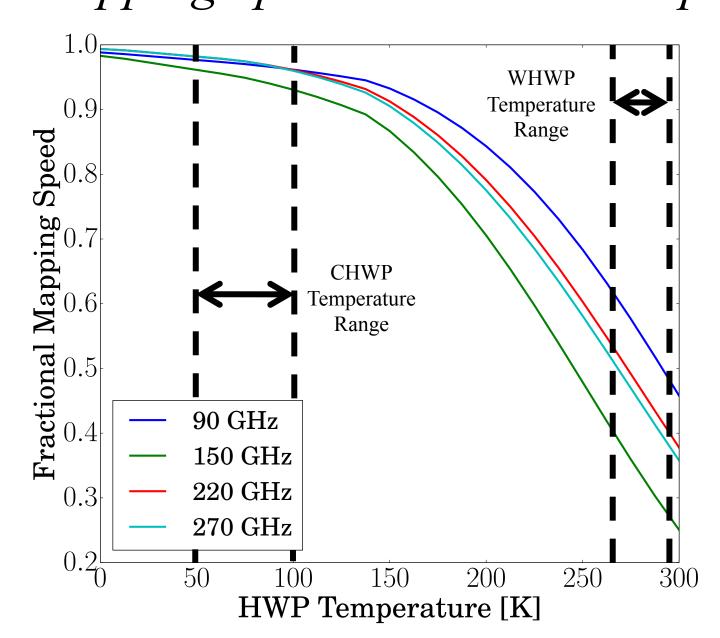
POLARBEAR-2 (PB2) Cryogenic HWP (CHWP) Specs





Parameter	Requirement	Design
Clear aperture	> 450 mm	454 mm
Temperature	< 100 K	< 65 K
Rot Freq	2 Hz	≤ 3 Hz
Angle Jitter	$< 1 \mu rad/\sqrt{Hz}$	$< 0.3 \mu rad/\sqrt{Hz}$
Heating	< 1 W	< 0.2 W
4f Mag Field	$< 10^{-1} G$	$< 10^{-5} \mathrm{G}$

Mapping Speed vs. CHWP Temp

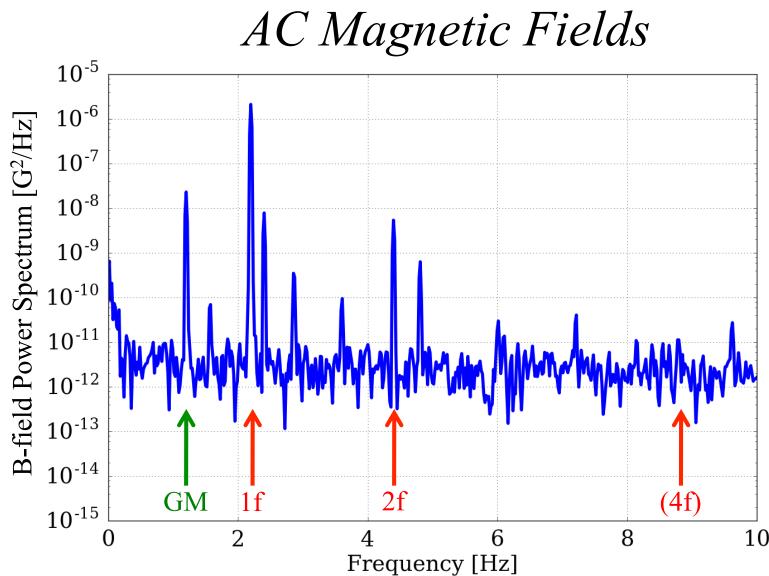


• The mapping speed impact of installing a < 100 K CHWP is < 10%, while the mapping speed cost of installing an ambient temperature HWP is ~50%.

• The measured power dissipation onto the stator at 2 Hz rotation due to rotor friction and solenoid dissipation is < 0.2 W at 35 K.

2.5

3.0



• The AC mag field \sim 1 m from the rotor is primarily at 1x and 2x the rotation frequency. The 4f line is below the \sim 10⁻¹¹ G² noise floor.