SAPIENZA
UNIVERSITÀ DI ROMA

INFN

HWP modulator in Rome

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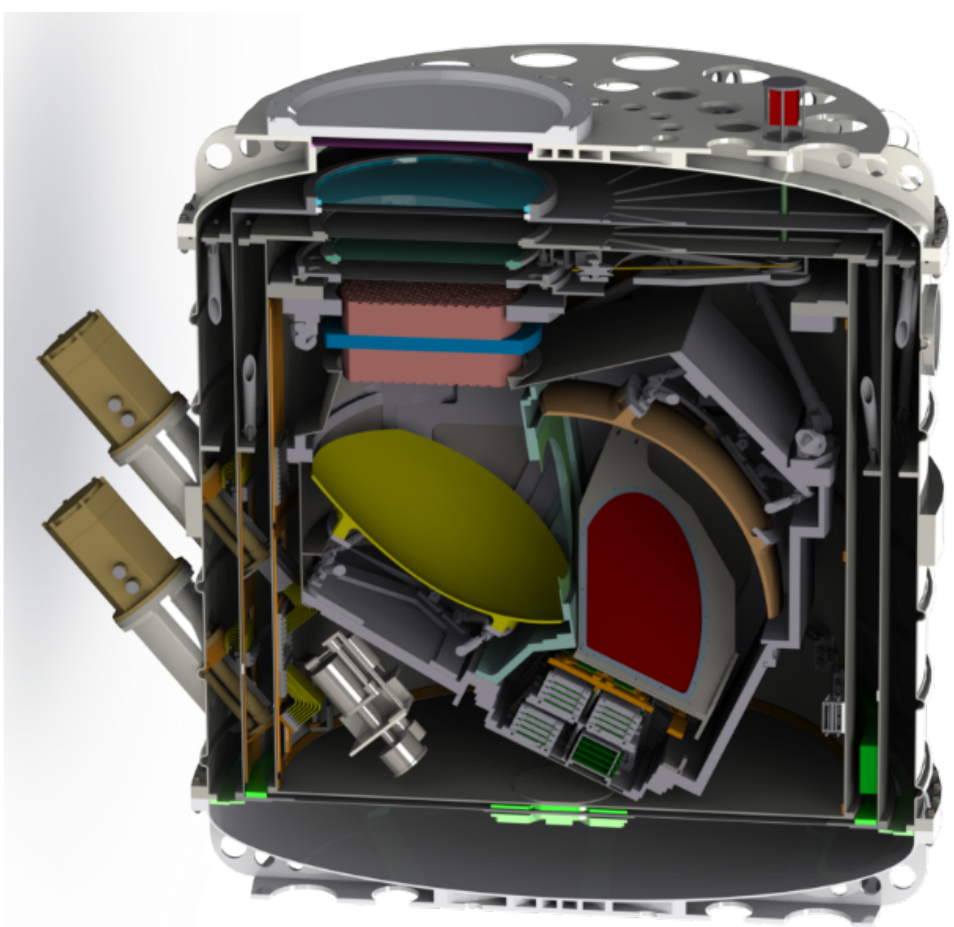
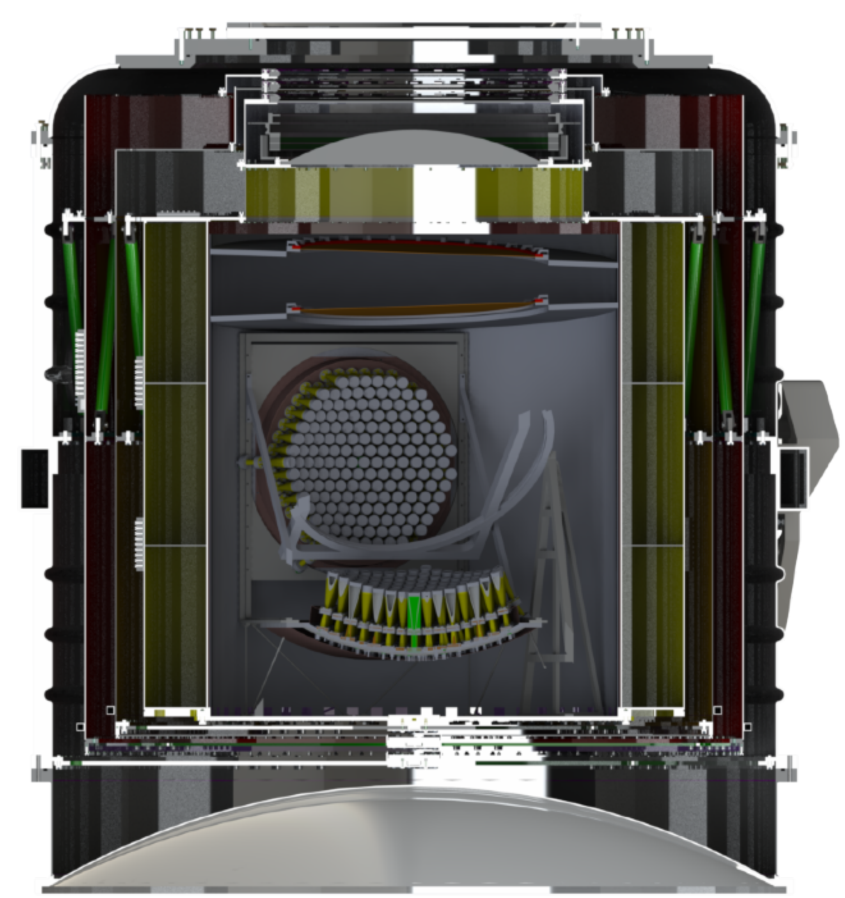
B-mode From Space, 4-6/12/2017, Berkeley

Polarization modulator

QUBIC		LSPE
Ground-Based	**Type**	Balloon
End of 2018	**Start**	2019
(T.D.)185 / (F.I.)400 mm	**Hwp Diameter**	500mm
4K	**Hwp Temperature**	4K
Step	**Rotation system**	Continuous

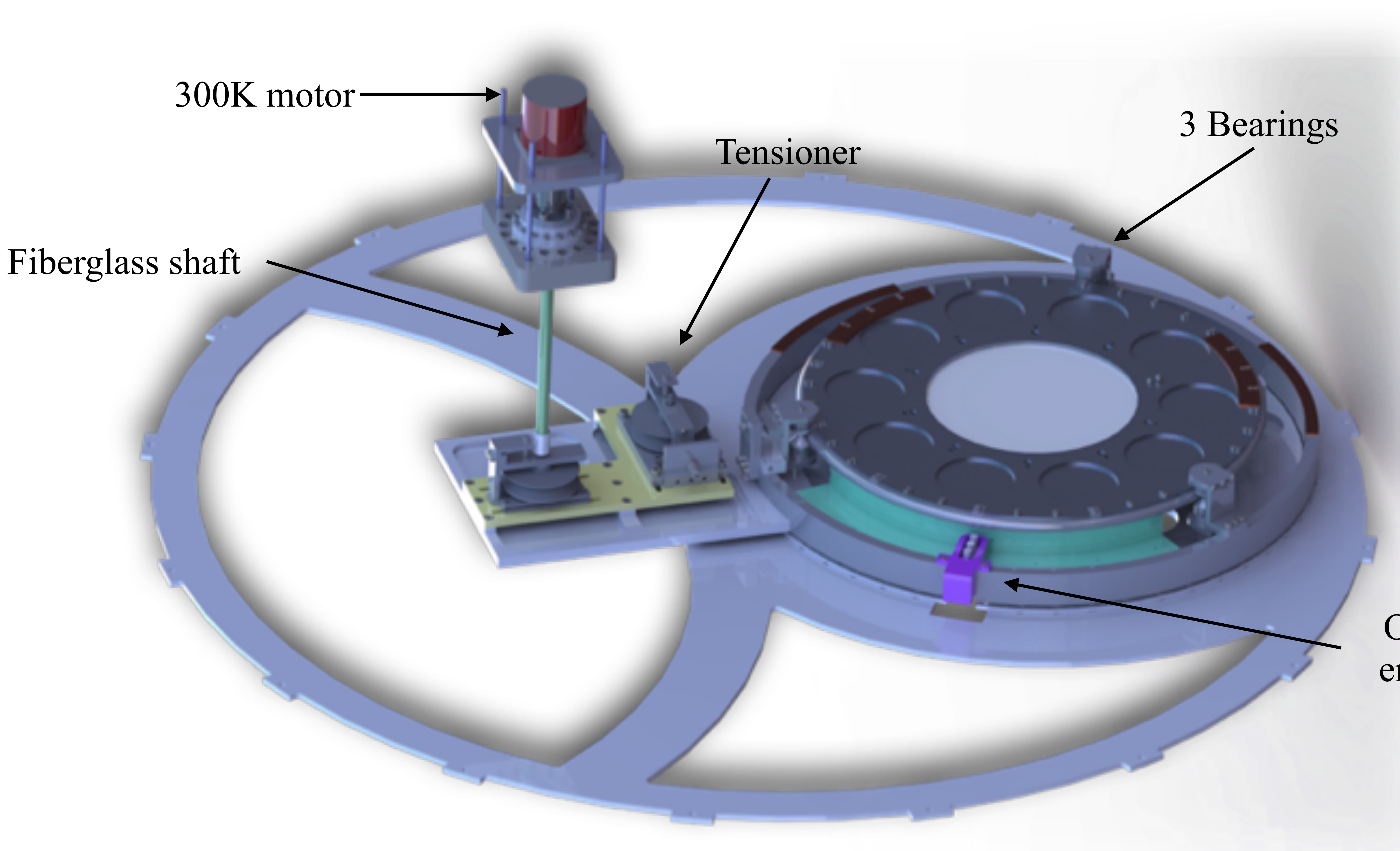




Courtesy of G. D'Alessandro

QUBIC Hwp

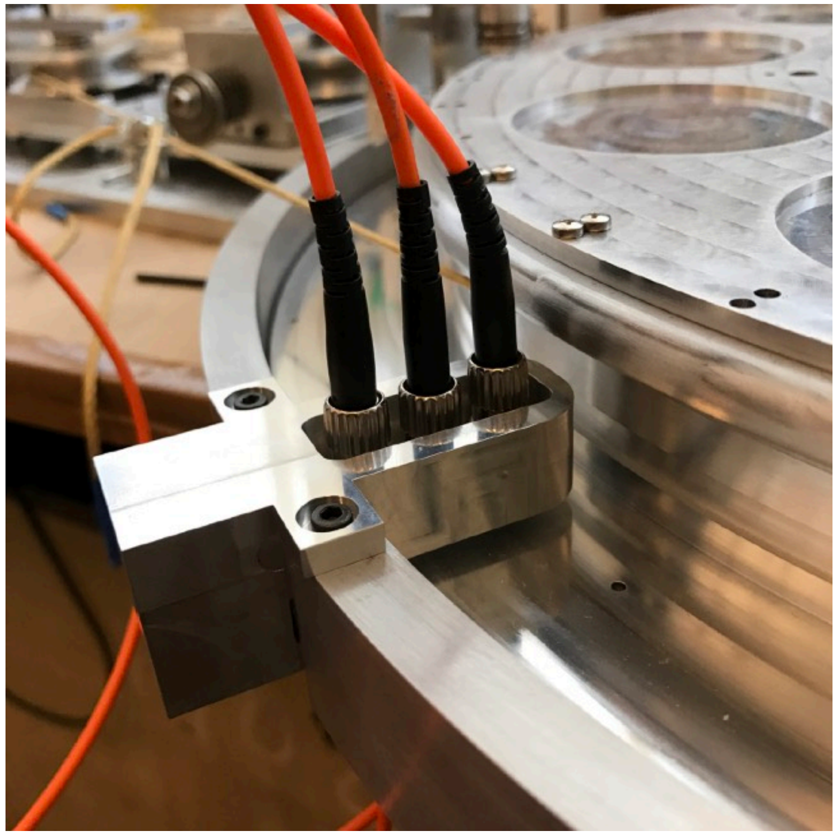
Crew: Giuseppe D'Alessandro, Fabio Columbro, Paolo de Bernardis, Silvia Masi, Lorenzo Mele



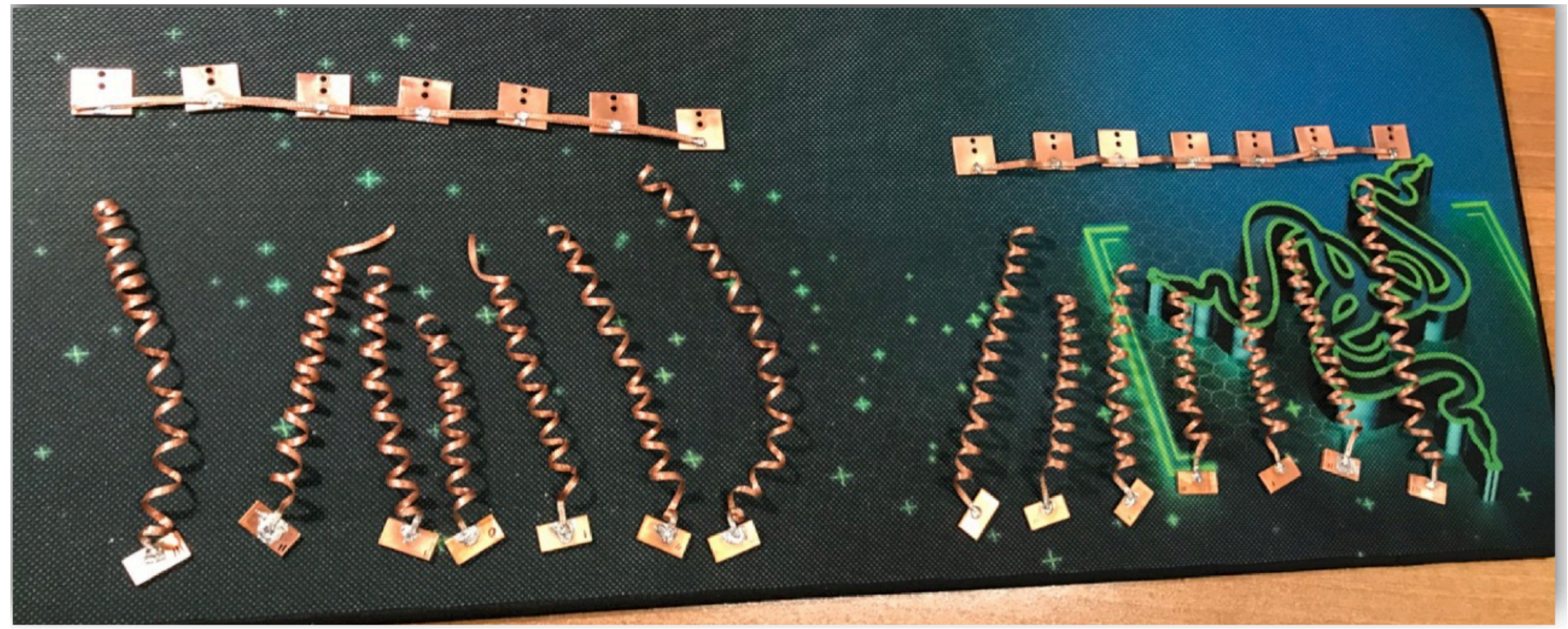
Courtesy of G. D'Alessandro

QUBIC Hwp

3 bits optical encoder

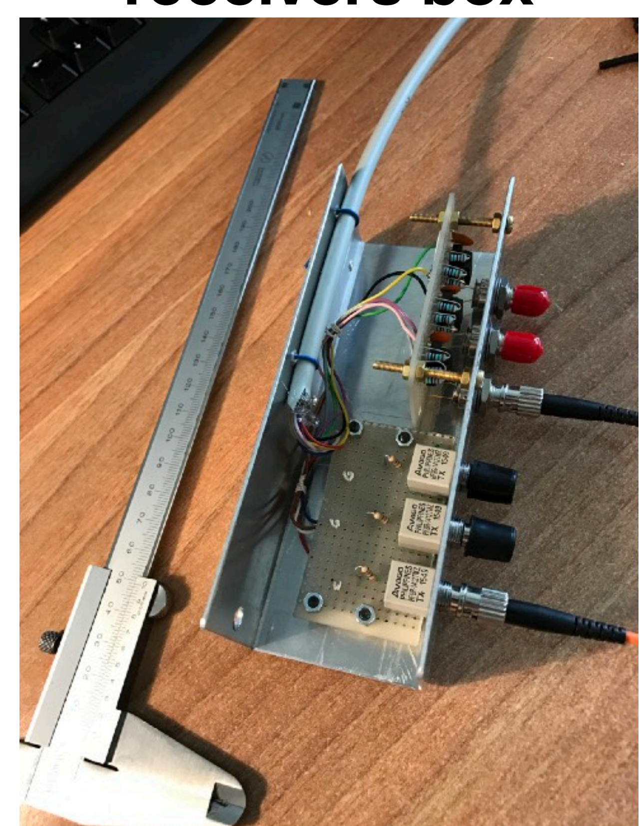


Elastic thermalization kit

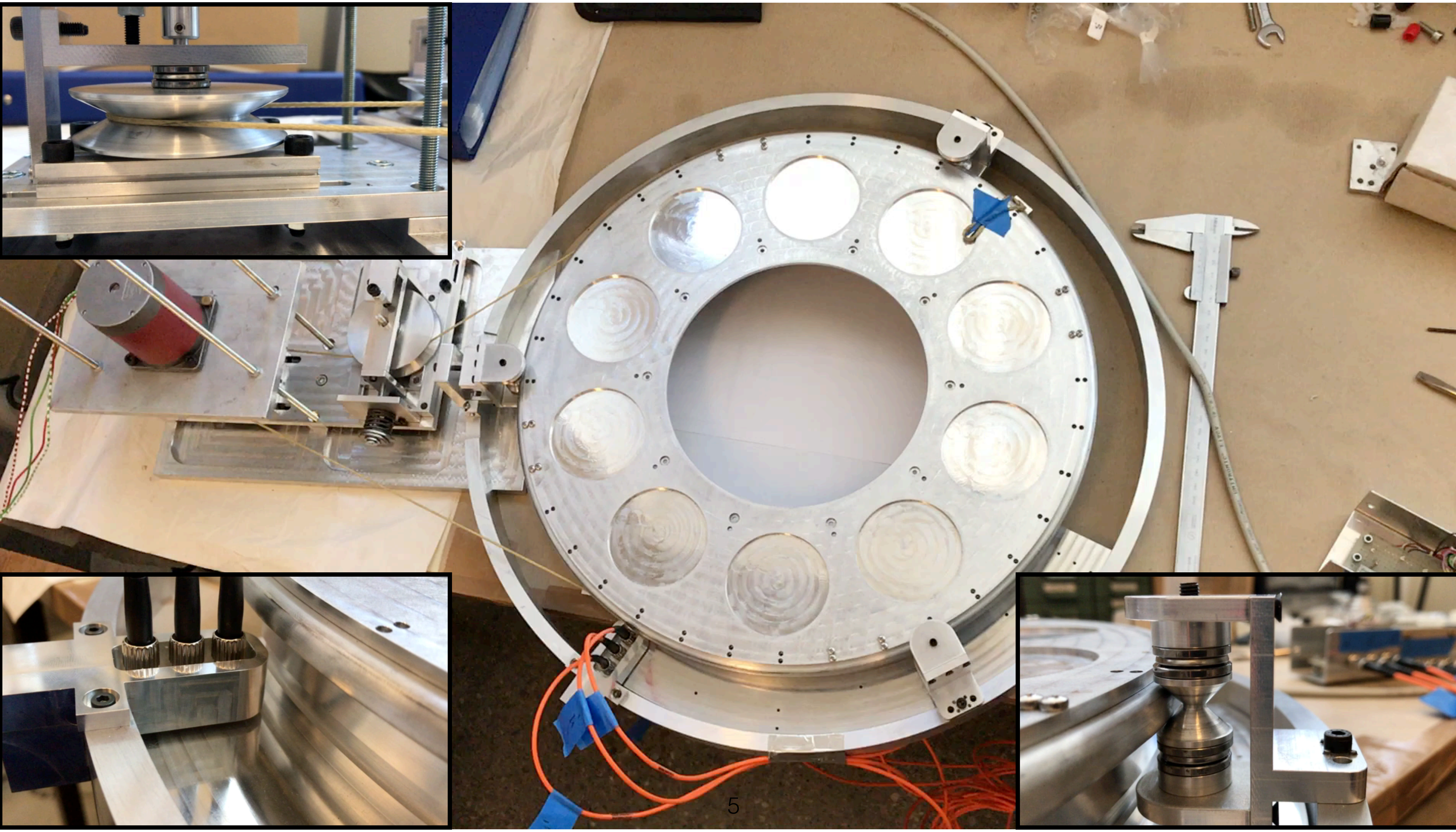


External control box

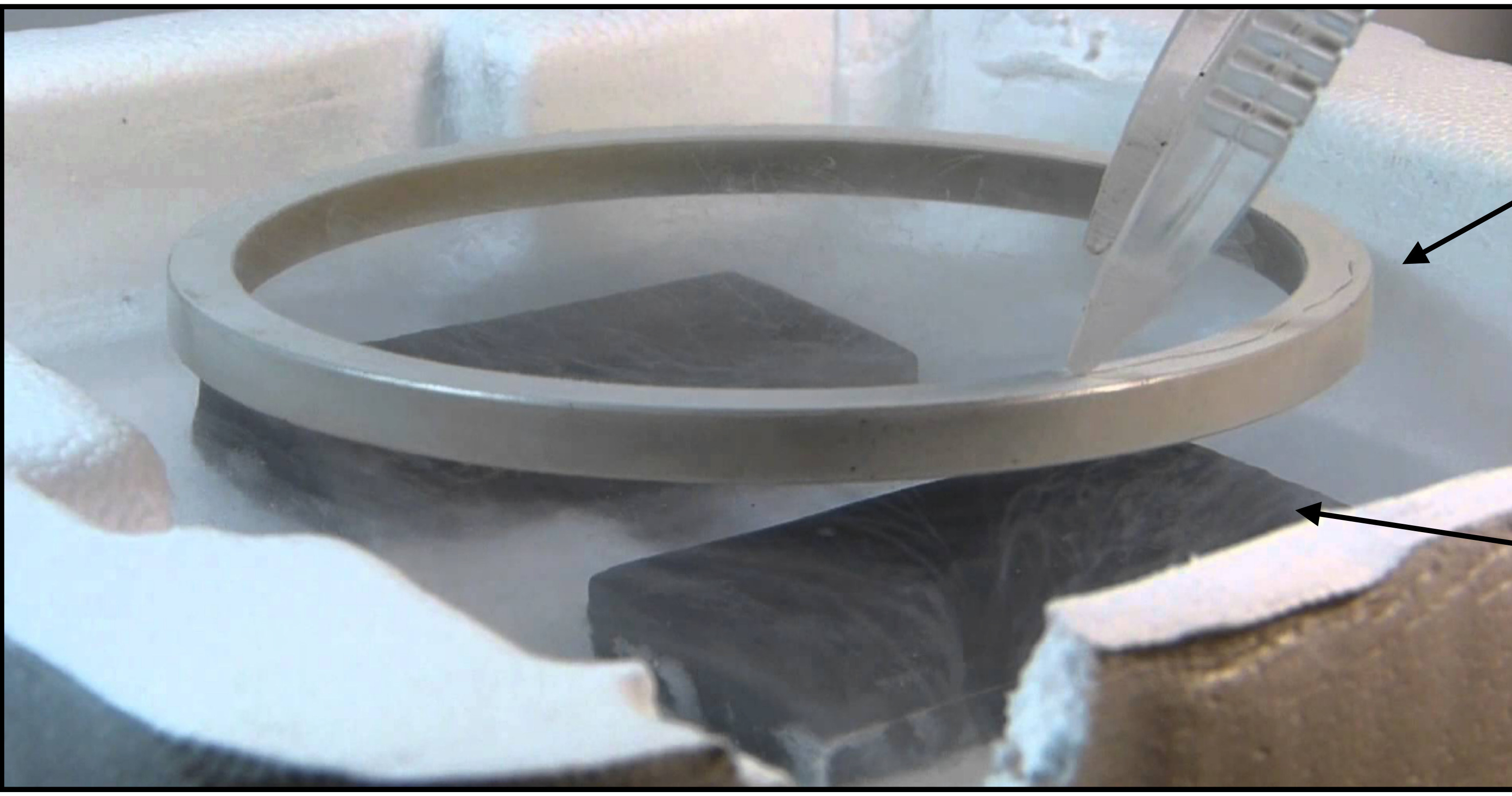
Transmitters and receivers box



QUBIC Hwp



Superconducting Magnetic Bearing



Permanent magnet ring

High Temperature Superconductors

Pros

- NO stick-slip friction
- NO extra-effort to cool HTSs
- Passive stable levitation
- Low Coefficient of friction
- Continuous rotation (0-10Hz)

Cons

- Variable magnetic field
- Clamp mechanism at 4K

S. Hanany et al., IEEE Trans.Appl.Supercond. 13 (2003) 2128-2133

T. Matsumura et al., IEEE Trans.Appl.Supercond. 26 (2016)

SMB prototype

REVIEW OF SCIENTIFIC INSTRUMENTS **88**, 105102 (2017)

A large-diameter hollow-shaft cryogenic motor based on a superconducting magnetic bearing for millimeter-wave polarimetry

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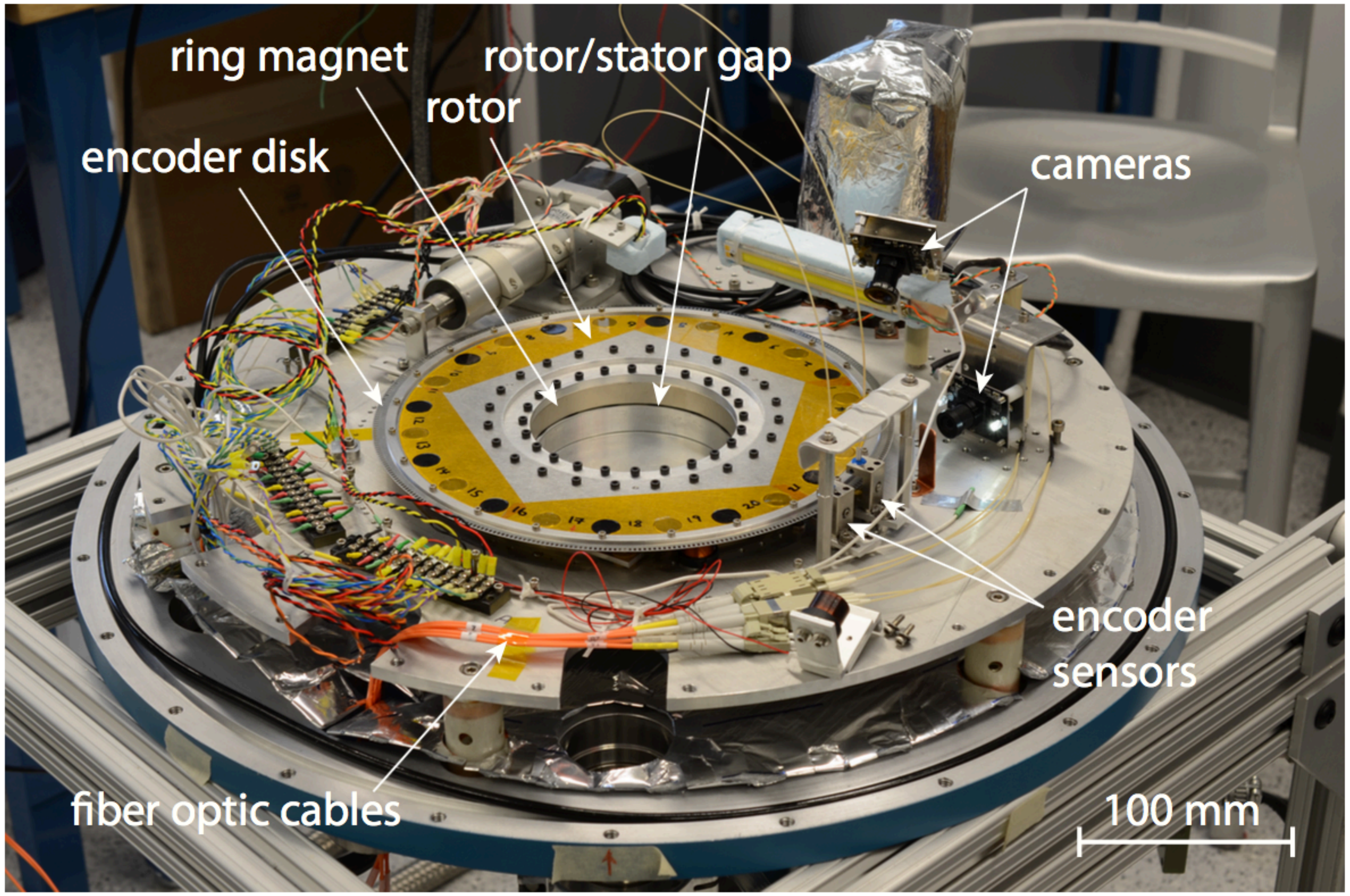
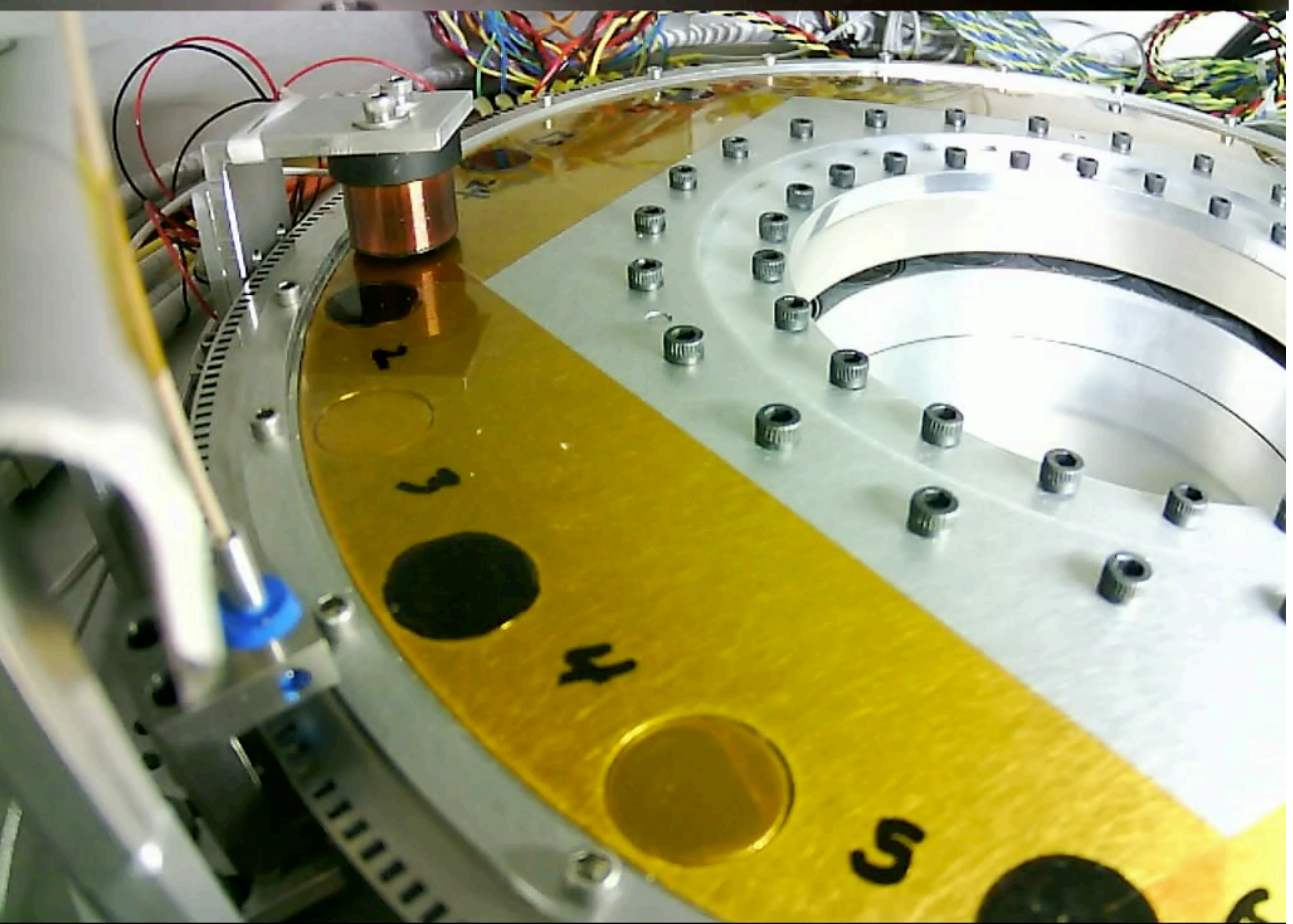


SMB Prototype



T ~ 60K

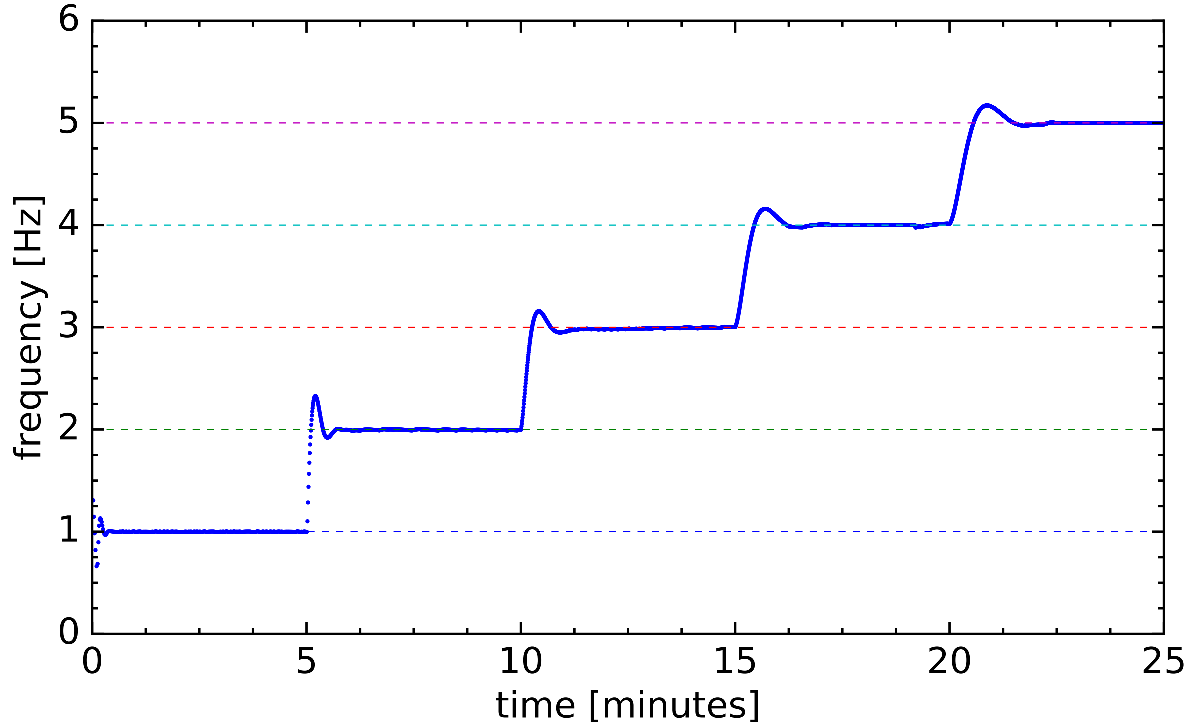
Encoder diameter 250mm

Frequency 0-10Hz

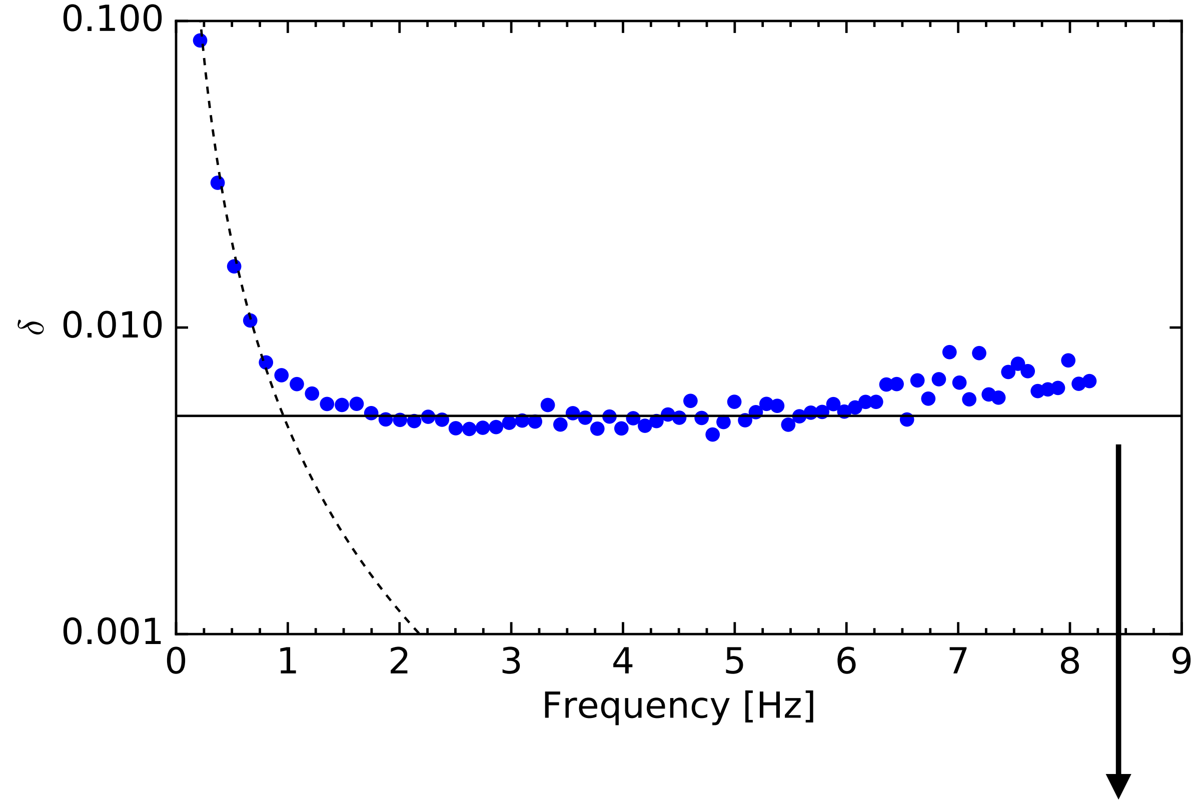
Angular position uncertainty <0.6”

SMB prototype

PID

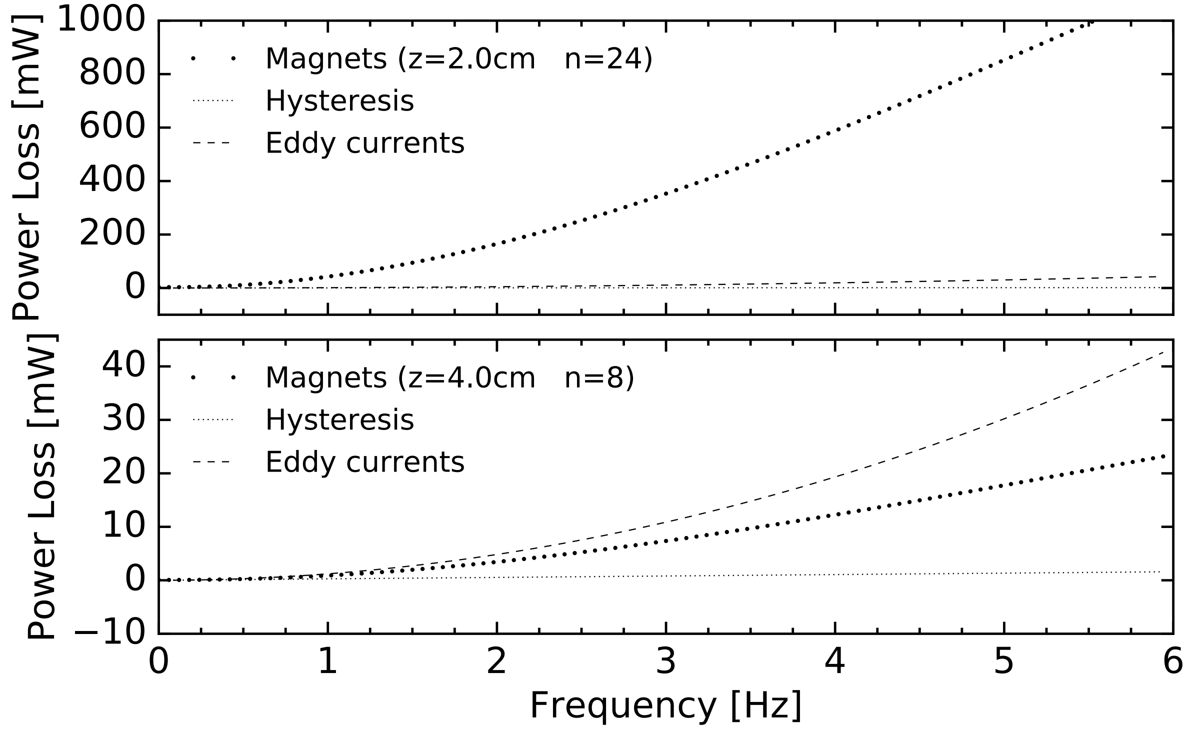


Frequency Variation



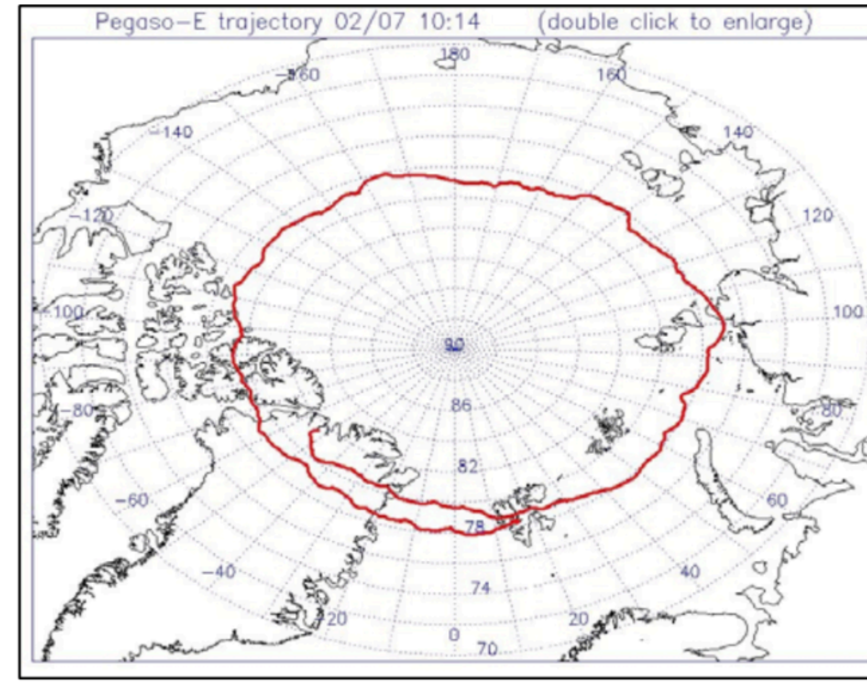
$$\Delta\theta_{max} = 0.15 \text{ deg}$$

Power Loss

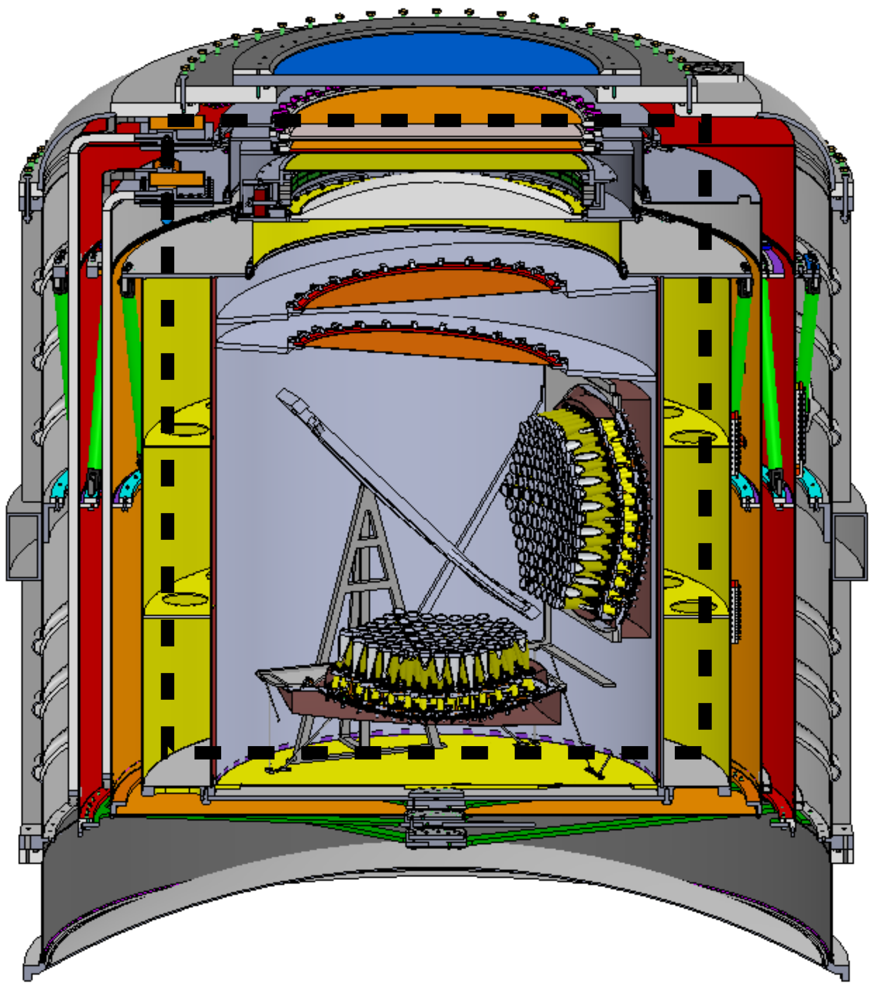


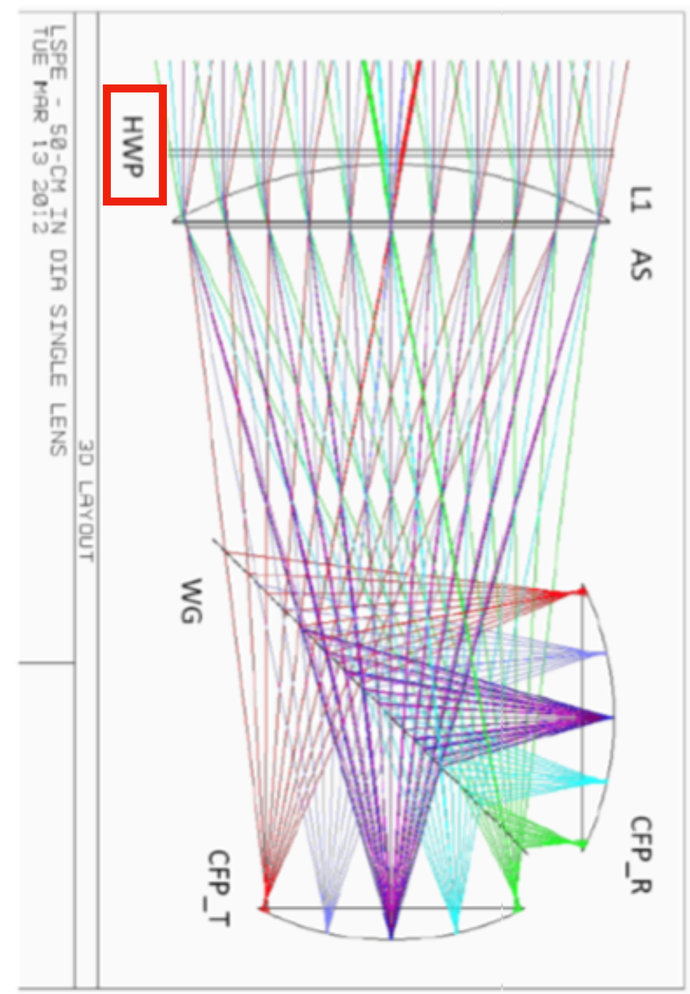
LSPE - SWIPE

The balloon will be launched from the Longyearbyen airport in Svalbard Islands in 2019. A demonstration flight was performed in 2011 shows the path of the test balloon to test the stratospheric circulation near the North Pole.



Target r = 0.03

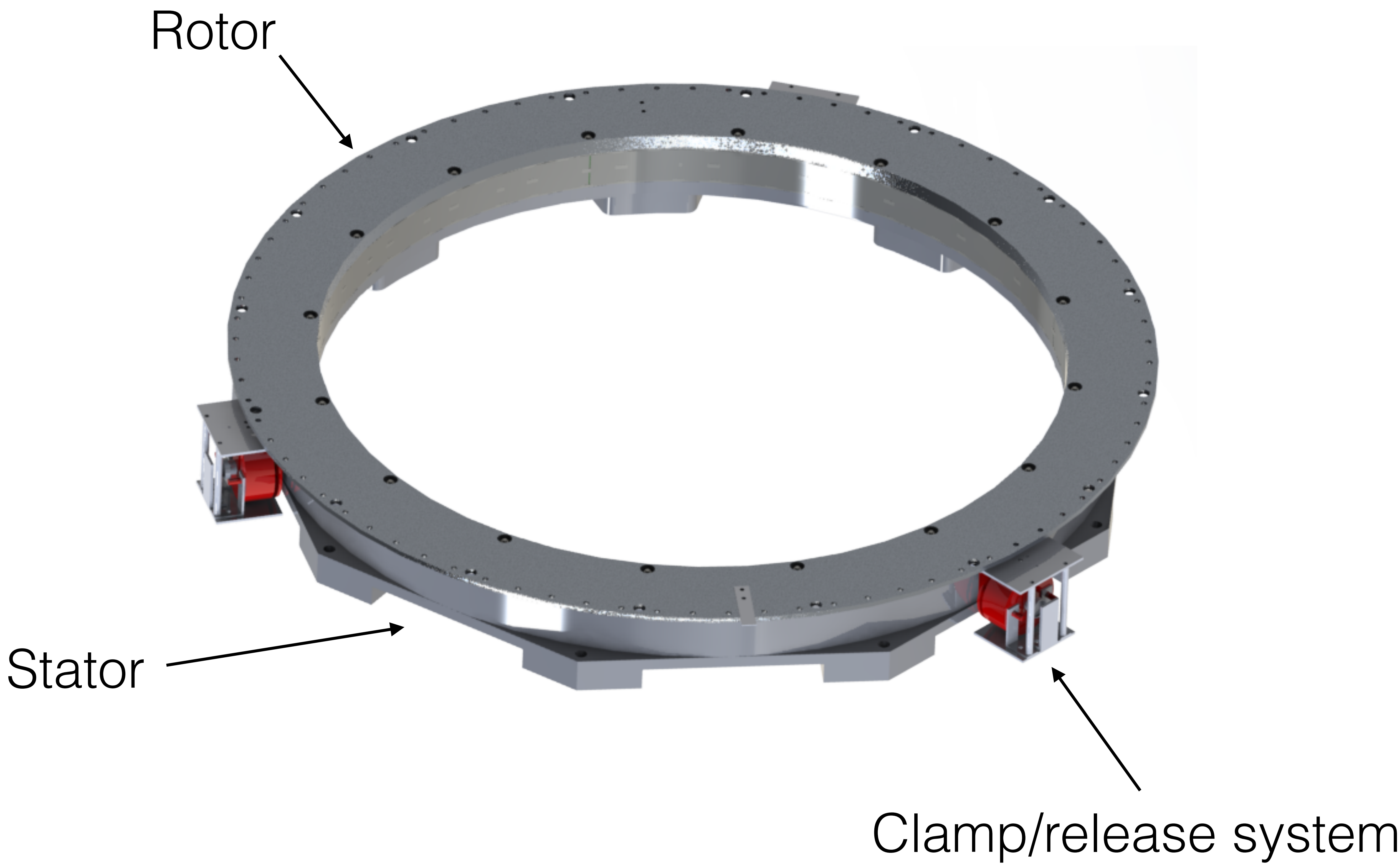




The LSPE collaboration, arXiv:1208.0281

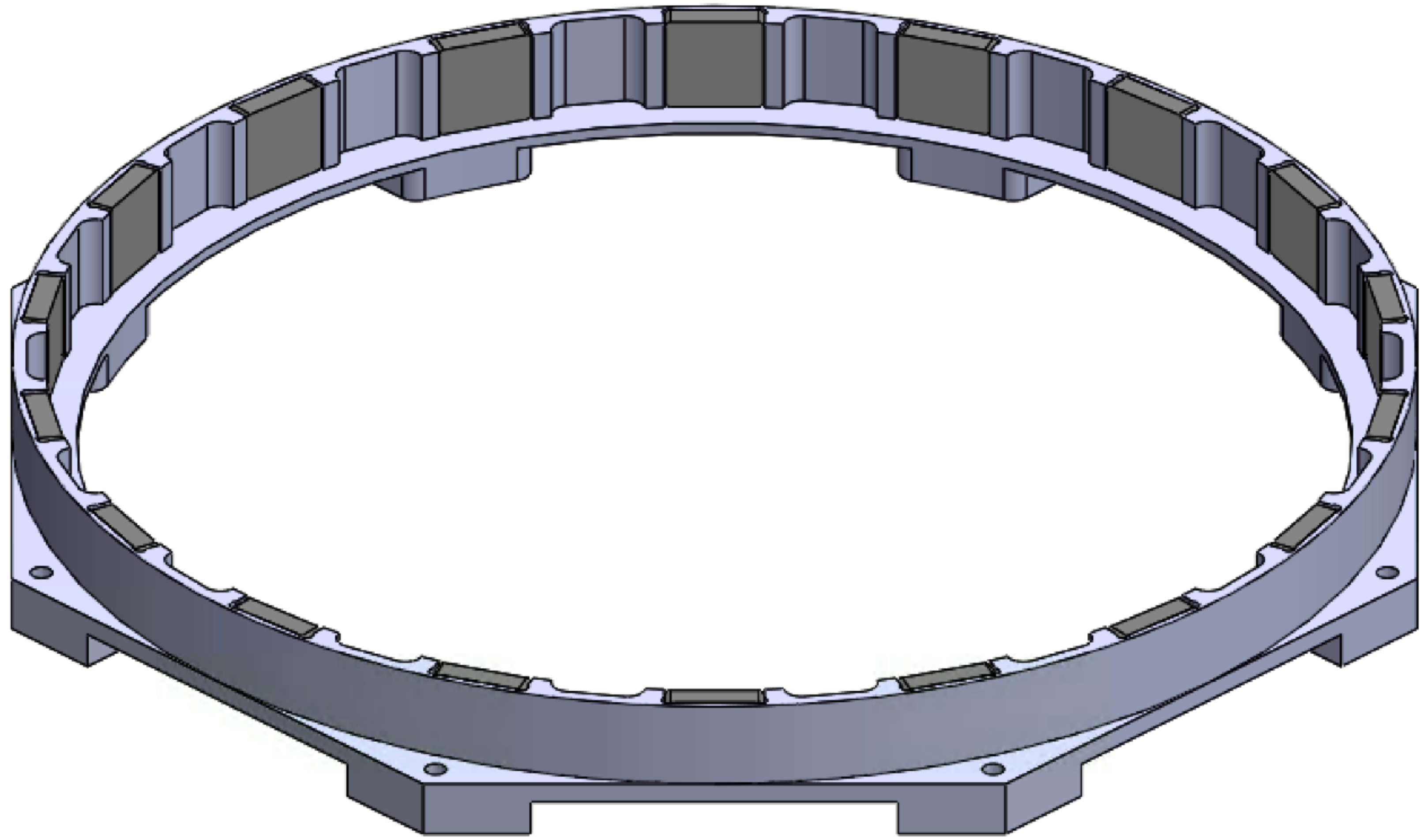
SWIPE Hwp

Crew: Fabio Columbro, Giuseppe D’Alessandro,
Paolo de Bernardis, Silvia Masi

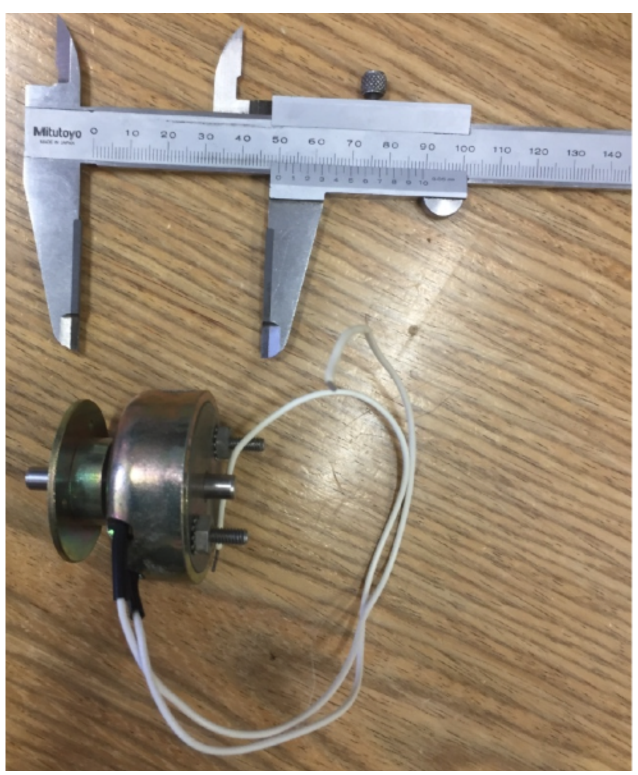


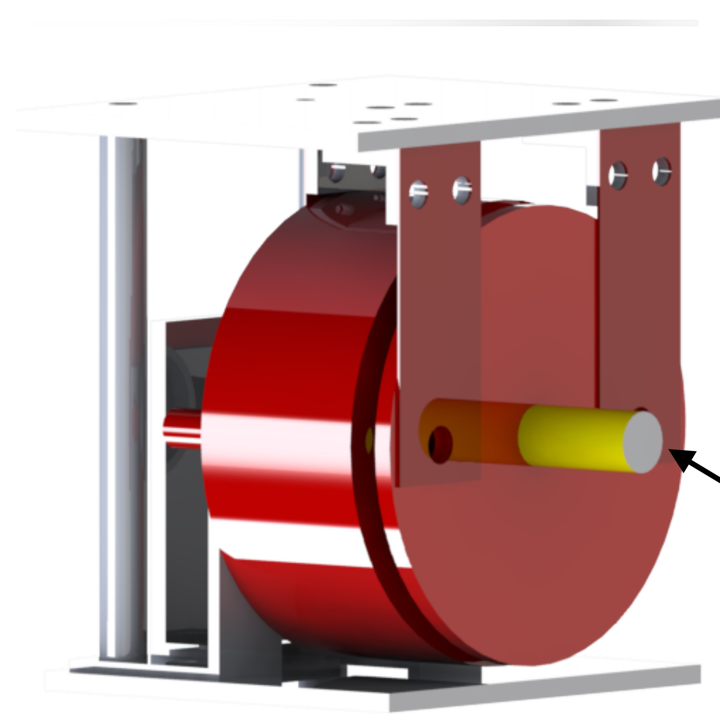
SWIPE Hwp - Stator

18 high temperature superconductor bulks



Linear actuator produced by Ledex Solenoids

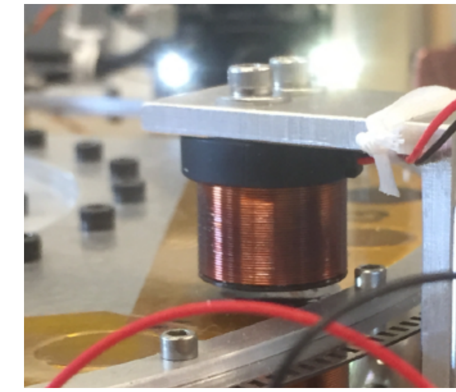




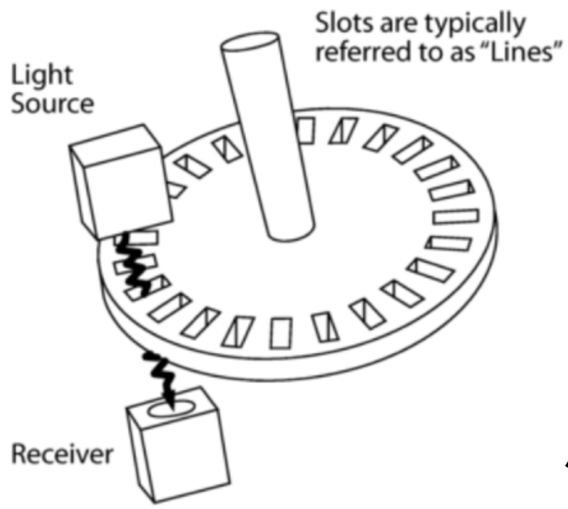
Shaft coupled with a groove in the rotor

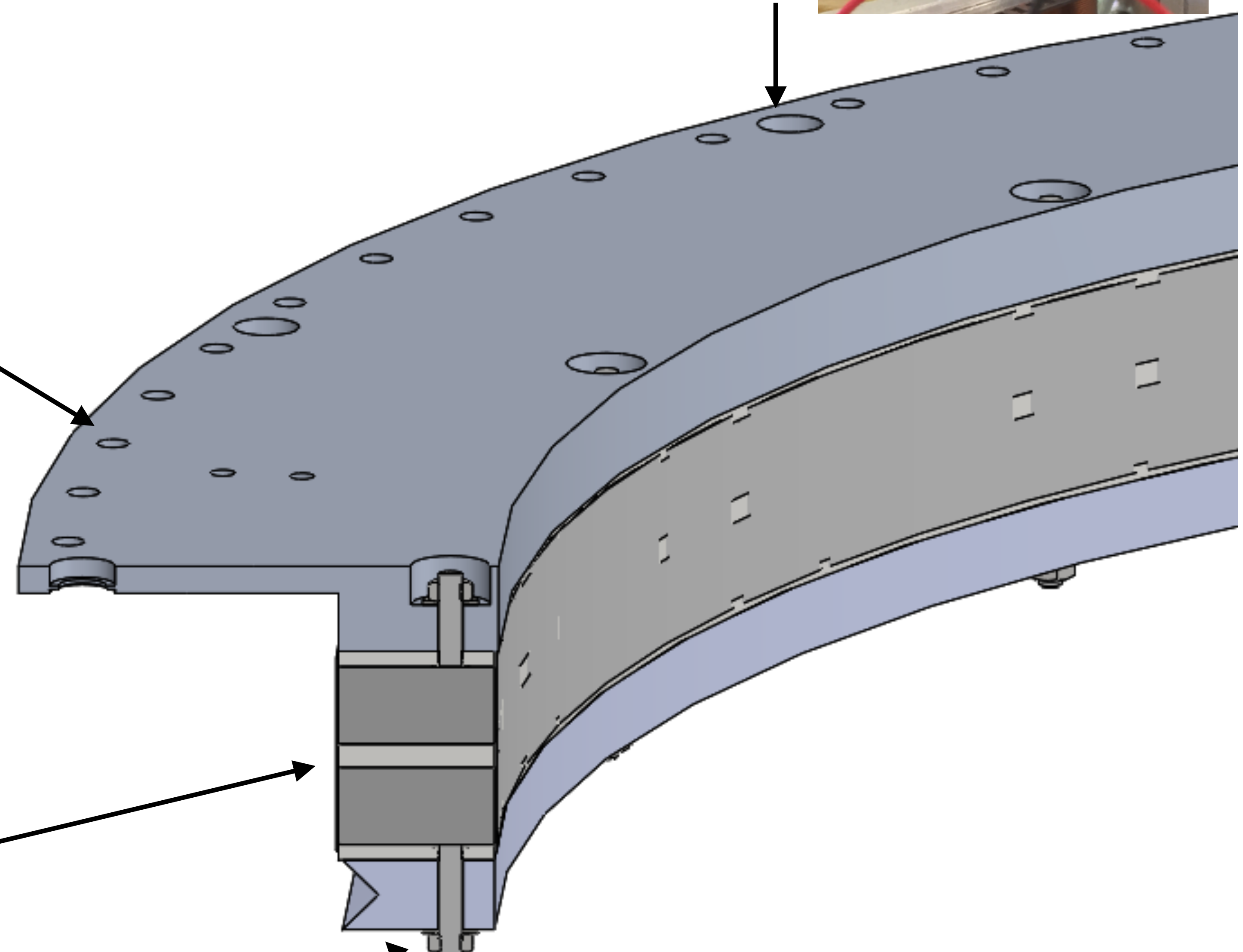
SWIPE Hwp - Rotor

32 coils paired with
8 small permanent
Samarium magnets

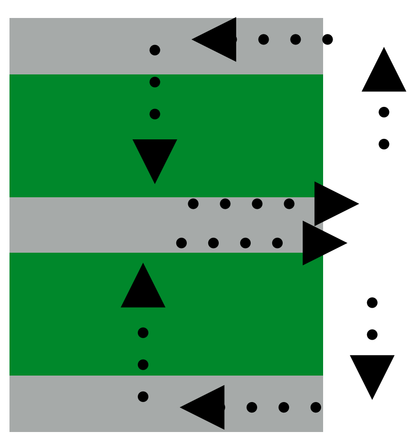


80 holes
($\Delta\theta$=4.5°)



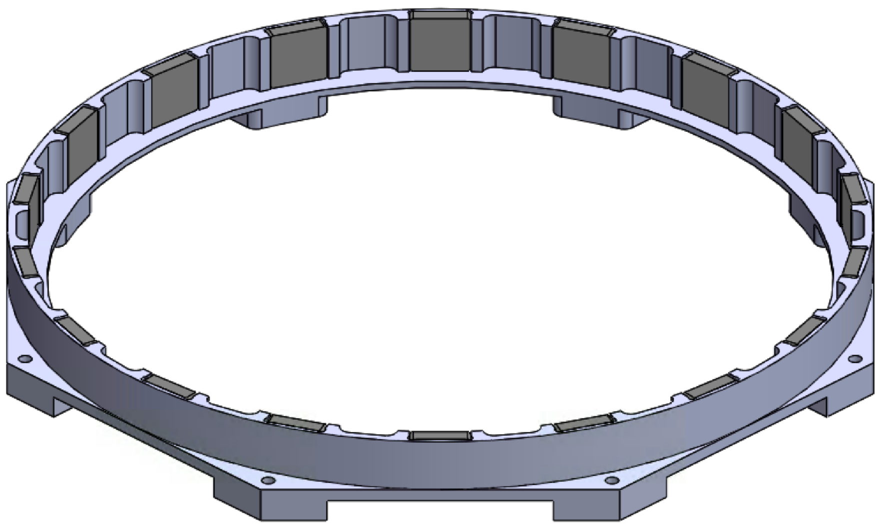


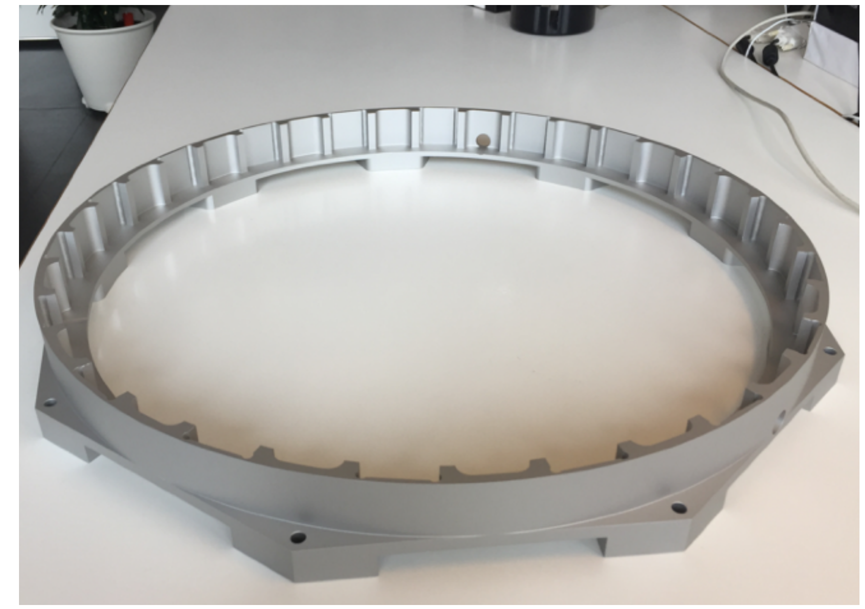
Iron
rings

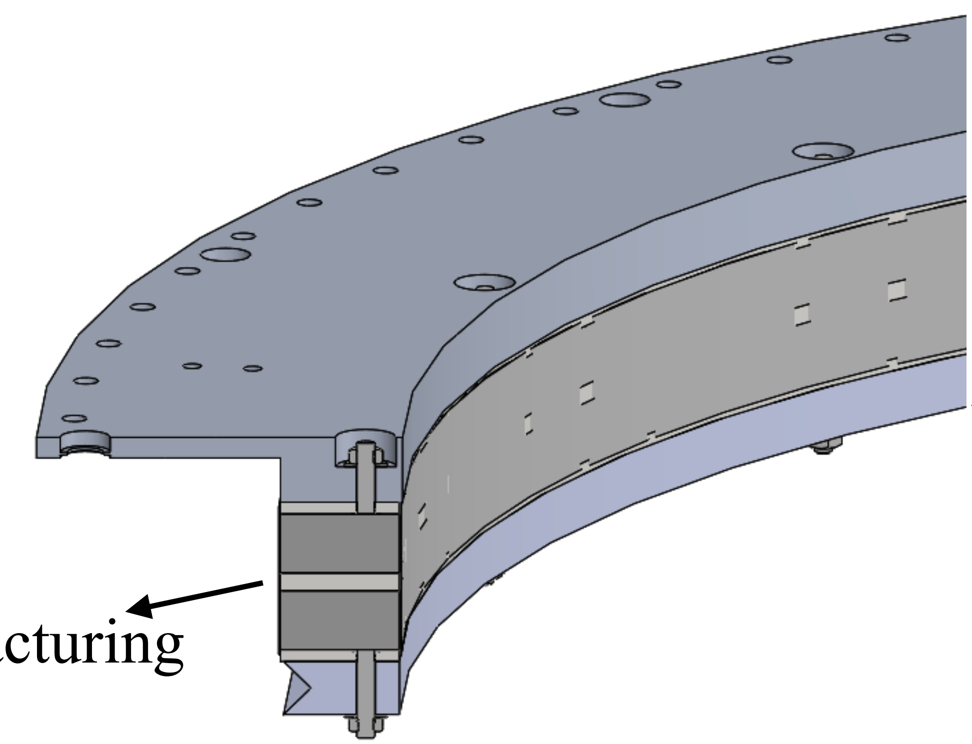


Groove ring to hold the rotor

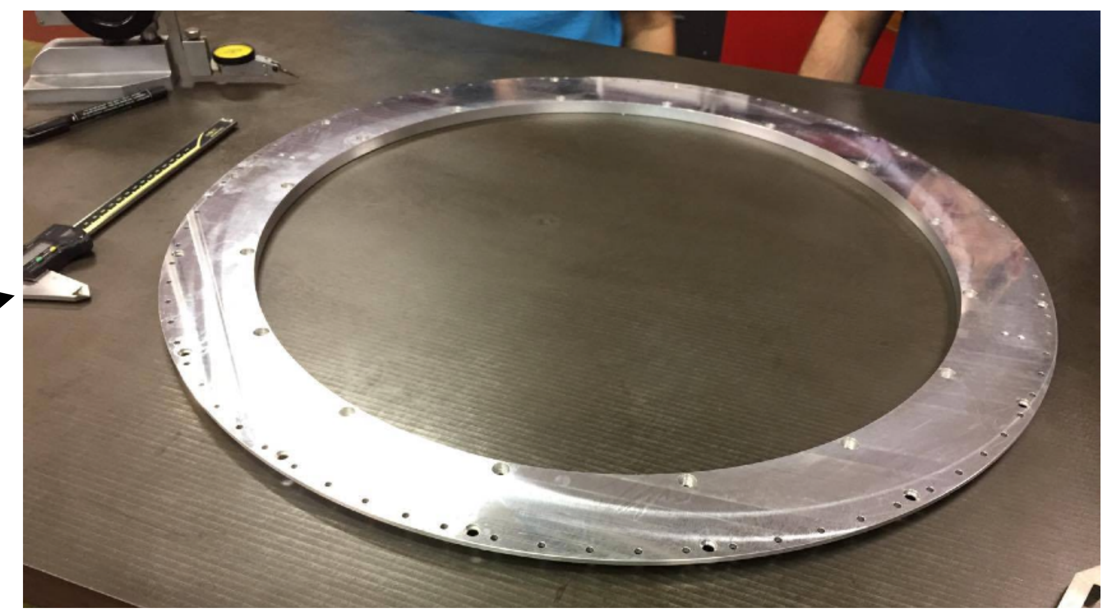
SWIPE Hwp - Work in progress

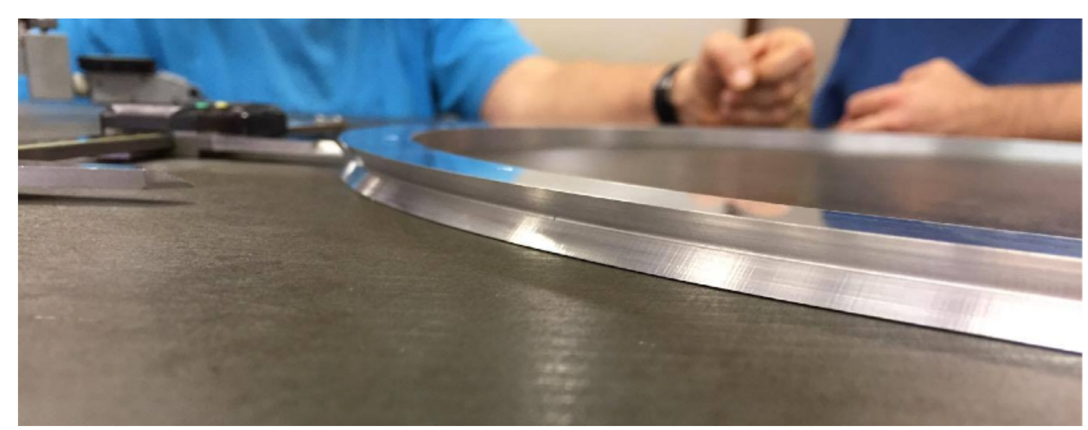






In manufacturing



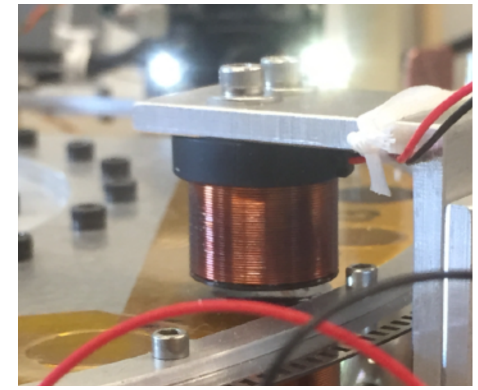


http://www.evico.de/en/superconductor-material/

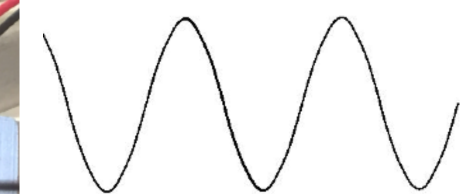
HWP Heating

During operations the HWP rotates contactless, so the only way to exchange heat is the radiation!

Variable magnetic field in each coil used to move the rotor dissipates power directly on it.



$$B(t) = B_0 \cos(\omega t)$$



$$P = \frac{V^2}{R}$$

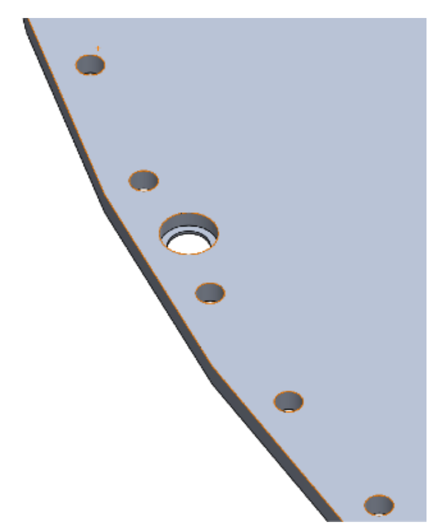
$$V = -\frac{d\Phi(B)}{dt} \propto \omega B a^2$$

$$R = \rho \frac{h}{S}$$

P ~ 0,20 mW

Load power upper limit

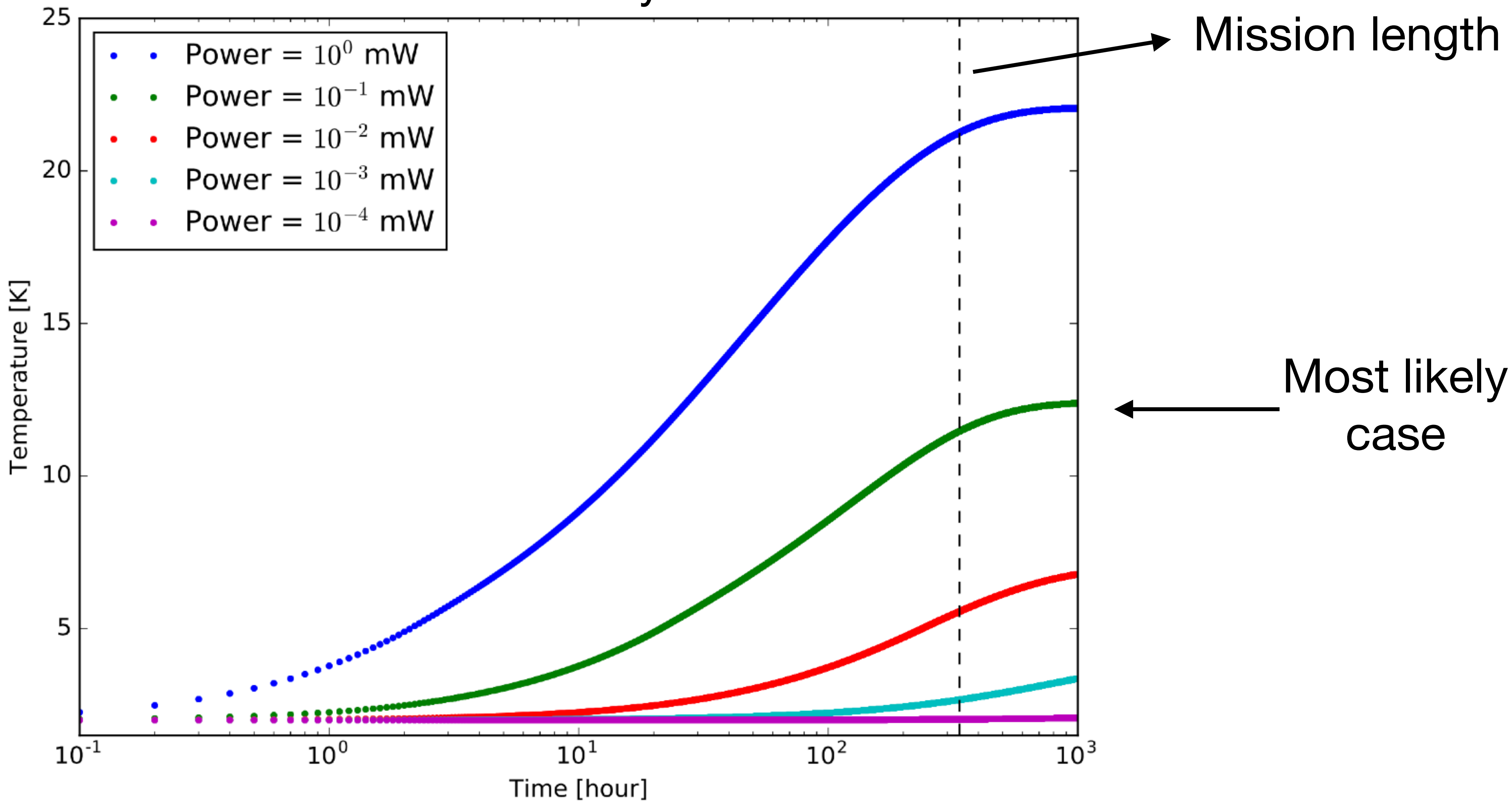
At the same radius of magnets there are 80 holes of relative encoder. They should reduce the typical length of eddy currents (like lamination).



HWP Heating

The main parameters are the emissivity of materials and the load power

Aluminum emissivity: 0.01
HWP emissivity: 0.01



- The drift in temperature can produce slight variations of the properties of the HWP and of its emission.
- However, this drift is ultra-slow, compared to the sky scan of the experiment
- Modern methods of polarized map-making easily remove ultra-slow drifts like this.

Conclusions

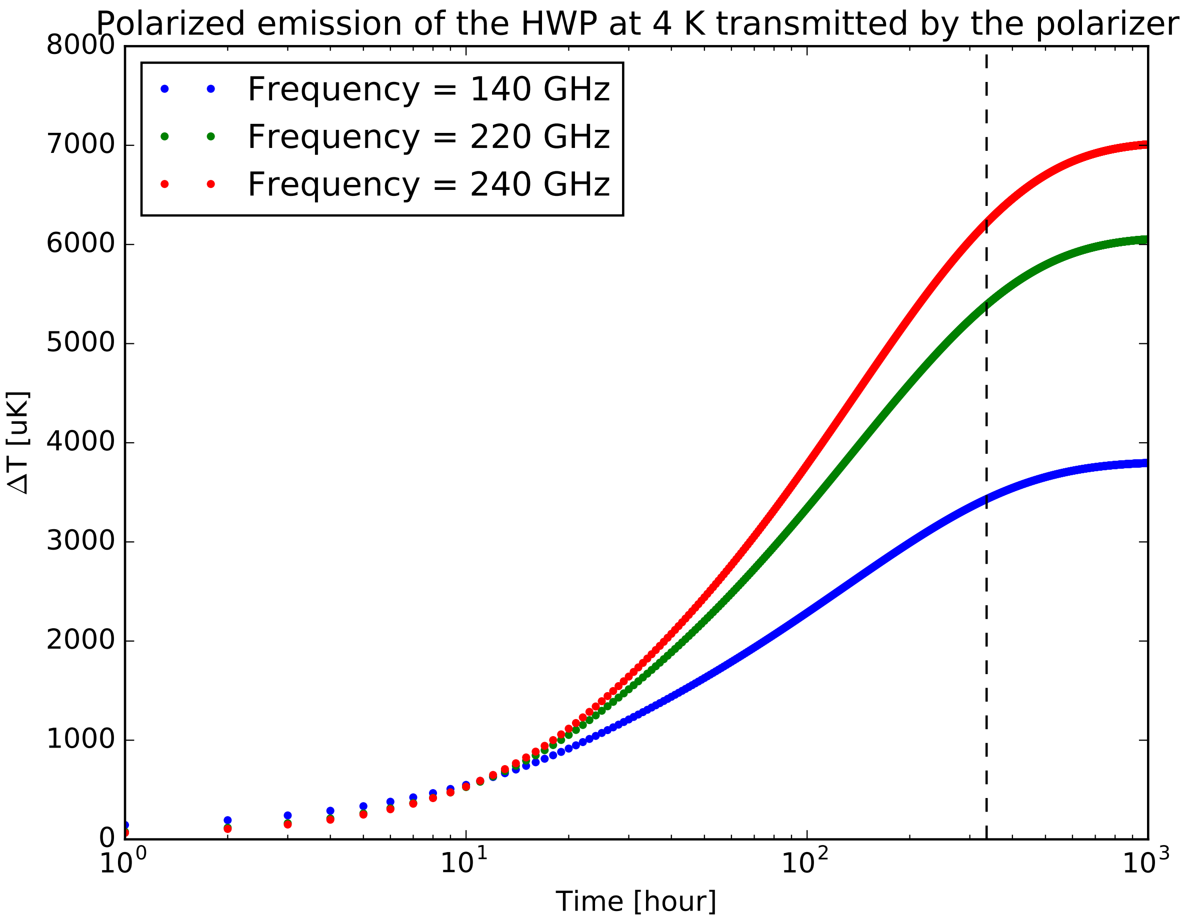
- QUBIC rotation system has already tested successfully at room temperature and will be tested at 4K very soon
- Starting from SMB prototype test, the SWIPE polarization modulator was designed and optimized
- The missing parts of SWIPE polarisation modulator will be delivered before the end of 2017, tests will start in 2018
- Heating: ~10-15K is a reasonable value, the slow temperature drift is unpleasant but easily removable in the data analysis
- We plan to use the experience gained with LSPE-SWIPE in the preparation of the HWP rotator for the HFT on LiteBIRD

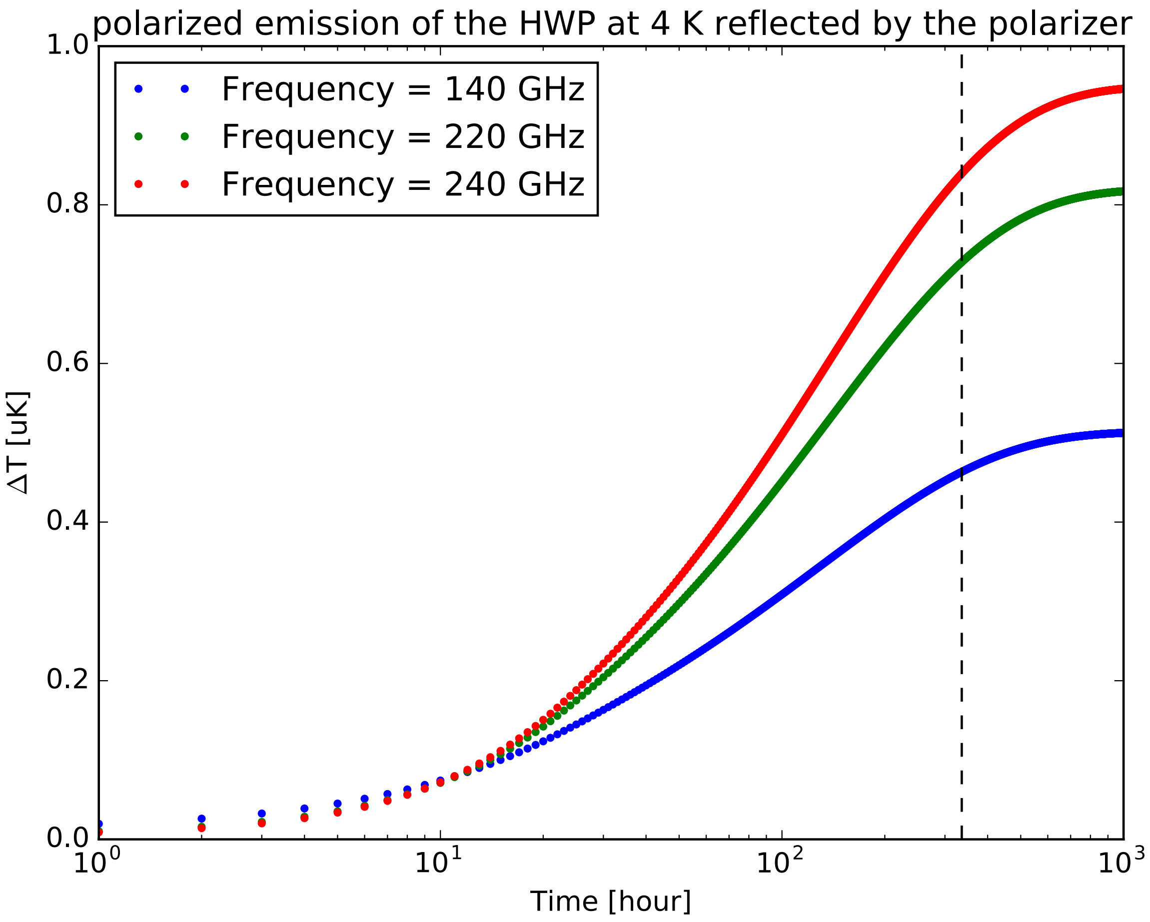
Backup Slides

Spurious signals (SWIPE)

There are lots of spurious signals which contribute to the total intensities on the detectors:

- Radiative background at 2.7 K (2f)
- Polarized emission of the polarizer at 2.5 K reflected by the HWP (2f) —> (1.1 0.7 0.6) uK
- Polarized emission of the HWP at 4 K transmitted by the polarizer (2f)
- Polarized emission of the HWP at 4 K reflected by the polarizer (4f)





Friction

3 different contributions:

- **Hysteris**

The variation of the magnetic field of the ring magnet drags flux through the type II superconductor as the rotor spins, creating hysteresis loss.

$$F_{Hy} \propto \frac{\Delta B^3}{J_c}$$

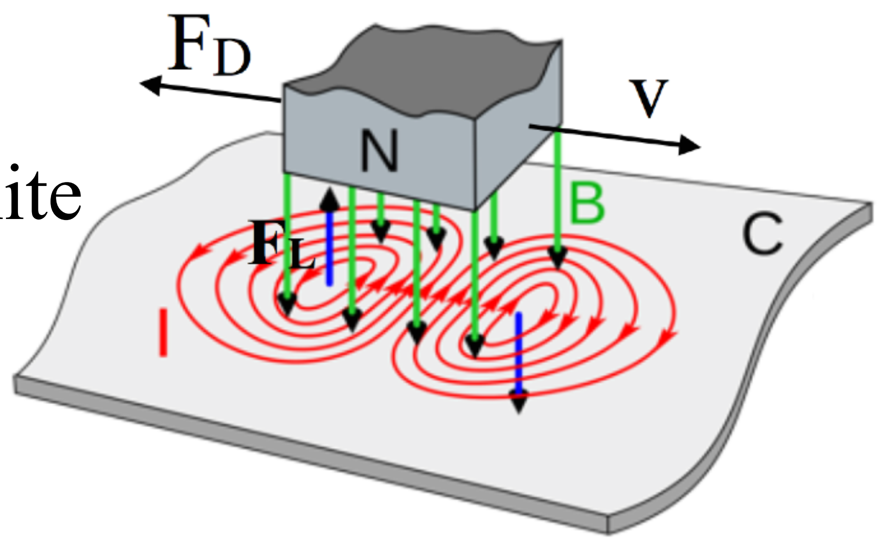
- **Eddy currents**

A time varying magnetic field ΔB dissipates as Joule heat in the surrounding conductor.

$$F_{EC} \propto \sigma (\Delta B)^2 f$$

- **Magnets**

A magnet moving with constant velocity above an infinite conducting plate, will experience magnetic lift and drag forces from the eddy currents induced in the plate.



$$F_D = \frac{3n\mu_0 m^2}{32\pi z_0^4} \frac{w}{v} \left(1 - \frac{w}{\sqrt{v^2 + w^2}}\right) \qquad w = \frac{2}{\mu_0 t \sigma}$$

J. R. Reitz, Journal of Applied Physics. 41 (1970)