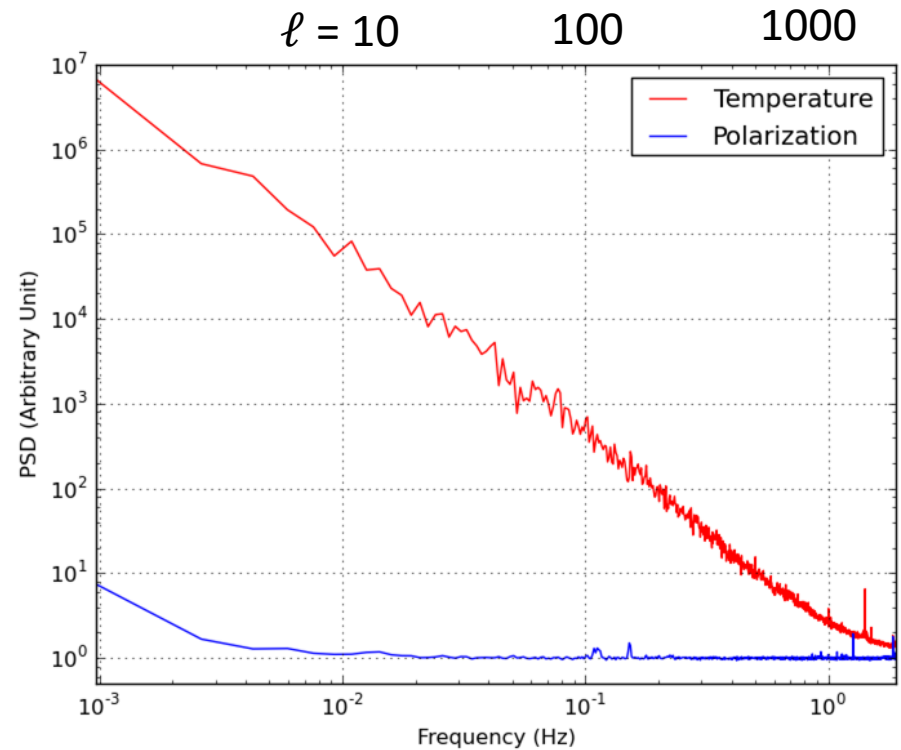
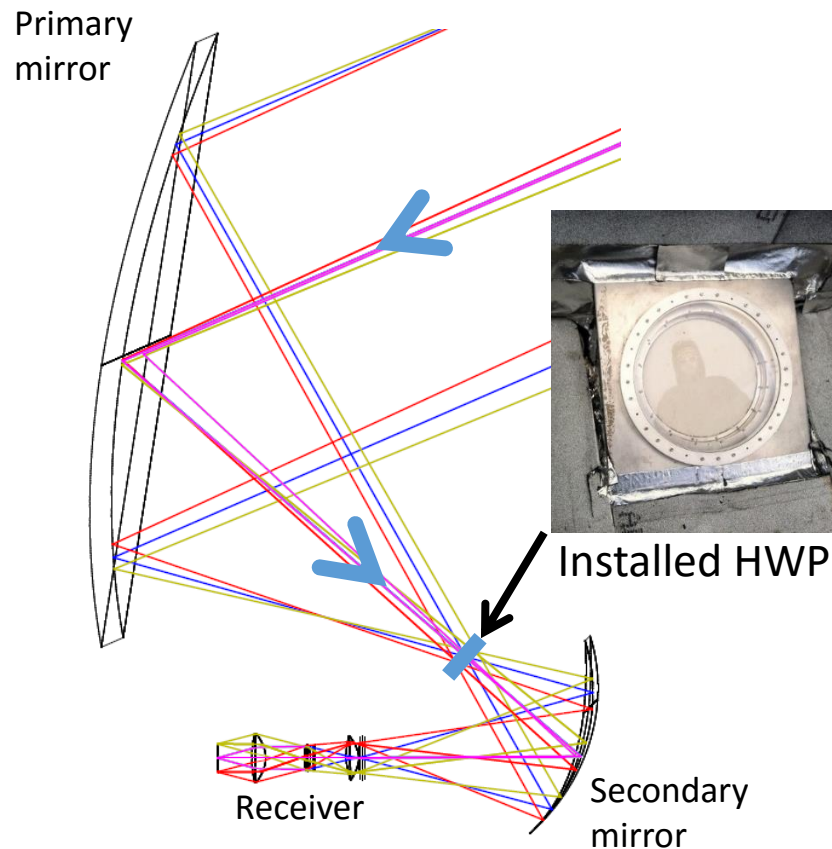


Sapphire HWP

Aritoki Suzuki

9/22/2015

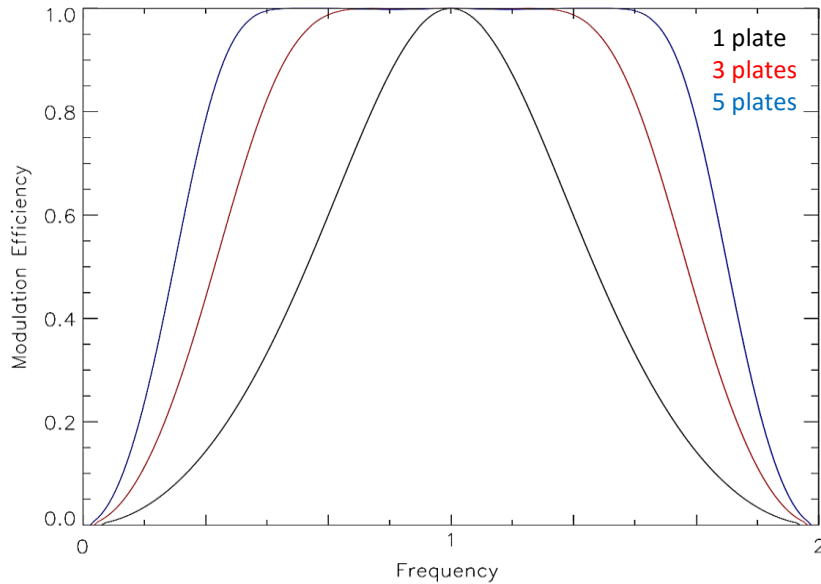
Polarization Modulation



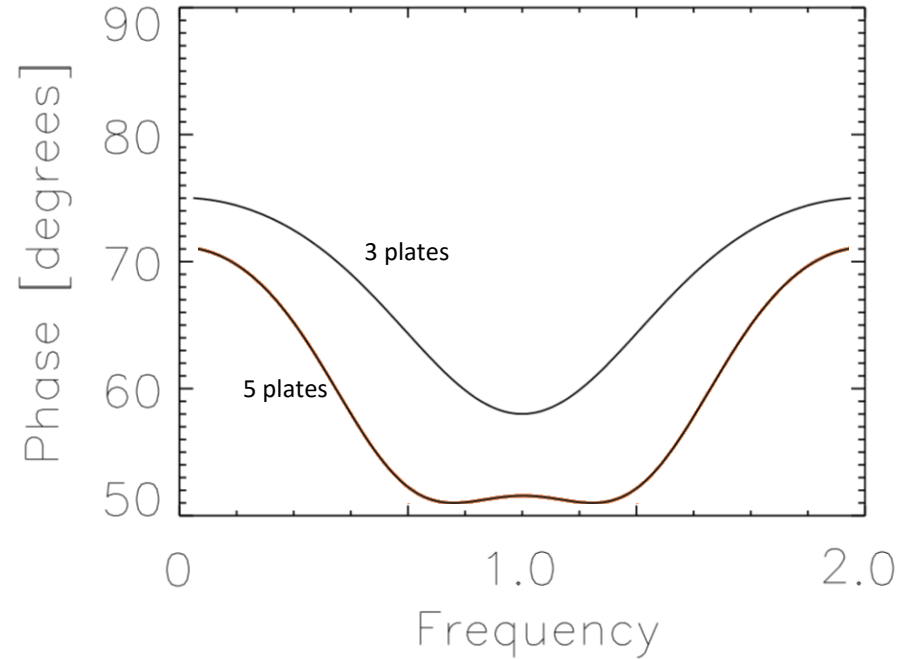
Demodulated signal

- Rotate birefringent sapphire plate to modulate polarization signal to $4f$
- POLARBEAR-1 is taking third season data with rotating HWP at primary focus

Broadband HWP



Polarization modulation efficiency as a function of frequency

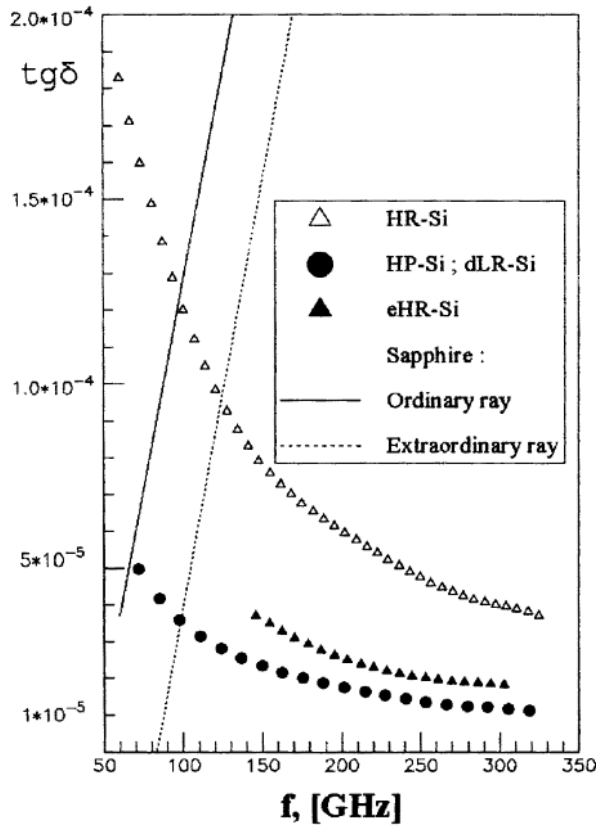


Polarization modulation angle as a function of frequency

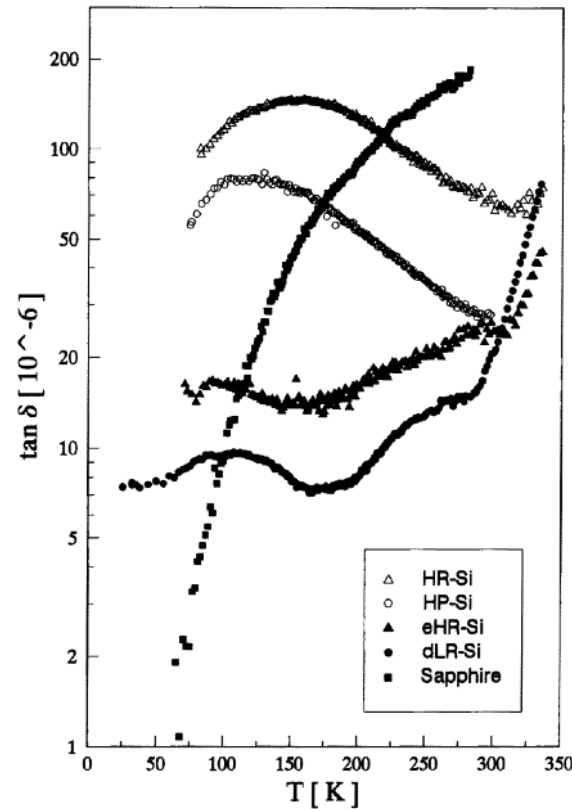
- Multiple wave plates could be used to increase bandwidth
- Polarization angle rotation as a function of frequency happens for multi-plate HWP
 - Bao et al. [arXiv:1112.3057](https://arxiv.org/abs/1112.3057), goes over its effect on leakage and correction

Sapphire Loss

Silicon as an advanced window material for high power gyrotrons, Parshin et. al



Sapphire $\tan \delta$ as a function of frequency at room temperature



Sapphire $\tan \delta$ as a function of temperature



510 mm diameter sapphire

- For maximum efficiency, purchasing low loss sapphire is important
- Cooling sapphire rapidly reduces loss-tangent