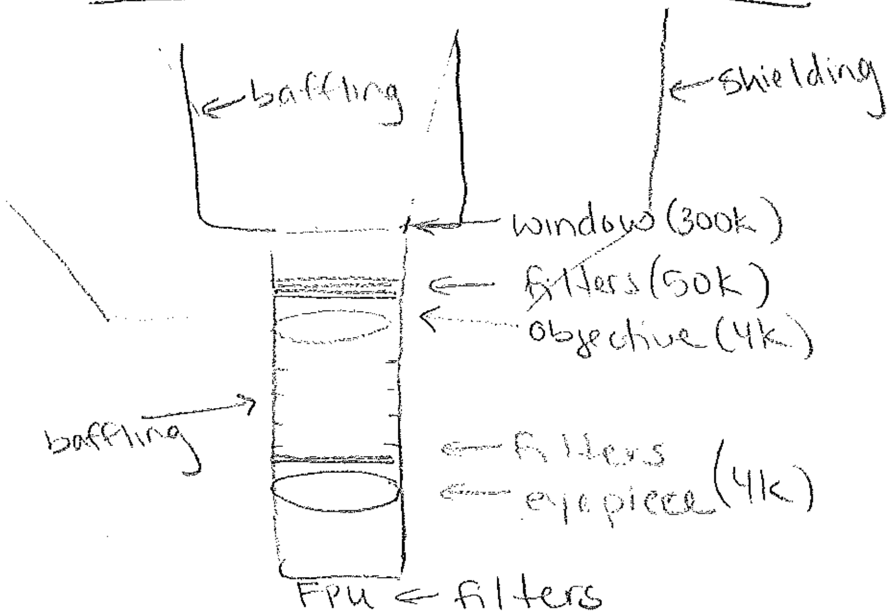
Cold Optics, Filtering, Baffling: A.G. Vieregg 8/8/2017



A schematic of BICEP optics.

Baffling: There are two basic types: absorptive & reflective.

- What baffling does: stops stray light that would cause some systematics issues from hitting the detectors. Another way to think about it - baffling redirects or terminates sidelobes
- Main issues: ground pickup: the ground is hot (300K), not uniform, and changes as you scan your telescope

  galactic pickup: the galaxy is (relatively) hot and you don't want pickup in your sidelobes.

- Absorptive (i.e. eccosorb lined aluminum can)
  - → absorbs stray light + emits a blackbody @ the temperature of the baffle. (300K?!)
  - → if the sidelobes have too much power, this causes lots of optical loading on your detectors.

BICEP has 2 absorptive baffle systems.

1) co-moving on front (300K)
2) Baffle rings in optics tube (4K)

- Reflective (i.e. Aluminum)
  - redirects sidelobes to the sky (~15K) so that you dont see the ground.
  - could be flat or have some bumps to "randomize" light coming in
  - advantage: less loading (15K vs 300K)
    disadvantage: less understanding of exactly what light is coming in.

BICEP has a large reflective ground shield

Vacuum Windows:

Turns out to be a harder problem than one might think

1 ATM ~15 psi

let's say you want a 12" window

$15 \cdot \pi(12)^2 = 6780$ lbs on your window.

Of course the problem gets harder the bigger your window.

2 choices: polyethelene + zote foam

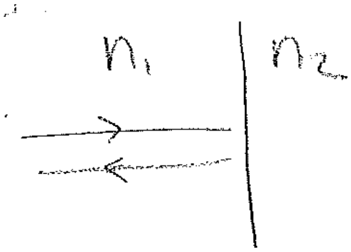
polyethelene:
- $n \approx 1.5$
- can be thin
- needs to be AR coated

zote foam:
- $n \approx 1$
- needs to be thick
- thickness ultimately limited by scattering!

aside:

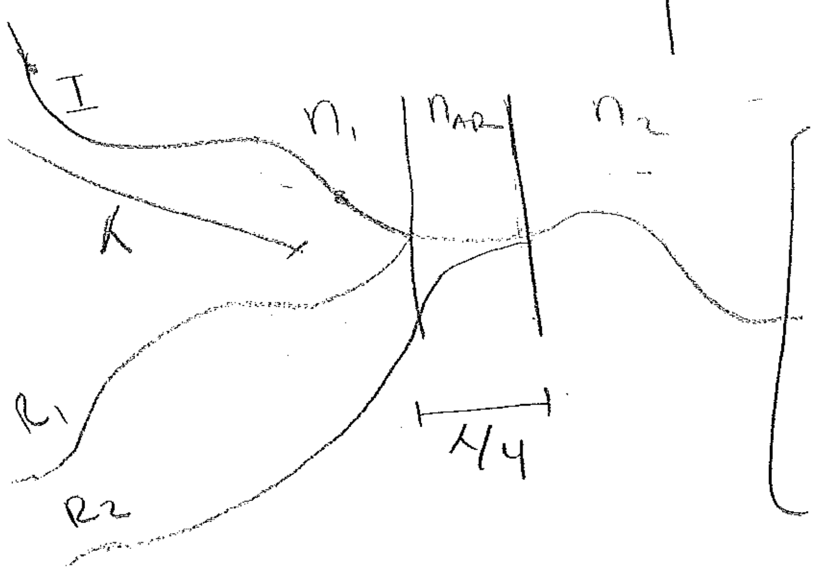
AR coatings:

idea



$$R = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2$$

$$T = 1 - R$$



- want $\lambda/4$ to cancel the 2 reflections.
- want $\sqrt{n_1 n_2}$ to maximize transmittance and have 2 reflections have same amplitude

Lenses:

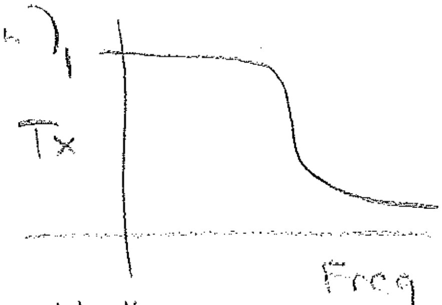
High-index lenses: silicon (n = 3.4) (need low
alumina (n ≈ 3) loss)

low-index lenses: PE (HDPE, UHMPE)
n ~ 1.5

Filtering:

Purpose: Reduce IR loading from warm stuff on detectors
- in-band loading increases noise
- out-of-band makes it hard to keep temperatures cold + stable

1) metal-mesh filters: reflective filters
embed metal mesh on a dielectric
(LP filters are common)



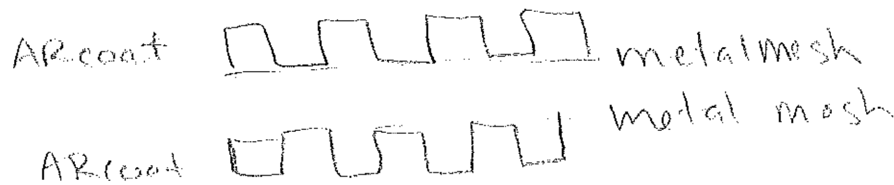
- Can do this also by laser ablation, making a mesh on mylar or BOPP

2) Nylon + Teflon. LP filters, Absorptive
- Teflon has higher freq. cutoff than Nylon
Teflon: lower loss in band
Nylon: higher loss in band

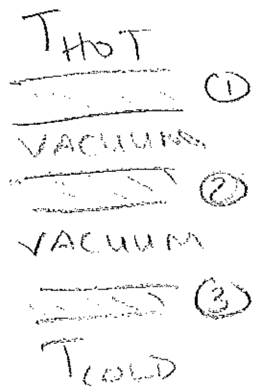
- Problem: big filters warm up in middle + re-radiate, causing loading

3) Alumina, advantage is thermally conductive
LP, cutoff ~ THz

4) Silicon Substrate



5) Stacks of foam



like MLI

AR Coats:

1) Glue plastic on your material

2) spray stuff on your material

3) mix up epoxy with the right index and adhere to your material

4) machine sub-λ structures into the surface of your material

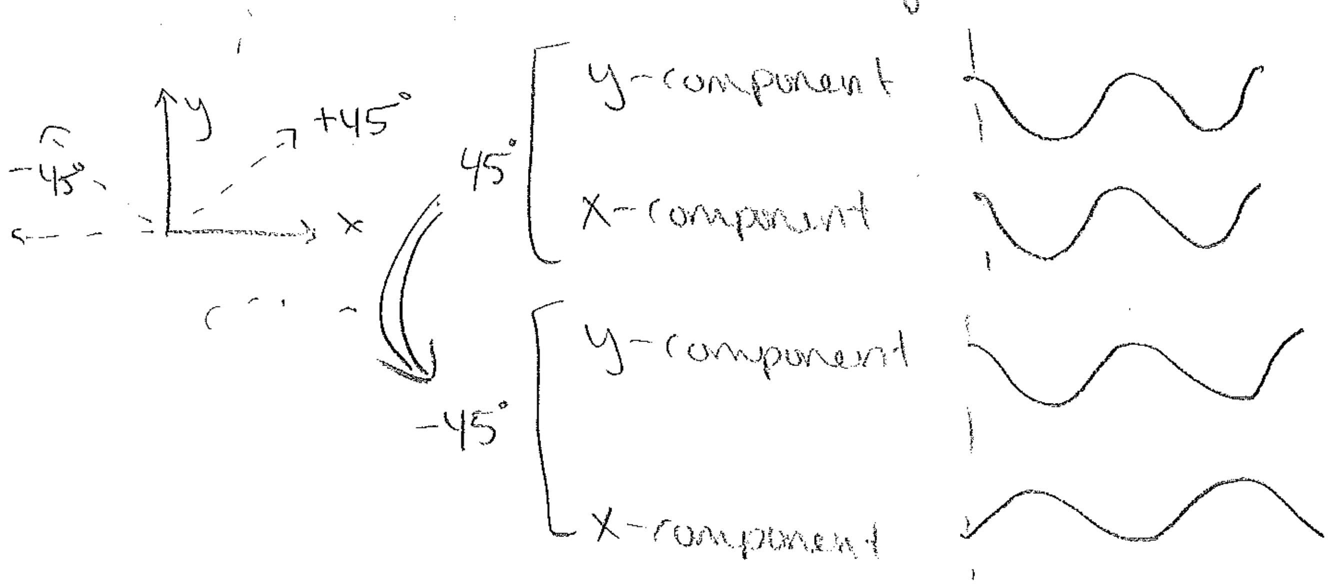
5) laser-ablate sub-λ structures

Broadband need multiple layers or structure scales

Polarization Modulators:

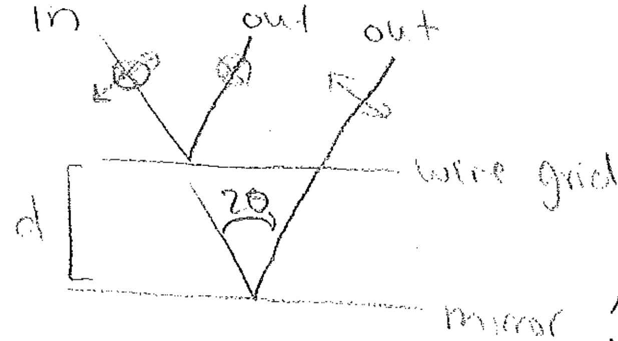
Half-Wave Plate:

- delays one axis λ/2 w/ respect to the other axis.
- birefringent material w/ thickness chosen for a given λ.



Achromatic HWP: a stack of HWPs w/ appropriately chosen angles

Variable delay polarization modulators:



↕ move mirror up and down

as d changes, the phase between ↔ & ⊗ changes, rotating polarization between linear + circular