CMB-S4 Cold Optics: Laminated Epoxy AR-Coatings for BA Alumina Optics

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High-Index AR-coating with Epoxy Sheets - Overview

- AR-coating technique aimed at alumina.
  - Goal is to match high index and low CTE.
  - Cast epoxy sheets with controlled thickness.
  - Heat-slump to conform to curved surfaces.
  - Pressure-laminate with LDPE. Alumina surface finish is important for adhesion.
  - Laser-dice for stress relief.

- Current status
  - Flat optic (IR filter) was deployed for BA1 at 30/40GHz.
  - Curved optics (lenses) will be integrated this year on BA2 (150 GHz) and BA3 (95 GHz).
High-Index AR-coating with Epoxy Sheets - Cost

- Challenges
  - Technique has yet to be implemented for SAT-sized lenses.
  - Scalability is not yet demonstrated (Sheet casting setup is currently unique at Stanford.)

- Cost estimate per SAT-sized optic:
  - 50+ skilled person-hours
    - This is dominated by the sheet casting step.
    - ~1 week for offsite laser-dicing.
  - $6K for materials and commercial laser-dicing.

Cost estimate for CMB-S4 SATs:
  - Assuming 14 tubes, 3 alumina optics per tube:
    ~$250K, ~2500 person-hours.
Further Work - Characterization

These tests are needed across all dielectrics and AR coatings/treatments.

- Scattering properties
  - Bulk material (epoxy, glue)
  - Dicing grooves, seams
- Transmission
  - Ambient temperature
  - Intermediate temperatures (IR filters)
  - 4K (lenses, filters)
Extra slides
Cast Epoxy Sheets

- Moulding plates adapted from granite metrology tables.
- Epoxy is mixed, then poured. Then the top plate is lowered to a thickness set by shims.
- Mold release is critical, we believe it to be solved now.
- Metrology on resulting sheets gives RMS thickness < 10µm.
Slumping on Curved Surfaces

- Many successful tests on small (< 12”) samples.
- Currently experimenting with hardware to avoid wrinkles that tend to occur for larger surfaces.
- Process is flexible:
  - Only requires 40-50°C
  - Sheets can be stored at room temperature for many months before slumping
  - Re-slump is possible
Layer Bonding

- Utilizes successful experience with HDPE/ePTFE AR-coating:
  - Surface prep
  - 2 mil LDPE (well-controlled thickness) as “glue”
  - Versatility of vacuum bagging
- AR layer can be stripped without damage, optic can be reused.
- Laser-dicing for differential CTE stress relief.
- Success demonstrated with BA1 IR filter.
Further Work - Fabrication

- **Slumping needs further tests:**
  - Large surfaces
  - Concave surfaces
- **Bonding/delamination**
  - Need to hone process in order to ensure repeatability
- **Index of Styca 1090**
  - Recent (last several years) batches of 1090 have much higher index than desired, pretty far from optimum for 2 layers on alumina.
  - Possible fixes:
    - Add silica microspheres to 1090 or 1266; high viscosity not a major problem thanks to molding technique
    - Eliminate epoxy and use loaded plastic or expanded (or solid) PTFE for outer AR layer.
Thin Sheet Metrology

- Small systematic offset in sheet thickness vs. shim height, can be predicted and corrected.
- For the worst sheet:
  - Mean -0.0169mm from goal.
  - RMS 0.0096mm, which includes contributions from measurement errors of ~0.0063mm.
  - Need more finely stepped shims to do better.
- Conclusion: thickness is controlled.