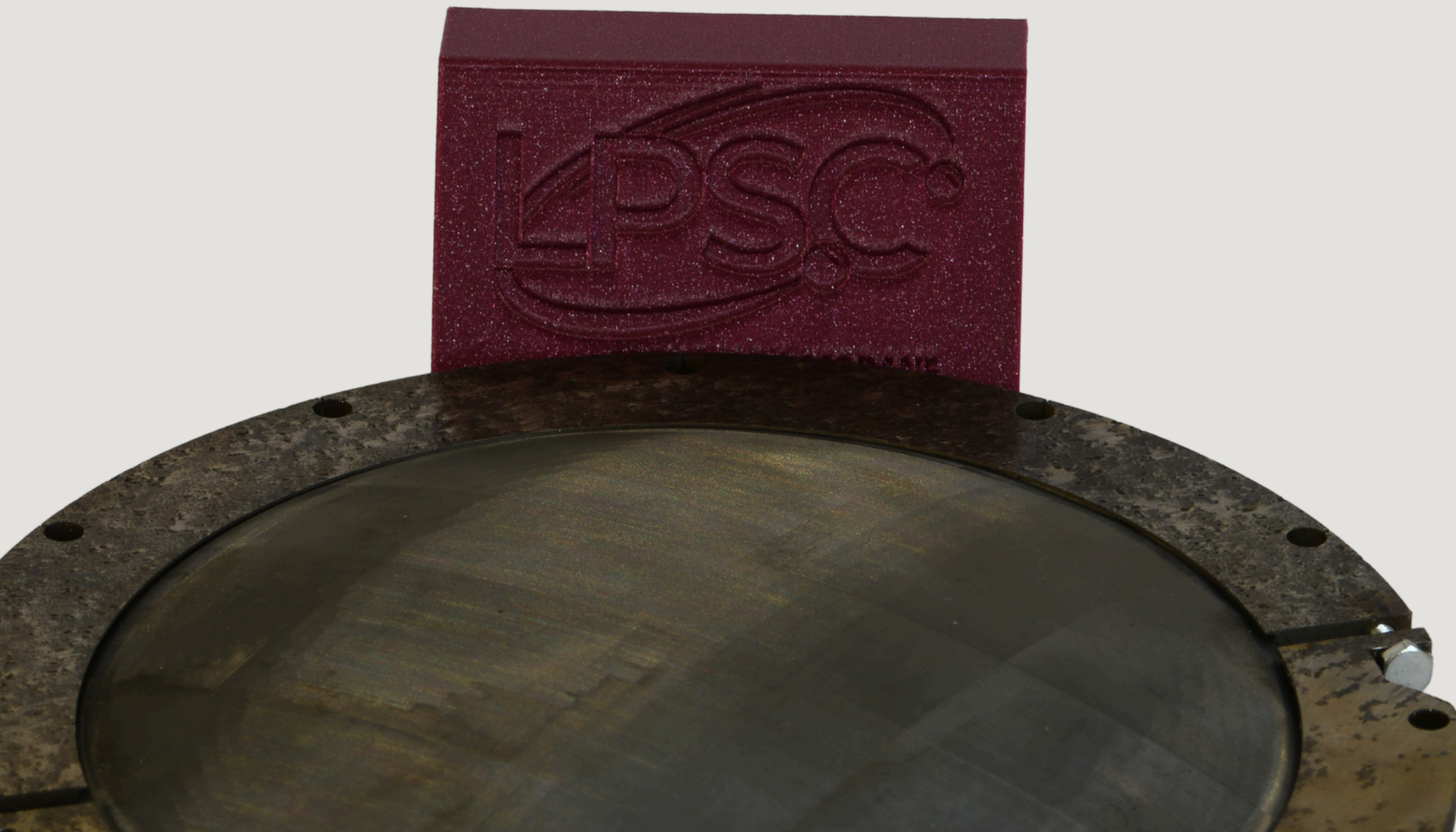


Anti-Reflective Technologies for Silicon and Alumina Lenses in CMB Experiments

Benedetta Kalemi, Romain Tempier-laencina, Sebastien Roudier, Andrea Catalano



ADVANCED DETECTION SYSTEMS
FOR ASTROPHYSICS

SF2A - 24/06/2026

Why do we need Silicon or Alumina?

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Next generation millimeter-wave observations require improved sensitivity.

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Next generation millimeter-wave observations require improved sensitivity.

Higher Sensitivity



Wider Fields of View

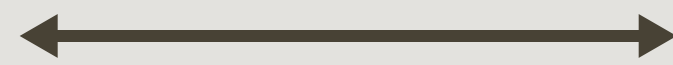


Higher Mapping Speed

Why do we need Silicon or Alumina?

Next generation millimeter-wave observations require improved sensitivity.

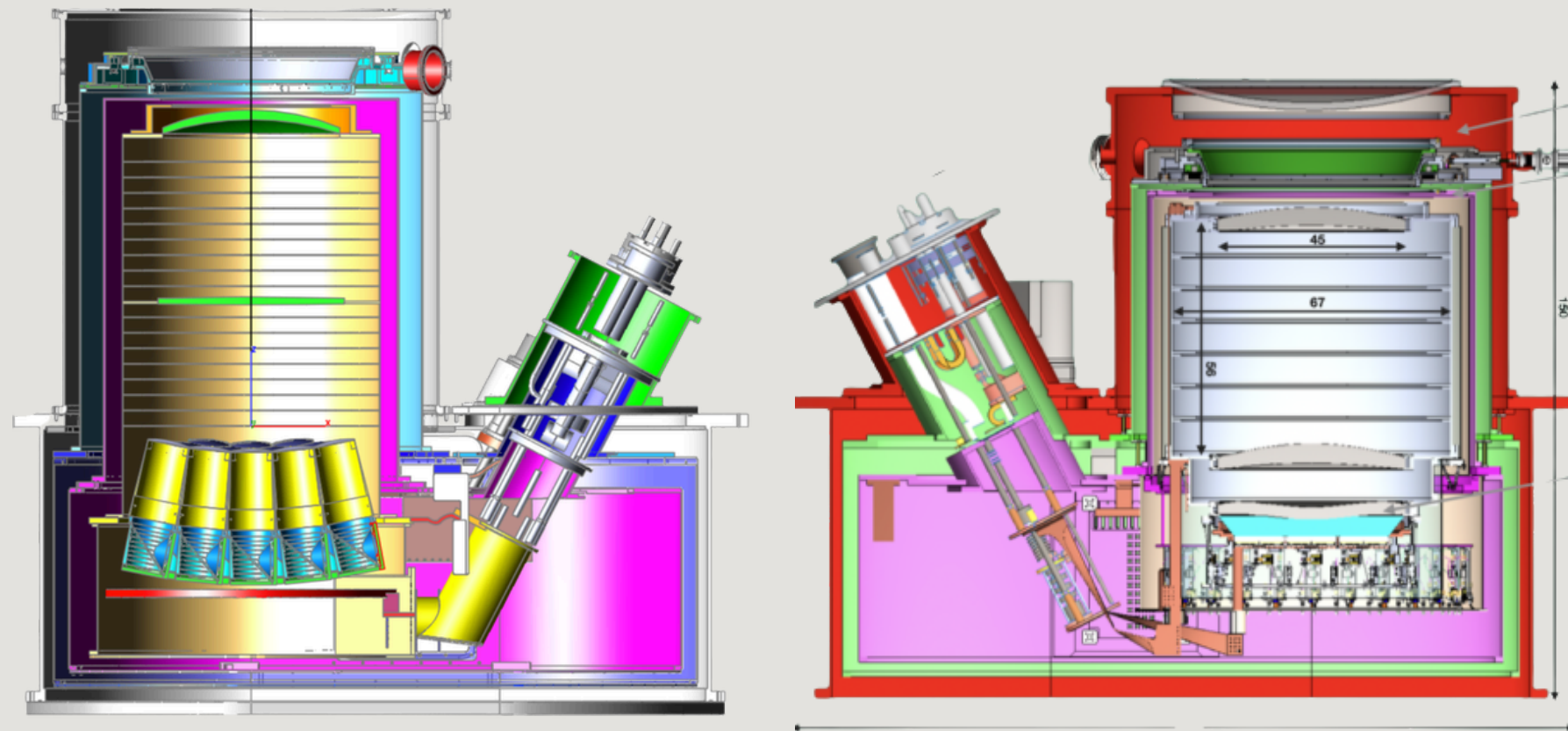
Higher Sensitivity



Wider Fields of View



Higher Mapping Speed



Examples of U.S. and French SAT proposals for the Simons Observatory (SO), dedicated to Cosmic Microwave Background (CMB) observations.

Why do we need Silicon or Alumina?

Next generation millimeter-wave observations require improved sensitivity.

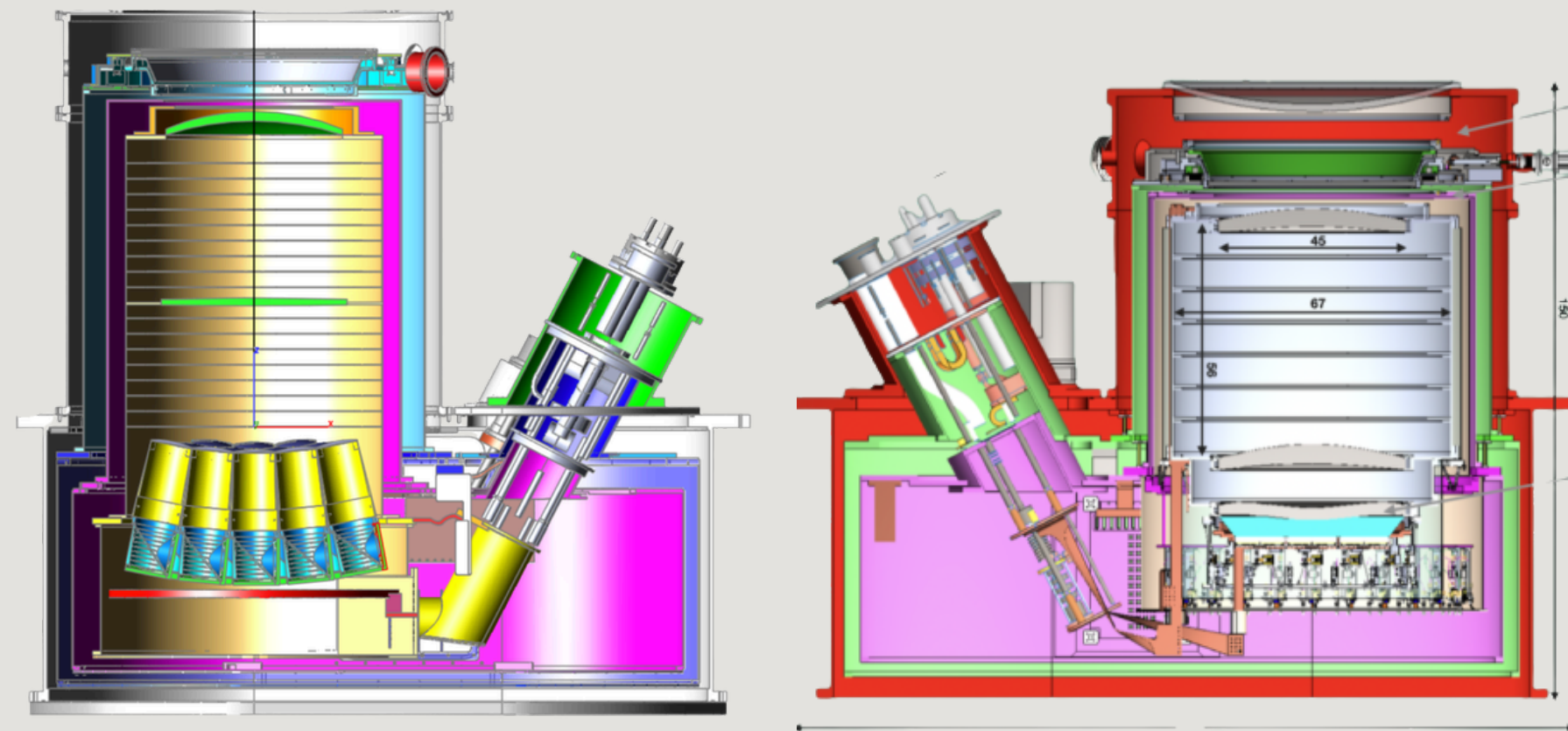
Higher Sensitivity



Wider Fields of View



Higher Mapping Speed



Larger and Larger
Instrumentation !

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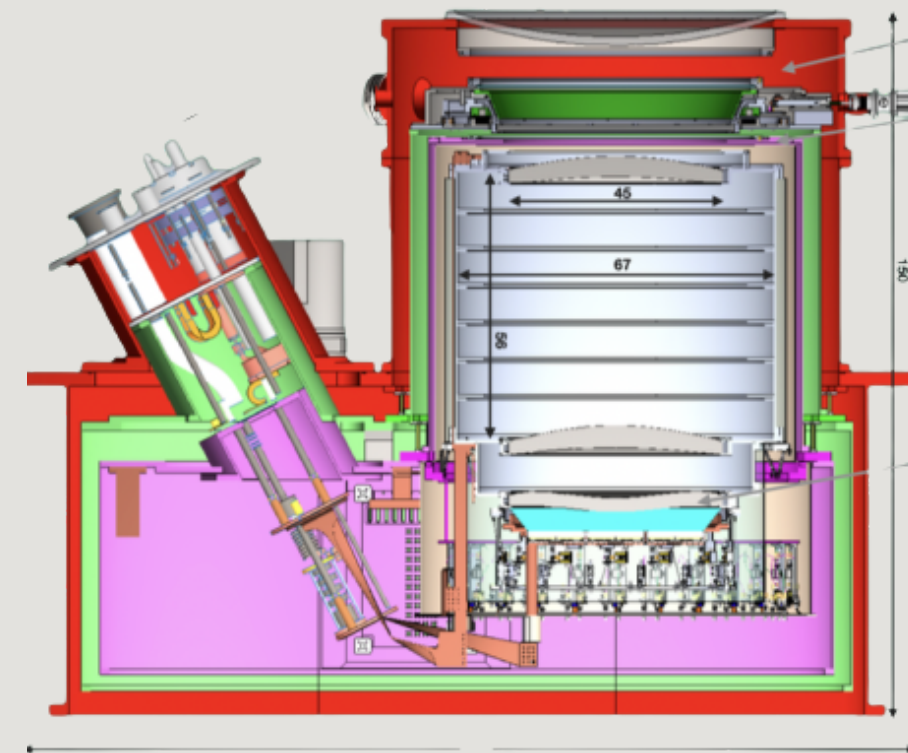
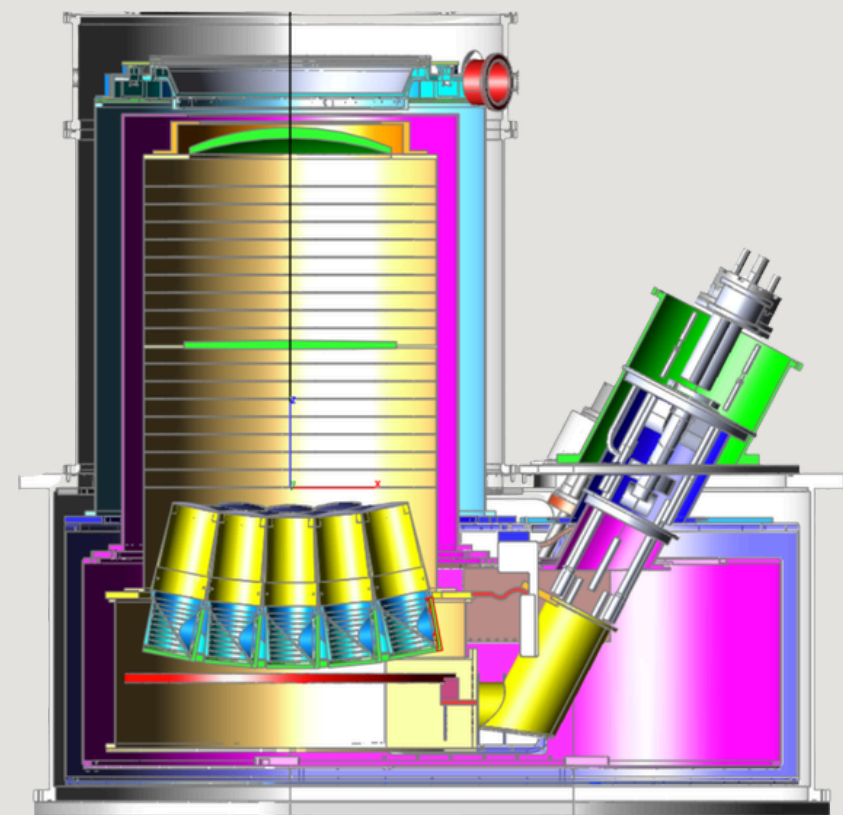
Higher Sensitivity



Wider Fields of View



Higher Mapping Speed



Larger and Larger Instrumentation!

Examples of U.S. and French SAT proposals for the Simons Observatory (SO), dedicated to Cosmic Microwave Background (CMB) observations.

Conventional Plastic Lenses (HDPE)

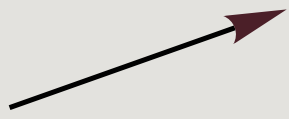


High Absorption Losses

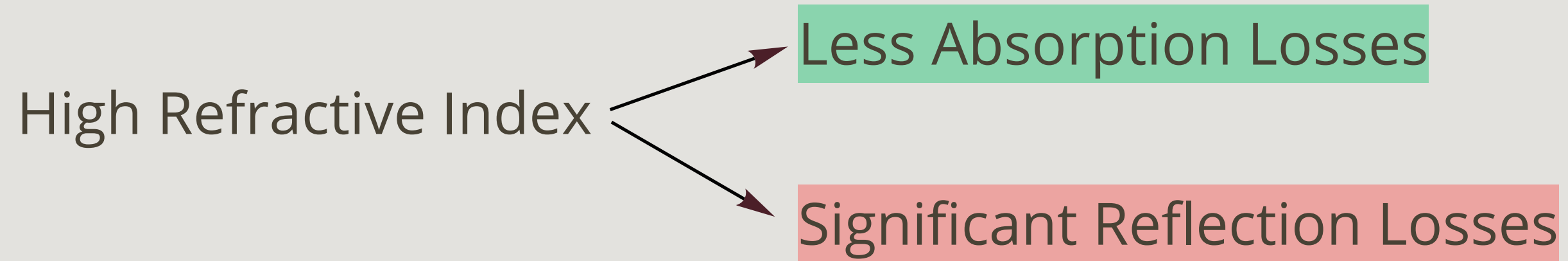
Low-loss materials are necessary.

Physical Description of Reflection Losses

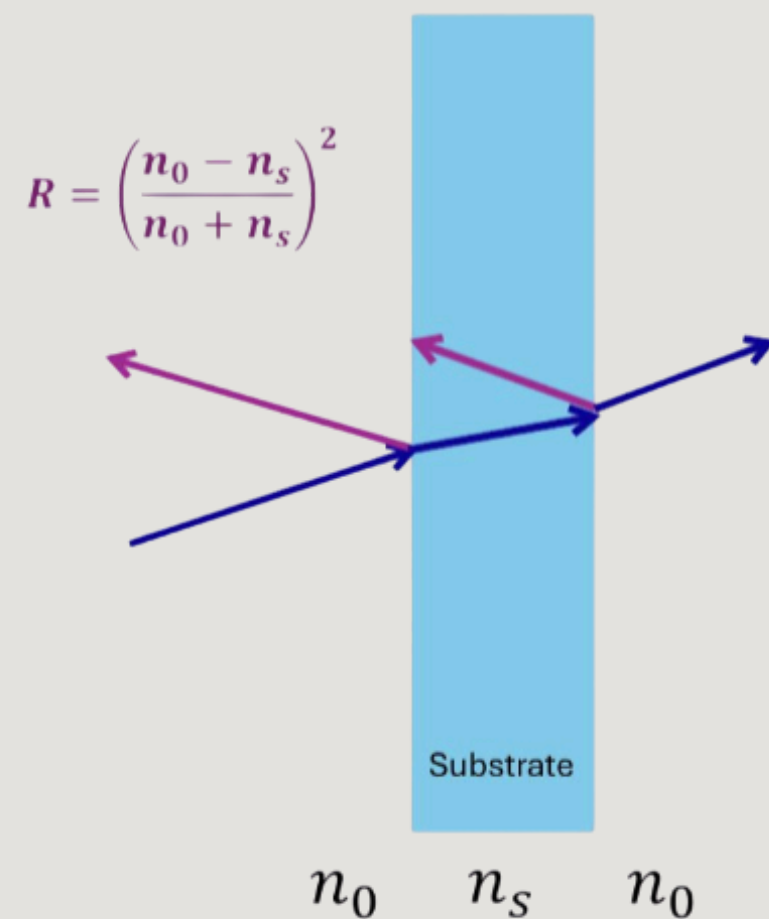
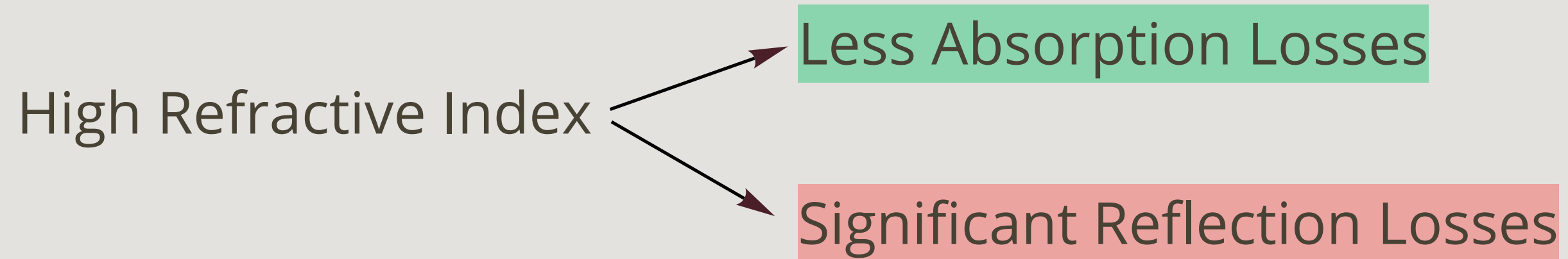
Physical Description of Reflection Losses

High Refractive Index  Less Absorption Losses

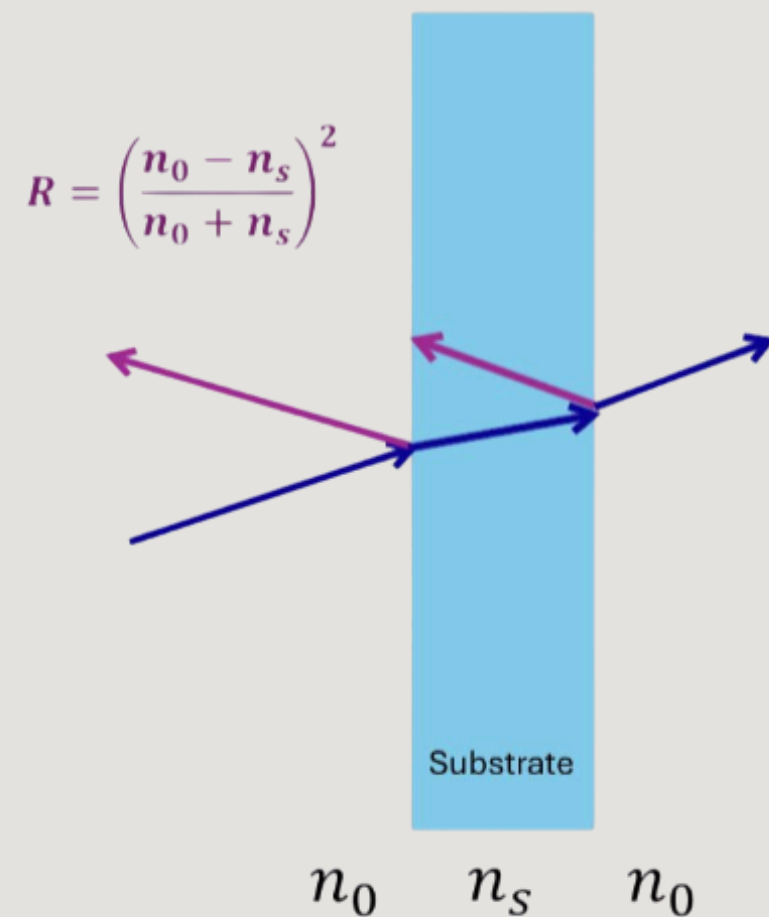
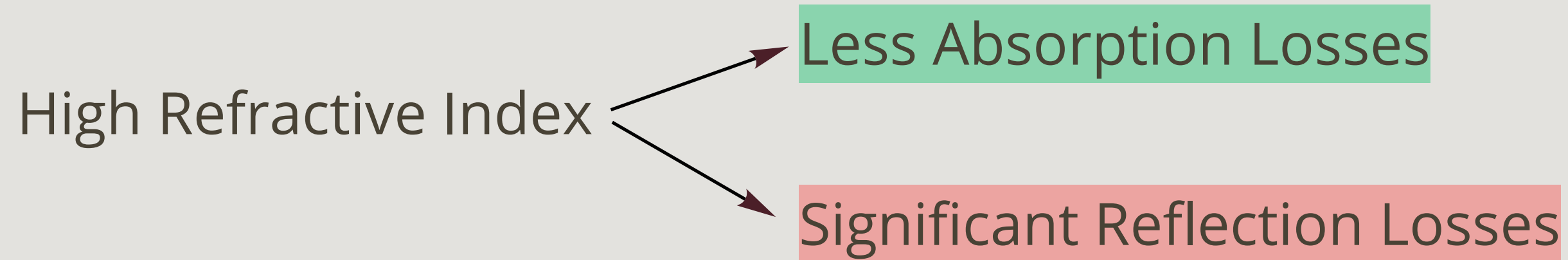
Physical Description of Reflection Losses



Physical Description of Reflection Losses

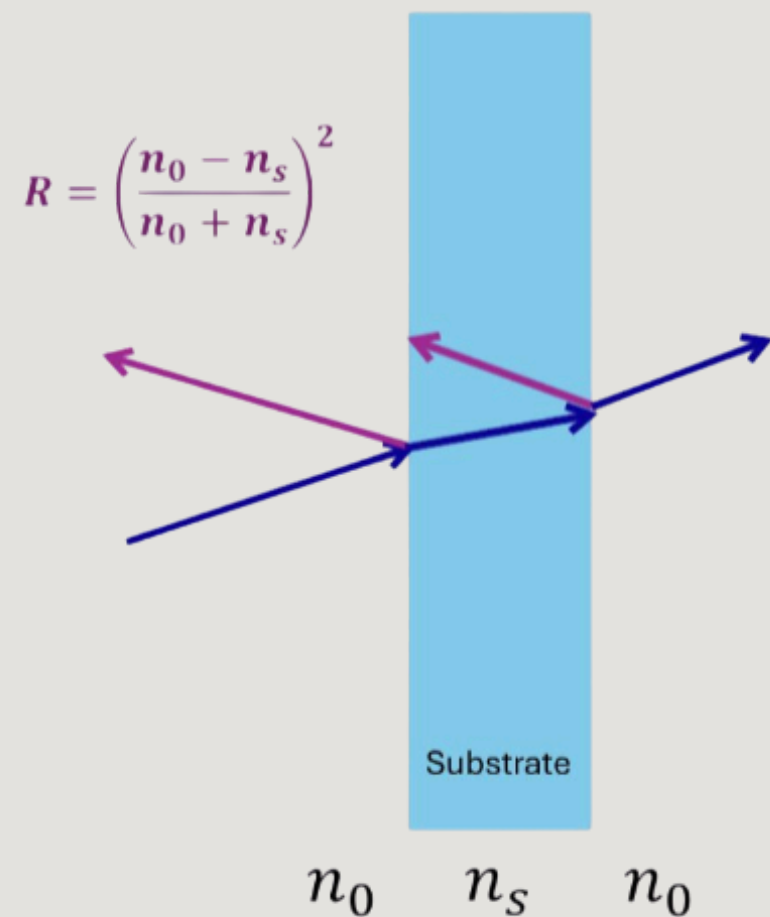
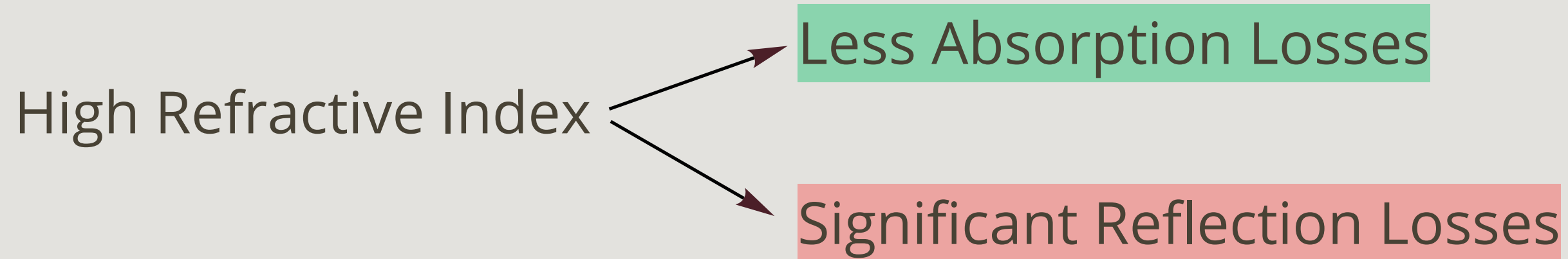


Physical Description of Reflection Losses



Plastic Materials (HDPE) : $n_s \sim 1.5$

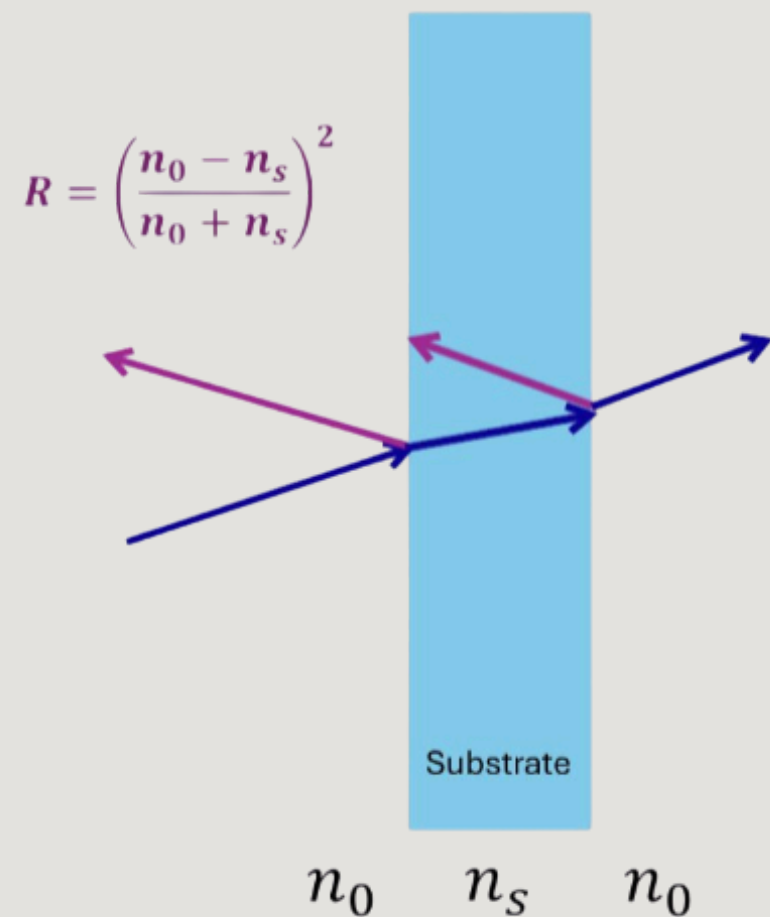
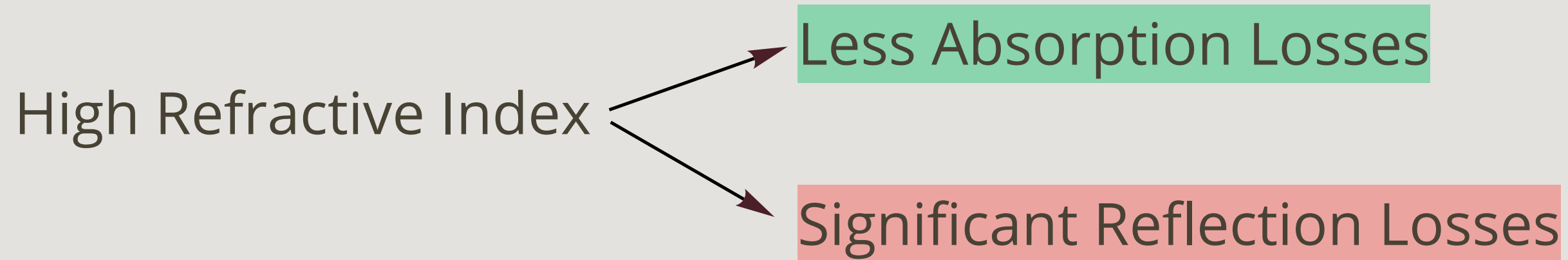
Physical Description of Reflection Losses



Plastic Materials (HDPE) : $n_s \sim 1.5$

$\sim 8\%$ Total Reflection Loss

Physical Description of Reflection Losses

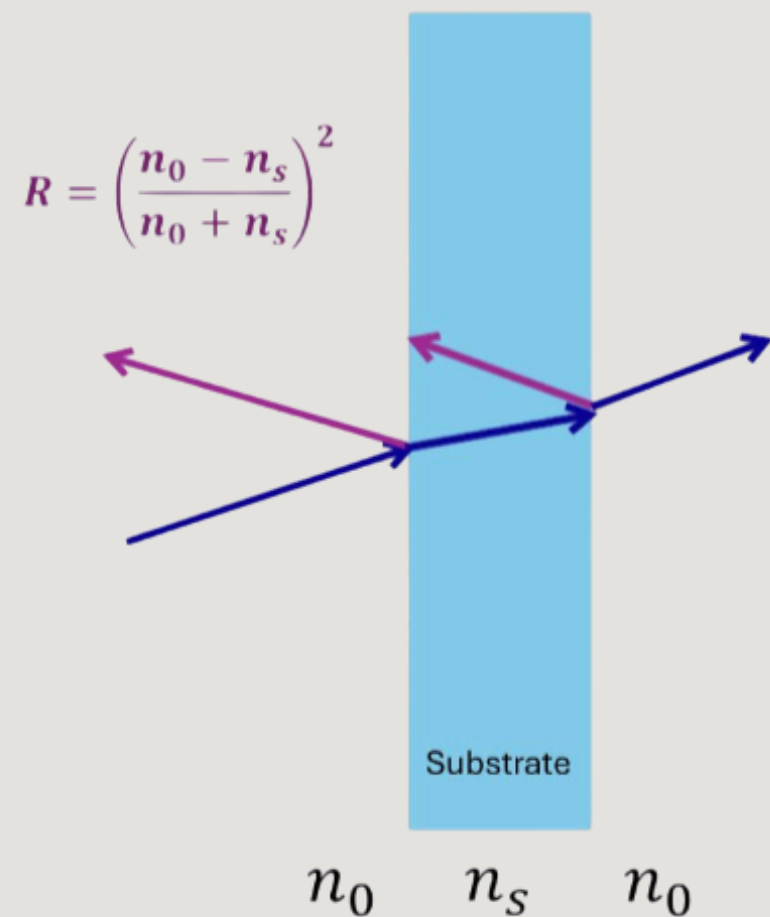
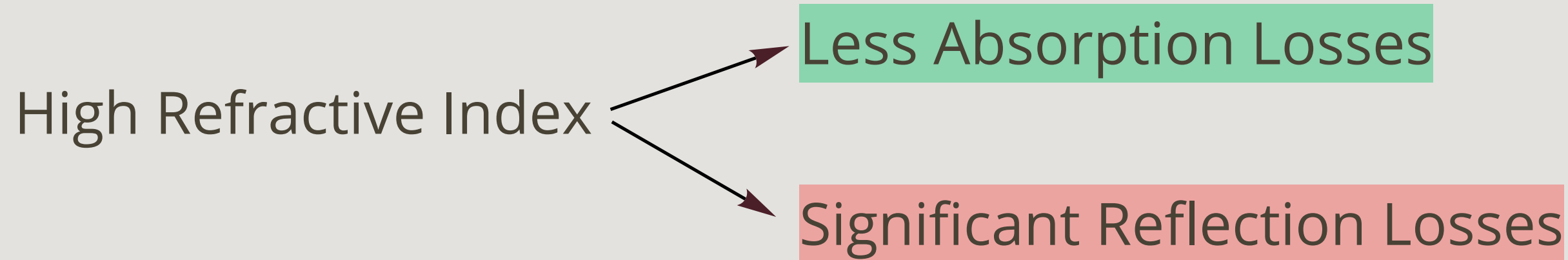


Plastic Materials (HDPE) : $n_s \sim 1.5$

$\sim 8\%$ Total Reflection Loss

Silicon/Alumina : $n_s \sim 3.5$

Physical Description of Reflection Losses



Plastic Materials (HDPE) : $n_s \sim 1.5$

$\sim 8\%$ Total Reflection Loss

Silicon/Alumina : $n_s \sim 3.5$

$\sim 60\%$ Total Reflection Loss

AR Design and Optimization

AR Design and Optimization

CST Simulation Software



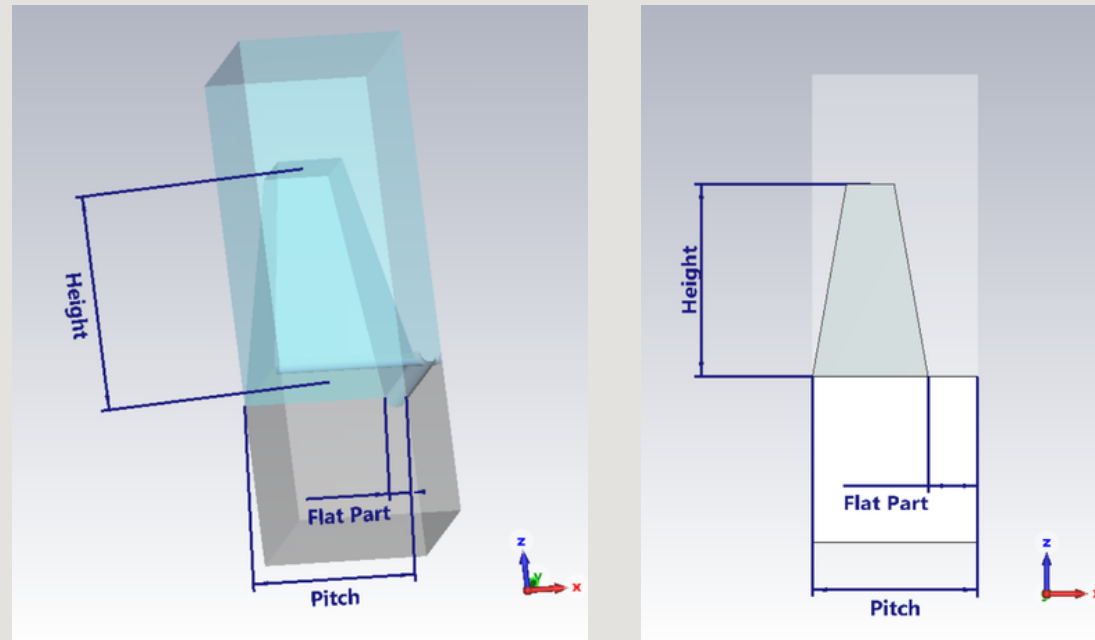
Pyramid Geometry Optimization

AR Design and Optimization

CST Simulation Software



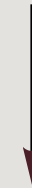
Pyramid Geometry Optimization



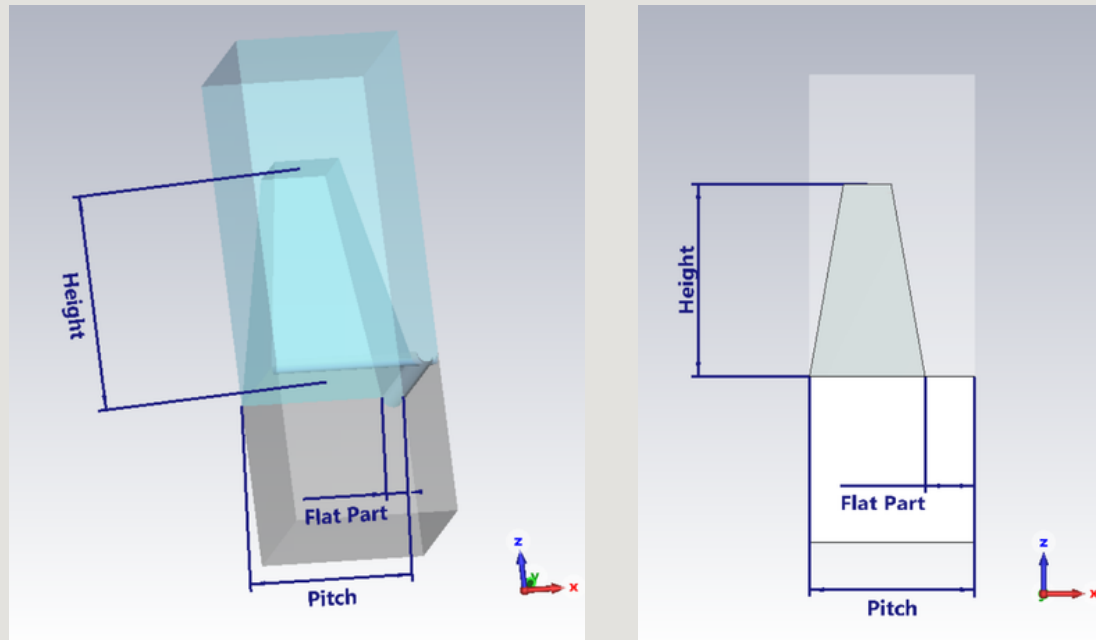
Parameter	200-400 GHz	100-200 GHz
Pitch (μm)	235	360
Height (μm)	260	400
Flat Part (μm)	80	80

AR Design and Optimization

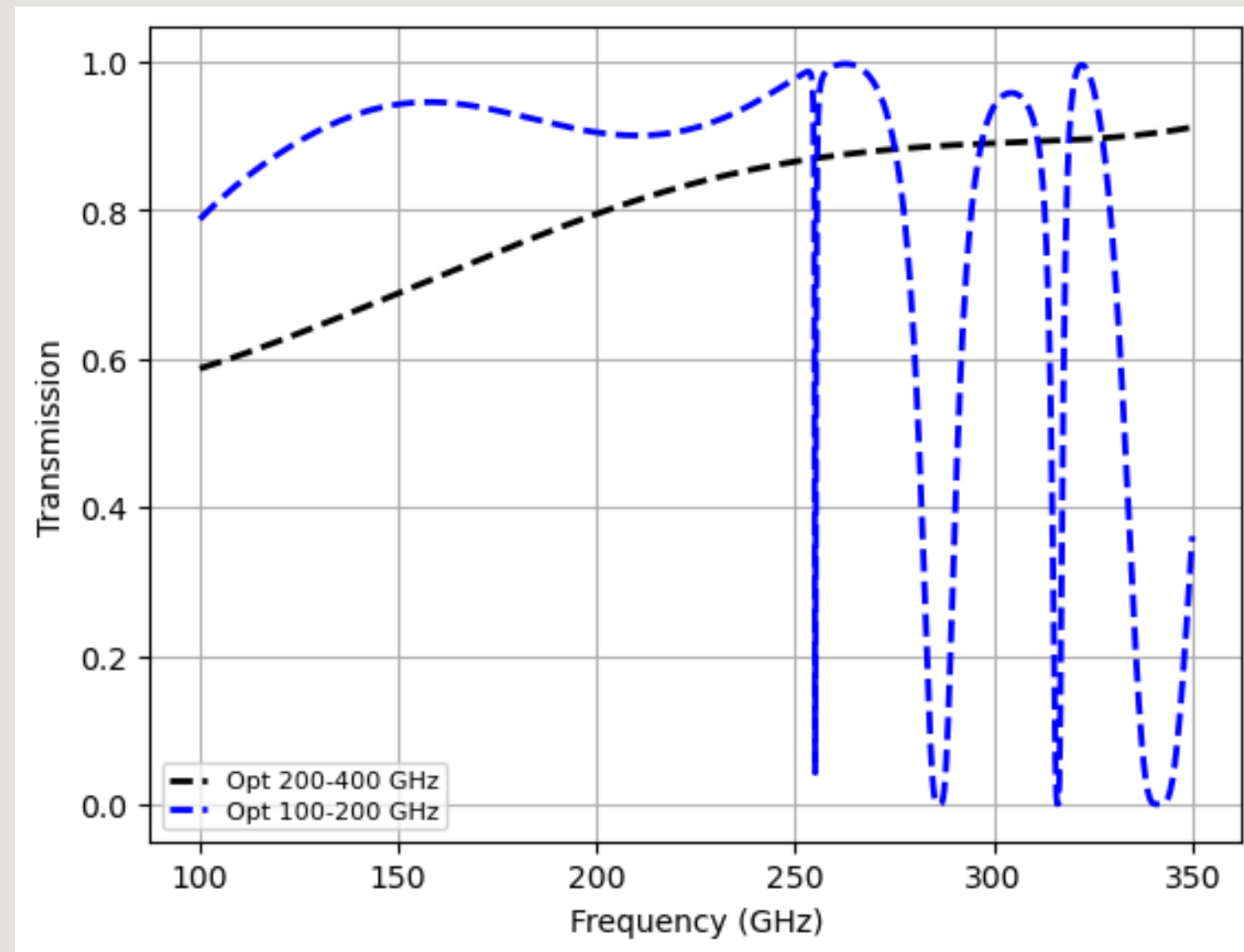
CST Simulation Software



Pyramid Geometry Optimization



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Silicon Surface Machining

Silicon Surface Machining



Milling machine for silicon



End mill diamond tip to machine the silicon surface

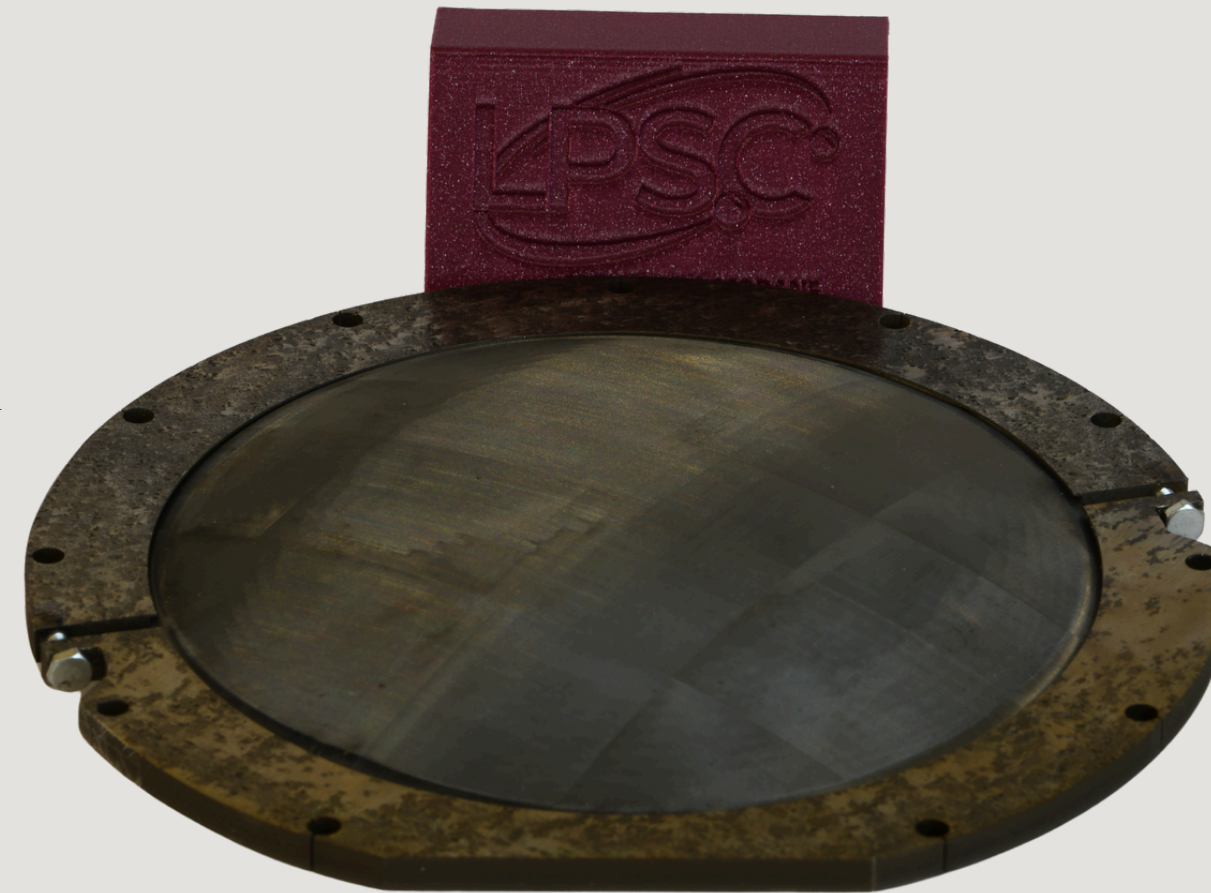
Silicon Surface Machining



Milling machine for silicon



End mill diamond tip to machine the silicon surface



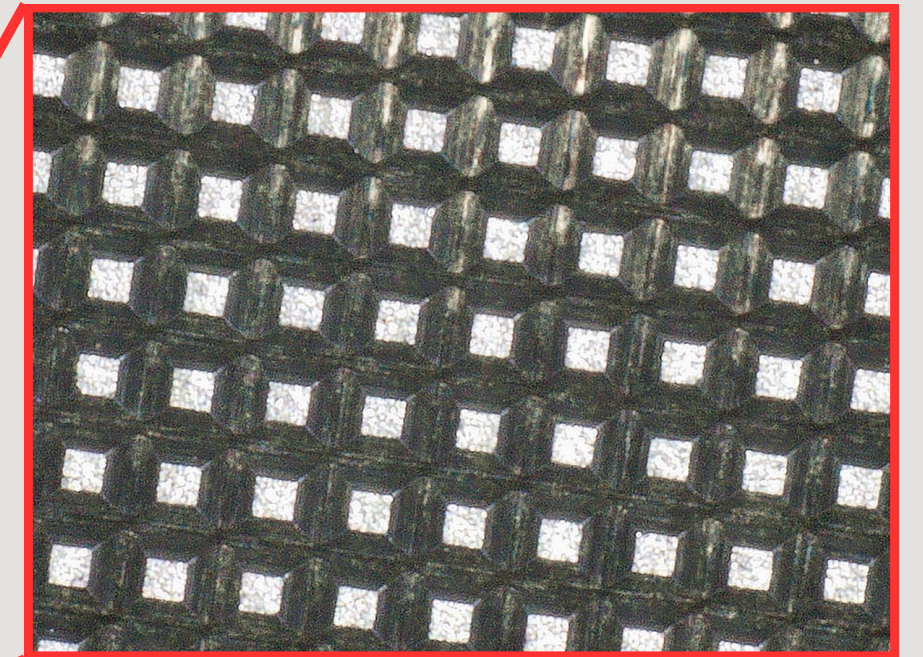
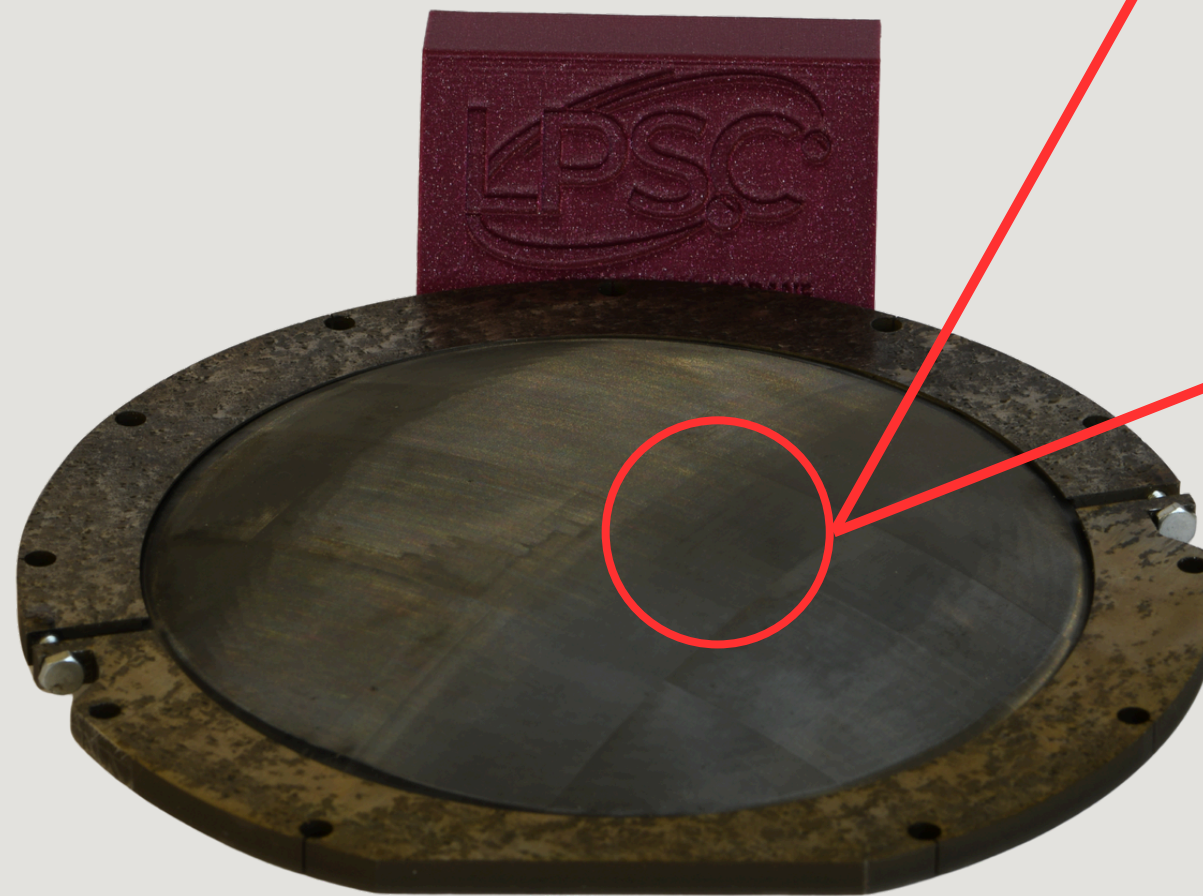
Silicon Surface Machining



Milling machine for silicon



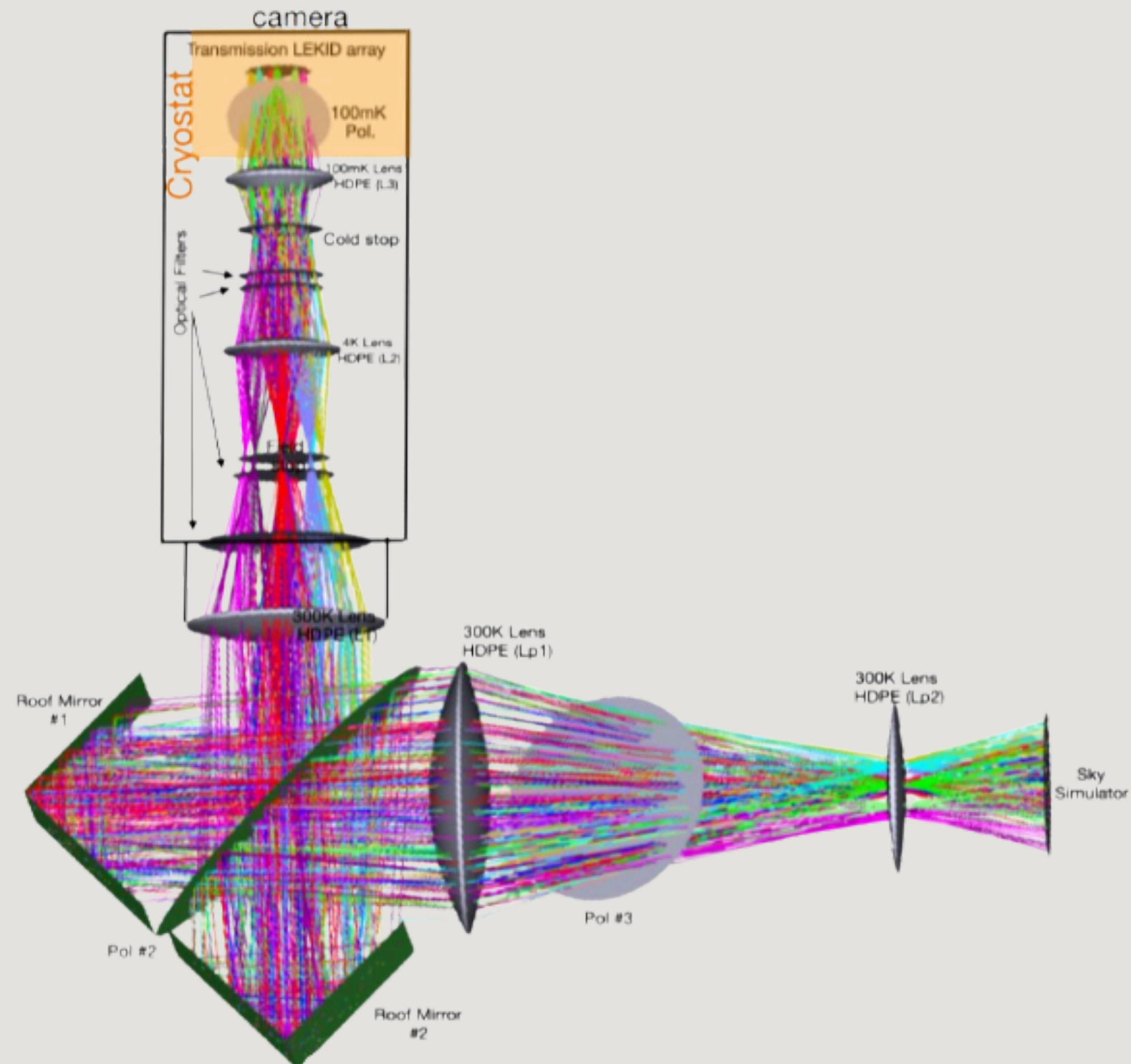
End mill diamond tip to machine the silicon surface



Zoom on AR machined surface

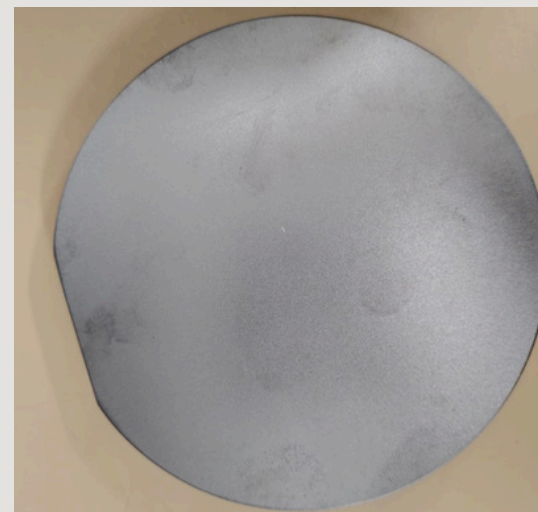
Performances Cryogenical Test

The facility in the LPSC-mm hall is equipped with a **Martin-Puplett interferometer**, featuring a ~ 20 K cold source at the input and two matrices of **Kinetic Inductance Detectors (KIDs)** at the output, mounted in a **Dilution Cryostat** operating at **100 mK**.



Performances Cryogenical Test

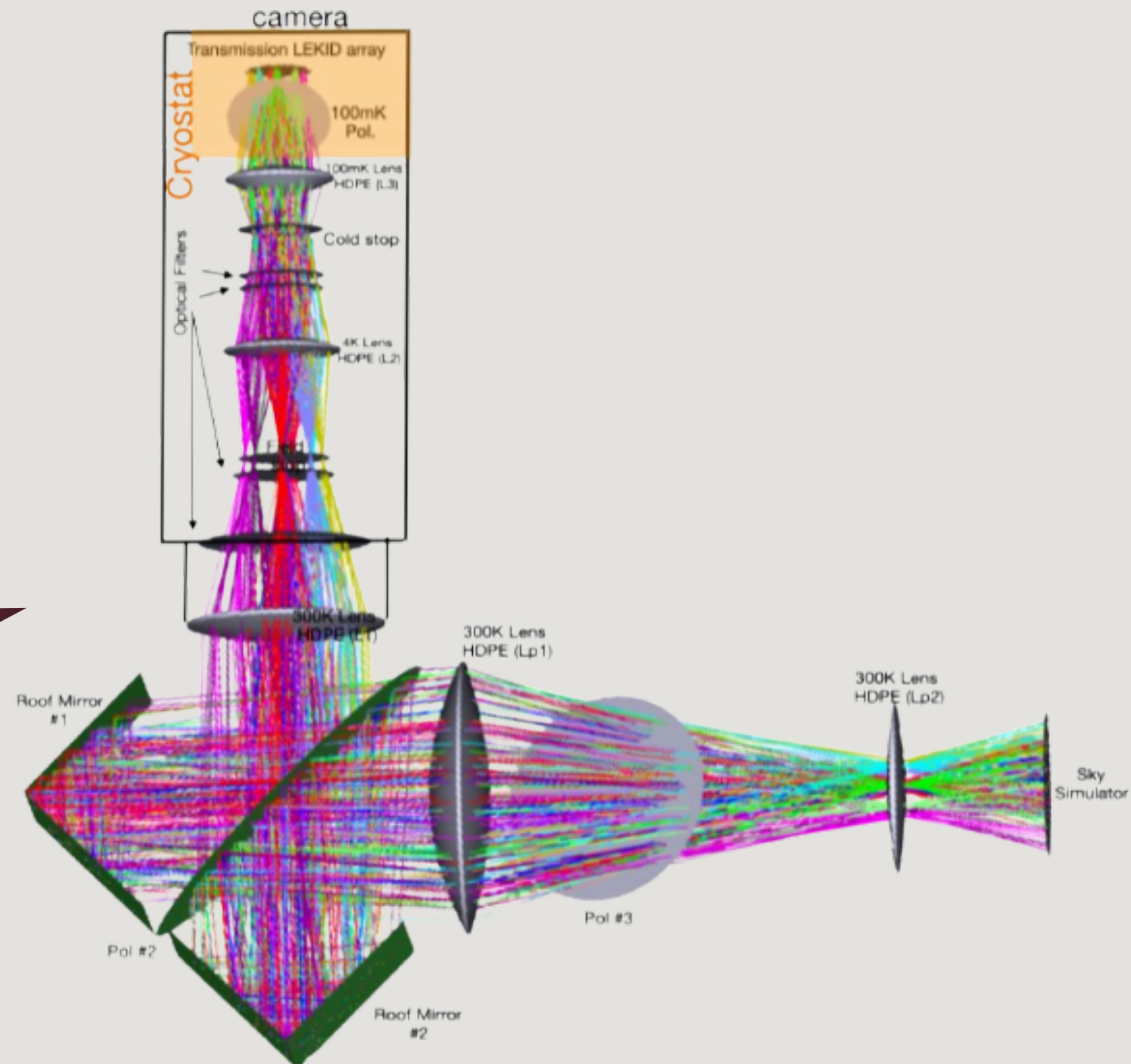
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Flat Silicon Sample

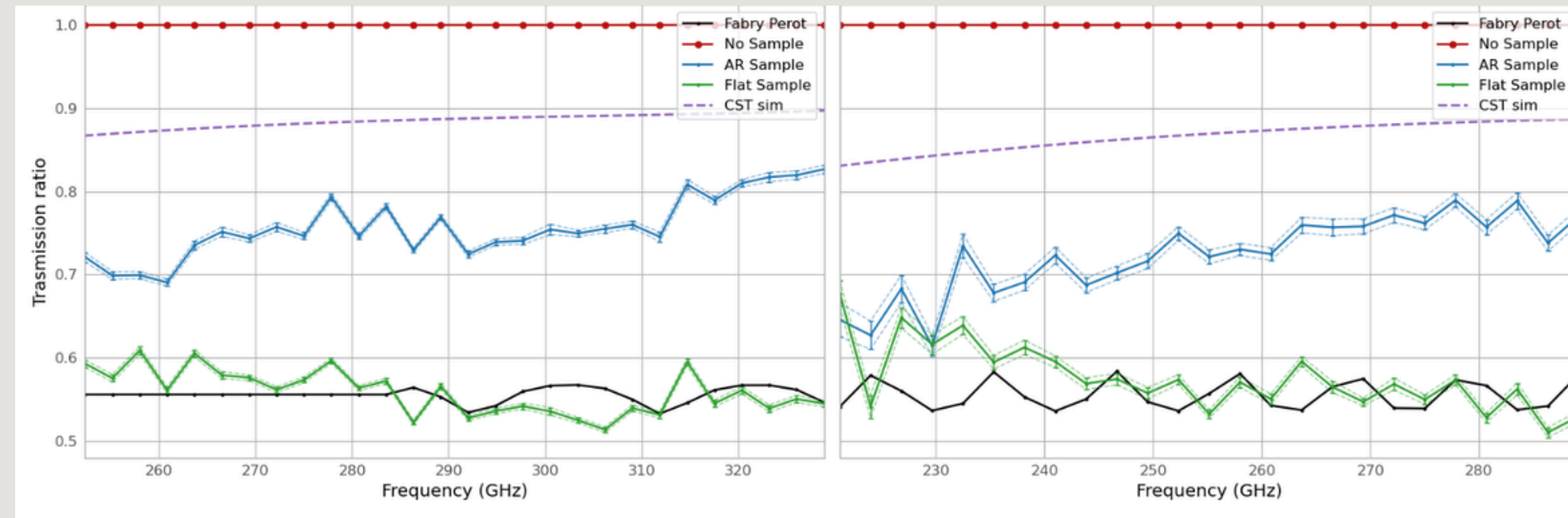


AR Machined Silicon Sample

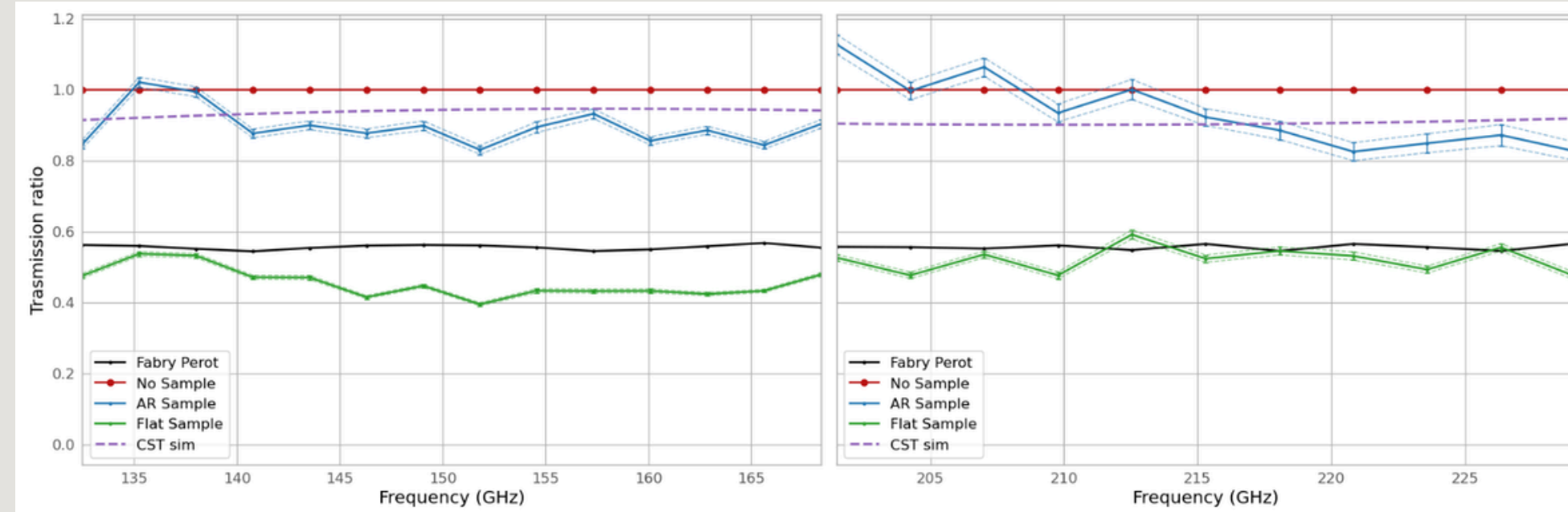


Cryogenical Performances Test

200-400 GHz



100-200 GHz



At 200-400 GHz, we achieve **80%** signal transmission, compared to 50% in the flat configuration.

At 100-200 GHz, the transmission reaches **90%**.

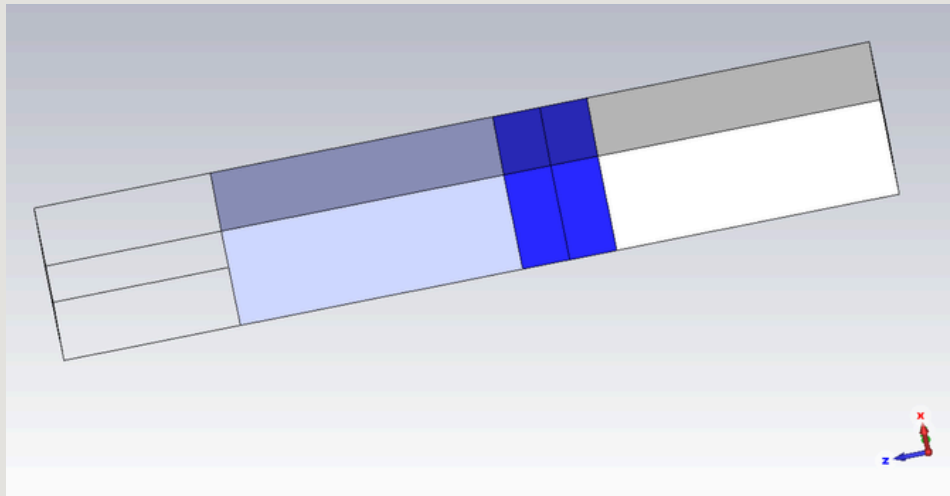
Alumina: an Alternative Lens Material

Alumina: an Alternative Lens Material

CST Optimization of
Coating
Properties

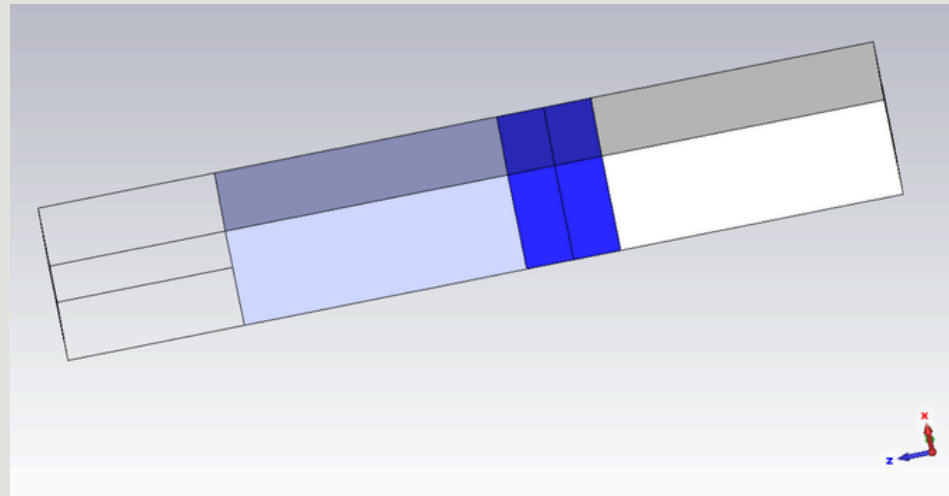
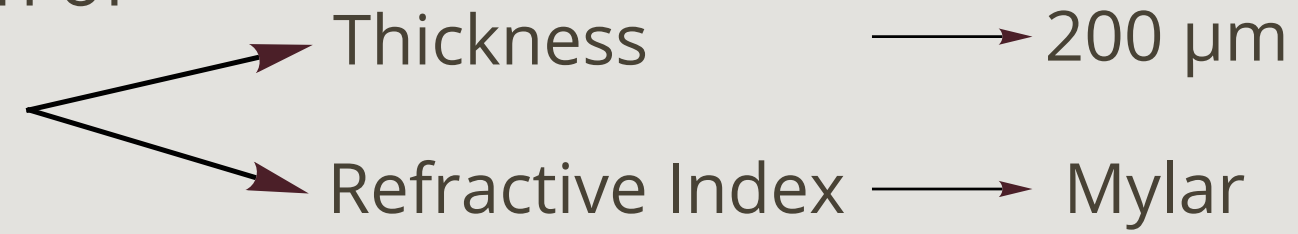
Thickness → 200 μm

Refractive Index → Mylar

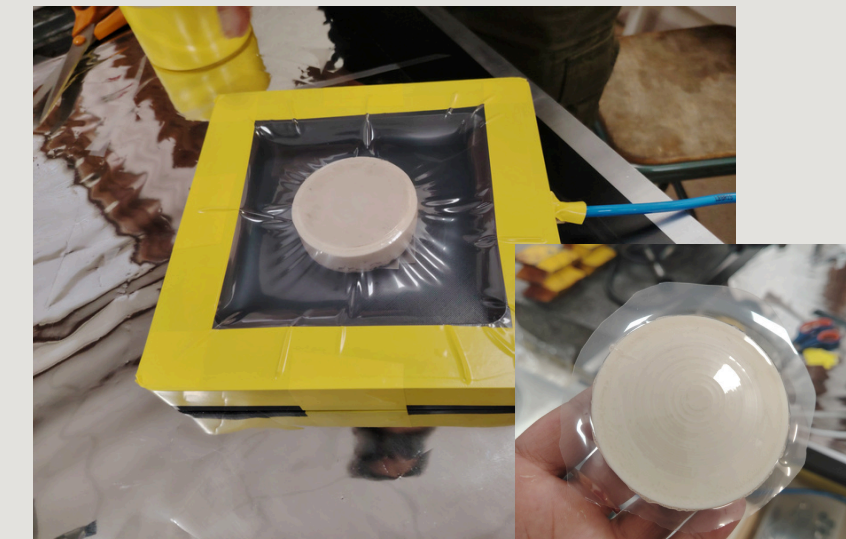


Alumina: an Alternative Lens Material

CST Optimization of
Coating
Properties



Custom-Built Vacuum System
for Mylar Attachment



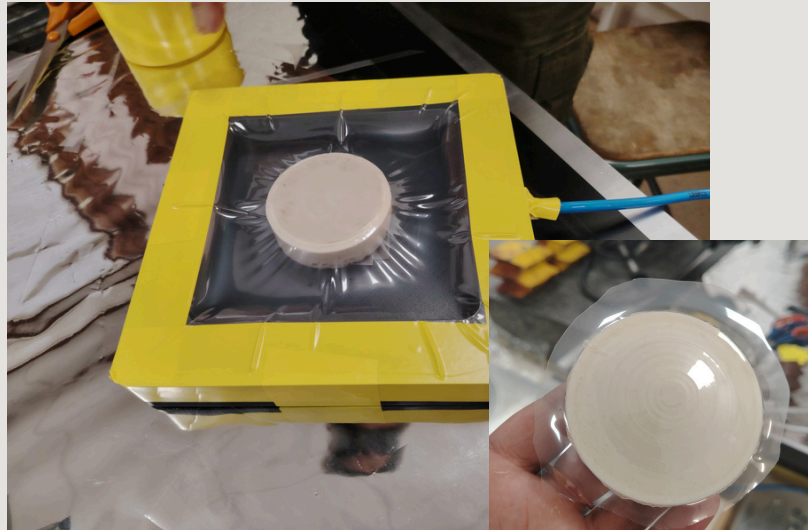
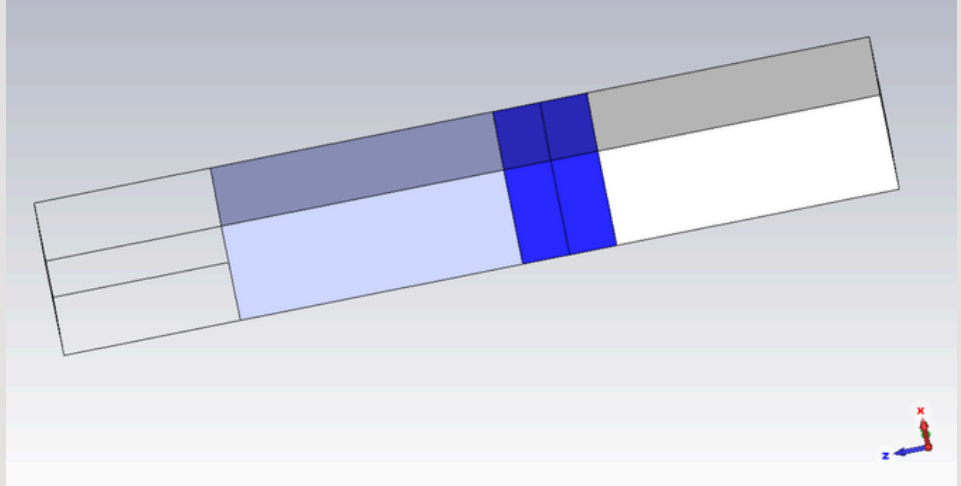
(in collab. with Olivier Guillaudin)

Alumina: an Alternative Lens Material

CST Optimization of Coating Properties

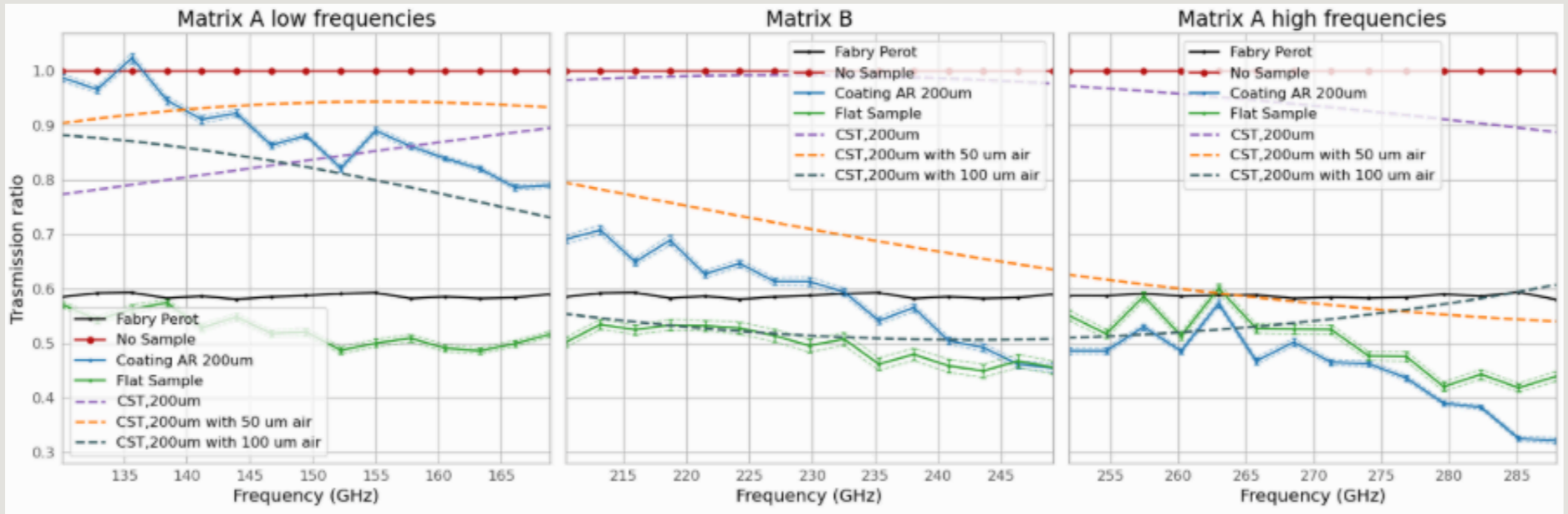


Custom-Built Vacuum System for Mylar Attachment



(in collab. with Olivier Guillaudin)

Cryogenical Performance Test Results



Thank you!
:)