

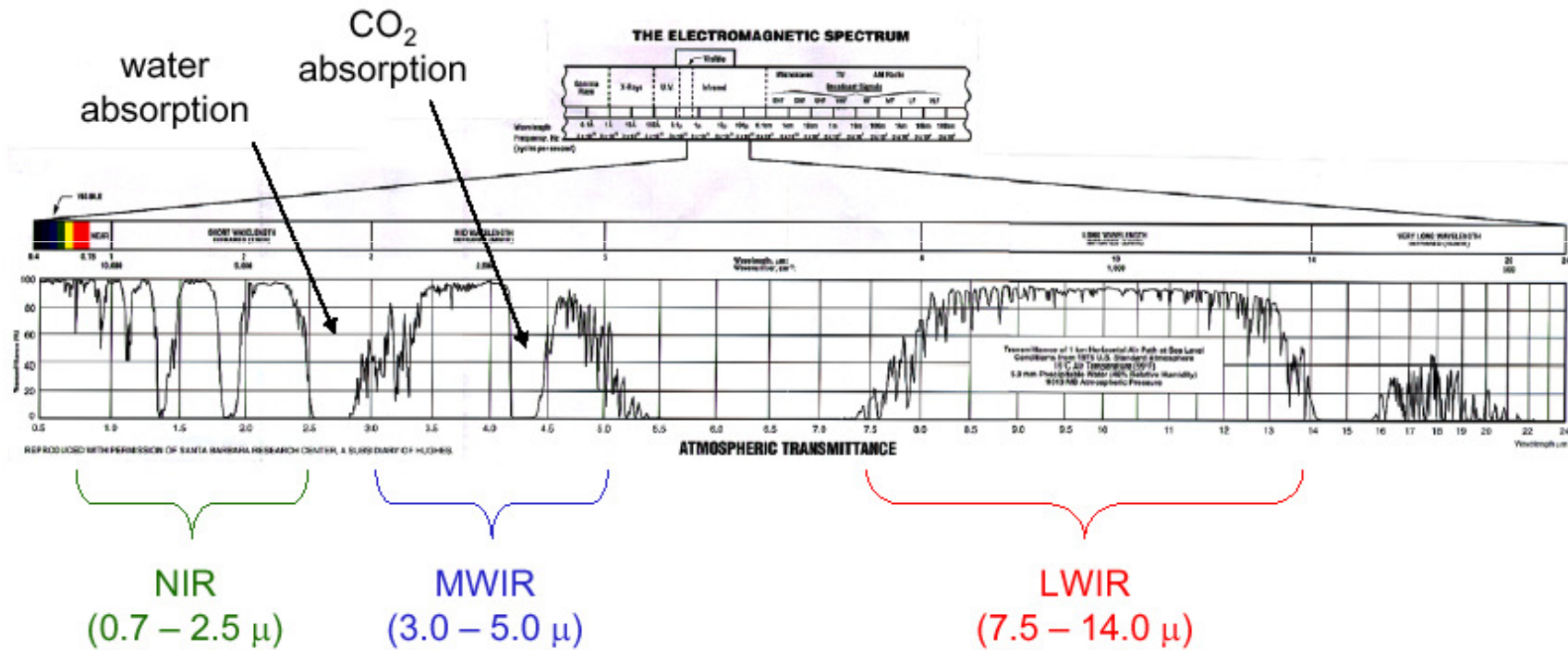
Materials for Infrared Optics

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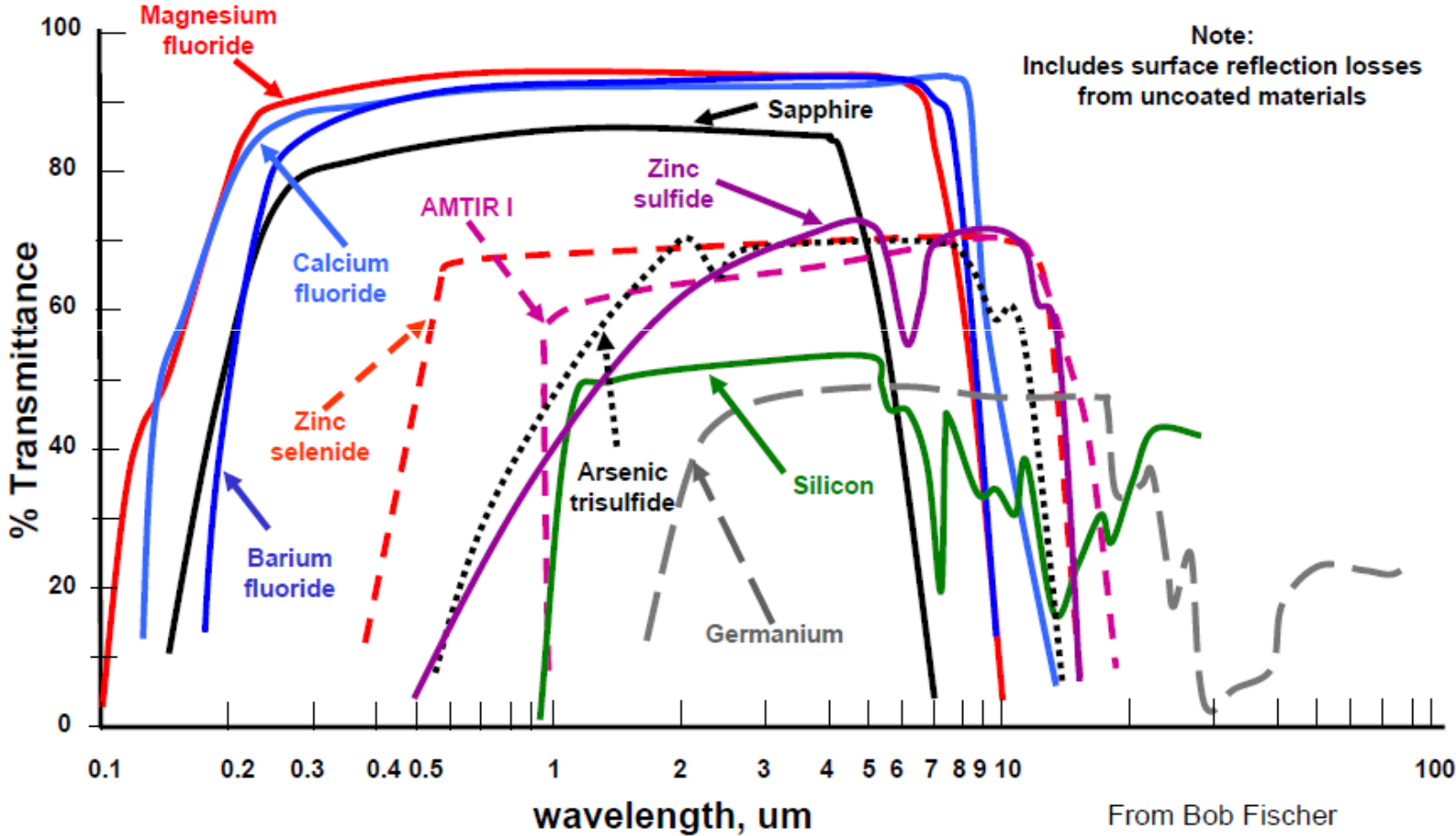
Overview

- Transmittance of IR glasses
- Comparison IR vs. Visible glasses
- Properties of some common IR glasses
 - Germanium
 - Silicon
 - Zinc Sulfide
 - Zinc Selenide
 - Magnesium Fluoride
 - Sapphire
- Concerns using lens design programs
- References

Atmospheric Transmittance



Transmittance of IR glasses



Comparison: IR vs. Visible Glasses

- There are much fewer IR glasses than visible glasses.
- Refractive indices for IR glasses much higher.
 - Visible: $n = 1.45 - 2.0$
 - IR: $n = 1.38 - 4.0$
- Dispersion is often much lower for IR glasses.
 - Visible: $v = 20 - 80$
 - IR: $v = 20 - 1000$

Comparison: IR vs. Visible Glasses

- Many IR glasses are opaque in the visible.
- Most visible glasses are opaque in the IR.
- IR glasses are often heavier than visible glasses.
- IR glasses have significantly higher dn/dT values (x10 or more) - athermalizing difficult.
- IR glasses are more expensive than visible glasses (x2 or more).

Germanium

- Most common IR material
- LWIR and MWIR
- High refractive index: $n = 4.0243$
- Large dn/dT (396 ppm/K) can cause large focus shift as a function of temperature.
- Expensive

Silicon

- Large dn/dT – 150 ppm/K
- Primarily 3 – 5 MWIR
- Large $n = 3.4255$
- Relatively low dispersion
- Can be diamond turned (with difficulty)

Zinc Sulfide

- Common material
- LWIR and MWIR
- Cleartran is the most common commercially available zinc sulfide

Zinc Selenide

- Similar to zinc sulfide but structurally weaker
- Expensive
- Very low absorption coefficient
- Transmits in the IR and visible

Magnesium Fluoride

- Low cost
- Transmits from UV to MWIR spectral band
- Poor thermal properties

Sapphire

- Extremely hard.
 - Difficult, time consuming and expensive to manufacture.
- Transmits deep UV through MWIR.
- Very low thermal emissivity at high temperature.
- Cannot be diamond turned.
- $n = 1.6753$, $dn/dT = 10 \text{ ppm/K}$

Summary of IR Material Properties

Material	Refractive Index		CTE (ppm/K)	dn/dT (ppm/K)	Knoop Hardness (g/mm ²)	Spectral Range
	@ 4 μ m	@ 10 μ m				
Germanium	4.0243	4.0032	6	396	800	2.0 – 17.0 μ m
Silicon	3.4255	N/A	2.7	150	1150	1.2 – 9.0 μ m
ZnS (Cleartran)	2.2523	2.2008	4.6	54	230	0.37 – 14.0 μ m
ZnSe	2.4331	2.4065	7.1	60	105	0.55 – 20.0 μ m
Magnesium Fluoride	1.3526	N/A	8	20	415	0.11 – 7.5 μ m
Sapphire	1.6753	N/A	5.6	13.7	1370	0.17 – 5.5 μ m
Gallium Arsenide	3.3069	3.2778	5.7	148	721	0.9 – 16.0 μ m
CaF₂	1.4097	1.3002	18.9	-11	170	0.13 – 10.0 μ m
BaF₂	1.458	1.4014	18.4	-15	82	0.15 – 12.5 μ m

Concerns using Lens Design Programs

- Most lens design programs use some literature source of data for IR materials, then fit the data to Sellmeier equations.
- Sometimes this data is inconsistent, coming from different measurement sources, and may not have sufficient significant digits.
- Thermal data, such as CTE and dn/dT , may vary widely for some materials, depending on who measured it.
- Often, the software does not include this data, as there is no official source.

References

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