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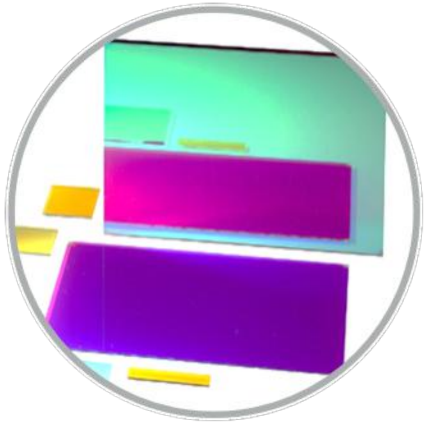
Multilayer Coatings Enabling Advanced Sensor Solutions

Source: © https://www.dlr.de/

SAFER ROADS

Provide the highest performance and most advanced LiDAR coatings.



Auer Lighting GmbH

- Auer Lighting GmbH is based in Bad Gandersheim, Lower Saxony, Germany.
- We have been known for over 70 years as an international glass optics supplier and support many TIER1 with primary and secondary glass optics for their headlights for example for ADB, Matrix LED or Laser systems.
- What many people do not know:
  - We also coat polymer optics for headlamps.
  - We have decades of experience in the coating sector with a lot of patents and technologies.

→ Our mission is to support LiDAR systems with our advanced coatings for increased safety.

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How to achieve the best possible road safety?

LiDAR is a key enabler for autonomous driving

Source: Shutterstock/Suwin

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2. Dichroic Coatings:
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   - Benefits
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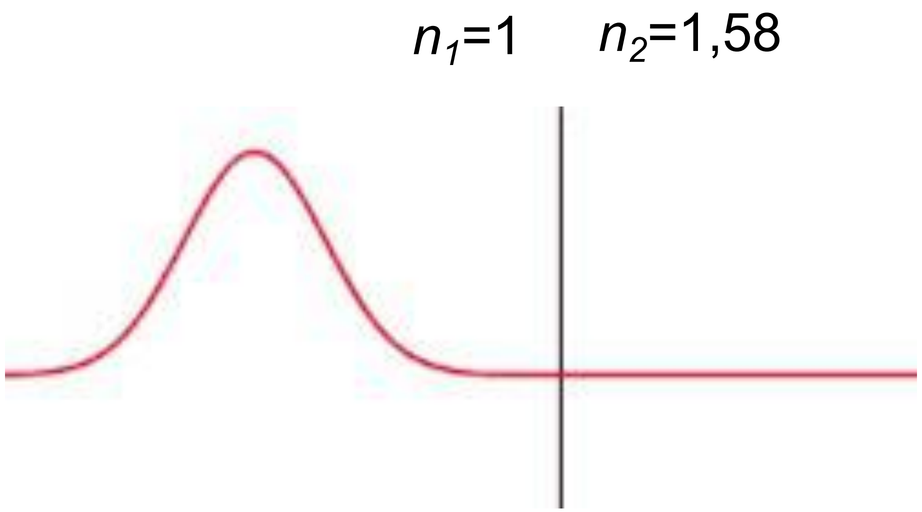
Dichroic Coatings
Basics

Basics

With each interface between different optical media, a laser beam loses intensity and thus the detector also loses signal. The higher the difference in refractive index the more light is reflected.



Partial transmission and reflection of a pulse travelling from a low to a high refractive index medium.

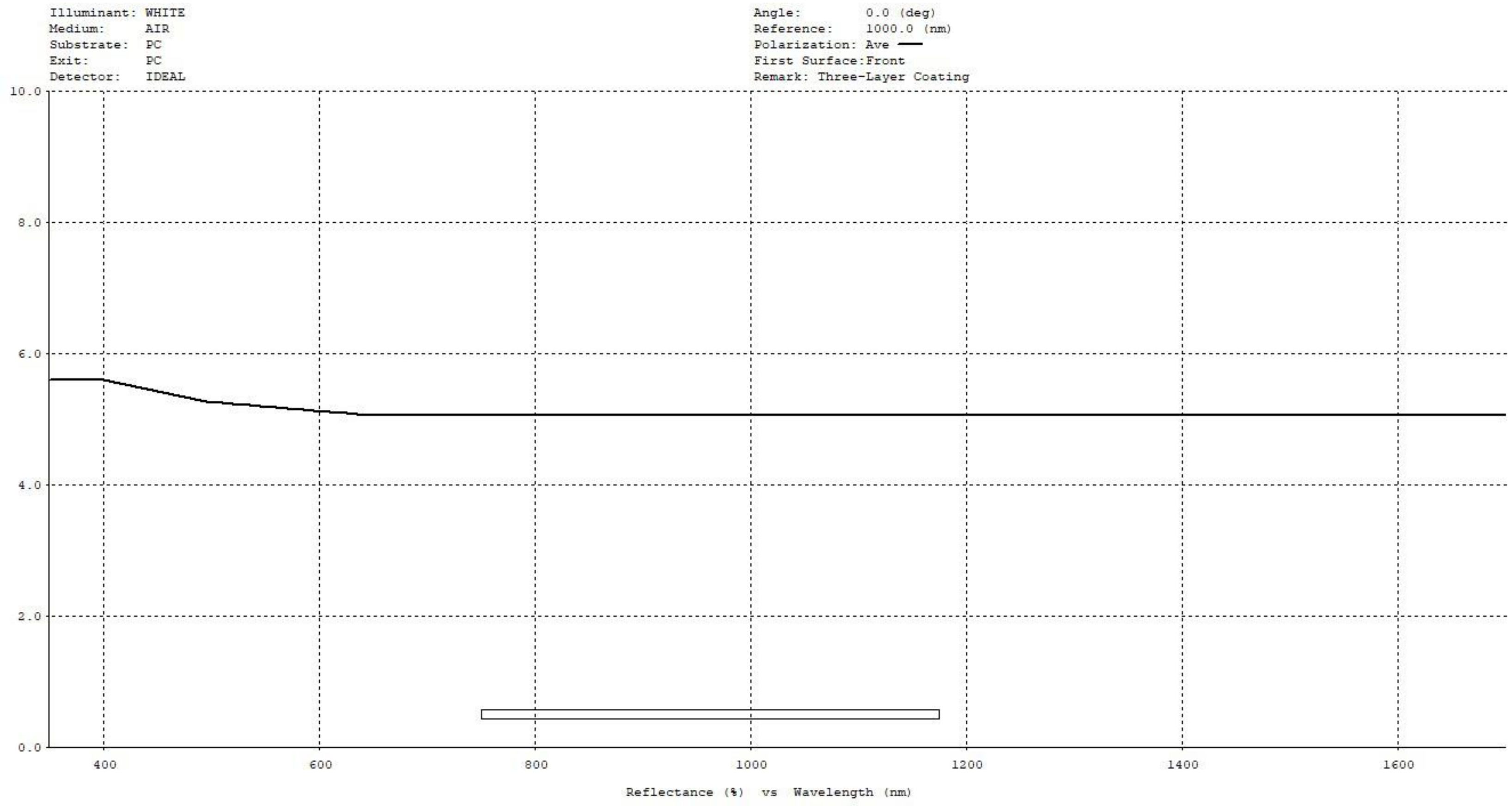
The percentage of reflected light at the material boundary can be calculated by the Fresnel equations.

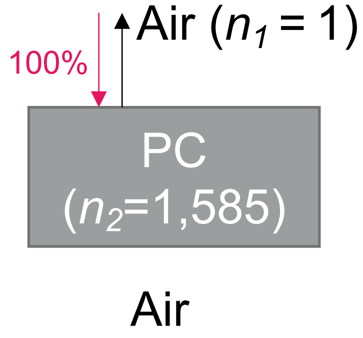
Under normal incidence the equation simplifies to:

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

Basics

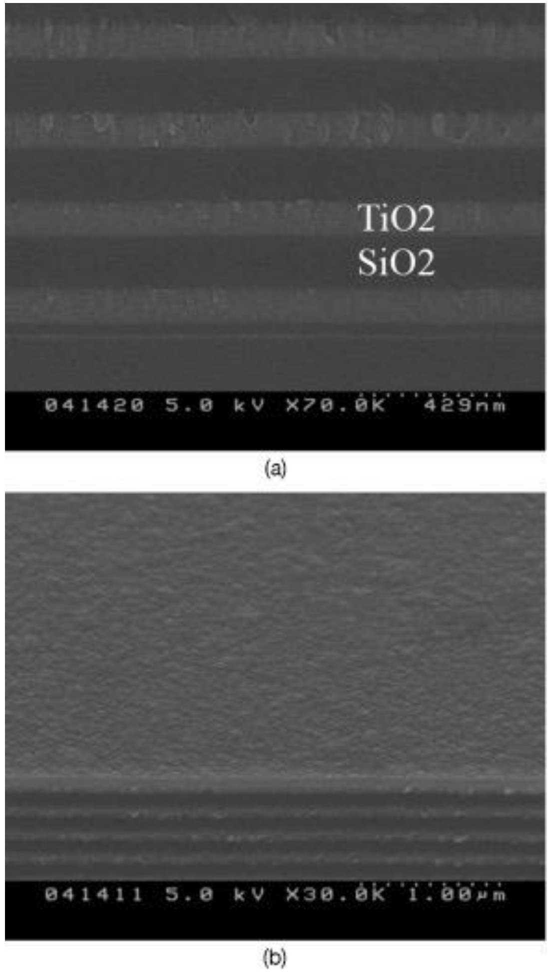
For PC ($n_2 \approx 1.585$) surrounded by air ($n_1 = 1$), the reflectance at normal incidence can be calculated to be about 5%, or 10% accounting for both sides of a PC sheet.





Basics

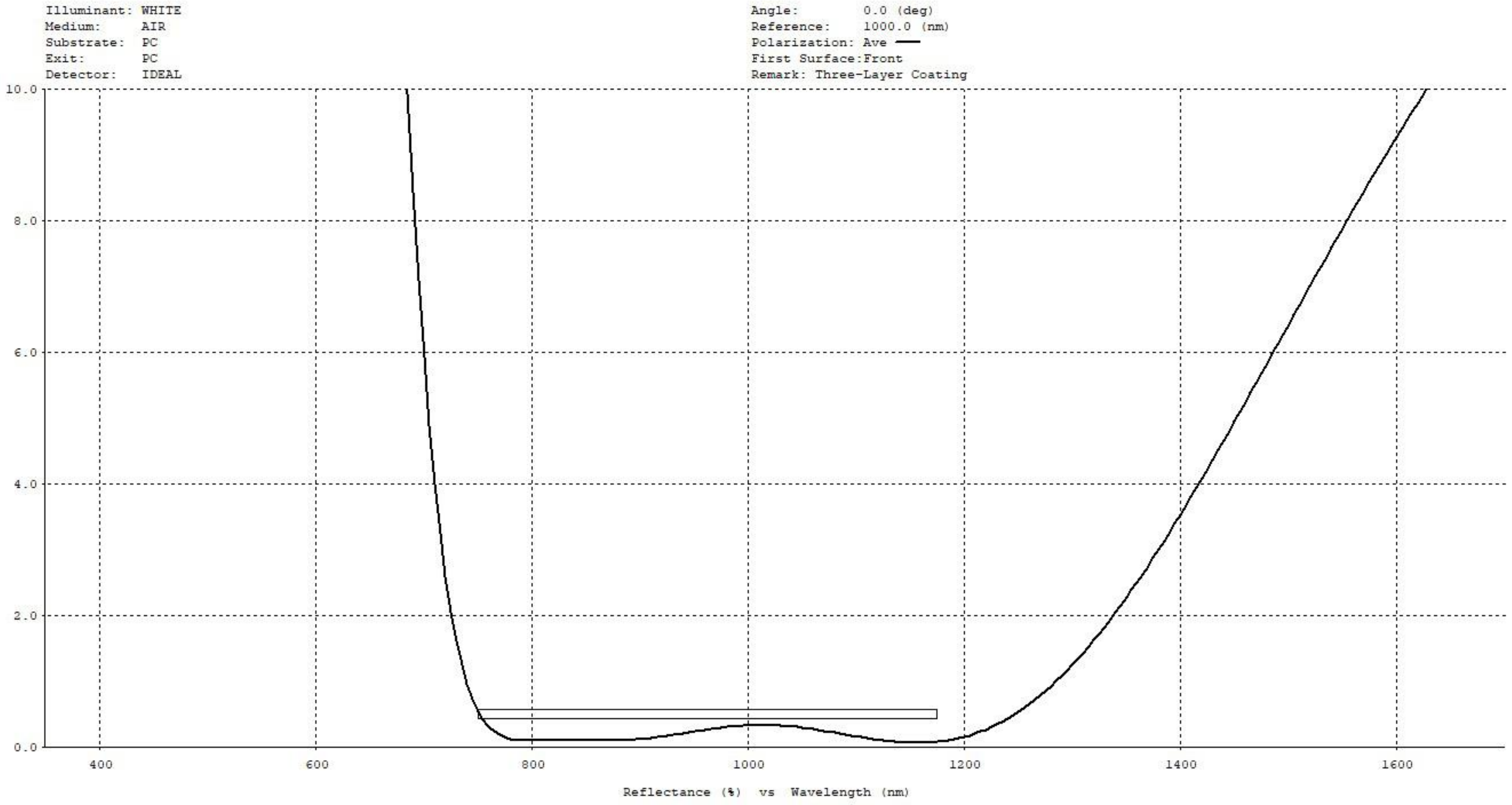
- In order to optimize the optical transition at a material interface, often dichroic coatings are used
- Dichroic coatings create precisely defined optical interference between the reflected or transmitted partial beams of incident light
- An alternating layer system is usually used, consisting of a material with a high refractive index like TiO_2 (n=2,7) and a material with a low refractive index like SiO_2 (n=1,46)
- Many dielectric layer materials have very low absorption
  $\rightarrow$ reflectivities and transmissions of almost 100% can be achieved for a certain wavelength range

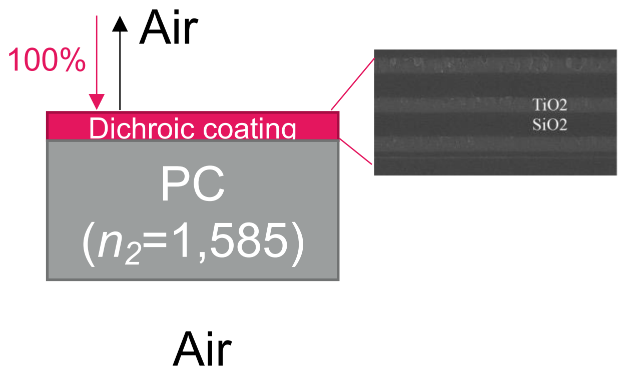


SEM image showing a cross-section of an optical filter with TiO2 and SiO2 layers [Ref.: Fan et. Al, Appl. Opt. 45, 1461-1464 (2006)]

Basics

An optimized SiO_2 /TiO_2 AR coating allows the reflection of a PC surface to be minimized to <0.5% in the 905 nm range. For the calculations, the back reflection was not considered.





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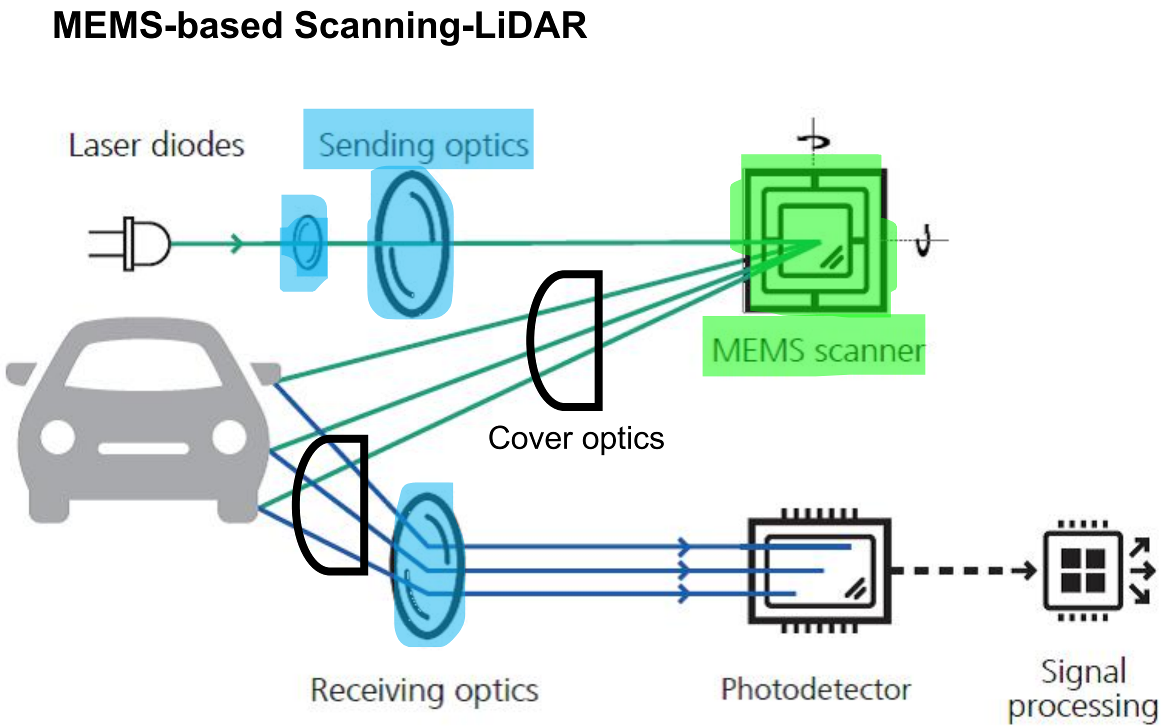
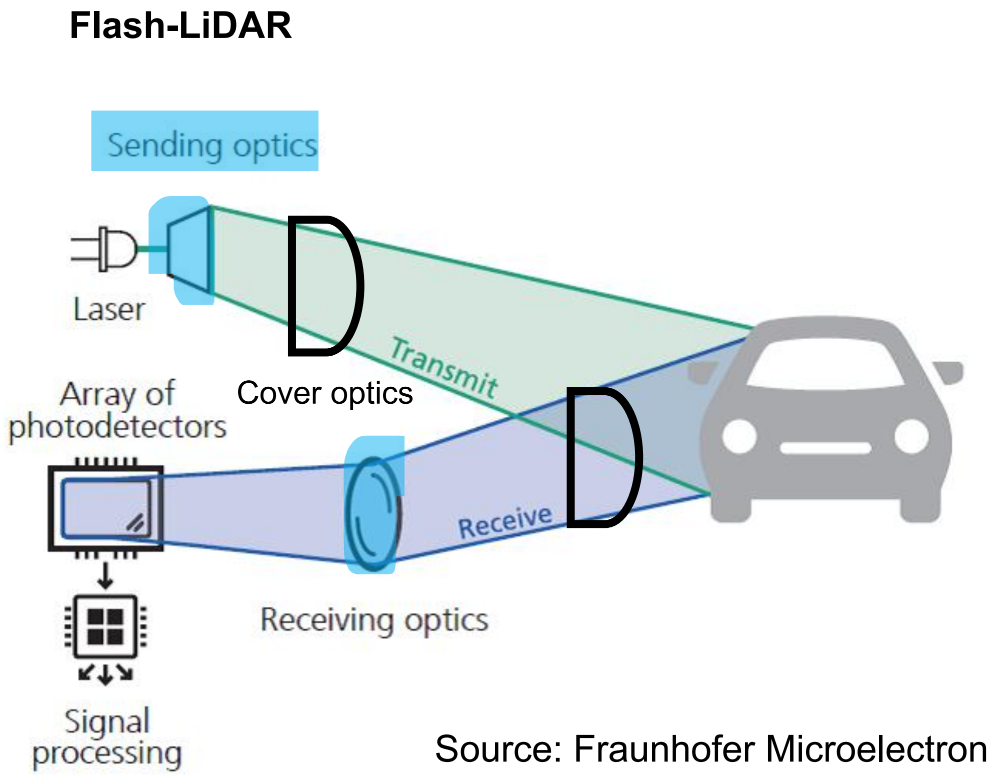
Basics





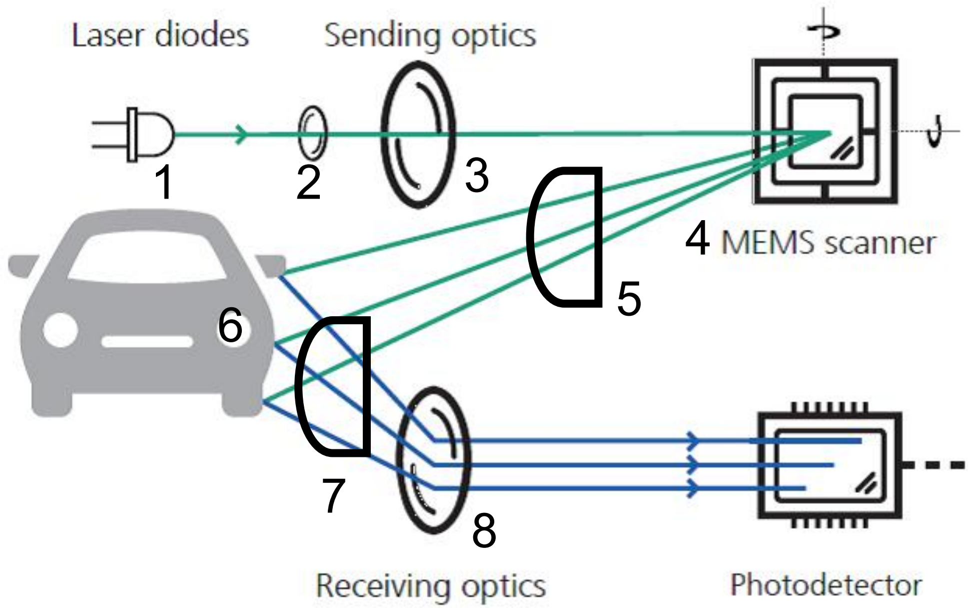
Source: Fraunhofer Microelectronics

The laser beam typically interacts with **MORE THAN 10 SURFACES** before arriving back at the detector!

Dichroic Coatings
Benefits

Benefits of Dichroic Coatings

As an example, we consider a MEMS scanner system and calculate its optical efficiency with PC optics under normal incidence:



Source: Fraunhofer Microelectronics

No.	Optical path	**Without AR coating** each air-optics interface loses 5% signal
1	Laser starting signal	100.0%
2	After 1. collimator	90.3%
3	After 2. collimator	81.5%
4	After MEMS (R=98%)	79.8%
5	After PC cover (single-side AR + single-side hard coat)	73.2%
6	Std glossy white paint (R=62% 905 nm)	45.4%
7	After PC cover	41.6%
8	After receiving optics / on detector	**37.5%**

> 60% of the signal is lost!!!

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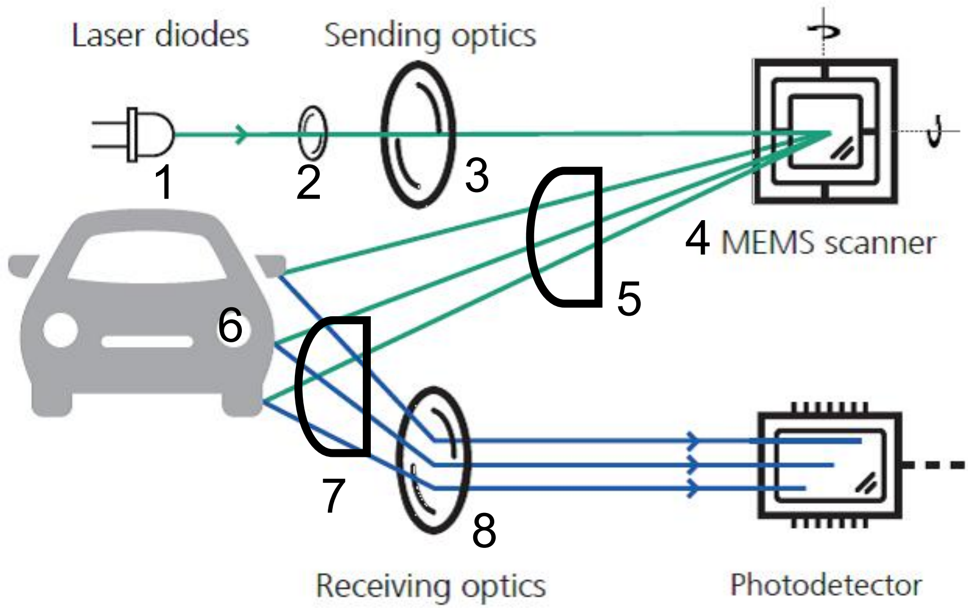
Benefits of Dichroic Coatings

As an example, we consider a MEMS scanner system and calculate its optical efficiency with PC optics under normal incidence:



Source: Fraunhofer Microelectronics

No.	Optical path	**Without AR coating** each air-optics interface loses 5% signal	**With AR coating** each air-optics interface loses 0.5% signal
1	Laser starting signal	100.0%	100.0%
2	After 1. collimator	90.3%	99.0%
3	After 2. collimator	81.5%	98.0%
4	After MEMS (R=98%)	79.8%	96.1%
5	After PC cover (single-side AR + single-side hard coat)	73.2%	92.2%
6	Std glossy white paint (R=62% 905 nm)	45.4%	57.2%
7	After PC cover	41.6%	54.9%
8	After receiving optics / on detector	**37.5%**	**54.4%**

45% higher signal with coatings!!!

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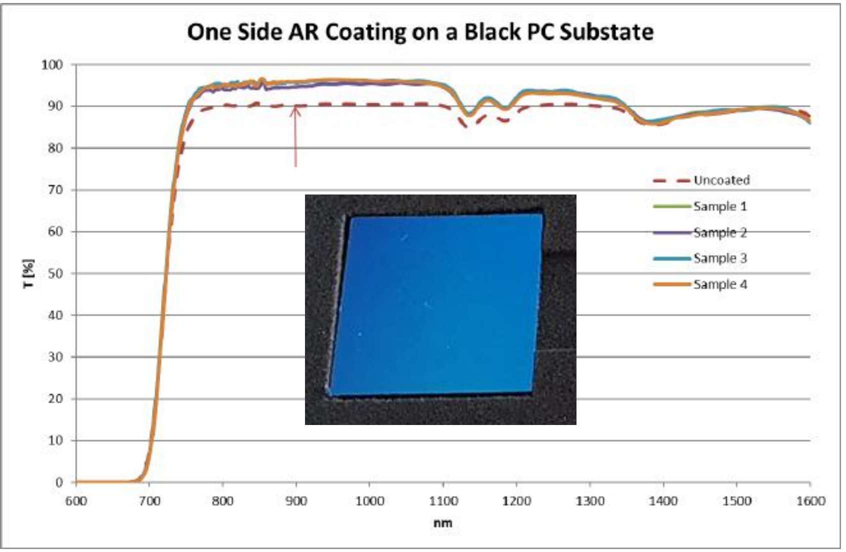
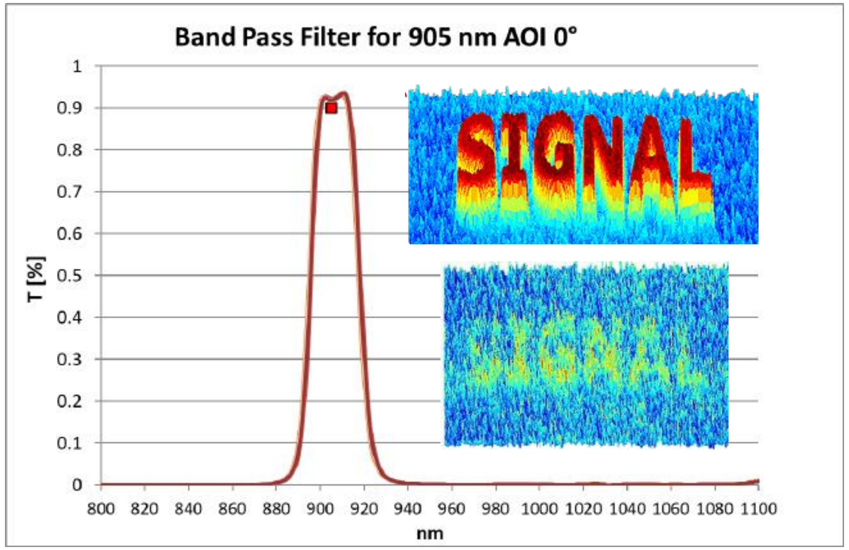
Benefits of Dichroic Coatings

3 examples of functional dichroic coatings for LiDAR optics:



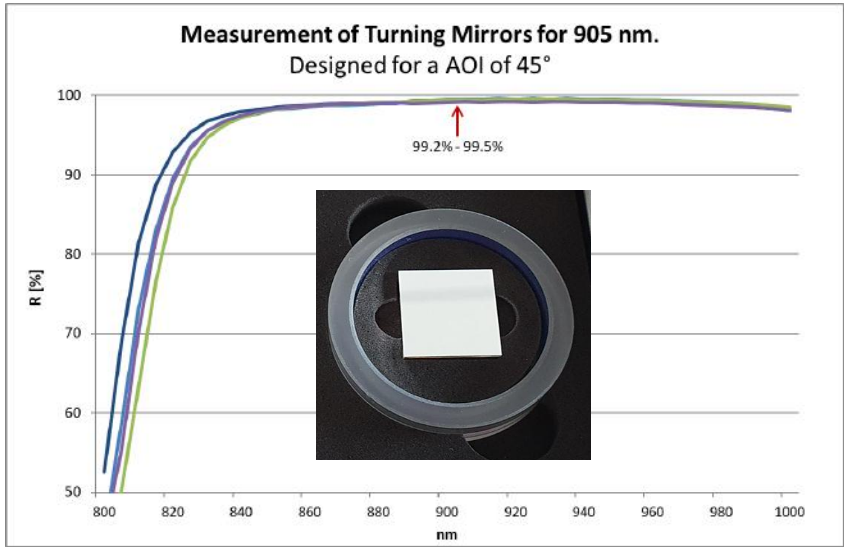
Transfer of the calculated AR layer system to the real world.

Spectral transmission measurements of a single-sided AR coating design for 905 nm on a black PC substrate.



With band pass coatings disturbing radiation can be avoided for the receiver.

Spectral transmission measurements of a BPF coating design for 905 nm on a transparent substrate.



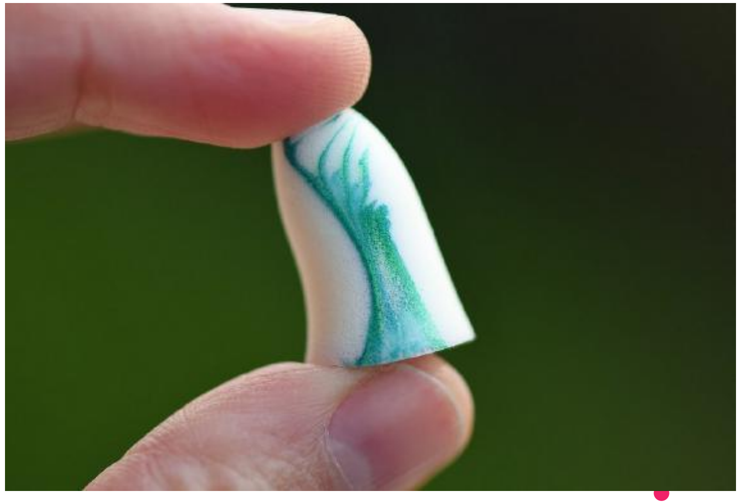
Scanning mirror systems require high reflectivities and a wide acceptance angle.

Spectral reflection measurements of a 45° turning mirror.

Benefits of Dichroic Coatings

1. Benefit:
   Coatings maximize the light signal and increase the distance and accuracy of the laser ranging

2. Benefit:
   Coatings minimize background noise



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Dichroic Coatings
Durability Requirements

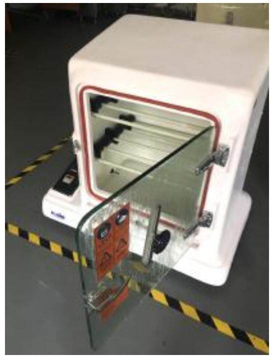
Durability Requirements

Dichroic coatings are undergoing tough stress tests to be automotive compliant:

Short-term temperature test: Temperature resistance 120°C/1h. No change of the coating allowed.

Long-term temperature test: Temperature resistance 120°C/240h. No change of the coating allowed.

Alkali test: parts are stored for 10 min in a 1% KOH solution. No delamination of the coating allowed.



Condensation water test: parts are stored at min. 40°C for 48h @ 100% humidity with condensation. No delamination allowed.

Climate change test: parts are stored at 120°C for 1h @ 95% rH. Then a cooling down to -40°C @ 0%rH and storage for one hour follows. The cycle is repeated 5 times. No delamination allowed.

Durability Requirements

Combination test of dry heat, alternating climate followed by humidity heat:

Dry heat test: parts are stored at 120°C for 240 hours, followed by

Alternating climate test: parts are stored 3h @120°C → 1h storage @ room temperature → 3h cold storage @ -40°C → 1h storage @ room temperature, followed by

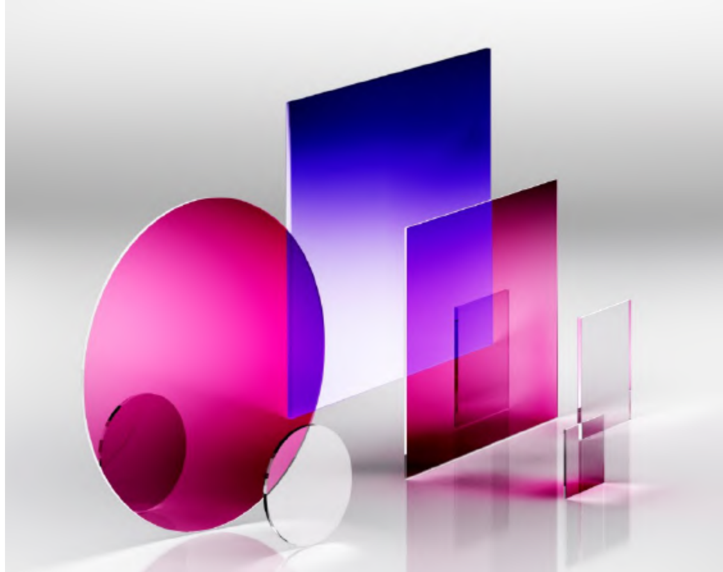
Humidity-heat test: parts are stored 15h @ 40°C in water condensation climate → 1h storage @ room temperature.

The cycle is repeated 2x

After the test no delamination of the coating is allowed.

Durability Requirements

- While a lot of other coatings have tough times with layer adhesion especially on polymer substrates, Auer Lighting's dichroic coating processes are the perfect match for best durability and longevity
- They protect against chemical and mechanical environmental influences like moisture, dust and yellowing from UV and blue light
- No wavelength / color shift with temperature variations
- High flexibility regarding substrate choice: polymer materials, soda lime glass, borofloat, quartz, sapphire, etc.



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Durability Requirements

3. Benefit:
   Coatings protect against environmental influences

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Summary

Presented benefits of dichroic coatings for LiDAR systems:

1. **Best light signal**
2. **Best signal-to-noise ratio**
3. **Substrate Protection**

Highest Safety

3D Geometry

In addition to the great properties of dichroic coatings, Auer Lighting's technologies bring even more spice to the table:

With our patented **PICVD technology** (Plasma Impulse Chemical Vapor Deposition) coating the inside of complex 3D geometries such as tubes, curved covers or even bottles is our daily business.

Source: Alibaba

Key Take-Away

Dichroic coatings significantly improve LiDAR systems!

Invitation

If you have interest in joining my obsession to make roads safer then let's stay in touch:

- Meet me and my colleague at the Auer Lighting booth #2
- Visit our website: https://www.auer-lighting.com
- Add me on LinkedIn: Christian Paßlick
- Write me an email: christian.passlick@auer-lighting.com

I wish you safe driving!

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