RhySearch
Das Forschungs- und Innovationszentrum Rheintal

Optical Coatings

Photonics 4 Luxury Coatings

21.06.2017, Genève

Dr. Andreas Bächli

Head of Optical Coatings at RhySearch, Buchs (SG)

RhySearch
The Research- and Innovation Center in the Rhine Valley

RhySearch
Das Forschungs- und
Innovationszentrum Rheintal

- RhySearch founded in 2013 (by St.Gallen & Liechtenstein)
- Board of directors with strong representation of the industry
- Further growth supported by strategy and approved investment plan
- Today 9 employees

PROVIDE A NETWORK TO LOCAL BUSINESS

APPLIED R&D
in three areas:

Optical coatings
Precision manufacturing
Packaging

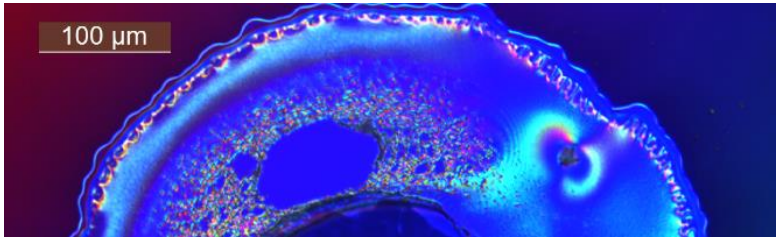
ENABLE INNOVATION PROZESSES

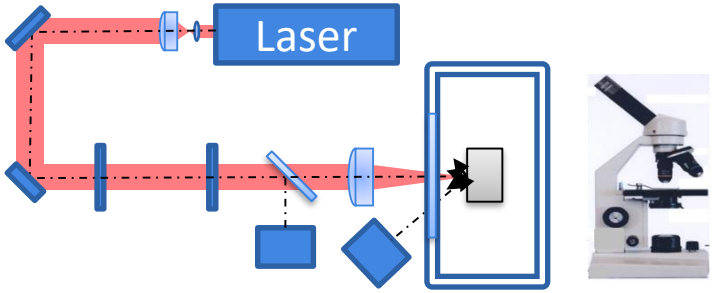
CTI approved
since Q1/2017

Optical Coatings Lab @ RhySearch in a nutshell

RhySearch
Das Forschungs- und Innovationszentrum Rheintal

- Dual-Ion-Beam Sputtering
  - Site acceptance test ongoing
  - VIS-NIR Broad-Band Monitoring
  - Ta_2O_5, HfO_2, SiO_2 , more upon request
- …





LIDT: Set-up and picture of damaged spot
acknowledge: CTI-project 16871.1

- Laser Induced Damage Threshold (LIDT)
  - ISO 21254 (e.g. S-on-1 test procedure)
  - λ = 1064, 532, 355 nm (ns-Pulse)
  - λ = 1030 nm (fs-Pulse)
- Degradation Chamber for Optical Components (cooperation with NTB)
  - Ar, N_2,O_2,humidity, Temp up to 250 °C
    - Investigate degradation under 355 nm irradiation (ns, up to 100 kHz)
    - LIDT under controlled harsh conditions
- Cavity-Ring-Down (CRD)
  - 1064 nm and 638 nm (ISO 13142)
  - Reflectivity measurements our goal → 1 ppm detection limit

Optical Coatings Lab @ RhySearch in a nutshell

RhySearch
Das Forschungs- und Innovationszentrum Rheintal

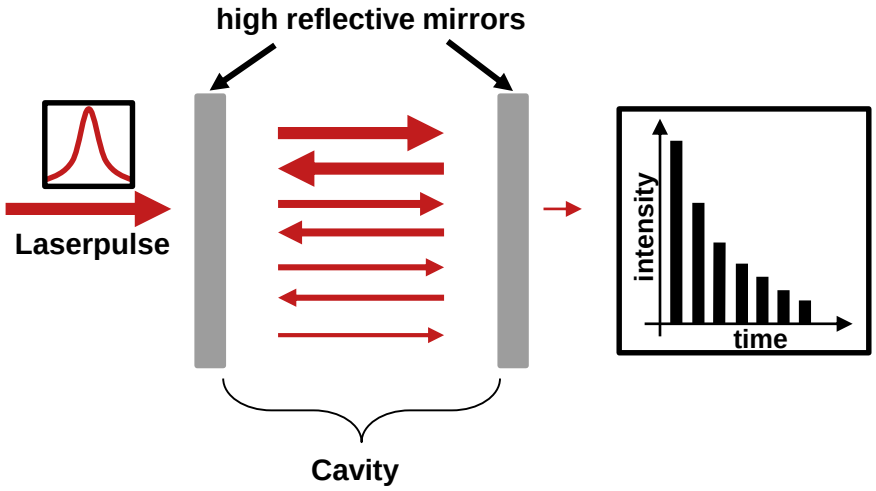
- Dual-Ion-Beam Sputtering
  - Site acceptance test ongoing
  - VIS-NIR Broad-Band Monitoring
  - Ta_2O_5, HfO_2, SiO_2 , more upon request
- …

Degradation Chamber
acknowledge: CTI-project 16871.1

- Laser Induced Damage Threshold (LIDT)
  - ISO 21254 (e.g. S-on-1 test procedure)
  - λ = 1064, 532, 355 nm (ns-Pulse)
  - λ = 1030 nm (fs-Pulse)
- Degradation Chamber for optical components (cooperation with NTB)
  - Ar, N_2, O_2, humidity, temp up to 250 °C
    - Investigate degradation under 355 nm irradiation (ns, up to 100 kHz)
    - LIDT under controlled harsh conditions
- Cavity-Ring-Down (CRD)
  - 1064 nm and 638 nm (ISO 13142)
  - Reflectivity measurements our goal → 1 ppm detection limit

Optical Coatings Lab @ RhySearch in a nutshell

- Dual-Ion-Beam Sputtering
  - Site acceptance test ongoing
  - VIS-NIR Broad-Band Monitoring
  - Ta_2O_5, HfO_2, SiO_2 , more upon request
  - …



Schematic illustration of Cavity-Ring-Down

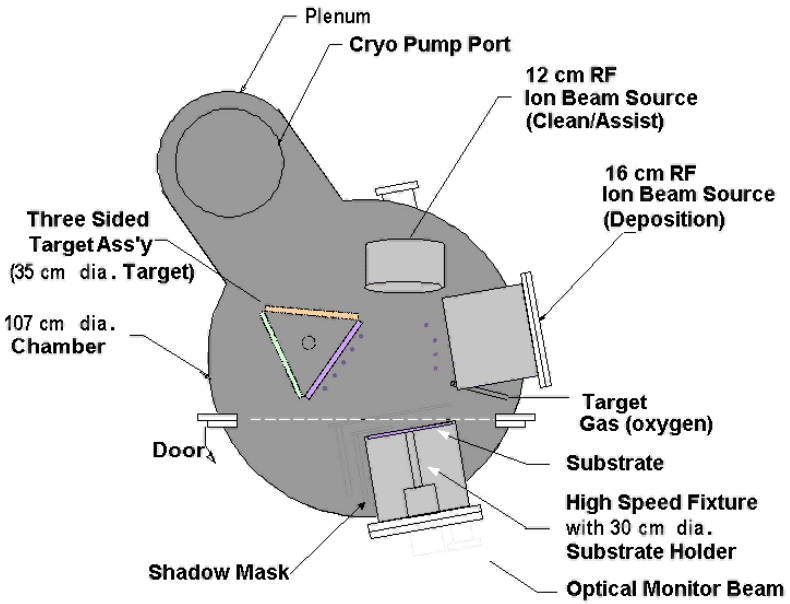
- Laser Induced Damage Threshold (LIDT)
  - ISO 21254 (e.g. S-on-1 test procedure)
  - λ = 1064, 532, 355 nm (ns-Pulse)
  - λ = 1030 nm (fs-Pulse)
- Degradation Chamber for optical components (cooperation with NTB)
  - Ar, N_2, O_2,humidity, Temp up to 250 °C
    - Investigate degradation under 355 nm irradiation (ns, up to 100 kHz)
    - LIDT under controlled harsh conditions
- Cavity-Ring-Down (CRD)
  - 1064 nm and 638 nm (ISO 13142)
  - Reflectivity measurements our goal → 1 ppm detection limit

Optical Coatings Lab @ RhySearch in a Nutshell

RhySearch
Das Forschungs- und Innovationszentrum Rheintal

Ion-Beam-Sputtering Coating Tool (IBS)

- Dual-Ion-Beam configurations
- VIS-NIR Broad-Band Monitoring
- Ta_2O_5, HfO_2, SiO_2 , more upon request



Setup of RhySearch DIBS /picture and tool from Veeco

Laser Induced Damage Threshold (LIDT)

- ISO 21254 (e.g. S-on-1 test procedure)
- λ = 1064, 532, 355 nm (ns-Pulse)
- λ = 1030 nm (fs-Pulse)

Degradation Chamber for optical components (cooperation with NTB)

- Ar, N_2, O_2, humidity, temp up to 250 °C
- Investigate degradation under 355 nm irradiation (ns, up to 100 kHz)
- LIDT under controlled harsh conditions

Cavity-Ring-Down (CRD)

- 1064 nm and 538 nm (ISO 13142)
- Reflectivity measurements
  our goal → 1 ppm detection limit

Overview

RhySearch
Das Forschungs- und Innovationszentrum Rheintal

- Introduction to RhySearch
- Optical Coatings
  - Coating Process
  - Optical Interference
- Applications
  - Function of optical coating
  - Application specific challenges

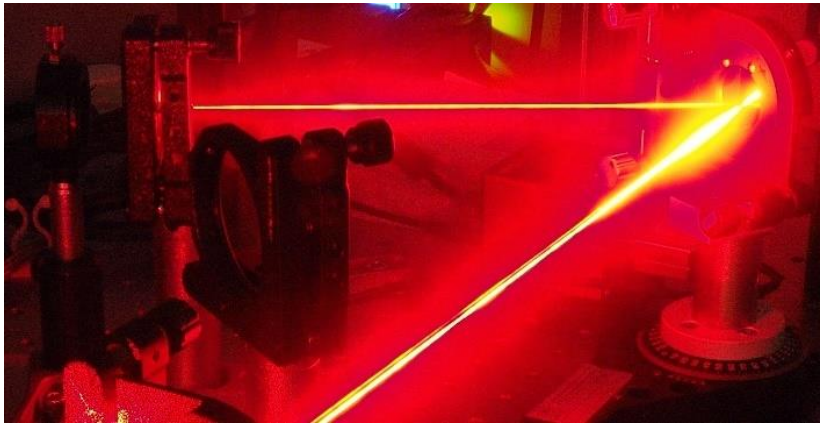
What are Optical Coatings ?

RhySearch
Das Forschungs- und Innovationszentrum Rheintal

Coatings make **functional glass**
in the path of the light non reflecting

Source: www.twenty20vision.co.za

Coatings are used
to **guide**, to **alter** or to **filter light**

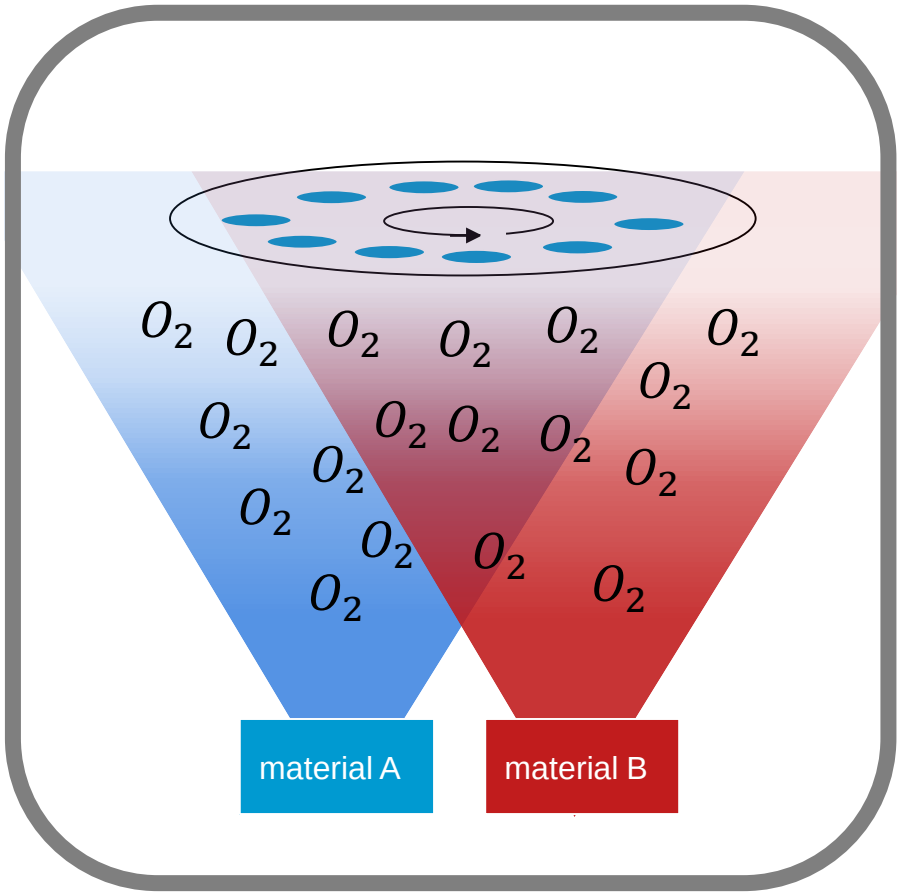


Source: RhySearch

Glass has a function

Coating has a function

Physical Vapor Deposition (PVD)



evaporation source(s)

substrate holder

vacuum chamber

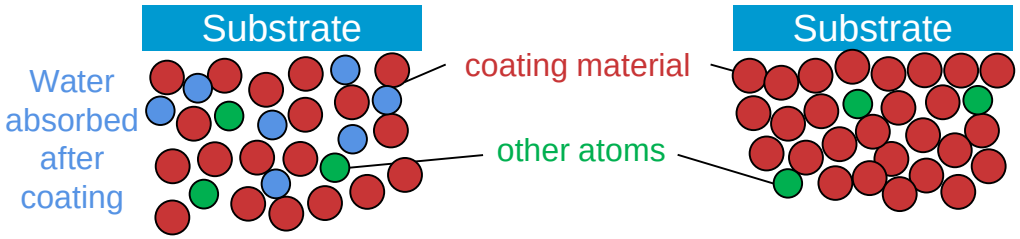
reactive gas (e.g. O_2, N_2, …)

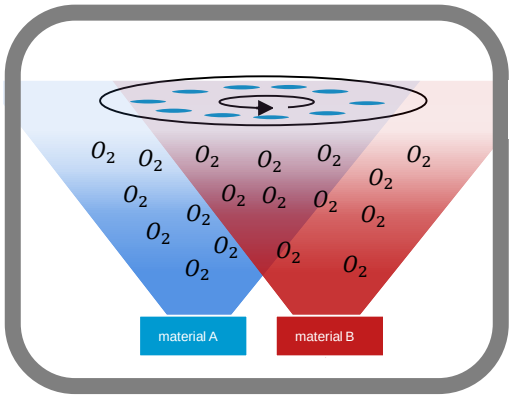
process control

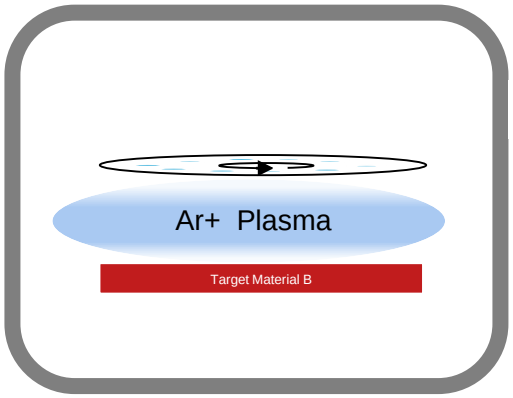
Various configurations available with different strengths and weaknesses

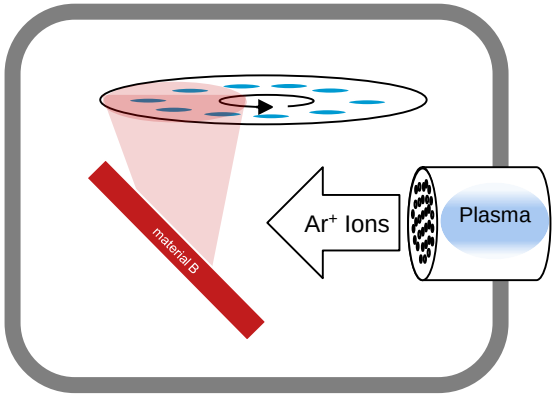
Coating Processes

RhySearch
Das Forschungs- und Innovationszentrum Rheintal







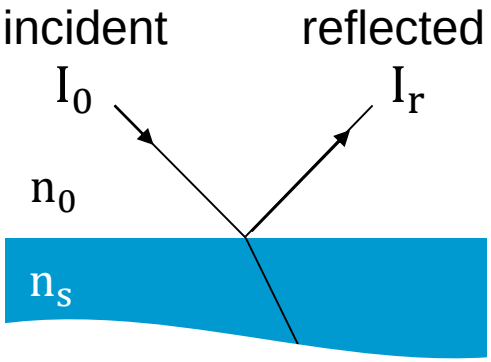


Evaporation (e-beam)	Magnetron sputtering	Ion-beam-sputtering (IBS)
standard coating	stable coating	very dense coatings
high reflectivity mirror	higher reflectivity mirror	highest reflectivity mirror
low edge performance	best edge performance	best edge performance
lower cost	medium cost	higher cost

Reflection and Interference of Light Waves

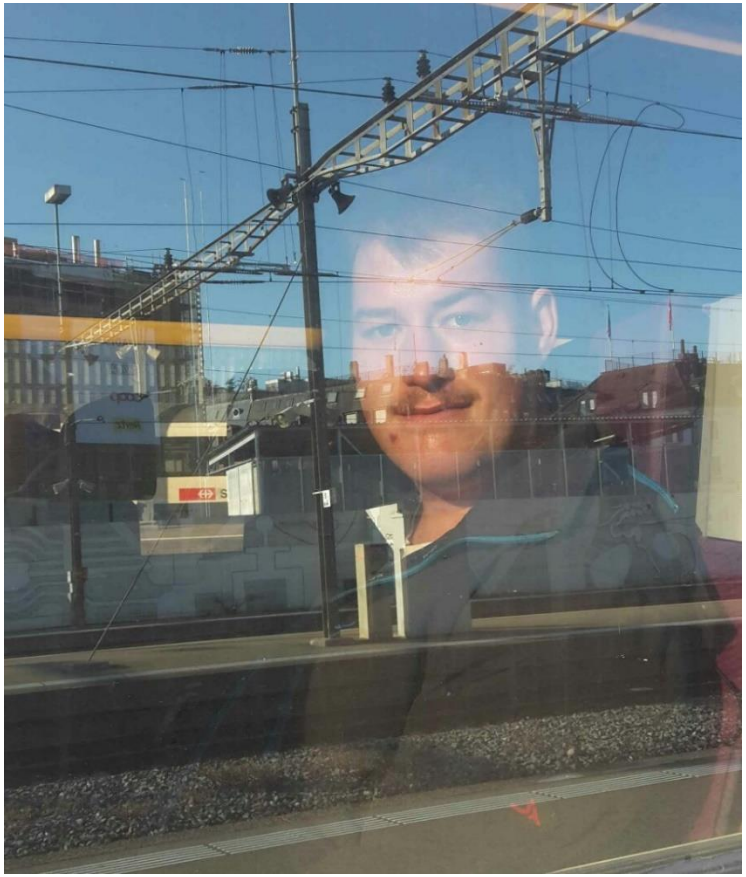
RhySearch
Das Forschungs- und Innovationszentrum Rheintal

speed of light c
is material dependent
$c = n\, c_0$



$$\frac{I_r}{I_0} = \left[\frac{n_s - n_0}{n_s + n_0}\right]^2$$

≈ 4 % window glass
≈ 8 % sapphire glass

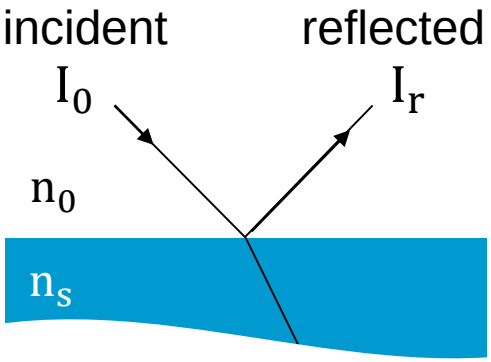


Source: RhySearch

Reflection and Interference of Light Waves

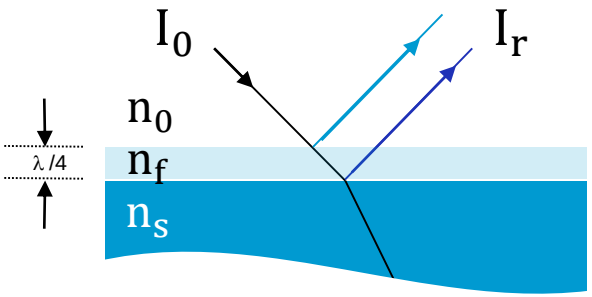
RhySearch
Das Forschungs- und Innovationszentrum Rheintal

speed of light c
is material dependent
$c = n\, c_0$

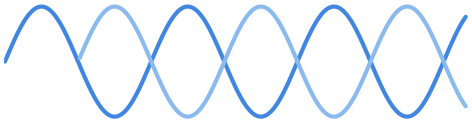


$$\frac{I_r}{I_0} = \left[\frac{n_s - n_0}{n_s + n_0}\right]^2$$

≈ 4 % window glass
≈ 8 % sapphire glass



peak meets valley



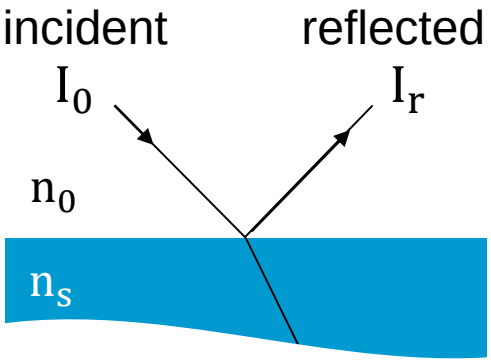
reflected waves cancel
for $\lambda/4$ film thickness

Note:
reflected light waves ≠ reflected light intensities

Reflection and Interference of Light Waves

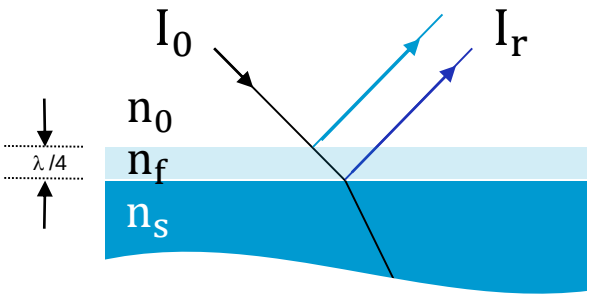
RhySearch
Das Forschungs- und Innovationszentrum Rheintal

speed of light c
is material dependent
$c = n\, c_0$

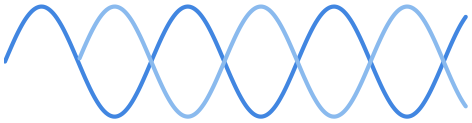


$$\frac{I_r}{I_0} = \left[\frac{n_s - n_0}{n_s + n_0}\right]^2$$

≈ 4 % window glass
≈ 8 % sapphire glass



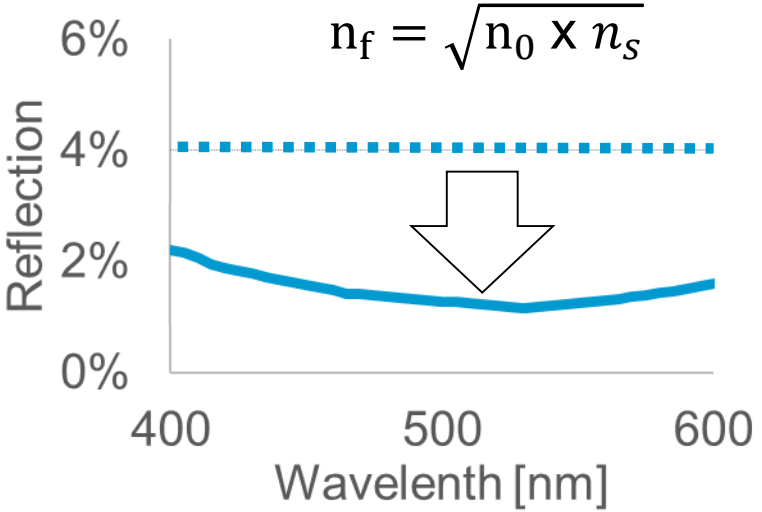
peak meets valley



reflected waves cancel
for λ /4 film thickness

single MgF_2 layer on glass
reduces R from 4 % to 1.5 %

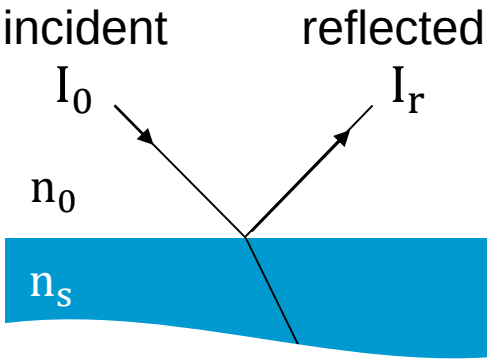
$$n_f = \sqrt{n_0 \times n_s}$$



Reflection and Interference of Light Waves

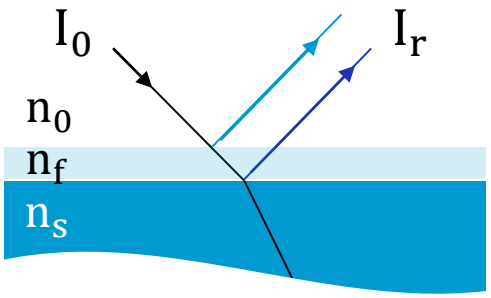
RhySearch
Das Forschungs- und Innovationszentrum Rheintal

speed of light c
is material dependent
$c = n\, c_0$

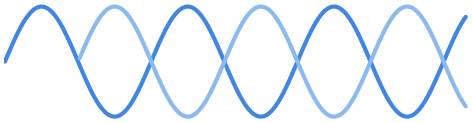


$$\frac{I_r}{I_0} = \left[\frac{n_s - n_0}{n_s + n_0}\right]^2$$

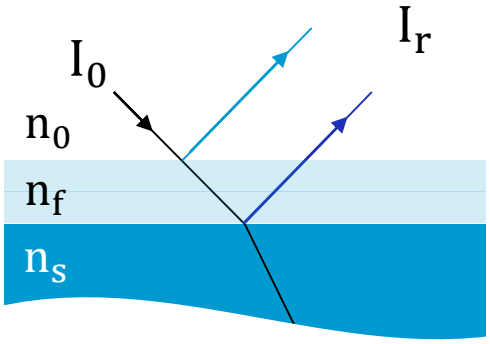
≈ 4 % window glass
≈ 8 % sapphire glass



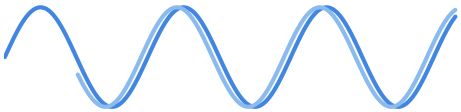
peak meets valley



reflected waves cancel
for $\lambda/4$ film thickness

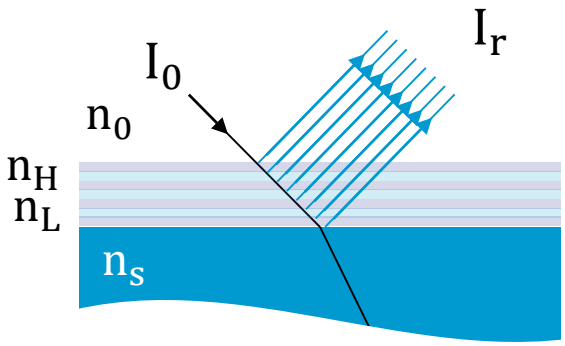


peak meets peak

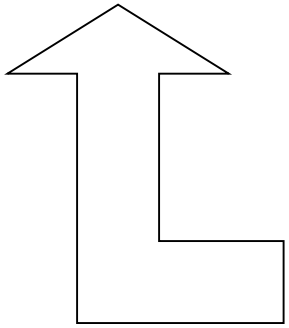


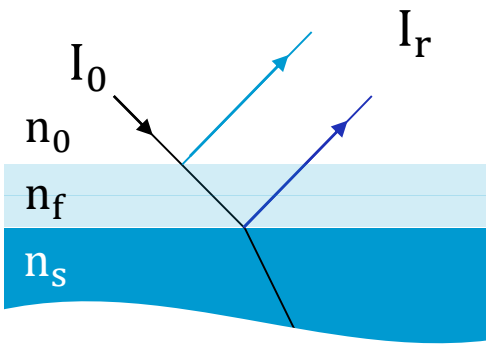
reflected waves
get more intense for
$\lambda/2$ film thickness

Perfect Mirror can be Formed by a Layer Stack

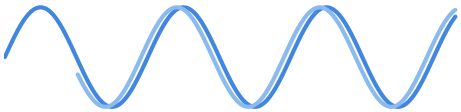


Alternating transparent thin layers with high and low index of refraction make a mirror with reflection for one λ





peak meets peak



reflected waves get more intense for λ/2 film thickness

Functions by Optical Coatings

RhySearch
Das Forschungs- und Innovationszentrum Rheintal

A wide range of functions

- function:
  - mirror
  - filter
  - beam-splitter
  - …
- incident angles
- spectral response
- polarization
- …

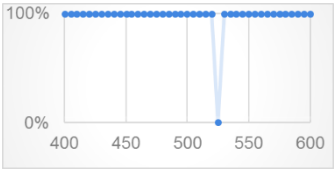
Coating types

- anti-reflection coating
- attenuation filter
- band pass filter
- broad-band mirror
- conductive coating
- color separation filter
- laser protection filter
- laser mirror
- longwave pass filter
- multi-band filter
- short-wave pass filter
- trichroic filter
- …

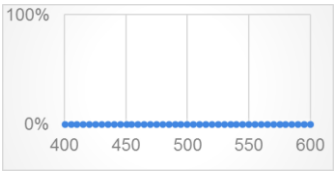
By varying

- layer material
  (oxides, fluorides, nitrides, metals …
- number of layers
  (one to [many] hundred)
- individual layer thicknesses (few nm to few µm)

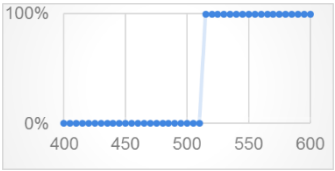
Transmission Spectra



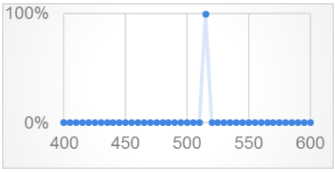
Single line blocking



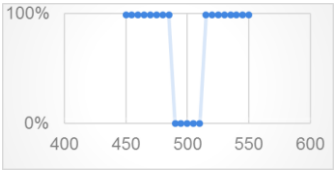
Broad band mirror



Longpasss filter



Narrow band transm



Laser mirror

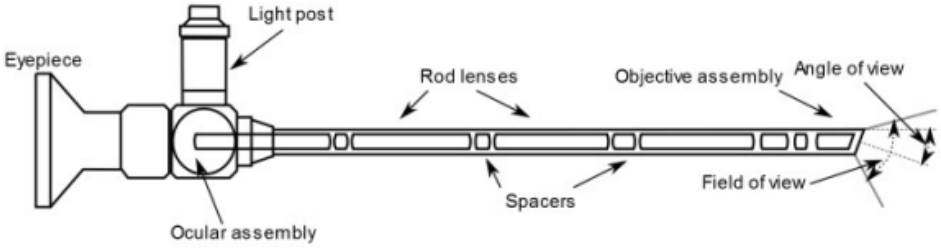
Anti-Reflective Coating

Source: www.twenty20vision.co.za

Glasses

Coatings enhance view and lifestyle

Scratch-resistant, easy to clean ...



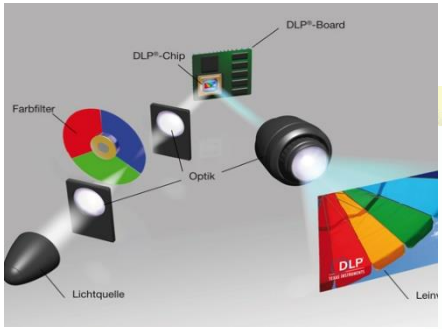
Source: Wientjes R et. Al PLoS ONE (2013)

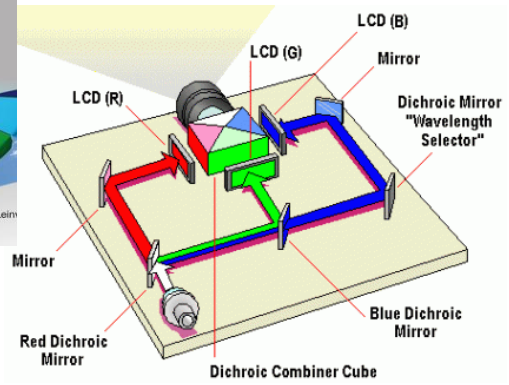
Endoscope

Coatings enable transmission

Many different glass types, size, …

Dichroic Filter (Color filter)





Source: www.beamerstation.de and www.pctechguide.com

Beamer

Filter to generate the colors

Long term color accuracy …

Source: http://www.promusik.de

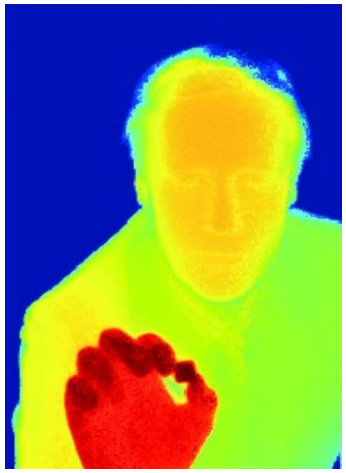
Entertainment Lighting

Heatresistant filter to generate colors

Consistent exact color …
and to get the artist's wish in a product, …

Narrow Band Transmission

Source: www.hilti.com

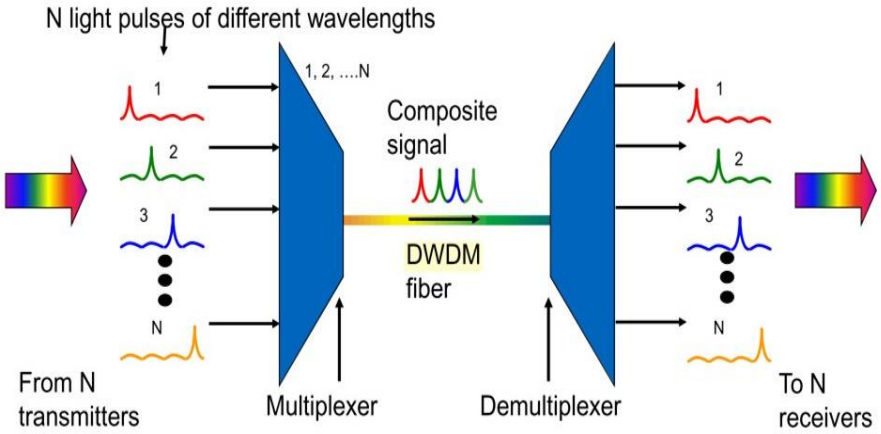


Source: http://image-sensors-world.blogspot.ch

Distance Measurement

Filter to boost signal to noise ratio in time-of-flight detection

High blocking, low angular dependence, …



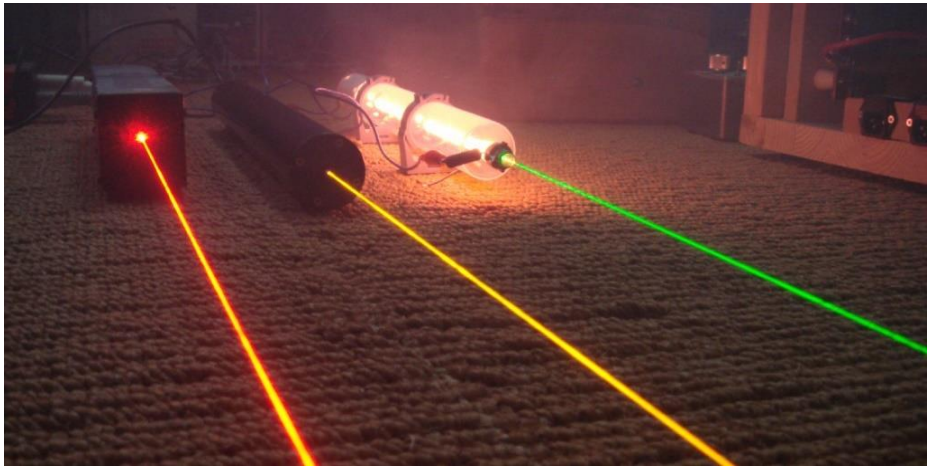
Source: https://fiberopticsof.wordpress.com/tag/dwdm-multiplexer/

Telecom

Filter to select a single wavelength

Extremely narrow band pass, …

Mirrors



Source: hoststar.ch

Laser cavity mirror

Mirrors with very high reflection

Low loss, laser damage resistant, …

Source: Scanlab

Laser scanner heads

Mirror with very high (broadband) reflection

High flatness, …

Optical Coatings

RhySearch
Das Forschungs- und Innovationszentrum Rheintal

- PVD coating processes
- Interference in thin film multilayer system
- Enabling technology for many applications
- Challenges are application dependent

There is a strong optical coating industry in Switzerland
across the entire value chain (tools, materials, vacuum, coating, …)
with players supplying the global marketplace

that can provide solutions to meet your requirements

Thank you

Andreas Bächli@RhySearch.ch