# OPTOMAN

YOUR SIDEKICK FOR
LASER OPTICS DEVELOPMENT


VOL. 2

2022

# WILL OPTOMAN BEAT DR. ABSORPTION?

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# ABOUT OPTOMAN

## OPTOMAN – YOUR SIDEKICK FOR LASER OPTICS DEVELOPMENT

OPTOMAN designs, develops and manufactures advanced, high accuracy, and repeatability IBS thin film coatings and laser optics since 2017. R&D driven culture forces the OPTOMAN team to constantly improve the performance and reliability of thin film coatings so our partners eventually could enjoy the benefits of lower total cost of ownership.

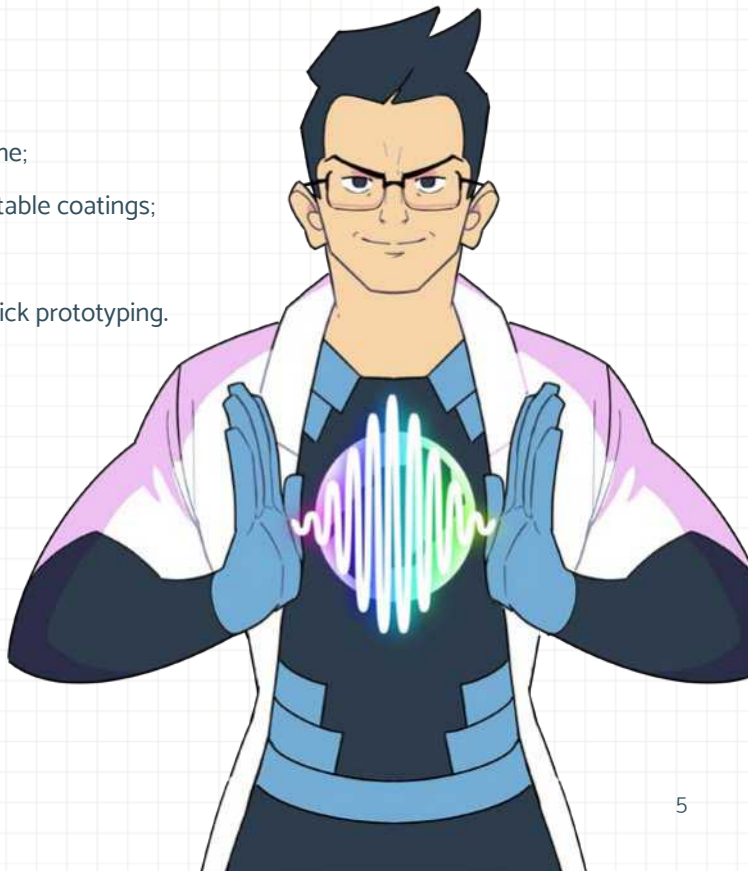
OPTOMAN as your sidekick is always willing and ready to help you with finding optimized solutions (ultra)fast and back you up in critical situations and finally get the job done as was promised.

High level development is possible with experienced staff and innovative ion-beam sputtering (IBS) technology. Progressive control and automated process allow the deposition of complex structures of several hundred thin film layers. The advantages of spectral control include features, such as: higher contrast, repeatable performance, and tighter tolerances. In combination with ISO-6 clean room environment, OPTOMAN manufactures outstanding overall quality laser optics.

**Do not forget that with great laser power comes great responsibility for coaters!**

## CORE COMPETENCE

- Ultrafast laser optics;
- High LIDT and enhanced lifetime;
- Durable and environmentally stable coatings;
- Extreme low loss coatings;
- Agility, flexibility, speed, and quick prototyping.



# CAPABILITIES

## High damage threshold optics:

- >80 J/cm², 1030 nm, 10 ns;
- >50 J/cm², 1064 nm, 10 ns, S-pol, 56°;
- >1 J/cm², 1030 nm, 1 ps;
- >30 kW/cm, 1070 nm CW;
- >1 J/cm² @ 1030 nm, 500 fs, 10 kHz, s-pol;
- >5 J/cm² @ 1030 nm, 10 ps, 10 kHz, s-pol;
- >0.25 J/cm² @ 266 nm, 180 fs, 10 kHz.

## Extreme low-loss coatings:

- Super Mirrors HR (R>99.998%);
- Precision Thin-film Polarizers (Tp/Ts ratio > 10000:1);
- R<0.01% Anti-Reflective Coatings;
- Coating with an absorption loss of <1 ppm.

## Optics for Mid-IR applications:

- Low absorption coatings;
- Spectral range 1  5 µm;
- Broadband turning/bending mirrors with R>99.8%;
- Chirped and GTI mirrors for ultrafast laser systems;
- Coatings on $CaF_2$, $MgF_2$, YAG, Sapphire, Silicon substrates.

## Application oriented optics for:

- Medical lasers (Er:YAG/glass, Ho:YAG, Nd:YAG, Alexandrite...);
- Mirrors for galvo-scanners (Silicon, UVFS...);
- Membrane mirrors for deformable mirror assemblies;
- OPO, OPA, OPCPA;
- Defense & Aerospace industries.

## Some of cool stuff we do:

- Knife-edge coated optics (edge chips <50 µm).
- 100% coated aperture components.
- Segmented/Masked coatings.
- Stress-compensated coatings (PV flatness <λ/20 @ 633 nm).
- Coatings on multi-surface prisms.
- Coatings on micro lens assemblies.
- Coatings on big size wafers (up to a diameter of 300 mm).
- Zero phase shift mirrors.
- Coatings on laser and nonlinear crystals.

## Bread and butter:

- Laser line and broadband mirrors (HR>99.99%).
- R<0.05% Anti-Reflective Coatings.
- Thin Film Polarizers (Tp/Ts extinction ratio > 1000:1).
- Pump, dichroic Mirrors (eg. HR>99.9% + HT>99%).
- Output couplers, plate beam splitters (eg. PR 50% +/-1%).
- Spectral range 200 nm - 5000 nm.
- Component size: from 3 mm up to 300 mm.
- Coatings can be applied on plane, spherical, cylindrical, aspherical, elliptical surfaces, prisms and other exotic configurations.
- Typical turnaround for custom coatings is between 5-7 weeks.
- Ultrafast (express) prototyping service available.

## MEASURING CAPABILITIES FOR LASER OPTICS

As with great laser power comes great responsibility for coaters, OPTOMAN acts responsibly during the whole supply chain process, including post-coating quality checks. OPTOMAN is carefully inspecting the quality of the optics produced, so the customer could enjoy seamless usage of optical components, without investing his time and effort to ensure that optics are compliant to the specifications.

### Measuring capabilities:

| | |
|---|---|
| **Cosmetic surface quality inspection** | MIL-PRF-13830B, ISO 10110, or customer-specific conditions |
| **Spectral measurements** | Tsp, Rsp @ 220 nm - 5000 nm, from 0° to 75° AOI |
| **LIDT & Lifetime testing** | ISO 21254 (CW, ns, ps, fs) |
| **Environmental testing** | MIL-C-484197 |
| **GD, GDD, TOD measurements** | 500 nm - 1400 nm |
| **Absorption measurements** (Photothermal technology) | 355 nm, 405 nm, 532 nm, 690 nm, 785 nm, 830 nm, 1064 nm, 1342 nm |
| **Cavity ring-down measurements** | 532 nm, 638 nm, 1064 nm, AOI=0° and 45° (S-pol, P-pol) |
| **Surface form errors** | Down to λ/20 @ 633 nm. Measured aperture up to 4 |
| **Product design verification** | First article inspection (FAI) |

## WHERE DOES OPTOMAN WORK?

OPTOMAN spends a significant amount of time in manufacturing facilities, therefore he wants to show you how does his workplace look like and what are the key processes that allow him to offer you top-notch optical components.

### Preparation of substrates

Firstly, thorough preparation of substrates is needed in order to make quality optical coatings as you don t want to start the coating process on unclean substrates:

OPTOMAN uses a 7-stage fully automated cleaning process, which makes the preparation of substrates efficient and effective.

## Coating deposition

As with great laser power comes great responsibility for coaters, OPTOMAN uses only the most advanced thin film deposition technology – Ion Beam Sputtering (IBS), which allows him to exploit his superpowers. IBS has the same meaning to OPTOMAN as Mjölnir hammer has to Thor. So yes, it s pretty important and OPTOMAN does not shy investments to have the best IBS machines in order to provide the best optics.

## Quality inspection and metrology

OPTOMAN doesn t call optical components high quality by default. Measurements and inspections are needed to define the quality. OPTOMAN is equipped to do it.

## Final optical component

Ta-da! OPTOMAN optics are ready to fulfill their purpose – become friends with your laser beam.

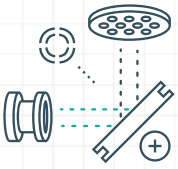
## R&D ACTIVITIES

- OPTOMAN heavily invests in R&D activities.
- OPTOMAN cooperate with leading research institutions for extensive characterization and proof of concepts.

### Ongoing R&D projects:

- INTENSITY Development of low total loss coatings for VIS-NIR range.
- UNIPULSE Development of high LIDT coatings for ps-fs applications for VIS-NIR range.
- INOSTART Development of MID-IR (1 5 μm) coatings based on oxide / semiconductor materials.
- Neo2Fast – Development of broadband mirrors with High LIDT performance for multi-pass cells sub-10 fs applications.

> **"INTELLIGENCE IS A PRIVILEGE, AND IT NEEDS TO BE USED FOR THE GREATER GOOD OF LASER PEOPLE."**
>
> Dr. Otto Octavius

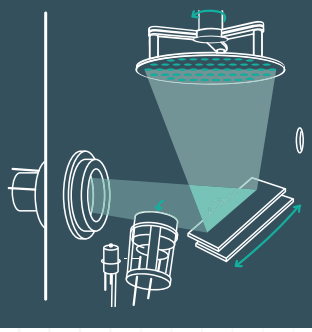


## ABOUT ION-BEAM SPUTTERING TECHNOLOGY

### Why IBS?

Ion Beam Sputtering (IBS) is a technique when the layer of a desired material is formed by molecules extracted from the target material by a highly energetic and precisely controlled ion beam.

As with great laser power comes great responsibility for coaters, OPTOMAN is equipped by IBS machines in order to meet the most demanding requirements from most demanding industrial and scientific applications.

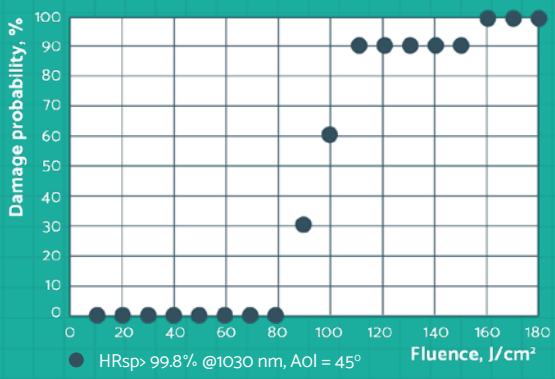


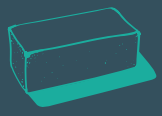
**Inherently stable sputtering process**

A very stable ion beam combined with high vacuum (~1x10$^{-4}$ mbar during the deposition) and ultra-high purity metal targets (>99.99%) result in a super stable deposition process. It enables a fully automatic deposition and the ability to precisely control refractive indices and thicknesses of each deposited layer.

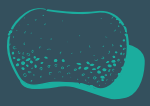
## High resistance to laser irradiation

By choosing proper deposition parameters and ensuring cleanliness in every step of the manufacturing chain, OPTOMAN is able to produce coatings with very low defect densities. That is the reason why IBS coatings exhibit excellent resistance to laser irradiation!



**IBS**
Near Bulk Density



**E-beam**
Porous Structure

## Bulk-like packing density

Due to the bulk-like layer's density, IBS coatings are completely immune to mechanical wear as well as changes in ambient temperature and humidity and ensure smooth operation of your laser under any circumstances. Moreover, OPTOMAN coatings may be used in harsh environments and even in outer space with no change in performance!

## Scattering? What's that?!

Due to the near-bulk IBS coating density, the surface roughness of the coated component is mainly determined by the initial substrate roughness. Combine this with the completely amorphous coating layers and you will end up with almost scatter-free optics!

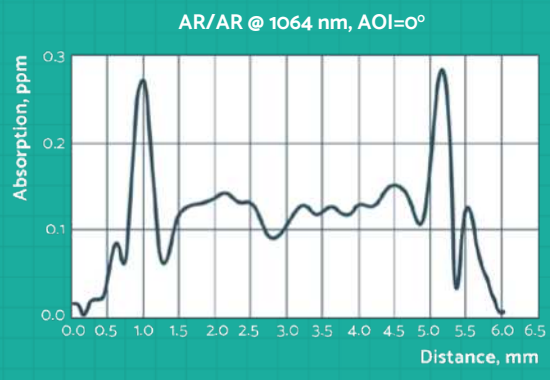
**IBS**

**E-beam**

## Forget short duty cycle issues!

It is well known that absorption losses are the main cause of thermal effects and a short duty cycle. A high and stable vacuum, extremely pure target materials, near bulk coating density, spatially separated sputtering and material condensation processes allow to form almost contamination-free layers with the absorption losses bellow 2ppm.

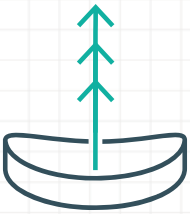
If you use high repetition rate fs, or a CW system and longevity is your concern, give OPTOMAN coatings a try and you will be surprised!



## SUSTAINABLE PRODUCT LIFECYCLE

OPTOMAN acts responsibly during the whole product lifecycle.

It starts from the thorough selection and assessment of suppliers according to OPTOMAN values.



OPTOMAN has optimized production processes to ensure a high yield of production and clean optics.

OPTOMAN also reuses optical components not compliant to specifications by repolishing them to limit waste.

## EXTREME LOW-LOSS COATINGS

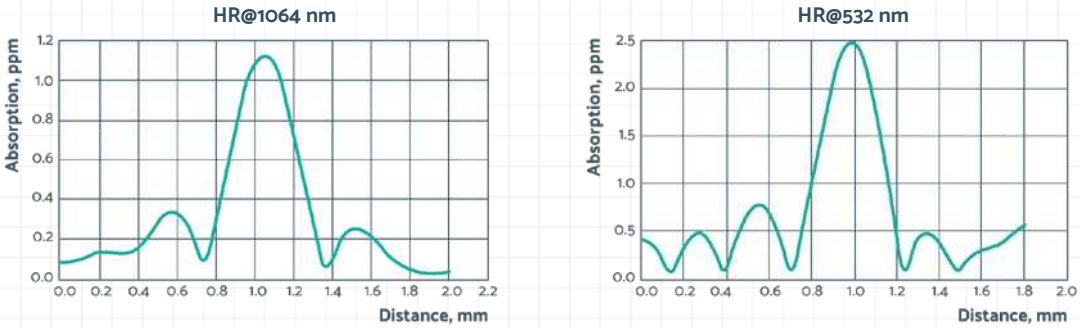
Absorption and scattering are the main limiting factors when trying to manufacture perfect coatings. But what if absorption loss and surface roughness were limited down to <2 ppm and <2 Å respectively? Pretty close to perfect, right? This has been an object of OPTOMAN R&D activities for the past few years. That is why OPTOMAN can manufacture Super Mirrors, 10000:1 contrast Thin Film Polarizers, R<0.01% AR Coatings, and many more extremely good stuff.


Roughness measurement results of super polished (A, B, C, D) and standard commercial grade substrates.

E* Standard commercial substrate.

Roughness plays a critical role in managing total integrated scatter to be as low as possible. The big goal is to stay below 2 Å RMS value, which is possible with fancy super-polished substrates.

Light absorption is another loss driver and is responsible for unwanted thermal effects in high power laser systems. Keeping absorption rates below 2 ppm, reflectance value above 99.998% is achievable as well as component heating effect is negligible if existing at all.

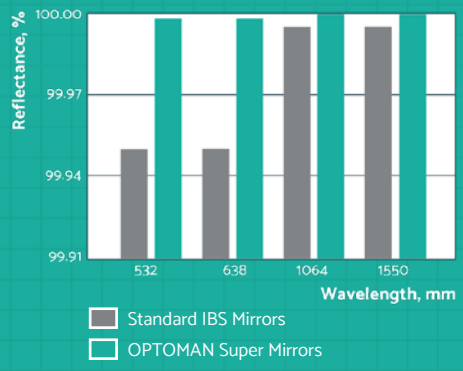



Longitudinal photothermal absorption measured of HR@1064 nm and HR@532 nm coatings.

## SUPER MIRRORS

Dielectric mirrors with extremely low losses become Super Mirrors. Their superpower of high reflectance comes from the OPTOMAN's continuous effort to add more and more nines after the point when talking about reflectance values.

**Standard IBS coated mirrors and super mirrors**




**CRD measurement results:**

HR>99.998% @ 532 nm, AOI=0°
Total loss=40 ppm

HR>99.9983% @ 638 nm, AOI=0°
Total loss=17 ppm

HRs>99.99857% & HRp>99.99816% @ 1064 nm, AOI=45°

Total loss = 14.3 ppm (S-pol) and 18.4 ppm (P-pol)

HR>99.9997% @ 1064 nm, AOI=0°
Total loss = 3 ppm

Disclaimer: Reflectance values for Super Mirrors illustrate the very best achieved values and illustrate current max level capabilities.

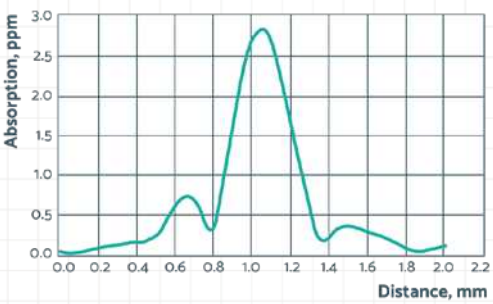
## EXTINCT THIN FILM POLARIZERS

Precise thin film polarizers have been extinct from the Earth for a few millennials, but OPTOMAN has found the recipe allowing to bring them back! OPTOMAN can manufacture thin film polarizers with a super high extinction ratio Tp/Ts~10'000:1 per coated surface at 45° or Brewster angle. And this is because of low scatter and absorption losses, which is the subject of proudness for OPTOMAN.

Different types of commercially available dielectric Thin Film Polarizers

**Precision Thin Film Polarizers**

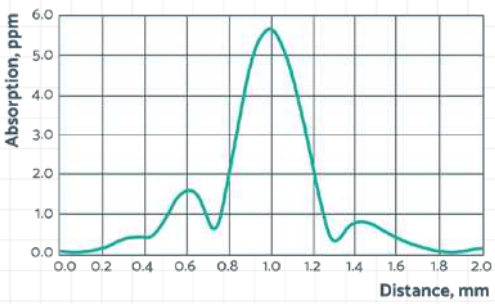
**Rs>99.99% & Tp>99% @ 1064 nm, 45°**
**Extinction ratio Tp/Ts~10'000:1**




s-pol component absorption measurement at 45°

**High contrast Thin Film polarizers**

**Rs>99.9% & Tp>98% @ 1064 nm, 45°**
**Extinction ratio Tp/Ts~1'000:1**




p-pol component absorption measurement at 45°

# R<0.01% ANTI-REFLECTIVE COATINGS

Typical commercial AR coatings feature residual reflectance below 0.25% per surface. 0.1% is becoming quite a common value as well. In any case, imagine having a laser beam with 1 kW passing through such a component. Transmittance loss is ~2 W – 5 W and this light goes somewhere back to the laser system

With the low loss coating technology, OPTOMAN can reduce this number down to 0.2 W, because residual reflectance per coated surface can go below 0.01%.

AR/AR @ 1064 nm coated window characterization

Cavity Ring Down transmittance measurement:

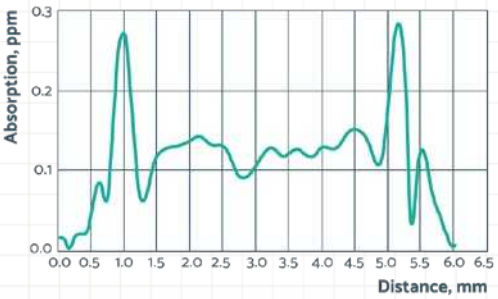
$R_{1\text{-}C1\text{-}2}$ : 0.9997570 +1.21E-5 / -1.21E-6

Decay time of 0° cavity (with AR): 6.1 µs

$T_{c1}$ : 99.9809%

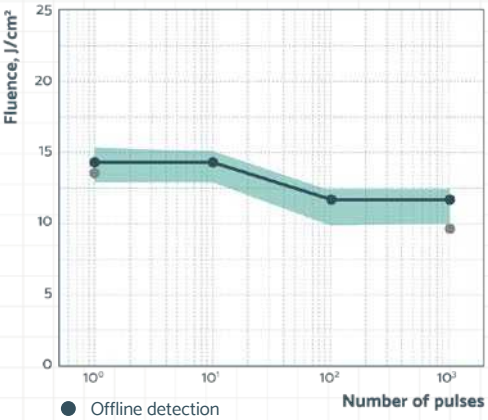
**Photothermal absorption measurement**

**AR/AR @ 1064 nm coating tested @ 1064 nm, AOI=0°**

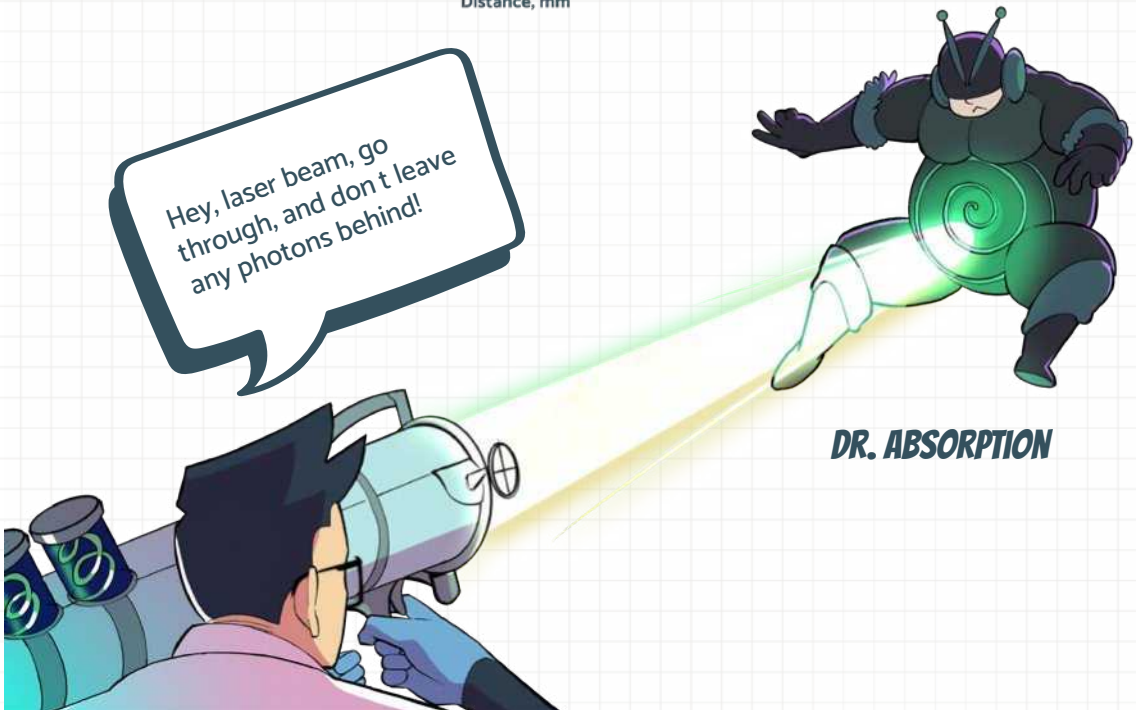



**Laser induced damage threshold**

**AR/AR @ 532 nm, AOI = 0°**

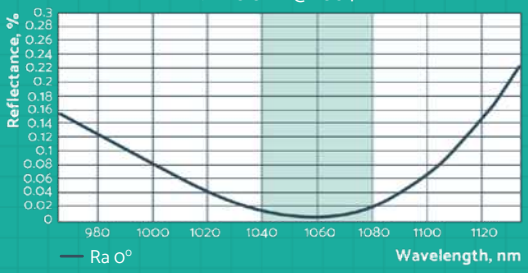



Wavelength: 532 nm
Pulseduration (FWHM): (5.3 ± 0.3) ns
Repetition rate: 100 Hz
AOI: 0°
Polarization: Linear
Beam diameter (1/e²): (216.7 ± 2.6) µm

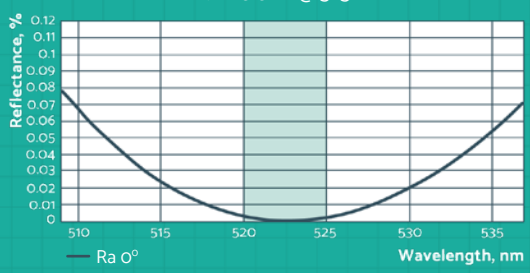


## Design example:

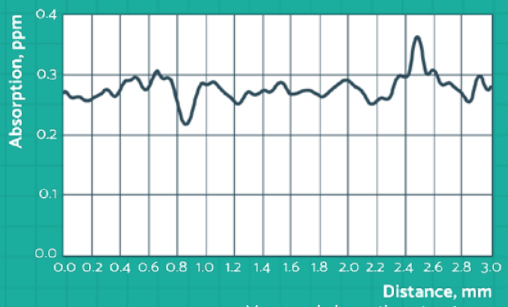
AR < 0.01% @ 1064 nm

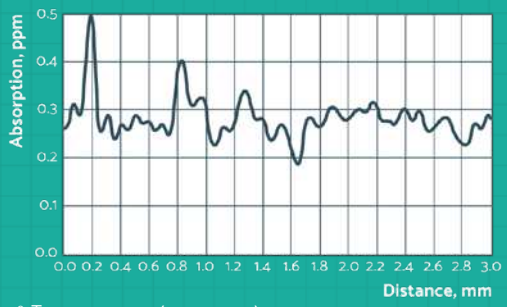



AR < 0.01% @ 523 nm

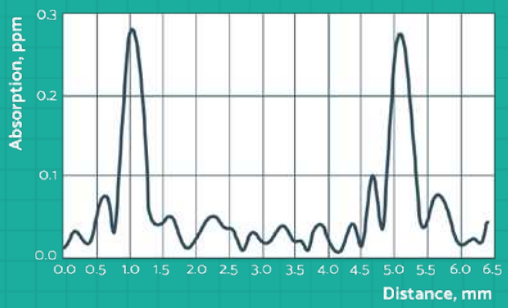


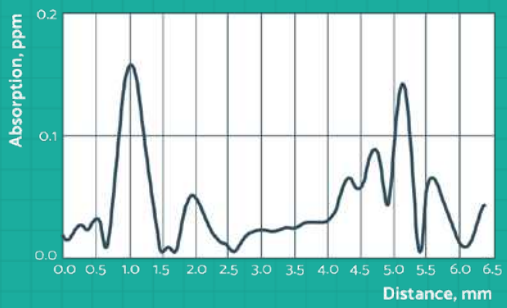

AR<0.1% @ 1030 nm - 1090 nm & R<4% @ 500 nm - 700 nm, AOI=0°



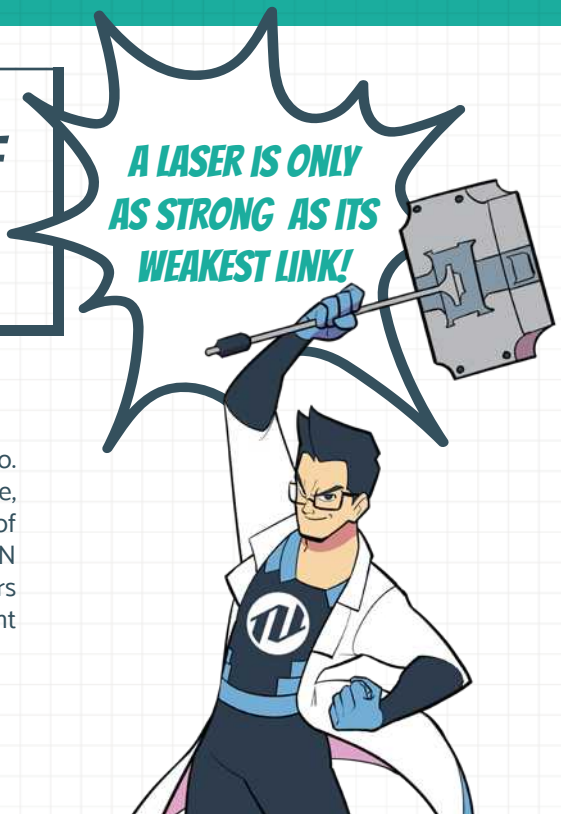

Measured absorption at 1064 nm at AOI=0°. Transverse scan (scan across).




Measured absorption at 1064 nm at AOI=0°. Longitudinal scan (scan through).

# LASER P[R]OOF MIRRORS



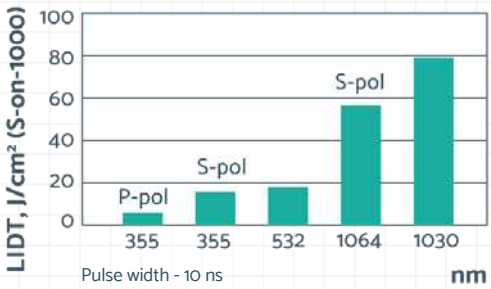

Yes, OPTOMAN hates that [R] same as you do. Truly laser proof mirrors would be awesome, but sadly, all mirrors are destined to poof under certain operating conditions. OPTOMAN works hard every day to maximize the mirrors resistance to laser irradiation and he's confident to say that results are above satisfactory.

HERE'S SOME PROOF!

## LASER LINE AND BROADBAND MIRROR DESIGNS

- Rs and Rp >99.95% and 99.9% respectively for spectral bandwidths up to 200 nm.
- Optimization for highest LIDT or enhanced duty cycle.
- Spectral range 200-5000 nm.

**Recorded Laser damage threshold examples**




Pulse width - 10 ns

## MIRRORS FOR BIG & SCARY FS, PS LASERS

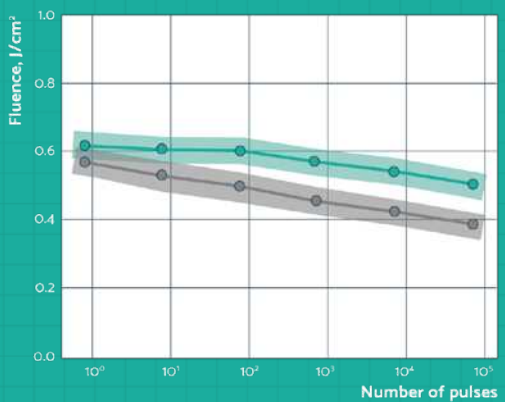
High laser power levels call for high-power measures. OPTOMAN is here to save the day with high reflectivity IBS mirror coatings designed for big & scary ultrafast Yb:YAG, Yb:KYW/KGW, Yb doped fiber lasers.

- Low GDD performance.
- Optimized for high average power ultrafast laser systems.
- Absorption within coating < 1 ppm @ 1064 nm.
- Zero-phase shift behavior.

While high laser-induced damage threshold is a buzzword when talking femtosecond & picosecond optics, it is not (only) the nominal LIDT value that matters. The separation of laser damage modes - catastrophic and color-change - is evident when measuring standard optics. The fatigue effect of color-change damage becomes even more significant for high-power mirrors after prolonged radiation (>103 pulses).

OPTOMAN has recently developed and introduced novel SuperHero League Mirrors (ULLM5SHL), which are optimized for low fatigue (color-change) effect and very high LIDT.

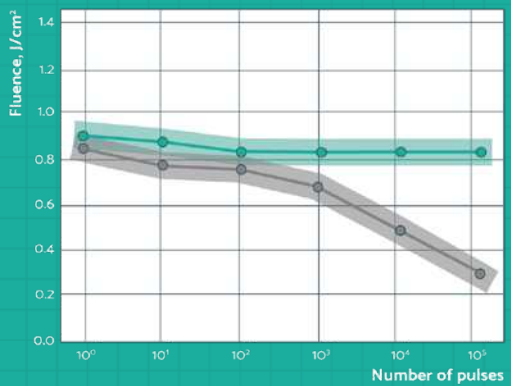
**Market-Standard Mirrors**




- ○ Catastrophic
- □ 95% confidence interval
- ● Color change
- ■ 95% confidence interval

Wavelength: 1030 nm
Pulseduration (FWHM): 491.1 fs
Repetition rate: 10 kHz
AOI: 45°
Polarization: Linear P
Beam diameter (1/e²): (177.4 ± 3.6) µm

**Market-Standard High Power Mirrors**




- ○ Catastrophic
- □ 95% confidence interval
- ● Color change
- ■ 95% confidence interval

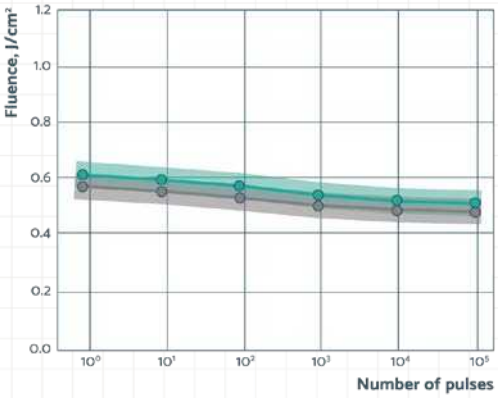
Wavelength: 1030 nm
Pulseduration (FWHM): 491.1 fs
Repetition rate: 10 kHz
AOI: 45°
Polarization: Linear P
Beam diameter (1/e²): (177.4 ± 3.6) µm

## STANDARD MIRRORS (ULLM5)

- Perfect price-to-performance ratio
- Industry standard specifications
- Fully characterized

LIDT ●●●○○
Lifetime ●●●○○
Price ●○○○○

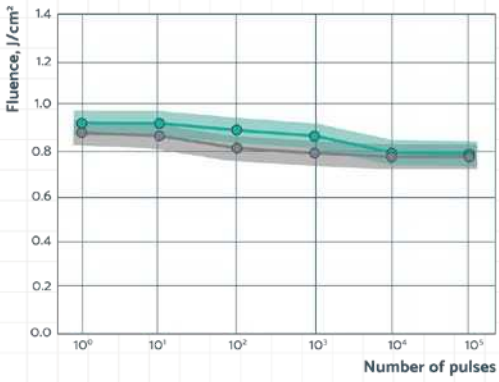
High confidence level >0.4 J/cm²




● Catastrophic
■ 95% confidence interval
● Color change
■ 95% confidence interval

Wavelength: 1030 nm
Pulseduration (FWHM): 491.1 fs
Repetition rate: 10 kHz
AOI: 45°
Polarization: Linear P
Beam diameter (1/e²): (177.4 ± 3.6) µm

High confidence level >0.7 J/cm²




● Catastrophic
■ 95% confidence interval
● Color change
■ 95% confidence interval

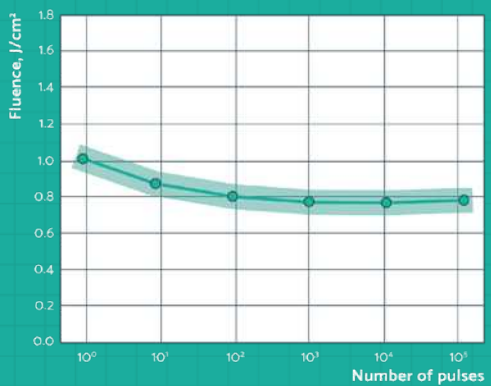
Wavelength: 1030 nm
Pulseduration (FWHM): 491.1 fs
Repetition rate: 10 kHz
AOI: 45°
Polarization: Linear S
Beam diameter (1/e²): (177.4 ± 3.6) µm

## SUPERHERO LEAGUE MIRRORS (ULLM5SHL)

- Very high LIDT
- No color-change damage
- Fully characterized

LIDT ●●●●○
Lifetime ●●●●○
Price ●●●○○

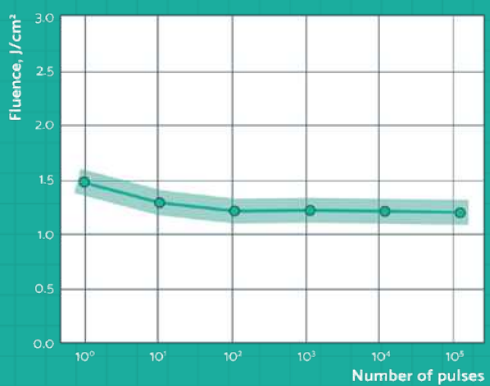
High confidence level >0.7 J/cm²




○ Catastrophic
□ 95% confidence interval

Wavelength: 1030 nm
Pulseduration (FWHM): 497.7 fs
Repetition rate: 10 kHz
AOI: 45°
Polarization: P
Beam diameter (1/e²): (176.8 ± 4.8) µm

High confidence level >1 J/cm²

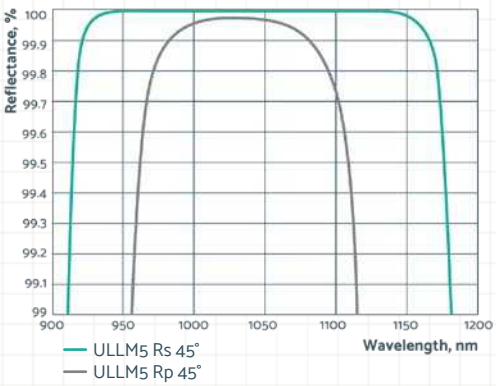


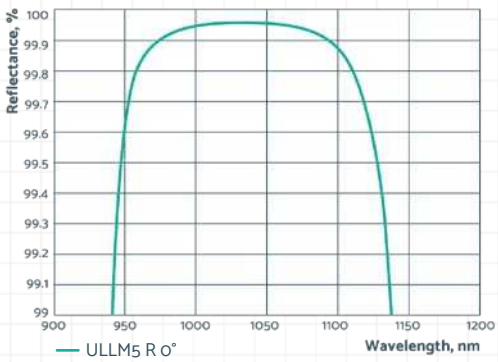

○ Catastrophic
□ 95% confidence interval

Wavelength: 1030 nm
Pulseduration (FWHM): 491.1 fs
Repetition rate: 10 kHz
AOI: 45°
Polarization: Linear S
Beam diameter (1/e²): (177.4 ± 3.6) µm

| | Standart (ULLM5) | SuperHero League (ULLM5SHL) |
|---|---|---|
| **Substrate** | UVFS | |
| **Surface Quality, S1** | 10-5 S-D (MIL-PRF-13830B) | |
| **Surface Flatness, S1** | <λ/10 @ 633 nm over CA | |
| **AOI** | 0° or 45° or which ever ° | |
| **Coating (IBS)** | HRs>99.95% & HRp>99.9% @ 1010 1050 nm<br>(Yes, custom bandwidths available) | |
| **Laser Induced Damage Treshold** | **Femtosecond:**<br>> 0.4 J/cm², 1030 nm, 500 fs, 10 kHz, p-pol<br>> 0.7 J/cm², 1030 nm, 500 fs, 10 kHz, s-pol<br><br>**Picosecond:**<br>> 2 J/cm², 1030 nm, 10 ps, 10 kHz, p-pol<br>> 3 J/cm², 1030 nm, 10 ps, 10 kHz, s-pol | **Femtosecond:**<br>> 0.7 J/cm², 1030 nm, 500 fs, 10 kHz, p-pol<br>> 1 J/cm², 1030 nm, 500 fs, 10 kHz, s-pol<br><br>**Picosecond:**<br>> 3 J/cm², 1030 nm, 10ps, 10 kHz, p-pol<br>> 5 J/cm², 1030 nm, 10ps, 10 kHz, s-pol |

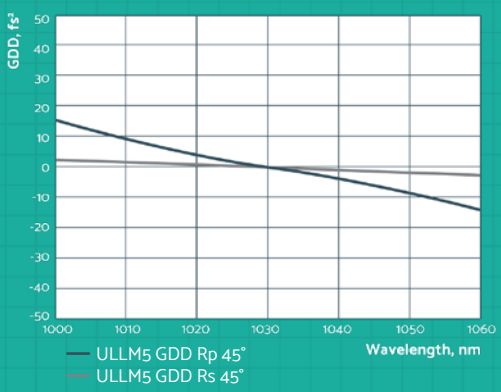
**Rs > 99.95% & Rp > 99.9% @ 1010-1050 nm**

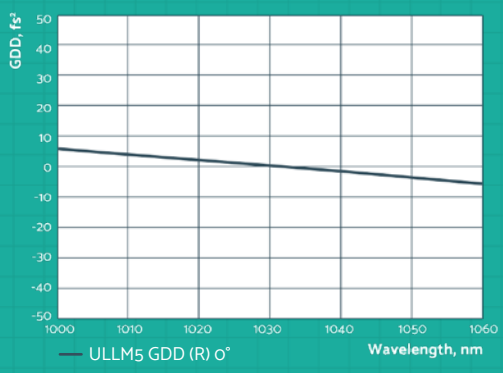



## Reflected Group Delay Dispersion

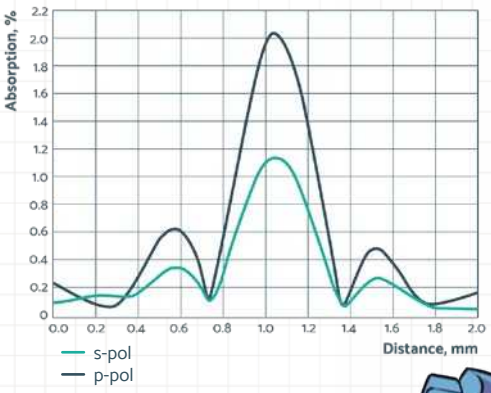
**IGDD Rsl<20 fs², IGDD Rpl<50 fs²**

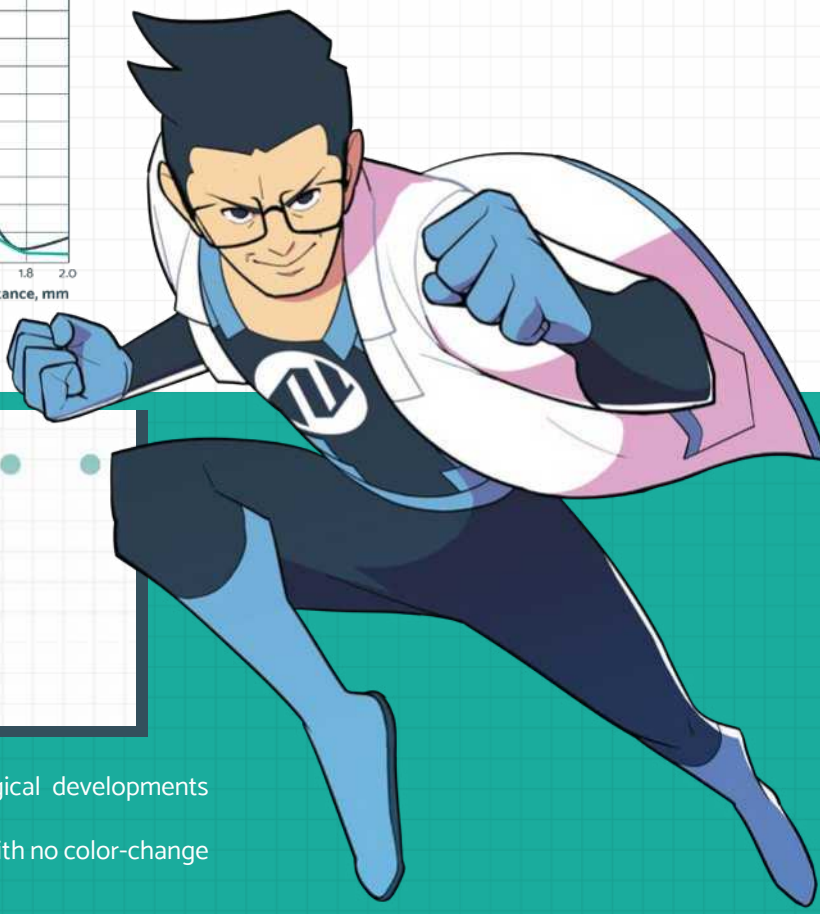


**Absorption @ 1064 nm ~1 ppm for s-pol component and ~2 ppm for p-pol component.**

Measured by PCI technology.

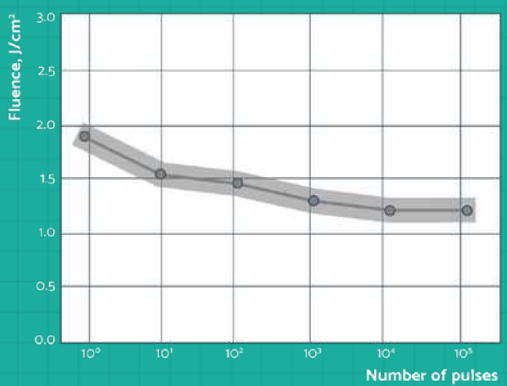


# OPTOMAN DOESN'T STOP HERE...

Keep an eye out for our technological developments that are still in progress.
Coatings featuring super high LIDT with no color-change degradation are under development.
Preliminary R&D figures:

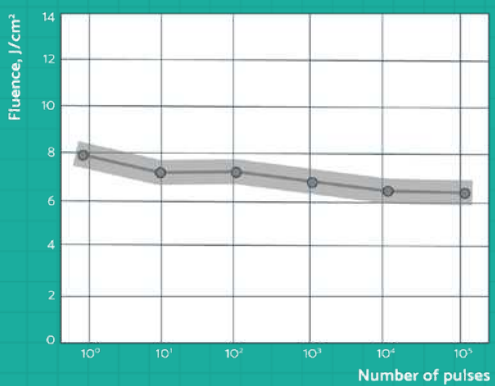
**LIDT > 1.2 J/cm², 1030 nm, 500 fs, 10 kHz, s-pol**




Catastrophic
95% confidence interval

Wavelength: 1030 nm
Pulseduration (FWHM): 500.3 fs
Repetition rate: 10 kHz
AOI: 45°
Polarization: Linear S
Beam diameter (1/e²): (176.0 ± 1.1) µm

**LIDT > 6 J/cm², 1030 nm, 10 ps, 10kHz, s-pol**




Color change
95% confidence interval

Wavelength: 1030 nm
Pulseduration (FWHM): 10.1 ps
Repetition rate: 10 kHz
AOI: 45°
Polarization: Linear S
Beam diameter (1/e²): (113.2 ± 0.8) µm

# LASER LINE MIRRORS FOR ULTRA-VIOLENT LASERS

## 343 NM & 355 NM HIGH REFLECTIVITY MIRRORS

## OPTIMIZED FOR NANOSECOND & PICOSECOND HIGH-POWER LASERS

### Can OPTOMAN defend optics from ULTRA-VIOLENT lasers?

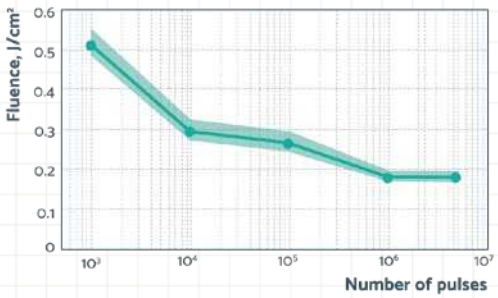
To ensure a high degree of reflection in the UV range, scattering and absorption losses need to be well managed, as they increase considerably, when the wavelengths go down. Long-term degradation of the mirrors is another big issue when working with intense UV lasers.

However, OPTOMAN by exploiting his superpowers of a strong focus on the surface quality and well-optimized coating technology CAN defend his optical components from most of UV lasers and increase the longevity of optics.

### What makes OPTOMAN UV optics different?

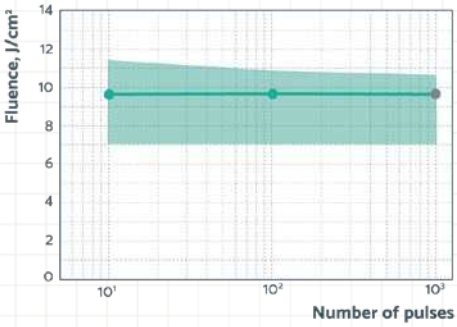
## 1. HIGH LIDT

Laser damage is the arch-enemy of UV optics. To fight it, one must measure it. So OPTOMAN does, for picosecond and nanosecond scale.



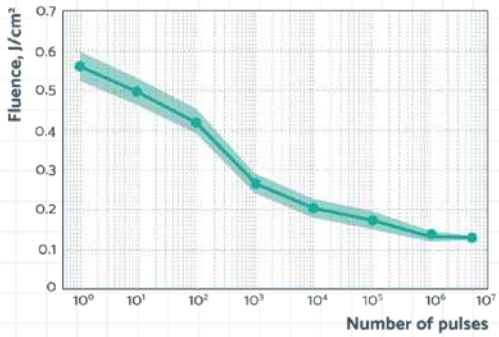

Offline dettect on
95% confidence interval

Wavelength: 343 nm
Pulse duration (FWHM): 1.0 ps
Repetition rate: 50 kHz
AOI: 45°
Polarization: Linear S
Beam diameter (1/e²): (62.3 ± 0.5) µm



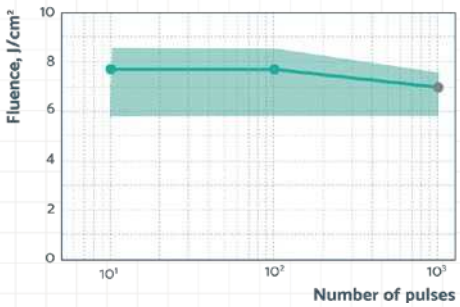

Offline dettect on
Online dettect on
95% confidence interval

Wavelength: 355 nm
Pulse duration (FWHM): (5.7 ± 0.3) ns
Repetition rate: 100 Hz
AOI: 45°
Polarization: Linear S
Beam diameter (1/e²): (230.8 ± 4.0) µm




Offline dettect on
95% confidence interval

Wavelength: 343 nm
Pulse duration (FWHM): 1.0 ps
Repetition rate: 50 kHz
AOI: 45°
Polarization: Linear P
Beam diameter (1/e²): (62.3 ± 0.5) µm




Offline dettect on
Online dettect on
95% confidence interval

Wavelength: 355 nm
Pulse duration (FWHM): (5.7 ± 0.3) ns
Repetition rate: 100 Hz
AOI: 45°
Polarization: Linear P
Beam diameter (1/e²): (230.8 ± 4.0) µm

## 2. COST-EFFECTIVE COATING DESIGN

OPTOMAN Superhero League mirrors feature high batch-to-batch repeatability and are suitable for high volume serial production.

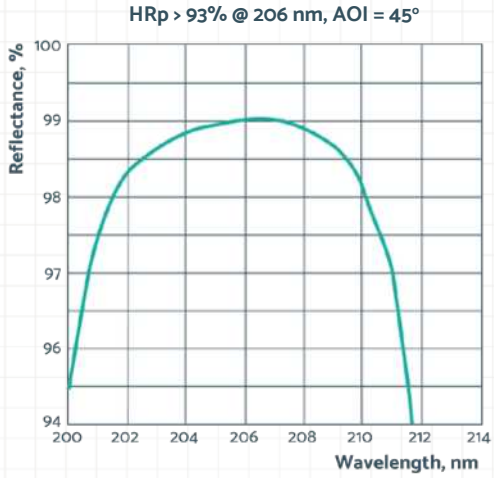
## 3. CONSISTENT QUALITY

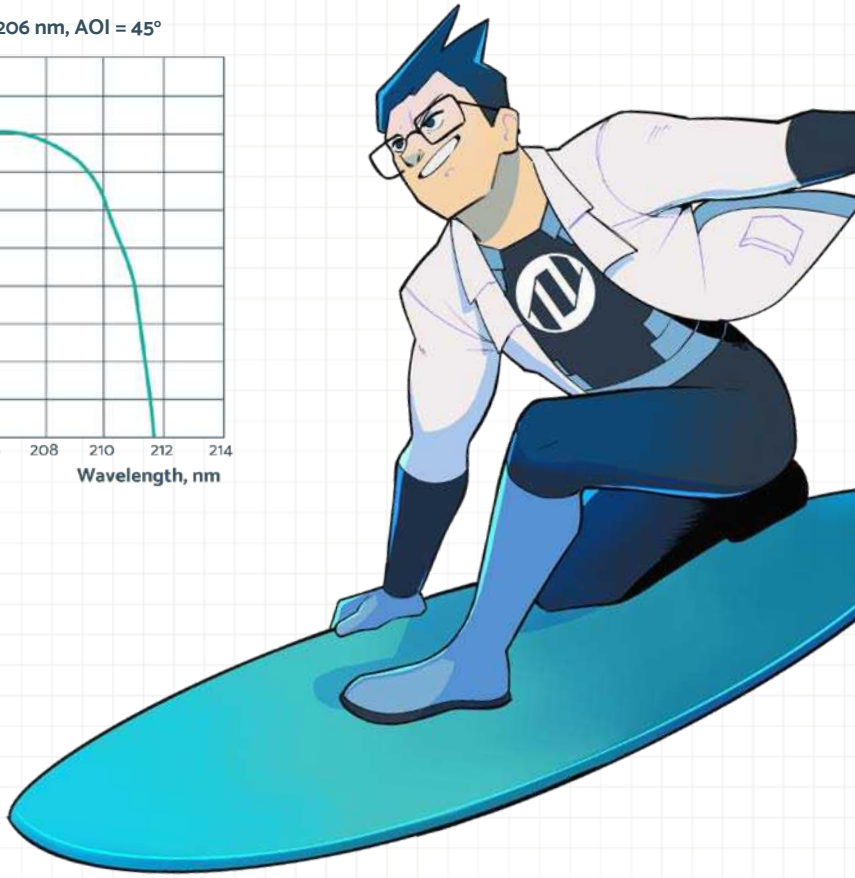
OPTOMAN Superhero League mirrors feature high batch-to-batch repeatability and are suitable for high volume serial production.

| Parameters | Require-ments | Measured parameters | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Standard mirrors as samples | | | | | OPTOMAN samples | |
| | | #1 | #2 | #3 | #4 | #5 | 1562 | 1563 |
| Rabs @ 343 nm, AOI=45° | >99.8 % | 99.66% | 99.64% | - | - | - | 99.79% | 99.70% |
| Ravg @ 339-346 nm, AOI=45° | >99.5 % | 99.68% | 99.67% | - | - | - | 99.82% | 99.73% |
| Surface flatness @633 nm over CA | <λ/10 | - | - | 0.088 λ | 0.087 λ | 0.053 λ | 0.093 λ | 0.035 λ |
| Surface quality over CA | 20-10 S-D | 20-20 | 20-20 | 20-10 | 20-10 | 20-10 | 20-10 | 20-10 |

| | SuperHero League @ 343 nm | SuperHero League @ 355 nm |
|---|---|---|
| **Substrate** | UV FS | |
| **Surface Quality** | 10-5 S-D | |
| **Surface Flatness** | <λ/8 @ 633 nm over CA | |
| **AOI** | 45° | |
| **Coating** | HRsp > 99.7% (at design wavelength) | |
| **Laser Induced Damage Treshold** | **Picosecond (measured values):** > 0.27 J/cm², 343 nm, 1 ps, 50 kHz, p-pol > 0.52 J/cm², 343 nm, 1 ps, 50 kHz, s-pol | **Nanosecond (measured values):** > 6.97 J/cm², 355 nm, 6 ns, 100 Hz, p-pol > 9.6 J/cm², 355 nm, 6 ns, 100 Hz, s-pol<br><br>**Picosecond (scaled values):** > 0.25 J/cm², 355 nm, 1 ps, 50 kHz, p-pol > 0.5 J/cm², 355 nm, 1 ps, 50 kHz, s-pol |

**Design example:**



# GTI AND CHIRPED MIRRORS

The Gires-Tournois Interferometer (GTI) mirror is a dielectric dispersive mirror with a spatial variation of the layer thickness values. Such mirrors are used for dispersion compensation in mode-locked lasers, for example.

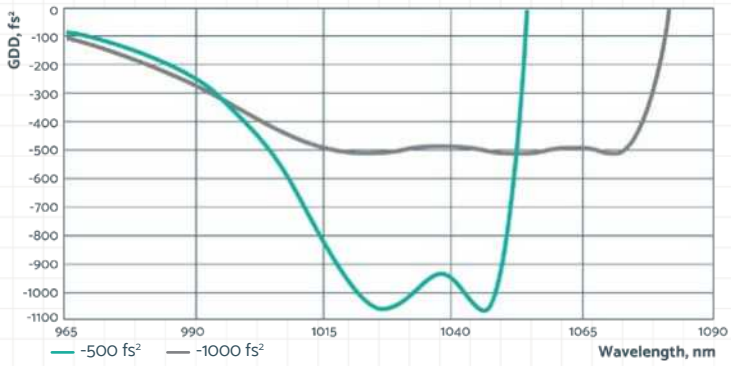
**Pulse compression analysis:** OPTOMAN can do a pulse compression analysis and present you with a data analysis after a specific number of bounces. Send OPTOMAN a message for more details.

## FEATURES:

- Dispersive mirrors – chirped and GTI design;
- Spectral range 250nm - 5000 nm;
- Negative GDD down to -5000 $fs^2$;
- Positive dispersion mirrors;
- Low (flat) or predefined GDD behavior;
- LIDT >0.3 J/$cm^2$ @ 1030nm, 50 fs, 150 kHz;
- LIDT >0.25 J/$cm^2$ @ 266 nm, 180 fs, 10 kHz.

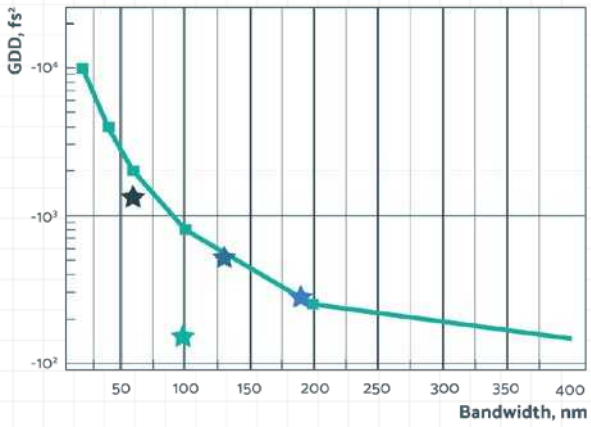
# GDD VS BANDWIDTH

It is important to note that bandwidth and GDD are closely connected. A high value of negative GDD results in a very narrow bandwidth. For a better understanding, see the graph below.




GDD vs Wavelength for different chirped mirror designs. A more negative GDD value results in a narrower operational bandwidth.

Below graph indicates GDD dependence on operational bandwidth at a fixed coating thickness of 10 µm. Stars on the graph indicate experimentally produced designs,




**Theoretical design:**
10 µm

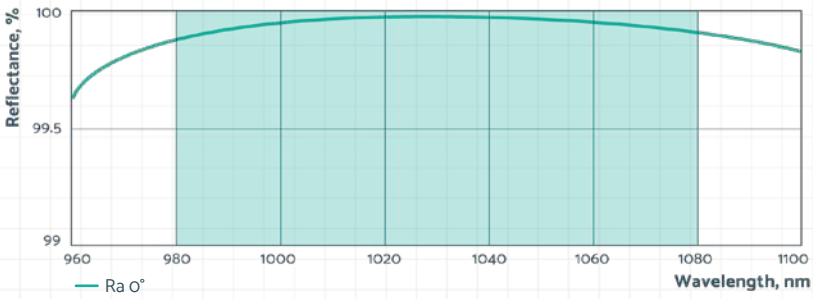
**Produced coatings:**
10.3 µm
12.2 µm
11.9 µm
9.9 µm

Relation between dispersive mirror operational bandwidth and average achievable GDD.

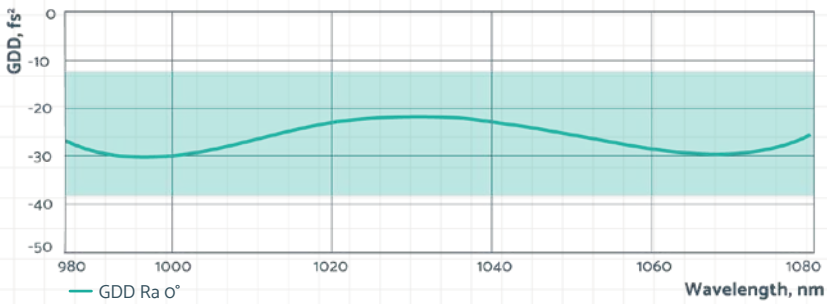
Source:
PERVAK, V., et al. Empirical study of the group delay Optics express , 2013, 21.15: 18311-18316. dispersion achievable with multilayer mirrors.

## Design example:

**Chirped Mirror**
**HRsp > 99.9% @ 980 - 1080 nm, AOI = 10°**
**GDD constant -25 fs² +/-10 fs² @ 980 - 1080 nm**




Absolute reflectance Rs and Rp exceeds 99.9% at broadband 980 nm - 1080 nm range.




The most challenging part is to keep GDD at predefined level of -25 fs² and maintaining LIDT to be over 0.3 J/cm², 50 fs, S-on-1

# ULTRAFAST AND ZULTRALOW GDD MIRRORS

Low GDD Ultrafast Mirrors are designed to handle high peak powers, provide reflectance greater than 99.95% and keep the GDD as close to 0 $fs^2$ as possible. This makes these mirrors ideal for femtosecond laser systems, like the Ti: Sapphire, where pulse broadening is a concern.

Can be designed and optimized for any ultrafast laser application.

Group Delay Dispersion (GDD) compensated as close as possible to 0 $fs^2$.

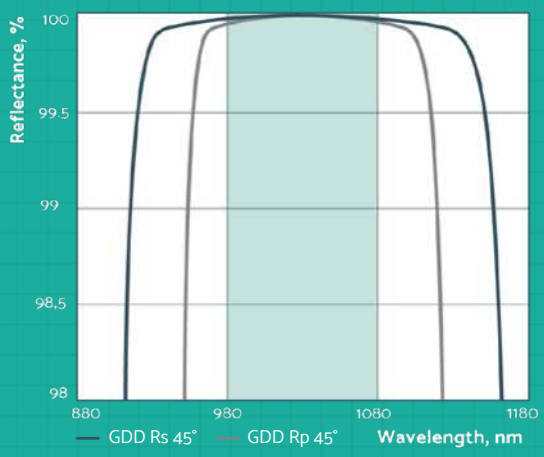
High Laser Induced Damage threshold, reaching >1 $J/cm^2$ at 1030 nm, 500 fs, 10 kHz conditions.

Reflectance Rs>99.99% and Rp>99.95% while maintaining optimized GDD.

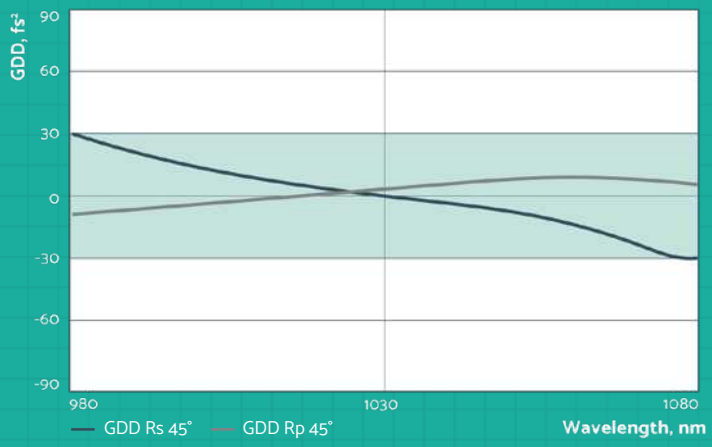
Wide spectral bandwidth and high reflection.

**Design example:**

**Ultrafast Broadband mirror**
**HRs > 99.95% & HRp > 99.95% @ 980 - 1080 nm, AOI = 45°**
**I GDD Rs, Rpl <30 fs² @ 980 - 1080 nm**




Mirror is optimized for highest possible spectral performance, where reflectance for both s and p polarization components is greater than 99.95 %




At the same time I GDD I for reflected laser light is controlled to be below 30 fs².

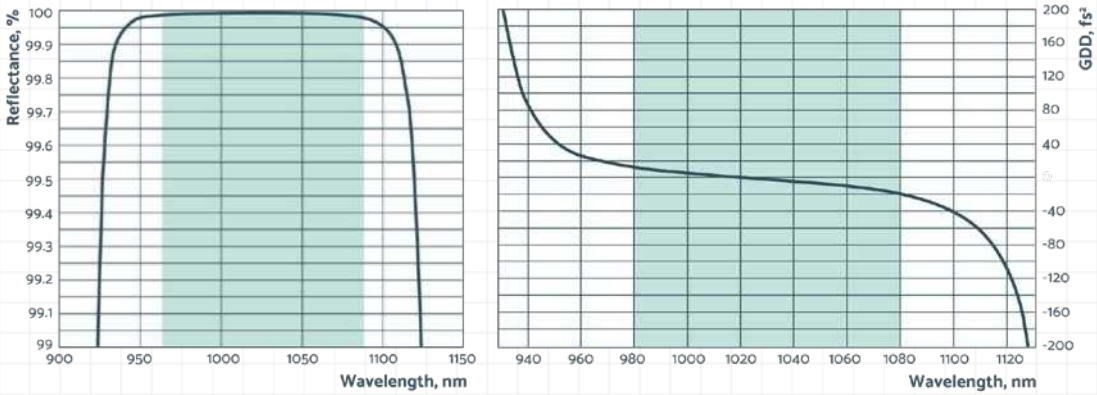
## MIRRORS FOR MULTIPASS CELLS (MPC)

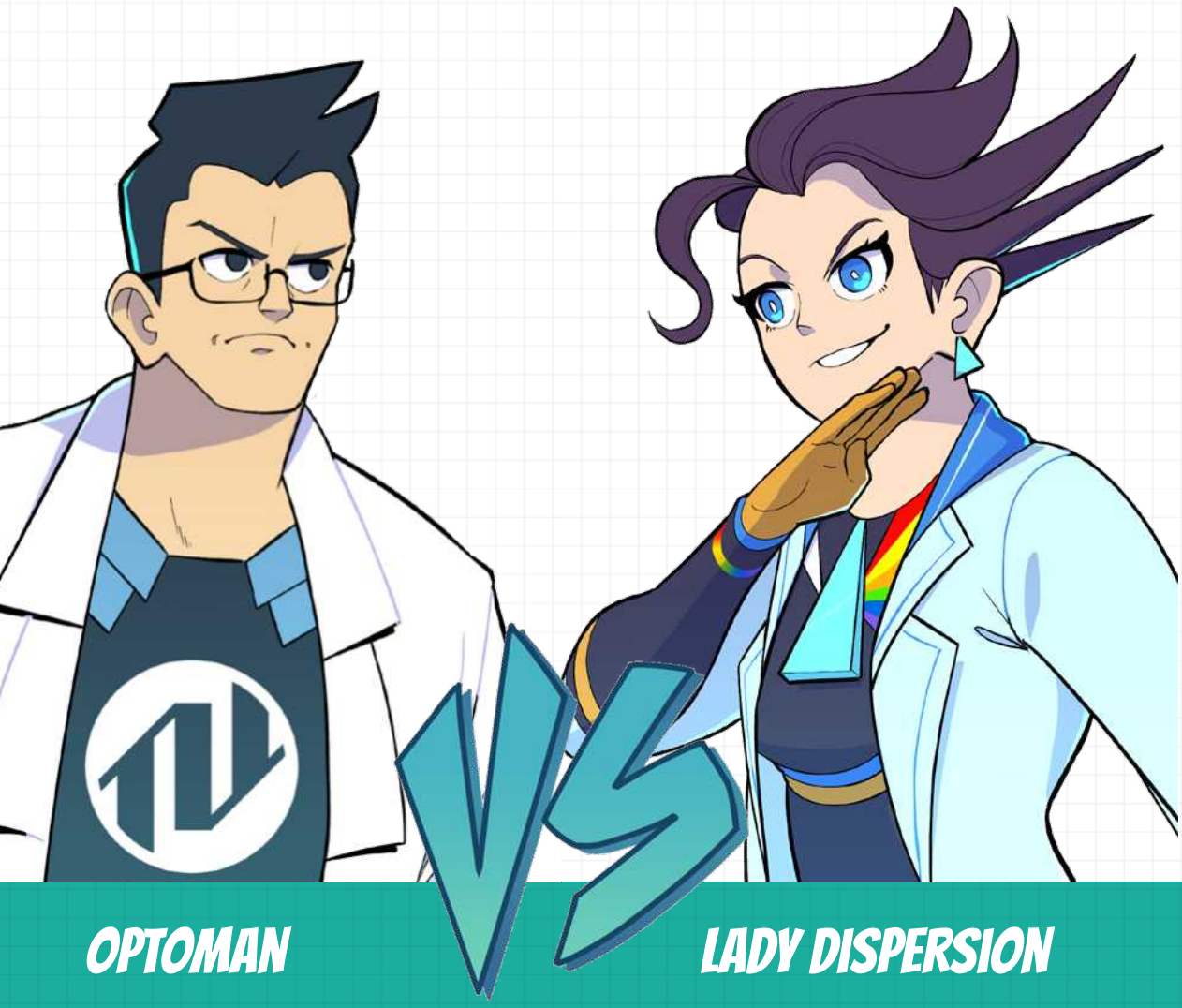
MPC are used for spectral broadening and compression of pulses. Nonlinear compression of laser pulses with tens of millijoule energy in a gas-filled multipass cell is a promising approach to realize a new generation of high average power femtosecond sources. HR mirrors are a key element of MPC as it enables to have a large number of reflections with low losses. OPTOMAN applied his superpowers for this application too and offers flat, concave, and convex mirrors with low GDD.

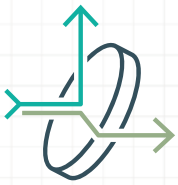
- Mirrors available in spectral range of 400-2000 nm;
- GDD up to ± 100fs² per bounce;
- HR (in gas) > 99.99%;
- LIDT: >1 J/cm² @ 1030 nm, 1 ps;
- Absorption: <2 ppm @ 1030 nm.

## Design example:

HR>99.99% @ 970-1090 nm, AOI=0° (IGDDrl < 50 fs² @ 980-1080 nm)





# WAVELENGTH SEPARATORS & LONG/SHORT PASS FILTERS

Wavelength Separators are very useful for several applications, and you always want that these laser optics would be strict about wavelength tolerances. IBS coated Wavelength Separators feature spectral drift-free performance, which is why very sharp edge configurations are feasible at optics made by OPTOMAN.

Can be designed as harmonic separators, OPO/OPA/OPCPA mirrors.

Low absorption UV or IR grade fused silica substrates.

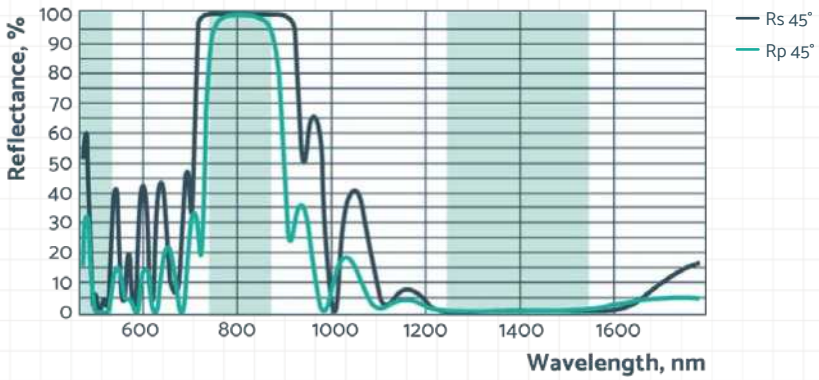
Optimized for high power applications.

Available in short pass, long pass or bandpass configuration

Can be optimized for ultrashort laser pulses.

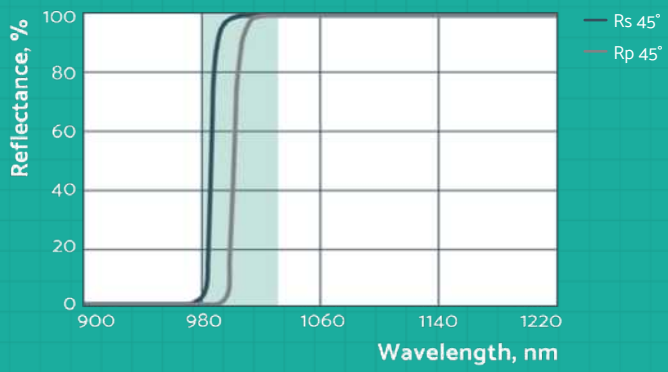
## Design example:

**HRs>99.8% @ 760-870 nm + HTp>99% @ 510-520 nm + HTs>98% @ 1250-1550 nm, AOI=45° (IGGDrsl < 20 fs² @ 760-870 nm)**



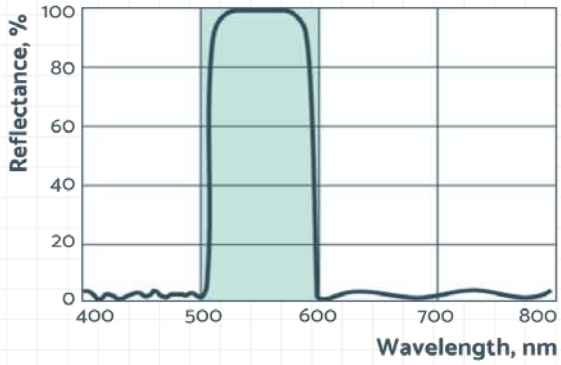

# PUMP/SIGNAL SEPARATOR

**HRsp>99.9% @ 1030-1200 nm + HTsp>98% @ 900 - 980 nm, AOI=45°**




Dichroic design incorporates precisely located and very steep transition between HT and HR zones maintaining polarization insensitive performance.

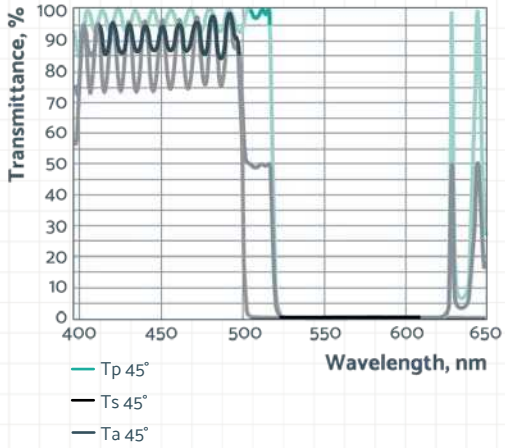
# BROADBAND NOTCH FILTER



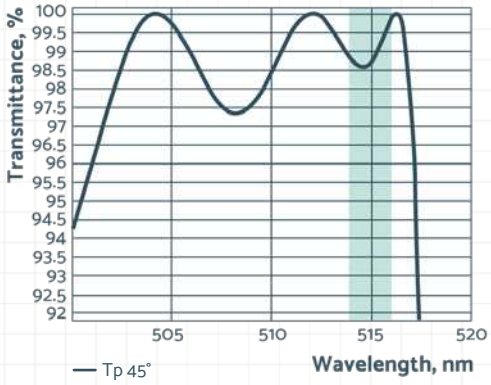

HRs_avg >99% @ 530 - 570 nm,
HTs_avg >97% @ 400 - 500 nm,
HTs_avg >97% @ 600 - 800 nm,
AOI = 45°

## Design example:

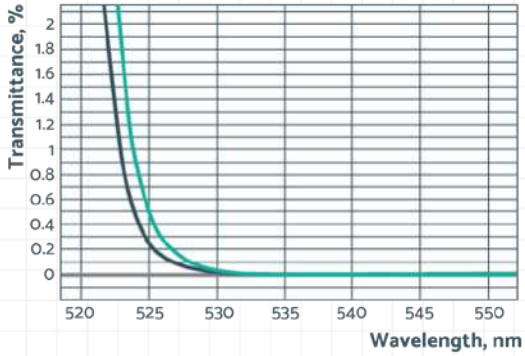
HTp > 93% @ 515 nm + HTa ~ 90% @ 415-515 nm + HRa_average > 99.9% @ 525-615 nm, AOI=45°

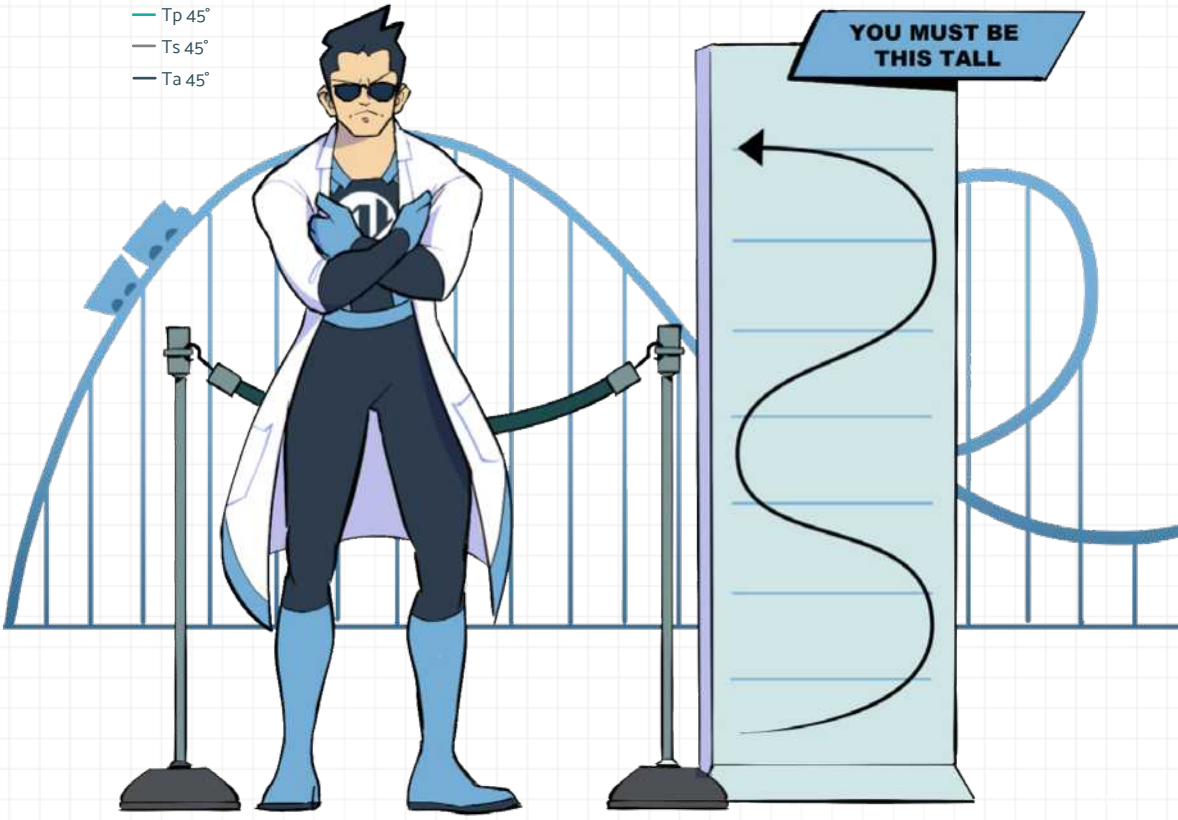



HTp > 93% @ 515 nm zoom, AOI=45°




HRa_average > 99.9% @ 525-615 nm, AOI 45°, transition zone



# THIN FILM POLARIZERS

When it comes to a need for polarizing light from high power laser, thin film polarizer is the only valid choice. Fortunately, OPTOMAN has invested his efforts to optimize thin film polarization coatings by IBS technology.

Thin film polarizers have many variations of design:

- Angle of incidence: 45°, 56°, 72° or any other angle;
- Laser power: Standard or LIDT optimized;
- Extinction ratio: Standard (1'000:1) or Extinct (10'000:1);
- Bandwidth: Single wavelength, Twin wavelength or Broadband Low GDD.

OPTOMAN designs and manufactures all of them. But the list is not definite, OPTOMAN can optimize thin film polarizer design according to your specific application.

**LET OPTOMAN BE YOUR SIDEKICK FOR LASER OPTICS DEVELOPMENT!**

Standard extinction of 1'000:1 (and up to the Extinct 10'000:1)

Application optimization: reflectance Rs>99.99% or transmittance Tp>99.9%

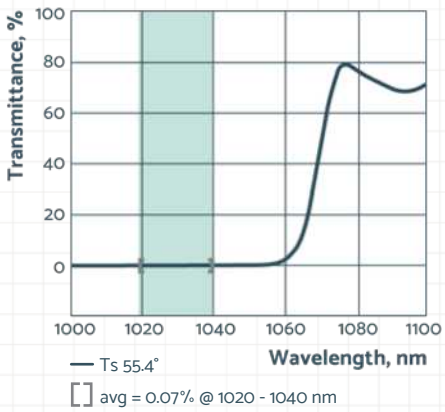
Various angles of incidence 45°, 56°, 72°...

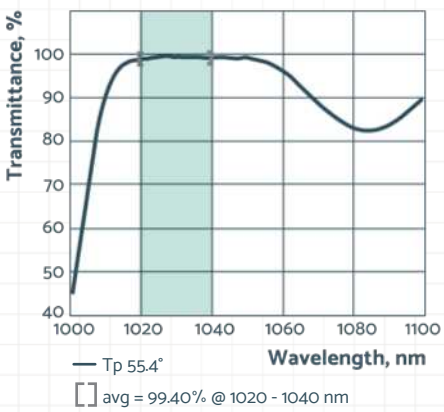
Laser damage threshold for s polarization >0.7 J/cm², 1030 nm, 500 fs, 10 Hz

Single wavelengh, dual-wavelengh, ultrafast and broadband polarizers

## Design example:

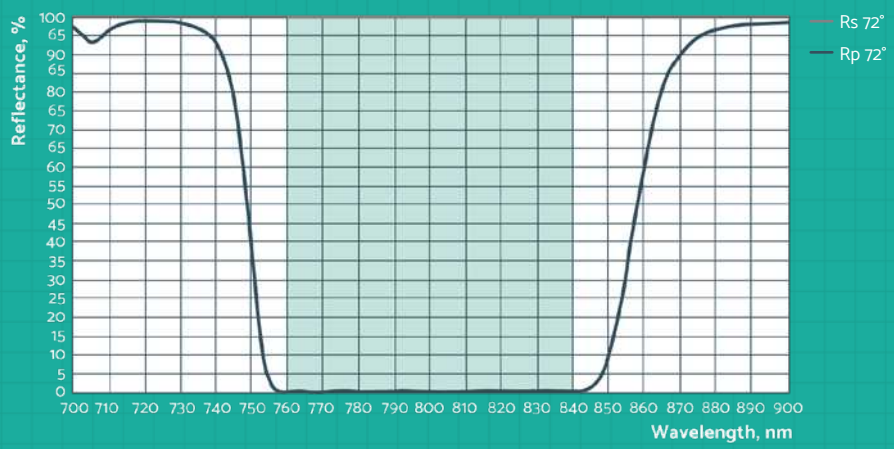
**Rs>99.9% @ 1020-1040 nm + Tp>99.0% @ 1020-1040 nm, AOI=55.4°, Tp/Ts>1000:1**



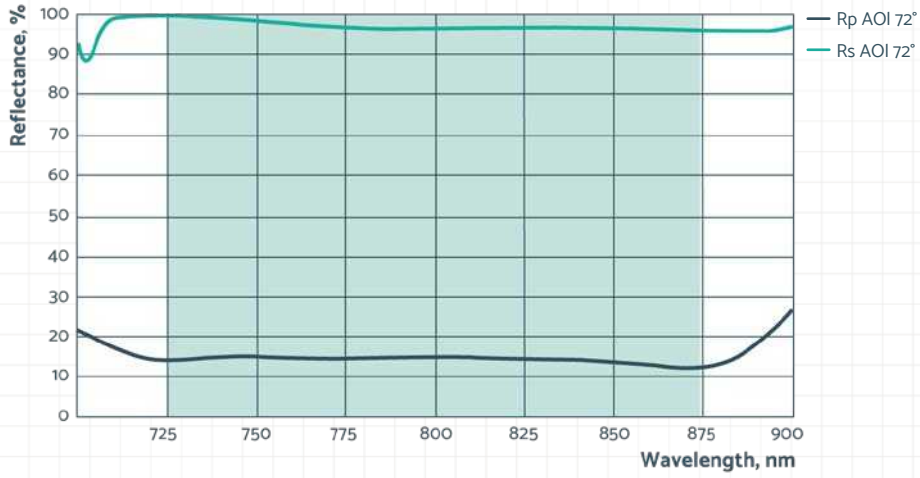

## Design example:

**Rs_avg>99.8% @ 760 nm – 840 nm + Rp_avg<2% @ 760 nm – 840 nm, AOI=72°**




Calculated reflectance ant transmittance graphs for s and p pol components at AOI=72°

**Rs>95% @ 725 nm - 875 nm, AOI=72°**
**Tp>85% @ 725 nm - 875 nm, AOI=72°**

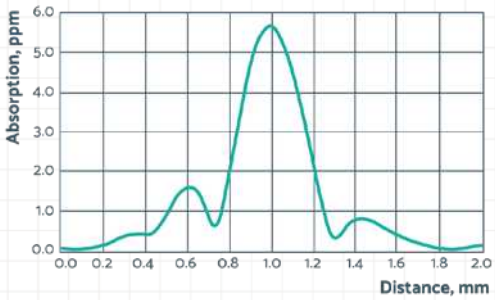



Measured s and p-polarization reflectance graph at AOI=72°. Reflectance accumulated from both sides

Because of low scatter and absorption losses, OPTOMAN can manufacture thin film polarizers with a super high extinction ratio of Tp/Ts~10'000:1 per coated surface at 45° or Brewster angle.

**High contrast Thin Film polarizers**

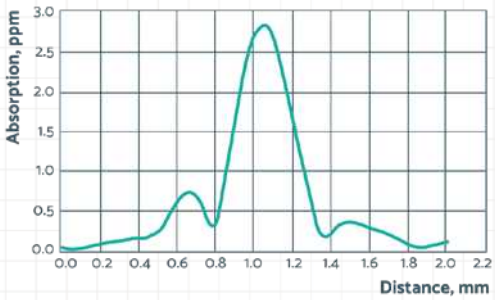
**Rs>99.9% & Tp>98% @ 1064 nm, 45°**
**Extinction ratio Tp/Ts~1'000:1**




p-pol component absorption measurement at 45°

**Precision Thin Film Polarizers**

**Rs>99.99% & Tp>99% @ 1064 nm, 45°**
**Extinction ratio Tp/Ts~10'000:1**




s-pol component absorption measurement at 45°

# NON-POLARIZING BEAMSPLITTERS

It's not an easy task to split a laser beam into virtually two identical beams without destroying the polarization ratio. Fortunately, OPTOMAN thrives on difficult tasks, therefore he manufactures polarization insensitive beamsplitters with Rs and Rp matched within 1-2%.

S and P polarization components matched to within 5%, or down to 1% upon request

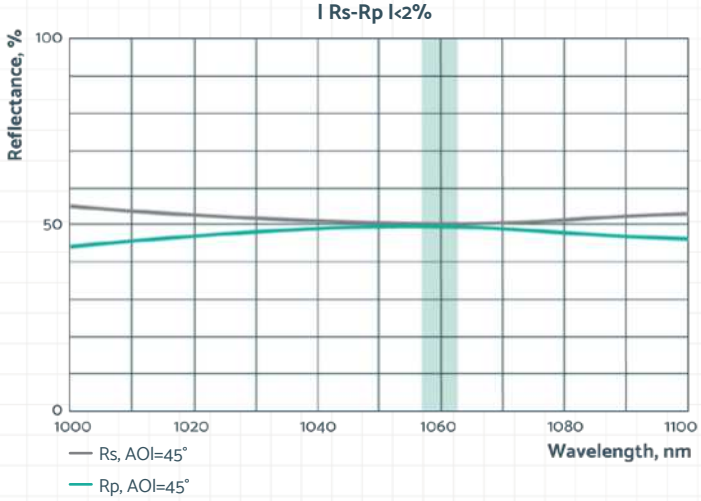
Wedge on back surface eliminates unwanted internal fringes

Back surface wedged or AR coated to eliminate ghosting

Laser Damage Threshold >10 J/cm$^2$, 1064 nm, 20 ns, 20 Hz

**50% completely dielectic beamsplitter**

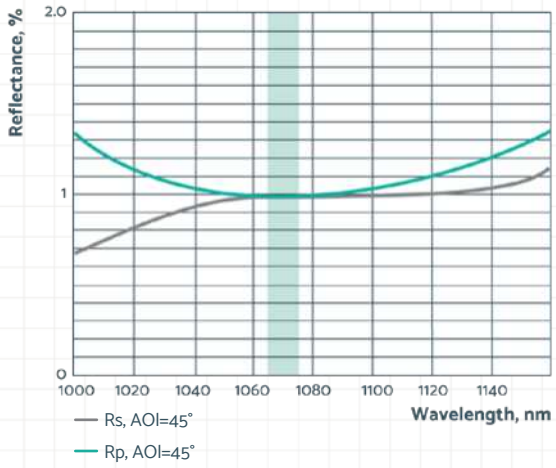
**Rsp=50% +/-2% @ 1064 nm & R=50% +/-5% @633 nm, AOI= 45°, I Rs-Rp I<2%**

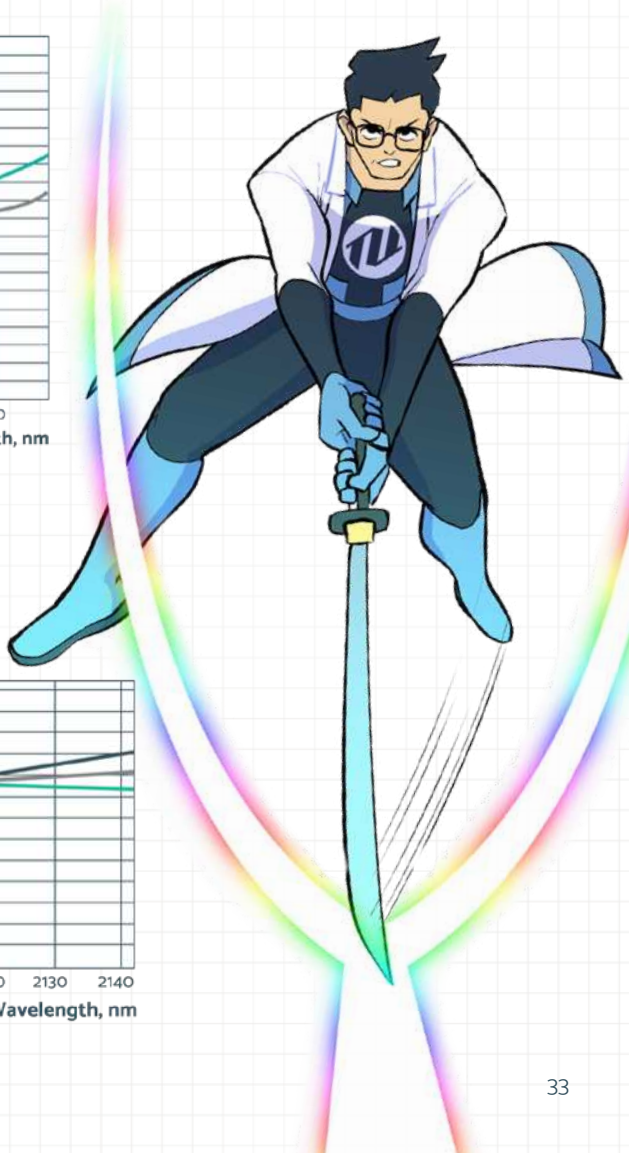



Small R ratio beam samplers are used for beam diagnostics. This means that Rsp stability at any environmental conditions is critical. As IBS coatings are not affected by temperature and humidity, it s the perfect choice for beam samplers.

**1% beam sampler**

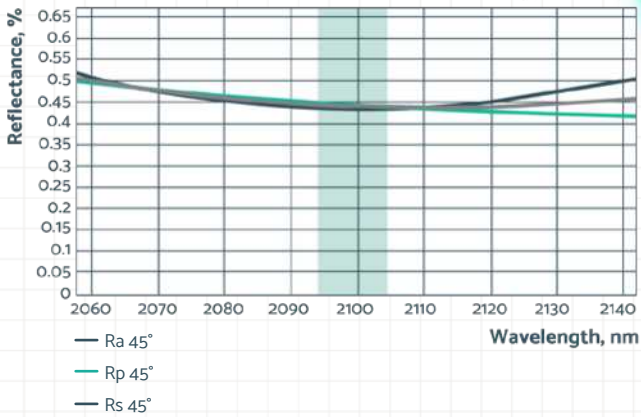
**Rsp=1% +/-0.35% @ 1064 nm, AOI= 45°**



## Design example:

**ARs & ARp = 0.5+/-0.15% @ 2100 nm, AOI=45°**



# PARTIAL REFLECTION MIRRORS AND OUTPUT COUPLERS

Partial reflection mirrors enable beam splitting or combining at a specific ratio and they are quite challenging optical components to make. It may not surprise you anymore, but OPTOMAN is an expert in this field too. OPTOMAN offers a variety of PR mirrors options, not limited to 45° angle of incidence or 50:50 splitting ratio.

Output couplers are an essential part of the laser cavity. By transmitting part of the circulating intracavity optical power, output couplers allow generating a useful output of the laser. It differs from PR mirrors by the angle of incidence as output couplers operate at 0° degree. Depending on the laser system design, output couplers can be coated on spherical substrates to enable focusing or defocusing effect on the output beam.

High LIDT output coupler designs optimized for intracavity applications

R:T split ratio accuracy down to 0.05%

Segmented, knife-edge coated components for compact setups

Water-free OC coatings for 2.6 µm 3.4 µm spectral range

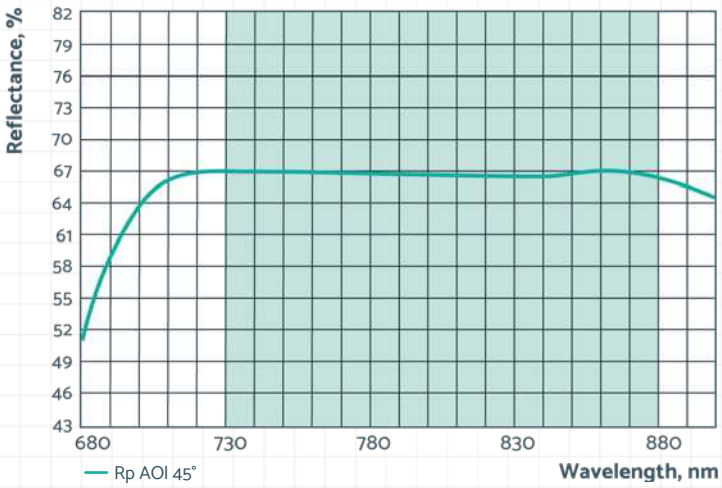
Optimization for ultrafast applications – GDD control

## Design example:

Partial Reflection Mirror optimized for p polarization component with reflectance of 67% +/- 1%. Moreover, GDD for Rp and Tp beams is controlled to be <10 fs$^2$.

**Low GDD Partial Reflection Mirror**

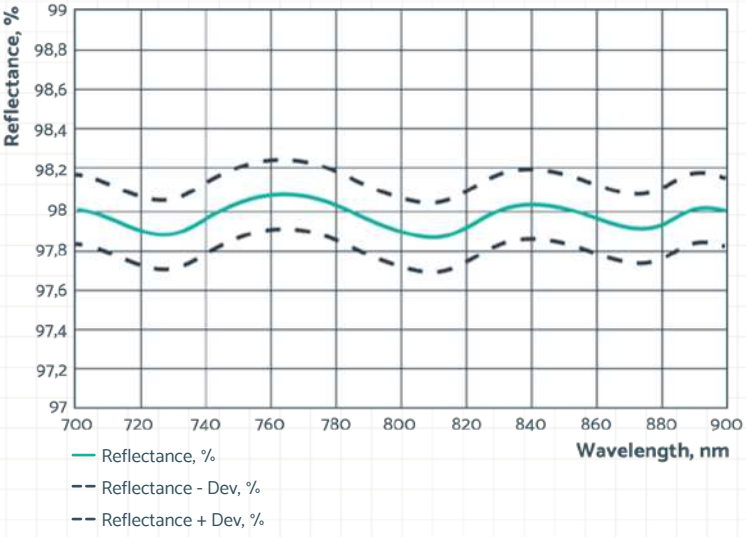
**PRs=67% +/-1% @ 730 - 870 nm, AOI = 45°**



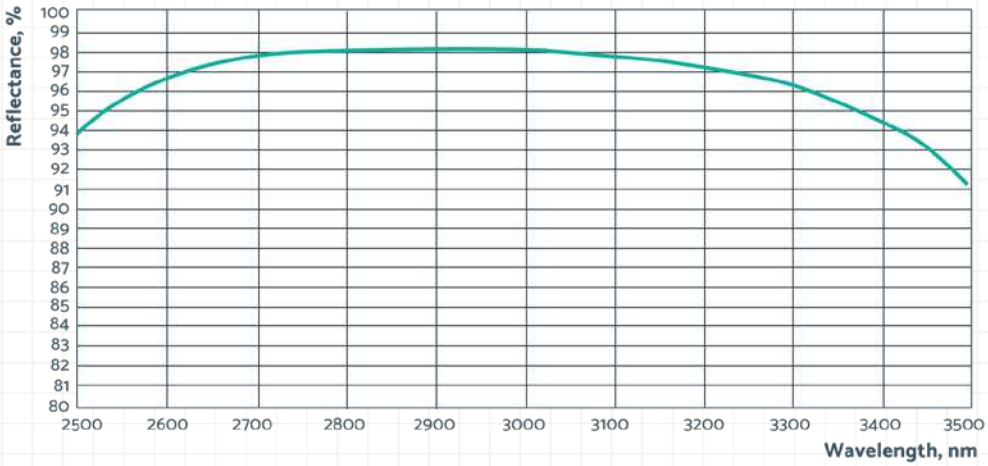

OC performance is optimized in 700 900 nm range with reflection tolerance of only +/- 0.5%.

**98% Broadband Output Coupler**

**PR=98% +/- 0.5% @ 700 - 900 nm, AOI = 0°**



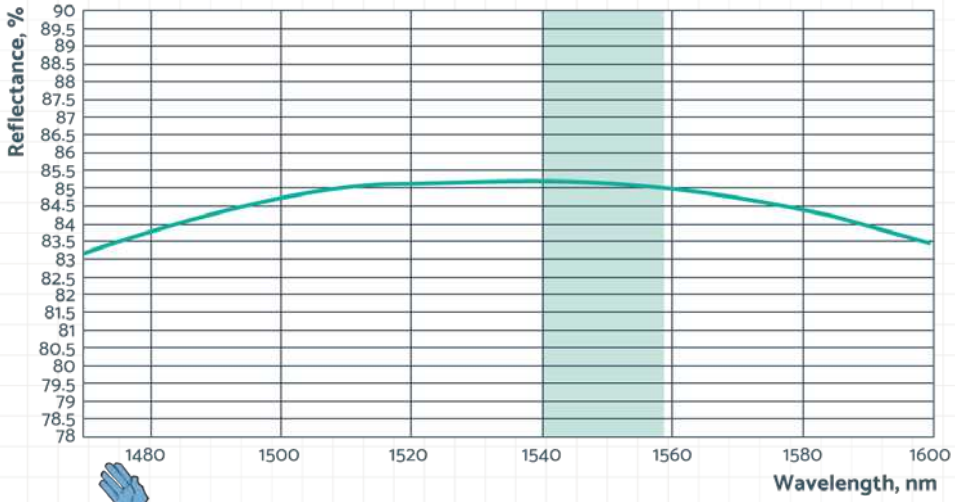

**98% Output coupler design for intracavity of widely used Er:YAG laser.**

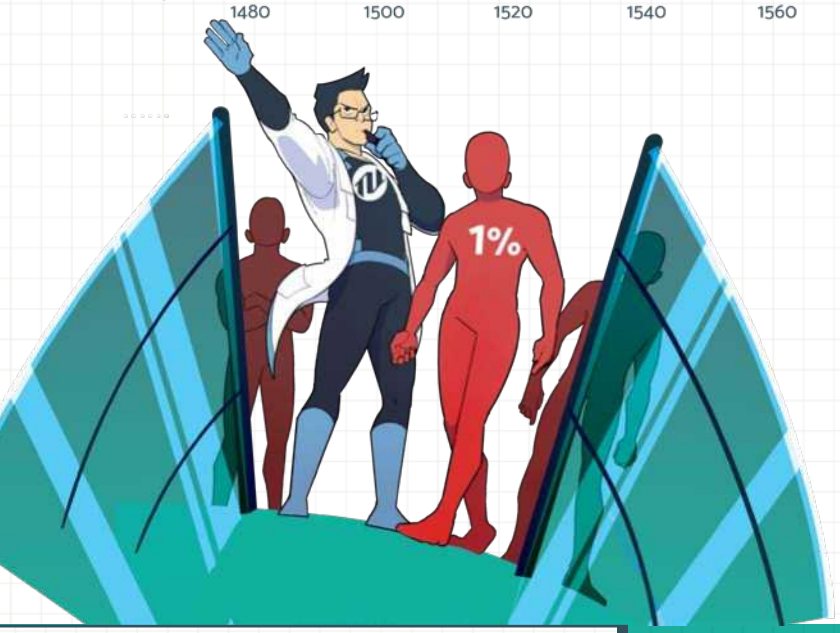


**Design example:**

R=85% +/-0.5% @ 1550 nm, AOI=0°

LIDT: >50 J/cm², 1535 nm, 20 ns, 1 Hz

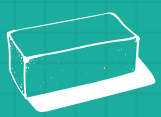



# ANTI-REFLECTION COATED OPTICS

Hundreds of companies Worldwide manufacture Anti-Reflection (AR) coated optics. What is so special about AR coated components from OPTOMAN?

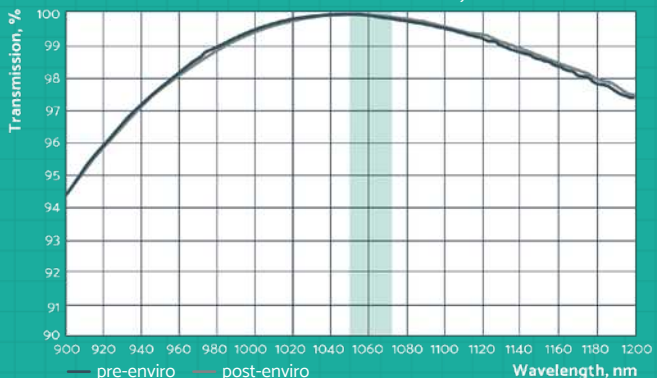
**IBS AR coatings are extremely durable and environmentally stable due to the density of layers. Incredible resistance makes them perfect for on-field applications.**



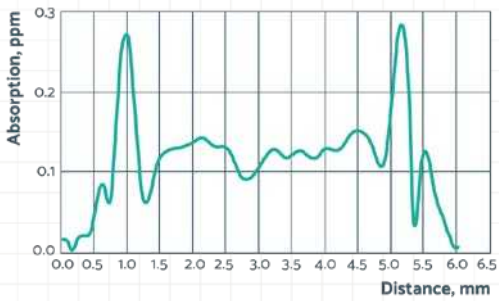
**IBS**
Near Bulk Density

**E-beam**
Porous Structure

AR@1064 nm coated sample performance before and after environment treatment cycles.



**Low loss configuration allows transmittance higher than 99.98% of AR/AR coated components and absorption lower than 0.3 ppm @ 1064 nm, for example.**




Absorption measurement@ 1064 nm. Low absorption is responsible for thermal shift-free performance and negligible fatigue of coated surfaces.

Typical commercial AR coatings feature residual reflectance below 0.25% per surface. 0.1% is becoming quite a common value as well. In any case, imagine having a laser beam with 1 kW power passing through such a component. Transmittance loss is ~2 W – 5 W and this light goes somewhere back to the laser system.

With the low loss coating technology, OPTOMAN can reduce this number down to 0.2 W, because residual reflectance per coated surface can go below 0.01%.

**Damage threshold >20 J/cm², 1064 nm, 10 ns, S-on-1.**

## TYPES OF AVAILABLE AR COATINGS

| Low loss (R<0.01%) | Laser Line | Double-line | Triple-line | Multi-line | Broad-band | Wide acceptance angle |
|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |

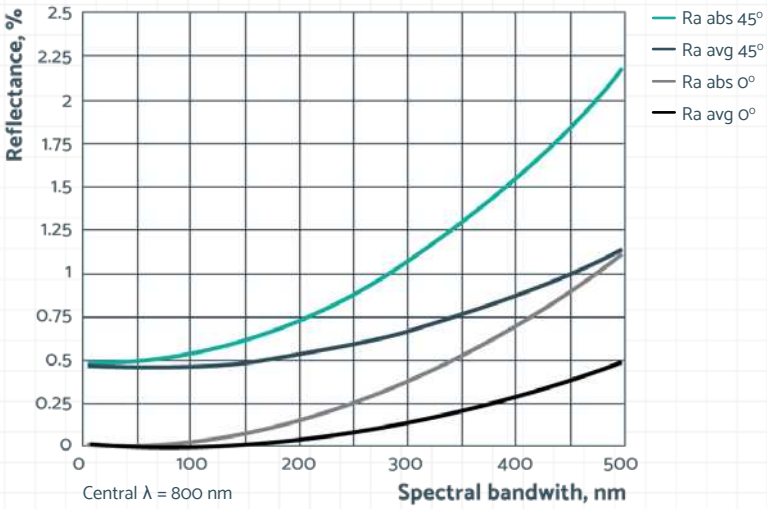
## AR COATINGS AVAILABLE WITHIN RANGE FROM 200 NM UP 5000 NM ON

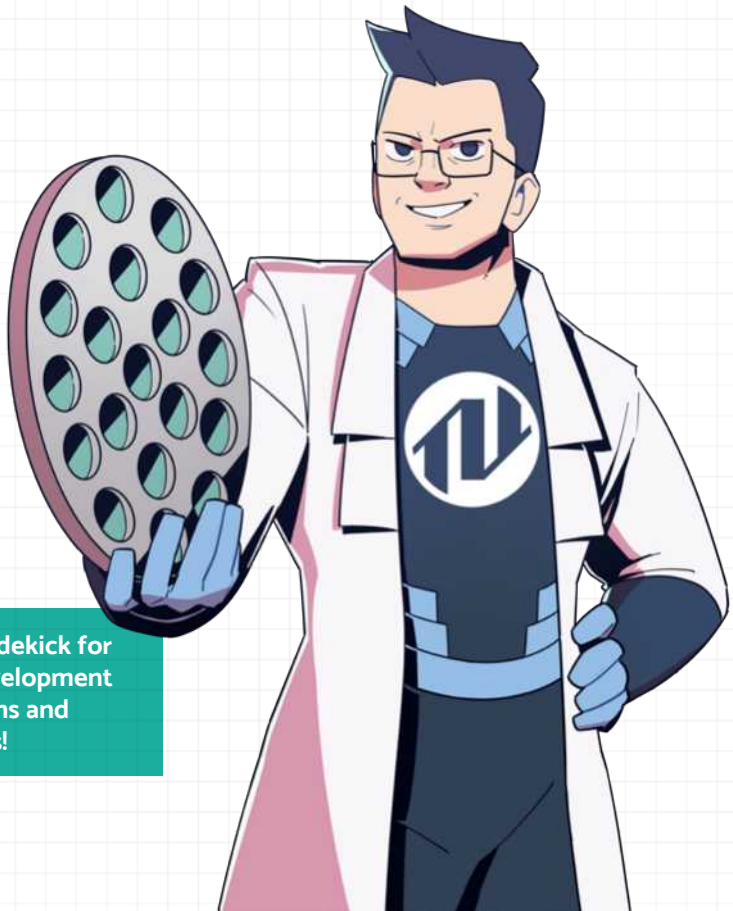
| Glasses | Semicon-ductors | Laser crystals | Nonlinear crystals | Other |
|---|---|---|---|---|
| · Fused Silica<br>· Borosilicate<br>· Flint glass<br>· Crown glass | · Silicon<br>· SiC<br>· Germanium<br>· GaAs | · Nd:YAG<br>· Yb:YAG<br>· Pr:YLF<br>· Ti:Sapphire<br>· Yb:KYW/KGW<br>· Er:YAG, Ho:YAG | · LBGO<br>· Crystalline Quartz<br>· Sapphire<br>· YAG<br>· BBO<br>· TGG | · Big size wafers (up to Ø250 mm)<br>· CaF2 and MgF2<br>· Spherical, cylindrical, aspherical surfaces |

# BROADBAND AR COATINGS

Have a broad-spectrum light source or a laser with multiple-harmonic generation? OPTOMAN thinks about you too and produces broadband AR coatings to serve your versatile needs.

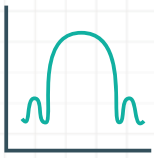
Note that broadband AR coatings tend to have higher reflectivity values than AR coatings designed for one specific wavelength. Reflectivity values depend on the spectral bandwidth, which can be seen in the figure below. Moreover, Ra has a sharper increase at higher spectral bandwidth for absolute values compared to the average ones, due to the difficulties to maintain stable transmission values throughout the whole desired spectral region.



**Contact your sidekick for laser optics development for consultations and custom designs!**

# SPECIAL COATINGS AND OPTICS



## MID-IR IBS COATED OPTICS

It is common knowledge that the Mid-IR region becomes more and more popular for laser applications. OPTOMAN is not only the lab guy, focused on developing innovations with the technology push approach. No, OPTOMAN has an open mind and listens to what the market has to say, therefore OPTOMAN, driven by the market, extends its capabilities into the Mid-IR region and now provides dielectric coatings in 1.5 - 5 µm region.

Can be designed and optimized for any (ultrafast) laser application

Group Delay Dispersion (GDD) compensated as close as possible to 0 $fs^2$

Coating types: HR, AR, Polarizing, Dispersive, Dichroic

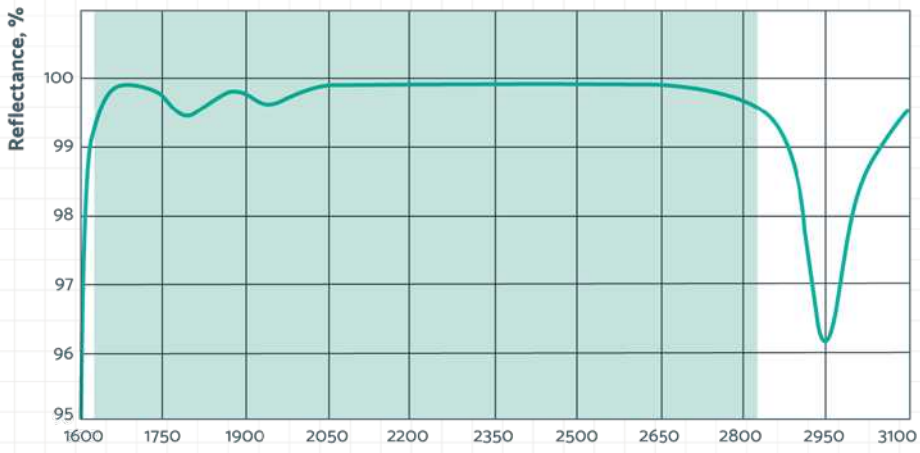
Wavelength range:
1.5 µm 5 µm

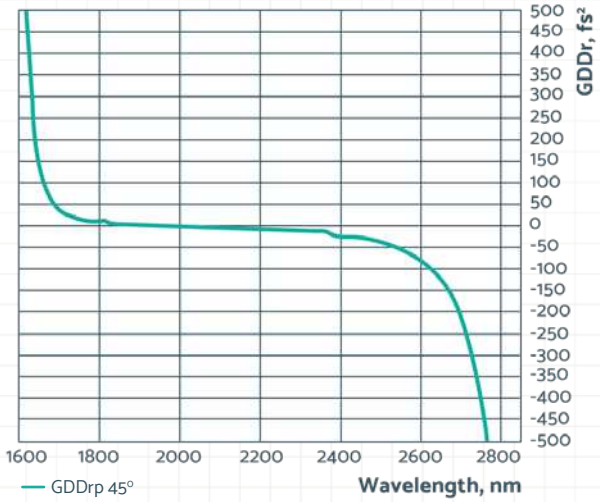
Fully dielectic coatings

Measured/tested/used at ELI-ALPS & ETH Zurich

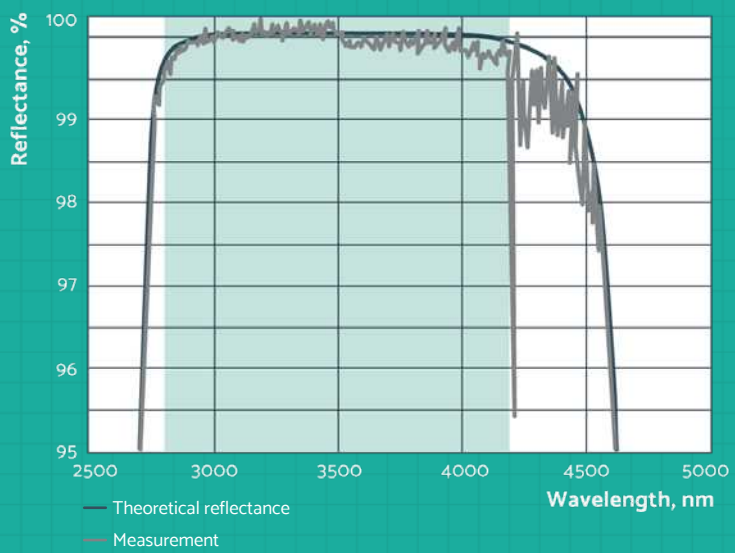
## Design example:

HRp>99.5% @ 1650 - 2850 nm, AOI=45°




# MID - IR BROADBAND MIRROR




Theoretical and measured reflection graphs at AOI=0°

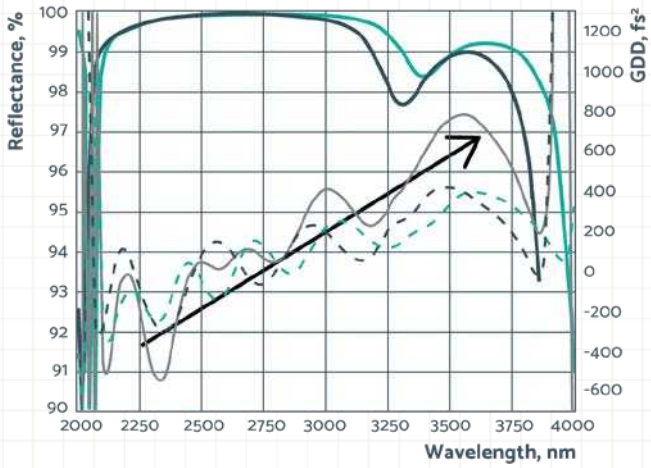
- HR >99.8% @ 2.8-4.2 µm AOI 0°;
- GDD & TOD Rs, Rp optimized;
- LIDT: >10 mJ/cm² @ 15 fs.

# DISPERSIVE MIRRORS FOR MID-IR RANGE

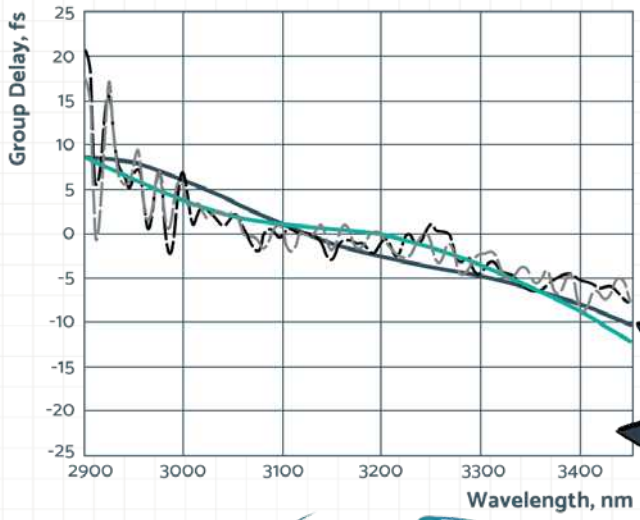
OPTOMAN is one of the first companies worldwide offering IBS coated dispersive and broadband low GDD mirrors made for 2-5 µm.

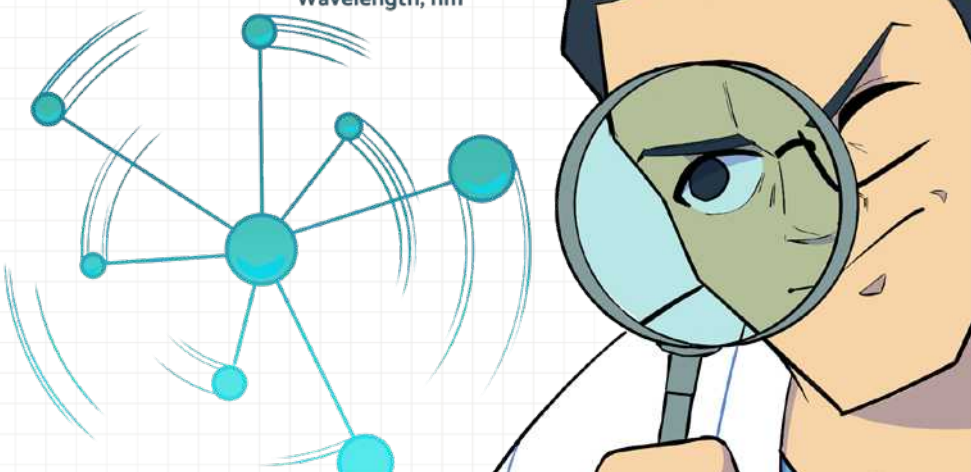
Broadband dispersive mirrors for mid-IR range can reduce, or even eliminate, the need to use combinations of various materials to compensate dispersion and finally recompress broadband pulses close to Fourier limit duration in the sub-2 cycles regime.

## Mirror specifications:




Theoretical reflectance and GDD curves at 10° and 25° AOI.



# UV IBS COATED OPTICS

**343 nm & 355 nm High Reflectivity Mirrors**
**Optimized for Nanosecond & Picosecond High-Power Lasers**

**Can OPTOMAN defend optics from ULTRA-VIOLENT lasers?**

To ensure a high degree of reflection in the UV range, scattering and absorption losses need to be well managed, as they increase considerably when the wavelengths go down. Long-term degradation of the mirrors is another big issue when working with intense UV lasers.

However, OPTOMAN by exploiting his superpowers of a strong focus on the surface quality and well-optimized coating technology CAN defend his optical components from most of the UV lasers and increase the longevity of optics.

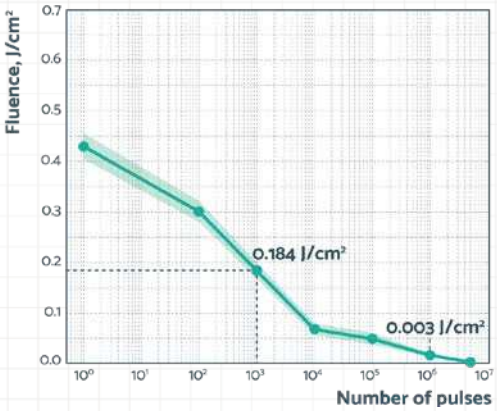
**What makes OPTOMAN UV optics different?**

## 1. HIGH LIDT

Laser damage is the arch-enemy of UV optics. To fight it, one must measure it. So OPTOMAN does, for picosecond and nanosecond scale.

**OPTOMAN also loves competition and presents you the fight:**
**Standard mirror vs. OPTOMAN mirror**

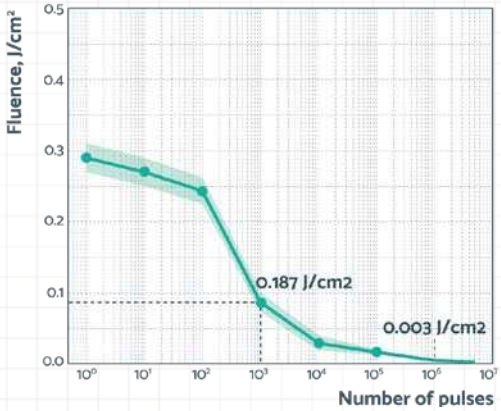
**Which one are you betting on?**




● Offline dettecion
■ 95% confidence interval

Wavelength: 343 nm
Pulse duration (FWHM): 1.0 ps
Repetition rate: 50 kHz
AOI: 45°
Polarization: Linear S
Beam diameter (1/e²): (62.3 ± 0.5) µm

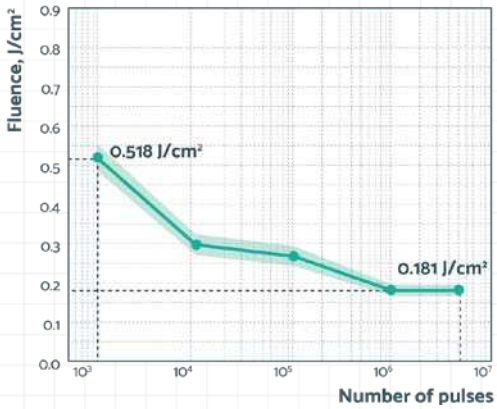
Characteristic damage curve of standard mirror (S polarization).




● Offline dettection
■ 95% confidence interval

Wavelength: 343 nm
Pulseduration (FWHM): 1.0 ps
Repetition rate: 50 kHz
AOI: 45°
Polarization: Linear P
Beam diameter (1/e²): (62.3 ± 0.5) µm

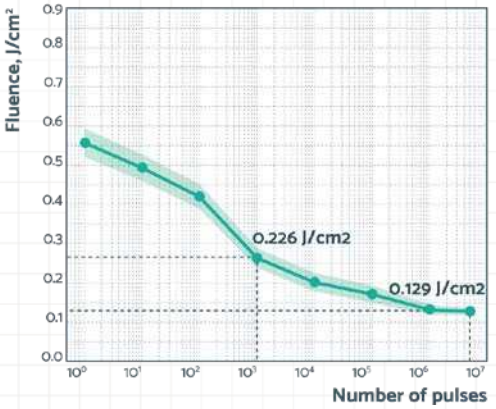
Characteristic damage curve of standard mirror (P polarization).




Offline dettecion
95% confidence interval

Wavelength: 343 nm
Pulse duration (FWHM): 1.0 ps
Repetition rate: 50 kHz
AOI: 45°
Polarization: Linear S
Beam diameter (1/e²): (62.3 ± 0.5) µm

Characteristic damage curve of OPTOMAN mirror (S polarization).

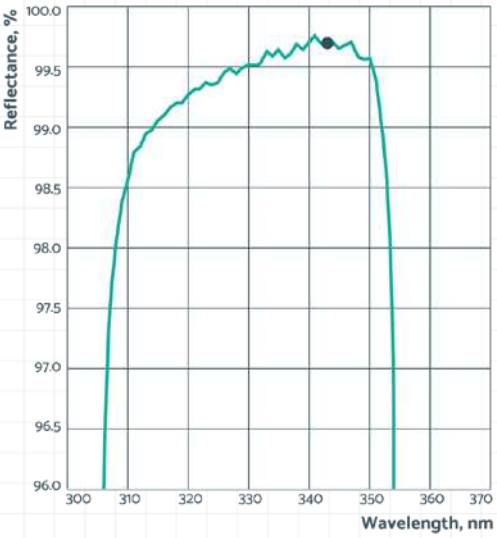



Offline dettection
95% confidence interval

Wavelength: 343 nm
Pulseduration (FWHM): 1.0 ps
Repetition rate: 50 kHz
AOI: 45°
Polarization: Linear P
Beam diameter (1/e²): (62.3 ± 0.5) µm

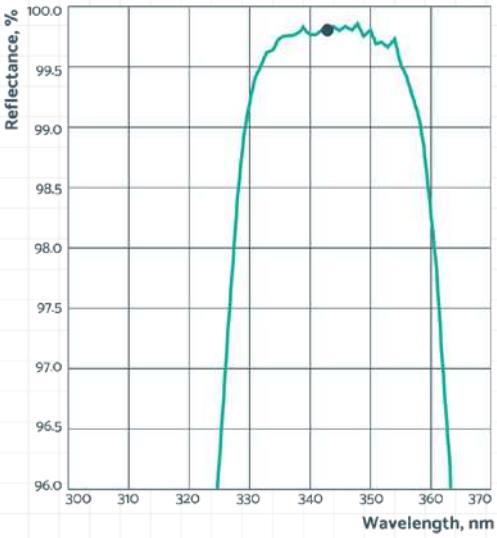
Characteristic damage curve of OPTOMAN mirror (P polarization).

| Test mode | Standard mirror | | OPTOMAN mirror | |
|---|---|---|---|---|
| | S-pol | P-pol | S-pol | P-pol |
| $10^3$ on 1 | 0.184 J/cm² | 0.087 J/cm² | 0.518 J/cm² | 0.266 J/cm² |
| $5x10^6$ on - 1 | 0.003 J/cm² | 0.003 J/cm² | 0.181 J/cm² | 0.129 J/cm² |




99.66% @ 343 nm

Measured average reflectance spectrum a standard mirror #1 AOI=45°.




99.79% @ 343 nm

Measured average reflectance spectrum of OPTOMAN sample No. 1562, AOI=45°.

## 2. COST-EFFECTIVE COATING DESIGN

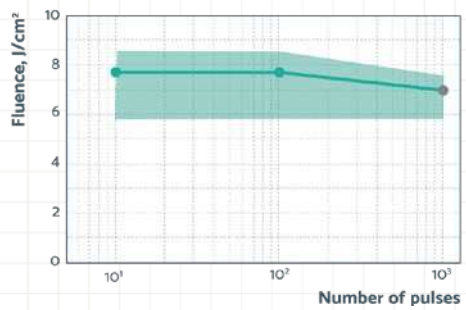
OPTOMAN Superhero League mirrors feature high batch-to-batch repeatability and are suitable for high volume serial production.

## 3. CONSISTENT QUALITY

| Parameters | Require-ments | Measured parameters | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Standard mirrors as samples | | | | | Optoman samples | |
| | | #1 | #2 | #3 | #4 | #5 | 1562 | 1563 |
| Rabs @ 343 nm, AOI=45° | >99.8 % | 99.66% | 99.64% | - | - | - | 99.79% | 99.70% |
| Ravg @ 339-346 nm, AOI=45° | >99.5 % | 99.68% | 99.67% | - | - | - | 99.82% | 99.73% |
| Surface flatness @633 nm over CA | <λ/10 | - | - | 0.088 λ | 0.087 λ | 0.053 λ | 0.093 λ | 0.035 λ |
| Surface quality over CA | 20-10 S-D | 20-20 | 20-20 | 20-10 | 20-10 | 20-10 | 20-10 | 20-10 |

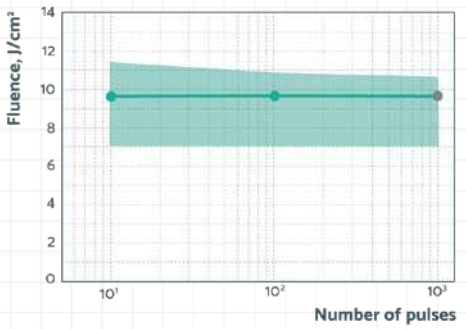
| | SuperHero League @ 343 nm | SuperHero League @ 355 nm |
|---|---|---|
| **Substrate** | UV FS | |
| **Surface Quality** | 10-5 S-D | |
| **Surface Flatness** | <λ/8 @ 633 nm over CA | |
| **AOI** | 45° | |
| **Coating** | HRsp > 99.7% (at design wavelength) | |
| | Rs, Rp, GDD | |
| **Laser Induced Damage Treshold** | **Picosecond (measured values):**<br>> 0.27 J/cm², 343 nm, 1 ps, 50 kHz, p-pol<br>> 0.52 J/cm², 343 nm, 1 ps, 50 kHz, s-pol | **Nanosecond (measured values):**<br>> 6.97 J/cm², 355 nm, 6 ns, 100 Hz, p-pol<br>> 9.6 J/cm², 355 nm, 6 ns, 100 Hz, s-pol<br><br>**Picosecond (scaled values):**<br>> 0.25 J/cm², 355 nm, 1 ps, 50 kHz, p-pol<br>> 0.5 J/cm², 355 nm, 1 ps, 50 kHz, s-pol |

## SuperHero League @ 355 nm nanosecond LIDT measurements:




Offline dettect on
Online dettect on
95% confidence interval

Wavelength: 355 nm
Pulse duration (FWHM): (5.7 ± 0.3) ns
Repetition rate: 100 Hz
AOI: 45°
Polarization: Linear P
Beam diameter (1/e²): (230.8 ± 4.0) µm

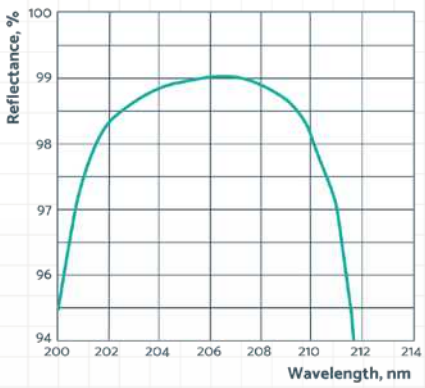


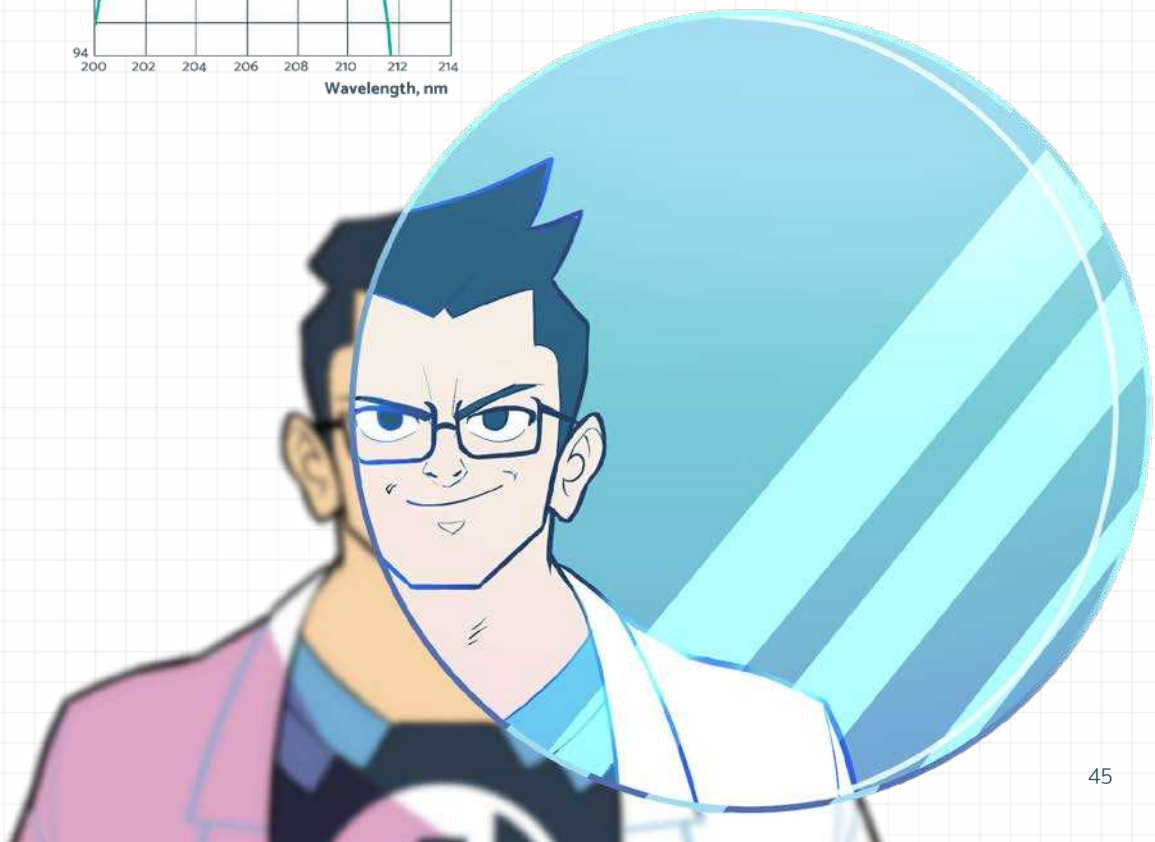

Offline dettect on
Online dettect on
95% confidence interval

Wavelength: 355 nm
Pulse duration (FWHM): (5.7 ± 0.3) ns
Repetition rate: 100 Hz
AOI: 45°
Polarization: Linear S
Beam diameter (1/e²): (230.8 ± 4.0) µm

## Design example:

**HRp > 93% @ 206 nm, AOI = 45°**



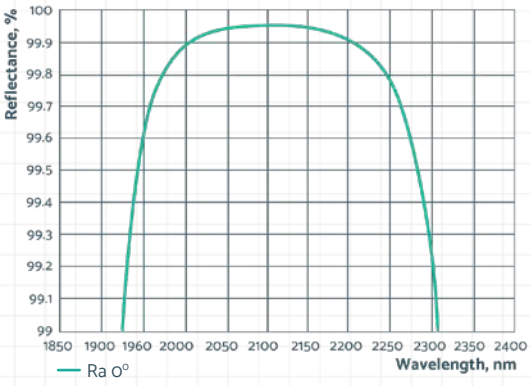



# OPTICS FOR MEDICAL LASER APPLICATIONS

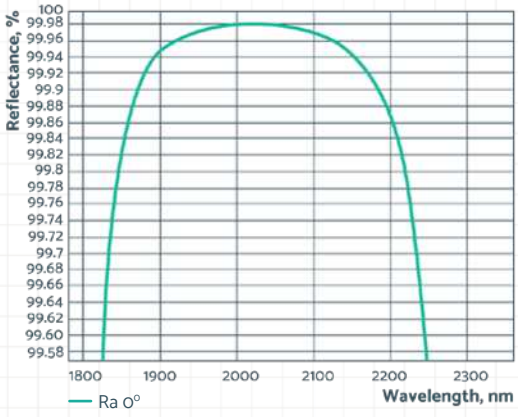
As OPTOMAN successfully fights water absorption due to advanced IBS technology, which makes coatings near bulk structure, OPTOMAN offers high LIDT coated optics for Ho:YAG, Tm:YAG and Er:YAG lasers, which are found very useful for a handful of medical applications.

## COATINGS FOR HO:YAG AND TM:YAG LASERS

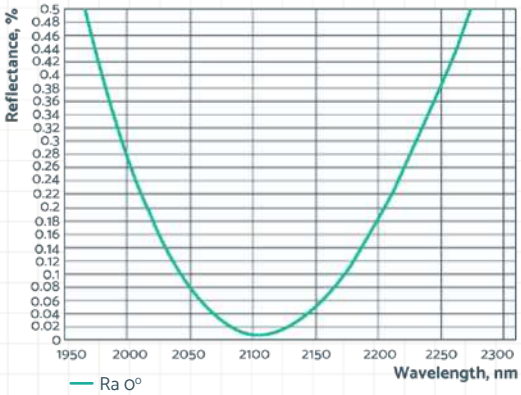
**LIDT Optimized Cavity Mirrors**
**HR>99.9% @ 2100 nm, AOI=0°**



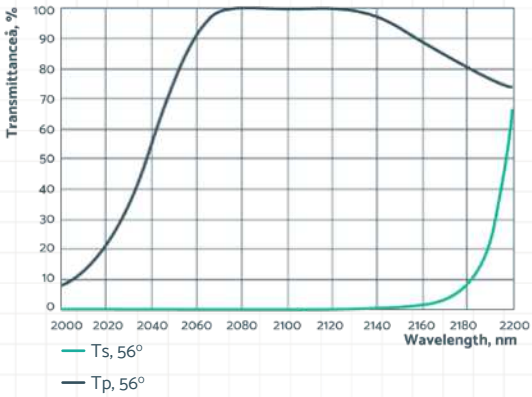

**Broadband Bending Mirror**
**HR>99.9% @ 1900 nm – 2100 nm, AOI=0°**



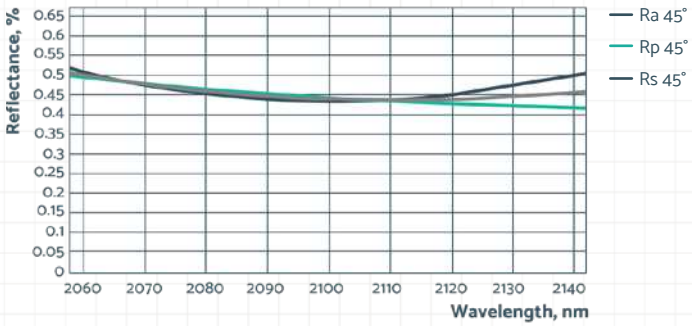

**LIDT Optimized Cavity AR Coated Lenses**
**AR<0.1% @ 2100 nm, AOI=0°**



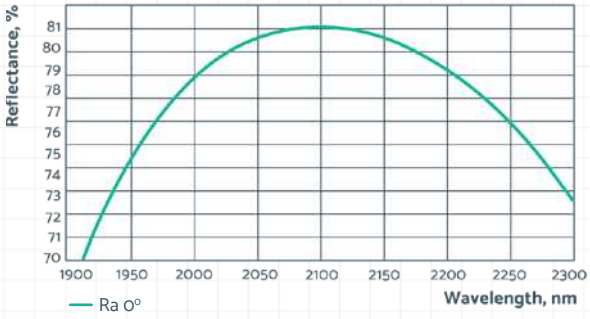

**Thin Film Polarizers**
**HRs>99.9% @ 2100 nm & HTp>98% @ 2100 nm, AOI=56°**
**HRs>99.8% @ 2100 nm & HTp>97% @ 2100 nm, AOI=45°**



**Sampler Window / Non-polarizing Power Pick Up Plate**
**PRs & PRp=0.5% +/-0.15% @ 2100 nm, AOI=45°**




**LIDT Optimized Output Coupler**
**PR=80% +/- 1% @ 2100 nm, AOI=0°**

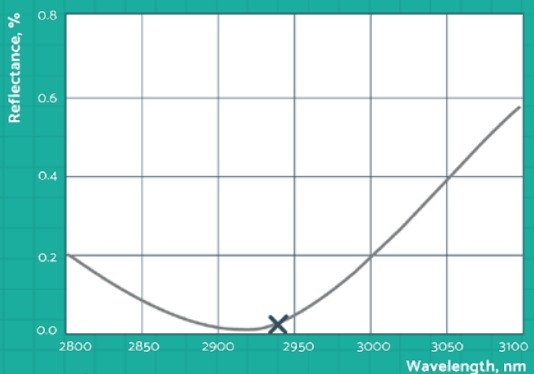



**Your laser is as durable as its weakest link.** Having that in mind, OPTOMAN makes customized, high-performance and durable optical components to help medical laser manufacturers minimize the cost of ownership by avoiding laser systems breakdowns caused by low-quality optical components.

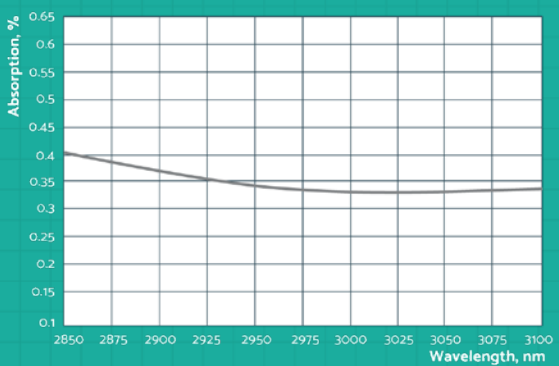
## COATINGS FOR ER:YAG LASERS

2900 nm 3000 nm range is more complicated and is still under intense development @ OPTOMAN.

**Sapphire AR/AR Coated Window**
**AR<0.1% @ 2940 nm, AOI=0°**

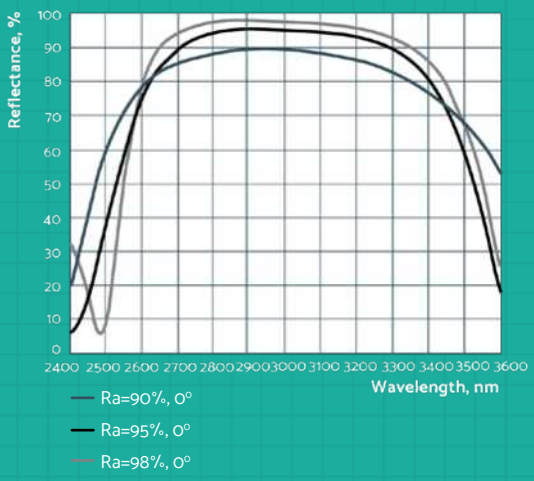



Typical residual reflectance graph per single surface.

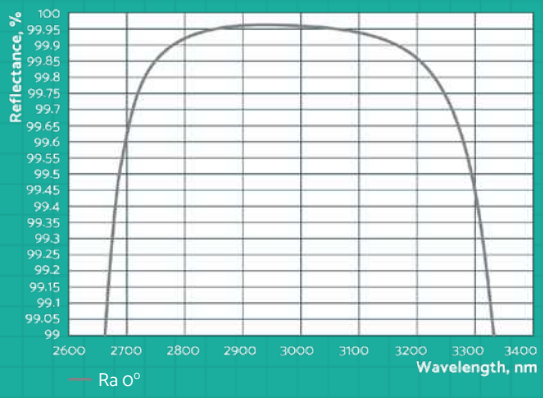



Measured absorption per AR@2940 nm coated surface.

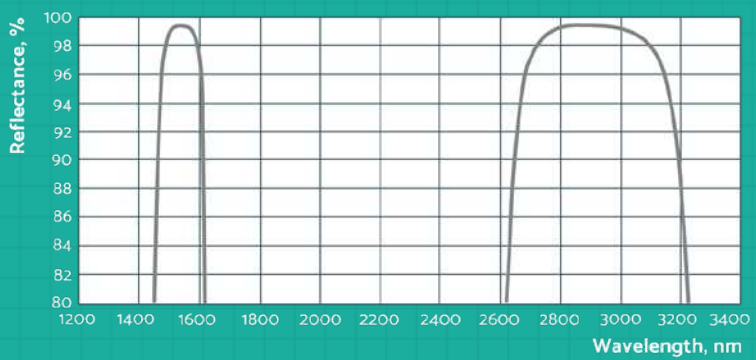
**Output Couplers**
**PR=90% +/-1% @ 2940 nm, AOI=0°**
**PR=95% +/-1% @ 2940 nm, AOI=0°**
**PR=98% +/-0.5% @ 2940 nm, AOI=0°**




**Cavity Mirror**
**HR>99.9% @ 2940 nm, AOI=0°**




**Multi Wavelength Bending Mirror**
**HR>99% @ 2940 nm + HR>99% @ 1535 nm + Ta>20% @ 635 nm, AOI=0°**




# MEMBRANE MIRRORS


Let's say ugly laser beam wavefront is making your images worse: the object in a picture looks distorted and it's due to not-good-enough quality mirrors. The distortion sounds good in rock music with all those guitars, but definitely not in optics. OPTOMAN offers a weapon against distortion – IBS coated membrane mirrors!

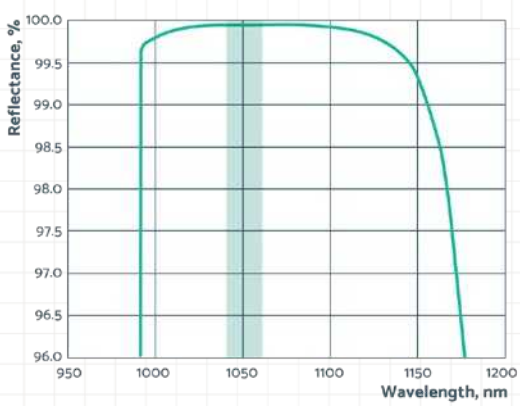
OPTOMAN can help to correct the distorted wavefront with IBS dielectric coatings. The main exceptionality of this product is that OPTOMAN is able to control surface flatness and can make coatings on very thin substrates.

## Features & Benefits

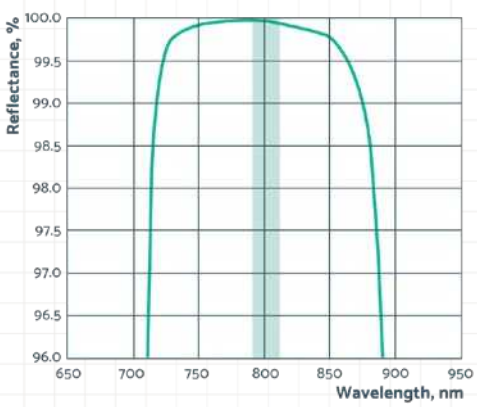
- Substrate diameter up to Ø270mm;
- Variety of angle of incidence;
- HR > 99.9%;
- GDD maintenance;
- Flatness definition per various parts of clear aperture;
- High LIDT.

## Design example:

**HR Membrane Ø150mm x 1.8mm 1043-1053nm Mirror**
**HR>99.8% @ 1043-1053 nm, AOI=0-10°**




**HR Membrane Ø200mm x 2.5 mm 800 nm Mirror**
**HR>99.5% @ 750-850 nm, AOI=0-10°**




# MIRRORS FOR GALVO-SCANNERS

Scanning mirrors can be used for scanning laser beams in one or two dimensions. They are used in galvo-scanning systems – motorized mirror mounts for laser-beam steering or scanning applications. As galvo-scanning systems are ideal for moving small laser beams fast, with incredible accuracy, mirrors needed for these systems have to be lightweight, but precise. Here comes the superpower of OPTOMAN – optimized IBS coating processes enable OPTOMAN to offer custom design, high reflectance mirrors with controllable flatness on relatively thin substrates.

Low-loss laser line or broadband design

More durable and environmentally stable than metallic coated mirrors

Optimization for fs, ps laser processing systems


Wide acceptance angle of incidence

Measured linear power density - 30 kW/cm @ 1070 nm, CW.

Optical coatings on Silicon, SiC, Berillium and UVFS substrates

# DIELECTRIC VS METALLIC

Metal-coated mirrors have a quite uniform reflectivity over a wide spectral range and are insensitive to the angle of incidence and polarization, so they have their place under the sun and are useful in galvo-scanning systems. Nevertheless, metal coated mirrors have drawbacks which can significantly influence the performance of galvo-scanning system:

**METAL MIRRORS FEATURE HIGH ABSORPTION**

- LIMITED REFLECTIVITY (E.G. ~98% FOR PROTECTED SILVER MIRRORS)
- LOW LIDT (ABSORBED LIGHT LEADS TO HEATING AND EVENTUALLY TO DAMAGE)

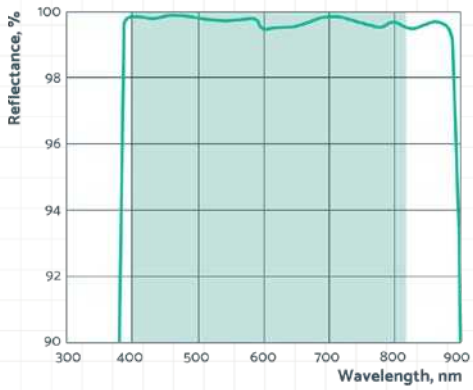
OPTOMAN manufactures dielectric coated mirrors, which not only by its nature have significantly lower absorption than metallic ones, OPTOMAN went an extra mile to minimize the absorption and thus increase the reflectivity and resistance to your laser beam. In addition, OPTOMAN knowing the challenges of galvo-scanning systems, enlarged the acceptance of angle of incidence.

**Let's do a test - finish the following sentence:**
If you want to improve the performance of your galvo-scanning system...

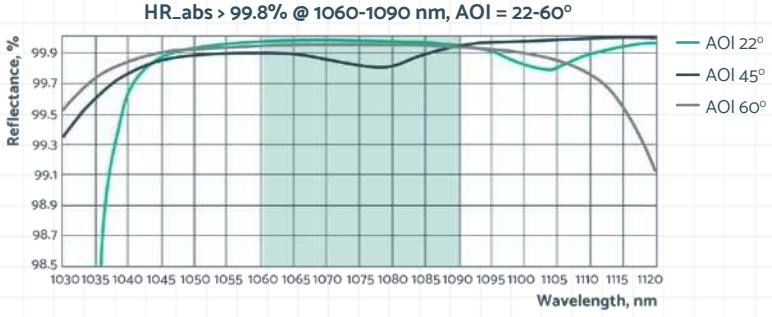
---

**Design example:**

HRa_average > 99% @ 400-820 nm, AOI = 36.5-48.5°




HR_abs > 99.8% @ 1060-1090 nm, AOI = 22-60°



# COATINGS ON CRYSTALS

Optimized pre- and after-coating processes as well as a high yield of production enables OPTOMAN to reliably make dielectric coatings on various laser crystals, to reduce the energy losses and increase the overall efficiency.

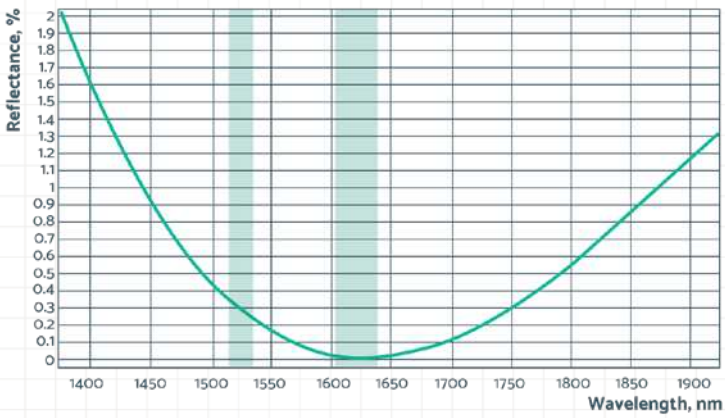
OPTOMAN offers the final product or can serve your needs by coating crystals.

Coatings on variety of laser and nonlinear crystals (Yb:Yag, Yb:KYW, KTF, Er:YAG, LBO, BBO...)

High yield of production

Single wavelength, dual-wavelenght, broadband AR and HR coating

## Design example:



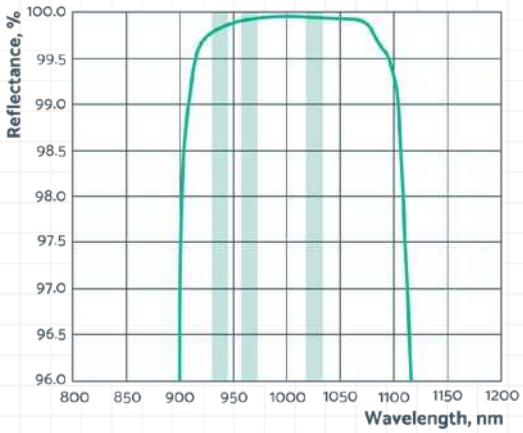

Material: Er:YAG

Coatings (IBS):

AR (R<0.1%) @ 1620-1640 nm + AR (R<1%) @ 1532 nm, AOI = 0°

LIDT: >10J/cm² @ 1532nm, 10 ns, up to 2 kHz

## Design example:




Substrate material: Yb:YAG

Coatings (IBS):

HR>99.96% @ 1030 nm, AOI=0° + HR>99.5% @ 940 nm + 969 nm, AOI=12-25° (cone)

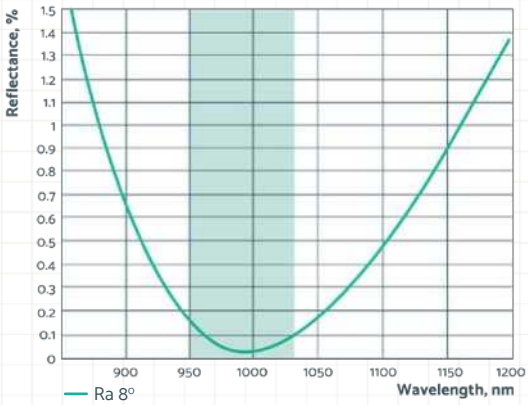
LIDT: >2 J/cm², 10 ps, 1030 nm, kHz

# R&D EFFORTS ON IMPROVING LIFETIME

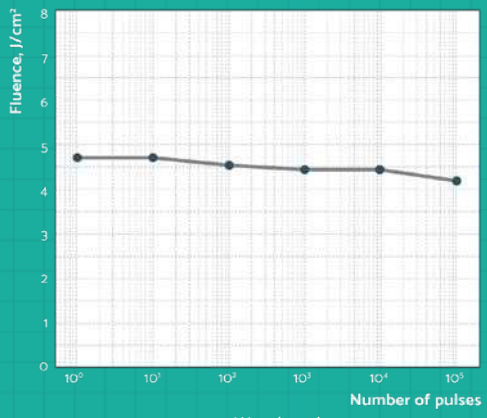
OPTOMAN is aware of laser and nonlinear crystals degradation problem at high power laser applications and is applying his superpowers to solve it by increasing LIDT values and improving the lifetime.

Here are some intermediate results of hours and hours of brutal R&D on precious Yb:YAG laser and LBO & BBO nonlinear crystals:

**Yb doped YAG crystal coated with AR<0.1% @ 950 nm – 1030 nm, AOI=0°**



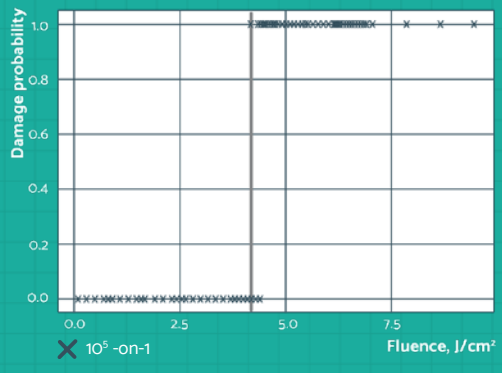

**LIDT measurement results**

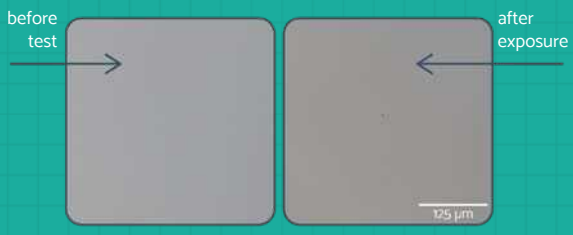



Catastrophic

95% confidence interval

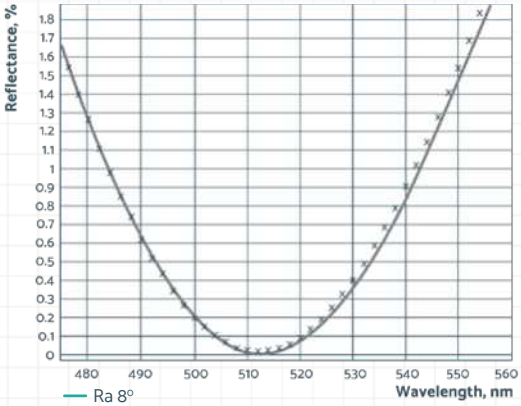
Wavelength: 1030 nm
Pulse duration (FWHM): 10.0 ps
Repetition rate: 10 kHz
AOI: 0°
Polarization: Linear
Beam diameter (1/e²):
(112.4 ± 0.6) µm

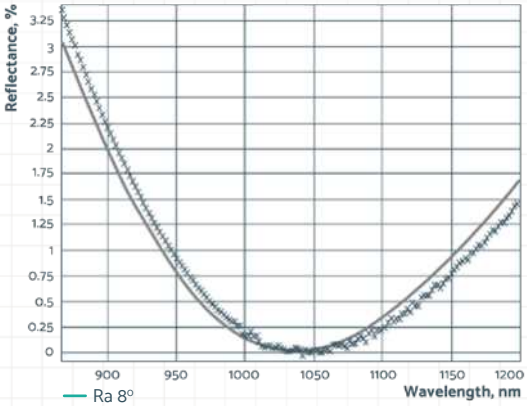


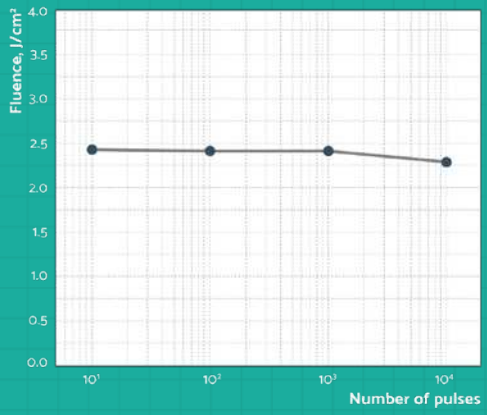

Typical damage morphology: fluence 4.39 J/cm², damage after 100 000 pulse(s).

## Nonlinear BBO crystal coated with AR<0.1% @ 515 nm + 1030 nm, AOI=0°



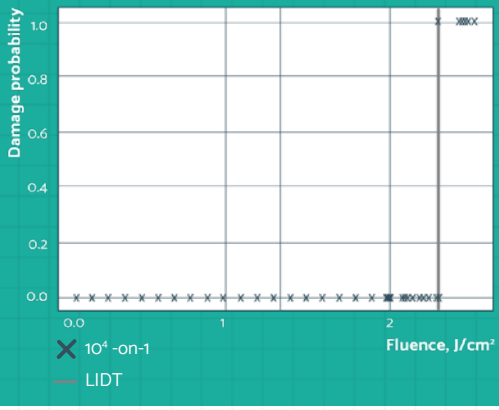



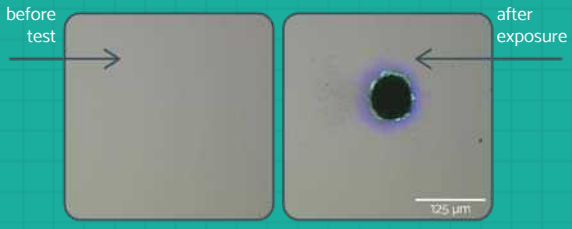

## LIDT measurement results




Wavelength: 515 nm
Pulse duration (FWHM): 10.0 ps
Repetition rate: 10 kHz
AOI: 0°
Polarization: Linear
Beam diameter (1/e²): (110.8 ±0.6) µm

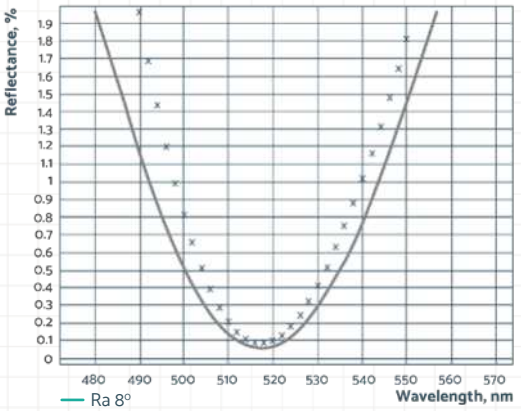
● Catastrophic
— 95% confidence interval

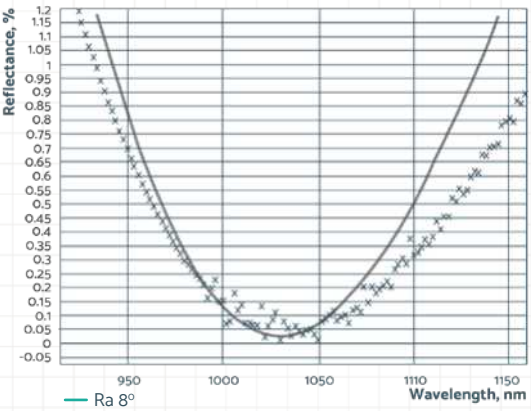


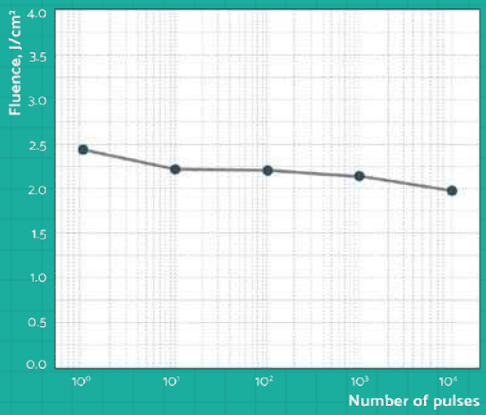

Typical damage morphology: fluence 2.48 J/cm², damage after 100 pulse(s).

## Nonlinear LBO crystal coated with AR<0.1% @ 515 nm + 1030 nm, AOI=0°



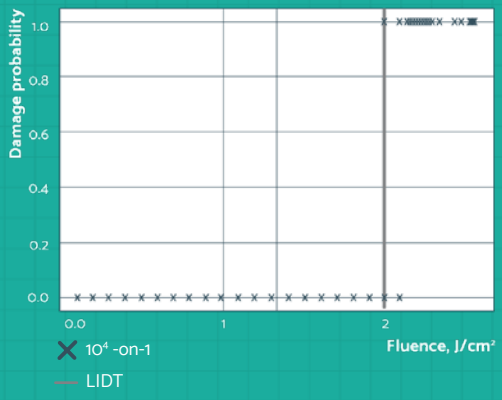



## LIDT measurement results




Wavelength: 515 nm
Pulseduration (FWHM): 10.0 ps
Repetition rate: 10 kHz
AOI: 0°
Polarization: Linear
Beam diameter (1/e²): (120.3 ±0.7) µm

● Catastrophic
— 95% confidence interval

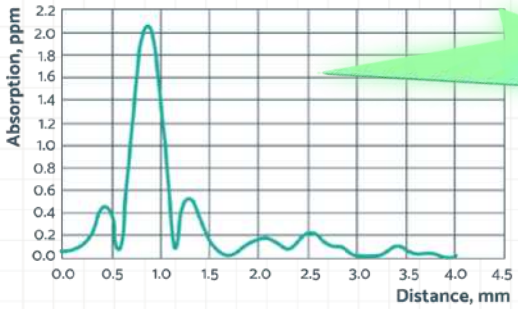




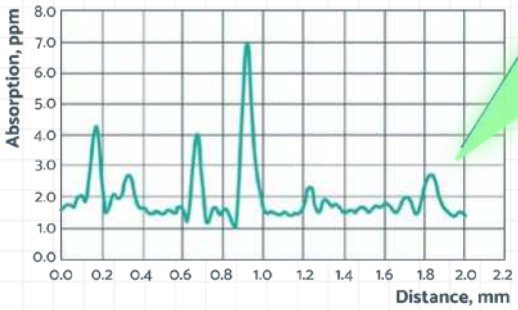
Typical damage morphology: fluence 2.19 J/cm², damage after 10 000 pulse(s).

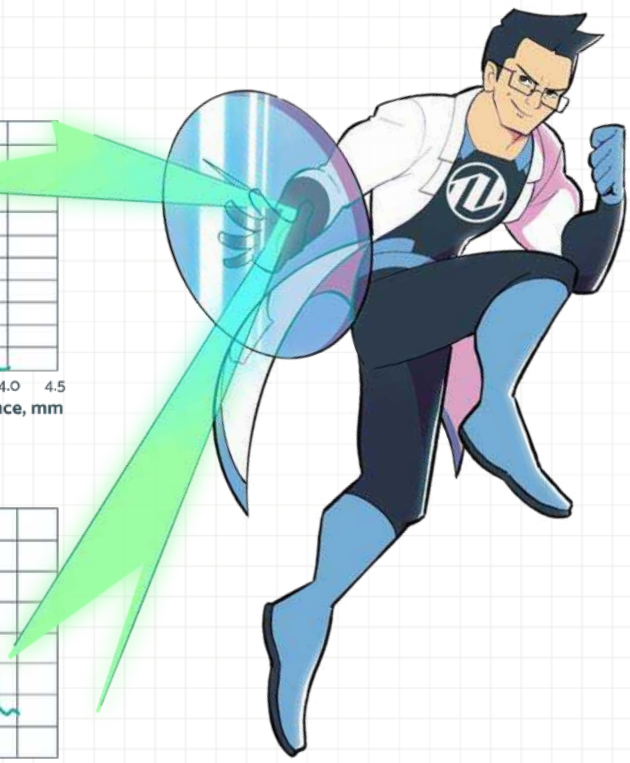
## Absorption measurement results

LBO @ 1064 nm AOI = 0° (L-scan)




LBO @ 1064 nm AOI = 0° (T-scan)



# SEGMENTED COATINGS

Have an application that could use different types of coatings on the same substrate? You re at the right place! OPTOMAN can make HR, AR, PR, or Polarizing coatings sandwich and do it according to your taste. The same optical substrate can be segmented and placed at different coating processes.

High yield of production

Wedge on back surface eliminates unwanted internal fringes

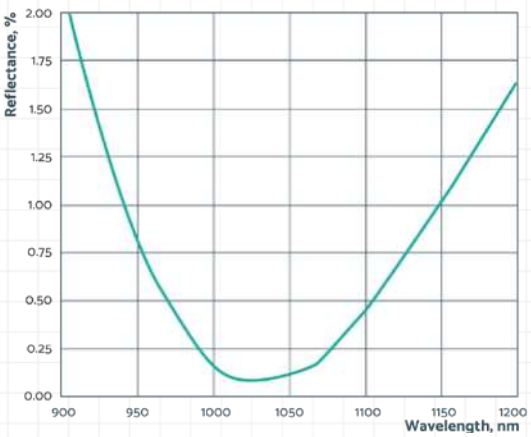
Back surface wedged or AR coated to eliminate ghosting

Each segment can have any type of coating (HR, AR, PR, Polarizing)

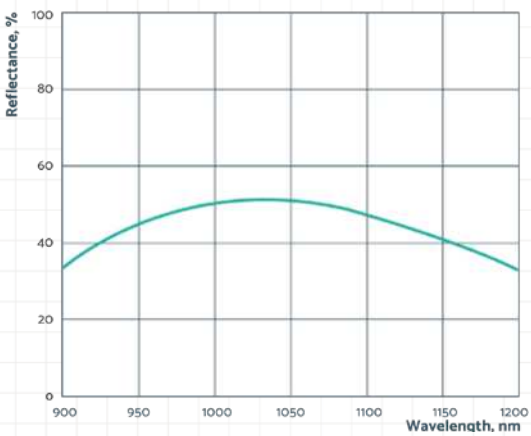
## Design example:

**Segment1: AR<0.25% @ 1010 - 1060 nm, AOI=0°**
**Segment2: PR=50% +/-2% @ 1010 - 1060 nm, AOI=0°, GDD R, T= 0 fs² +/- 10 fs²**
**Segment3: PR=72% +/-2% @ 1010 - 1060 nm, AOI=0°, GDD R, T= 0 fs² +/- 20 fs²**
**Segment4: PR=83% +/-2% @ 1010 - 1060 nm, AOI=0°, GDD R, T= 0 fs² +/- 20 fs²**

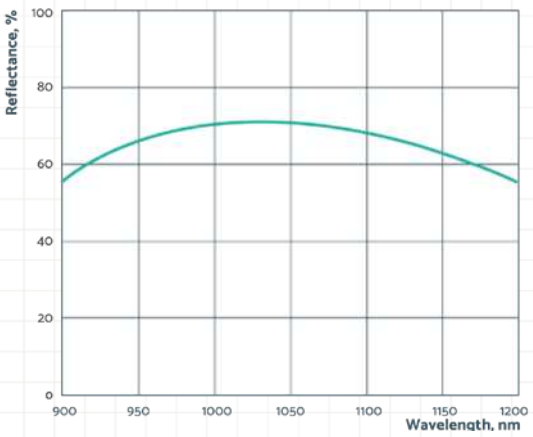
Segment 1: AR<0.25% @ 1010 - 1060 nm, AOI=0°



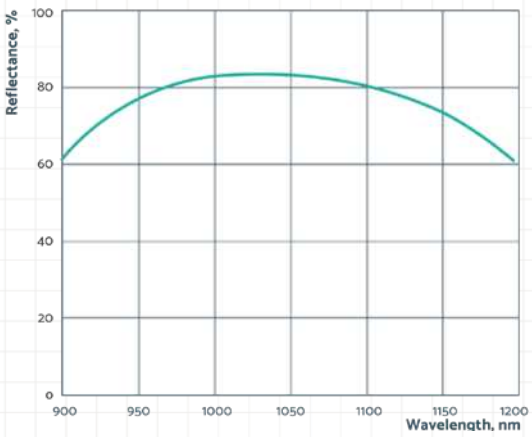

Segment 2: PR=50% +/-2% @ 1010 - 1060 nm, AOI=0°, GDD R, T= 0 fs² +/- 10 fs²



Segment 3: PR=72% +/-2% @ 1010 - 1060 nm, AOI=0°, GDD R, T= 0 fs² +/- 20 fs²



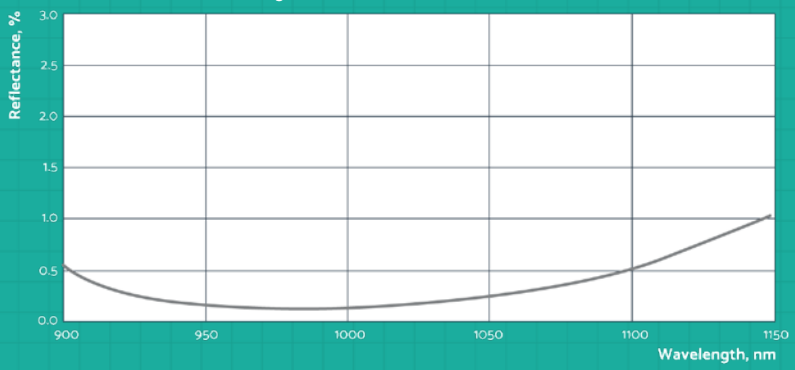

Segment 4: PR=83% +/-2% @ 1010 - 1060 nm, AOI=0°, GDD R, T= 0 fs² +/- 20 fs²



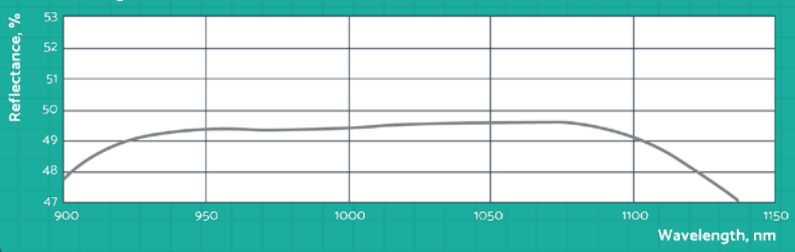

## Design example:

**Segment1: AR@950 nm - 1080 nm, AOI=0°**
**Segment2: PR=50% +/-2% @ 950 nm - 1080 nm, AOI=0°, GDD R, T= 0 fs² +/- 10 fs²**
**Segment3: PR=66% +/-2% @ 950 nm - 1080 nm, AOI=0°, R, T= 0 fs² +/- 20 fs²**
**Segment4:PR=75% +/-2% @ 950 nm - 1080 nm, AOI=0°, GDD R, T = 0 fs² +/- 20 fs²**

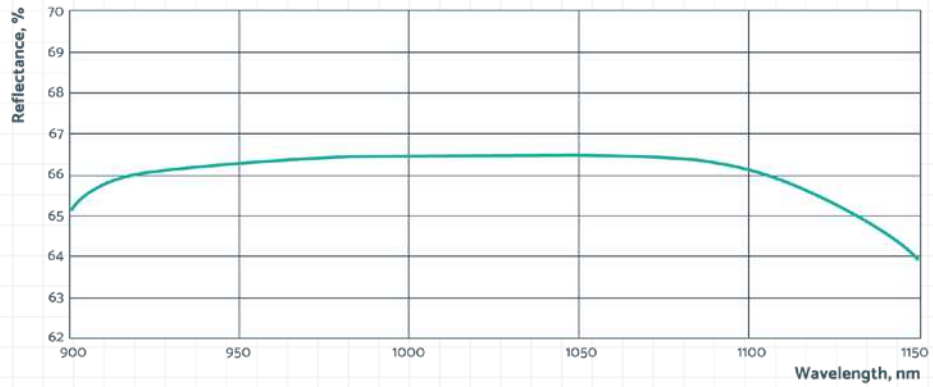
Segment1: AR@950 nm - 1080 nm, AOI=0°



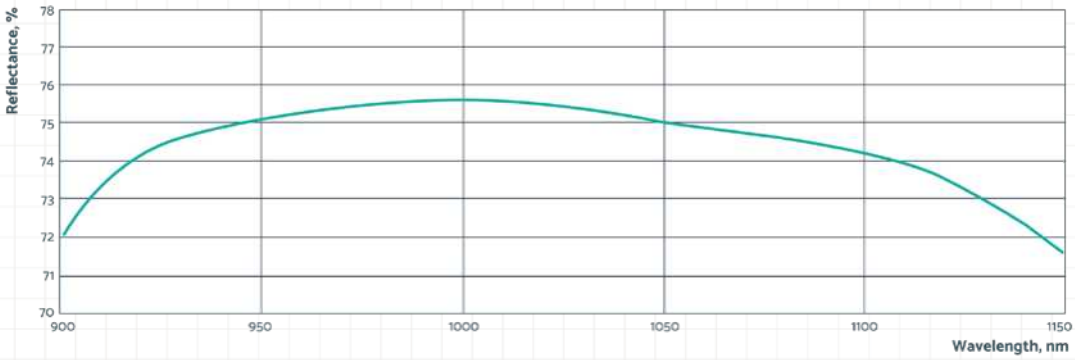

Segment 2: PR=50% +/-2% @ 950 nm - 1080 nm, AOI=0°, GDD R, T= 0 fs² +/- 10 fs²



Segment3: PR=66% +/-2% @ 950 nm - 1080 nm, AOI=0°, GDD R, T= 0 fs² +/- 20 fs²




Segment 4: PR=75% +/-2% @ 950 nm - 1080 nm, AOI=0°, GDD R, T = 0 fs² +/- 20 fs²

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