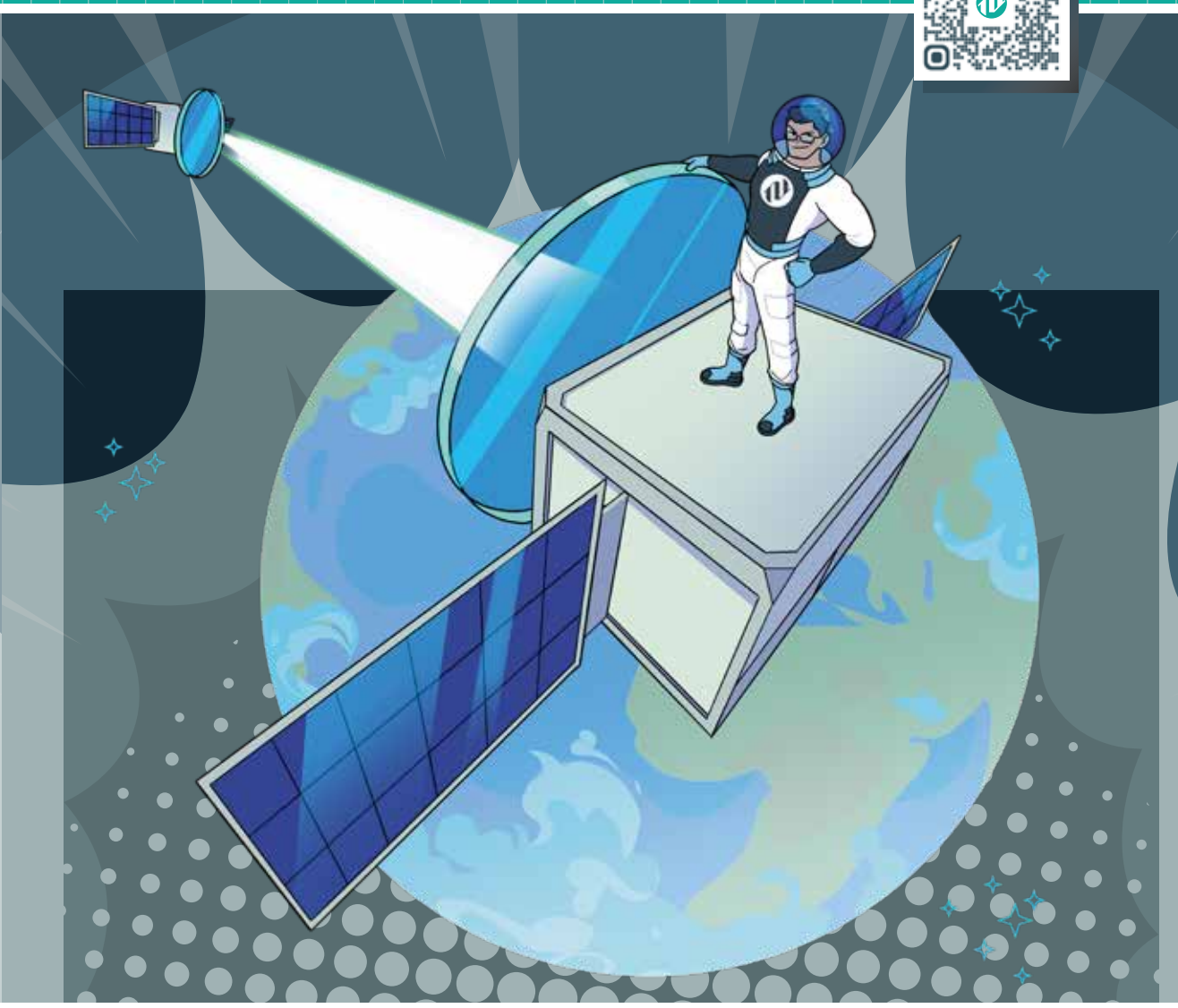
# OPTICS FOR SPACE & DEFENCE APPLICATIONS



OPTOMAN

YOUR SIDEKICK FOR
LASER OPTICS DEVELOPMENT

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# ABOUT OPTOMAN

Born in 2017 in Vilnius, Lithuania, OPTOMAN is a coatings SuperHero that employs 35 highly skilled sidekicks, that design, develop, and manufacture advanced, high accuracy and repeatability thin film coatings.

OPTOMAN digs deep into each application in order to provide customized and space-optimized laser optics that feature high longevity and reliability.To meet the most demanding industry and scientific requirements, OPTOMAN is set and focused exclusively on in-house ion-beam sputtering (IBS) technology that allows offering low absorption (<1ppm), high LIDT, increased longevity, and high spectral performance laser optics.

And remember - your laser system is as strong and durable as its weakest link!

## What makes OPTOMAN different?

Imagine you're the high-tech SuperHero, say Batman, and you need high-tech gadgets. You can try and find appropriate gadgets to buy, maybe even an Iron Man suit, but you're the Batman, you're unique, you have kick-ass martial arts skills and your gadgets need to support them. That's when Batman turns to Alfred, who develops gadgets, consults you and basically shares the same KPI - protect Gotham. OPTOMAN is Alfred.

### 80 % OF CUSTOMERS CONSIDER OPTOMAN A STRATEGIC PARTNER

(in OPTOMAN terms - a sidekick for laser optics development)*

## CORE COMPETENCE

- High LIDT and enhanced lifetime.
- Durable and environmentally stable coatings.
- Extreme low-loss coatings.
- Agility, flexibility, and quick prototyping.

*Customer satisfaction survey results from 140 participants , 2023.

# DESIGN CAPABILITIES

### Extreme low-loss coatings:

- Super Mirrors HR (R>99.995%).
- Precision Thin-film Polarizers (Tp/Ts ratio > 10000:1).
- R<0.01% Anti-Reflective Coatings.
- Coating with an absorption loss of <1 ppm.

### 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%).
- Coatings can be applied on plane, spherical, cylindrical, aspherical, elliptical surfaces, prisms and other exotic configurations.
- Ultrafast (express) prototyping service available.

### 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.
- Zero phase shift mirrors.
- Coatings on metal substrates.
- Optical assemblies.
- Coatings on fast axis collimators (FAC).
- Coatings on fibers and end caps.

- Custom shape, curvature and size.
- High reflection, anti-reflection, polarizing and other type of coatings available.
- **Spectral range 193 nm - 5000 nm.**
- **Size range from 3 mm up to 360 mm (500 mm is under development).**
- Optimization for 2, 3, 4 or more wavelengths.
- Various angles of incidence.

## METROLOGY CAPABILITIES

OPTOMAN metrology capabilities are based on partners oriented investments. Current metrology capabilties are below, but soon they will be supplemented.

- **LIDT & lifetime** - CW, ns, ps, fs
- **GD, GDD, TOD** - 500 nm – 1400 nm
- **Surface form errors** - Down to λ/20
- **Environmental testing** - To MIL-C-484197
- **Cosmetic surface quality** - To MIL & ISO
- **CRD** - 532 nm, 1064 nm
- **Absorption** - 355 nm, 532 nm, 1064 nm
- **Roughness/scattering** - 355 nm, 532 nm, 1064 nm
- **Spectral measurements** - Tsp, Rsp @ 200 nm – 5000 nm

# LIDT CAPABILITIES

High laser-induced damage threshold (LIDT) is a buzzword when talking about laser optics. Laser damage is a complex phenomenon and, while the result is the same – the optical component is ruined and not suitable for further use, there are different laser damage types and mechanisms. OPTOMAN takes innovation very seriously and makes sure that optical components are able to resist the ongoing increase of laser power and decrease in pulse duration, thus high LIDT is OPTOMAN's bread and butter.

Dr. Damage – the antagonist of the world of OPTOMAN can be beaten by measuring LIDT of laser optics. And OPTOMAN does just that.

**Reading the values:**
> Fluence @ Wavelength, pulse duration, repetition rate, beam diameter

## Femtosecond pulse

**High reflectance coatings:**
> 1.183 J/cm² @ 1030 nm, 507 fs, 1 kHz, 136.5 µm
> 0.286 J/cm² @ 343 nm, 180 fs, 10 kHz, 30 µm
> 0.267 J/cm² @ 258 nm, 180 fs, 10 kHz , 30 µm

**Anti-reflective coatings:**
> 0.052 J/cm² @ 515 nm, 191.4 fs, 300 kHz, 58.7 µm

**Polarizing coatings:**
> 0.77 J/cm² @ 1030 nm, 500 fs, 10 kHz, 175 µm

## Nanosecond pulse

**High reflectance coatings:**
> 168 J/cm² @ 1064 nm, 9.8 ns, 100 Hz, 223 µm
> 29.5 J/cm² @ 532 nm, 6 ns, 100 Hz, 137.6 µm

**Anti-reflective coatings:**
> 44 J/cm² @ 1064 nm, 10 ns, 100 Hz, 225 µm
> 10 J/cm² @ 532 nm, 10 ns, 10 Hz, 421 µm

**Polarizing coatings:**
> 49.4 J/cm² @ 1064 nm, 10 ns, 100 Hz, 206 µm

## Continuous-wave

**High reflectance coatings:**
> 426 kW/cm @ 1070 nm, 30 s, 137.6 µm*

**Anti-reflective coatings:**
> 426 kW/cm @ 1070 nm, 30 s, 137.6 µm*

* 426 kW was the power limit of the laser.

## Picosecond pulse

**High reflectance coatings:**
> 2.58 J/cm² @ 1064 nm, 370 ps, 20 Hz, 2.4 mm
> 1.64 J/cm² @ 532 nm, 350 ps, 20 Hz, 2.1 mm
> 8.313 J/cm² @ 1030 nm, 10 ps, 1 kHz, 154 µm

**Anti-reflective coatings:**
> 5.5 J/cm² @ 1064 nm, 370 ps, 20 Hz, 2.3 mm
> 2.1 J/cm² @ 532 nm, 350 ps, 20 Hz, 2.1 mm
> 0.39 J/cm² @ 343 nm, 1 ps, 1 kHz, 1 mm
> 0.353 J/cm² @ 800 nm, 1 ps, 1 kHz, 163 µm

**Polarizing coatings:**
> 2.7 J/cm² @ 1030 nm, 10 ps, 10 kHz, 115 µm

DISCLAIMER: Values are the result of LIDT test procedure according to ISO standards or based on the measurements done at customer sites. While the values are trustworthy, it doesn't mean that they can be transferred to final product specifications as the safety factor should be considered.

## BEATING DR. DAMAGE

# OPTICS FOR SPACE & DEFENCE APPLICATIONS

In space and defense applications, laser systems play a critical role in various areas, including communication and navigation. Extreme conditions require these systems and their components, especially laser optics, to feature high environmental stability and spectral performance OPTOMAN has developed application-optimized laser optics with increased longevity and LIDT, while maintaining low degradation. OPTOMAN's laser optics not only survive the harsh space, but also thrive and showcase excellent spectral performance.

## KEY PROBLEMS

OPTOMAN has fought many battles. From the experience gathered throughout these years he highlighted the main problems the space and defense markets face.

Short duty cycle and lifetime of laser optics caused by coating absorption and laser damage.

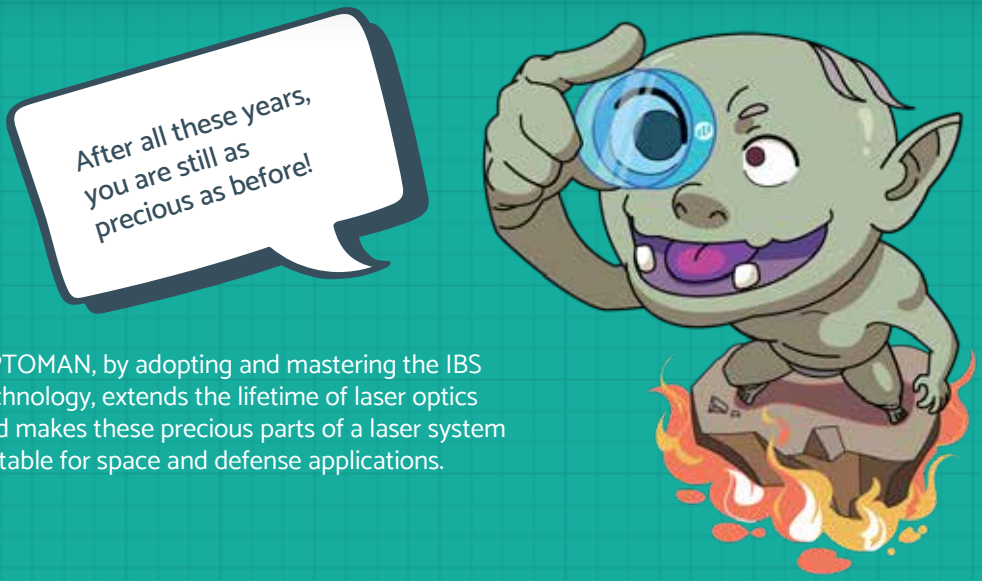
Beam profile deformation.

Polarization sensitivity requires beam delivery components to be optimized for s and p at he same time.

Multiple wavelengths coverage in the system.

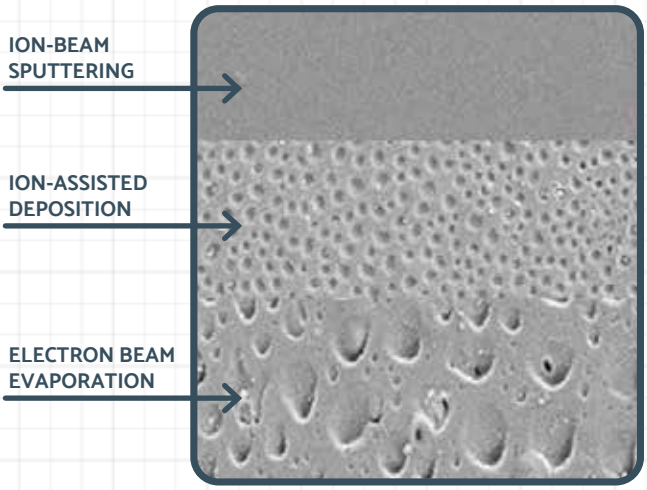
**What can OPTOMAN do for the space & defense markets?**

Enhanced lifetime, reliable laser optics featuring excellent spectral performance



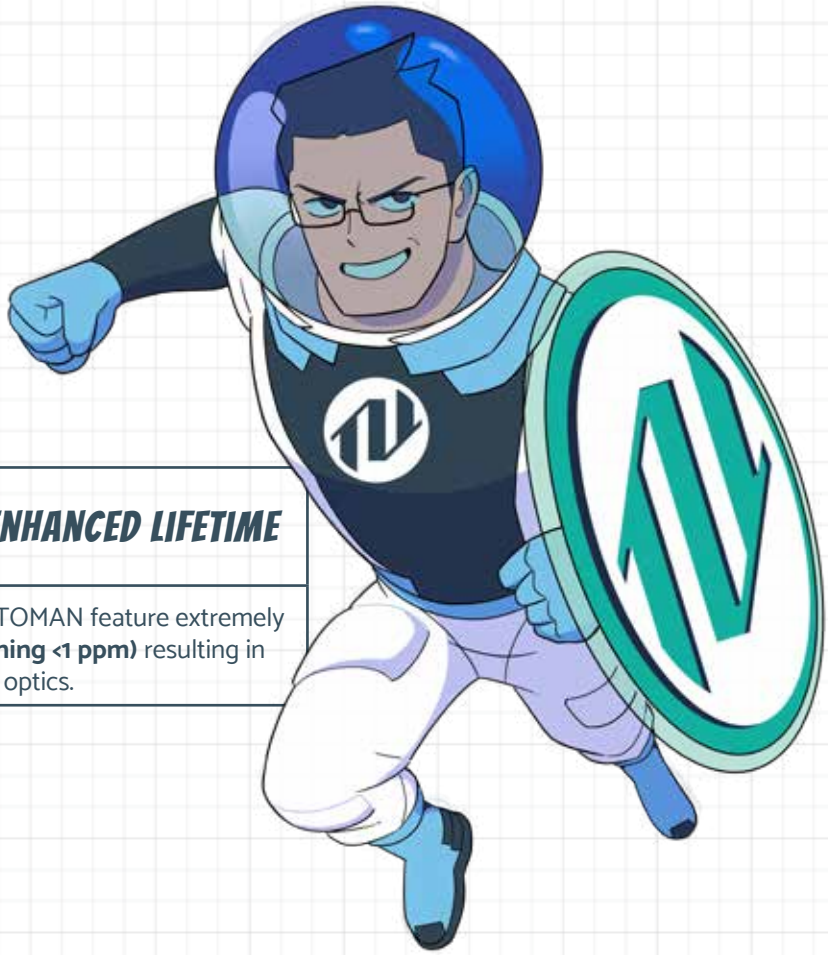

OPTOMAN, by adopting and mastering the IBS technology, extends the lifetime of laser optics and makes these precious parts of a laser system suitable for space and defense applications.

## Why OPTOMAN?




**OPTOMAN characteristics:**

- ISO 9001:2015 certified
- Collaborative and open innovation culture
- Sustainable throughout the whole product lifecycle
- Extensive technical and planning resources and capacity
- Flexibility leading towards scalable business



### ENHANCED LIFETIME

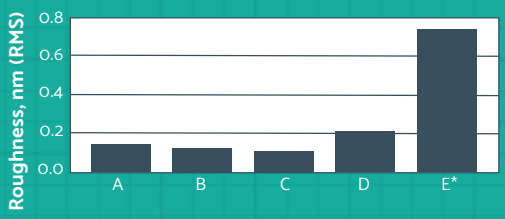
Coatings made by OPTOMAN feature extremely **low absorption (reaching <1 ppm)** resulting in increased longevity of optics.

As with great laser power comes great responsibility for coaters, OPTOMAN solves your problem with ultrafast turnaround and uses only the most advanced thin film deposition technology – Ion Beam Sputtering (IBS).

IBS coatings have bulk-like layer density, thus have low absorption and are immune to spectral shifting, mechanical wear, changes in ambient temperature and humidity. That's why OPTOMAN ensures optics longevity and reliability.

# 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.

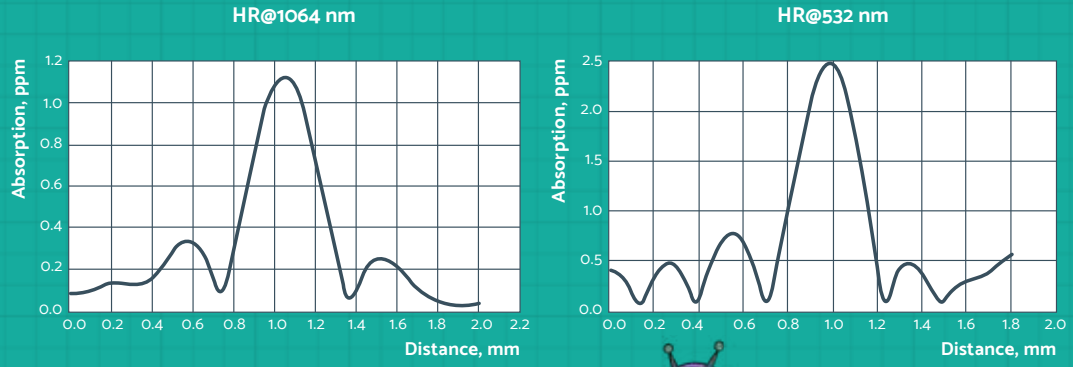



Roughness measurement results of super polished (A, B, C, D) and standard commercial grade substrates.

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.



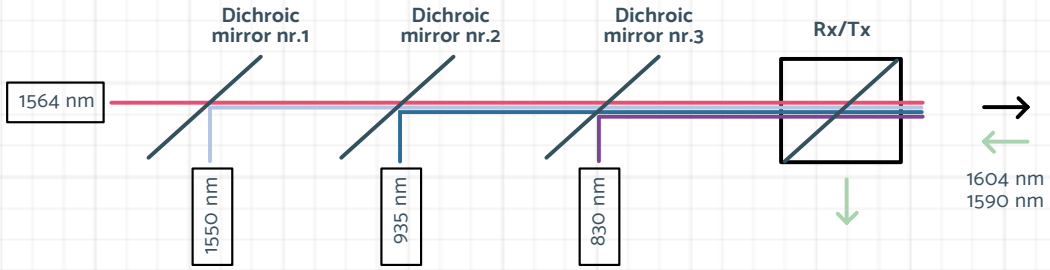

Longitudinal photothermal absorption measured of HR@1064 nm and HR@532 nm coatings.

DR. ABSORPTION

# DICHROIC MIRRORS

Dichroic mirrors are essential for many space & defense related applications.

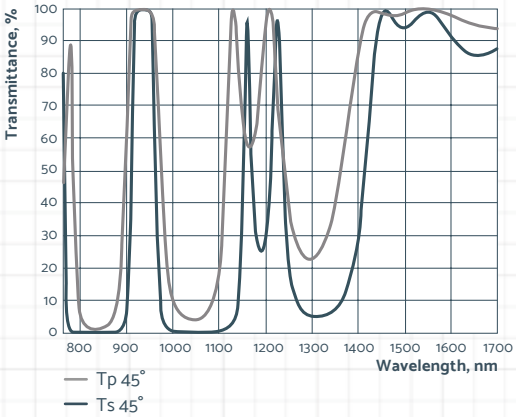
Here is a typical schematic of a laser system used in space communication, demonstrating the importance of dichroic mirrors:




OPTOMAN's dichroic mirrors feature all of the requirements – environmental stability, low degradation, high LIDT – **to not only survive in space, but thrive**.

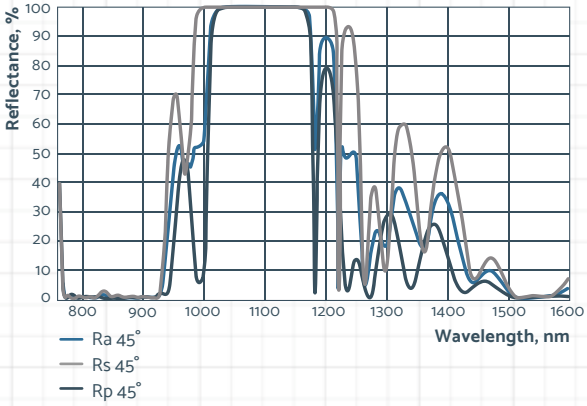
## Design examples

**HRsp>95.0% @ 845-855 nm + HTsp>92% (95% best effort) @ 933-937 + HTsp>90% @ 1530-1566 nm, AOI=45°**

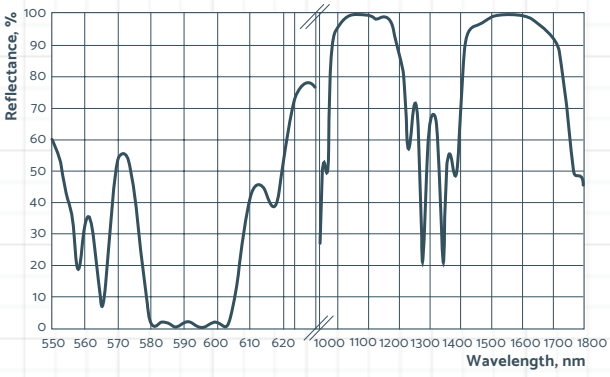



**HRsp >99.9% @ 1060 - 1070 nm + T~50% @ 975 - 985 nm + Ta>98 % @ 900 - 910 nm + T>98% @ 865 - 875 nm + T>98% @ 800 - 810 nm + T>98% @ 1535 - 1545 nm, AOI=44 - 46°**

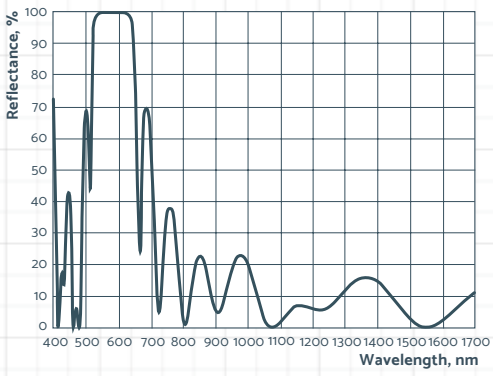
**Absorption: <5 ppm @ 1064 nm**




**HTa> 95% @ 589.159 nm & Ta<0.1% @ 1064.627 nm + 1561.42 nm, AOI = 45°**




**HTa>99% @ 1075 nm + 1548.51 nm & Ta<0.5% @ 589 nm, AOI=22.5°**

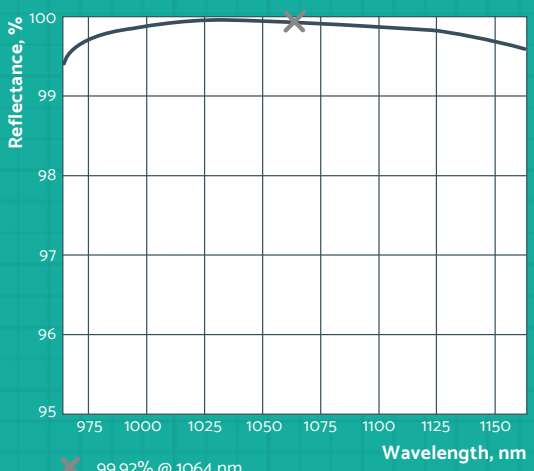


# HR MIRRORS

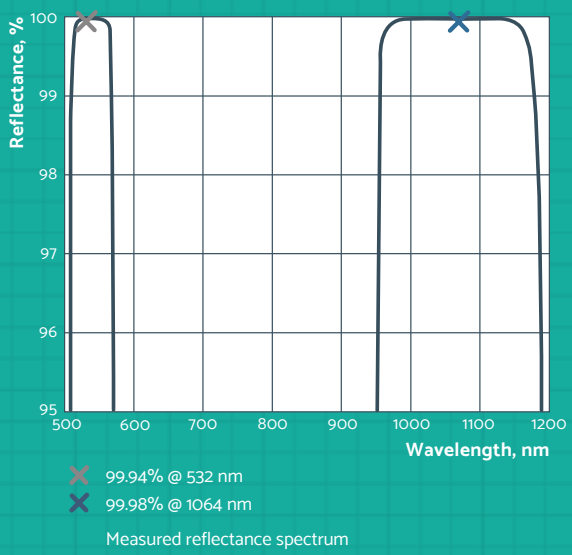
IBS-coated laser mirrors feature high reflectivity and LIDT values as well as low absorption, making them a perfect choice for space & defense applications.

## Design examples

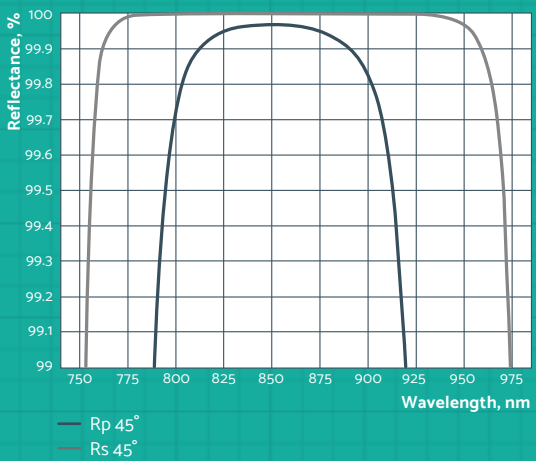
**HRs>99.9% @ 1064 nm, AOI=45°**



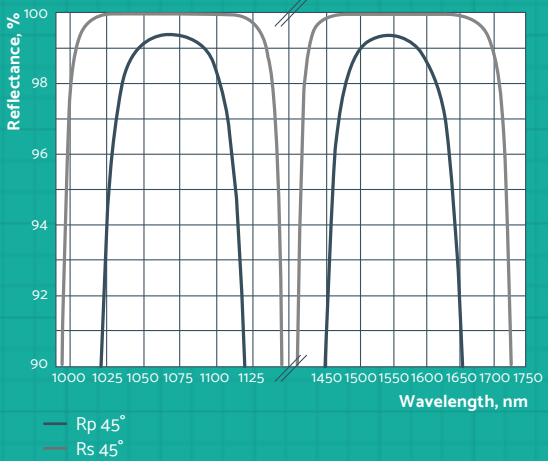

**HRsp>99.9% @ 1064 nm + 532 nm, AOI=45°**



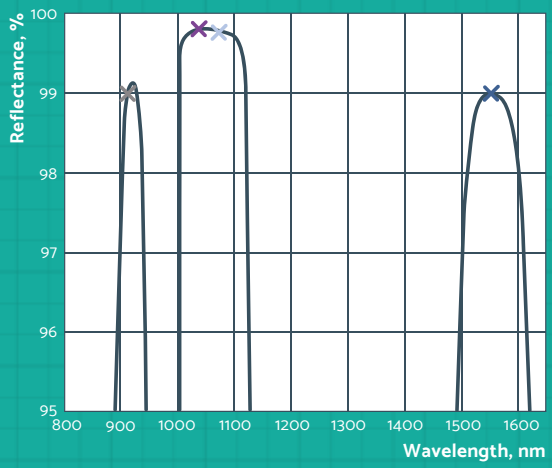

**Output Coupler**
**Rsp=99.95% @ 850 nm, AOI = 45°**

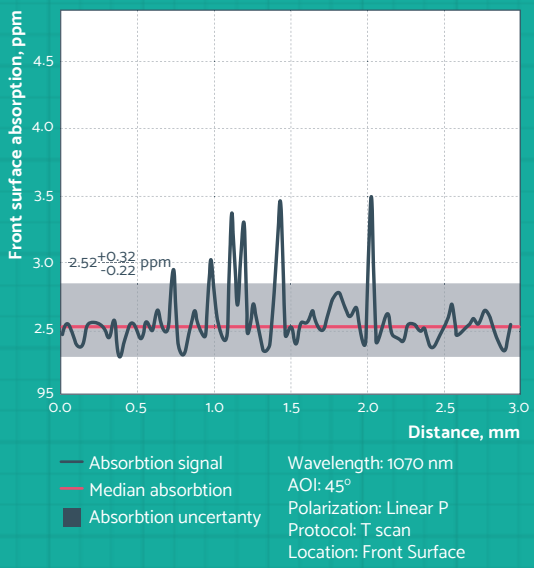



**HRsp>99% @ 1064 + 1070 nm + 1550 nm**

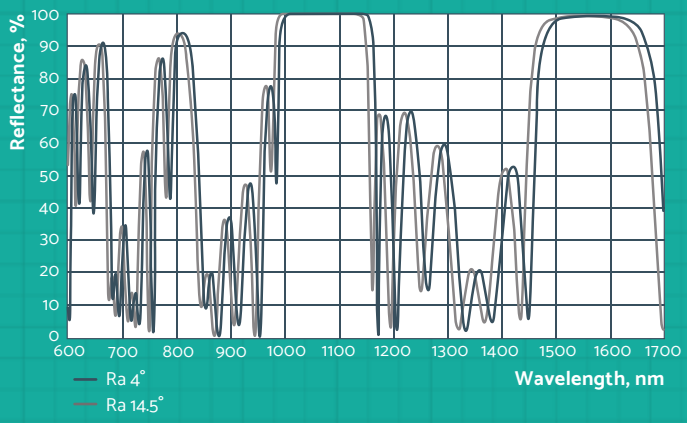


**HRa >99.95% @ 1035-1075 nm + HRa >99% @ 1550 nm + HRa>99% @ 915 nm, AOI = 45°**

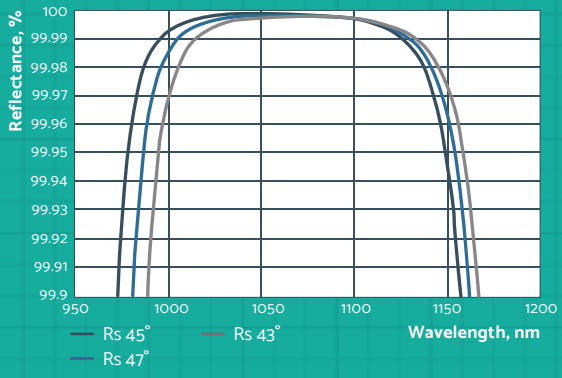



**Ravg > 99.95% @ 1061-1067nm + Ravg > 97% @ 1540-1580nm + Rmin >20% @ 633nm, AOI = 4 – 14.5°°**



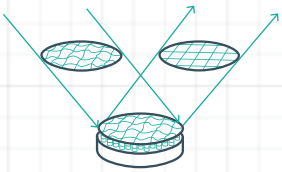

**HRs >99.98% @ 1060 – 1068nm, AOI = 45±2°, Absorption <10ppm @ 1064nm, optimized for high power CW laser**




## LOOKING FOR ROBUST MIRROR MOUNTING SOLUTIONS?

PHOTONICPARTS

OPTOMAN recommends highly precise and robust mounting and packaging solutions from PHOTONICPARTS.



# MEMBRANE MIRRORS

Let's say an 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.

In deformable mirrors, the distortion then needs to be compensated using a dynamic range of piezo elements. But not anymore! **You can save precious energy using 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.

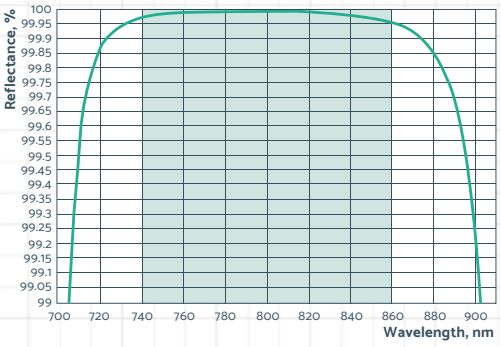
Surface Flatness <λ/10
per each Ø12.7 mm region

High reflectance
>99.95%

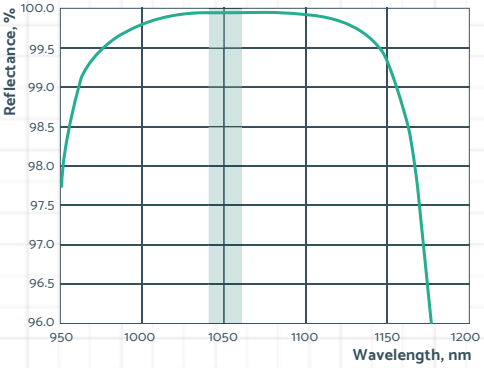
Substrate diameter
up to Ø400 mm

## Design examples

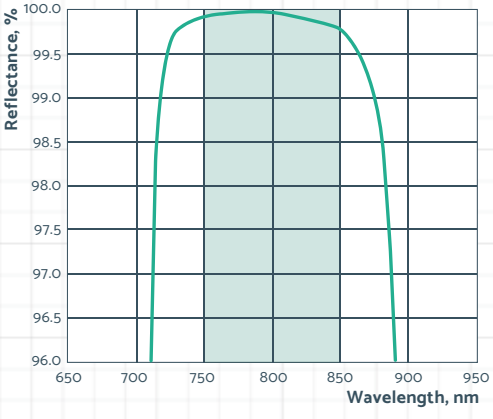
**HR Membrane Mirror Ø200 mm x 4.0 mm**
**HRa>99% @ 740-860 nm, AOI=10°**
**GDD<20 fs²**




**HR Membrane Mirror Ø150 mm x 1.8 mm**
**HRa>99.9% @ 1043-1053 nm, AOI=0-10°**




**HR Membrane Mirror Ø200 mm x 2.5 mm**
**HR>99.5% @ 750-850 nm, AOI=0-10°**



# COATINGS ON METAL SUBSTRATES

Inspired by optical challenges in beamshaping industry, OPTOMAN has developed the capablity to produce dielectric coatings on metal substrates with good adhesion.

**Why this dielectric - metal union is a good idea?**

Many diamond-turned metals have very high infrared reflectivity and corresponding low absorption. But, with the restriction of the optical constants of the metal material, the reflectivity couldn't be large enough. So the reflectivity of the metal surface must be improved by depositing multi-layer dielectric films. Dielectric coatings can reduce absorption, increase the laser damage threshold, and improve surface durability. Metal reflectors with high reflectivity resulting from high quality dielectric coatings and good thermal conductivity could improve the resistance to laser irradiation in high-power laser systems.

**Metal coatings:**

High absorption

↓

Heating

↓

Laser damage

IBS coatings are available on Nickel, Aluminum, Copper, Stainless steel and other metal substrates;

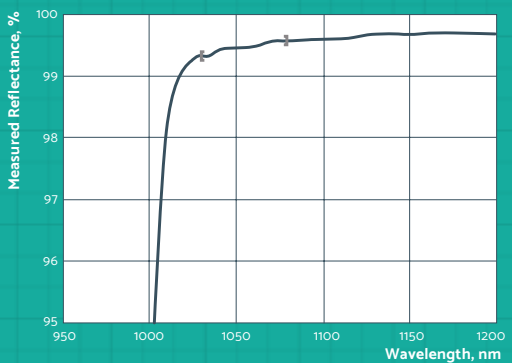
Dielectric coatings of OPTOMAN get along with metal substrates - good adhesion was one of the main product development elements.

High reflectance of >99% for diamond turned components in wide-angle range.

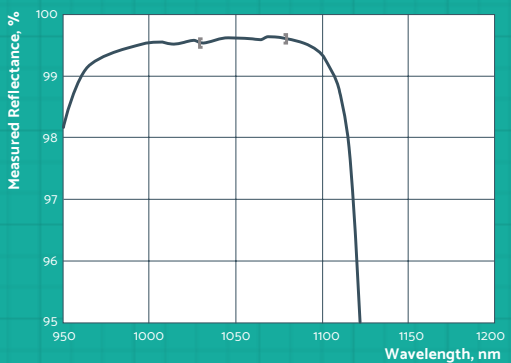
Coated elements have an excellent surface quality of 10/5.

## Design examples

**IBS coating on diamond turned Aluminum substrate:**
**HRa>99.9% @ 1030-1080 nm, AOI=22.5-50°**




avg = 99.46% @ 1030 - 1080 nm, AOI = 22.5°

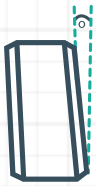



avg = 99.60% @ 1030 - 1080 nm, AOI = 50°

# 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

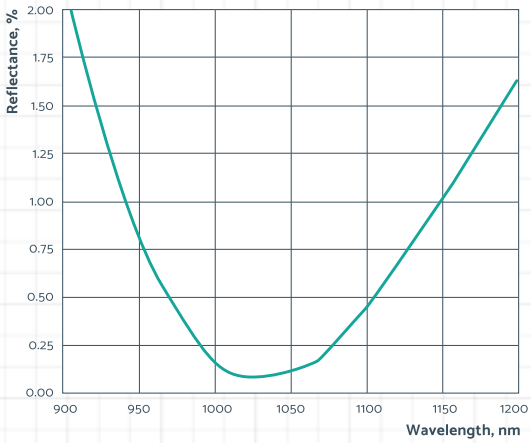
Back surface wedged or AR coated to eliminate ghosting

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

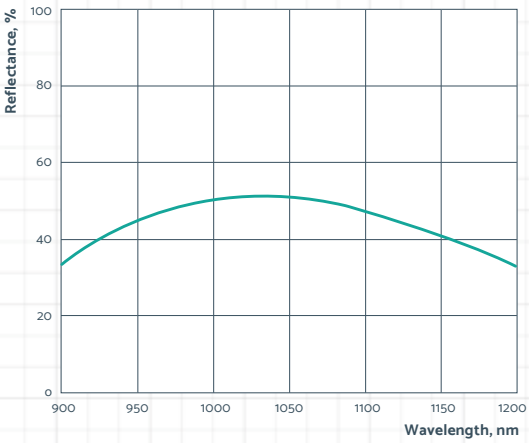
## Design examples

**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**

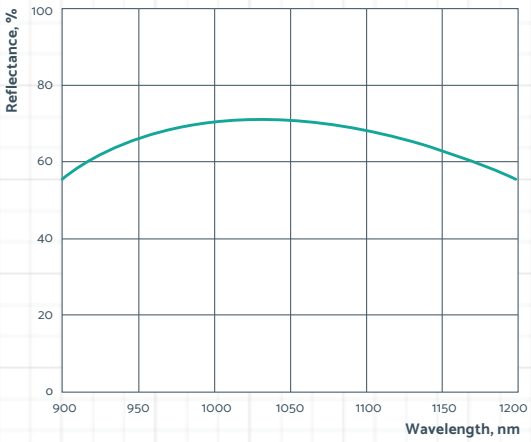
**Segment 1: AR<0.25% @ 1010 - 1060 nm, AOI=0°**



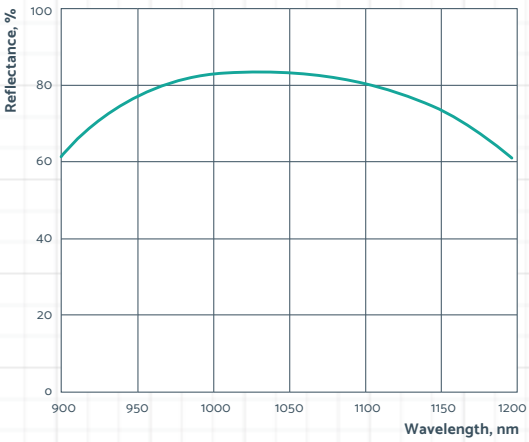

**Segment 2: PR=50% +/-2% @ 1010 - 1060 nm, AOI=0°, GDD R, T= 0 fs² +/- 10 fs²**




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



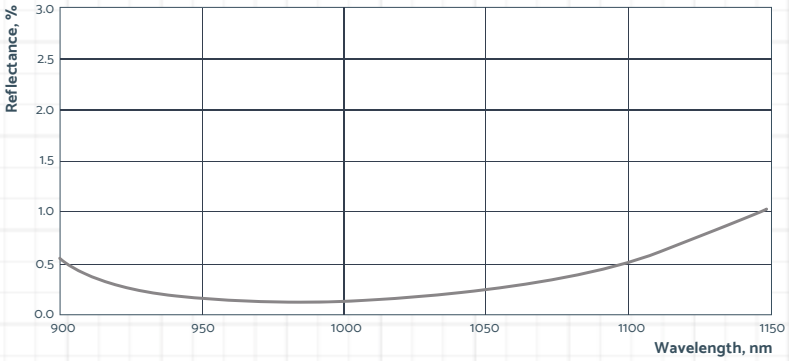

**Segment 4: PR=83% +/-2% @ 1010 - 1060 nm, AOI=0°, GDD R, T= 0 fs² +/- 20 fs²**



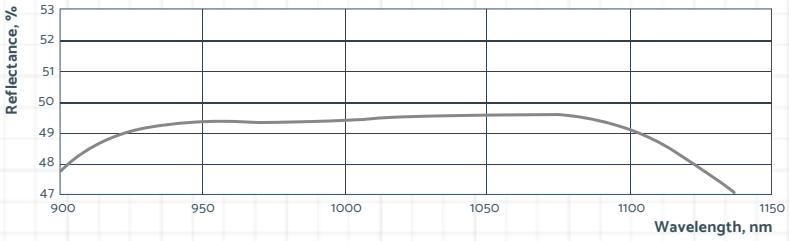
## Design examples

**Segment 1: 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**
**Segment 3: PR=66% +/-2% @ 950 nm - 1080 nm, AOI=0°, R, T= 0 fs² +/- 20 fs²**
**Segment 4:PR=75% +/-2% @ 950 nm - 1080 nm, AOI=0°, GDD R, T = 0 fs² +/- 20 fs²**

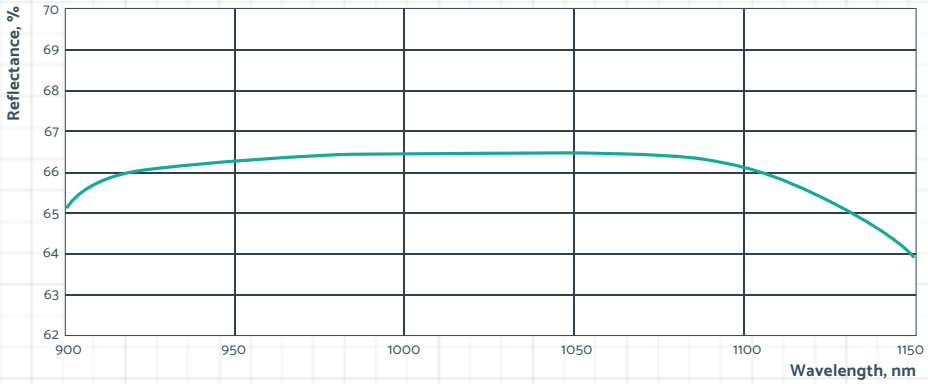
Segment1: AR@950 nm - 1080 nm, AOI=0°



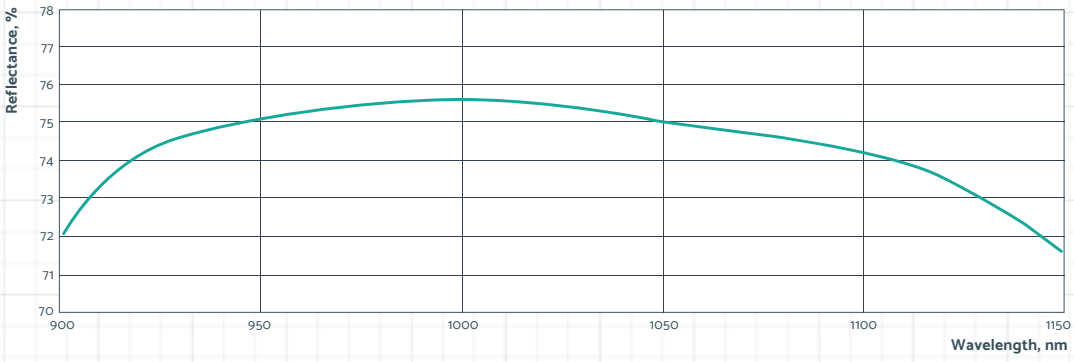

Segment 2: PR=50% +/-2% @ 950 nm - 1080 nm, AOI=0°, GDD R, T= 0 fs² +/- 10 fs²




Segment 3: PR=66% +/-2% @ 950 nm - 1080 nm, AOI=0°, GDD R, T= 0 fs² +/- 20 fs²



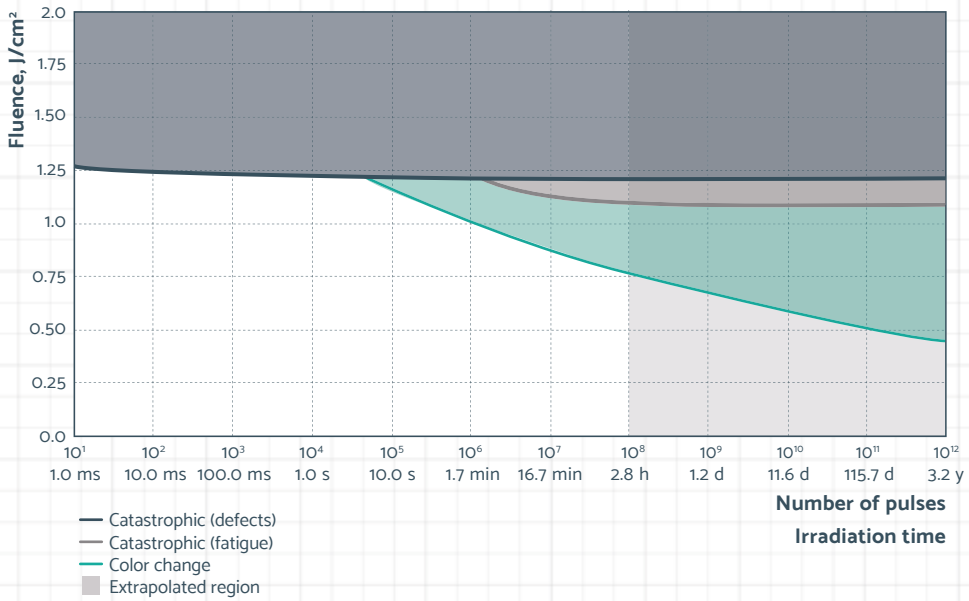

Segment 4: PR=75% +/-2% @ 950 nm - 1080 nm, AOI=0°, GDD R, T = 0 fs² +/- 20 fs²



# HOW OPTOMAN ENSURES SPACE SUITABILITY OF LASER OPTICS

## Lifetime measurements

**HRs>99.95% + HRp>99.9% @ 1010-1050 nm**



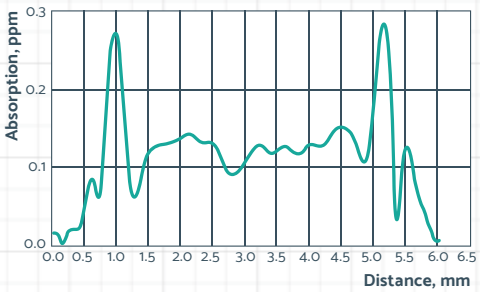

**LIDT measurement parameters:**

Wavelength: 1030 nm
Pulse duration (FWHM): 500 fs
Repetition rate: 10 kHz
AOI: 45°
Polarization: Linear S
Beam diameter ($1/e^2$): 185 µm

Catastrophic LIDT ($10^8$-on-1): **1.119 J/cm²**
Color change LIDT ($10^8$-on-1): **0.78 J/cm²**

**Extrapolated**
Color change LIDT ($10^{12}$-on-1): **0.48 J/cm²**

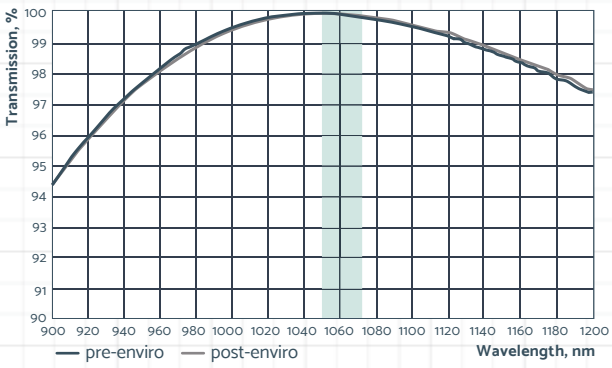
## Absorption measurements




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

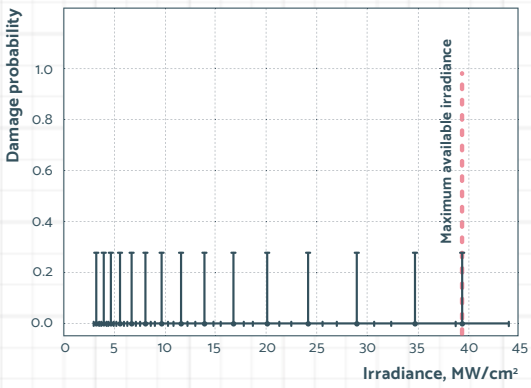
## Environmental treatments

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



## LIDT measurements

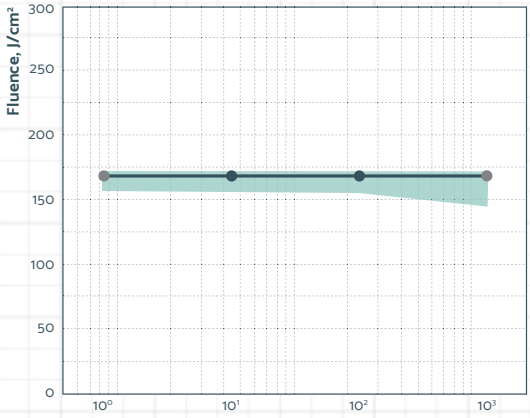
**HRa_avg>99.8% @ 1065-1075 nm, AOI=39-51°**
**>426 kW/cm @ 1070 nm, CW**




● T(30 s)-on-1

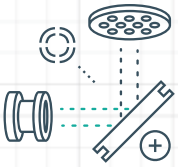
Wavelength: 1070 nm
AOI: 45°
Polarization: Random
Effective beam diameter: (137.6 ± 4.0) µm

**Rp>99%; Rs>99.8% @ 1064 nm, AOI = 45°**
**>168 J/cm² @ 1064 nm, 10 ns, 100 Hz**




● Offline detection
● Online detection
■ 95% confidence interval

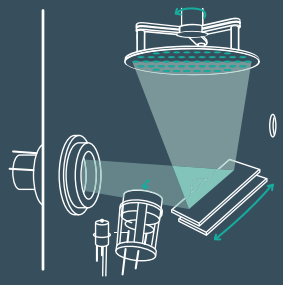
Wavelength: 1064 nm
Pulse duration (FWHM): (9.8 ± 0.3) ns
Repetition rate: 100 Hz
AOI: 45°
Polarization: Linear S + P
Beam diameter (1/e²): (223.5 ± 3.9) µm



# ABOUT ION-BEAM SPUTTERING TECHNOLOGY

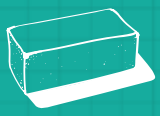
Ion Beam Sputtering (IBS) is a technique when the layer of a desired material is formed by molecules extracted from the target material by a highly energetic and precisely controlled ion beam.

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.



**IBS**
Near Bulk Density

**E-beam**
Porous Structure

## Bulk-like packing density

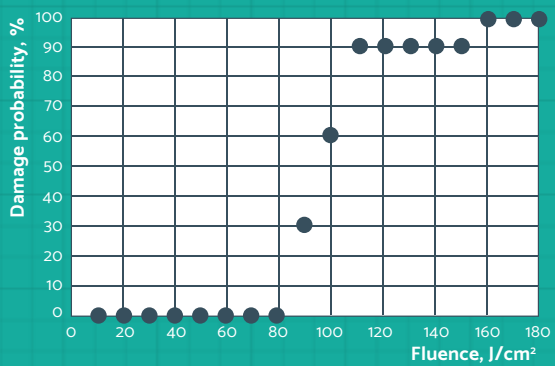
Due to the bulk-like layer's density, IBS coatings are completely immune to mechanical wear as well as changes in ambient temperature and humidity and ensure smooth operation of your laser under any circumstances. Moreover, OPTOMAN coatings may be used in harsh environments and even in outer space with 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!

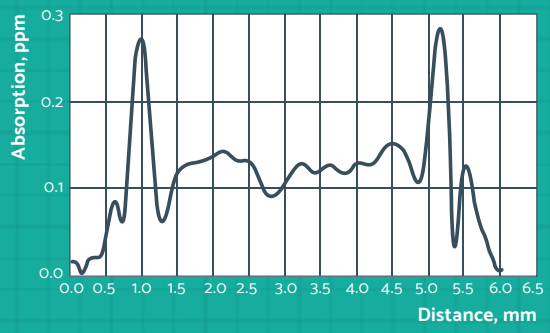
**IBS**

**E-beam**




## 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!




**Forget short duty cycle issues!**

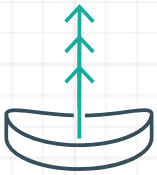
It is well known that absorption losses are the main cause of thermal effects and a short duty cycle. A high and stable vacuum, extremely pure target materials, near bulk coating density, spatially separated sputtering and material condensation processes allow to form almost contamination-free layers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

## LOOKING FOR STANDARDIZED SOLUTIONS?

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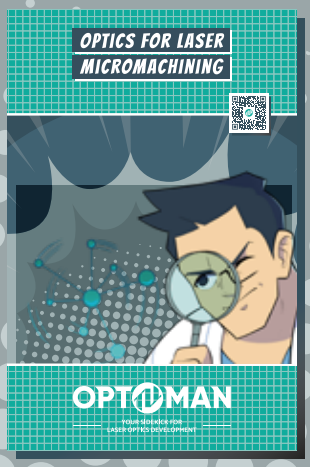
# OPTOMAN

YOUR SIDEKICK FOR
LASER OPTICS DEVELOPMENT

## OTHER CAPABILITIES





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