Innovation in AR Lens Coatings: High Quality Coatings for High-Power Lasers

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Lens coatings are an essential part of high-power CO2 laser systems. Coatings must protect the lens and allow for the highest levels of optical performance, with low levels of absorption and a long life expectancy. Transparency is another coveted characteristic for use with visible HeNe red laser pointers. The cost/benefit ratio of a coating must also be considered, as well as the environmental impact of the substrates used. For optical manufacturers, the challenge is in developing a lens coating that excels in all of these areas.

Introduction

In a high-power CO2 laser, an electric current is discharged through carbon dioxide to produce a laser beam output. These lasers deliver large amounts of concentrated energy through their optical components. To protect components from degradation and improve performance, laser lenses must have an anti-reflection (AR) coating. Without a high-quality coating, even the best high-power laser system will experience degradation and loss of functionality in a short space of time. The antireflective nature of the lens coating reduces losses from scattering and absorption, for optimum performance.

Manufacturers are tasked with creating an AR lens coating that can provide the desired levels of performance. At the same time, the coating itself is subject to high levels of energy, so it must be durable for a satisfactory life expectancy, especially when used with high-power lasers. To achieve this durability, manufacturers may choose a colored lens coating, with black lens coatings increasing lens life expectancy the most. However, this creates a problem when using visible HeNe red laser pointers. To overcome this challenge, a transparent lens must be used. Already, the balancing act between functionality and durability is clear.

Of course, at the same time, the coating must remain affordable, with a good cost/benefit ratio. Another important aspect to consider when producing an AR coating is the increase of environmental regulations in regard to the management of radioactive waste. Many coatings are radioactive; only a radioactive-free lens coating avoids these problems.

Looking at Ophir's line of optics for high-power CO2 lasers (see table below), there are three main types of lenses, each with a different type of coating. The coatings rate differently in the qualities previously discussed – transparency, absorption rates, product life expectancy, pricing and radioactivity of the coating used.

CO_2 optics product name	HeNe* transparency	Maximum absorption@10.6µ	Product lifetime	Pricing	Radioactive (ThF4)
Duralens	V	0.20%	Standard	Standard	Yes
Black Magic	_	0.15%	High	Mid	No
Clear Magic	V	0.13%	High	High	No

Table 1: Ophir's CO2 laser lenses

The Duralens® has a standard AR coating, <0.2% absorption rate, HeNe transparency, a standard product lifetime, and a decent cost/benefit ratio. The Black Magic has a lower absorption rate, but it is not transparent, although it is more durable – with an extended product lifetime. The Clear Magic, as its name suggests, it transparent, and has an ultra-low absorption rate of <0.13%, as well as an extended product lifetime, but for a higher price. Both the Black Magic and the Clear Magic coatings are made from a radioactive-free coating.

Ophir recognized the absence of a lens coating that consolidated all of the best qualities: a radioactive-free coating with low absorption, which is also HeNe transparent, with a prolonged life expectancy, and a superior cost/benefit ratio. With this in mind, a new lens coating was developed, the DuralensExtra™. Creating this lens coating involved a combination of new methodologies and innovative technologies throughout the manufacturing and quality assurance stages.

Methodology

To achieve all of the qualities above, the materials and coating processes were reviewed, and a hybrid AR coating was generated. A coating recipe was engineered to shorten the coating time, using radioactive-free materials, while increasing the evaporation rate of the coating layers, adjusting the process parameters and maintaining both low-absorption and high-transmittance for high laser power.

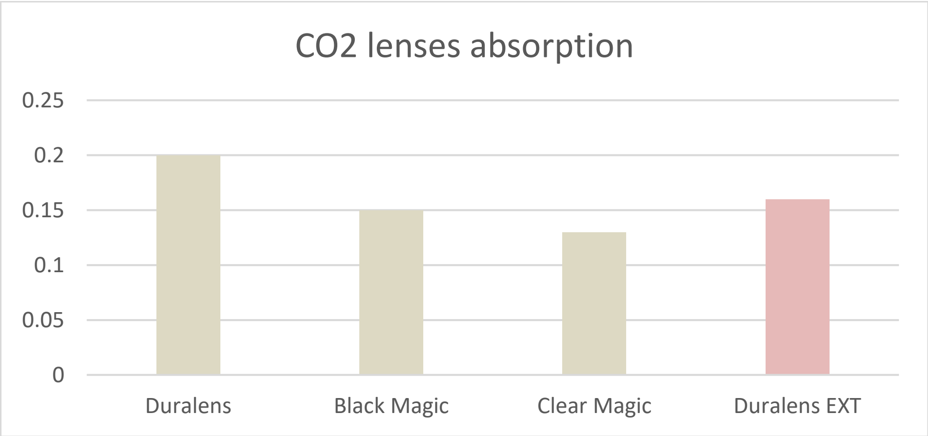


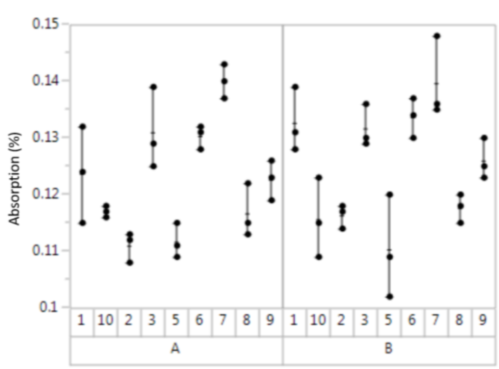
Figure 1: CO2 lenses absorption comparison

*Helium Neon laser wavelength – 0.633µ

Quality Assurance

High lens performance, low absorption, and low reflectance levels were obtained through the use of strict QA processes and cutting-edge measurement technologies. Ophir's multi-disciplined engineers and R&D physicists joined forces to develop new, in-house laser measurement tools. The main challenge was to develop an absorption station, where no ISO standard exists. Absorption values were determined using calorimetric methodology, by measuring the lens temperature increase caused by the absorbed laser radiation.

To reduce measurement error, a series of improvements were made in the measurement system. Starting with Repeatability & Reproducibility (R&R) over 30%, the measurement baseline was stabilized, neutralizing the environment temperature impact. The process was also fully automated. These improvements significantly reduced the measurement error, lowering the R&R to less than 20%.



5.15	K (99.9% certainty)
0.13	Tolerance = USL-LSL
0.1985	Precision/Tolerance Ratio = RR/(USL-LSL)
±0.013%	Measurement Error

Figure 2,3: R&R absorption test results of the Duralens Extra

In addition, reflectance measurement accuracy was improved. Reflectance was previously measured using FTIR spectrophotometers, but the error in a single wavelength measurement needed to be minimized further. Similar to the absorption measurements, the CO2 laser was used for reflectance measurements. A power measurement tool was created, comparing the laser power to the reflectance of the witness sample, resulting in an impressive measurement error of ±0.025%.

5.15	K (99.9% certainty)
0.2	Tolerance = USL-LSL
0.29	Precision/Tolerance Ratio = RR/(USL-LSL)
±0.025 %	Measurement Error

Figure 4: R&R laser reflectance test results

Conclusion

AR coatings must be of a high standard to enable high-power CO2 lasers to function optimally. They must be able to withstand high levels of energy and provide superior optical performance. In addition, other desired characteristics exist, such as transparency for HeNe laser pointers, and avoidance of radioactive coatings. To produce such a coating, Ophir researched and developed new technologies and methodologies. This allowed them to create a new lens coating that balances low absorption, high durability, and low cost – while also maintaining transparency and using a radioactive-free coating.

About Duralense Extra

The Duralens Extra is a new and improved low absorption coating for ZnSe lenses used in high-power CO2 lasers. The Duralens Extra enables longer life time expectancy, as well as reduced thermal lensing, result an improved focus accuracy and stability, with an impressive absorption of <0.16%, vs. <0.20% for the standard Duralens™. This coating allows for maximum transmittance and minimum focal shift. Environmental regulations, in relation to the management of radioactive waste, create another challenge for high performance lens coatings. The Duralens Extra meets this challenge, due to the absence of radioactive material in its recipe. These features, together with an attractive price, make the Duralens Extra an ideal solution for job shops worldwide.

About Ophir Laser Optics

With vast knowledge and extensive experience accumulated over four decades, Ophir Laser Optics Group, an MKS (NASDAQ: MKSI) company, offers a full range of high quality OEM and replacement optics for high power CO2 laser and 1μm laser applications. Used by leading laser manufacturers around the world, our products meet the highest industry standards and have been widely tested, with outstanding results. All manufacturing is carried out in-house using automated CNC, patented diamond turning technologies, and advanced, cutting-edge coating processes and measuring equipment. With a global distribution and support network, our commitment to our customers is unparalleled.

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