Ion-Beam Sputtered High-Laser-Damage Coatings on YAG for CW Applications

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Ion Beam Sputtered (IBS) optical coatings offer low scatter and absorption losses, superior durability and environmental stability compared to conventional or ion-assisted evaporated coatings. This makes them ideal for high fluence solid state applications which face extreme temperatures or other environmental factors that can affect optical or mechanical performance [1]. While notable research has been done with IBS coatings in recent years, much of this work has been focused on pulsed applications [2,3]. With the high thermal load and fluences seen in current continuous wave (CW) solid state lasers a better understanding and optimization of CW fluence handling capability for these coatings is warranted. We present data for common laser coatings (AR, Dichroic) on undoped YAG substrates at lasing wavelengths (1064nm). In addition, observations on coating materials and performance optimization for these applications are provided.

The coatings tested for this paper were deposited on 1-inch diameter by 1-mm thick undoped laser-grade random-axis YAG substrates. The substrates were polished to a less than 10 Angstrom rms roughness. All the substrates were cleaned with a mechanical cleaning process using DI water, acetone and iso-propanol. The coatings where deposited using an automated IBS coating chamber. Ion assist was not used during the deposition. The laser damage testing was performed by a commercial testing service, Spica Technologies, using a CW wavelength source at 1064 nm with a 15um 1/e^2 beam diameter and a 100μm x 100μm scan over 10 sites for each fluence level.

Sample	1	2	3	4
Coating type	AR	AR	Dichroic	Dichroic
Incident side	Air side	Air side	Substrate side	Substrate side
Damage threshold at 1064nm	*>16.6 MW/cm^2*	*>16.6 MW/cm^2*	*>17.6 MW/cm^2*	*>17.6 MW/cm^2*

Table 1. *Results of CW damage testing at 1064nm. Damage threshold exceed testing services available laser fluence peak irradiance without any observed damage.*

Two types of coatings were tested: Dual Wavelength Anti Reflective (1064nm AR / 808nm AR) and Dichroic (1064 nm HR / 808nm AR) coatings. The Dichroic coating was tested with light incident from the substrate side of the coating. The testing results are summarized in table 1.

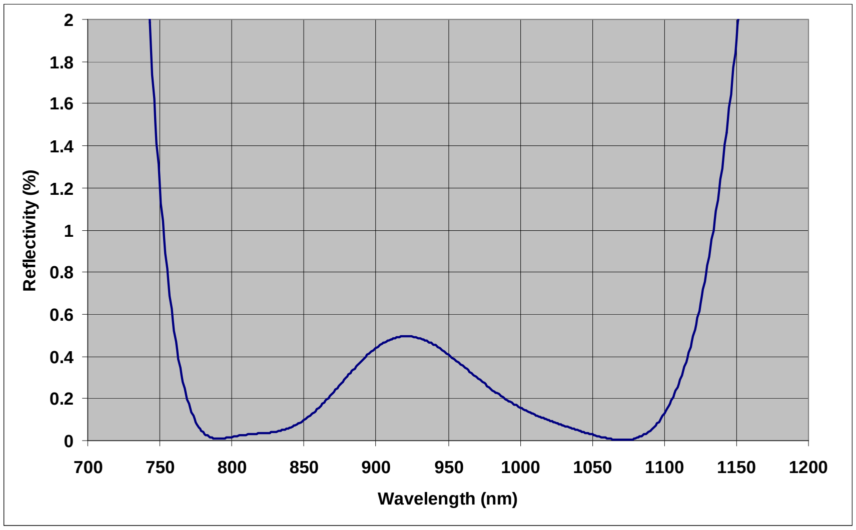

Figure 1. *Reflection spectrum of dual AR coating on YAG.*

Dual AR coatings

The AR coated samples were coated with a 6 layer Ta_2O5/SiO_2 coating with total thickness of 1200nm. The reflectivity was below 0.1% at both 1064 nm and 808nm. See Figure 1 for the spectral trace.

We tested two samples coated in the same coating run. The results are shown above in Table 1. Each irradiance level was scanned over a 100μm x 100μm area at ten sites and the irradiance was ramped up from 0.1 MW/cm^2 to 16.6 MW/cm^2. This was the maximum power achievable with the Spica test set up given the power of their laser and minimum spot size. Neither sample showed any damage in 10 out of 10 sites at any of the power levels up to the maximum.

Dichroic coating

The dichroic coating was a 29 layer Ta_2O_5/SiO_2 design with total thickness of 4728nm. The design was optimized for maximum reflection at the 1064nm lasing wavelength and high transmission at the 808nm pump wavelength. The transmission spectra is shown in Figure 2.

Two samples were tested similarly to the AR samples except that the light was incident from the back side to simulate the usual application configuration of internal reflection of the dichroic mirror. The results are shown in Table 1. A maximum fluence level of 17.6MW/cm^2 was obtained. Neither sample showed any damage in 10 out of 10 sites at any of the power levels up to the maximum.

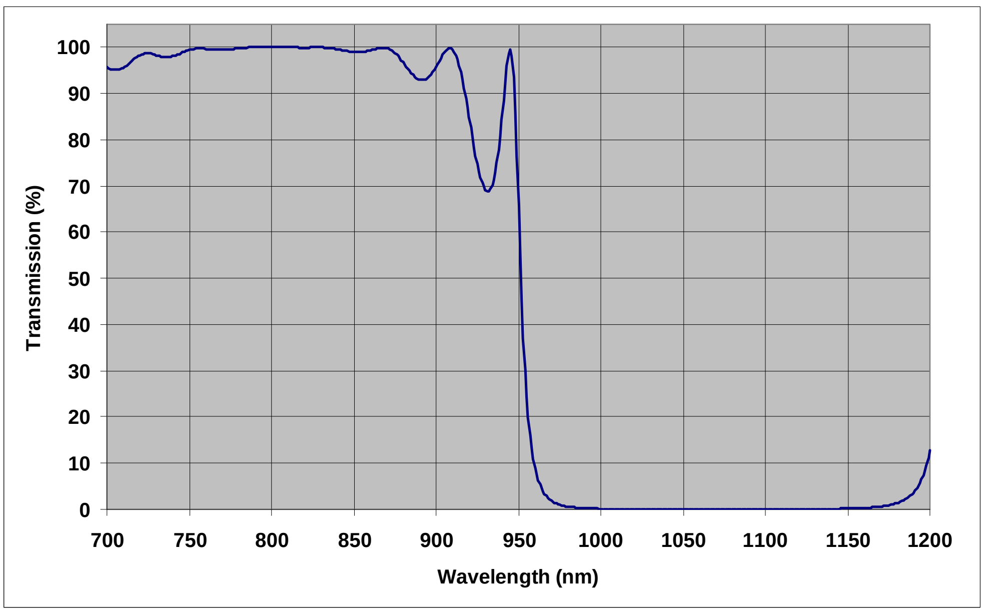

Figure 2. *Transmission spectrum of dichroic coating on YAG.*

Conclusion

While the values tested should be satisfactory for most applications the authors are aware of, it is unfortunate that the test set-up was not sufficient to find the ultimate limit of these coating designs. Further testing should be done in similar test set-ups that allow for a higher irradiance.

The CW laser damage threshold is expected to be dominated by thermal effects connected to residual absorption levels of the coatings. Local electromagnetic field levels are much lower in CW applications then in nanosecond pulsed applications. As a result, field dependant damage mechanisms such as multiphoton absorption and ionization are not expected to be limiting factors to the laser damage levels. Given the low absorption levels we have measured in ion beam sputtered coatings, <2ppm bulk absorption, this type of coating deposition process should be ideal for producing high damage threshold, low loss coatings for CW applications [4].

References

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[4] Bulk absorption testing performed by Stanford Photo-thermal Solutions on 1064nm HR coatings deposited with ion beam sputtering at Precision Photonics Corp, (2007).

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