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Optical coatings for fiber lasers

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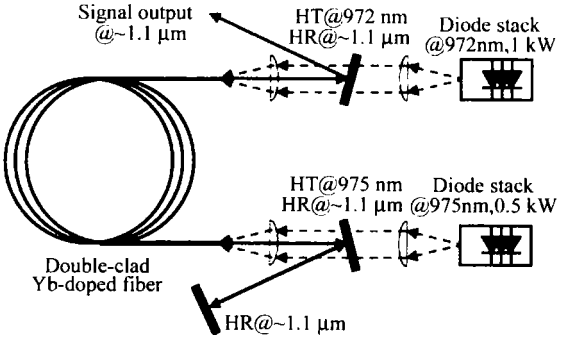
Abstract: Fiber laser is the future development direction for the high energy lasers. This paper describs two kinds of optical coatings for fiber laser, including long and short wave pass filters. The one characteristic of fiber laser coatings lies in that coatings should separate two closely wavelength light including laser pump wavelength (980 nm) and laser irradiation wavelength (1 050～1 100 nm). At the same time, the coatings should have high laser damage threshold.

Key words: fiber laser; edge filter; plasma ion assisted deposition

1 Introduction

High Power Fiber Lasers (HPFLs) and High Power Fiber Amplifers (HPFAs) promise a number of benefits in terms of their high optical efficiency, degree of integration, beam quality, reliability, spatial compactness and thermal management. These benefits are driving the rapid adoption of HPFLs in an increasingly wide range of applications and power levels ranging from a few Watts, for example in analytical applications, to high-power >1 kW material processing (machining and welding) applications. In silica, neodymium (Nd^{3+}), ytterbium (Yb^{3+}), erbium (Er^{3+}), Thulium (Tm^{3+}), are common dopants, with which one can access different wavelengths from the near infrared range to the so-called eye safe range (0.9～2 μm).

End-coupling of the pump beam into the inner cladding of double-clad fiber through its ends in a so-called end-pumping scheme (Fig. 1) is the simplest and most efficient way to pump a double-clad fiber with a diode-stack pump source. The optical coatings for this scheme, including long and short wave pass filters, are described in this paper.



HR: high reflectivity, HT: high transmission.

Fig. 1 Yb-doped fiber laser arrangement used with two diode stack pump sources.

2 Coating design

In long- and short-wave pass filters, the steepness of edge is not usually a parameter of critical importance. But for fiber laser coatings which should separate two closely wavelength light including laser pump wavelength (975 nm)

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and laser irradiation wavelength (1 030 ~ 1 100 nm), the steepness is the most important factor we should consider.

An method for increasing the steepness of edge without major alterations to the basic design concept is the use of higher-order stacks: $(H3L)^S$. We used this method to design a short wavelength pass filter for a pump mirror for the diode pumped solid state laser (Fig. 2): Transmittance $T > 95\%$ at 975 nm, reflectance $R > 99.5\%$ at 1 030~1 100 nm.

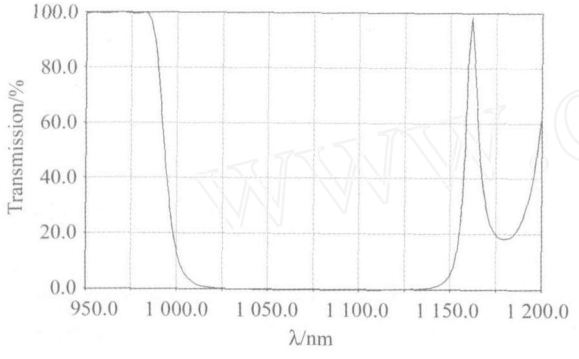

Fig. 2 Design curve of short wave pass filter: Transmittance $T > 95\%$ at 975 nm, reflectance $R > 99.5\%$ at 1 030~1 100 nm.

Fig. 3 is the design curve for combiner for pump laser diodes (long wave pass filter). the steep edge filter separates 940 nm and 975 nm for unpolarized light at 22.5.

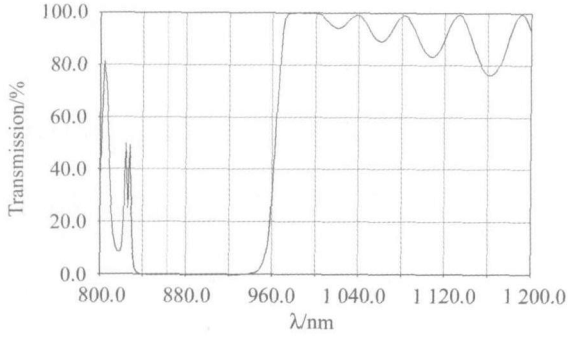

Fig. 3 Design curve for the steep edge filter which separate 940 nm and 975 nm for unpolarized light at 22.5

3 Experiment results

Thermal evaporation is the most commonly used process for the production of optical coatings. The structure and the achieved properties of thermally evaporated films are quite different from the respective bulk material. The typical columnar structure of many metals and oxides has been investigated by various authors. The low packing density implies optical constants and mechanical properties such as adhesion and hardness which are inferior to those of the bulk materials. Deposition process using particles with higher kinetic energies than by thermal evaporation can improve the above-mentioned properties. The plasma-IAD with the APS is one of the techniques.

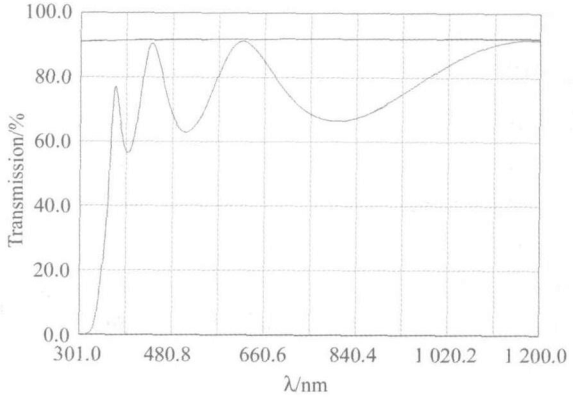

Fig. 4 Single layer TiO_2 deposited with plasma-IAD ($n_{550} = 2.392$), the straight line is the transmittance curve of BK7.

We obtained two different modifications of TiO_2. The spectral curve of the single layer TiO_2 deposited with plasma-IAD is shown in Fig. 4. We obtained a refractive index of 2.392 at 550 nm. Fig. 5 is the spectral curve of the single layer TiO_2 deposited with conventional electron beam gun evaporation. The layer has a refractive index of 2.272. Fig. 4 and Fig. 5 show that we can get lower absorption loss film with plasma-IAD depositon.

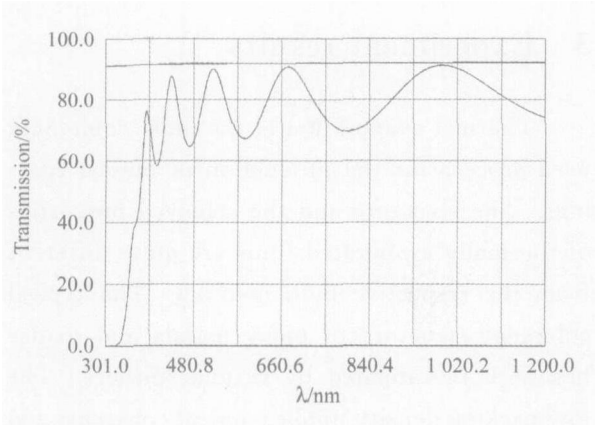

Fig. 5 Single layer TiO_2 deposited with conventional electron beam gun evaporation. (n_{550} = 2.272) ,the straight line is the transmittance curve of BK7.

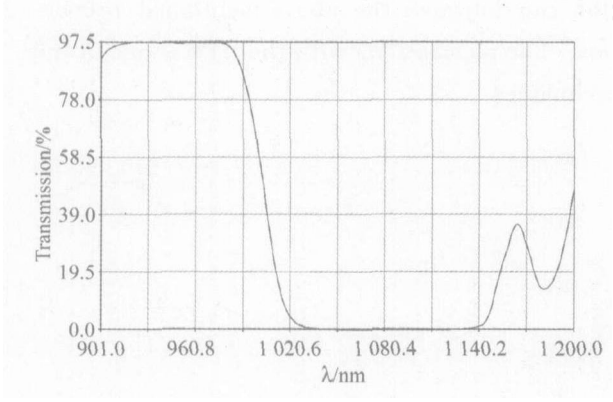

Fig. 6 Measured curve of short wave pass filter Transmittance $T > 95\%$ at 975 nm, reflectance $R > 99.5\%$ at 1 030～1 100 nm.

The multilayer experiments were done in a standard APS 1104 box coating system equipped with a high-power plasma source, the APS. The layer thickness was controlled by an optical monitor, Model OMS3000. A quartz-crystal sensor was used to control the deposition rate. TiO_2 was used as the high-index layer. For the low-index layer, SiO_2 was used. The deposition rate was 0.25 nm/s for TiO_2, 0.6 nm/s for SiO_2.

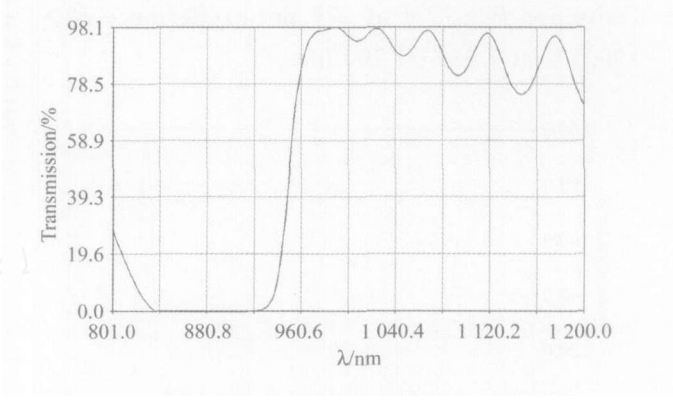

Fig. 7 Measured curve for the steep edge filter which separate 940 nm and 975 nm for unpolarized light at 22.5

4 Conclusion

We designed the extremely steep short and long wavelength pass filters for fiber laser. The result deposited with plasma-IAD can meet the requirements.

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