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ABSTRACT

Using two argon-ion lasers to pump a CW Ti:Sapphire laser we have demonstrated consistent high power (19 watts) operation with a low order spatial mode. Thermal lensing effects were controlled by enclosing the laser in a vacuum and cooling the rod with liquid nitrogen. Using this laser we also demonstrated a CW Ti:Sapphire amplifier with an efficiency of 20%.

INTRODUCTION

Continuous wave operation of Ti:Sapphire at liquid nitrogen temperatures was first reported by Moulton in 1984 [1]. Over the last few years, several commercial CW Ti:Sapphire lasers have been introduced to the market with output powers of several watts. The peak absorption at 500 nm makes Ti:Sapphire ideally suited for pumping with argon-ion lasers. The output power of commercial Ti:Sapphire lasers is limited not only by the output power of the argon-ion pump laser, but also by the strong thermal gradients induced in the rod while pumping with high powers [2]. In this paper, we report on a laser which is designed to be pumped with two argon-ion lasers with a total pump power of 57 watts. Thermal lensing effects were controlled by taking advantage of the large increase in thermal conductivity of Ti:Sapphire when cooled to liquid nitrogen temperatures [3]. We also report on preliminary results of a CW Ti:Sapphire amplifier with an efficiency of 20% and a total output power of 24 watts.

LASER EXPERIMENTS

In previous work [4], we described a similar laser system where the rod was cooled by conduction through a copper mount with liquid nitrogen. The rod was enclosed in a small vacuum vessel fitted with Brewster windows. This prevented condensation from forming on the surface of the rod when cooling to liquid nitrogen temperatures. The introduction of the Brewster windows into the resonator design caused additional losses in the laser cavity and also caused astigmatism in the output beam. Although it would be possible to design a resonator to compensate for the astigmatism [5], there would still be the loss associated with the four Brewster surfaces. In our new design we have eliminated the Brewster windows by enclosing the entire laser in a vacuum vessel. This not only eliminates the problems associated with the Brewster windows but also provides a clean, dust free environment. The vacuum vessel was fitted with mechanical feed-throughs to control various mirrors and tuning elements of the laser. Windows with appropriate AR

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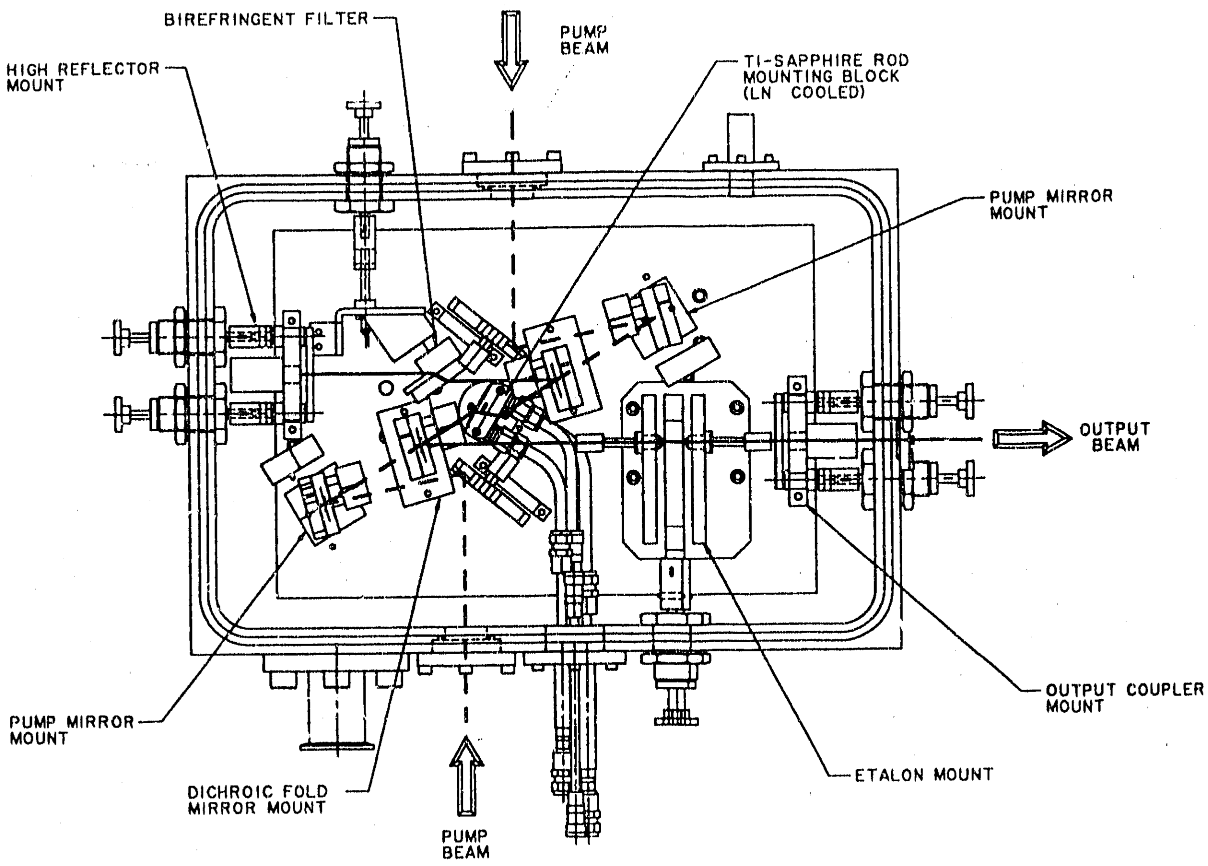

FIGURE 1 Mechanical layout of vacuum enclosed Ti:Sapphire laser

coatings were provided for the output beam and pump beams. A schematic of the laser is shown in Figure 1. The laser optical design is similar to the one described in our earlier work [4]

A plot of an input-output curve with a slope efficiency of 35% is shown in Figure 2. The two ion lasers were adjusted for equal output powers in the measurement. At 57 watts of total pump power, the output power was 19 watts. This data was taken at 850 nm which was at the peak of the tuning curve for the particular mirror-set used. Slightly higher powers would be expected at 780-800 nm which is the peak of the gain curve for Ti:Sapphire. The high quality spatial mode of the output beam at high pump powers is shown in Figure 3. The smooth Gaussian-like profile suggests the laser is operating in a TEMoo mode.

In operating the laser on a day to day basis with the system remaining under vacuum we have observed consistent high

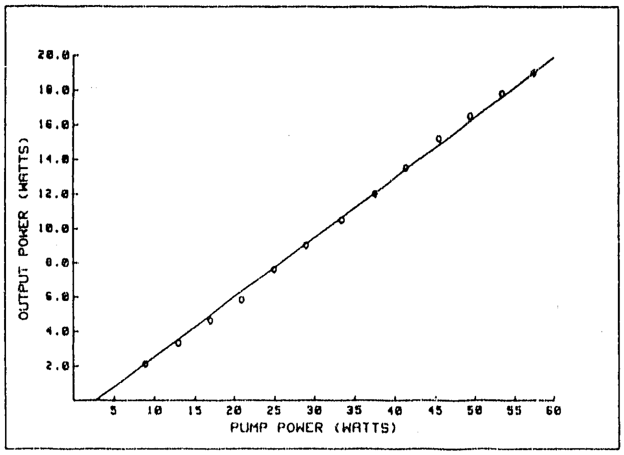

FIGURE 2 Ti:Sapphire laser output vs. pump power at 850 nm

power performance with a spatial mode typical of that shown in Figure 3. The clean environment of the vacuum enclosure eliminates the need to constantly clean optical components and also reduces the risk of optical damage to critical elements. We have observed no loss in performance of the laser over several weeks of operation.

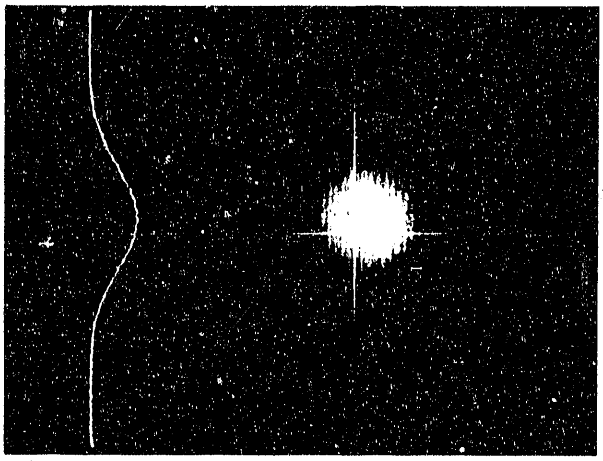

FIGURE 3 Spatial mode observed with 19 watt output at 850 nm and 57 watts of total pump power

CW AMPLIFIER

Using a simple laser kinetics model we have predicted that efficient CW amplification with Ti:Sapphire is possible. To be efficient, the amplifier must be well saturated by the input signal. Figure 4 shows the calculated efficiency of a CW Ti:Sapphire amplifier as a function of the input signal power for a 45 micron spot size at 850 nm. To test this result we constructed a simple single-pass amplifier shown in Figure 5. The amplifier rod was cooled by conduction through a water cooled copper block. Although the amplifier could be pumped with two argon-ion lasers, at high pump powers thermal distortions adversely affected the performance.

In a preliminary experiment we injected 17.4 watts of 850 nm signal into the amplifier provided by the Ti:sapphire laser described above. The amplifier was pumped by two argon-ion lasers with a total power

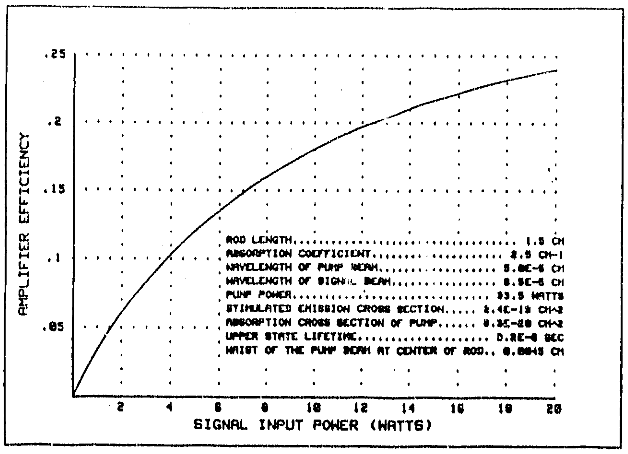

FIGURE 4 Calculated efficiency vs. input power for a single pass Ti:Sapphire amplifier

of 33.5 watts. Under these conditions the amplifier efficiency was 20% with a 24.0 watt output. This performance is slightly less than predicted by the model which assumes a perfect overlap of the pump and signal beams. The less than perfect overlap in our amplifier probably results from astigmatism introduced by the optical design and by thermal distortions in the rod. A carefully designed amplifier that maximizes the overlap of the pump and signal beam and allows the rod to be cooled to liquid nitrogen temperatures should produce better agreement with the model.

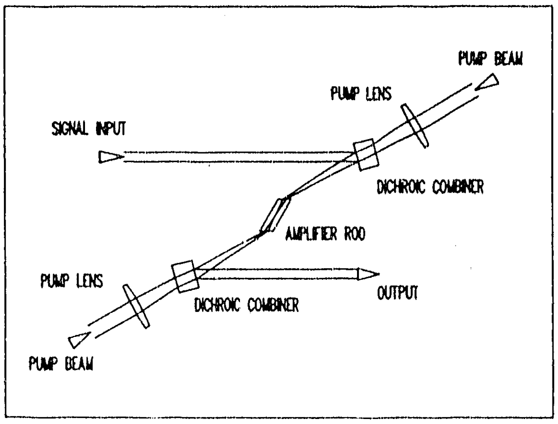

FIGURE 5 Optical schematic of single pass Ti:Sapphire amplifier using two argon-ion pump lasers

CONCLUSIONS

We have demonstrated a CW Ti:sapphire laser design which is capable of producing 19 watts of output power. Using the high intensities and low order spatial mode of this laser we demonstrated a CW, single-pass Ti:Sapphire amplifier with an efficiency of 20% and a total output power of 24 watts. The results of this work suggest that Ti:sapphire could be scaled to very high CW powers by the use of amplifiers in a MOPA chain configuration.

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