be see in the x-intercept of Fig. 5(a), the actual pump threshold increases with larger w_0. A straightforward calculation of the mode-averaged gain shows that $P_{th}(w_0) = P_{mth}(1+\delta)$ where $\delta = w_0^2/w_p^2$. On the other hand, it can be seen that the slope efficiency is low for small w_0 (black line), while the slope efficiency is nearly the same for $\delta = 1$ as it is for $\delta = 4$. The end result is that for operation near the minimum threshold, it is possible to obtain higher output power for $\delta < 1$ than for $\delta = 1$.

Figure 5(b) shows how the output power varies with δ for different pump powers. Lasers are normally operated with $x >> 1$. Consider, for example, the red curve in Fig. 5(b) where $x = 10$. The output power maximizes at equal pump and laser mode size ($\delta = 1$). If the mode-locked mode size is near this maximum, operation at CW with a larger mode size will result in lower output power. This is the conventional regime for Kerr-lens modelocking. However, for low pumping power, it can be seen that the maximum output power is at a laser mode size that is smaller than the pump ($\delta < 1$). This results from the strong dependence of the threshold power on laser mode size for low pump power. In our laser, the power discrimination between mode-locked and CW is a factor of 2, showing strong preference for the laser to operate in the mode-locked regime. For a given available pump power and a laser mode size (defined by the cavity), the operational variable is the size of the pump mode. Decreasing w_p leads to an increase both in x and δ, so as we are able to focus our diodes to a smaller spot, we anticipate still higher output power in the mode-locked regime. This simple model only accounts for lowest-order mode overlap in the transverse direction. We are investigating a more complete model [22] that accounts for overlap over the whole crystal volume. For operation near threshold, higher-order modes should be suppressed in spite of the large pump mode volume. We note that relative to a crystal with high absorption efficiency, the gain in the current system is less concentrated at the entrance face of the crystal. This may help in the discrimination against larger and higher-order modes.

4. Conclusion

We believe that this is the first demonstration of stable Kerr lens modelocking, by a direct diode pumped Ti:sapphire laser oscillator. In the previous demonstration of modelocking of a Ti:sapphire laser, [14] which required an SBR to sustain modelocking, the authors reported 12mW of average power in a 114fs pulse. We achieve 34mW of output power in a 15fs pulse without the need for an SBR mirror. We anticipate that with better modematching of the pump beams with the cavity mode, we could increase the output power from 34mW to 100mW. This work opens the door to much more inexpensive and robust femtosecond oscillator, and the potential for cost effective amplifier systems.

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