Acousto-Optically Induced Single-frequency Operation of a Monolithic Nd:Phosphate Glass Ring laser

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ABSTRACT

A diode-pumped single-frequency monolithic Nd:phosphate glass ring laser is described, in which the acousto-optic effect is used to enforce unidirectional lasing. Output powers up to 30mW for 400mW of pump have been achieved.

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SUMMARY

Monolithic single-frequency solid-state lasers are attractive due to their high stability and have important applications in a number of areas where a highly stable single-frequency light source is required.

Microchip lasers provide the simplest of these monolithic sources[1], but they are not easily scaled to higher output powers. Another approach is the nonplanar monolithic ring laser[2], using the Faraday effect to enforce unidirectional lasing. These devices can be scaled to higher output powers than microchip lasers, but are restricted to laser materials having a large enough Verdet-constant and no birefringence.

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An alternative technique for enforcing unidirectional and hence single-frequency lasing in a ring laser is via the acousto-optic effect[3]. This technique has been applied to non-monolithic diode-pumped lasers such as Nd:YAG and Nd:YLF where the acousto-optic effect is provided in a high figure of merit material separate from the gain medium.

However, recent reports have shown, that there are two mechanisms for acousto-optically induced unidirectional operation, one of which relies on differences in the Bragg-angle to provide the necessary loss difference[4], while the other technique involves deliberately feeding back the diffracted beams[5]. The latter can yield a very high loss difference even for a very small diffraction loss, so it can be applied very effectively in a low figure of merit material such as the solid-state laser material itself, thus opening up the prospect of a fully monolithic device.

To test the feasibility of this approach, we have made use of this `self-feedback-technique'[6] to enforce unidirectional and single-frequency operation of a monolithic Nd:phosphate glass ring laser. The laser was made from 4% doped Nd:phosphate laser glass (Schott LG760), with a cavity configuration as shown in Fig. 1. An acousto-optic transducer was attached to the top surface. The radius of curvature of the output coupler was chosen to be equal to the round trip length (20mm). This ensured feedback of the diffracted beam after four round trips, being then diffracted back into the main laser path, so that it interferes with the main beam. The path length for the fed-back diffracted beam is exactly the same for both counter propagation directions, but because the frequency shift of the diffracted wave is opposite for these two directions, the fed-back waves have different phase shifts, hence different degrees of feedback, ie different effective losses.

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When no RF-power was applied the device had a threshold of 63mW and a slope efficiency of 9%. This resulted in an output power of 30mW when pumped by 400mW. We believe that the low slope efficiency is due to a not optimized output coupler and parasitic losses. To enforce unidirectional operation it was sufficient to apply 0.05W of RF power, although typically we have used a RF power of 0.2W at which reliable single-frequency output could be maintained indefinitely. The extra loss due to the higher RF power only degraded the output power by 5%.

When tuning the temperature we observed a large tuning range of 40GHz without any mode hopping, a range which is four times the mode spacing of the cavity. We believe that this is due to a shift of the gain curve with temperature which seems to be of the same order as the mode shift. The mode tuning rate was measured to be 2.3GHz/°C, which is ~twenty times higher than that expected from the data provided by Schott. We do not yet have a conclusive explanation for this behaviour.

Since this type of device only requires a low diffraction-loss it should be possible to extend this technique to many other laser materials and should complement the existing range of monolithic single-frequency devices. In addition this technique can, in principle, allow Q-switching via the acousto-optic effect, thus offering the prospect of a Q-switched single-frequency monolithic laser.

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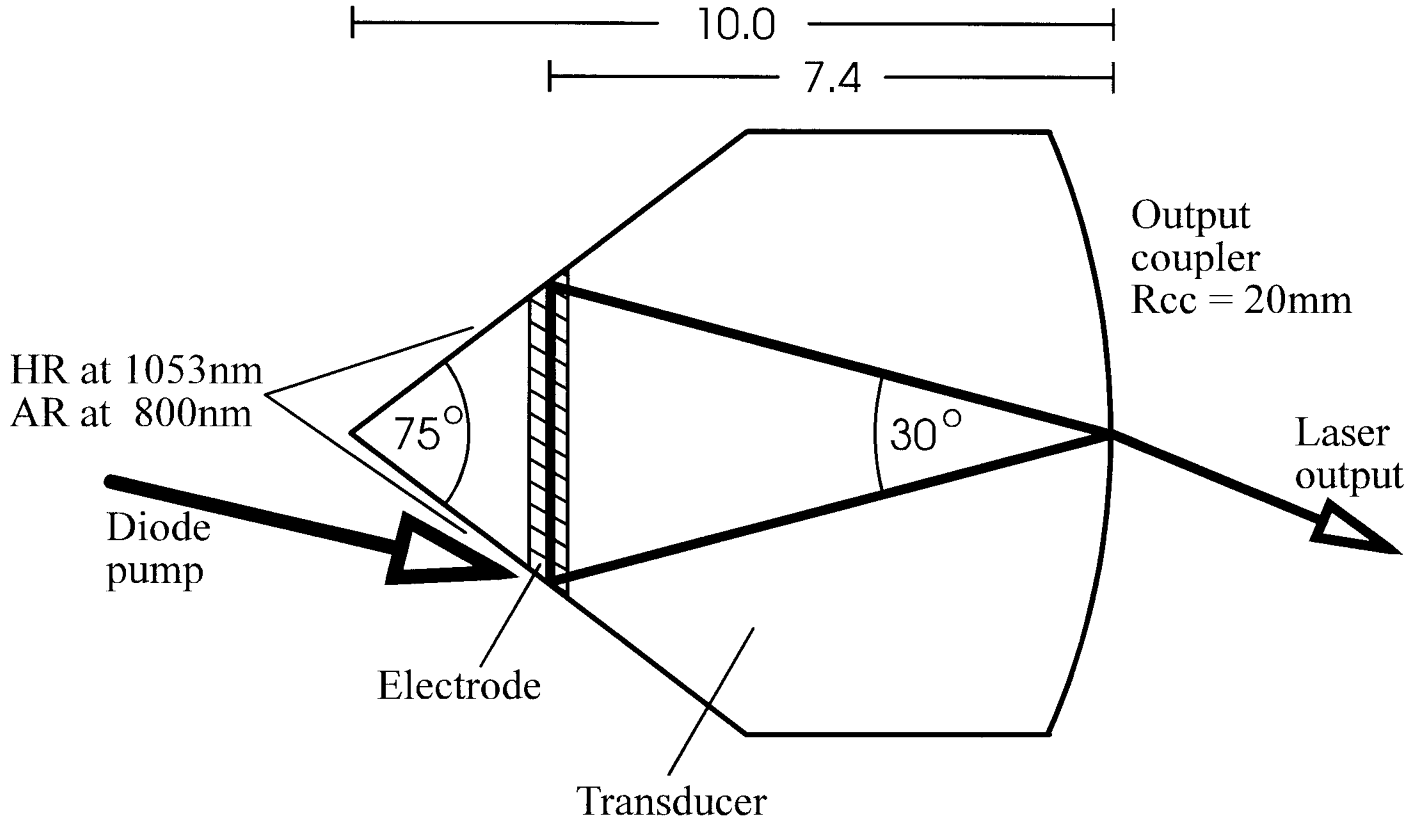
FIGURE CAPTIONS

Fig. 1 Cavity Configuration of the Nd:Phosphate monolithic ring laser using the acousto-optic effect for unidirectional operation


10.0
7.4
Output coupler
Rcc = 20mm
HR at 1053nm
AR at 800nm
75°
30°
Laser output
Diode pump
Electrode
Transducer