Single-frequency operation of a diode-pumped green laser using multi-Brewster plates

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In a diode-pumped, KTP intracavity frequency-doubled green laser, multi-Brewster plates are used to achieve high power single-frequency operation. With a simple experimental setup, single-frequency operation of the diode-pumped green laser with output of 46 and 218 mW is obtained by one and three Brewster plate, respectively.

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LD-pumped $Nd:YVO_4/KTP$ green laser has attracted much attention in recent years. However, there is a disadvantage that low-frequency amplitude instability, called "green problem", is unavoidable in such intracavity second harmonic generation (SHG) due to sum-frequency generation (SFG) inherent in the KTP crystal[1]. The amplitude fluctuations have been a persistent problem which has made the SHG inappropriate for many applications, such as high speed printing, photo processing, semiconductor inspection, DNA sequencing and so on.

A direct method of eliminating amplitude fluctuation in SHG is to use a single-frequency laser[2]. Resonator length less than 1 mm is sufficient for this purpose in an infrared laser. However, it is difficult to reduce the resonator length in the intracavity-doubled solid-state lasers. As alternatives, therefore, several methods for the noise reduction have been developed by using intracavity elements such as an etalon, a quarter-wave plate, or by placing the doubling crystal in an external resonator. A disadvantage of the former two methods is that the end-pumped laser output is highly sensitive to such losses that may be introduced by the insertion of intracavity elements. On the other hand, a disadvantage of the latter method is that the external resonator requires active tuning by varying the resonator length as the laser frequency drifts.

A particularly attractive way to achieve single frequency operation in type-II phase-matched geometry is to use a novel birefringent filter technique consisting of a polarizing element, usually a Brewster plate, and a birefringent crystal (KTP) with its slow axis at 45° to the high transmission axis of the polarizer[3]. If the filter is placed in a cavity, only modes with wavelengths such that the KTP acts as a half- or full-wave plate are transmitted along the low-loss axis of the polarizer. For modes with other wavelengths, their polarization at the polarizer is such that they incur an elevated loss. However, calculations also show that the mode selection ability of single Brewster plate inserted in a $Nd:YVO_4/KTP$ green laser is limited[4].

Figure 1 showed the reflectivity loss of one, two and three Brewster plates to the s and p components of the laser at different incident angle, respectively (the plate is made by a glass with $n = 1.53$). It means that more than one Brewster plate has the abilities of further increasing the selective loss to ensure single-frequency operation in the condition of higher incident pump power.

First, we use the design shown in Fig. 2 to study the effects of a Brewster plate. The resonator consists of a 1-mm-thick piece of $Nd:YVO_4$, a 0.5-mm-thick Brewster plate made of K9 glass, a 9-mm-long piece of type-II phase-matched KTP, and an output mirror (ρ = 50 mm). All the components are placed closely to shorten the cavity length and to increase the frequency intervals.

In Fig. 2, the left facet of $Nd:YVO_4$ is coated with 808 nm anti-reflection (AR) and 1064 nm high-reflection (HR) coatings as the all reflective mirror. The output mirror M is with 1064 nm HR and 532 nm AR coatings. Both facets of KTP are with 1064/532 nm AR coatings. By the thermoelectric controller (TEC_1), the central emission wavelength of laser diode is adjusted to 808.9 nm to match the absorption peak of $Nd:YVO_4$ crystal. The temperature of $Nd:YVO_4$ and KTP should be controlled by TEC_2 to maximize the available discrimination. Thus, variation of the temperature is a very important experimental parameter.

When the pump power is 0.8 W, 46-mW single-frequency green laser is obtained, as shown in Fig. 2. However, if increasing the pump power, mode hops would happen or more than one longitude modes would appear, which means single Brewster plate is not able to achieve high power single frequency operation.

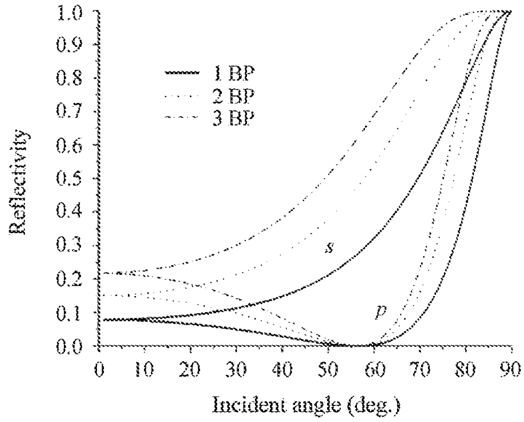

Fig. 1. Reflectivity loss of multi-Brewster plates vs. incident angle.

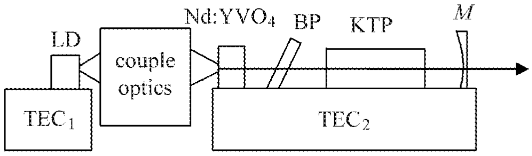

Fig. 2. A laser resonator with a Brewster plate.

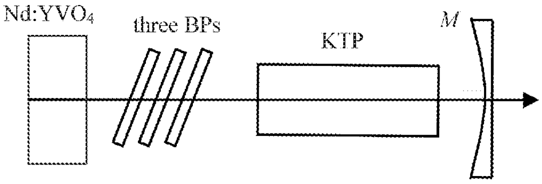

Fig. 3. A resonator with three Brewster plates.

In order to achieve higher power single frequency operation, more than one Brewster plate can be used to further increase the reflectivity loss to other modes. In Fig. 3, the resonator consists of a 1-mm-thick piece of Nd:YVO_4, three 0.2-mm-thick Brewster plate made of K9 glass, a 9-mm-long piece of type-II phase-matched KTP, and an output mirror (ρ = 200 mm). The resonator's length is about 15.5 mm. With 1.6-W pump power, single frequency green laser with power of 218 mW is obtained. It proves that the arrangement shown in Fig. 3 is a practical setup to obtain high power single-frequency operation with simple structure and low cost. Figure 4 is the frequency scan by a Fabry-Perot interferometer.

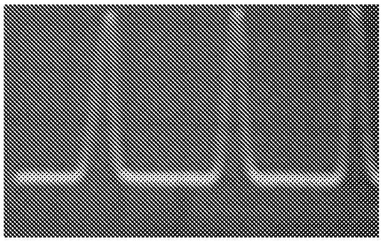

Fig. 4. Fabry-Perot scan of the single-frequency green laser.

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