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Holographic laser resonators using degenerate four-wave mixing in a continuous wave diode side-pumped Nd:YVO_4 amplifier

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Abstract

Degenerate four-wave mixing results are presented for continuous wave diode pumped Nd:YVO4, yielding >800% reflectivity, and an adaptive phase conjugate resonator has thereby been constructed.

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Self-adaptive laser resonators formed by diffraction from a gain grating have shown considerable promise for correction of distortion in high average power solid-state laser systems as well as for spectral and temporal control of the laser radiation [1-4]. In these systems, the gain grating is formed by spatial hole burning caused by interference of coherent beams in the laser amplifier and modulation of the population inversion. The gain grating formation can be used for phase conjugation by using the amplifier in a four-wave mixing geometry [2], for self-pumped phase conjugation by using an input beam in a self-intersecting loop geometry [3] and for formation of a self-starting adaptive oscillator by providing additional feedback from an output coupler and requiring no external optical input. Experimental demonstrations have been performed successfully in several laser systems including flashlamp-pumped and quasi-c.w. pumped neodymium-doped amplifiers [1,2], in laser-pumped titanium-doped sapphire [4] and CO_2 lasers. We present for the first time, demonstration of a continuous-wave diode-pumped adaptive holographic laser resonator using four-wave mixing in a Nd:YVO_4 solid-state laser amplifier.

Degenerate four wave mixing (DFWM) experiments were performed with a transversely-pumped Nd:YVO_4 amplifier (20x5x3 mm^3) using a 20W diode bar (Figure 1).

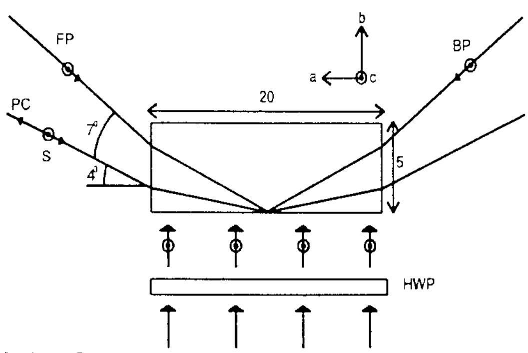

Figure 1. Schematic of the four wave mixing geometry used for the phase conjugate reflectivity measurements

Phase conjugate reflectivities higher than 800% were achieved using this setup. Experimental results for the reflectivities achieved along with theoretical modelling of the four wave mixing process are depicted in figure 2a and 2b respectively, showing reasonable agreement between them. The model used separates the four wave mixing volume from the gain volume, assuming different gains experienced by different beams which are transmitted through the amplifier.

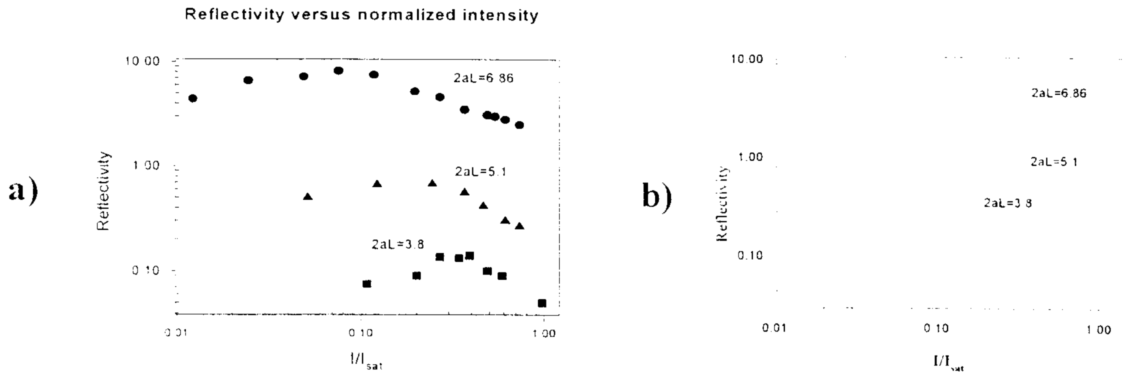

Figure 2a. Phase conjugate reflectivity versus pump beam intensity normalised to I_{sat} for various small signal gain values. Figure 2b represents the modelling results. (I_{sat} for $Nd:YVO_4 \sim 900$ Wcm^{-2}).

The good DFWM results made possible the continuous-wave operation of an adaptive self-starting solid-state laser resonator. Figure 3 shows the setup used.

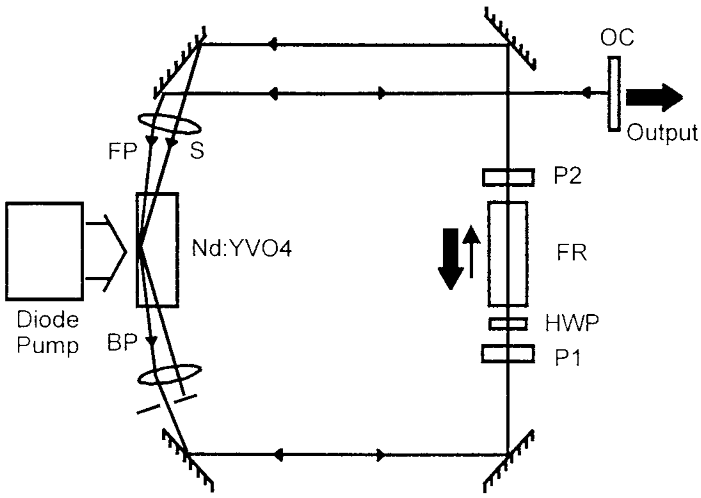

Figure 3. Setup for the self starting adaptive laser resonator

The resonator's loop is "closed" by the gain grating which is recorded in the saturated amplifier by forward pump (FP) and signal (S) beams. A non reciprocal transmission element consisting of a Faraday isolator plus a half wave plate (HWP), provides an adjustable feedback to the amplifier in order to maximize the index of modulation of the recorded grating. The undiffracted part of the backward pump (BP), which is the phase conjugate of beam S forms the output of the resonator. Because of the phase conjugate nature of the output all distortions caused by the amplifier, or other elements in the loop are corrected. The operation of the resonator starts from gain gratings recorded by the amplified spontaneous emission.

A non-optimized (mainly due to poor mode volume) output of 140 mW has been obtained and is the subject of further improvement using modified setups in order to exploit most of the available gain volume leading to an expected multi-Watt operation with diffraction limited beam outputs is expected from this system

To test for phase conjugation and distortion correction inside the laser resonator an aberrator was placed inside the cavity. Figure 4a depicts the form of the distortion produced by the aberrator while figure 4b shows the corrected output of the resonator with the aberrator placed inside the cavity.

a)

b)

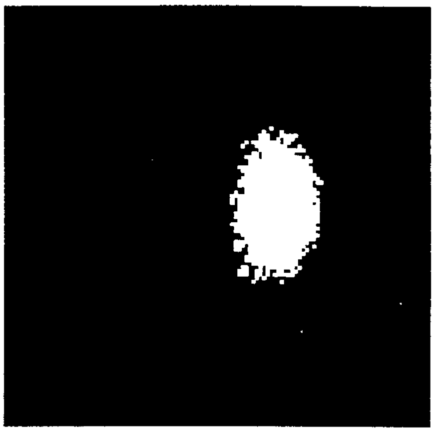

Figure 4a: Aberrated beam profile. b) corrected output

In conclusion, we have shown that continuous-wave operation of a self starting, adaptive laser resonator is possible using DFWM in a cw diode pumped $Nd:YVO_4$ solid-state laser amplifier. High phase conjugate reflectivities have been measured and compared with numerical modelling results. Distortion correction for an aberrator inserted in the cavity has been demonstrated. Future work will include improving the resonator's output, by exploiting the available gain volume as well as separating FWM from gain.

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