High-reflectivity continuous-wave phase conjugation by four-wave mixing in a diode-pumped Nd:YVO_4 amplifier

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Abstract

We present the first demonstration of continuous-wave diode-pumped four-wave mixing in a Nd:YVO_4 amplifier and achieve phase conjugate reflectivity > 800%. Results for different amplifier gains and pump geometries are compared to numerical results.

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Summary

Self-adaptive laser resonators formed by diffraction from a gain grating have shown considerable promise for correction of distortions in high average power 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 continuous-wave diode-pumped operation of four-wave mixing in a solid-state laser amplifier (Nd:YVO$_4$). Experiments have been performed in both a transversely-pumped Nd:YVO$_4$ amplifier (20x5x3mm^3) using a 20W diode bar (see Figure 1a) and a longitudinally-pumped Nd:YVO$_4$ amplifier (3x3x1mm^3) using a 2W broad-stripe diode laser (Figure 1b). The transversely-pumped amplifier, when run as a laser oscillator by placing it between a high reflectivity mirror and a partially-transmitting output coupler, produced 8.5W of output power for 18W of available diode pumping power. Very high small-signal gains >5,000 were also demonstrated in this amplifier system allowing the prospect of high efficiency four-wave mixing. Figure 2 shows results of phase conjugate reflectivity of a probe beam in a four-wave mixing geometry as a function of pump beam power in this side-pumped amplifier geometry (Figure 1a). A phase conjugate reflectivity > 800% has been achieved, and is the highest value obtained from a solid-state amplifier using a simple four-wave mixing geometry. Figure 3 shows corresponding numerical solutions for the continuous-wave four-wave mixing reflectivity versus pump intensity in a saturable amplifier. We compare the theoretical and experimental results including a discussion of the important issues of spatial overlap and thermal lensing in the amplifier system.

In conclusion, we have shown that high gain and high diffraction efficiency gain gratings are possible in a continuous-wave mode of operation from a diode-pumped solid-state (DPSS) laser amplifier, and this is the first such demonstration of a continuous-wave diode-pumped solid-state (DPSS) laser amplifier as a four-wave mixing medium. This result is of considerable importance since it now makes possible the operation of continuous-wave self-adaptive solid-state lasers and the compensation of thermal lensing when operating at high powers.

References

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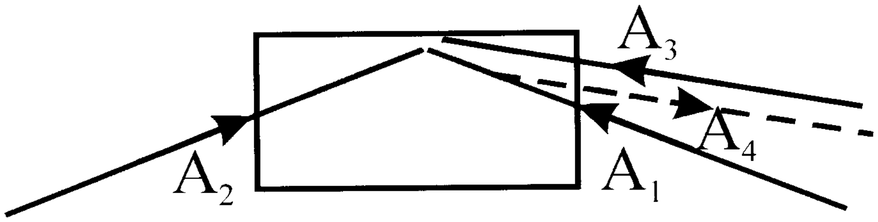
CAPTION FOR FIGURES

Figure 1. Experimental four-wave mixing schemes in a c.w. diode-pumed Nd:YVO$_4$ amplifier in a) transversely-pumped and b) longitudinally-pumped geometries.

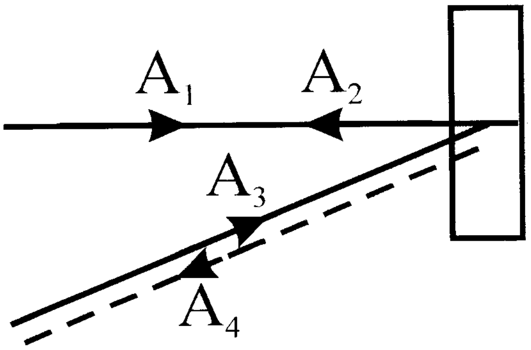
Figure 2. Experimental phase conjugate reflectivity versus four-wave mixing pump power in c.w. tranversely-pumped Nd:YVO$_4$ amplifier at different small-signal amplifier gains.

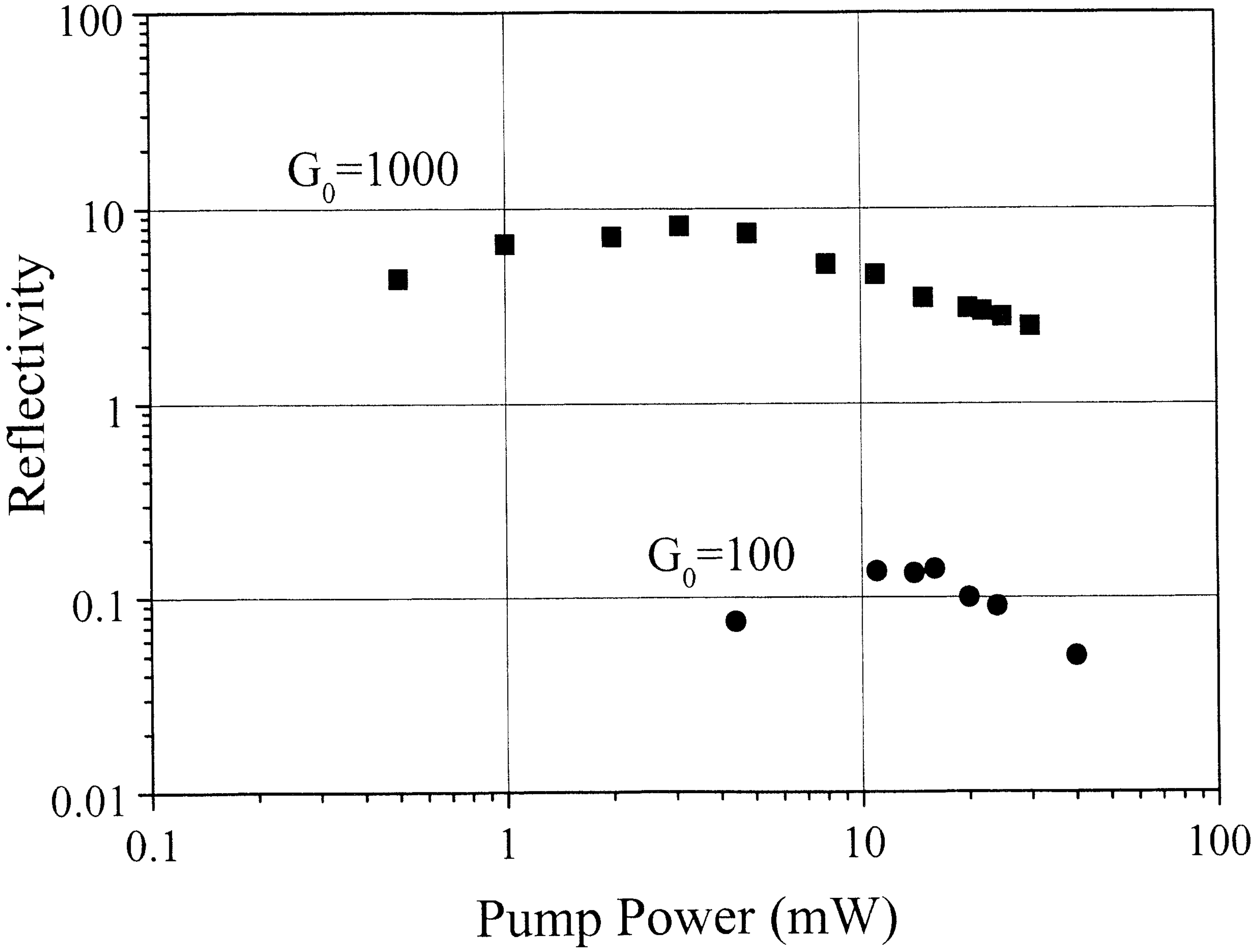
Figure 3. Numerical results of continuous-wave four-wave mixing reflectivity versus pump intensity (normalised to saturation intensity) for different small-signal amplifier gains.

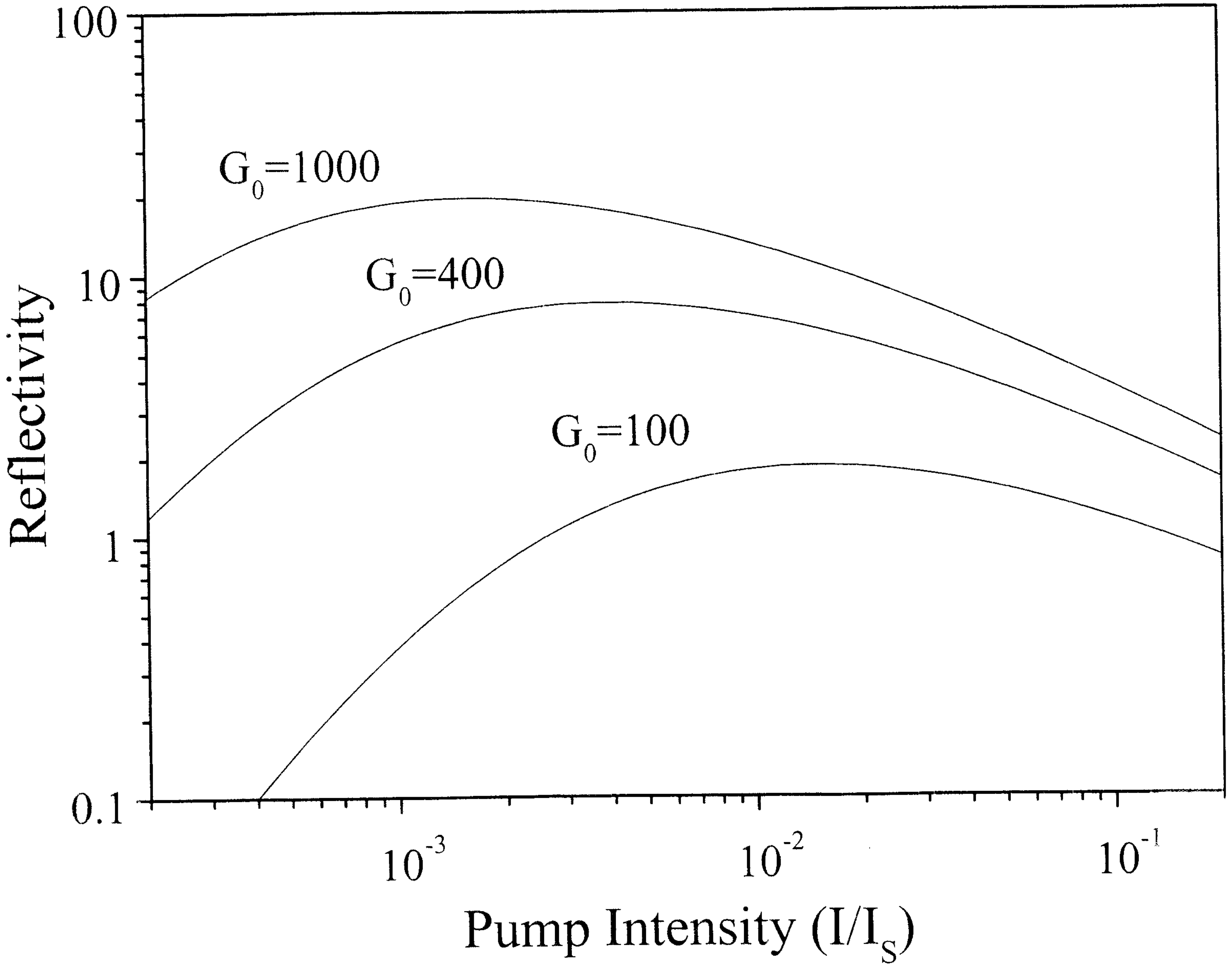
a) Transverse-pumping geometry



b) Longitudinal-pumping geometry




G$_0$=1000
G$_0$=100
Reflectivity
100
10
1
0.1
0.01
0.1
1
10
100
Pump Power (mW)


G_0=1000
G_0=400
G_0=100
Reflectivity
100
10
1
0.1
10^{-3}
10^{-2}
10^{-1}
Pump Intensity (I/I_S)