

# The design and performance of high gain parametric amplifiers for Petawatt Class Lasers

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**Abstract:** The paper presents the design of an OPCPA based front end for Petawatt class lasers. The issues of beam quality, jitter, spectral and temporal distortion are modeled and compared with experimental results on a novel system producing 100 mJ class pulses from the parametric amplifier section.

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## Introduction

In recent years, Optical Parametric Chirped Pulse Amplification (OPCPA) has become an attractive option for amplification of broadband pulses near 1  $\mu\text{m}$  wavelength [1,2]. The high gain and broad bandwidth have been particularly attractive for the initial amplification in high energy, Petawatt class CPA lasers [3-5]. These groups have reported good results, but a common outstanding issue has been the quality and efficiency of the pump laser. The pump pulse length has been much larger than the seed and often the pump-cavity employed an unstable resonator, unsuitable for the OPCPA process. We report results from an OPCPA system to be used as the frontend of a Nd:Glass based Petawatt laser at Sandia National Laboratory (SNL). We focus on optimizing the pump performance by employing a single-mode pump laser design. Furthermore we developed an OPCPA code that accounts for strongly chirped pulses ( $\sim 25,000$ ) by separating the amplitude and instantaneous frequency of the signal. This code is used to stage the parametric amplifiers in the front end for optimum performance.

## Pump Laser

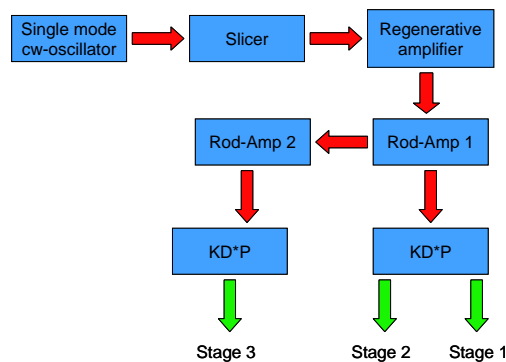


Fig. 1. Schematic of the pump laser.

As shown in Figure 1, we employ a small-scale cw-oscillator that operates in one longitudinal mode. Its output is chopped using a half-wave slicer. The pulse enters a regenerative amplifier employing a diode-pumped amplifier head. The pulse is amplified up to 6 mJ and provides a stable output. This design has the advantage that the pump-pulsewidth can be chosen to match the pulsewidth of the stretched input pulse and is only limited by the roundtrip-time of the cavity. Initial experiments showed that the temporal jitter is as low as 250 ps and the energy stability as good as 1 %. Then the pulse is amplified further using two flashlamp-pumped rod-amplifier heads in a two-pass configuration. The output of the first head pumps the first and second OPCPA stage as well as seeds the second head. The frequency conversion into 532 nm is

achieved using KD\*P crystals in an SHG-Type II configuration. The overall pump energy available is 1 J. The maximum repetition rate of the rod-amplifiers is 20 Hz.

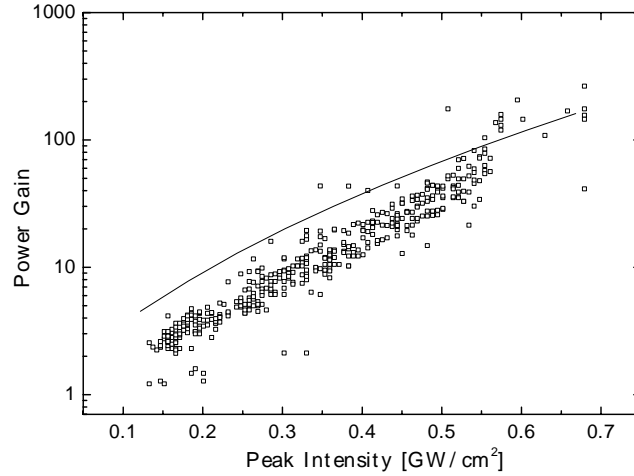


Fig. 2. Single shot gain measurement using an 8 mm BBO crystal. The residual spread is due to temporal jitter and pointing stability.

### OPCPA Stages

The frequency-doubled pump light is used to pump three OPCPA stages. Common computer codes, used to simulate a three-wave mixing process for highly chirped pulses, exceed the available computing power of desktop computers due to the large sampling required. The complexity of the model can be reduced by separating the amplitude and the instantaneous frequency. The reduction in complexity allows spatial modeling of the parametric process.

Simulations for our configuration predict an overall energy gain of  $10^8$ . Staging calculations suggest the following configuration:

Table 1: Design parameters of the OPCPA frontend.

	X-T Length	Pump Energy	Signal Energy In	Signal Energy Out
1 <sup>st</sup> stage	8 mm	30 mJ	0.5 nJ	300 nJ
	8 mm	30 mJ	300 nJ	250 $\mu$ J
2 <sup>nd</sup> stage	8 mm	200 mJ	200 $\mu$ J	35 mJ
3 <sup>rd</sup> stage	4 mm	600 mJ	30 mJ	180 mJ

The nonlinear crystal employed is BBO in a Type I configuration. The first stage uses two crystals with a relay-telescope in between to compensate for the walk-off and to reduce the gain per crystal. In initial experiments we observed competing processes above a gain of  $10^4$ - $10^5$ . The signal and pump geometry is slightly non-collinear in order to block the idler between the crystals. The intensity of the pump beam is 1 GW/cm<sup>2</sup> in order to minimize the crystal length for a given gain thereby reducing the effect of beam walk-off

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