

# Northrop Grumman Cutting Edge Optronics *Application Note #14*

## PowerPULSE™ Gain Modules



Northrop Grumman Cutting Edge Optronics has developed a family of Quasi-CW pumped gain modules with output energies in excess of 4 Joules and small signal gains of over 600. The PowerPULSE™ gain modules can be configured with rod sizes from 2mm to 10mm and diode bar counts of 3 to 300.

Data from a selection of gain modules is presented in this application note. Included are expected pulse energy outputs while operating in a free running oscillator. For amplifier applications, the total small signal gain and the stored energy are also reported.

The PowerPULSE™ gain modules utilize reliable QCW laser diode bars packaged in Golden Bullet™ arrays to enable long product lifetimes. Quasi-CW pumped module lifetimes exceeding 10,000 hours and 20 billion shots are available.

January 19, 2010

## 1. PowerPULSE™ GAIN MODULES IN OSCILLATORS

PowerPULSE™ gain modules can be used in a variety of oscillator configurations. Operating the gain modules in a short, free running oscillator gives a reasonable basis for comparison. Typical performance of a selection of modules is given in Table 1. The RBA models cover the 20mJ to 400mJ output energy ranges while the REA series of gain modules allows output pulses exceeding 4J.

**RBA PowerPulse Modules**

Model	Rod Type	Output Energy <sup>3</sup>	Operating Voltage <sup>4</sup>	Peak Drive Current
RBA20-2P5	2 mm, YAG <sup>2</sup>	> 50 mJ	36V	60A
RBA30-2P5	3 mm, YAG <sup>2</sup>	> 60 mJ	36V	60A
RBA35-2P5	3 mm, YAG <sup>1</sup>	> 70 mJ	60 V	50A
RBA20-2P1	2 mm, YAG <sup>2</sup>	> 80 mJ	36V	95A
RBA25-3P5	3 mm, YAG <sup>1</sup>	> 100 mJ	54V	35A
RBA30-3P5	3 mm, YAG <sup>2</sup>	> 110 mJ	54V	60A
RBA30-2P1	3 mm, YAG <sup>2</sup>	> 120 mJ	36V	90A
RBA30-1P200	3 mm, YAG <sup>2</sup>	> 175 mJ	18V	175A
RBA30-3P1	3 mm, YAG <sup>2</sup>	> 200 mJ	54V	90A
RBA20-3P200	2 mm, YAG <sup>2</sup>	> 300 mJ	54V	175A
RBA30-4P200	3 mm, YAG <sup>2</sup>	> 400 mJ	72 V	170A

<sup>1</sup> Rod length is 83 mm with flat/flat faces and 0.6% Nd doping  
<sup>2</sup> Rod length is 63 mm with flat/flat faces and 0.6% Nd doping  
<sup>3</sup> Minimum pulse energy at 100Hz with a 250 μs drive current  
<sup>4</sup> Required voltage at the pump module.

**REA PowerPulse Modules**

Model	Rod Type	Output Energy <sup>5</sup>	Operating Voltage <sup>6</sup>	Peak Drive Current
REA5006-3P5	5 mm, YAG <sup>1</sup>	> 400 mJ	180 V	50A
REA5006-2P1	5 mm, YAG <sup>1</sup>	> 500 mJ	120V	95A
REA10008-2P1	10 mm, YAG <sup>2</sup>	> 725 mJ	160V	95A
REA7008-3P1	7 mm, YAG <sup>2</sup>	> 1J	240V	95A
REA6308-3P200	6.35 mm, YAG <sup>2</sup>	> 1.4J	240V	145A
REA10008-3P200	10 mm, YAG <sup>2</sup>	> 2.5J	240V	175A
REA10010-3P200	10 mm, YAG <sup>3</sup>	> 3.3J	300V	175A
REA10012-3P200	10 mm, YAG <sup>4</sup>	> 4J	360V	175A

<sup>1</sup> Rod length is 126 mm with flat/flat faces and 0.6% Nd doping  
<sup>2</sup> Rod length is 146 mm with flat/flat faces and 0.6% Nd doping  
<sup>3</sup> Rod length is 167 mm with flat/flat faces and 0.6% Nd doping  
<sup>4</sup> Rod length is 188 mm with flat/flat faces and 0.6% Nd doping  
<sup>5</sup> Minimum pulse energy at 100Hz with a 250 μs drive current  
<sup>6</sup> Required voltage at the laser module.

**Table 1.** Free running oscillator energy, operating voltage, and drive current for a selection of PowerPULSE™ models.

Several of the modules have been placed in q-switched resonators and their performance measured. An empirical relationship, depending upon cavity design, pump parameters, and choice of output coupler, can be established between the free running resonator energy and the q-switched resonator energy. This relationship can then be used to predict the output energy of the PowerPULSE™ modules in q-switched resonators from the free running resonator energy output.

## 2. PowerPULSE™ GAIN MODULES AS AMPLIFIERS

PowerPULSE™ gain modules are also ideally suited for use as laser amplifiers. Two important parameters for laser amplifier design are small signal gain and stored energy. The small signal gain is a unitless number that indicates how much a small (well below the saturation limit) signal will be amplified upon a single pass of the module. The stored energy indicates the amount of energy that can be extracted from the module given a sufficient number of passes or input signal saturation. Table 2 reports the small signal gain and stored energy numbers for a selection of gain modules.

As a general rule, for a given pump power, smaller rods have larger small signal gains and larger rods can store more energy. Consideration of depolarization (due to the stress induced on the rod) and gain uniformity (due to pump light distribution) also play important roles in selecting the proper gain module for each application.

### RBA PowerPulse Modules

Model	Rod Type	Small Signal Gain <sup>3</sup>	Stored Energy	Peak Drive Current
RBA20-2P5	2 mm, YAG <sup>2</sup>	37	75mJ	60A
RBA30-2P5	3 mm, YAG <sup>2</sup>	4.9	75mJ	60A
RBA35-2P5	3 mm, YAG <sup>1</sup>	8.2	100mJ	50A
RBA20-2P1	2 mm, YAG <sup>2</sup>	420	125mJ	95A
RBA25-3P5	3 mm, YAG <sup>1</sup>	130	100mJ	35A
RBA30-3P5	3 mm, YAG <sup>2</sup>	11	115mJ	60A
RBA30-2P1	3 mm, YAG <sup>2</sup>	12	120mJ	90A
RBA30-1P200	3 mm, YAG <sup>2</sup>	15	130mJ	175A
RBA30-3P1	3 mm, YAG <sup>2</sup>	45	180mJ	90A
RBA20-3P200	2 mm, YAG <sup>2</sup>	205	110mJ	65A
RBA30-4P200	3 mm, YAG <sup>2</sup>	320	270mJ	100A

<sup>1</sup> Rod length is 83 mm with flat/flat faces and 0.6% Nd doping  
<sup>2</sup> Rod length is 63 mm with flat/flat faces and 0.6% Nd doping  
<sup>3</sup> Minimum total small signal gain (G) at 100Hz, 250µs drive

### REA PowerPulse Modules

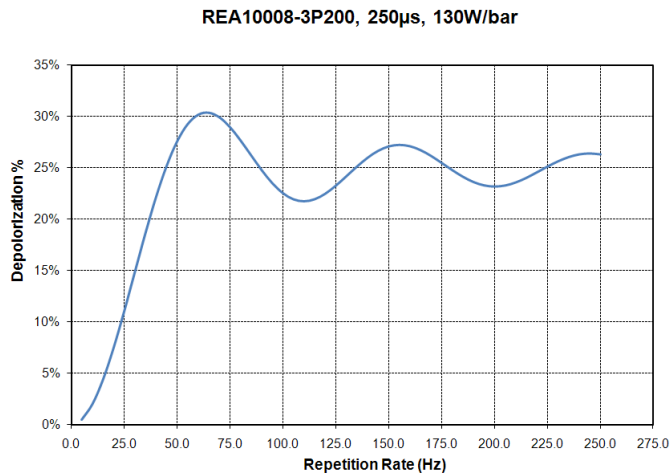
Model	Rod Type	Small Signal Gain <sup>5</sup>	Stored Energy	Peak Drive Current
REA5006-3P5	5 mm, YAG <sup>1</sup>	13	340mJ	50A
REA5006-2P1	5 mm, YAG <sup>1</sup>	24	420mJ	95A
REA10008-2P1	10 mm, YAG <sup>2</sup>	2.9	560mJ	95A
REA7008-3P1	7 mm, YAG <sup>2</sup>	26	840mJ	95A
REA6308-3P200	6.35 mm, YAG <sup>2</sup>	700	1350mJ	145A
REA10008-3P200	10 mm, YAG <sup>2</sup>	28	1740mJ	175A
REA10010-3P200	10 mm, YAG <sup>3</sup>	63	2170mJ	175A
REA10012-3P200	10 mm, YAG <sup>4</sup>	147	2600mJ	175A

<sup>1</sup> Rod length is 126 mm with flat/flat faces and 0.6% Nd doping  
<sup>2</sup> Rod length is 146 mm with flat/flat faces and 0.6% Nd doping  
<sup>3</sup> Rod length is 167 mm with flat/flat faces and 0.6% Nd doping  
<sup>4</sup> Rod length is 188 mm with flat/flat faces and 0.6% Nd doping  
<sup>5</sup> Minimum small signal gain at 100Hz, 250µs drive pulse.

**Table 2.** Small signal gain and stored energy for a selection of PowerPULSE™ modules.

### 3. DEPOLARIZATION

Depolarization due to stress induced in the rod of the gain module is very important for oscillator and amplifier design. The amount of depolarization is dependent on the heat dissipated by the rod, which is a function of the pump duty cycle. For a fixed pump pulse width and drive current, the amount of depolarization can be calculated as a function of repetition rate. Figure 1 shows the amount of total depolarization for a single pass of a typical gain module.



**Figure 1.** Depolarization as a function of repetition rate for a REA10008-3P200 operating at 250µs, 130A.

# Our Products



## Laser Diode Arrays

CEO® offers a full line of conductively cooled, water cooled or microchannel cooled laser diodes and stacks. Choose from our wide range of standard product offerings including Golden Bullet arrays for long pulse ( $>500 \mu\text{s}$ ) applications. Wavelengths from 780 – 1550 nm are available.



## CW Pumped Laser Modules

Our range of diode modules are an ideal 'pump engine' solution for OEM manufacturers of Diode Pumped Solid State (DPSS) lasers. They are available with a variety of gain media options (Nd:YAG, Nd:YLF, Nd:YVO<sub>4</sub> etc.). Output powers ranging from 20 W (TEM<sub>00</sub>) to 800 W (multi mode) are available.



## QCW Pumped Laser Modules

For high energy pulsed laser applications, CEO offers the PowerPULSE family of modules to deliver output energies up to 4 J per pulse and small signal gain in excess of 600. CTE matched, 'hard solder' laser diode packaging technology ensures long operating lifetimes.



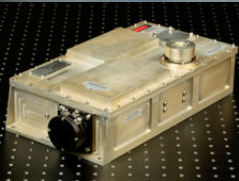
## Electronics & Support Equipment

Choose from CEO's complete line of proven and versatile OEM high powered diode drivers and laser system controllers along with all the support equipment needed to operate high power CW and QCW pump modules or other diode-based laser systems.



## Industrial Laser Systems

CEO offers industrial laser systems for micro-machining, marking, cutting, drilling, welding, soldering, and other industrial uses. These lasers utilize long-life diode pump sources to enable long laser lifetimes. Custom lasers can be built to a wide range of specifications.



## Military & Custom Lasers

CEO® offers complete custom laser design engineering and manufacturing services of diode pumped solid state lasers (DPSS), laser diode arrays and modules for military, aerospace and industrial OEM laser applications. CEO specializes in engineering systems that are required to operate in harsh rugged environments including military & civilian helicopters, fixed wing aircraft, ground vehicles, and submerged towed bodies.

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