

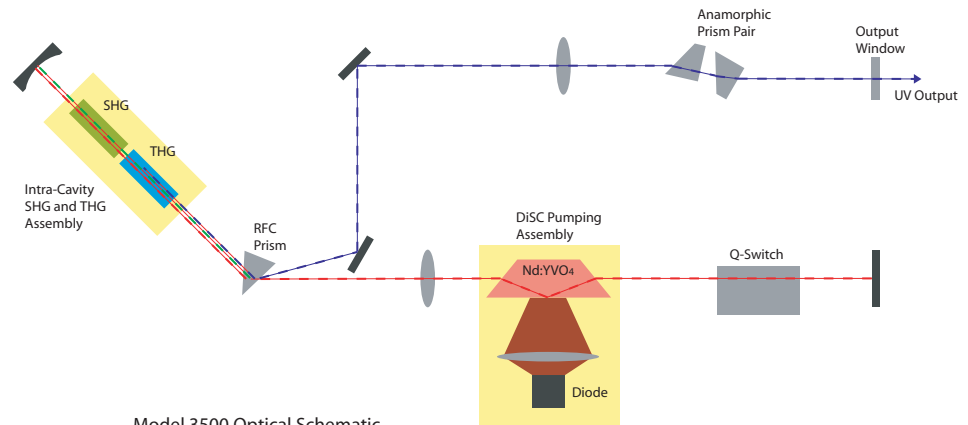
## Series 3500 Technology Sheet

### System Design

The Series 3500 DPSS laser (US Patent #6,002,695) is the most efficient, high power, quasi-CW DPSS UV laser commercially available. Using only a single 20W diode bar, the Series 3500 has demonstrated powers in excess of 3.0 Watts at 355 nm. This high efficiency conversion means that the laser can be operated at the normal specification, with minimum stress to the optical components and with a reduced diode current to extend the operating life. Minimizing the diode power required to generate the 355nm third harmonic output from the laser also minimizes the thermal effects in the gain medium (Nd:YVO<sub>4</sub>), which results in the lowest possible distortion to the beam. Both the second and third harmonics are generated intra-cavity, thus reducing the need for tight focusing into the non-linear crystals. The result is a stable, high power UV laser with an  $M^2$  specification of  $< 1.2$ , a near perfect TEM<sub>00</sub> mode.

### High Average Power

The high power capability of the Series 3500 is a result of a unique combination of efficient design criteria - in the diode pumping scheme, intra-cavity harmonic generation and low loss extraction of the 355nm pulses.



Model 3500 Optical Schematic

### Efficiency of Direct Side Coupled (DiSC™) Diode Pumping

DPSS Lasers, Inc. has pioneered the use of DiSC pumping of the gain medium to achieve the highest efficiencies and average power levels currently available in high repetition rate UV DPSS lasers. Unlike fiber coupled designs, the DiSC geometry minimizes the diode laser power losses, while ensuring the best possible overlap between the diode pump beam and the fundamental 1064nm cavity mode. Using a proprietary DiSC geometry, the Series 3500 achieves an unparalleled  $> 15\%$  peak conversion efficiency from the diode to the final UV output of the laser. Due to the high conversion efficiency, the diodes are operated at typically only 60-80% of rated power to achieve the UV output power specification, dramatically increasing the life of the diode, and eliminating the need for the frequent diode replacements found in fiber coupled systems.

### Efficient Intra-Cavity Harmonic Generation

By performing second harmonic and sum frequency generation inside the cavity where the power is approximately 20 times higher than outside, it is possible to increase the efficiency of conversion by an order of magnitude compared with other commercial high repetition rate UV DPSS lasers. Instead of using all of this excess power capability, the Series 3500 is designed to spread the power conversion process over a larger volume of the nonlinear crystals, increasing the lifetimes of the optical components in the laser and reducing beam distortion, while maintaining a factor of three to five times higher power output than competing system designs.

## Near Defraction Limited Beam

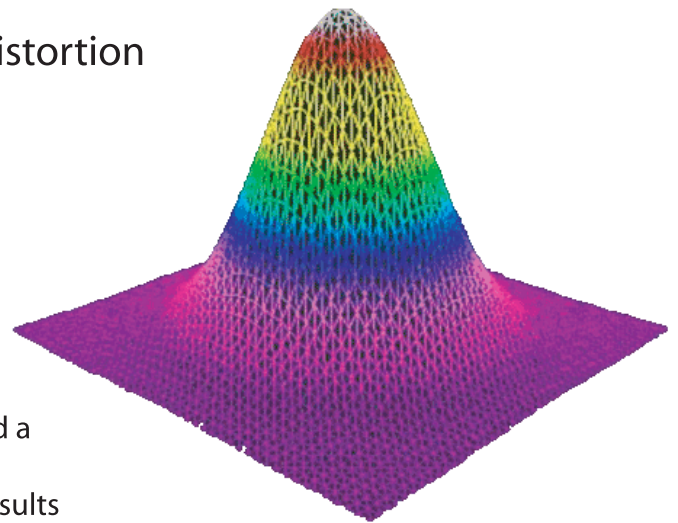
In most applications it is the ability to focus the laser to a small region, rather than just the overall power, which determines the effectiveness of the laser process. The beam quality of a laser is described by  $M^2$ , for which the lowest possible value of 1.0 (a diffraction limited beam, often called TEM<sub>00</sub> when referring to a cavity mode) describes a perfect Gaussian beam. A beam with an  $M^2$  value of  $N$  ( $N > 1.0$ ), will produce a focus region with  $N$  times larger diameter than that for a diffraction limited beam. The Series 3500 laser produces a near defraction limited beam ( $M^2 < 1.2$ ), making it an excellent choice for tight focus applications.

## DiSC Pumping--Gain Confined Mode Control on the Fundamental

The DiSC pumping scheme results in a gain profile in the fundamental wavelength which is closely matched to the TEM<sub>00</sub> mode of the laser cavity. The result is not only a high conversion efficiency from the diode power to the fundamental, but also a near perfect TEM<sub>00</sub> mode. As the THG beam quality can be no better than the fundamental, it is extremely important to optimize the fundamental mode of the laser before introducing any harmonic processes.

## Intra-Cavity Harmonic Generation Reduces Distortion

Due to the limited acceptance angle of harmonic and sum frequency generation in nonlinear crystals, the tight focusing angle of the fundamental beam into the crystals, used in extra-cavity harmonic generation to produce a higher harmonic conversion efficiency, results in distortion of the 355nm output beam. The beam inside the nonlinear crystals of the Series 3500 is more collimated and utilizes a larger volume of the crystals than that of extra-cavity designs. The result is less distortion and a reduced  $M^2$  value. In addition to distortion, the beam undergoes walk-off during the nonlinear process which results in an elongated Gaussian profile from the harmonic assembly. Walk-off is compensated for, using anamorphic prisms located inside the laser head, resulting in a round beam profile (see optical model illustration) at the output. The final UV output beam of the Series 3500 is circular to within 10% and has a typical  $M^2$  of  $< 1.2$



## Stability

In addition to the power and beam quality, stability is an important characteristic for all laser systems. The stability of the 3500 is defined in terms of the short term (pulse-to-pulse) energy stability, and the long term (quasi-CW) power stability. In general, the short term behavior is determined primarily by the design of the system, whereas the long term behavior is the result of the sensitivity of the laser to the environment. As with most laser systems, users will see the best stability when the laser is operated in a temperature controlled environment.

## Pulse to Pulse Energy Stability

All Series 3500 systems have a pulse-to-pulse energy stability specification of <10%. As the average pulse energy is dependent on the repetition rate of the laser, the pulse-to-pulse energy stability specification applies to a specific (user-defined) repetition rate.

## Maintenance

The Series 3500 DPSS laser is designed to operate completely hands-off in a commercial environment. The head is sealed against airborne contaminants, eliminating the need for optics cleaning or alignment. As with all laser systems, there will be a long term loss of power due to diode laser fade and other optics deterioration. Eventually, lasers will require refurbishing at the factory. DPSS Lasers Inc. offers annual service contracts on all models which ensures that users can plan and budget for scheduled maintenance.

## Control and Operation

Control and operation of the Series 3500 is extremely simple. All control functions are contained within the power supply. Three push buttons on the front of the power supply control the main power switch, STANDBY, LASER ON, AND Q-SWITCH settings. The laser head is hermetically sealed at the factory, with the optics permanently aligned and locked.

## Remote Control of Q-Switch

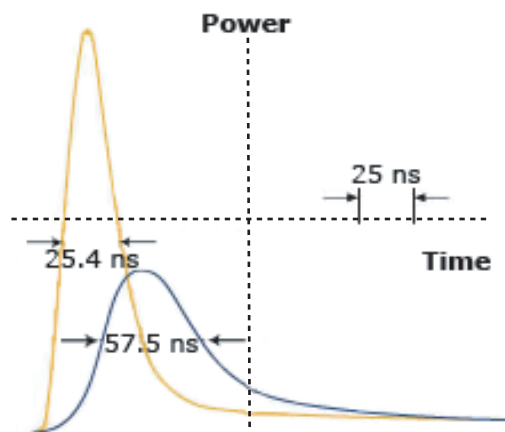
All Series 3500 lasers are Q-Switched using an acousto-optic Q-switch, and include first pulse suppression. Individual lasers are optimized at the predetermined pulse repetition rate for each model number. The control functions are available through external ports at the back of the power supply. During normal operation, the only external control available to a user is the Q-Switch "gate" which allows the laser to be turned on and off at the preset pulse repetition rate. The external Q-Switch gate control accepts a standard 5V TTL input, in either toggle or enable mode.

## Cooling System

The laser head is cooled using a small, closed circuit, solid state chiller. Water flows under the laser head in contact with the base plate to provide a reference temperature for the internal control elements.

## CW Power Stability--Drift

Solid state lasers operate at a single specified power level for best stability. Over a long period of time the power will decline as a result of the gradual "fade" of the pump diode. This is typically over many thousands



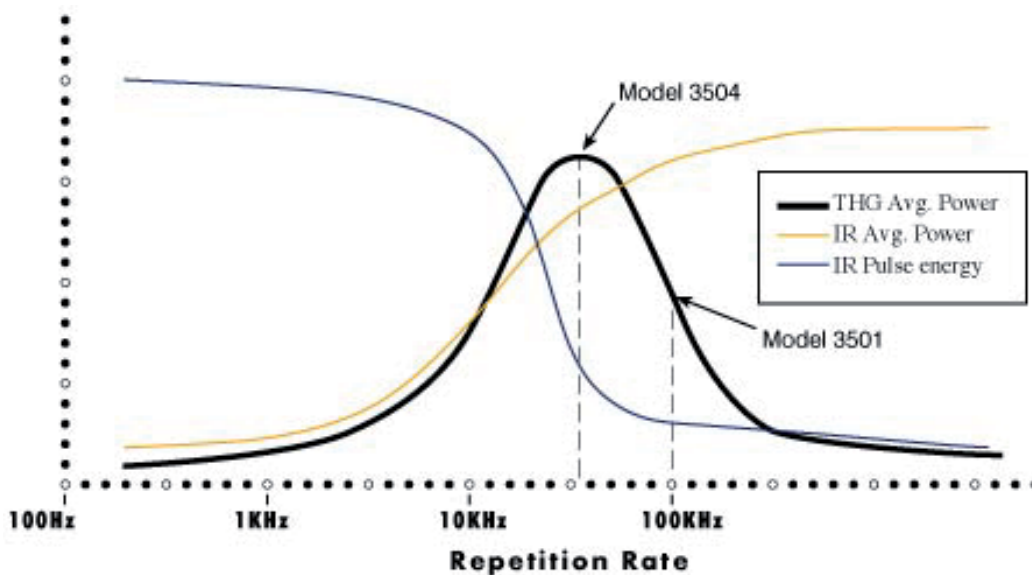
Typical Pulse Width of UV Output at 30 kHz and 100 kHz

of hours, and is not measurable during routine operation. The fade associated with the Series 3500 is especially slow as the diodes are typically driven below their rated specification. Superimposed on the long term fade is the power drift, which is typically a function of the local temperature. The Series 3500 has an inherent power drift of less than +/- 5% over an 8 hour period when operated in a stable environment.

## Power as a Function of Repetition Rate

As in all Q-Switched solid state lasers, the average output power and pulse energy are a function of the Q-Switch frequency. The figure below indicates schematically the form of both the fundamental and 355nm output power for repetition frequencies from single shot to 100 kHz.

Series 3500 lasers use a Nd:YV04 gain medium in which the highest average UV power occurs at approximately 25 kHz. At high repetition rates, an increase in the pulse width of the fundamental contributes to an accelerated decline in the UV pulse energy. For this reason, few DPSS lasers have significant UV power at high Q-Switched frequencies. The power capability and stable fundamental mode at high Q-Switched frequencies, a result of DiSC pumping, allow the Model 3500 to achieve repetition rates up to 150 kHz at >1.0 Watt average power.



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