**High Energy** Pulsed Nd:YAG Lasers

Litron Lasers

## High Energy Nd:YAG lasers for industry and research.

**Spectroscopy**
**Remote Sensing**
**Photochemistry**
**Non-Linear Optics**
**OPO Pumping**
**Ablation**
**PIV**
**ESPI**
**LIDAR**
**LIBS**
**LIF**

The LPY600/700 series of pulsed Nd:YAG lasers have been designed to suit almost any industrial of research application in which a high-energy or high-specification Nd:YAG laser is required. Based around a fully self supporting invar rail the LPY600/700 series exhibit both exceptional mechanical and thermal stability. A 'no-compromise' design approach is evidenced in the build quality, a parameter that sets these lasers well apart from any of their competitors.

The modular design of the laser head allows a wide variety of resonator configurations to be offered, from single rod oscillators to fully birefringence compensating twin-rod-oscillator, twin-rod-amplifier systems. Furthermore, a choice of stable, stable-telescopic or unstable Gaussian-coupled resonators is available, allowing the customer to specify a system that suits their requirements.

Harmonic generation and separation assemblies are fully integrated onto the invar rail and therefore require no user alignment.

With a choice of power supplies, q-switched outputs of up to 3J are available and output repetition rates of up to 200Hz.

## MECHANICAL

The invar rail provides the basis for all of the LPY600/700 series laser heads. It is a fully self supporting structure and is extremely stable. The fact that it is self supporting means that all components are mounted on the rail, as opposed to other arrangements where only the mirrors are mounted on a rail which is in turn mounted on a breadboard that holds all of the other components. Clearly the latter is far less robust. A self supporting invar structure has been well proven as a basis for industrial laser systems, yielding the strength, stability and reliability that is necessary for such applications. The completely modular structure provides the ideal basis for a scientific system as the resonators are 'field-reconfigurable', allowing for example a telescopic resonator to be re-configured as a Gaussian-coupled resonator. Such features, coupled with the ease of operation and integration set the LPY600/700 series of lasers apart.

At the heart of the laser system is the pumping chamber. The correct design of this is crucial for good beam quality.  The pumping chamber is machined from 316 surgical grade stainless steel, and houses a pair of close coupled ceramic reflectors. The pumping chamber is thermally decoupled from the resonator resulting in good thermal stability even at high flashlamp power loadings. The ceramic reflectors allow very uniform pumping of the laser rod, and as a direct consequence exceptional output beam quality. Other aspects of beam quality, such as pointing stability are affected by the efficiency with which the laser rod is cooled. By ensuring the laser rod is cooled before the flashlamp, and by ensuring a large turbulent flow over the laser rod, the pulse to pulse stability and the pointing stability of the LPY600/700 series are amongst the best available. Also the serial flow ensures very uniform cooling of the laser rod and flashlamp, leading to a longer flashlamp life, as there are no voids in the cooling as are commonly seen in parallel flow arrangements, where flashlamps may even distort due to extreme localised heating.

De-ionised water is corrosive, the cooling system therefore comprises entirely of hard plastic or stainless steel parts which are totally inert to de-ionised water. As a result there is no risk of contamination from the cooling system compromising laser performance, and further there is no need to worry about draining or running the laser system should it stand idle for protracted periods of time. An easily changeable de-ioniser cartridge is standard on all power supplies. The cooling system in all of the power supplies is a closed loop with a water to air heat exchanger. This means that the entire laser system is totally self contained with no need for an external coolant supply.

## OPTICAL

Optically the KD*P pockels cell is mounted in a fully sealed housing, eliminating any possibility of crystal damage due to moisture or dirt. All optics are coated with hard dielectric coatings that have extremely high damage thresholds. The diffuse cavity reflectors are arranged to give the highest pump uniformity of the laser rod, and therefore the best beam quality.

In any optical system, inevitably there is the need to periodically clean the optics. To this end, all optics are fully demountable for cleaning. Alignment of the laser system is by two adjustable mirror mounts that can be firmly locked in place. Whilst cleaning of the optics and system alignment should not normally be necessary, the design of the system allows the customer to undertake such procedures quickly and easily, without the need for any expensive service visits or protracted periods of down time.

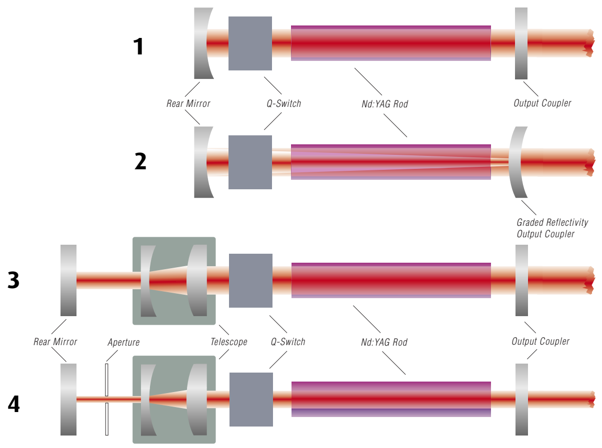
## STABLE RESONATOR

**A** stable resonator provides the most flexibility in terms of output energy and repetition rate, as both parameters can be varied with no effect upon the alignment of the system. In general, the output of such systems is multi-mode. With the addition of an intra-cavity aperture, a TEM00 output can easily be realised, but at the expense of overall efficiency.

## GAUSSIAN OPTICS

In a gaussian system, graded reflectivity mirrors are used, and form part of an unstable resonator. Such systems give a high energy single transverse mode with a low beam divergence. However this optical configuration does have drawbacks. The thermal lens formed by the laser rod is part of the optical arrangement. Such systems will therefore only work properly at one repetition rate, when the thermal loading on the laser rod is constant. As a direct result of this, the laser is factory set at one pulse repetition frequency and output energy. The repetiton rate can be divided by 2, 4, 8 or 16 by means of the repetition rate divide control. The output energy on a Gaussian-coupled system is adjusted by varying the q-switch delay.

In a system fitted with gaussian optics, the pulse length tends to be shorter than in a conventional stable resonator. This increases the peak power density that is seen by the resonator optics and subsequently by any beam handling optics that may be used.




*Schematics showing oscillator design.*
*1) Stable*
*2) Gaussian*
*3) Telescopic Multimode*
*4) Telescopic $TEM_{00}$*

## TELESCOPIC RESONATOR

**T**o obtain high energy, low divergence beams, the preferred method is the use of a telescopic resonator. In this configuration, an intracavity telescope is used to reduce the beam diameter in the rear leg of the resonator. This has the effect of making the resonator appear longer, increasing the losses in the higher order modes, leading to a superior output beam with very low divergence. With no adjustment at all, the laser can be adjusted over a wide range of pulse energies and repetition rates, whilst maintaining a high quality, low divergence beam. With slight adjustment to the telescope (a simple procedure) the full range of energies and repetition rates from single pulse to the maximum can be achieved. For high energy $TEM_{00}$ beams, an intracavity aperture can be fitted behind the telescope. Varying the sizes of these apertures allow output beams that are to within 15% of the diffraction limit to about 3.5 times the diffraction limit. That is from an almost pure gaussian $TEM_{00}$ to full energy in a uniform spatial profile. The output from a telescopic resonator is longer and smoother temporally, making it the system of choice for pumping dye lasers or OPO's. Such arrangements, by virtue of the longer pulse length are much less prone to optical damage.

## TWIN ROD OSCILLATORS

**T**he twin rod oscillator design compensates for the strain birefringence in the rod, which becomes a problem at very high output energies or very high repetition rates and with large diameter laser rods.

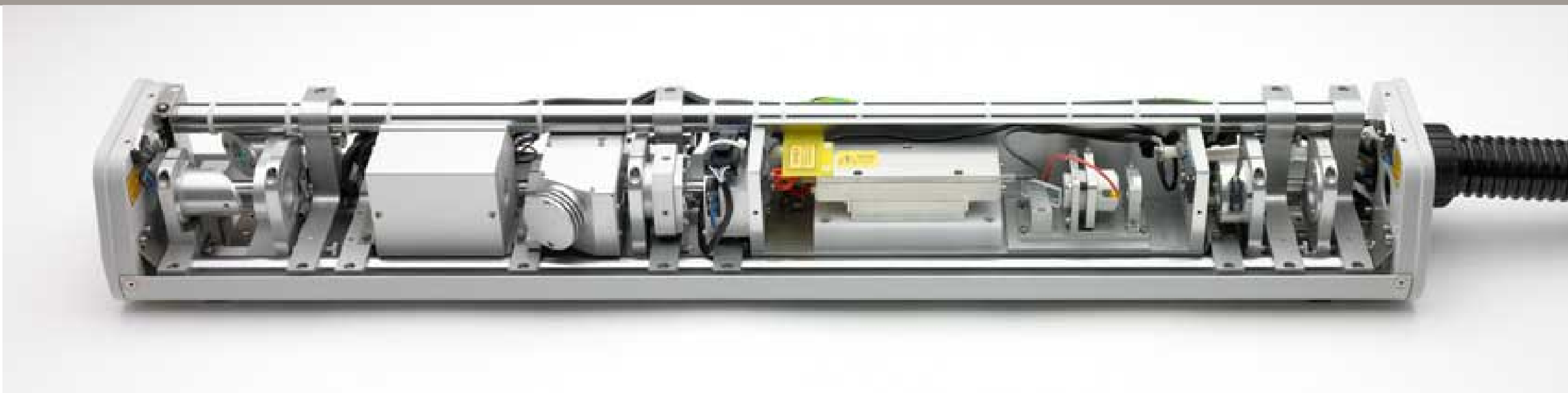
In a laser with just one oscillator rod, as the beam propagates the thermally-induced strain-birefringence will cause the beam passing through the rod to become partially de-polarised. The degree to which this depolarisation occurs depends upon the strain-birefringence, which is in turn a function of the mean flashlamp pump power. Therefore at higher output energies the depolarisation increases. The light whose polarisation has been changed will be rejected by the intra-cavity polariser. This leads to a loss in efficiency and a less uniform beam.

In a twin-rod oscillator, the beam exiting the first laser rod is passed through a 90° rotator before passing through the second laser rod. As the beam passes through the second rod, the birefringence is in the opposite sense, this has the effect of returning the beam to its original polarisation. Therefore almost no light is rejected by the polariser. This leads to a more uniform beam and a higher efficiency. This is the best way of efficiently extracting large amounts of stored energy from the laser rods.

## OSCILLATOR AMPLIFIER SYSTEMS

**I**n order to generate high energy beams of more than 1000mJ, or to generate lower energy outputs at high repetition rates, the use of an amplifier stage can be employed. An oscillator amplifier is advantageous over a single high energy oscillator for several reasons. In a single oscillator, the energy that can be extracted is governed by the q-switch hold off, parasitic oscillations and amplified spontaneous emission. In an amplified system, the oscillator is not usually run at its maximum output (as dictated by the maximum stored energy of the laser rod), therefore the peak powers are lower through the cavity optics and pockels cell, leading to longer life and more reliable service.

A range of both single-rod and twin-rod amplified systems allow fundamental outputs of up to 3J per pulse and repetition rates of up to 200Hz.



The LPY600/700 series have been designed with quality as the prime constraint. Implicit in this is the production of a reliable, rugged, user friendly system that will work continuously with no need for anything other than standard routine maintenance. Some of the more important design aspects of the LPY600/700 series are as follow.

INVAR RAIL

The invar rail is the basis for all of the laser heads in the LPY600/700 series. It provides an extremely rugged, thermally stable base upon which a multitude of options can be built.

PUMPING CHAMBER

The most important requirement for high beam quality, both in terms of spatial profile and pointing stability is that the pumping chamber is designed properly. Litron's pumping chambers are machined from solid 316 grade stainless steel. They contain two extremely close coupled diffuse ceramic reflectors, which give rise to a totally uniform pumping of the laser rod, something not achieved with elliptical specular reflectors. The laser rod and the flashlamp are separated by a tough ionic glass filter that totally absorbs all of the UV radiation emitted by the flashlamp, such radiation is of no use in pumping the laser rod, but can damage the rod over a period of time. The result of such a design is a system that will work reliably for many years with no problems. The flashlamp can be removed and replaced within 5 minutes, with no need for optical realignment at all.

Q-SWITCH ASSEMBLY

The Q-switch in LPY600/700 series are KD*P. The crystal is totally sealed within a rugged housing and immersed in an index matching fluid. Such a design of Pockels cell is well proven and it has the added benefit of protecting the hygroscopic KD*P from any moisture that it may encounter during the flashlamp change procedure, or if the laser head is uncovered in a humid laboratory. Avalanche transistors are used to switch the necessary quarter wave voltage onto the crystal, and this can be achieved at repetition rates of up to 1kHz with electronic jitter of <500ps with respect to the direct access trigger input.

Holdoff is achieved by means of a polariser and a quarter waveplate. Horizontally polarised light incident upon the quarter waveplate is circularly polarised, upon reflection from the rear mirror, there is a 180° phase shift, changing the sense of the circular polarsation. Upon passing back through the quarter waveplate the light is vertically polarised and is rejected by the polariser, giving hold off. During the flashlamp pulse, a quarter wave voltage is applied to the Pockels cell at the peak population inversion and the Pockels cell and quarter waveplate form an effective half wave plate. This is double passed, with the polarization returned to horizontal at the polariser, thus allowing pulse build up. An advantage of this method, over using the Pockels cell itself as a quarter waveplate (by biasing it and then removing the voltage at the peak inversion), is that there is no chance of post-lasing as the bias voltage is applied to the Pockels cell for only 1-2μs.

## MIRROR MOUNTS

The mirrors are held in aluminium mounts connected to a bracket that also serves to tie the invar bars together. Adjustment is made by two fine pitch ball ended screws giving independent horizontal and vertical adjustment, making alignment very easy. The mirrors can be firmly locked in position, eliminating any risk of the alignment changing. For gaussian optics the graded reflectivity output coupler is mounted in a precision x – y mount.

## ELECTRONIC SAFETY SHUTTER

All models feature a solenoid driven safety shutter. This shutter automatically closes when the laser turns off, therefore when it is started up the shutter will be closed. This makes the laser safer when used in a laboratory. As a further safety measure, the position of the shutter is monitored by the system control. Should the actual position of the shutter and the required position of the shutter not be in agreement the laser will automatically turn off.

**A** range of options and accessories are available, either at the time of purchase or for retro-fitting.

HARMONIC GENERATION AND SEPARATUION

Frequency generation of the 2nd, 3rd, 4th and 5th harmonics is offered. All harmonics on the LPY600/700 series are fully temperature controlled. The harmonic crystals and dichroic separation optics are all fully mounted on the invar rail, negating the need for any user alignment. The 5th Harmonic is separated by means of a pair of pellin-broca prisms.

LINE NARROWING

Line narrowing etalons allow the linewidth of the laser output to be reduced, leading to increased coherence lengths. In a stable resonator, the use of an output coupling etalon gives a linewidth of about 0.3cm$^{-1}$ and an additional intra-cavity etalon will reduce the linewidth to about 0.06cm$^{-1}$.
In an unstable Gaussian-coupled resonator an intracavity etalon will reduce the linewidth to about 0.15cm$^{-1}$.

INJECTION SEEDING

With the addition of an injection seeder output linewidths of 0.001cm$^{-1}$ are possible.

VARIABLE OPTICAL ATTENUATION

In certain circumstances where the pump energy and repetition rate of the laser system are fixed (eg in a gaussian resonator), adjustment of the laser output energy may be necessary. For this reason a variable optical attenuator is offered as an option on all of our laser systems. By the use of a half wave plate and polariser, the axial beam energy can be varied. The residual energy can either be dumped safely or utilized in some way.

Additionally a varible optical attenuator is useful if the temporal profile of the pulse needs to be maintained at different output energies. As the pump intensity is reduced, the gain of the laser rod decreases, this leads to a longer q-switched pulse at lower energies. By keeping the output at a given level, and using a variable optical attenuator, all pulses will be temporally of similar length.

MECHANICAL AND OPTICAL MOUNTS

A range of mechanical mounts to attach the laser to an optical table and optical mounts such as steering mirror mounts are available, giving the user maximum flexibility in handling and using the laser output. All accessories are designed to interface with standard optical tables. Optical breadboards of up to

600mm x 600mm with M6 holes on a 25mm pitch along with a complete range of optical mounts to facilitate the users experimental setup can be purchased from Litron, either with a laser system or as accessories.

## ENERGY MONITORING

Litron manufactures a comprehensive range of laser energy monitors. These are photodiode based instruments and allow extremely accurate analysis and measurement of laser performance. Unlike conventional energy measurement devices, Litron's range of monitors can measure every pulse from the laser system, rather than averaging the energy as many calorimetric devices do. This leads to unrivalled accuracy and flexibility of measurements. Typically the pulse to pulse measurement repeatability of these devices is better than 0.2%. The damage threshold of these energy monitors is extremely high, as the optics train scatters rather than absorbs the light. The input optic is ground fused silica, and is arranged such that easy removal is possible should it be damaged for any reason.

All energy monitors feature a bright 4 digit display and an RS232 output, which allows datalogging of the laser performance. A comprehensive software suite is provided as standard. For further information on Litron's range of energy monitors please refer to the specific data sheets.

*Litron's range of photodiode laser energy monitors, with 30mm and 50mm input apertures allow accurate measurement of laser performance.*

# **Stable Telescopic Resonators** Range Specification

All LPY7xx series systems feature a birefringence compensating twin rod oscillator design.
The LPY6xx series are single rod oscillators / oscillator-amplifiers

| **Model** | | **LPY704** | **LPY706** | **LPY664** | **LPY674** | **LPY764** | **LPY604T** | **LPY642T** |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Condition** | | | | | | **$TEM_{00}$ output** | |
| Pulse energy at wavelength (mJ)[2] | | | | | | | | |
| 1064nm | Up to 10Hz | 400 | 650 | 850 | 1000 | 1250 | 80 | 350 |
| 532nm | | 200 | 325 | 425 | 500 | 625 | 40 | 150 |
| 355nm | | 80 | 100 | 150 | 180 | 225 | 20 | 70 |
| 266nm | | 50 | 75 | 95 | 110 | 125 | 15 | 40 |
| 1064nm | Up to 20Hz | 380 | 600 | 800 | 850 | 1000 | 70 | 300 |
| 532nm | | 190 | 300 | 400 | 425 | 500 | 35 | 100 |
| 355nm | | 70 | 90 | 130 | 150 | 140 | 15 | 50 |
| 266nm | | 45 | 65 | 75 | 80 | 90 | 10 | 30 |
| **Beam Dia. (mm)** | Nominal | 6.4 | 8 | 8 | 9.5 | 8 | 6.4 | 6.4 |
| **Power supply unit** | Up to10Hz | LPU1000 | LPU1000 | LPU2000 | LPU1000 | LPU2000 | LPU350 | LPU1000 |
| | Cooling system | Air | Air | Water | Water | Water | Air | Air |
| | Up to 20Hz | LPU1000 | LPU1000 | LPU2000 | LPU2000 | LPU2000 | LPU1000 | LPU2000 |
| | Cooling System | Air | Water | Water | Water | Water | Air | Air |

| **Parameter** | **Condition** | **Wavelength (nm)** | **All Models** |
|---|---|---|---|
| Pulse width (ns) | Nominal ±2ns | 1064 | 6 to 13 |
| | | 532 | 5 to 12 |
| | | 355 | 5 to 11 |
| | | 266 | 5 to 10 |
| Energy stability (±%) | | 1064 | <2 |
| | | 532 | <4 |
| | | 355 | <6 |
| | | 266 | <10 |
| Beam divergence (mrad) | Fullangle for >90% of energy | | 0.8 |
| $M^2$ (Focussability) [5] | | 1064 | <3.5 |
| Linewidth ($cm^{-1}$) | No line-narrowing | 1064 | <1 |
| | With Etalons [1] | 1064 | <0.06 |
| | With Seeder [2] | 1064 | <0.003 |
| Pointing stability (µrad) | Full angle | | <70 |
| Timing jitter [3] | w.r.t direct access | | <500ps |
| Lamp life (pulses) | | | 10 million |

*Notes*
*(1) Insertion loss due to etalon is <20%.*
*Energy stability is reduced by up to a factor of 2*
*(2) Inserion loss of seeder is about 10%.*
*Third harmonic output is increased by about 20%*
*(3) Timing jitter with seeder is <1ns*
*(4) Please specify required voltage at time of order*
*(5) $M^2$ of $TEM_{00}$ systems is <1.3.*

| **Services** | |
|---|---|
| Electrical Supply [4] | Single phase<br>220-250VAC 50/60Hz or 100-120VAC 50/60Hz |
| Water Supply<br>(Where necessary) | <20˚C, >2bar |

Our policy is to improve the design and specification of our products. The details given in this brochure are not to be regarded as binding.

## **Gaussian Coupled Resonators** Range Specification

All LPY7xx series systems feature a birefringence compensating twin rod oscillator design.
The LPY6xx series are single rod oscillators / oscillator-amplifiers

| **Model** | | **LPY704G** | **LPY706G** | **LPY707G** | **LPY674G** | **LPY764G** |
|---|---|---|---|---|---|---|
| **Parameter** | **Condition** | | | | | |
| Pulse energy at wavelength (mJ)[2] | | | | | | |
| 1064nm | Up to 10Hz | 400 | 650 | 800 | 1000 | 1250 |
| 532nm | | 200 | 325 | 400 | 550 | 625 |
| 355nm | | 90 | 100 | 150 | 260 | 300 |
| 266nm | | 50 | 70 | 90 | 100 | 120 |
| 1064nm | Up to 20Hz | 380 | 600 | 725 | 850 | 1000 |
| 532nm | | 190 | 300 | 350 | 425 | 500 |
| 355nm | | 70 | 90 | 110 | 150 | 140 |
| 266nm | | 45 | 65 | 75 | 85 | 90 |
| **Beam Dia. (mm)** | Nominal | 6 | 8 | 9.5 | 9.5 | 9.5 |
| **Power supply unit** | Up to10Hz | LPU1000 | LPU1000 | LPU1000 | LPU2000 | LPU2000 |
| | Cooling system | Air | Air | Air | Water | Water |
| | Up to 20Hz | LPU1000 | LPU1000 | LPU1000 | LPU2000 | LPU2000 |
| | Cooling System | Air | Water | Water | Water | Water |

| **Parameter** | **Condition** | **Wavelength (nm)** | **All Models** |
|---|---|---|---|
| Pulse width (ns) | | 1064 | 6 to 9 |
| | | 532 | 5 to 7 |
| | | 355 | 4 to 6 |
| | | 266 | 3 to 5 |
| Energy stability (±%) | | 1064 | <2 |
| | | 532 | <4 |
| | | 355 | <6 |
| | | 266 | <10 |
| Beam divergence (mrad) | Fullangle for >90% of energy | | 0.5 |
| $M^2$ (Focussability) | | 1064 | <2 |
| Linewidth ($cm^{-1}$) | No line-narrowing | 1064 | <1 |
| | With Etalons [1] | 1064 | <0.15 |
| | With Seeder [2] | 1064 | <0.003 |
| Pointing stability (µrad) | Full angle | | <70 |
| Timing jitter [3] | w.r.t direct access | | <500ps |
| Lamp life (pulses) | | | 10 million |

*Notes*
*(1) Insertion loss due to etalon is <20%.*
*Energy stability is reduced by up to a factor of 2*
*(2) Inserion loss of seeder is about 10%.*
*Third harmonic output is increased by about 20%*
*(3) Timing jitter with seeder is <1ns*
*(4) Please specify required voltage at time of order*

| **Services** | |
|---|---|
| Electrical Supply [4] | Single phase<br>220-250VAC 50/60Hz |
| Water Supply | <20˚C, >2bar<br>None for LPY604G - LPY606G |

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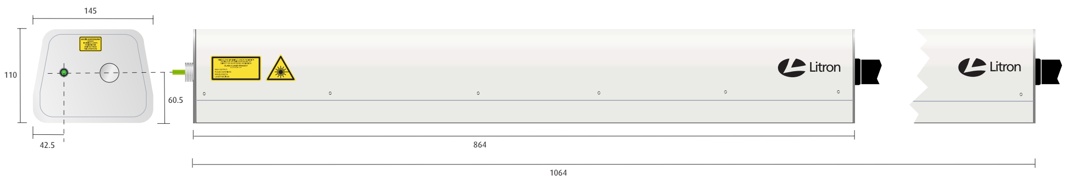
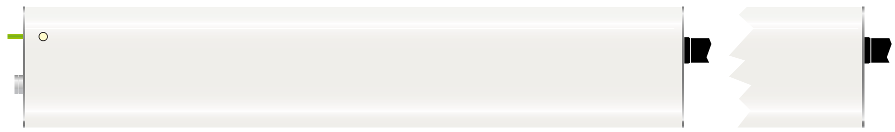
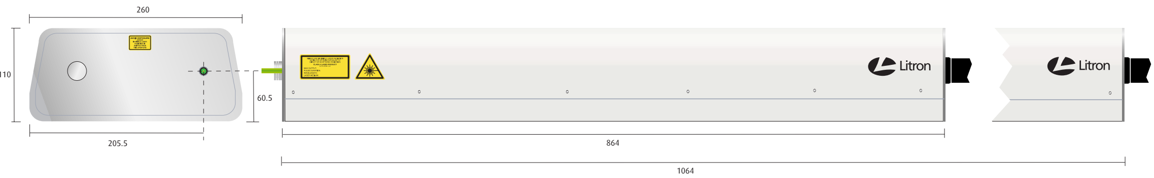
## The Litron High Energy Pulsed Nd:YAG laser range

All dimensions in mm.

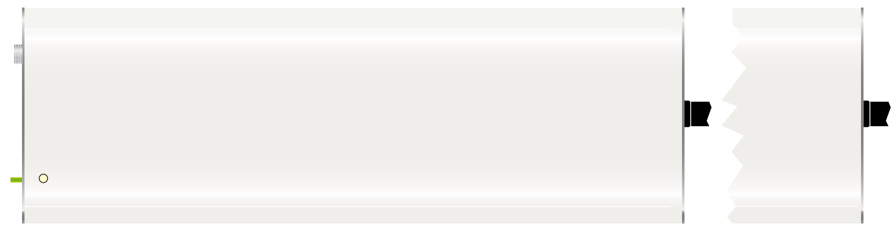


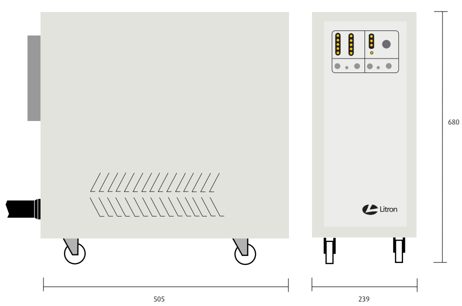

**LPY Single rail laser head arrangement**



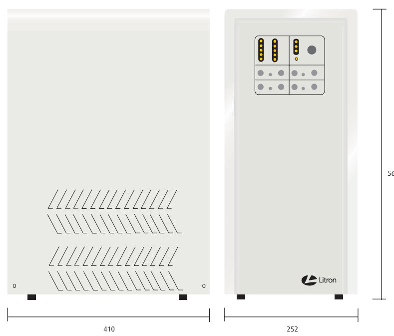



**LPY Twin rail laser head arrangement**

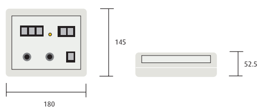




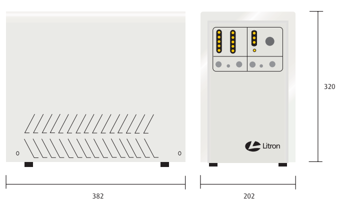

**LPU1000 power supply unit**



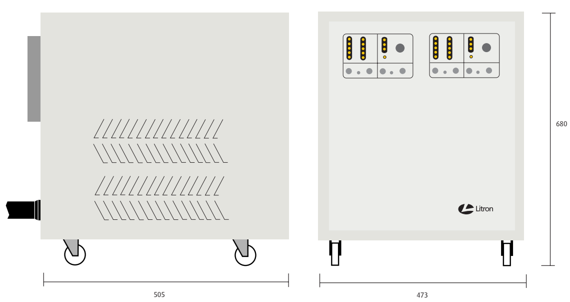

**LPU550 PIV power supply unit**



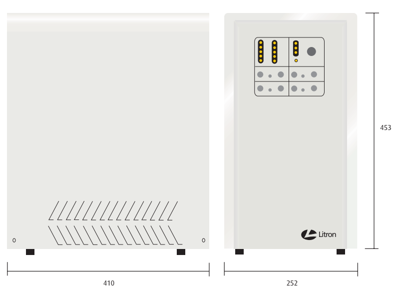

**Remote control unit**



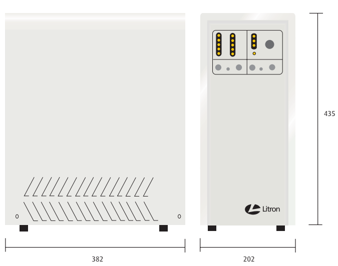

**LPU250 power supply unit**




**LPU1200 PIV power supply unit**




**LPU450 PIV power supply unit**




**LPU350 power supply unit**

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