Review of the DUNE-SP Ionization Laser System initial design

2020 September 16

Title: ioLaser System Laser Box Update

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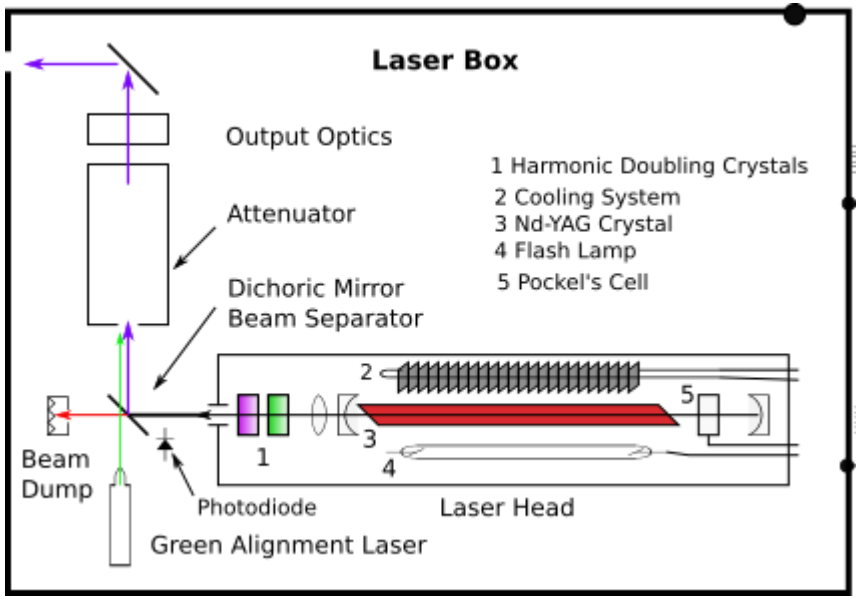


ioLaser System “Laser Box”

Function

The Laser Box contains the laser and optical system that delivers high power (60mJ/pulse), 5ns wide, < 6mm dia. Gaussian-beam profile, 266nm light at up to 10 pulses per second. These pulses provide for efficient ionization of Lar via multiphoton excitation processes. The Laser Box has an attenuator to control the intensity of the 266nm light and an optical aperture (an iris) to define the beam area.

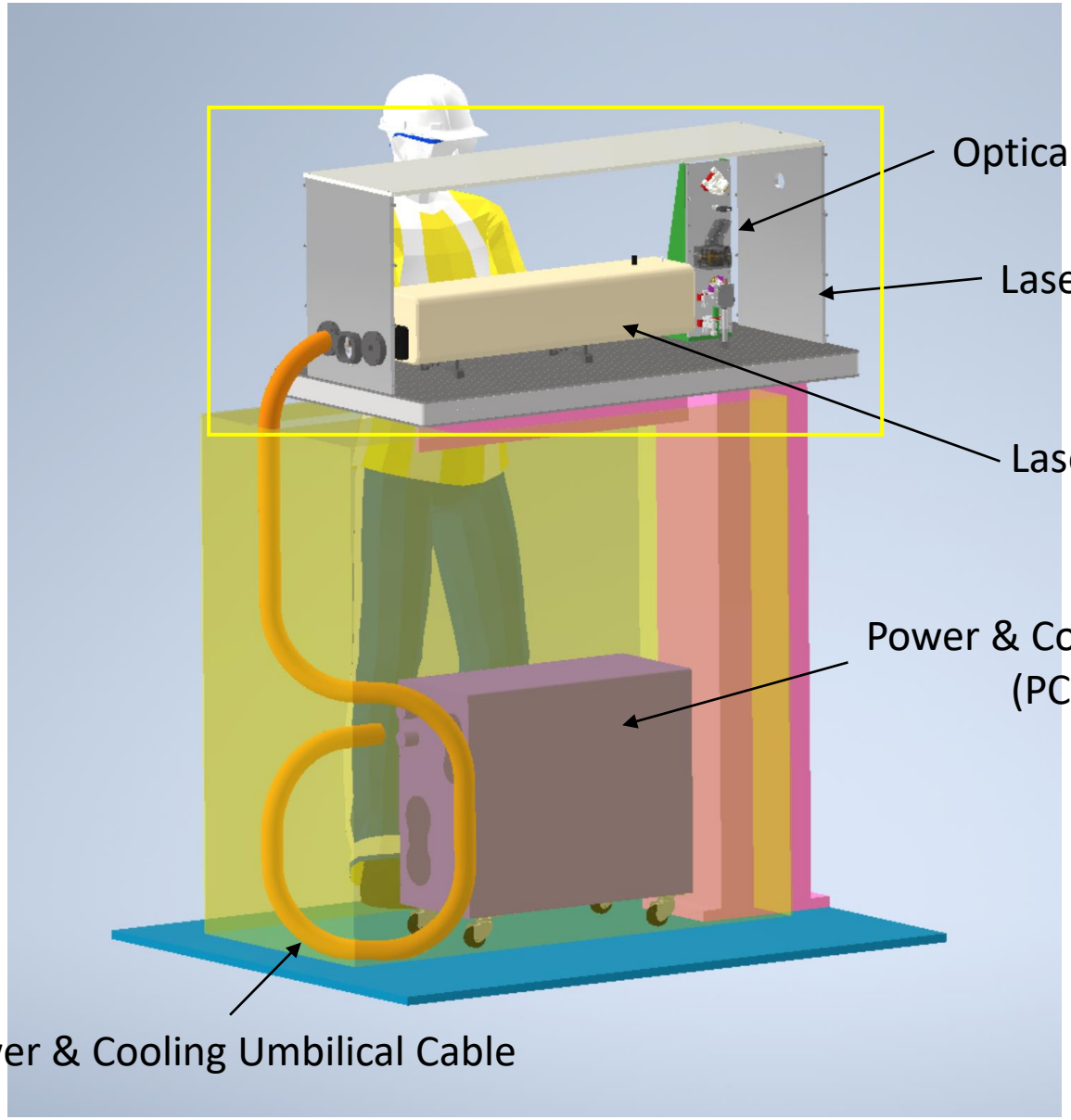
Purposes

Mechanically the Laser Box is an aluminum and steel box that encloses the laser head, an optical bench, beam monitor photodiode, and data networking equipment.
The box provides a hermetic enclosure for the laser beams (necessary for our Class IV UV pulsed laser) and to meet safety requirements.
The box is a Faraday Shield to protect the Detector from any EMI generated by the laser’s pulsed power systems.
The box provides a rigid mounting plate for the optical components.

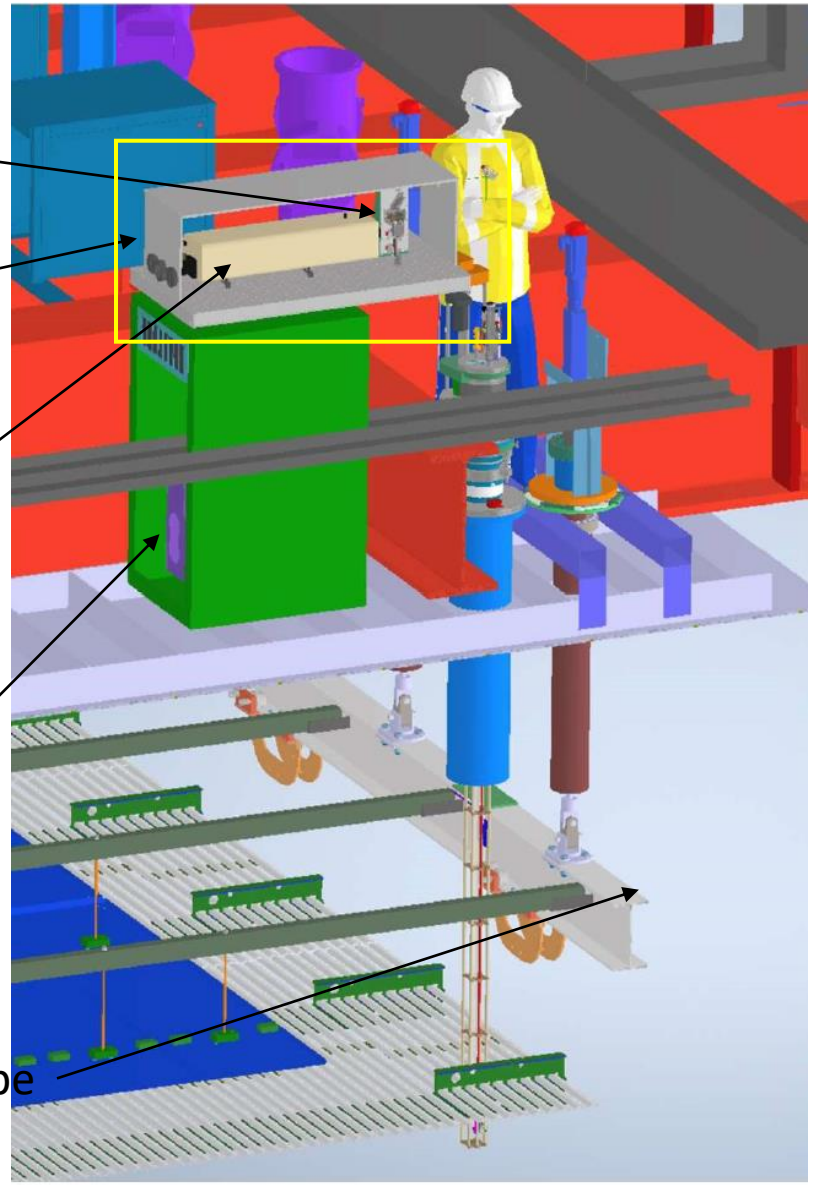
The Laser Box is connected to a Laser Power and Cooling Unit that supplies the pulse power, high voltage triggers (for the Q-switch in the laser head), heater current, and LVDC and control signals to the laser head. Additional LVDC and control and monitor signals are connected from the Laser Box to the ioLaser Electronics Rack.

Details of these sub-systems are presented in this talk.

Ionization Laser Layout on Top of the Detector Cryostat



ioLaser System



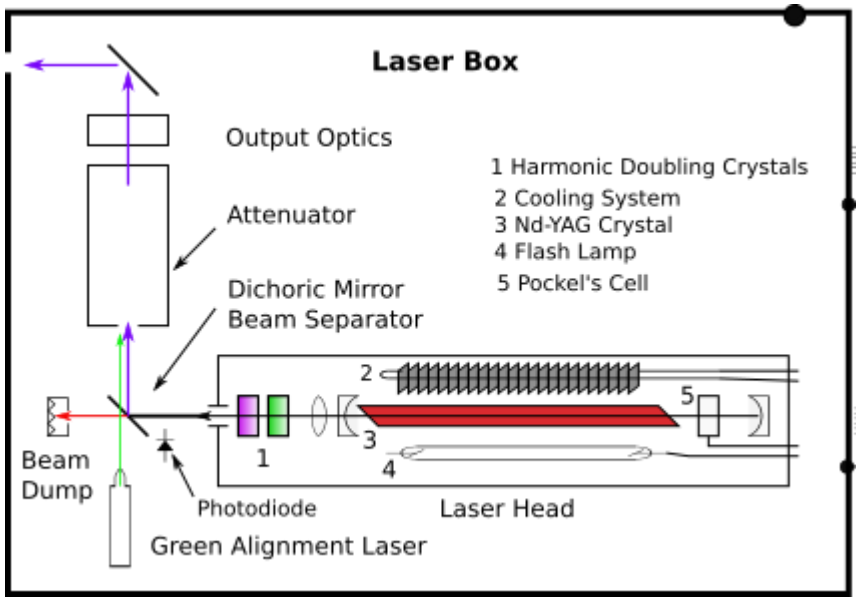
ioLaser System on Top of Cryostat at ProtoDUNE-II

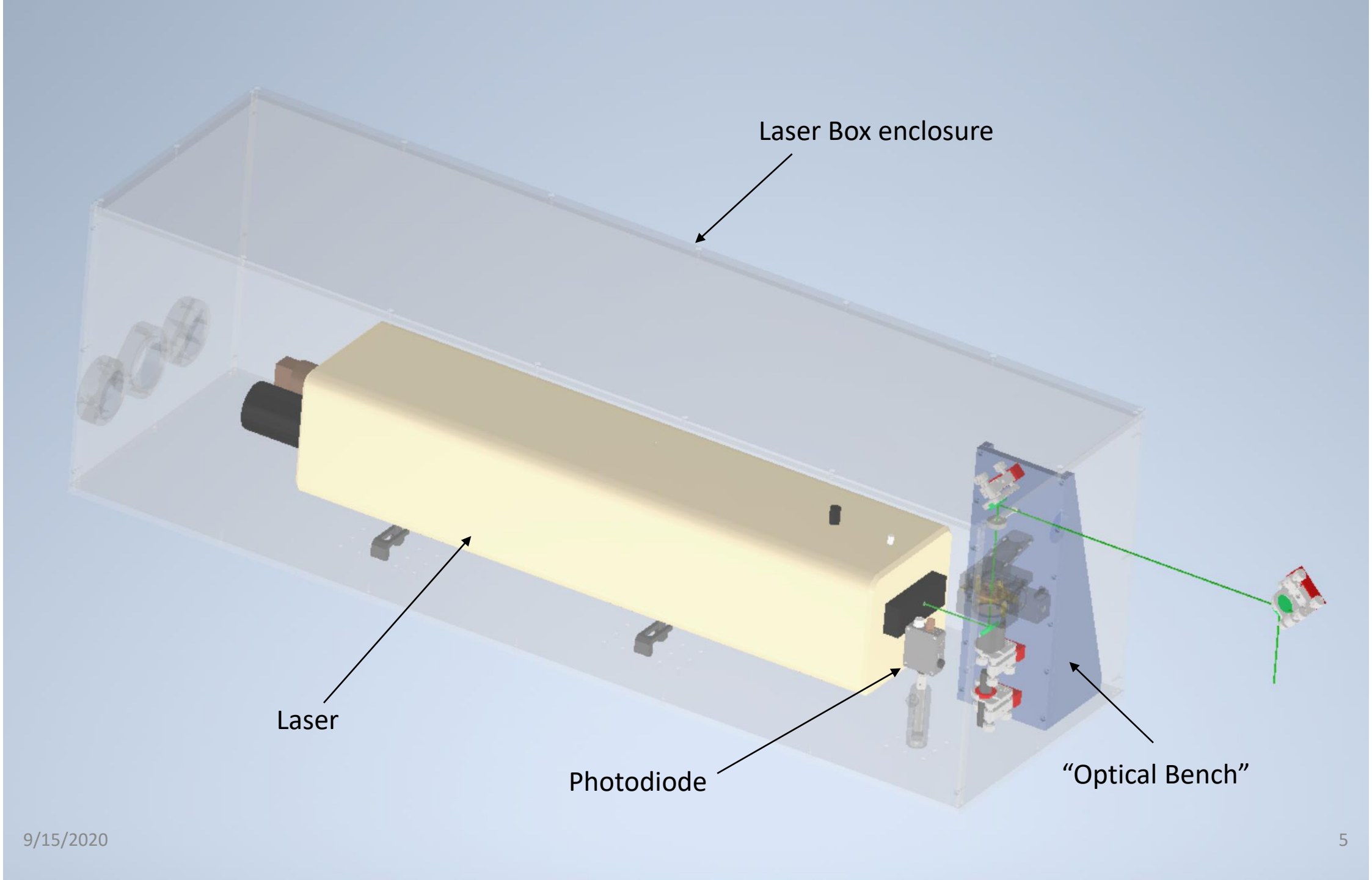
Ionization Laser Box Update

Purpose:
Provides a mechanically rigid enclosure to mount the laser head and the optical bench

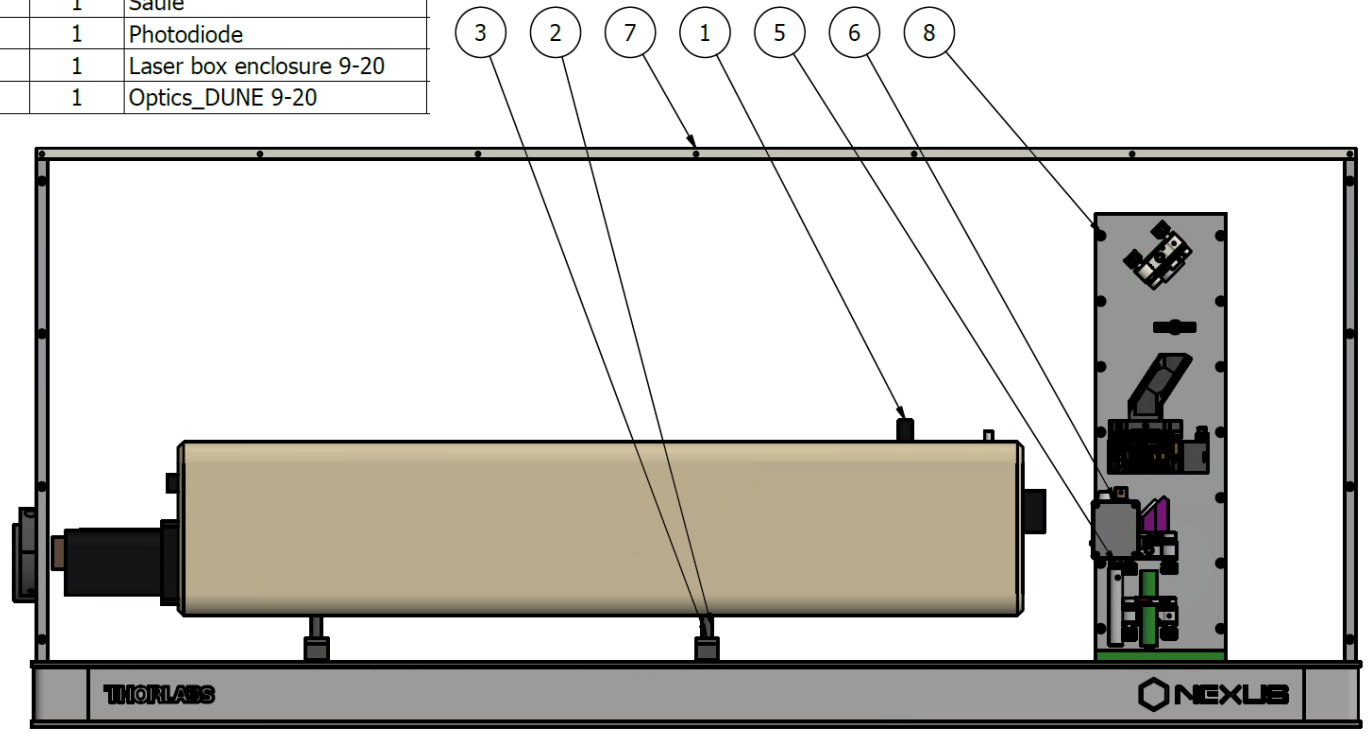
The laser box contents:

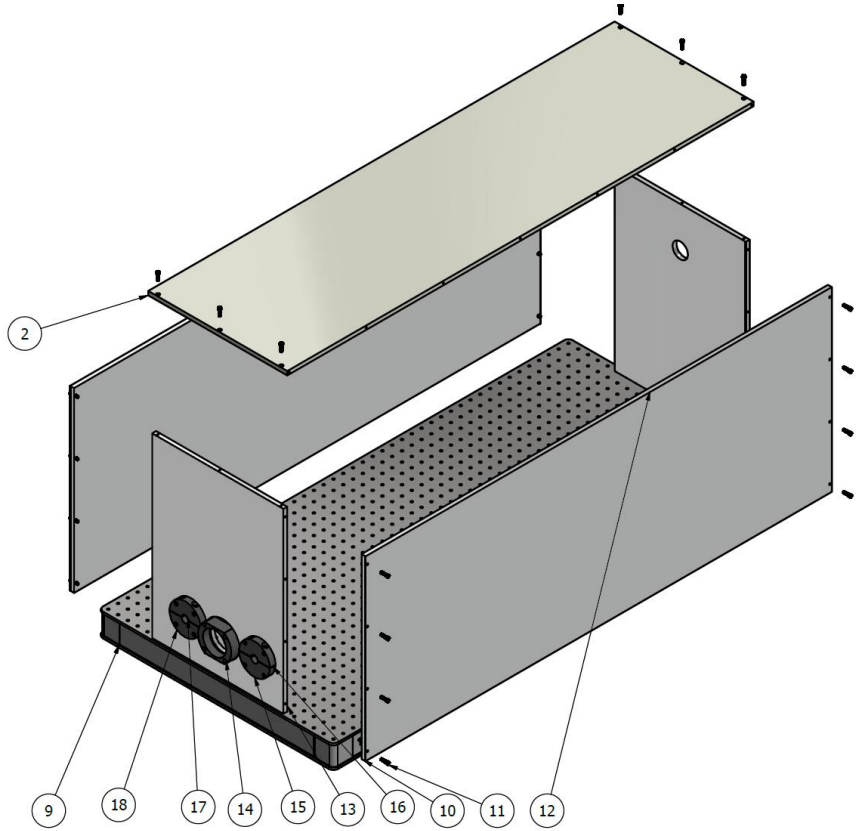
- A Nd:YAG laser head
- Optical bench to mount optical components:
  - A dichoric mirror (M1) to separate the 266nm light
  - An attenuator, Altechna's "Watt Pilot
  - An iris and related optical beam forming elements
  - A photodiode to supply a TPC-independent trigger signal.
  - A low-power green alignment laser, aligned with the UV laser
  - Top steering mirror (M2)
- A Faraday cage to provide electromagnetic shielding




Laser Box enclosure
Laser
Photodiode
“Optical Bench”

ITEM	QTY	PART NUMBER
1	1	Laser
2	4	Laserfuss
3	4	Laserfixwinkel
4	1	Distanzbock
5	1	Säule
6	1	Photodiode
7	1	Laser box enclosure 9-20
8	1	Optics_DUNE 9-20



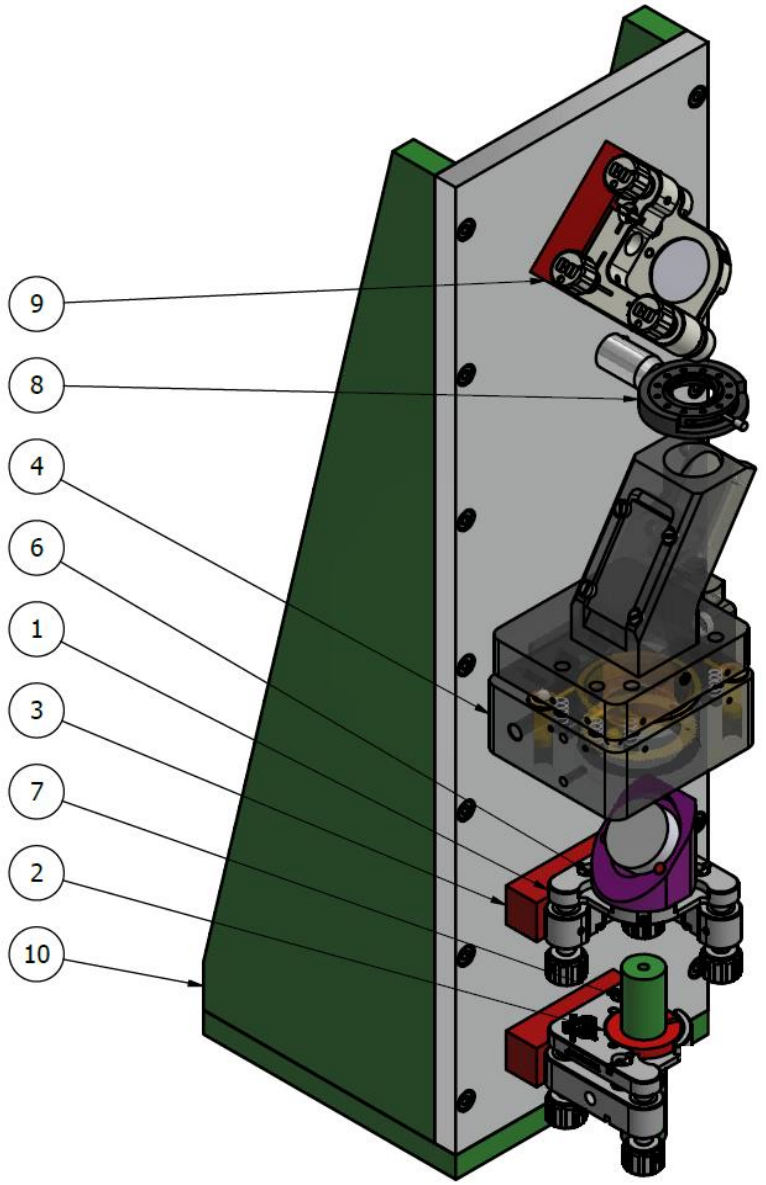


ITEM	QTY	PART NUMBER
2	1	laser box top
9	1	B2448F-Step
10	2	laser box side plate
11	22	91292A118_TYPE 18-8 SS SOCKET HEAD CAP SCREW
12	1	laser box front plate
13	1	laser box rear plate
14	1	laser box cable strain relief C
15	1	laser box cable strain relief B
16	1	laser box cable strain relief A
17	1	laser box cable strain relief D
18	1	laser box cable strain relief E

ioLaser “Laser Box”

ioLaser Optical Bench

ITEM	QTY	PART NUMBER
1	2	EO-Verstellung
2	1	Spannring
3	2	optics mount spacer block DUNE
4	1	attenuator
5	10	91292A118_TYPE 18-8 SS SOCKET HEAD CAP SCREW
6	1	mirror A subassy 9-20
7	1	alignment laser green
8	1	Thorlabs ID20 w mount
9	1	mirror top assembly
10	1	Optics frame DUNE 9-20

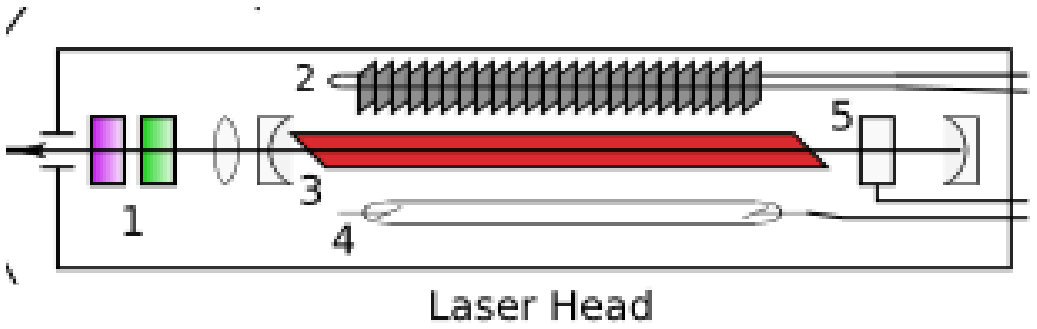


Laser Box Enclosure

- The laser box enclosure will be made of aluminum. When in operation all beams will be fully enclosed.
- The beams coming out of the box and reaching the periscope will be fully enclosed by an aluminum laser beam pipe.
- Any maintenance or alignment adjustments that will require opening the box during installation, commissioning, or operations will follow class-IV laser safety rules and personnel involved will have corresponding training and appropriate PPE.

Amplitude/Continum Laser “Surelite I-10”

Power from PCU through “Umbilical” cable



Laser Head

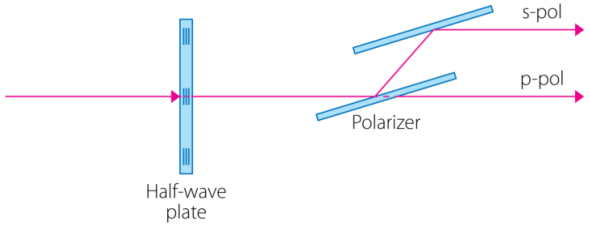
Inside Laser Head:

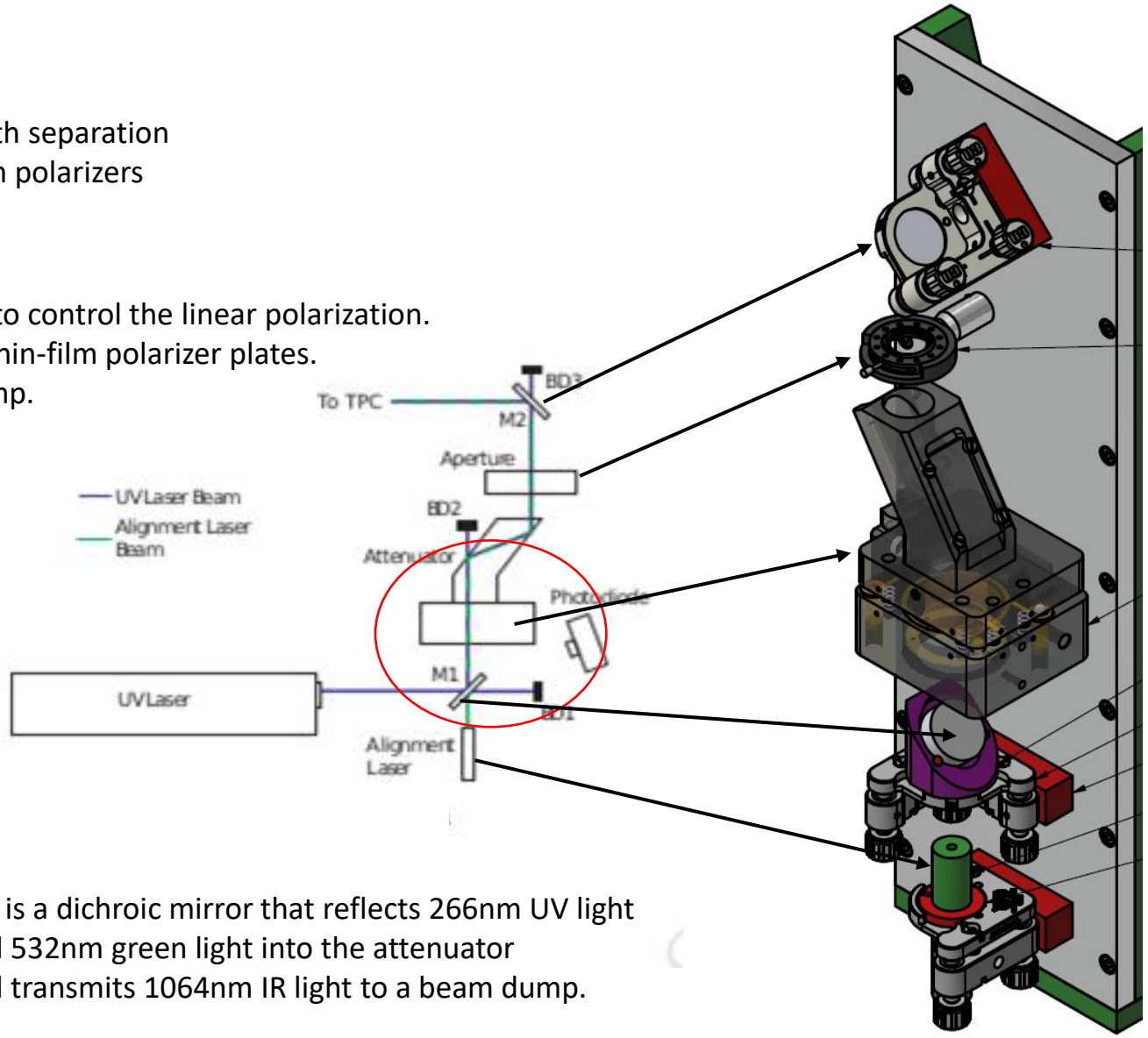
1. KDP Crystal Harmonic Doublers
2. Water Cooling (flash lamp & NdYAG)
3. Nd-YAG Crystal
4. Linear Flash Lamp
5. Q-Switch Pockel’s Cell &Gaussian-beam forming Optics

ioLaser Optical Bench

- Dichroic Mirror provides beam wavelength separation
- Beam Intensity Attenuation with thin-film polarizers

Inside the attenuator:
A stepper motor rotates a half- lamda waveplate to control the linear polarization.
The p-polarized light reflects off of the Brewster thin-film polarizer plates.
The s-polarized light is transmitted to a beam dump.





M1 is a dichroic mirror that reflects 266nm UV light
and 532nm green light into the attenuator
and transmits 1064nm IR light to a beam dump.

Vendor Identification and Procurement

- A Surelite I-10 laser has already been procured and delivered to LANL.
- The Watt Pilot Attenuator from Altechna is the choice for the attenuator and is on order.
- Dual-band dielectric mirrors, reflecting at both 266 nm and 532 nm (greenish), are available in the market and are our current choice for all the mirrors in the laser's path (except the harmonic separator).
- Vendor selections for other optical components of the laser box are being finalized and will most likely follow MicroBooNE.

Mirrors and Optical Elements

- The reflectivity at 266 nm of the dichroic mirror ≥ 95%.
- The combined transmission of the optical elements in the laser optical path shall be higher than 50%. The laser beam intensity is expected to be 60 uJ, six times higher than required for ionization. A transmission of 50% still allows for a reasonable margin.

Supplemental Material

ioLaser Optical Bench

ITEM	QTY	PART NUMBER
1	2	EO-Verstellung
2	1	Spannring
3	2	optics mount spacer block DUNE
4	1	attenuator
5	10	91292A118_TYPE 18-8 SS SOCKET HEAD CAP SCREW
6	1	mirror A subassy 9-20
7	1	alignment laser green
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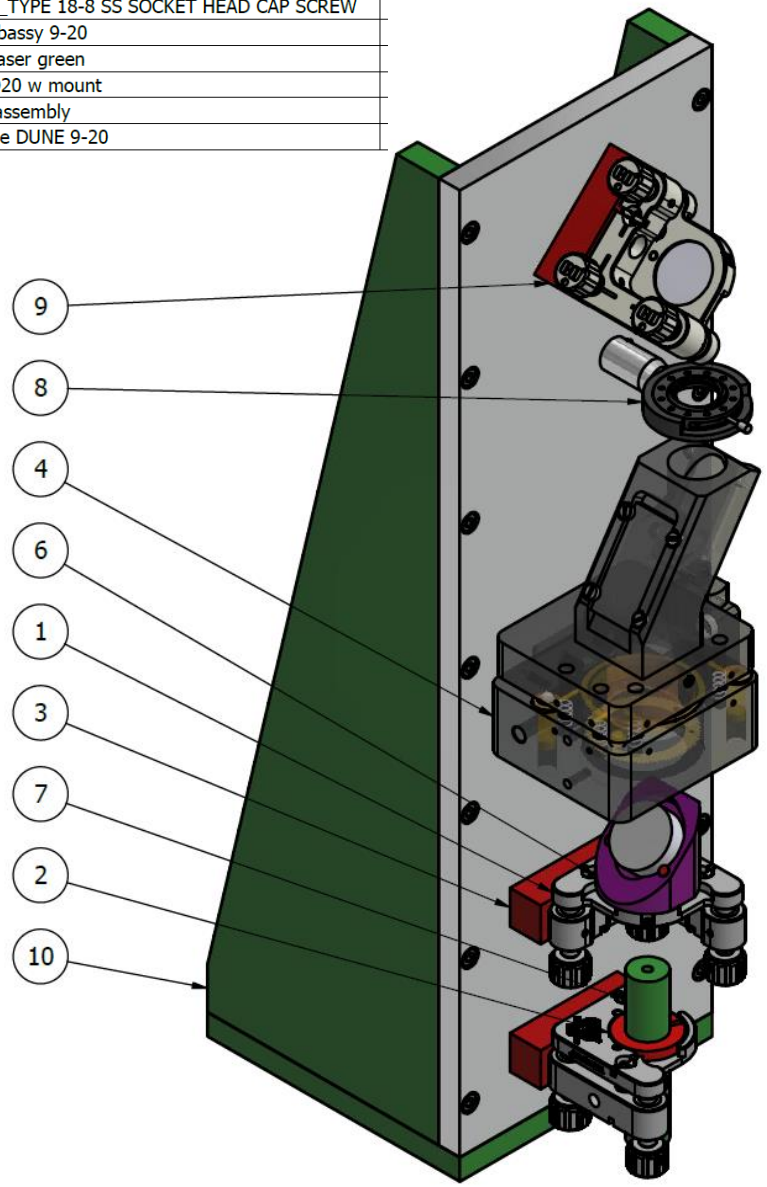
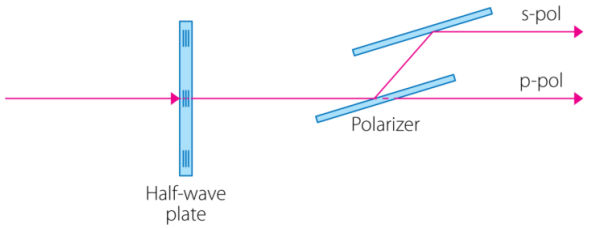




Attenuator Operation

Watt Pilot - Motorized Attenuator Enhanced Version

Product ID: EWP-R-0266

Clear aperture, mm: Ø18

Recommended maximum input beam diameter at $1/e^2$, mm: Ø12

Wavelength, nm: 266 (±5)

Attenuation range, Tmin - Tmax: 0.3-99%

Configuration: λ/2 Optically bonded waveplate + 2 x TFP

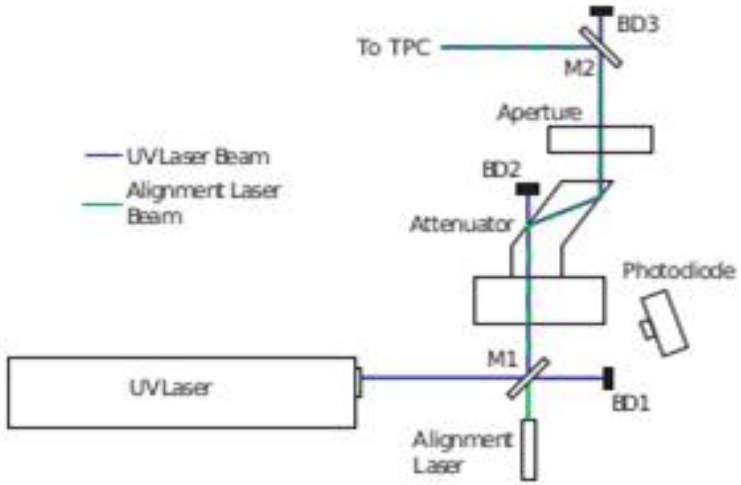
Optimization: Reflection

Open - close time, sec: <3

Resolution, arcsec/step: <42

Laser induced damage threshold: >1 J/cm^2 @ 266 nm; 10 ns; 10 Hz

Dimensions H x L x W, mm: 63 x 108 x 91



SURELITE™ FEATURES & BENEFITS

RS-232 or TTL interface for remote or local operation

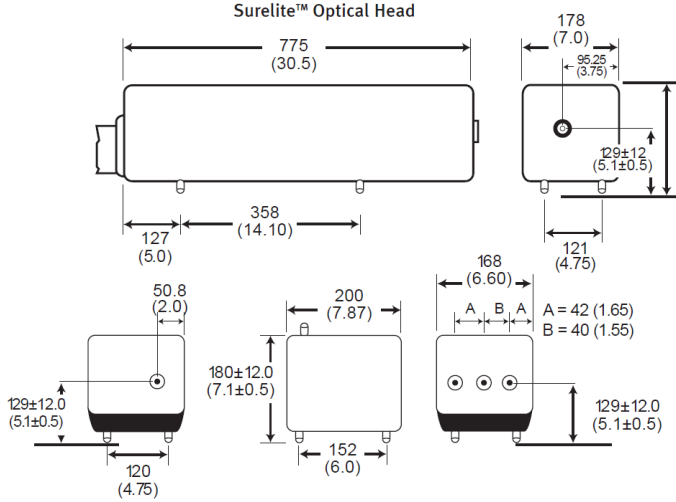
Water to air heat exchanger eliminates the need for external water cooling

Gaussian optics incorporated to provide low divergence and high spatial uniformity in beam

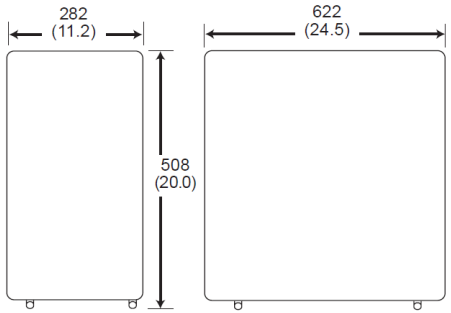
Graphite resonator structure ensures long-term therma' and mechanical stability

Size	Optical Head (L x W x H)	775 x 178 x 190 mm (30.5 x 7.0 x 7.50 in.)
	Power Supply (L x W x H)	622 x 282 x 508 mm (24.5 x 11.20 x 20.0 in.)
Weight	Optical Head	24 kg (52 lbs)
	Power Supply	44 kg (96 lbs)
Water Service		Closed loop water to air heat exchanger: external cooling water not required (1 gal deionized water)
Electrical Service		220/240 V, single Φ, 10 A
		208 V, single Φ, 10 A
Room Temperature		18.3 to 29.4°C (60 to 85°F)

Surelite™ Optical Head

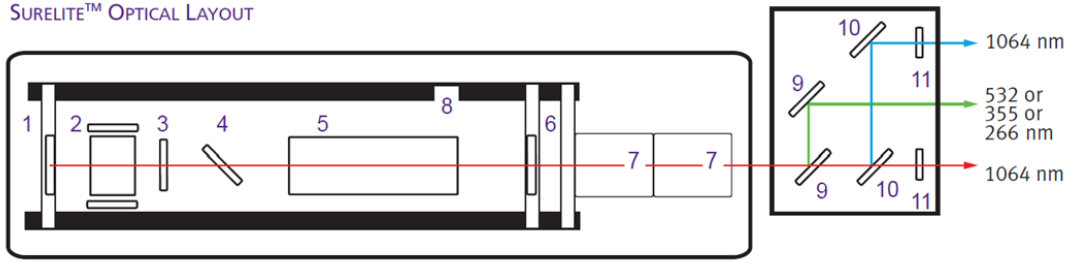


Surelite™ Electronics



DESCRIPTION	I-10
Repetition Rate (Hz)	10
Energy (mJ)	
1064 nm	450
532[1] nm	200
355 nm	65/100[2]
266 nm	60
Pulsewidth[3] (nsec)	
1064 nm	5-7
532 nm	4-6
355 nm	4-6
266 nm	4-6
Linewidth (cm^{-1})	
Standard	1
Injection Seeded[4]	0.005
Divergence[5] (mrads)	0.6
Rod Diameter (mm)	6
Pointing Stability (±μrads)	30
Jitter[6] (±ns)	0.5
Energy Stability[7] (±%)	
1064 nm	2.0; 0.7
532 nm	3.5; 1.2
355 nm	4.0; 1.3
266 nm	7.0; 2.3
Power Drift[8] (±%)	
1064 nm	3.0
532 nm	3.0
355 nm	3.0
266 nm	6.0
Beam Spatial Profile[9]	
Near Field (<1 m)	0.70
Far Field (∞)	0.95
Deviation from Gaussian[10]	
Near Field (<1 m)	30

SURELITE™ OPTICAL LAYOUT



1. Rear Mirror
2. Pockels Cell
3. λ/4 Plate
4. Dielectric Polarizer
5. Oscillator Rod
6. Gaussian Output Coupler
7. Optional Harmonic Generators
8. Graphite Resonator Structure
9. Dichroic Separation
10. 1064 nm Mirrors
11. Beam Block

NOTES

1. With Type II doubler
2. High Energy UV option with Type I doubler
3. Full width, half maximum
4. Injection seeding reduces energy by 20 %
5. Full angle for 86% of energy
6. With respect to external trigger
7. The first value represents shot-to-shot for 99.9% of pulses, the second value represents RMS.
8. Average for 8 hours with ΔT_{room} <±3 °C
9. A least squares fit to a Gaussian profile. A perfect fit would have a coefficient of 1
10. Maximum deviation at beam center (±%)

All specifications at 1064 nm unless otherwise noted.
As a part of our continuous improvement program, all specifications are subject to change without notice.

Amplitude/Continum Laser “Surelite I-10”

Surelite I-10 Laser

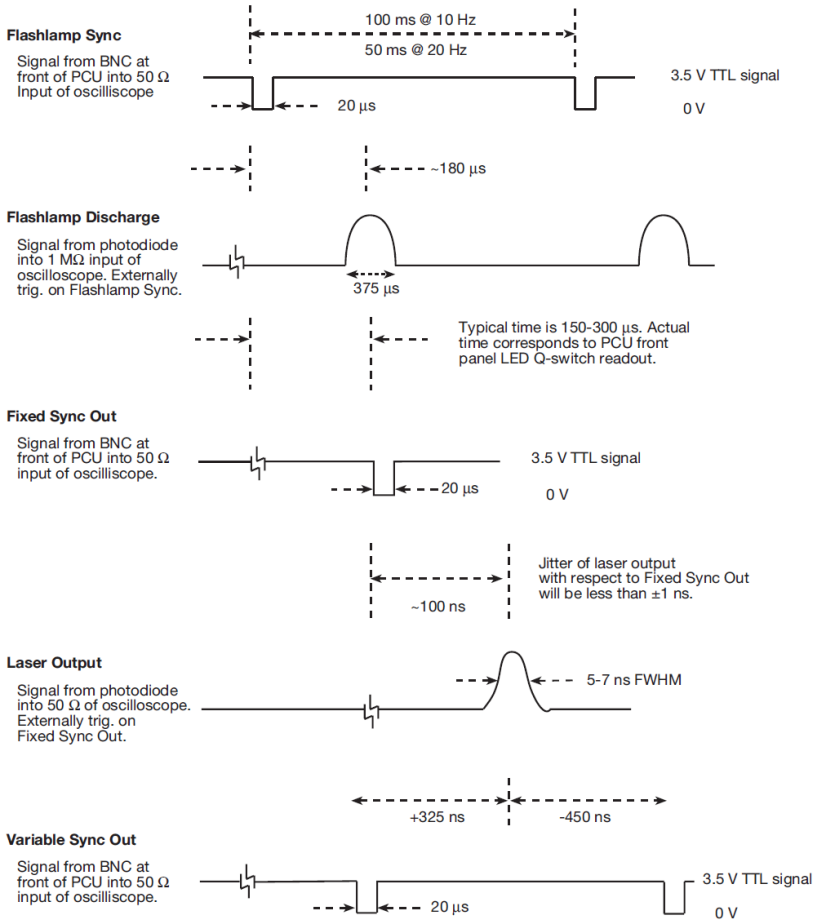


Figure 1 Location of labels on front and rear panels of Surelite oscillator

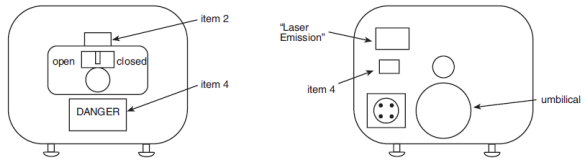


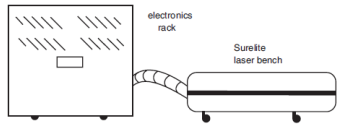
Figure 3 Labels on the 811 Laser Head

	Each month	Every 6 months	Every 12 months
Check system alignment. See Troubleshooting.	X		
Clean/inspect optics. See page 5-1.	X		
Change DI filter in cooling unit. See page 5-3.		X	
Replace flashlamps. See page 5-2.			X
Clean CG radiator.		X	
Inspect cooling water loop connections.		X	

Power/Cooling Unit (PCU)

The PCU unit generates the following:

- control of the system with the necessary power-up time delays, clock rep rate signals, charge/fire commands and Q-switch delays.
- monitoring of the 9 security loops on the front panel.
- power for state-of-the-art MOSFET switching power boards that run at a drive frequency of 40 kHz. Current from the board charges up the storage capacitor.
- capacitance of 30 µF at 2.0 kV. In addition to energy storage for the flashlamp, the system also provides an initial trigger pulse to ionize the gas in the flashlamps.



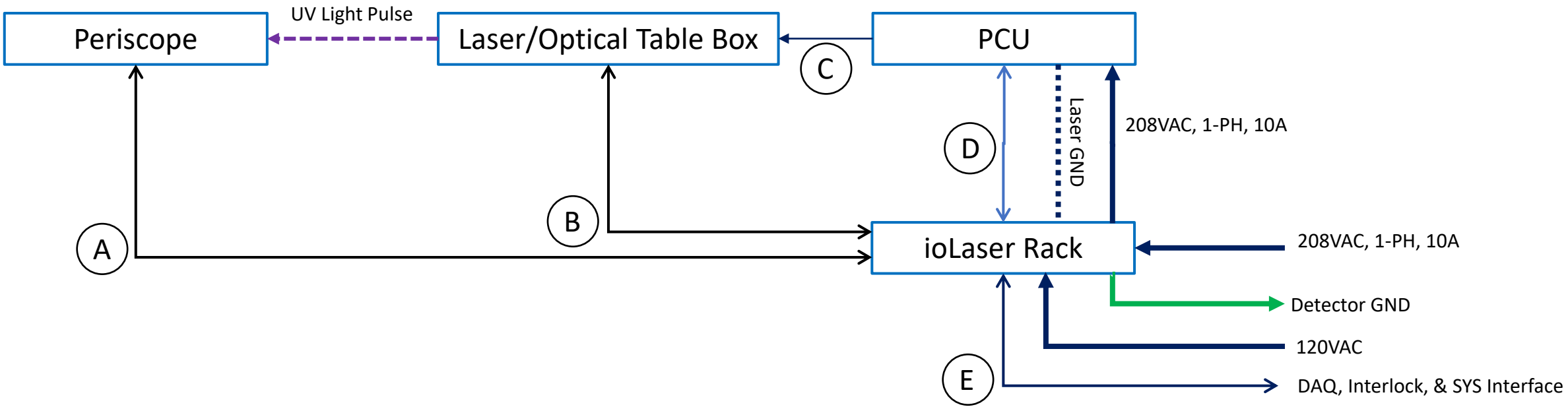
MARX BANK (750V)

This board charges 7 capacitors in parallel and then discharges them through fast switching transistors in series so that the voltage on each capacitor is summed. This generates an ~-4 kV pulse with a rise time of 20 ns. This board is in a metal box next to the Pockels cell.

750 VOLT POWER BOARD

This board, located above the oscillator cavity in a small box with the Marx bank, generates the dc voltage necessary to power the Marx board. The dc voltage is adjustable by a pot accessible through a hole in the top of the laser bench. Turning the pot clockwise raises the voltage.

Electrical Interconnection for Ionization Laser System



Abbreviations used
PCU = Power/Cooling Unit
MDB = Motor Drive Box
EIB = Encoder Interface Box
LIC = Laser Instrumentation Control box
LILV = Laser Instrumentation Low Voltage chassis