Photonics DP2-447 Laser

Ren-yuan Zhu

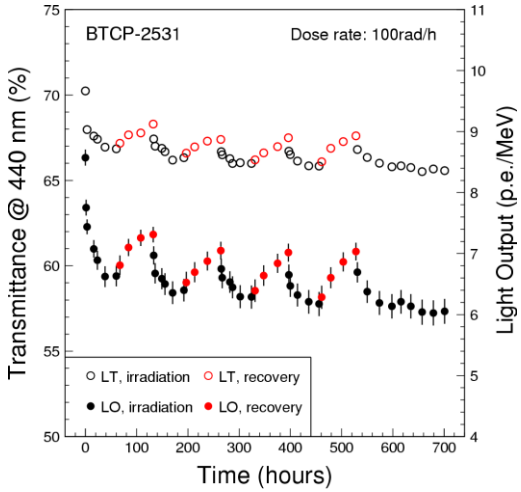
Caltech

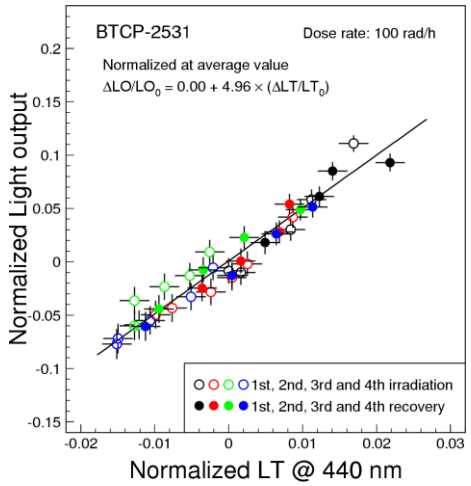
February 28, 2012

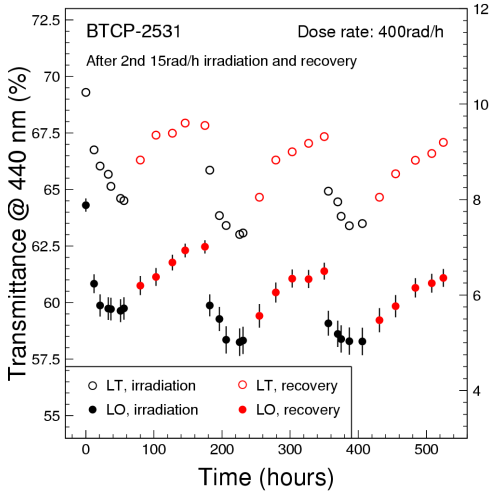
Talk Given in CMS ECAL General Meeting, CERN

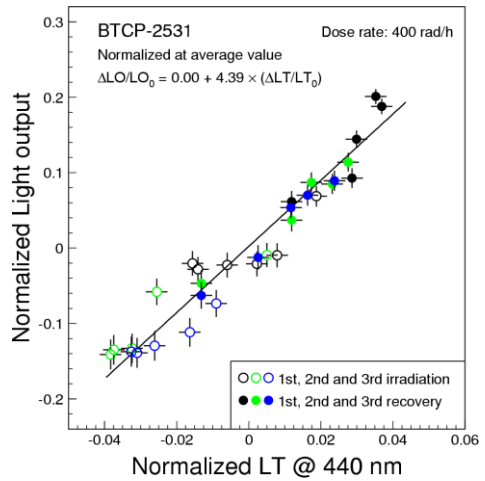
PWO Monitoring is Crucial

Significant light output loss in PWO crystals and its variations require precision light monitoring

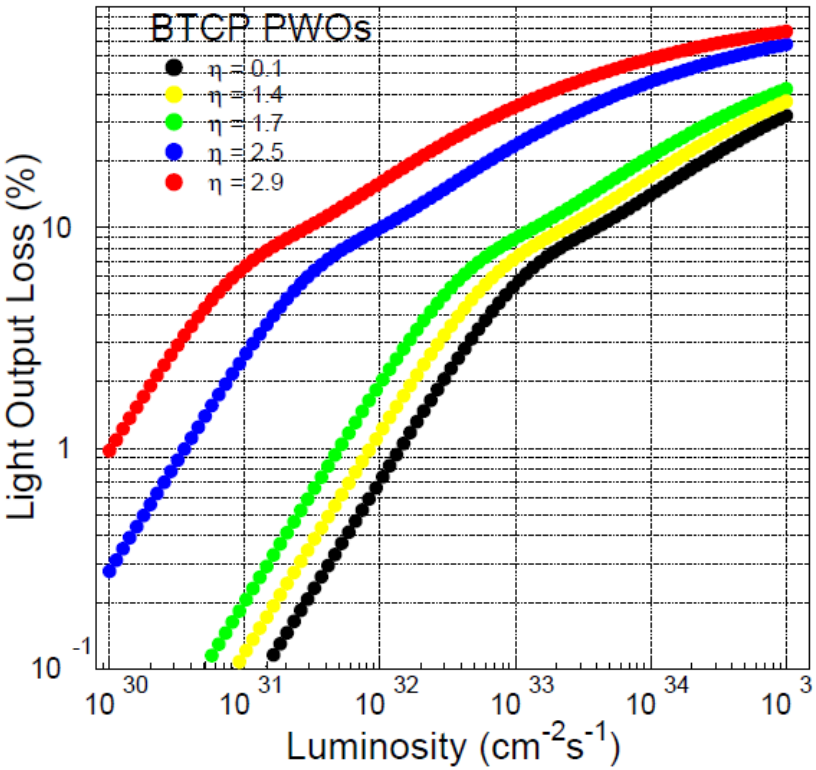








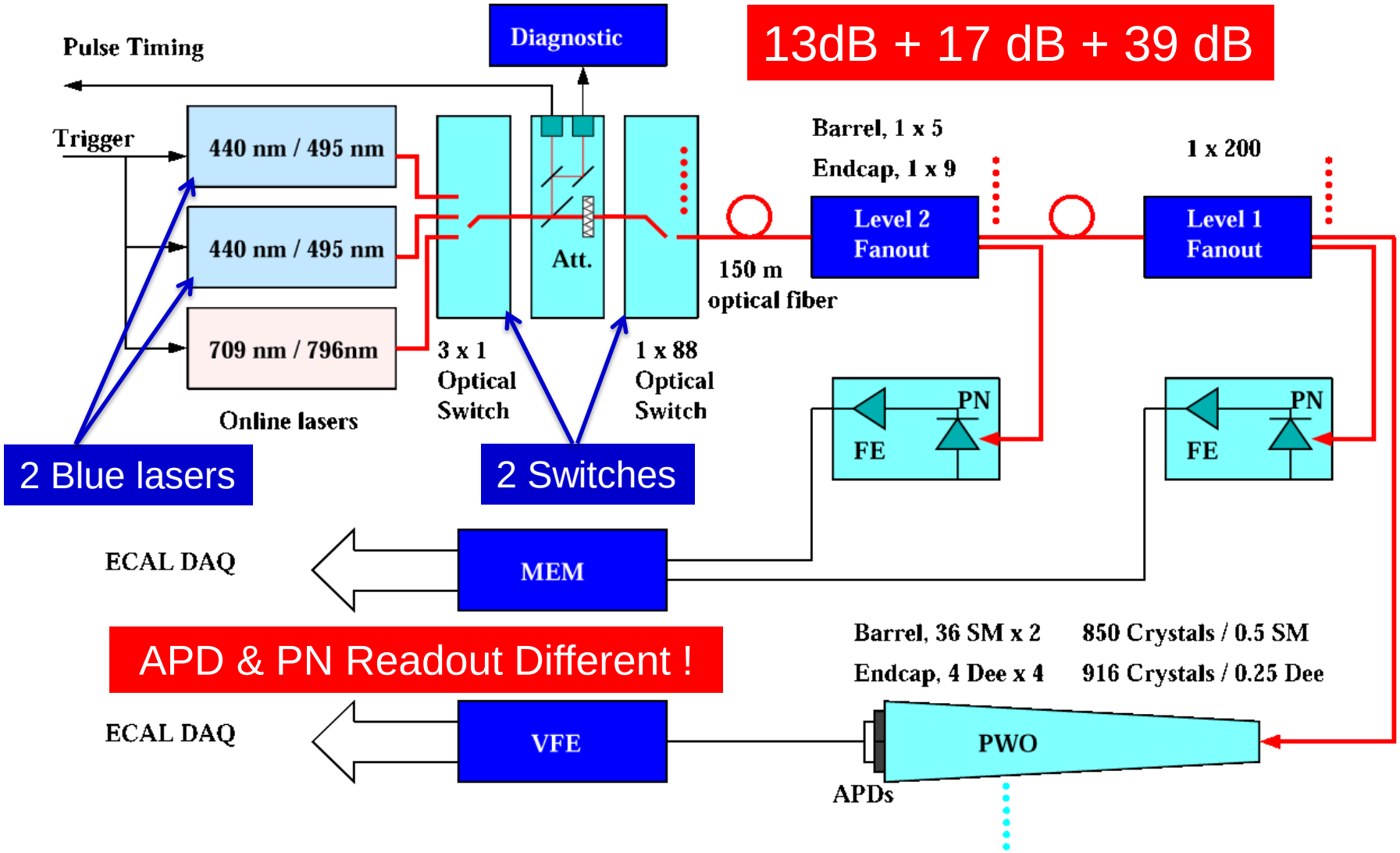
AIP Conference Proceedings 867 (2006) 252-257



Talk in forward calorimeter taskforce meeting 12/9/2010

Laser System in 2011

Two lasers to guarantee 100% availability of 440 nm



Four Known Issues

1. No spares Dicon optical switch.

2. Quantronix discontinued lamp pumped Nd:YLF laser in 2005. Laser parts are no longer in production since 2009. Some parts, e.g. lamp power supply and pumping lamp housings etc., are no longer available**. Quantronix is merged into Continuum in 2012. The prospect of spare parts is unclear**.

3. Quantronix Ti:S lasers are custom made for CMS. They are more reliable than the Nd:YLF lasers with about 10% failing rate as compared to the YLF lasers. Long delays are experienced in obtaining replacement parts (LBO etc.) from Quantronix.

4. ECAL has not reached its designed resolution. APD/PN steps were observed, some of which are laser intervention and swap related. **A stable blue laser with no frequent interventions would help**.

Laser Upgrade

The issue of laser upgrade was raised to the ECAL management in 2008 with a proposal submitted in March, 2009, and presented in 2010 December ECAL Meeting.

- New optical switches
- New solid state pump laser for Ti:Sapphire laser to replace Kr-lamp
- New orange laser for the EE to replace the LED system
- Spares for IR/orange lasers in EB and EE

Laser Committee Members: Brad Cox, Marc Dejardin, Roger Russack, Wolfram Zeuner, Ren-Yuan Zhu

Task – review modifications/upgrades of the laser system
Benefits, risks, integration, time schedule, costs
→ Recommendations

Laser Committee Recommendations

W. Zeuner, 6/28/2011, ECAL Meeting

- The system must be kept running in today's configuration until LS1
  (this might be as long as until spring 2013 !)
  Therefore enough spares must be procured now

No retirement of Quantronix lasers

- A second large optical switch must be procured a.s.a.p.

- In view of the long term operation, it is not sufficient to replace only the pumping laser of the blue laser system.
- The entire blue laser system must be replaced.
  It can be expected that the new system will show much less jumps in the APD/PN ratio
  A market survey should be performed before purchasing
  One laser should be procured in FY12 to perform tests of long term stability
  The general parameters (wavelength, pulse length, shape and stability, jitter…. can be used from the current system
  The energy of the current laser is an advantage, but not absolutely mandatory depending on the chosen technology it might come as by product of the required stability.

Procure a new blue laser in FY12

- There is no need for yet another frequency laser (green)

ECAL Decision (9/29/2011)

- W. Zeuner: laser committee final recommendations:
  - https://indico.cern.ch/conferenceDisplay.py?confId=155389

1. Phase-in a new blue laser, in parallel to the current one
2. Procure a spare 1 x 100 switch
3. Don't move the system to the surface in 2011-2012 Winter Stop

- Initial laser procurement and commissioning schedule (28 weeks)
  - At CERN: preparation of infrastructure, contingency plan for operation in B field (ECAL FTC + Tech Coord.)
  - At Caltech (Ren-yuan Zhu: a schedule of 28 weeks)
    - Order Placed: Day 0;
    - Laser Construction and Delivery to Caltech: 16 weeks + 1 week;
    - Laser acceptance tests and control software development: 8 weeks;
    - Laser delivery to CERN: 1 week;
    - Laser installation at P5 make it operational: 2 weeks

→ Dave Barney agreed to oversee this activity

Revised Specifications for RFQ

→ **Pulse FWHM: < 30 ns to match ECAL readout**

→ Pulse jitter: < 3 ns for synchronization with LHC

→ **Pulse rate: 0-100 Hz, scan of full ECAL in 20min**

→ **Pulse intensity instability: < 3%**

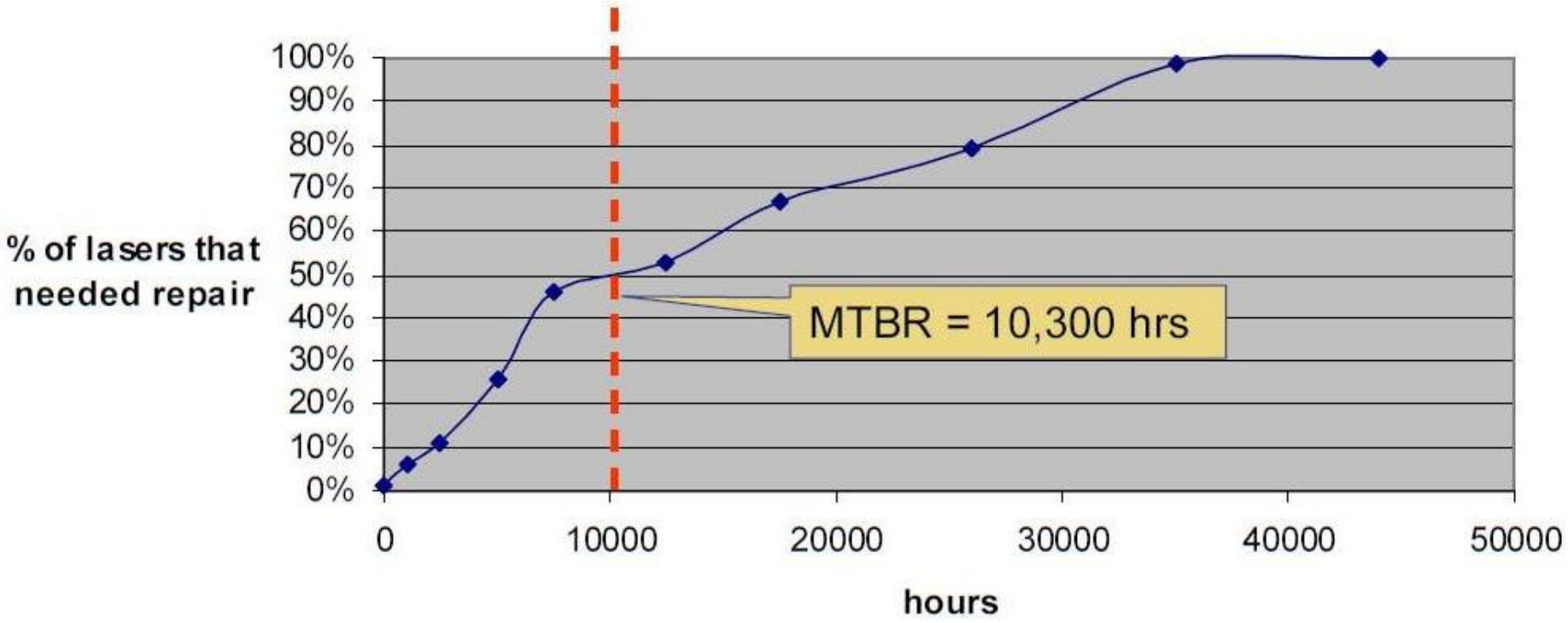
→ Pulse energy: 1 mJ/pulse at 440 nm, equivalent to 1.3 TeV in dynamic range

→ **Pulse delay from external trigger: < 90 μs, for monitoring trigger to stay in one LHC beam cycle**

The laser will be integrated into the existing monitoring system, so a compact system is highly desired. The laser will be run in the 24/7 mode, MTBR (mean time between repairs) is required to be longer than 3 months.

Expected DPSS Laser Reliability

Unlike lamp pumped lasers, this kind of lasers does not need lamp changing and retuning.



MTBF is at 10,000 h for Diode pumped solid state lasers

12 Manufactures Contacted

1. Photonics Industries International, Inc, 390 Central Ave., Bohemia, NY 11716
2. Continuum Sub. of GSI Group, 3150 Central Expy., Santa Clara, CA 95051
3. Quantronix, 41 Research Way, East Setauket, New York 11733
4. CrystaLaser LC, 4750 Longley Lane, Reno, NV 89502
5. Spectra-Physics Lasers, A Newport Corp. Brand, 3635 Peterson Way, Santa Clara, CA 95054
6. New Focus, A Newport Corp. Brand, 3635 Peterson Way, Santa Clara, CA 95054
7. JDSU, 430 N McCarthy Blvd., Milpitas, CA 95035
8. Coherent Inc., 5100 Patrick Henry Dr., Santa Clara, CA 95054
9. Teem Photonics USA, Sub. of Teem Photonics SA, 3594 Nyland Way, Ste. TP1, Lafayette, CO 80026
10. IPG Photonics Corporation, 50 Old Webster Rd., Oxford, MA 01540
11. Laserglow Technologies, 216-5 Adrian Ave., Toronto, ON M6N 5G4, Canada
12. Quantel USA, 601 Haggerty Lane, PO Box 8100, Bozeman, MT 59715-2001

Liyuan Zhang and Ren-Yuan Zhu visited Photonics and Quantronix on 10/19/2011 and 10/20/2011

Offers and Final Decision

- Quantronix (manufacturer of the existing ECAL lasers)
  - Diode pumped YLF + Ti:Sapphire laser @ 440nm
  - Met specifications
  - **Long delivery time** (~6 months)
- Two options from Photonics
  - Diode pumped YLF + Ti:Sapphire laser @ 440nm
  - Diode pumped YVO_4 laser @ 447nm (DP2-447)
  - Met specifications & **good delivery time** (16 weeks)
- **DP2-447 selected on 11/5/2011**
  - http://cern.ch/go/W9VD

Photonics DP2-447 Quotation

Photonics Industries International, Inc.
390 Central Ave., Bohemia, NY 11716, USA
Tel: 631-218-2240 Fax: 631-218-2275
www.photonix.com info@photonix.com

Order placed verbally on 11/11/11
Delivery promised on 1/31/2012

QUOTATION

Quotation Number: Q11-1107AI 2
Date: 11/7/11
Valid until: 12/7/11
Payment: 25/50/25 (Pending credit approval)
Freight: F.O.B Bohemia, NY
Delivery: Standard delivery time frame is 12-14 weeks.

To:	California Institute of Technology 1200 E California Blvd, Pasadena CA 91125	From:	Photonics Industries 390 Central Avenue Bohemia, NY 11716
Tel:		Tel:	631-218-2240
Fax:		Fax:	631-218-2275
Attn:	Liyuan Zhang	Attn:	Andrew Iadevaia

Description	Unit Price	Qty	Total
DP2-447 Diode Pumped laser Wavelength 447nm Energy per Pulse 1mJ Pulse Width (FWHM) 15 ns (nominal) Stability of laser pulse width under random external trigger up to 100 Hz: < 5% rms; Spatial Mode TEMoo Polarization Horizontal Beam Divergence <2 mrad Pointing Stability: <50 µrad Pulse to Pulse Stability <3%rms Pulse Jitter <3ns rms Pulse delay from external trigger ~90us Repetition Rate Single Shot to 200 Hz Laser Dimensions 7.5" (W) x 22" (L) x 3.75" (H)	**$165,000.00**	**1**	**$165,000.00**
Customer will perform a measurement at our facility to verify the specification for stability of the laser pulse width. If the above quoted specification for pulse width stability can not be met, the customer will have the option to cancel the order with no penalty.	Included	1	Included
Customized Option for two separate external triggers	$5,000.00	1	$5,000.00

Photonics Industries International, Inc.
390 Central Ave., Bohemia, NY 11716, USA
Tel: 631-218-2240 Fax: 631-218-2275
www.photonix.com info@photonix.com

DP Power Supply Unit Electrical input 110VAC or 220VAC, 50-60Hz, single phase power. Q-switch external input by TTL via BNC and External Gating Input, RS232 communication. **Dimensions**:13.5"(L)x19"(W)x5.25"(H)	Included	1	Included
Chiller 19" rack mountable closed loop water to air chiller	Included	1	Included
System Software DP Control software provides basic system operating controls in a convenient graphical user interface configuration.	Included	1	Included
Warranty Standard Photonics Industries one-year parts and labor warranty. Warranty repairs are to be performed at Photonics Industries facilities or at customer's site. Travel and living expenses to be paid by customer.	Included	1	Included

Standard warranty and Terms and Conditions attached.

Authorized Signature

Photonics Industries
P: 631-218-2240
F: 631-218-2275

There were concerns about the pulse width stability. A clause was added.

There were concerns about the pulse delay. Two triggers were added.

User References

Photonics Industries claims that most of its diode pumped lasers are used in military and private industry.

Zebra Imaging Inc.

Michael A. Klug commented two 447 nm lasers purchased from Photonics Industries (PI) about 1.5 years ago. The lasers are run in 24/7 mode at 120 Hz with pulse energy of about 1 mJ and pulse width of about15 ns. The required pulse energy instability is about 3% rms and jitter < 3ns rms. There is no requirement for the delay from external trigger. While do not have laser diagnostic data registered, they believe the long term stability is good by looking at an imaging threshold. These two 447 nm lasers have been run for about 7,000 hours and no significant degradation in output is noticed. Zebra Imaging started using PI lasers more than 5 years ago. They have about 15 PI lasers, most of them are green (532 nm). The average pump diode lifetime is about 15,000 hrs. They are satisfied by the PI' lasers.

Oakridge National Lab

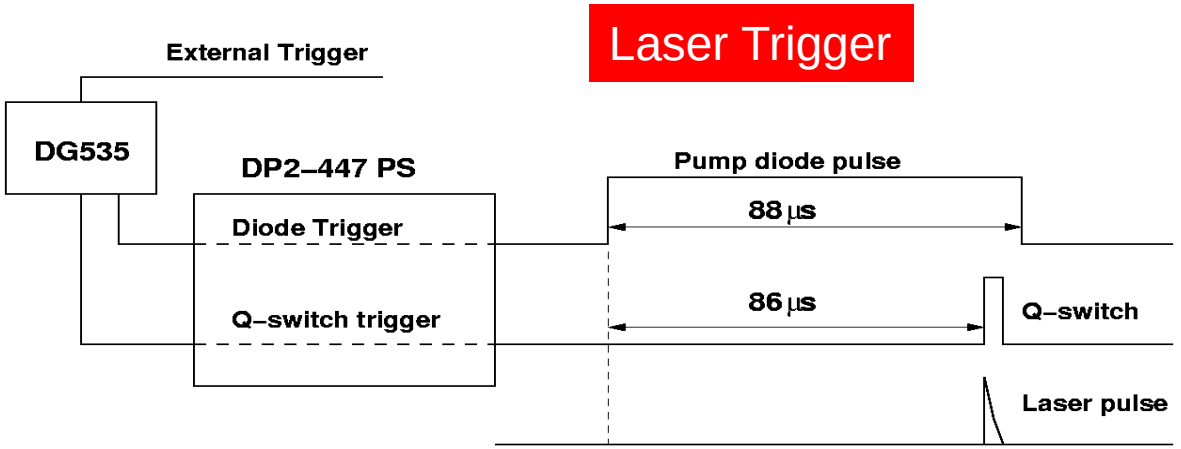
Dr. Yuan LIU commented on a diode pumped Nd:YLF pumped Ti:Sapphire laser system of Photonics Industries procured about one and half year ago. The laser system is run at 10 KHz in 24/7 mode for several weeks each run. While the Ti:Sapphire laser has no problem, the Nd:YLF had a problem caused by condensed water and it was fixed by Photonics Industries. She recommended Photonics Industries.

University of Washington (Prof. Thomas SPIRO group)

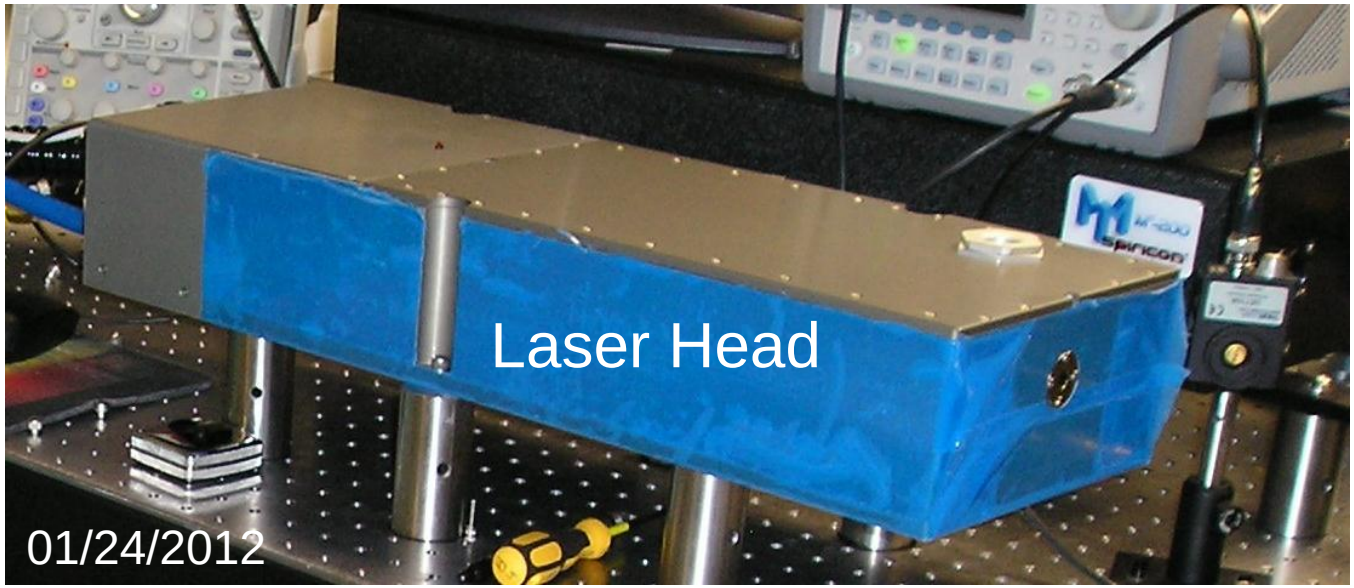
Dr. Balakrishnan commented on their Nd:YLF pumped OPO system of Photonics Industries purchased about 5 yrs ago. They are basically satisfied with the laser. The laser is run at 1 KHz, but NOT in 24/7 mode. The original diode module is still in good shape with accumulated time of over 3,500 hrs. There were some small issues like power dropping, chiller not working properly etc. The service is not as good as expected. While hoping Photonics will improve its service, they recommended the Photonics Industries.

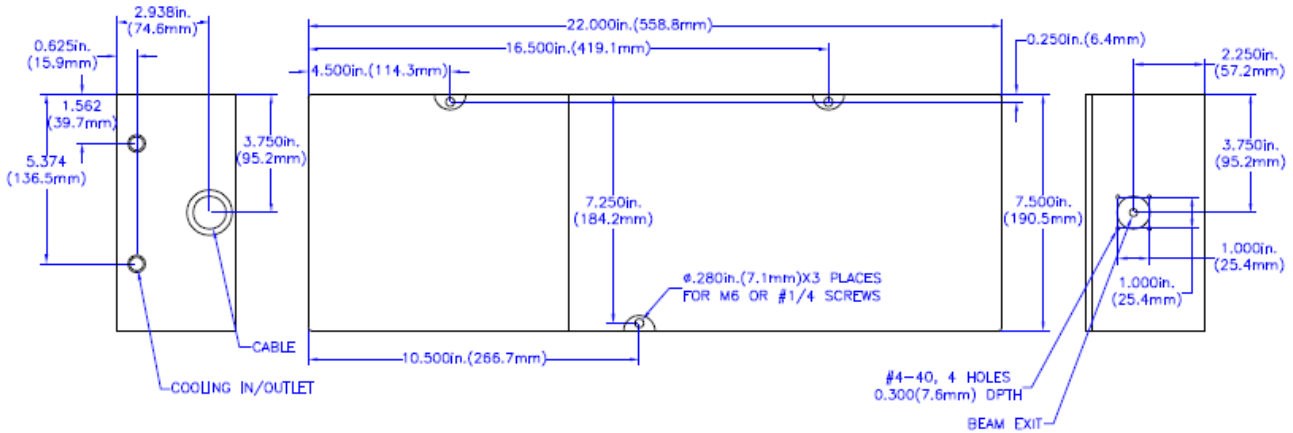
Photonics DP2-447 Laser

- A Simple Laser:
  - 1 laser system (c.f. 2)
  - Compact laser head: 7.5” x 22” x 3.75”
  - Low power: no external chilled water needed.
- Designed to be rigid and reliable: no user alignment needed.
- David Bailleux, Guy Chevenier and Liyuan Zhang visited Photonics on 1/23 and 1/24 for laser M&O training.

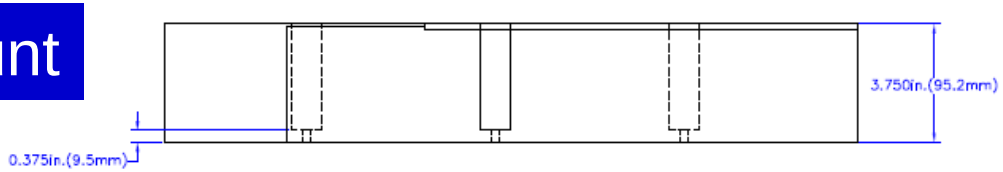


DP2-447 at Photonics (1/24/2012)

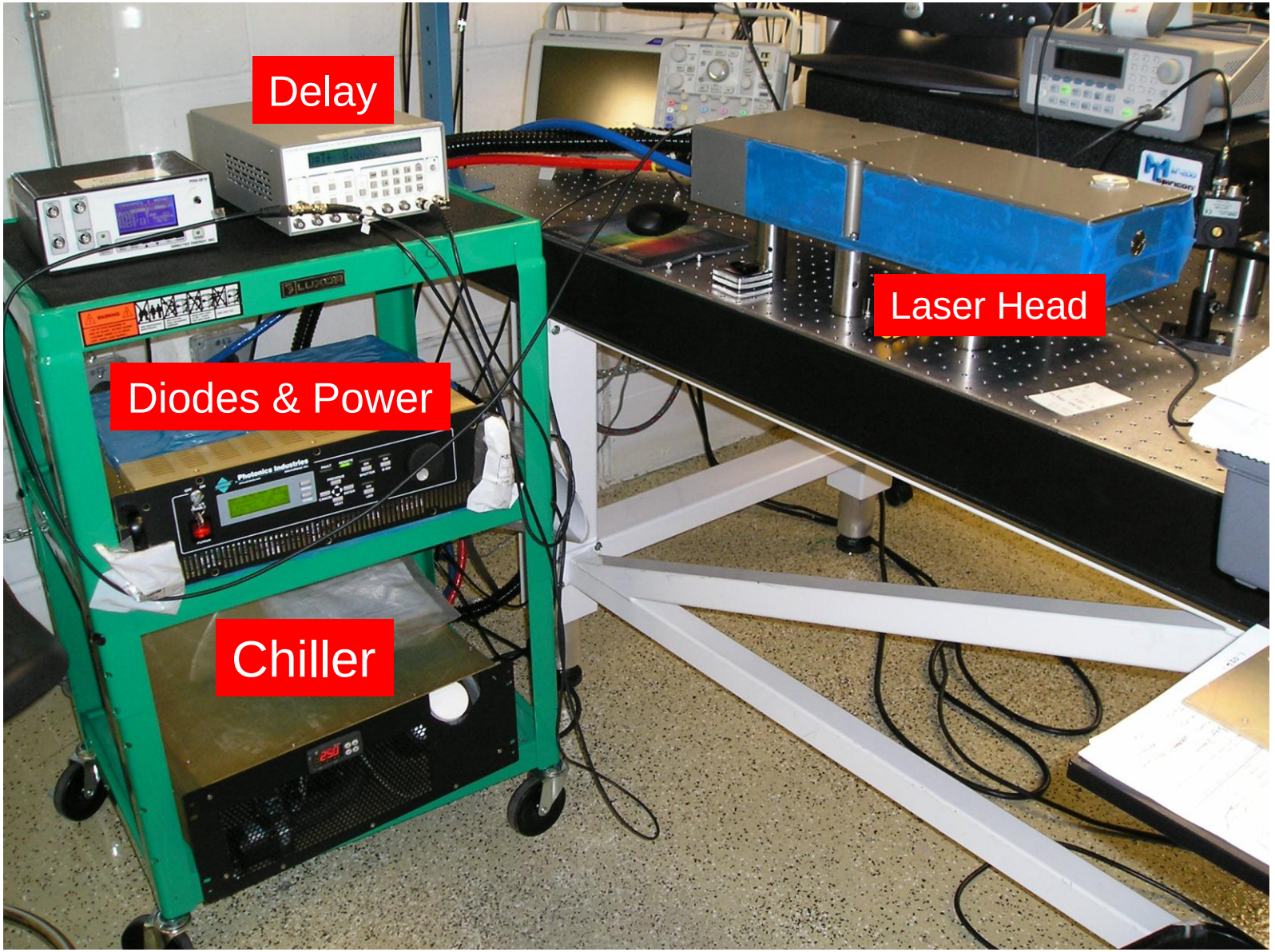




Laser Mount



DP2-447 at Photonics (1/24/2012)



Clause of DP2-447 Pulse Width

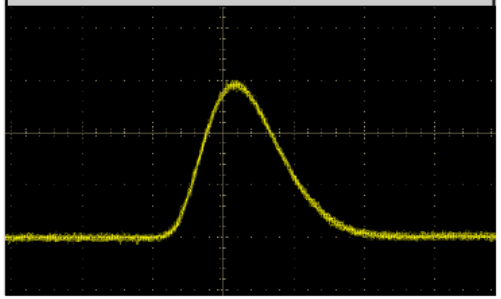
PHOTONICS INDUSTRIES
INTERNATIONAL, INC.
390 Central Avenue, Bohemia, NY 11716
Tel.: (631) 218-2240 Fax: (631) 2182275

Test Data and Operational Parameters

Date: April 29, 2011 Model Number: DP2-447 Serial Number: 10-115

Operational Parameters		
Parameter	**Set Point**	**Actual**
Operating Current (I_{op}) (A)	30.5	0.00
Chiller Temperature (°C)	24.5	N/A
SHG Temperature (°C)	50.0	50.0
THG Temperature (°C)	50.5	50.7

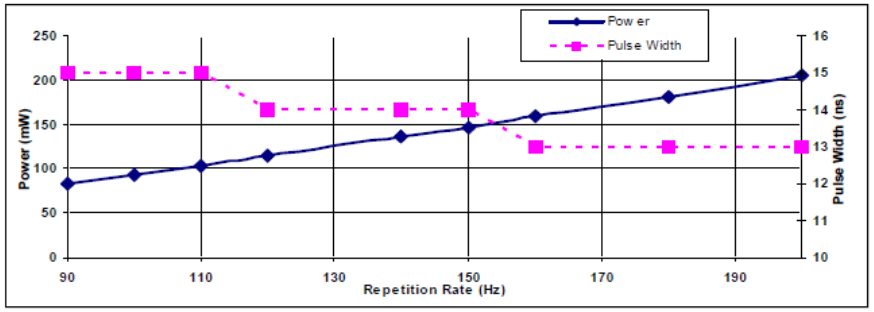
Pulse Envelope at 180Hz



Power / Pulse Data at Constant I_{op}= 30.5A

P.R.F. (Hz)	Average Power (mW)	Pulse Width (ns)
90	83	15
100	94	15
110	104	15
120	115	14
140	137	14
150	147	14
160	159	13
180	181	13
200	205	13

Polarization Direction	Polarization Ratio	Operational P.R.F. Range	Wavelength
Vertical	>500:1	0-200Hz	447nm

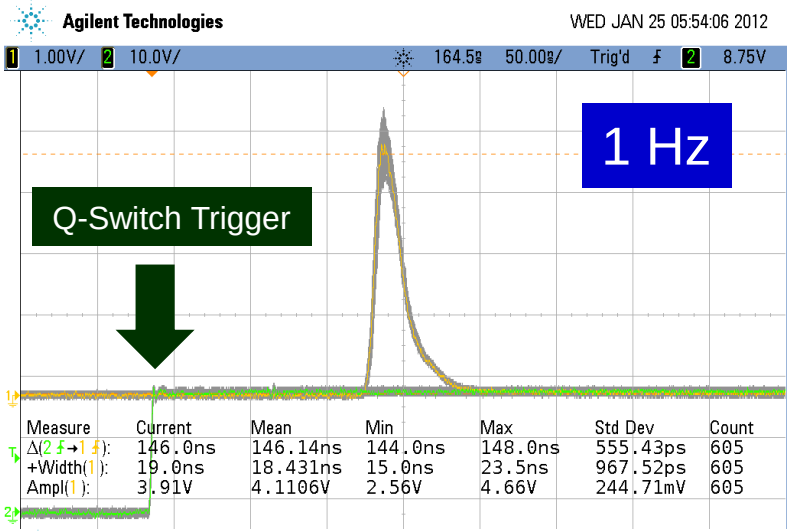


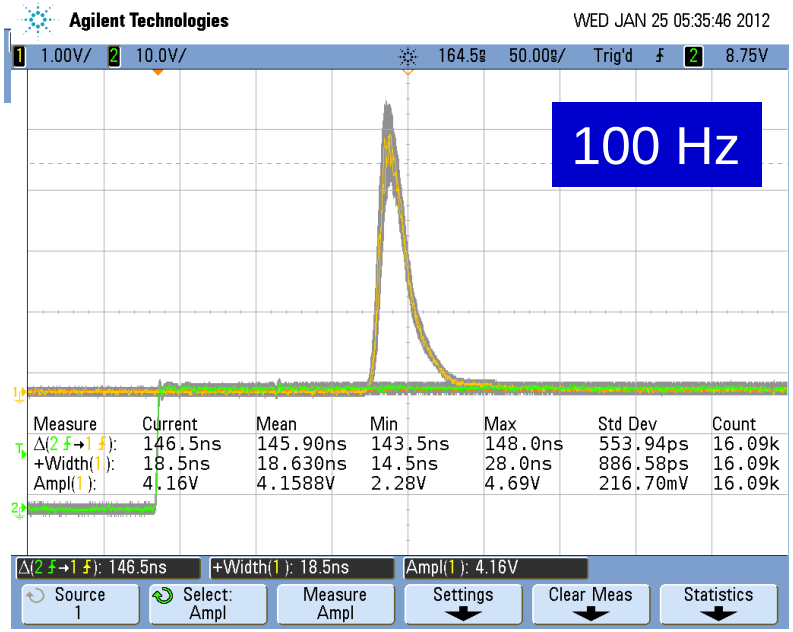
A report from Photonics shows pulse width reduced from 15 ns to 13 ns when the trigger rate is increased from 90 Hz to 200 Hz.

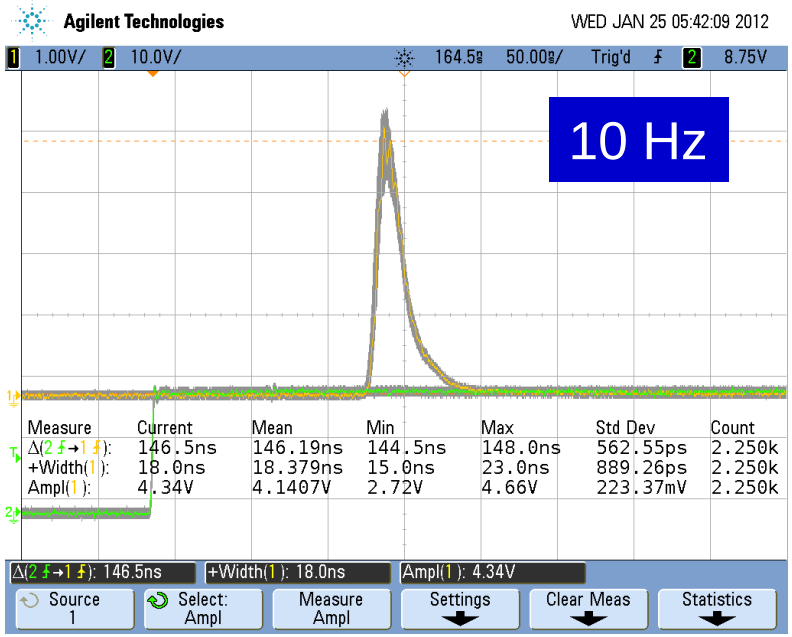
Photonics explanation: a simmer function which stabilizes the thermal load was not activated.

A test on 1/24/2012 at Photonics show that pulse width varies from 18.4 ns to 18.6 ns when the trigger rate is increased from 1Hz to 100 Hz, indicating that the simmer function indeed stabilizes thermal load and thus the pulse width.

Pulse Width at Photonics (1/24/2012)







Trigger (Hz)	1	10	100
Width (ns)	18.4	18.4	18.6

Based on this measurement the clause in the Photonics quotation was waived. The laser shipped on 2/3/2012.

Photonics Report (2/3/2012)

> 1 mJ; Stability: Intensity 0.4%, width < 5%, Jitter < 2 ns

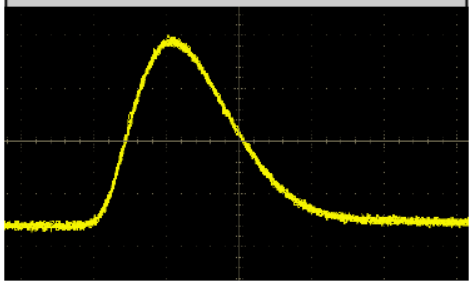
390 Central Avenue, Bohemia, NY 11716
Tel.: (631) 218-2240 Fax: (631) 2182275

Test Data and Operational Parameters

Date: February 3rd, 2012 Model Number: DP20-447 Serial Number: 11-381

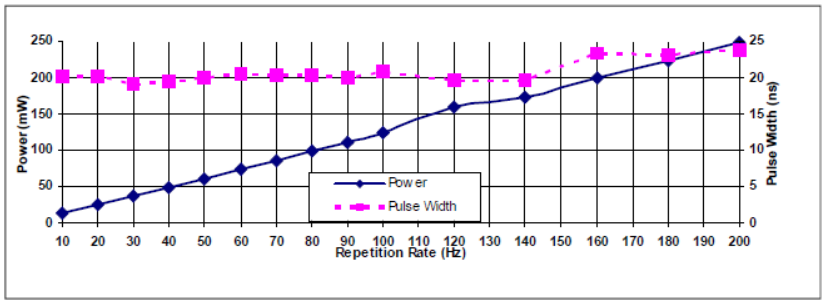
Operational Parameters		
Parameter	Actual	Set Point
Operating Current (I_{op}) (A)	N/A	65.00
Chiller Temperature (°C)	25.0	25.0
SHG Temperature (°C)	49.9	50.1
THG Temperature (°C)	51.1	51.1

Pulse Envelope at 100Hz



Power / Pulse Data at Constant I_{op}= 65.00A		
P.R.F. (Hz)	Average Power (mW)	Pulse Width (ns)
10	12.6	20.1
20	24.8	20.2
30	36.6	19.2
40	49.0	19.5
50	61.1	20.0
60	73.4	20.4
70	85.7	20.3
80	98.2	20.3
90	110.7	20.0
100	123.5	20.8
120	159.7	19.6
140	173.4	19.7
160	199.2	23.3
180	223.2	23.2
200	248.6	23.8

Polarization Direction	Polarization Ratio	Operational P.R.F. Range	Wavelength
Vertical	>100:1	0-200Hz	447 nm



390 Central Avenue, Bohemia, NY 11716
Tel.: (631) 218-2240 Fax: (631) 2182275

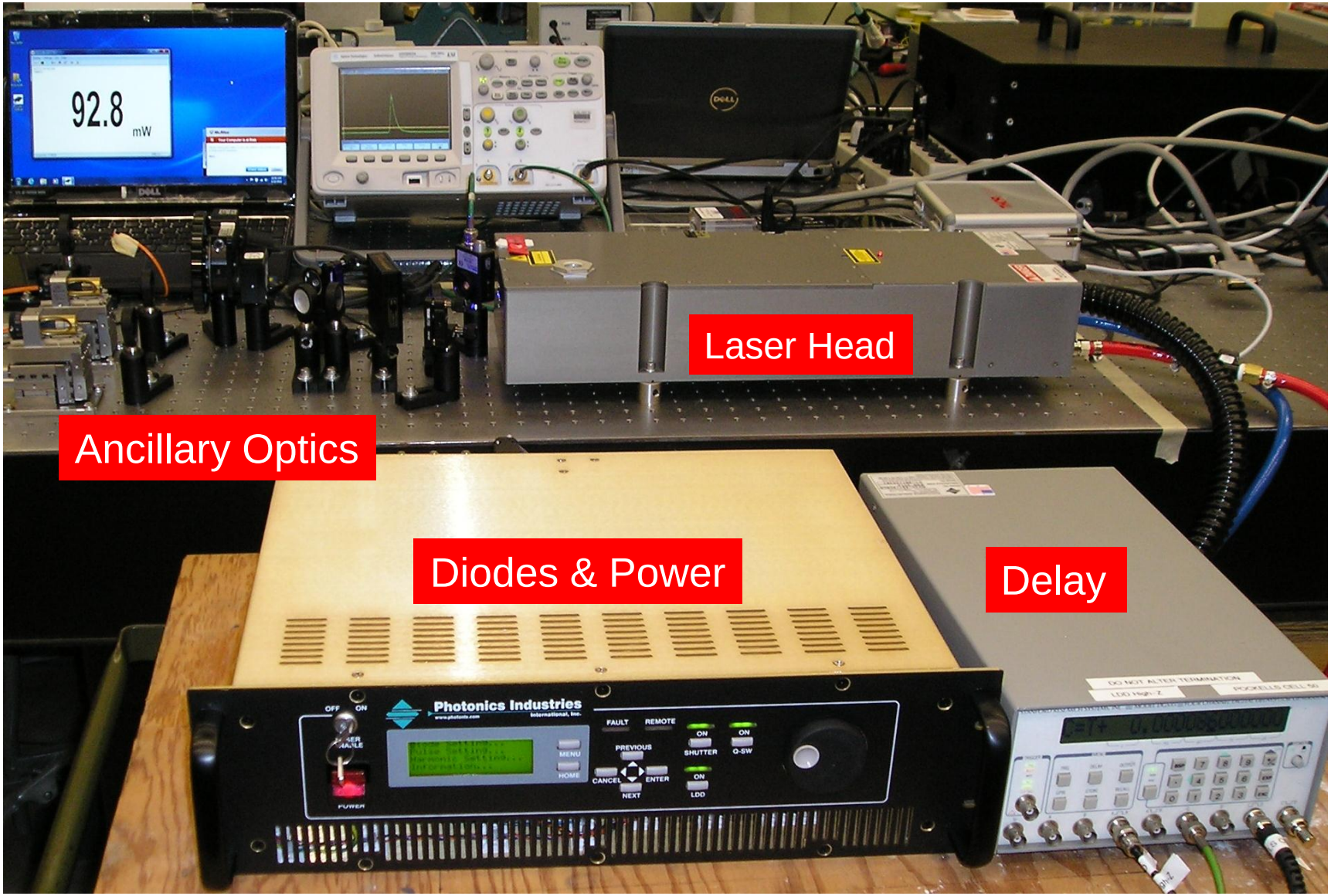
Beam Characteristics and Stability

Date: February 3rd, 2012 Model Number: DP20-447 Serial Number: 11-381

Pulse Characteristics					
PRF (Hz)	Pulse Width (ns)	Pulse Width Stability (%)	Pulse Jitter (ns)	Pulse Intensity (mJ)	Pulse Intensity Stability (%)
10	20.1	3.0	2.0	1.25	0.4
20	20.2	3.0	2.0	2.20	0.4
30	19.2	4.1	1.5	1.23	0.4
40	19.5	4.1	1.5	1.24	0.4
50	20.0	4.0	1.5	1.25	0.4
60	20.4	3.9	1.5	1.24	0.4
70	20.3	4.4	1.5	1.24	0.4
80	20.3	4.2	1.5	1.24	0.4
90	20.0	4.3	1.5	1.25	0.4
100	20.8	4.3	1.5	1.25	0.4
120	19.6	3.6	1.5	1.25	0.4
140	19.7	3.7	1.5	1.24	0.4
160	23.3	3.0	1.5	1.24	0.4
180	23.2	2.5	1.5	1.24	0.4
200	23.8	2.5	1.5	1.24	0.4

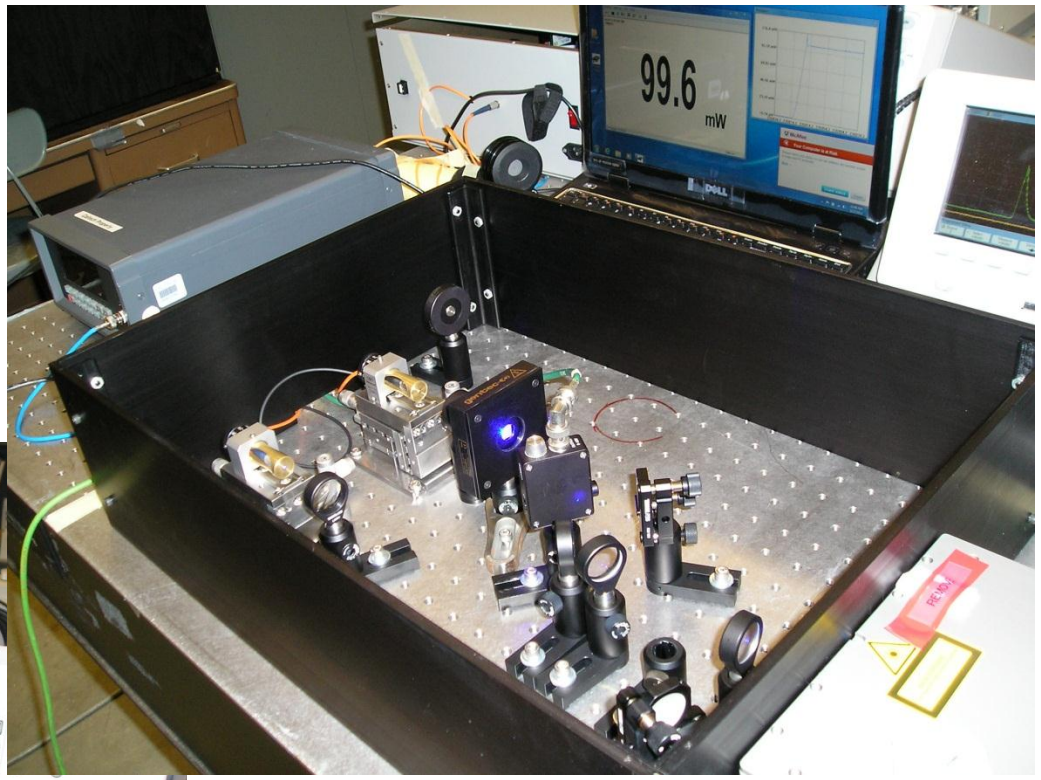
Diode current pulse width: 88 μs
Peak pulse current: 65 A
Pockel cell delay: 86 μs, on: 2 μs.

DP2-447 at Caltech (2/17/2012)



DP2-447 at Caltech (2/23/12)

Ancillary Optics

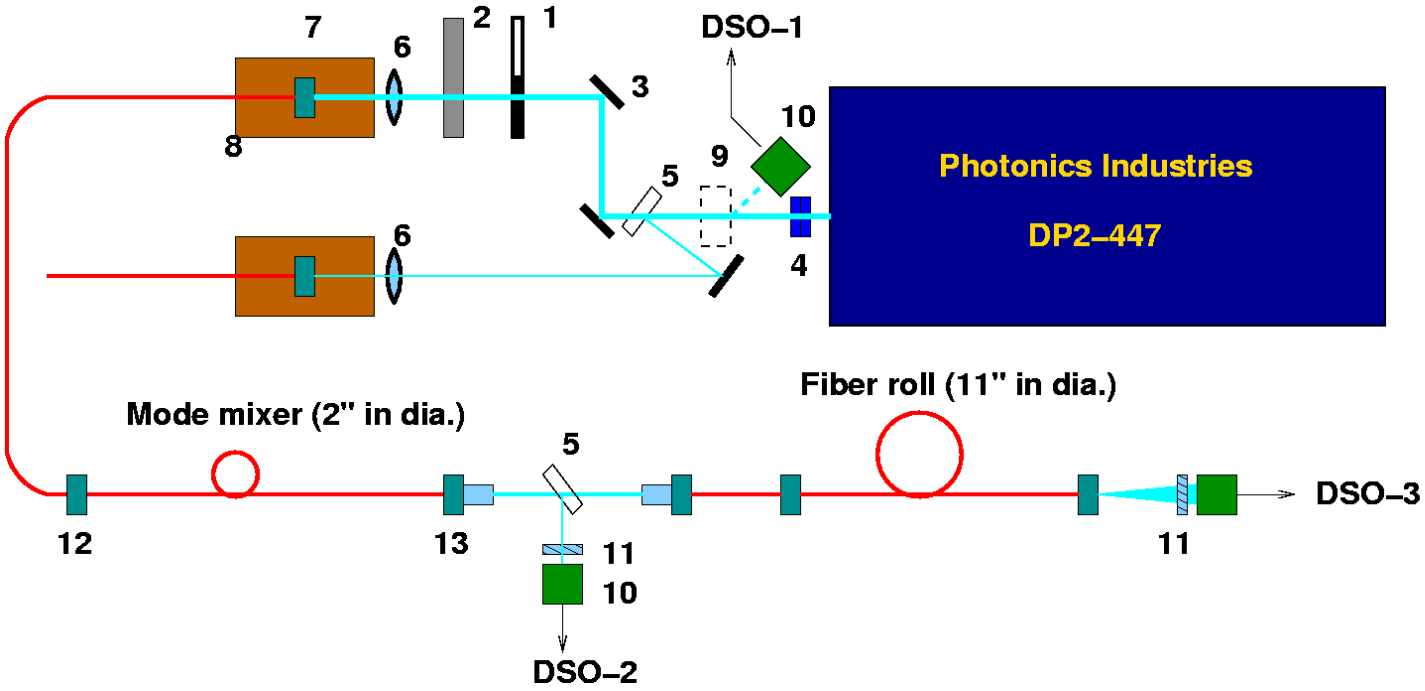


Set-Up for DP2-447 Evaluation

DSO-1 was used to evaluate DP2-447 Performance

DSO: Agilent 6052A, 500 MHz, 2 Gsa/s

Photodiode: Thorlabs DET10A, risetime < 1 ns

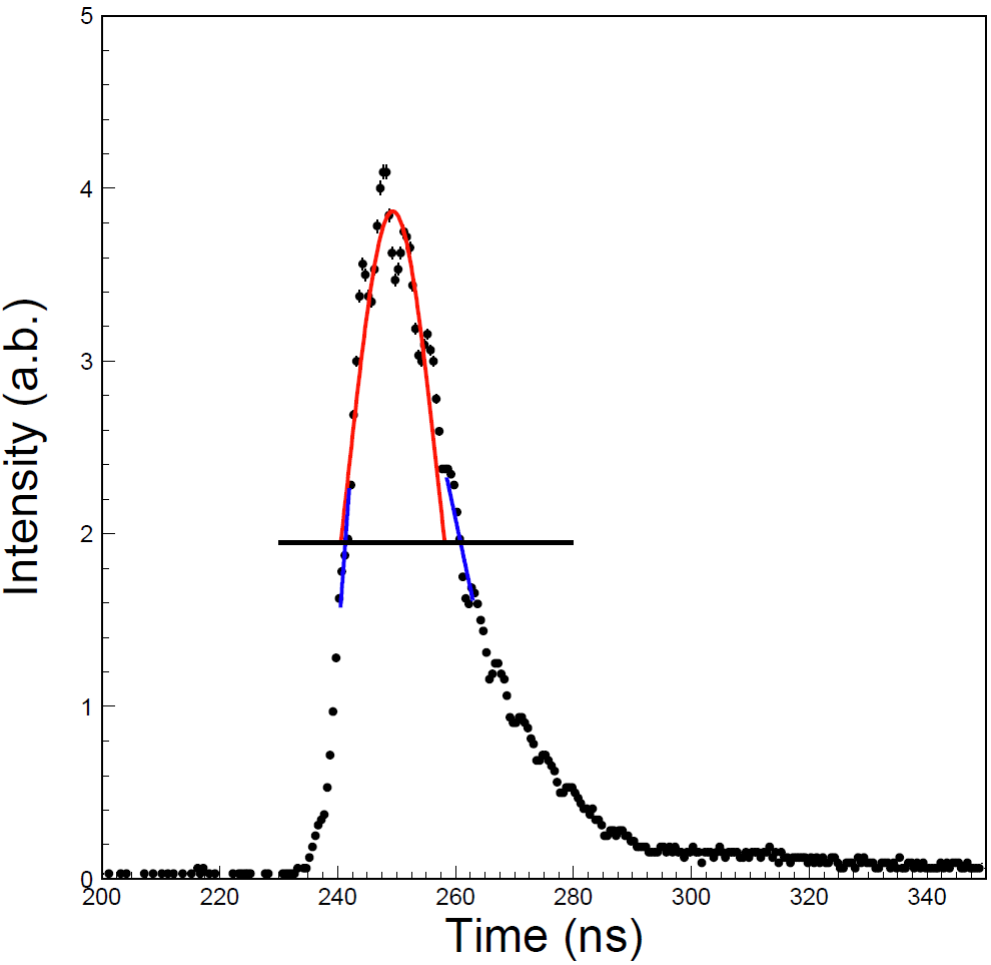


1: Beam shutter
2: Attenuator
3: Fold mirrors
4: Filter(s)
5: Beam sampler
6: Lenses
7: Fiber coupling stages
8: Optical fiber
9: Power meter
10: Photodiode
11: ND filter
12: FC connector
13: FC collimator

DSO-2 and 3 were used to measure fiber dispersion

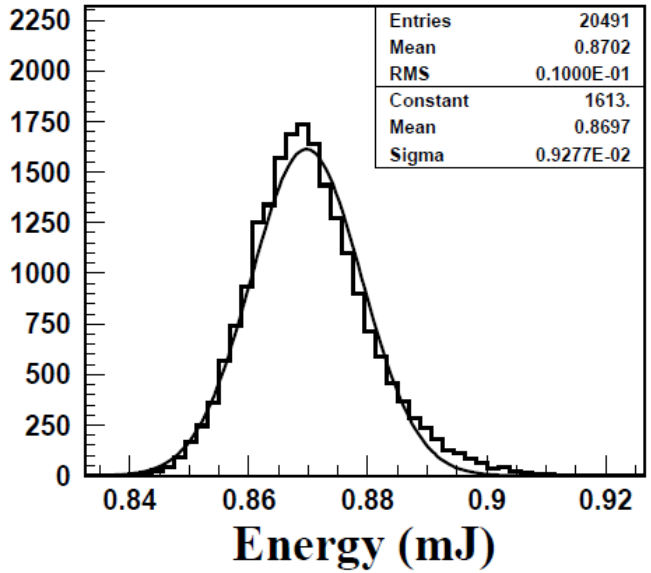
Pulse Shape Reconstruction

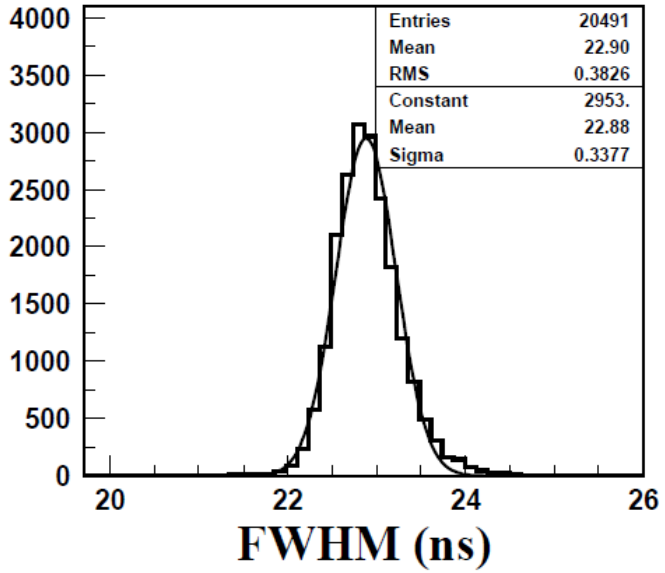
500 MHz, 2 GS/s DSO

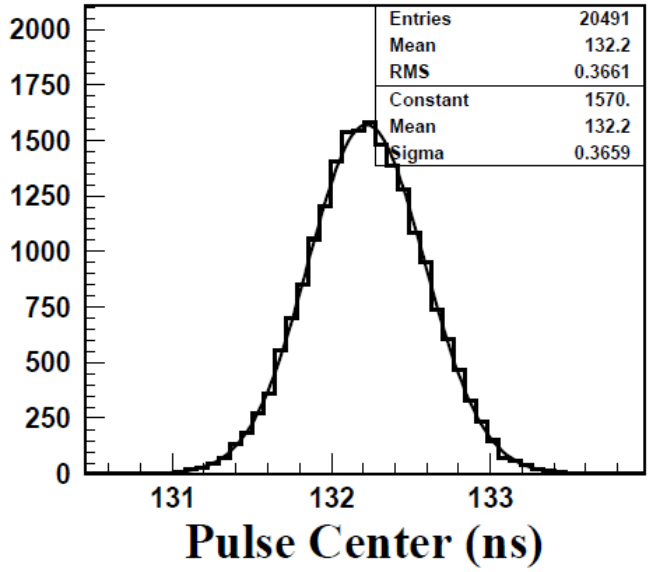


- Find maximum pulse V_m
- Find time at $V_m/2$: t_1 and t_2
- Gaussian fit in (t_1, t_2)
- Pulse energy: Σy_i in (-4σ, 8σ)
- Pulse center: $\Sigma t_i y_i / \Sigma y_i$ in (-4σ, 8σ)
- Pulse width: 5 points (2 before and 2 after) linear fits to find t_{1f} and t_{2f} at $V_m/2$. FWHM = $t_{2f} - t_{1f}$

Over Night Data at Caltech (2/23/2012)



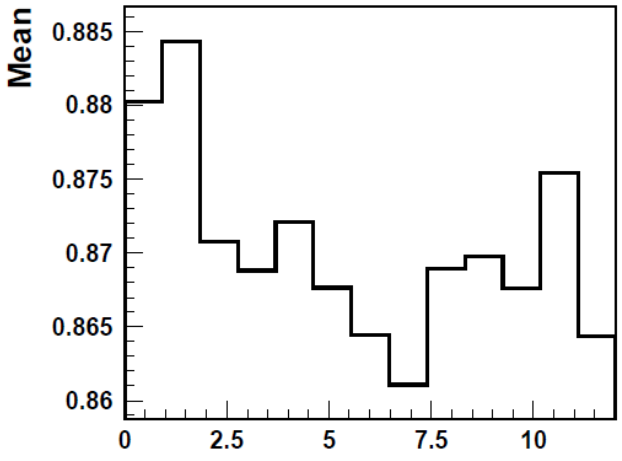


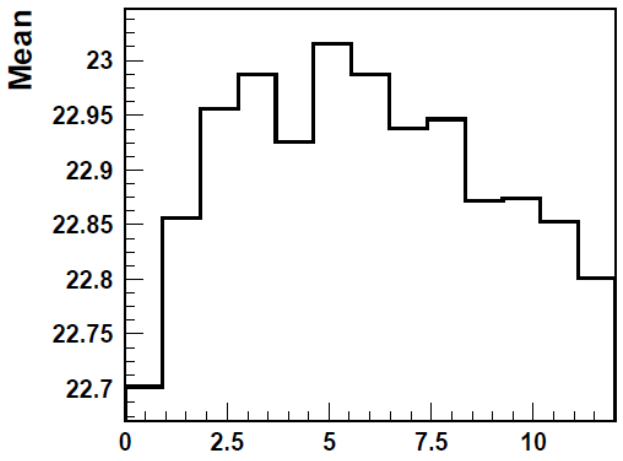


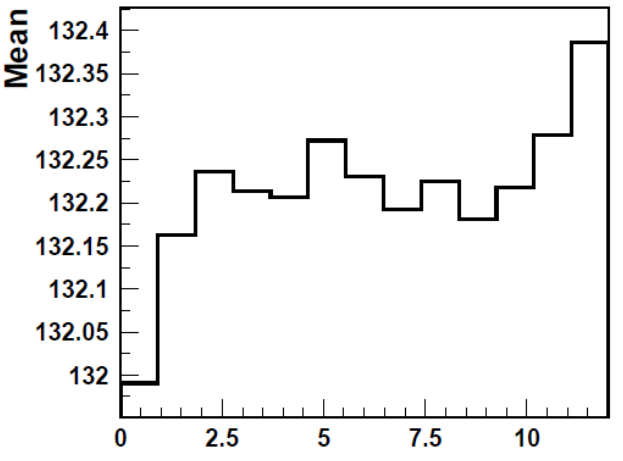
A typical 12 h run at 0.87 mJ and 23 ns FWHM shows the following stability.
Intensity: **1.1 %**
FWHM Width: **1.7%**
Jitter: **0.37 ns**

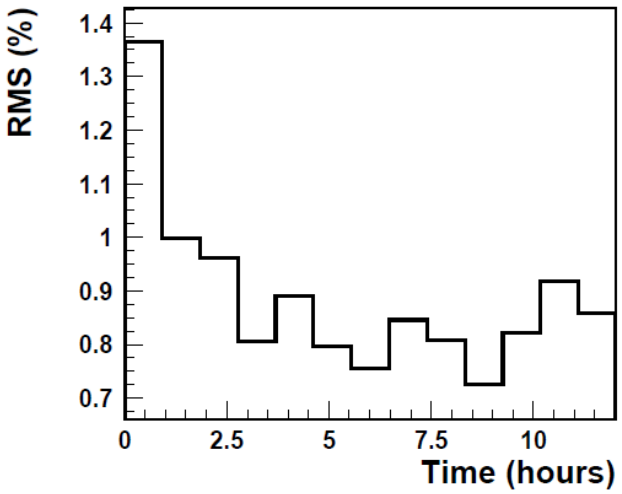
History of 12 hour Data

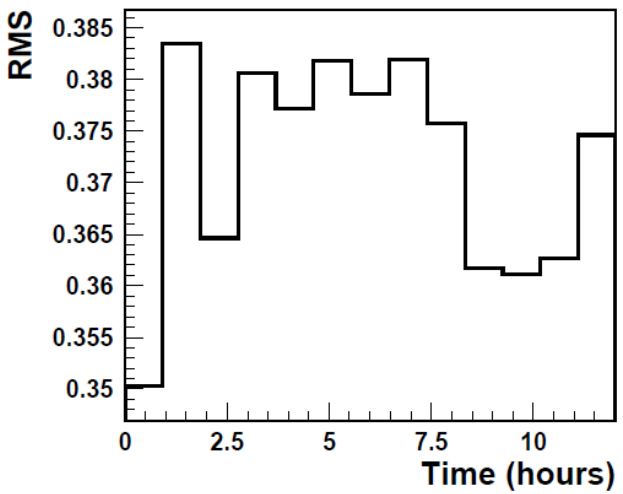
Up to 2% pulse intensity drifting noticed: temperature?

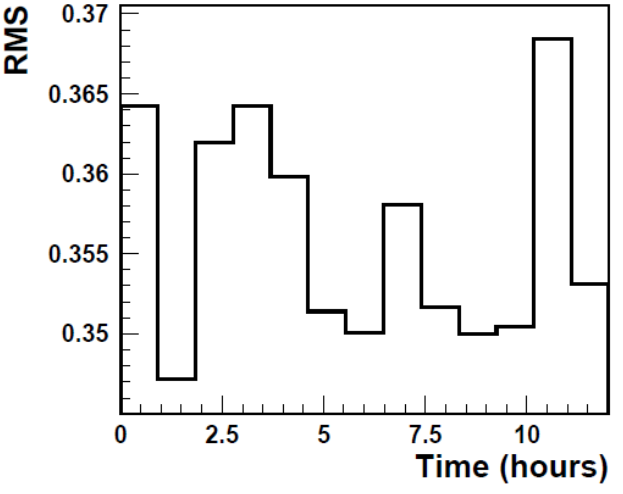




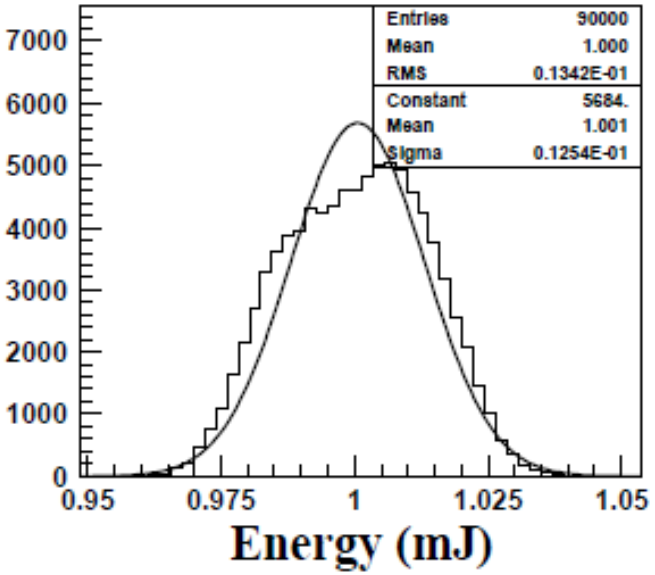


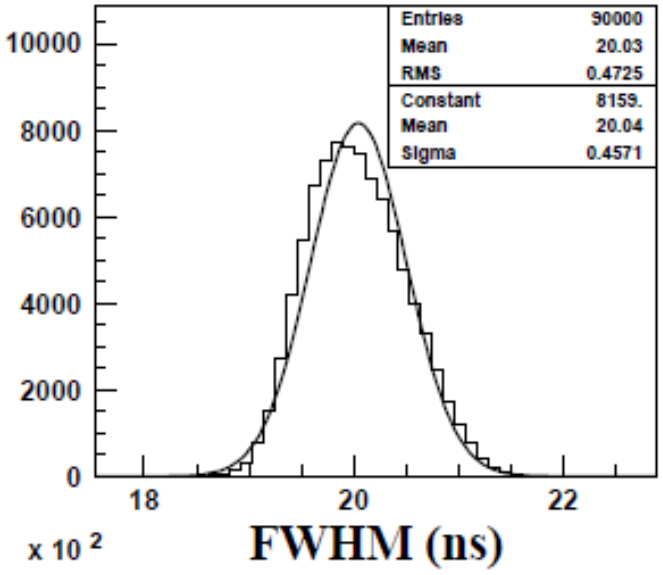


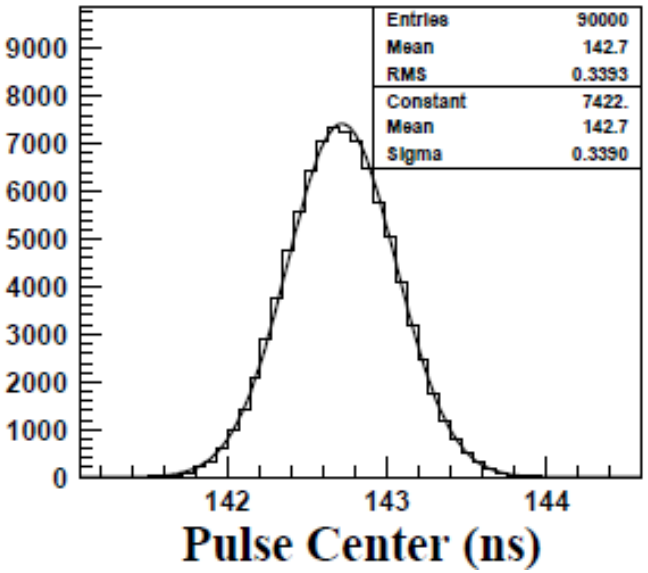




Over Weekend Data (2/26/2012)



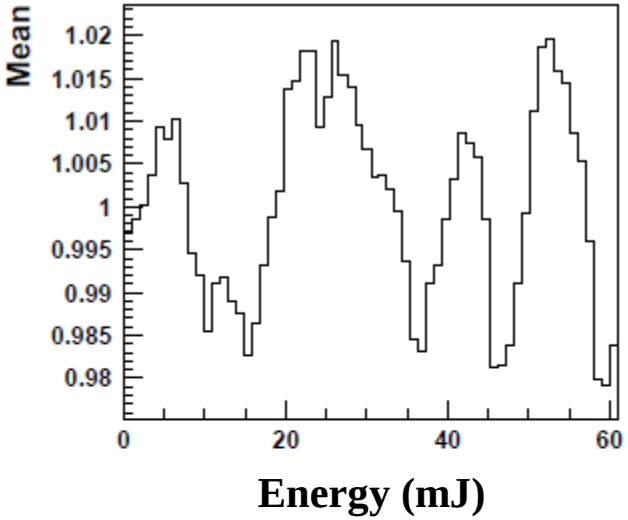


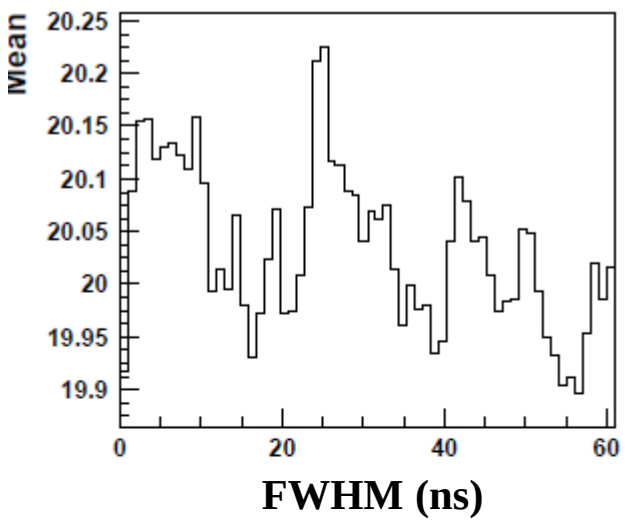


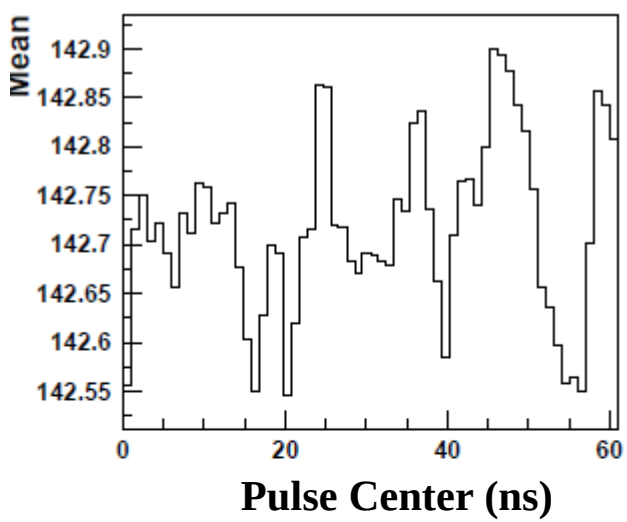
A 60 h run over the last weekend with
1 mJ and 20 ns FWHM shows the stability.
Intensity: 1.**3 %**
FWHM Width: **2.3%**
Jitter: **0.34 ns**

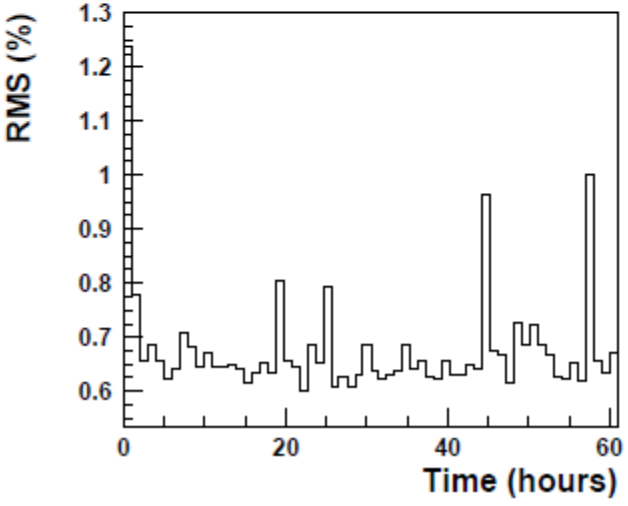
History of 60 hour Data

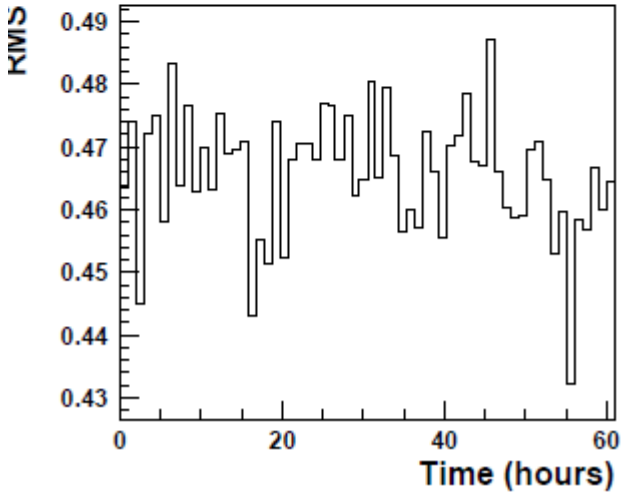
More than 3% draft in pulse intensity observed

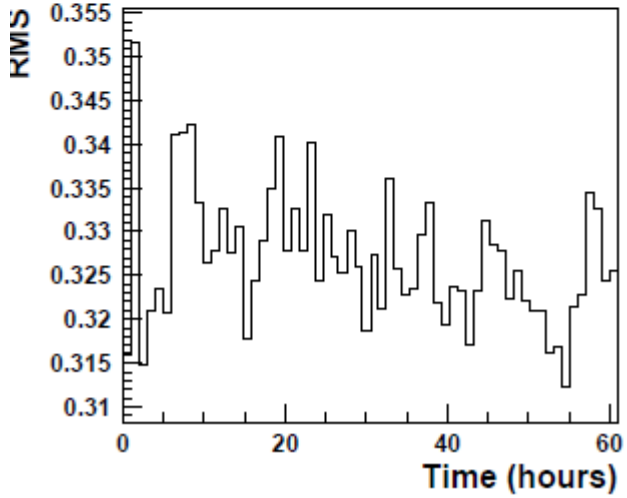






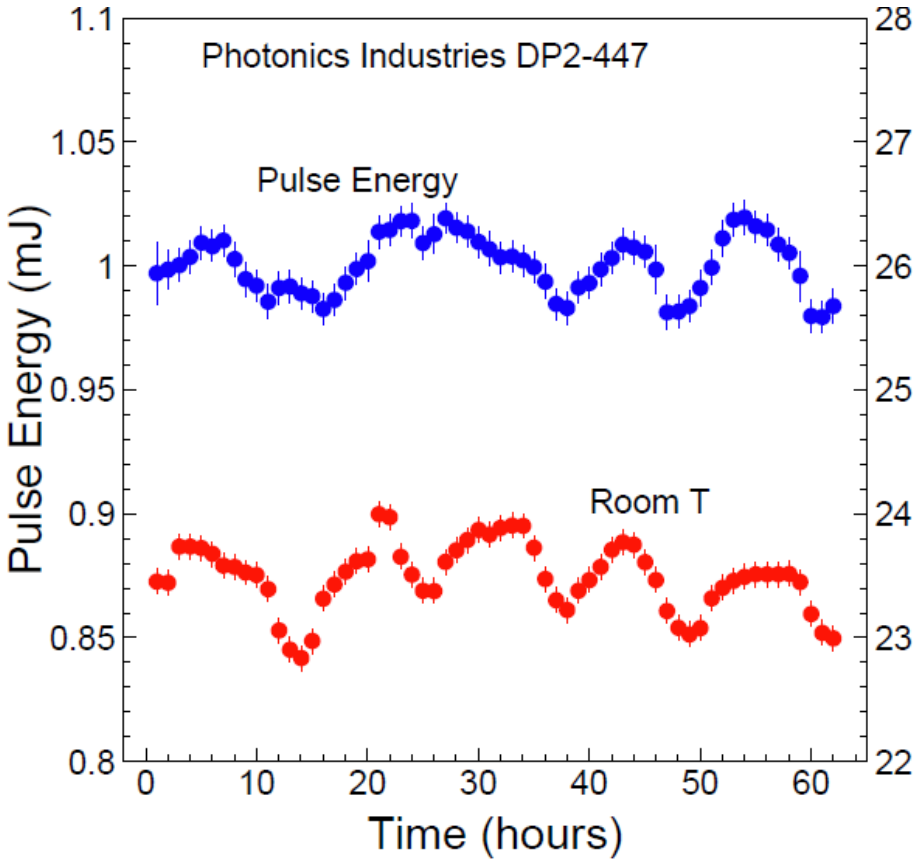


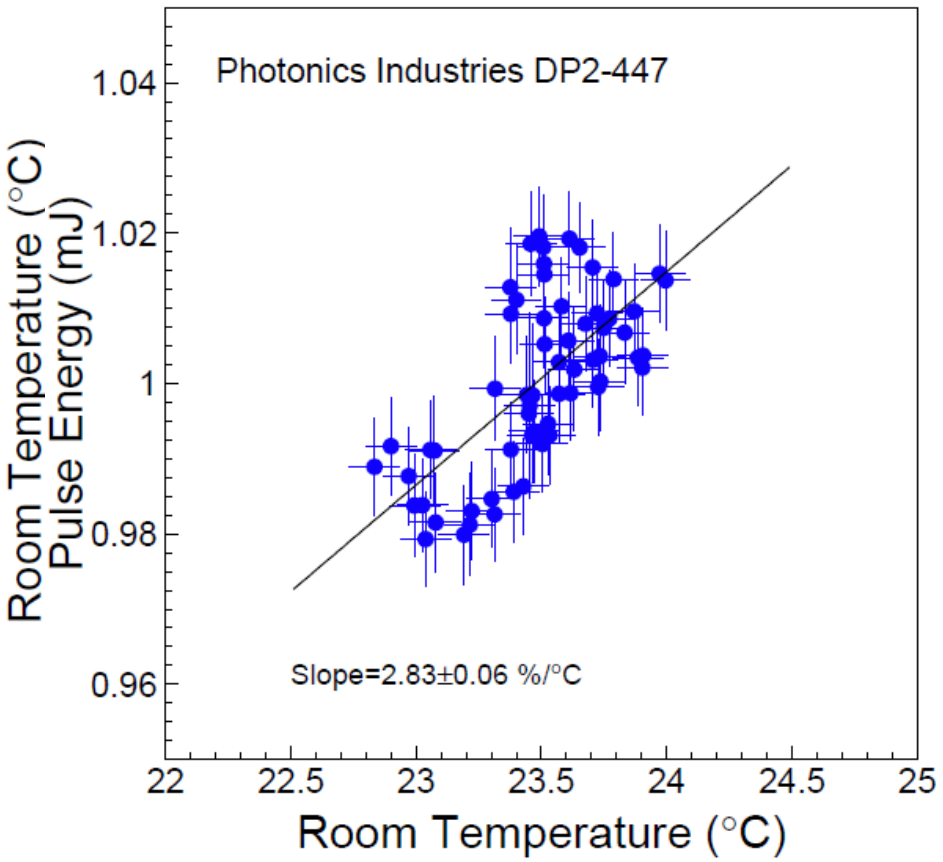




Pulse Energy versus Room Temperature

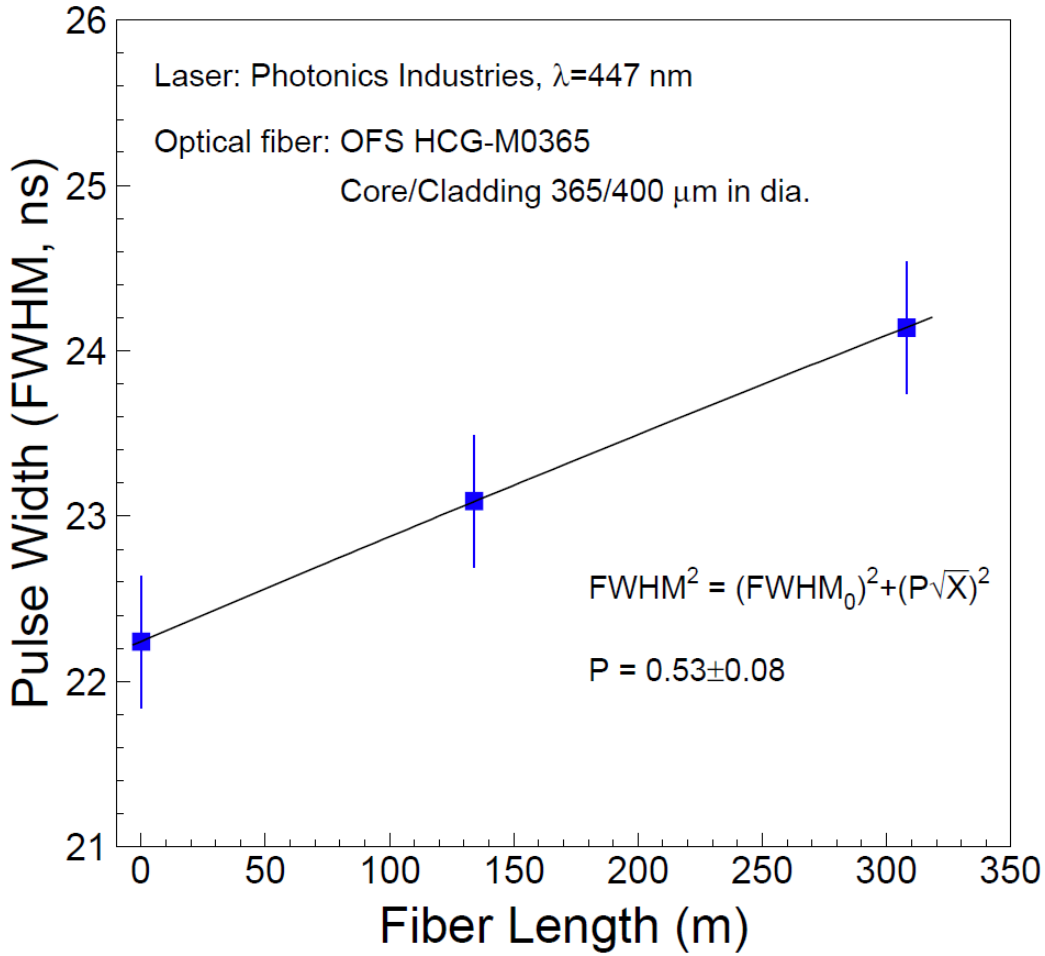
Room temperature needs to be stabilized to 0.3°C to maintain pulse energy stability at a level of 1%





Pulse Width Broadening in Fiber

Wavelength (nm)	HCG-M0365T Fiber (m)	Input Pulsewidth (ns)	Output Pulsewidth (ns)	Broadening Rate (ns/100 M)	Broadening Rate (ns/(100 M)$^{0.5}$)
447	134	22.25	23.09	4.61	5.33
447	308	22.23	24.14	3.06	5.36



Laser pulse width broadening (time dispersion) was observed, which seems following square root of fiber length.

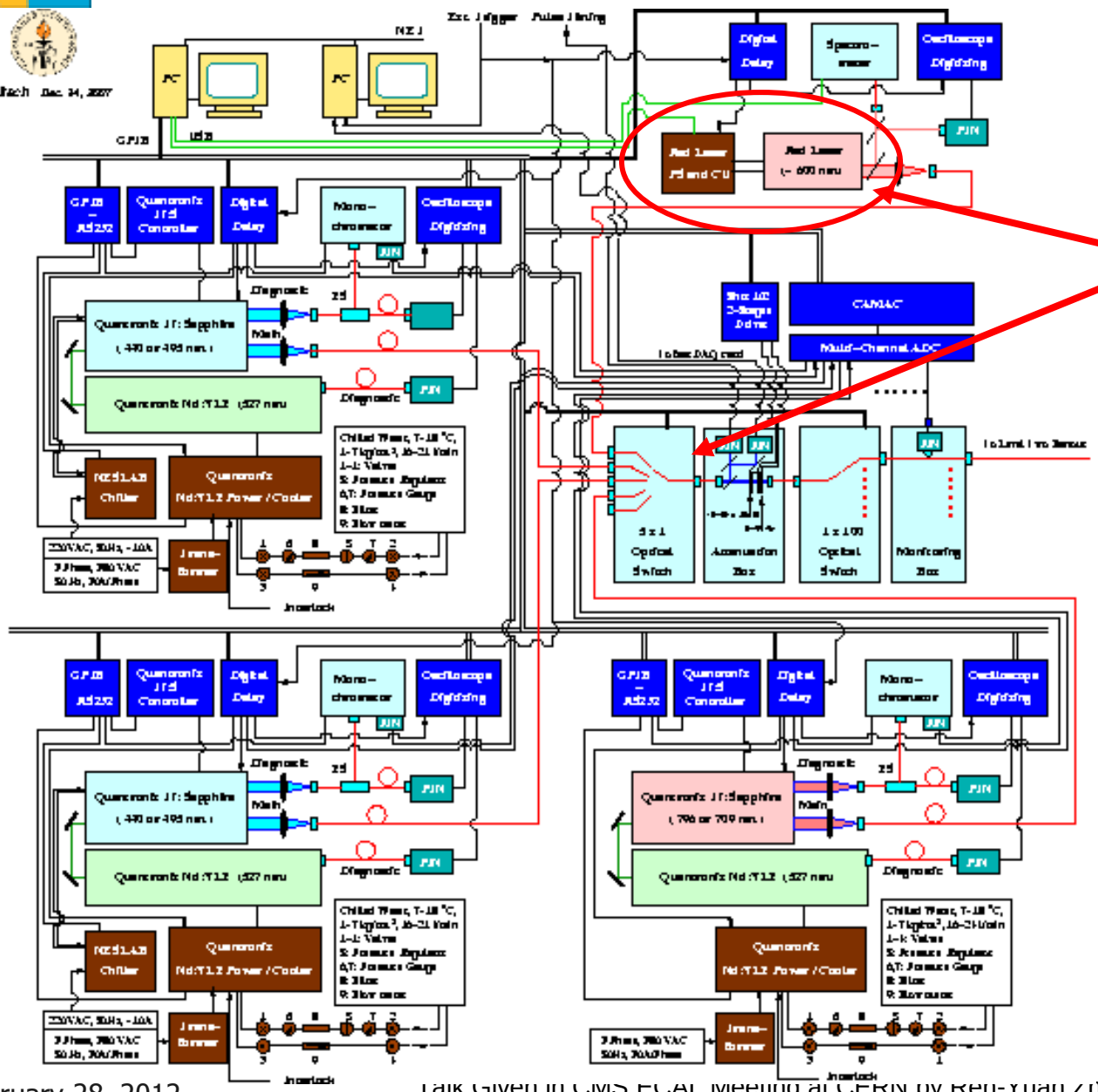
The dispersion effect would be more serious for narrow laser pulses.

Will measure this effect again with narrow laser pulses and at different wavelengths.

DP2-447 Commission at P5

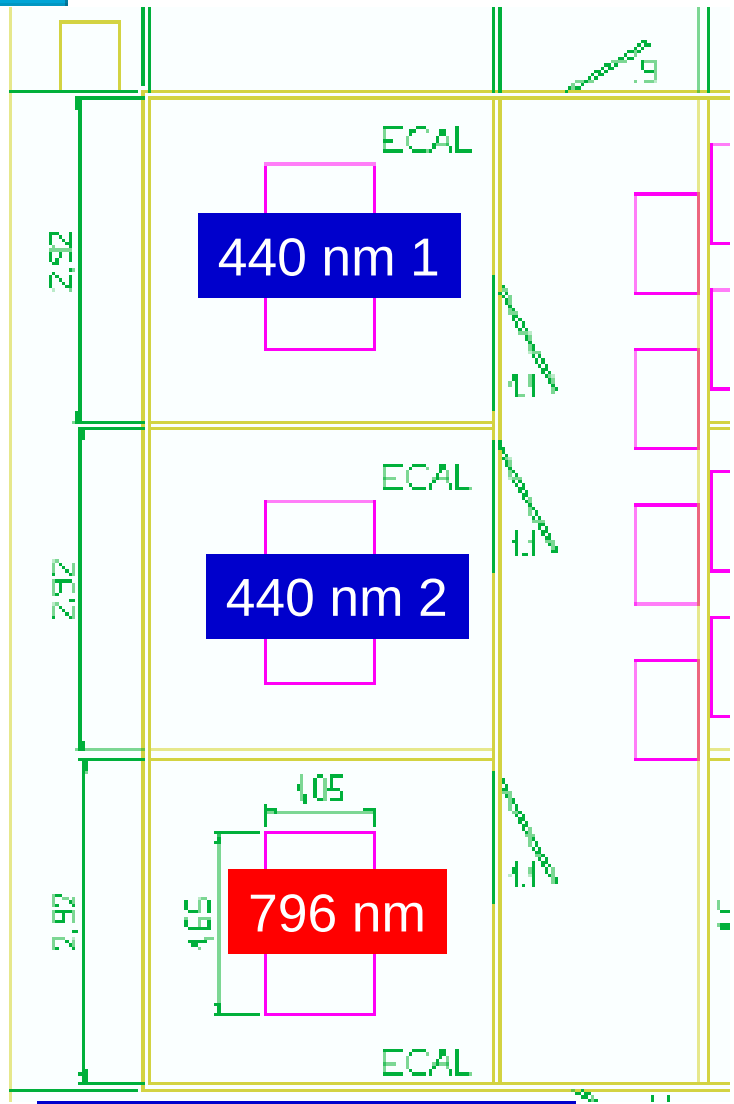
- Location for the laser
  - New area located in the existing barracks
- Operation in the magnetic field (no info from manufacturer)
  - Preparations for magnetic shielding
- Integration with existing lasers
  - Switches, laser supervisor, MATACQ etc.
- Modifications to timing/triggering
  - New laser may use a delay of ~90 μsec (>1 bx)

Integration to the Existing System

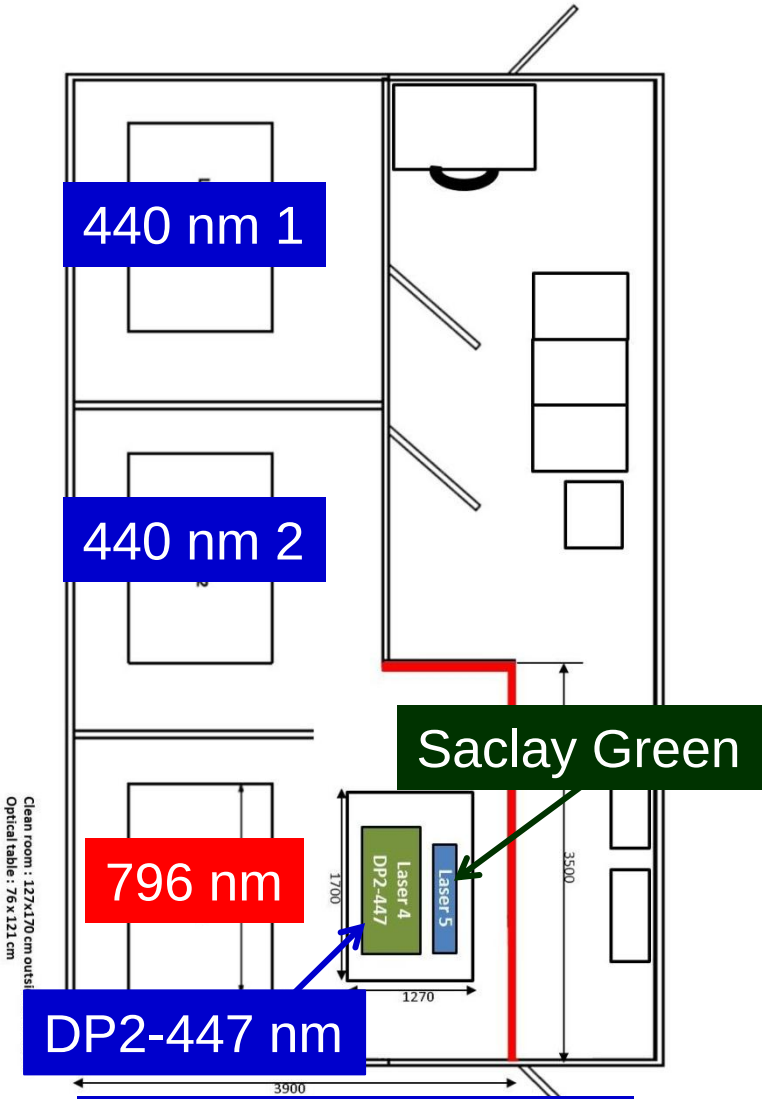


Two additional lasers: Photonics DP2-447 at 447 nm and Saclay green will be added using the existing 5 x 1 switch

Laser Barracks & Modification

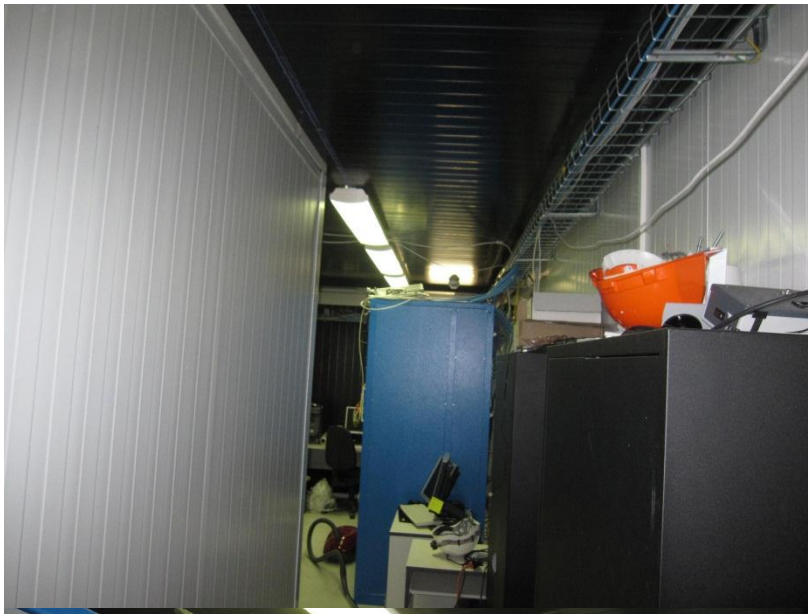


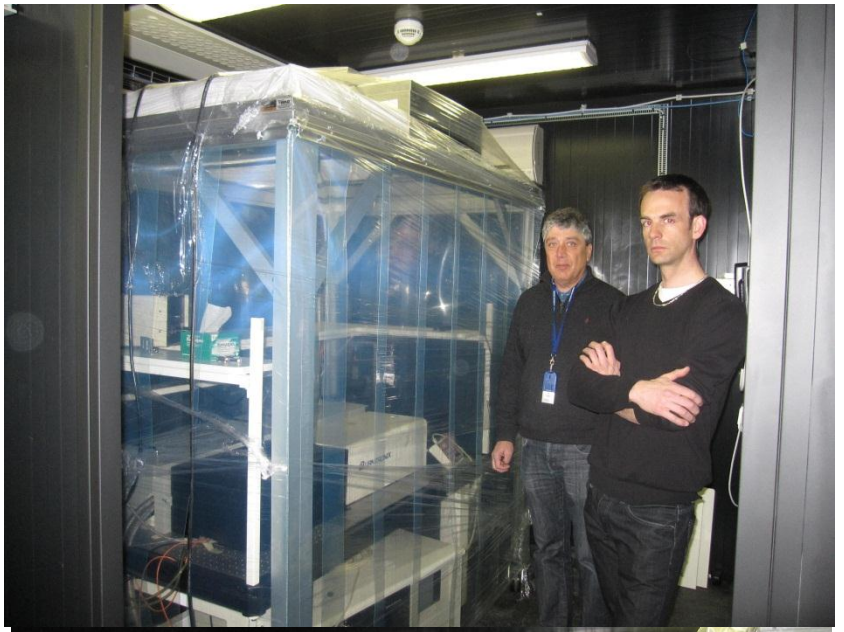
Existing Barracks



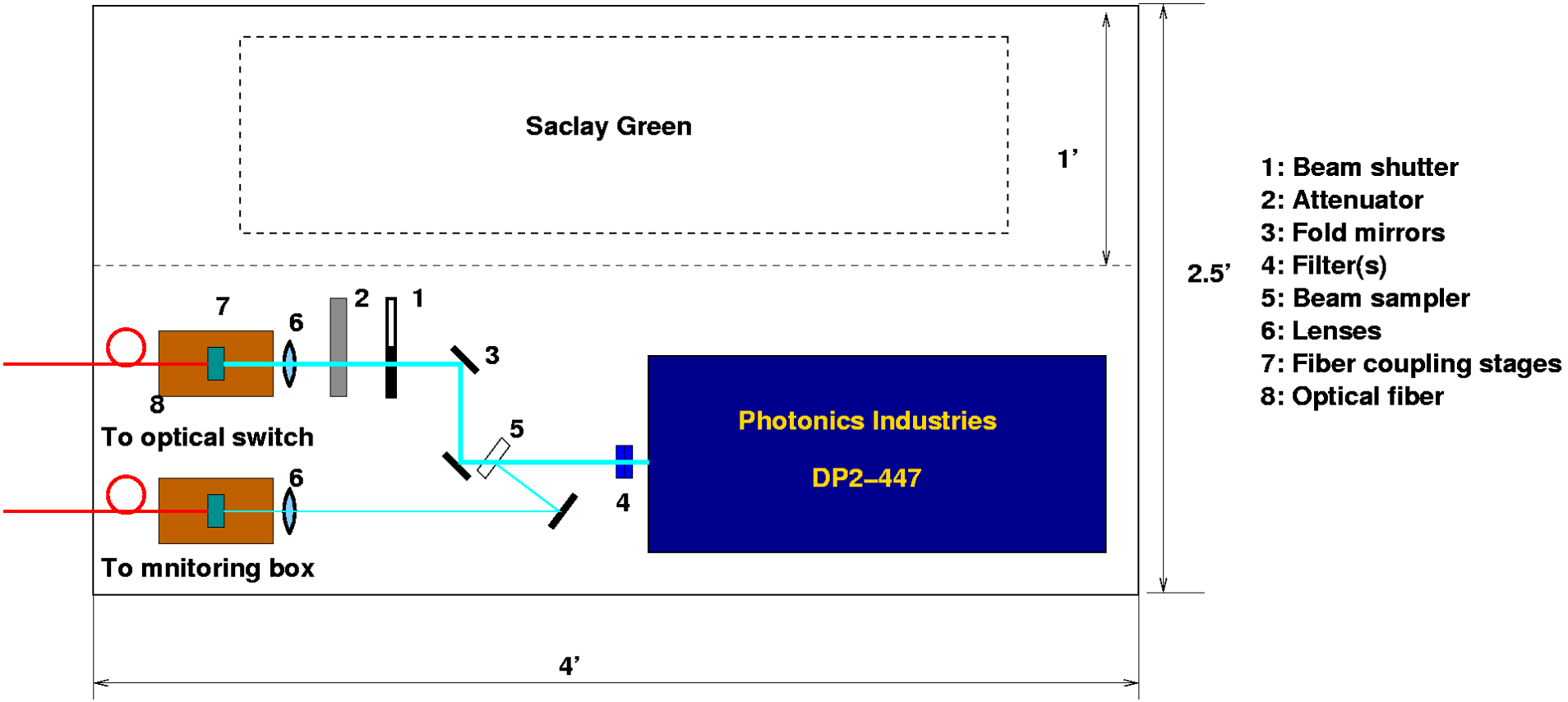
Modified Barracks

Laser Barracks (2/27/2012)





New Lasers on 2.5’ x 4’ Table

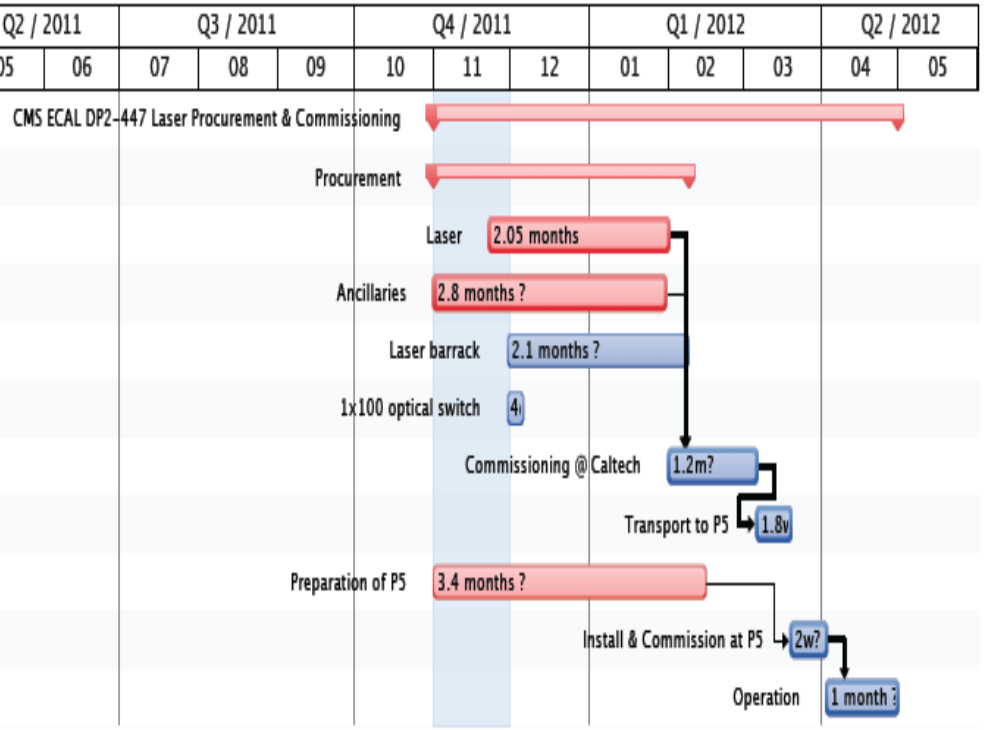


Both DP2-447 and the Saclay Green lasers will be installed on a 2.5’ x 4’ optical table in the existing laser barracks

Schedule

- Order placed 11/11/11, laser at Caltech: 2/6 to 3/8/12;
- Packing: 3/6 and 3/7; Shipping: 3/8/2012;
- Commissioning at P5: 3/19 to 3/30/2012;
- Run: 3/31 to 4/30/2012...

#	Info	Title	# Predecessors	Expected Start	Expected End	% Complete
0		CMS ECAL DP2-447 Laser...		11/1/11	4/30/12	2%
1		Procurement		11/1/11	2/8/12	3%
2		Laser		11/23/11	1/31/12	0%
5		Ancillaries		11/1/11	1/30/12	4%
81		Laser barrack		11/30/11	2/8/12	0%
101		1x100 optical switch		11/30/11	12/5/11	0%
106		Commissioning @ Caltech	2; 5	2/1/12	3/6/12	0%
110		Transport to P5	106	3/7/12	3/19/12	0%
114		Preparation of P5		11/1/11	2/15/12	0%
124		Install & Commission at P5	113; 114	3/20/12	4/2/12	0%
130		Operation	124	4/3/12	4/30/12	0%



Because of the simple laser, schedule is reduced to 20 weeks

Summary

Light output variations in PWO crystals present a challenge for precision crystal calorimeter at the LHC. A DP2-447 blue laser is expected to provide a reliable light source.

Tests at Caltech show that the DP2-447 laser meets original specifications in pulse intensity and stability. The system will be commissioned at P5 in March and start operation in April. The construction project is on schedule.

Laser pulse width broadening (time dispersion) was observed for blue laser pulses from DP2-447. It seems following square root of the fiber length. The net effect depends on the laser pulse width, and is more serious for narrow pulses.

Future Plan

Before 3/8/2012: put system together, measure correlations, optimize run parameters, such as delay etc. and packing.

3/8/2012: Ship DP2-447 from Caltech to CERN.

3/19 – 3/30/2012: Commission DP2-447 at P5.

2012: Gain experience for DP2-447 laser M&O. Keep three Quantronix lasers operational.

Long shutdown: M&O for one Photonics DP2-447 laser. Need to make decisions on (1) Quantronix lasers, (2) 2nd blue laser and (3) additional lasers for the secondary wavelength, such as IR and orange.

After long shutdown: M&O for two blues lasers, plus addition if any.

DP2-447 Warranty & Spare Parts

Photonics Industries International, Inc.
390 Central Ave., Bohemia, NY 11716, USA
Tel: 631-218-2240 Fax: 631-218-2275
www.photonix.com info@photonix.com

Field Replaceable Spare Parts and Warranty Options for DP2-447 Laser System

Part #	description	Price	Quantity	Lifetime
5027842	Diodes	$6,600.00	2	guaranteed for 5,000hours
8227500	Output Window	$550.00	1	3-5 Yrs
2026715	Laser Diode Driver	$3,750.00	1	5 Yrs +
2026244, 2026257, 2027899, 2027074	Power Supplies	$1,000.00	4	5 Yrs +
8027164	Dawn Board	$300.00	1	3-5 Yrs

Extended Warranty Options for DP2-447 Laser System:

Service Plan I
Service Plan I is available to cover Photonics Industries laser systems. This plan provides coverage for a service engineer or a laser system to allow for rapid replacement of a laser requiring service. Under this plan, Photonics Industries will either send an engineer to the customer site to repair the laser or if it is deemed that the laser can not be repaired in the field will send a replacement laser to the customer within 24 hours of notification. If a replacement laser is sent then the laser to be serviced will be returned to Photonics Industries or a Photonics Industries designated service center at the discretion of Photonics Industries. The laser will be serviced to conform and meet original specifications. The customer may choose to keep the replacement laser or have the original laser returned to them.

This agreement may be purchased at any time provided the system is still under original warrantee or currently covered under Service Plan I

The advantage of this plan is that the customer does not have to purchase and maintain a spare laser. For this service, a yearly fee of 30% of the laser price will be charged.

Service Plan II
Service Plan II is an extension of the standard warrantee. Under this plan a laser that requires service is to be returned to Photonics Industries or a Photonics Industries designated service center at the discretion of Photonics Industries. The laser will be serviced and returned to the customer. During the time the laser is being serviced, a laser will be lent to the customer, if available. Upon return of the serviced laser, the customer must return the loaner laser to Photonics Industries within one (1) week. If the laser has to be returned to Photonics Industries, the customer will be responsible for all the shipping charges, taxes and duties related to shipping the lasers Photonics Industries.

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www.photonix.com info@photonix.com

This agreement may be purchased at any time provided the system is under original warrantee or currently covered under Service Plan II.

For this service Photonics will charge a yearly fee of 20% of the laser price will be charged.

Service Plan III
Service Plan III is available to cover Photonics Industries laser systems. Lasers in need of repair should be returned to Photonics Industries for evaluation. Upon evaluation Photonics Industries will give the customer a detailed quotation for the required repair. If the customer accepts this quotation, Photonics will make the repairs and return the laser to the customer. The customer will be responsible for all the repair charges, shipping charges, taxes and duties related to shipping the lasers to and from Photonics Industries.

Plan 1: Photonics sends a replacement 30% of laser cost, or $51k/year.

Plan 2: Photonics sends a loaner if available, which is required to be sent back within a week after service. 20% of laser cost/year, or $34k/year.

Plan 3: Laser returned to Photonics Pay service fee each time. Service time needed is 6 to 8 weeks.

User self-service is not recommended.

M&S Cost for DP2-447 Maintenance

Initial spare parts procurement: $40k; Yearly cost: $20k

Item	Description	Part#	Unit Price	Quantity	Price2	Est. Lifetime (Year)	Cost/Year
1	Pump Diodes	5027842	$6,600	2	$13,200	1	$13,200
2	Laser Diode Driver	2026715	$3,750	1	$3,750	5	$750
3	Output Window	1028134	$1,500	1	$1,500	3	$500
4	Power Supply Module	2026244	$1,000	1	$1,000	5	$200
5	Power Supply Module	2026257	$1,000	1	$1,000	5	$200
6	Power Supply Module	2027899	$1,000	1	$1,000	5	$200
7	Power Supply Module	2027074	$1,000	1	$1,000	5	$200
8	Dawn Board	8027164	$300	1	$300	3	$100
9	Laser Crystal	5027658	$4,000	1	$4,000	3	$1,333
10	SHG Crystal	5000051	$3,000	1	$3,000	3	$1,000
11	THG Crystal	5000056	$3,500	1	$3,500	3	$1,167
12	Q-switch		$3,500	1	$3,500	5	$700
13	Lens	5110387	$500	1	$500	5	$100
14	Lens	5110389	$500	1	$500	5	$100
15	Mirror	5127497	$495	1	$495	5	$99
16	Mirror	5127577	$495	1	$495	5	$99
17	Mirror	5110907	$495	1	$495	5	$99
18	Waveplate	5211009	$500	1	$500	5	$100
19	Waveplate	5327000	$500	1	$500	5	$100
				Total	$40,235		$20,247

Additional cost for manpower, travel and M&S for ancillary equipment