



---

# Monitoring Laser Upgrade

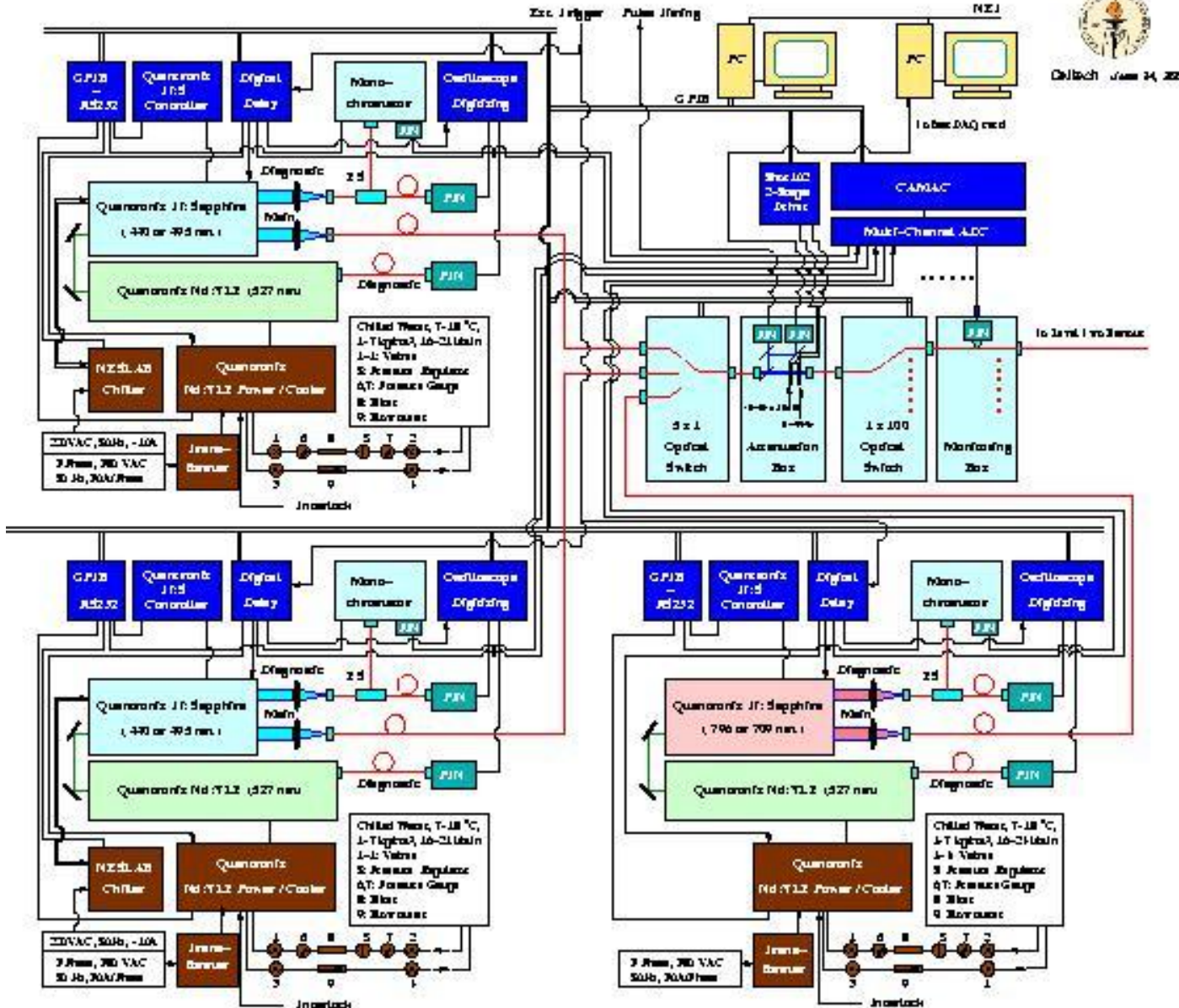
**Ren-yuan Zhu**

**Caltech**

December 7, 2010



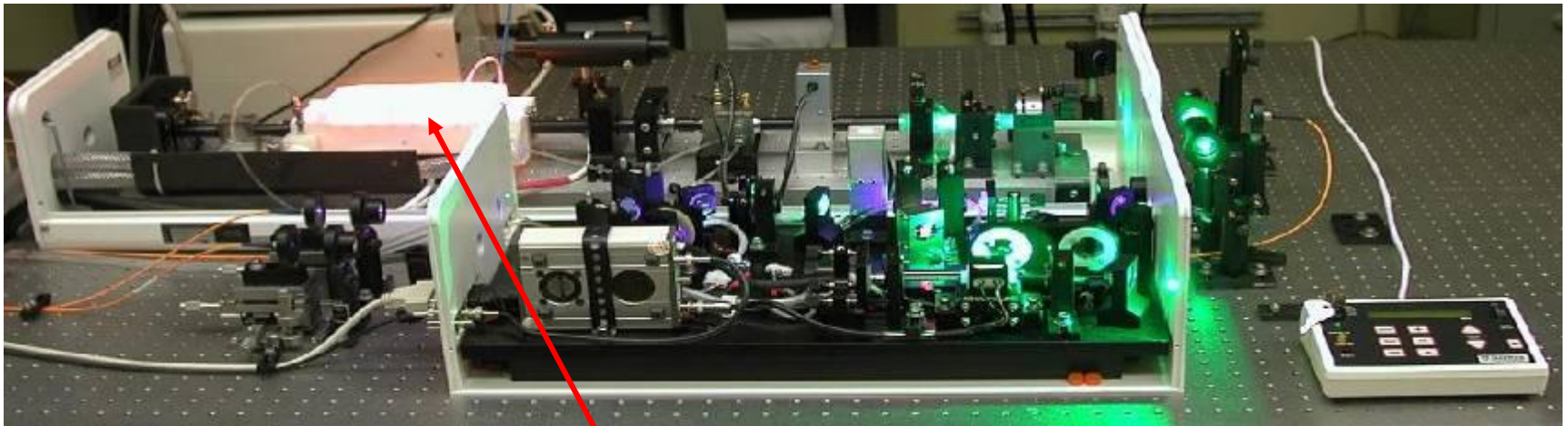
# Existing Laser System



It includes three lasers (2 blues and 1 IR) with diagnostics, two optical switches and intensity attenuators.

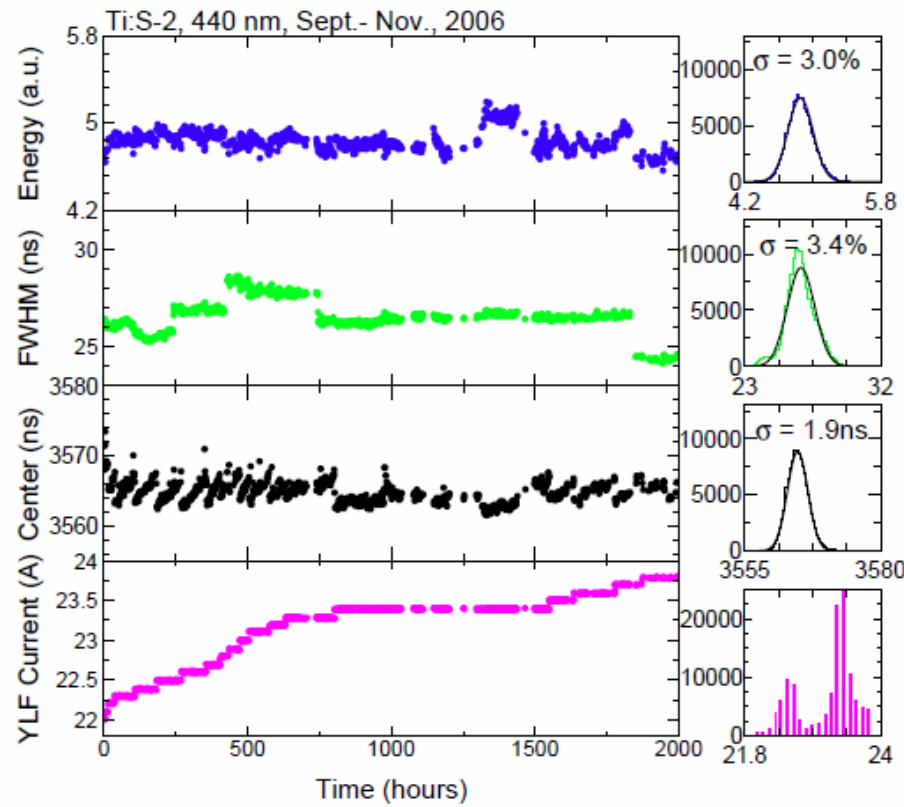
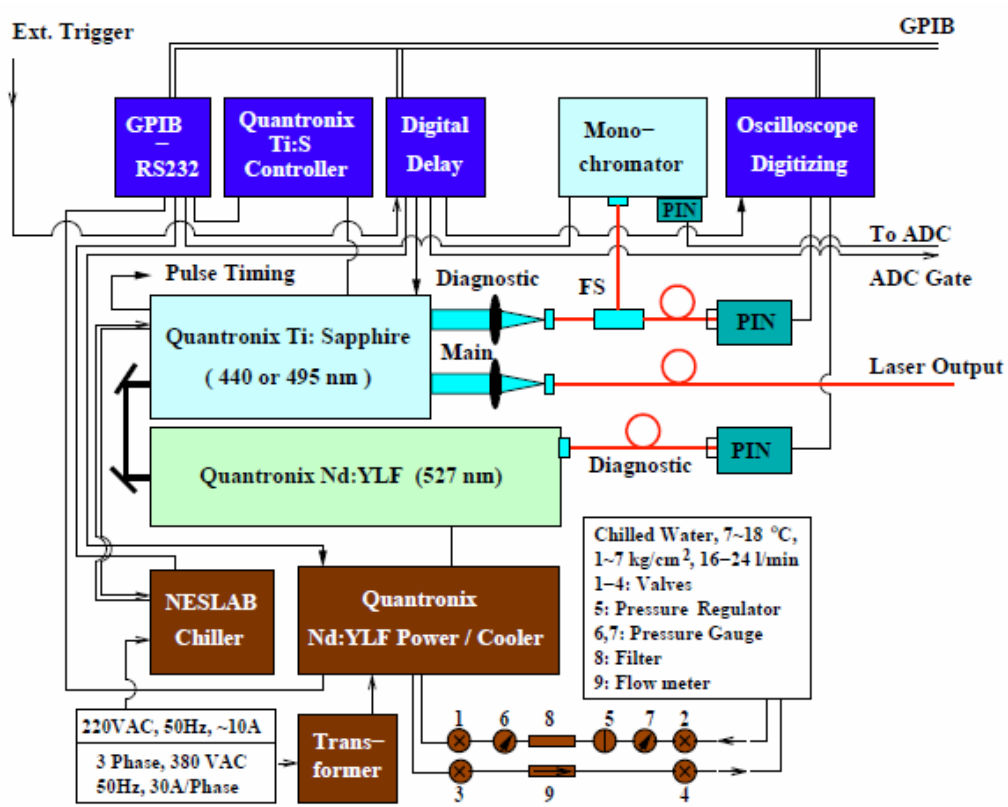
1<sup>st</sup> laser at H4: 08/2001  
 2<sup>nd</sup> & 3<sup>rd</sup> lasers: 8/2003  
 Software Feedback: 05/2006  
 Lasers at P5: since 03/2007

# DC Kr Pumped Nd:YLF & Ti:S Lasers



DC Kr lamp which ages in time, so reduces laser pulse intensity, increases laser pulse width and timing.

With a software feedback and an inserted delay the laser pulses show the same intensity and width with about 3% instability and 3 ns jitter.



The system operates 24/7 as designed, providing 100% availability of the blue (440 nm), and the IR (800 nm) as the 2<sup>nd</sup> wavelength for the barrel.

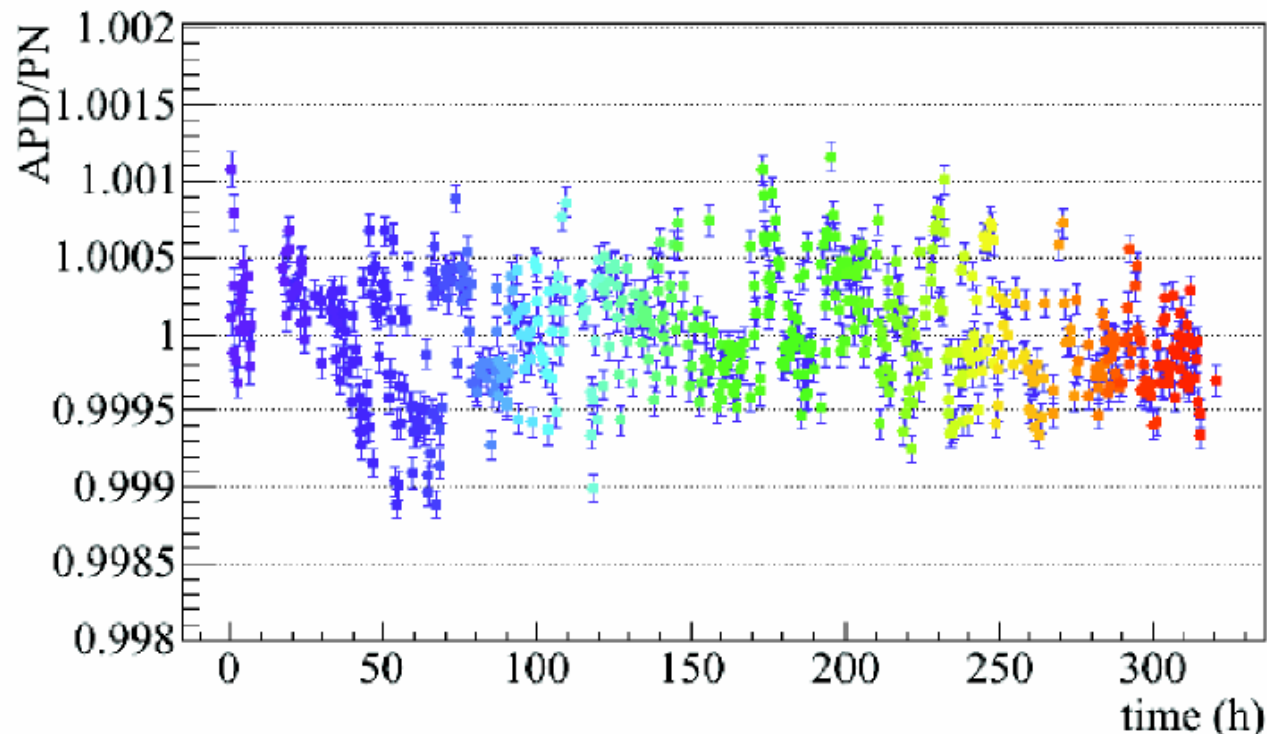
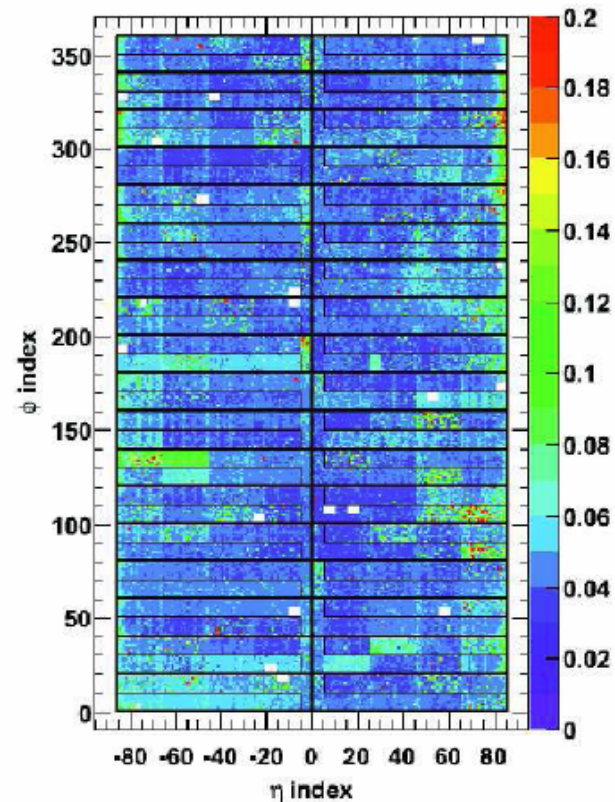


# ECAL Monitoring Stability



Julie Malcies, talk in CMS Weekly General Meeting, Nov 17, 2010

The blue laser data, taken between runs 132226 and 132914 for about 350 h in 2010, shows a mean stability of 0.05% for the barrel, and 0.06% for endcaps.





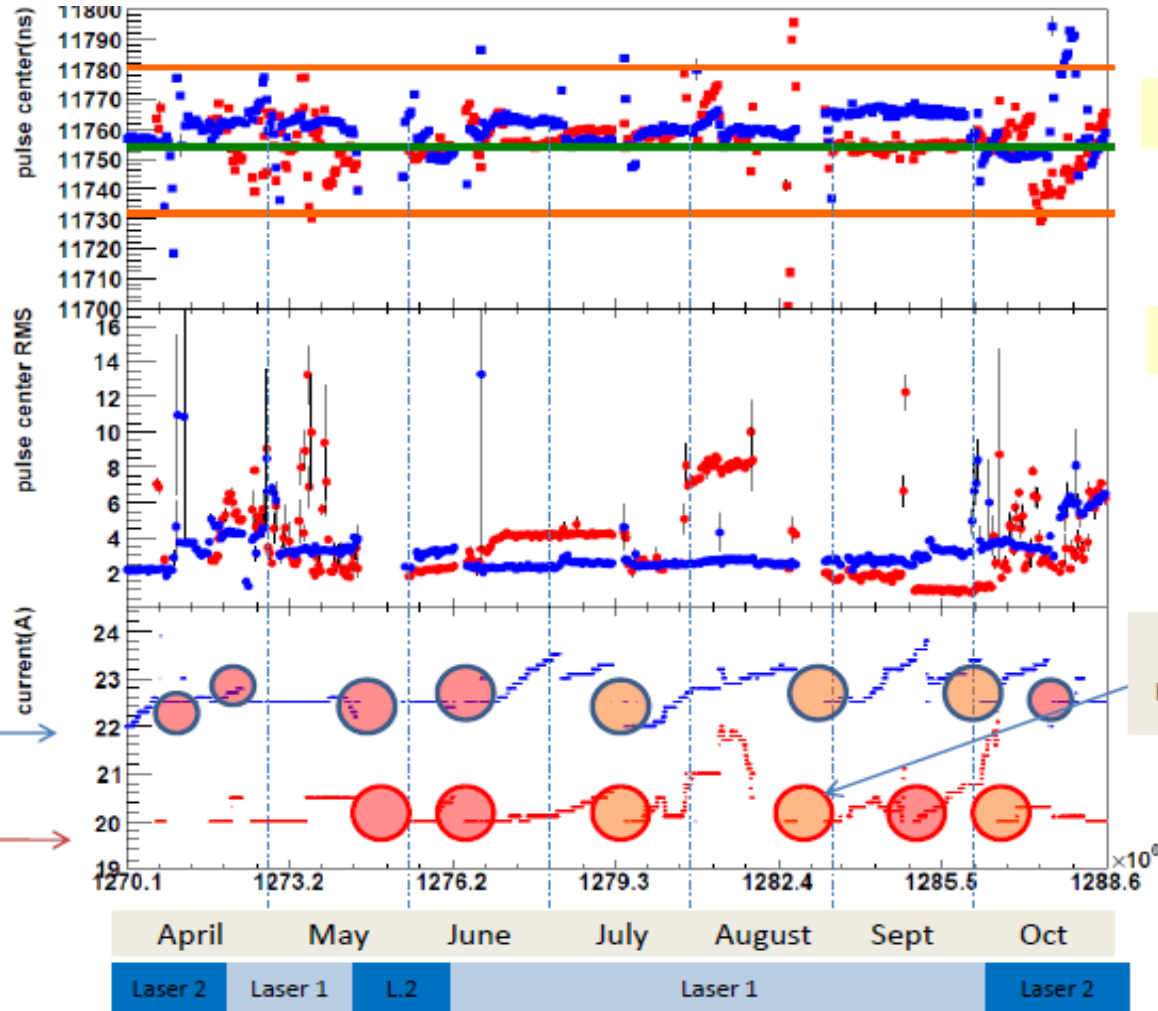
# 2010 Laser Run Experience



David Bailleux, Summary of Laser Runs

Current evolution show any laser interventions of adjustments:

- when it's get high something wrong;
- when restart from low current, working point, mean tuning;
- when current goes to decrease it's not so well, current should increased to compensate lamp aging. But this is theoretical because feedback is set on TIS timing now, not on the YLF energy



Blue laser intervention →

Red laser intervention →

Maintenance



Services



Long interruption RED laser: 1 week

With laser diode pump the lamp aging effect may be eliminated



# Four Existing Issues



1. Need spare Dicon optical switches: 5 x 1 and 1 x 100. The system will not function when they break.
2. Quantronix discontinued DC Kr lamp pumped Nd:YLF laser in 2005. All parts, e.g. RF driver, power distribution unit etc., are discontinued since 2009. Consumable, e.g. pumping housings etc., are no longer available.
3. There has been a discussion since 2008 about adding a 2<sup>nd</sup> wavelength at 600 nm for the endcaps, where both PWO transparency and VPT gain change *in situ*.
4. Spare lasers for the second wavelengths are needed if 100% availability is required.



# Quotation: GP700 Optical Switch



**DiCon**  
**FIBEROPTICS, INC**  
 1689 REGATTA BLVD.  
 RICHMOND, CA 94804  
 TEL (510) 620-5200  
 FAX (510) 620-4102  
 sales@diconfiber.com  
 www.diconfiber.com

TO:  
 LIYUAN ZHANG  
 ZHANG\_L@LIGO.CALTECH.EDU  
 CALIFORNIA INSTITUTE OF TECHNOLOGY  
 MS 256-48, CALTECH  
 391 S. HOLLISTON  
 PASADENA, CA 91125  
 UNITED STATES  
 TEL: 626-395-6618  
 FAX: 626-795-3951

<b>Sales Quotation</b>		Quote ID No. & Rev.	<b>7077B</b>
FOB	ORIGIN	Quote Issue Date	10/5/2010
Payment Terms		NET30 FROM SHIPMENT DATE	
DiCon Contact		DICON SALES (510) 620-5200, SALES@DICONFIBER.COM	

Item	DiCon's Part No. / Buyer's Part No. / Description	Quantity / Unit Price	Shipment Dates
1	DiCon's P/N: GP700-2-1/1X5-8-365-FC-B-Z Description: GP700 PROGRAMMABLE PLATFORM SPECIAL Buyer's P/N: <b>Note:</b> Special pricing for educational purposes. <b>Special Requirements:</b> 365um Silica-Silica HCG-M0365T fiber to be supplied by the customer. FC/PC stainless steel connectors to be ordered by DiCon. Alignment & testing will be done at 850nm.	\$8,745.00 each  Pricing valid if both lines, 1 and 2, are purchased together.	4 - 6 weeks OAD
2	DiCon's P/N: GP700-4-1/1X100-8-365-FC-B-Z Description: GP700 PROGRAMMABLE PLATFORM SPECIAL Buyer's P/N: <b>Note:</b> Special pricing for educational purposes. <b>Special Requirements:</b> 365um Silica-Silica HCG-M0365T fiber to be supplied by the customer. FC/PC stainless steel connectors to be ordered by DiCon. Alignment & testing will be done at 850nm.	\$62,150.00 each  Pricing valid if both lines, 1 and 2, are purchased together.	6 - 8 weeks OAD





# Replacing DC Kr Lamp Pumped Nd:YLF with Laser-Diode Pumped Nd:YLF

Quantronix replaced DC Kr pumped Nd:YLF laser with laser-diode pumped Nd:YLF laser in their product line starting 2005. The diode pumped Nd:YLF has the following advantages.

1. Better pulse intensity stability;
2. Better life time over 10,000 h;
3. Less maintenance requirement;
4. Less power consumption.

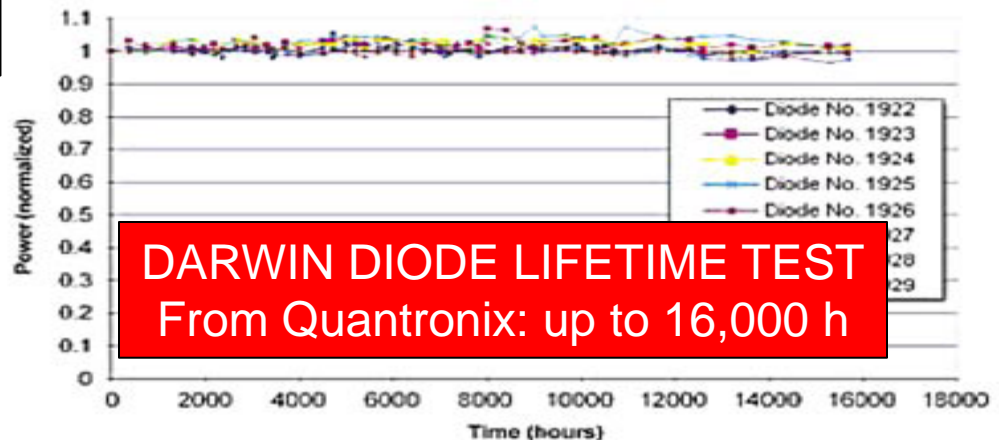
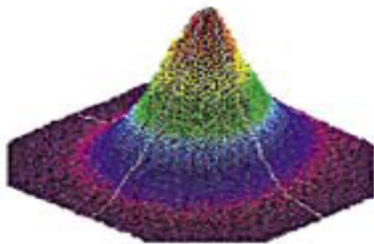


# Pump Laser Comparison



Parameters at 1KHz	DC Kr Lamp pumped 527DQ-S	Diode pumped Darwin 527-40-M
Average Output power (W)	20	25
Power instability (% , RMS)	2	0.5
Pulse energy (mJ)	20	25
Pulse width, typical (ns)	150	150
Beam pointing stability ( $\mu$ rad)	30	25
Beam diameter (mm)	3	2.5
Divergence (mrad)	5	8

## DARWIN 3D BEAM PROFILE





# Darwin Laser User Reference



Prof. Michael Fayer of Stanford university replaced three Quantronix 527DQ Nd:YLF lasers with diode pumped Darwin lasers five years ago and provided the following comments.

- Low maintenance: water filters replaced once per three months; fine tuning optics some times.
- The diode module needs to be run continuously for extended lifetime, which is the case of our application.
- Good reliability: none of the three lasers was sent back for a reparation. One of the three pumping diode modules was replaced (~\$10K) after 40,000 hrs, other two are still working with accumulated run times of 20,000 and 30,000 hrs without significant degradation in the laser output.
- Two additional failures happened in the last five years: one was in an RF driver and other in a water chiller.



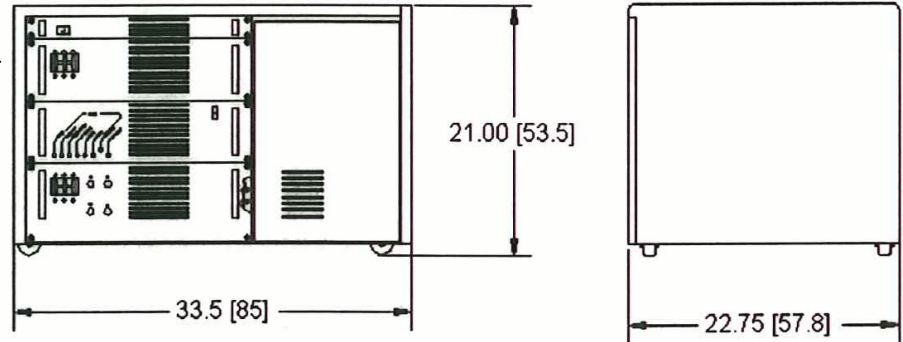
# Issues to be Addressed

Replacing the DC Kr lamp pumped Nd:YLF laser with diode pumped model is not straight forward. Three issues need to be addressed.

- Quantronix claims that the Darwin 527-40-M works in the residual B-field in the laser barrack at P5, but not guaranteed. An return option is offered in their quotation with 30% restocking fee within one month.
- Because of the change of the beam divergence the coupling optics between YLF and Ti:S needs to be redesigned with new parts. Quantronix will **NOT** provide this service. We'll have to do it by ourselves.
- The laser power supply for the diode pumped laser is a new model. The laser DAQ software needs to be updated for this replacement.

# Power Supply Unit Comparison

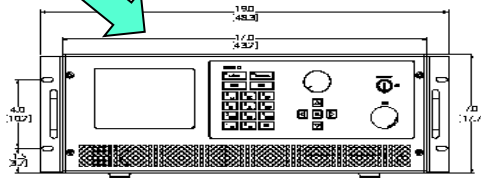
**Kr lamp pumped 527DQ:**  
 33.5"(L)×22.8"(D) ×21.0"(H)



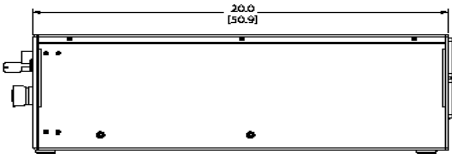
**Diode pumped 527-40-M, two units:**  
 19.0"(L)×20.0"(D) ×7.0"(H)  
 19.0"(L)×27.5"(D) ×16.2"(H)



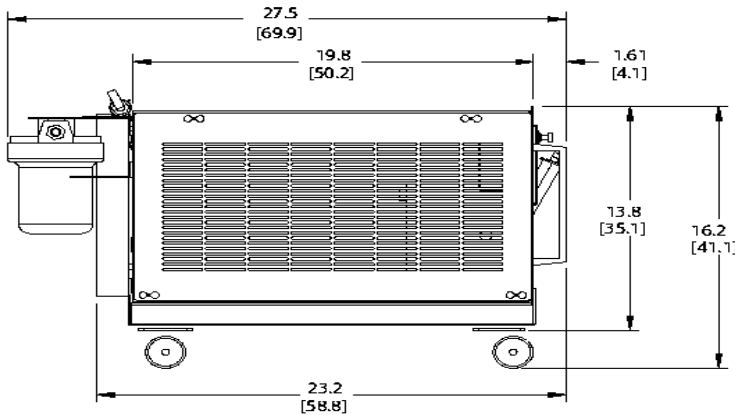
FRONT VIEW  
(POWER SUPPLY)



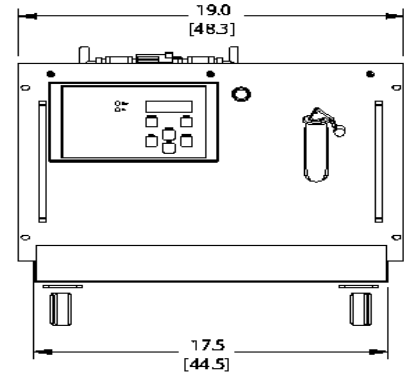
SIDE VIEW



SIDE VIEW  
(CHILLER)



FRONT VIEW





# Quotation: Darwin-Pro-527-40-M



41 Research Way  
East Setauket, NY 11733  
Phone (631)784-6100 FAX (631)784-6101

### Quotation No

2191 - 001-10

### CUST REF #:

DATE: November 15, 2010

VALID FOR: 30 Days

PAGE NO. 1 of 3

Attn: Dr. Liyuan Zhang  
California Institute of Technology  
244 Lauritsen Laboratory  
Pasadena CA 91125  
Tel: (626) 395-6618 Fax:  
E-mail: liyuan@hep.caltech.edu

Send Purchase Order to:  
Quantronix Corp  
41 Research Way  
East Setauket, NY 11733  
Email: hseferyan@quantronixlasers.com  
Phone: 1-631-784-6100  
Fax: 1-631-784-6101

### WE ARE PLEASED TO QUOTE THE FOLLOWING:

ITEM	QTY	DESCRIPTION	UNIT PRICE	TOTAL	
1	1	<b>Darwin-Pro-527-40-M (DPSS Nd:YLF Laser)</b> * Wavelength: 527nm * Power: 40W at 3kHz * Please refer to the attached spec sheet for more information * Price includes standard diode module warranty	65,000.00	65,000.00	
2	0	<b>Upgrade to Water/Water Heat Exchanger</b>	500.00	0.00	
3	0	<b>Longer Umbilical Cable (20 ft)</b>  * Please note that the return of Item #1 is possible within 30 days of the purchase; a 30% restocking fee will be applied based on the current list price.	1,000.00	0.00	
			Subtotal	65,000.00	
<b>F.O.B.</b>		<b>Payment Terms</b>	<b>Delivery</b>	<b>Sales Tax %</b>	0.00
East Setauket, NY		Net 30 days	60 - 90 days ARO	Transportation	
			Total USD	\$65,000.00	

All Items In This Quote Is Subject To The Quantronix Scientific Standard Terms And Conditions. Please Reference Quote Number When Ordering. Customs, Taxes Are Extra, If Applicable. All Prices In Quote Are In Us Dollars.

for additional information contact:  
Hrant Seferyan, Regional Sales Manager  
hseferyan@quantronixlasers.com



# 2<sup>nd</sup> Wavelength for Endcaps



2<sup>nd</sup> wavelength is needed to disentangle variations of PWO and VPT. Because of the VPT response it should not be longer than 610 nm. This light source may be provided by two approaches: (1) multiple sources distributed to all L1 fan-outs on detector or (2) a centralized laser source in the laser barracks at USC55, which should satisfy the following original specification.

- Pulse Width: Full width at half maximum (FWHM) < 40 ns to match the ECAL readout.
- Pulse Jitters: < 3 ns for trigger synchronization to the LHC beam.
- Pulse Rate: 100 Hz, which is the rate at which the “spy mode” ECAL DAQ used for monitoring events can operate.
- Pulse Energy: 1 mJ/pulse at monitoring wavelength, corresponding to 1.3 TeV in full dynamic range, and a linear attenuator at 1% step down to 13 GeV.
- Pulse Intensity Instability: < 10% to guarantee moni-



# Monitoring Light Source Power Requirement



To keep 1.3 TeV dynamic range, the required pulse energy/power with a pulse width of  $< 40$  ns would be

In laser barracks to switches:

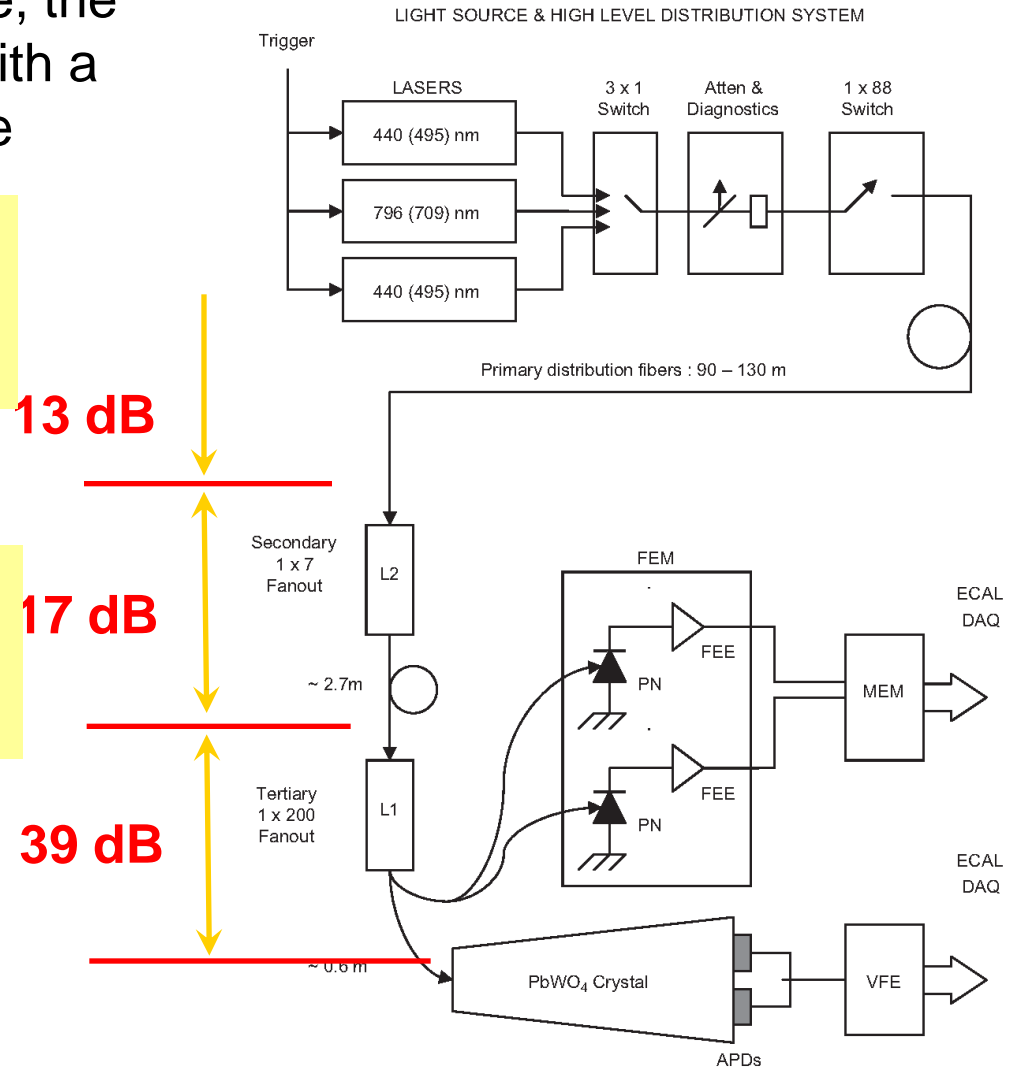
**1 mJ** (or peak power **25 kW**)

On detector to L1 Fanouts:

**1  $\mu$ J** (or peak power **25 W**)

**Commercial LED or laser diode does not provide 25 W, pointing to the laser solution.**

*M. Anfreville et al. / Nuclear Instruments and Methods in Physics Research A 594 (2008) 292-320*



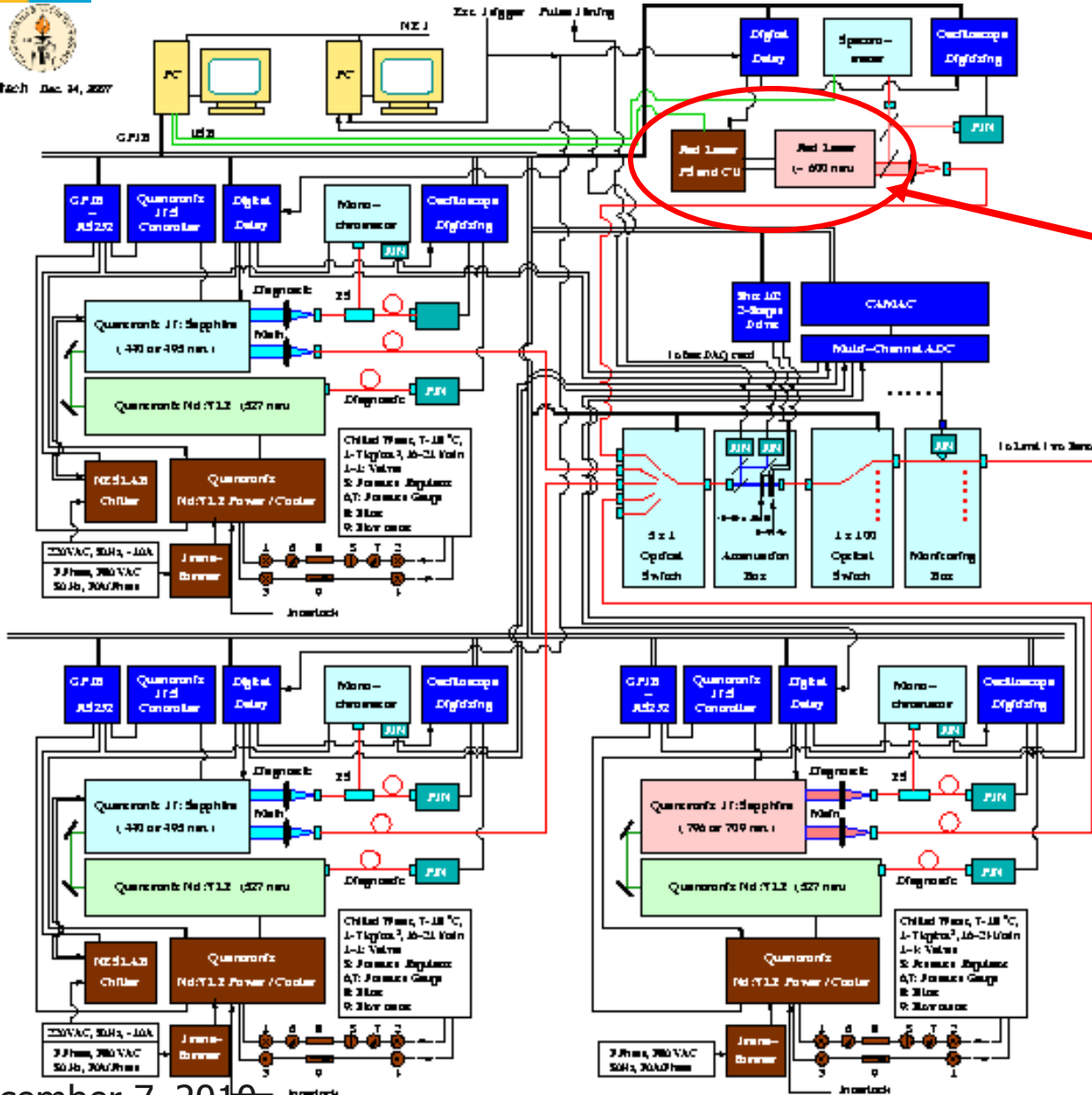




# Adding an Orange Laser



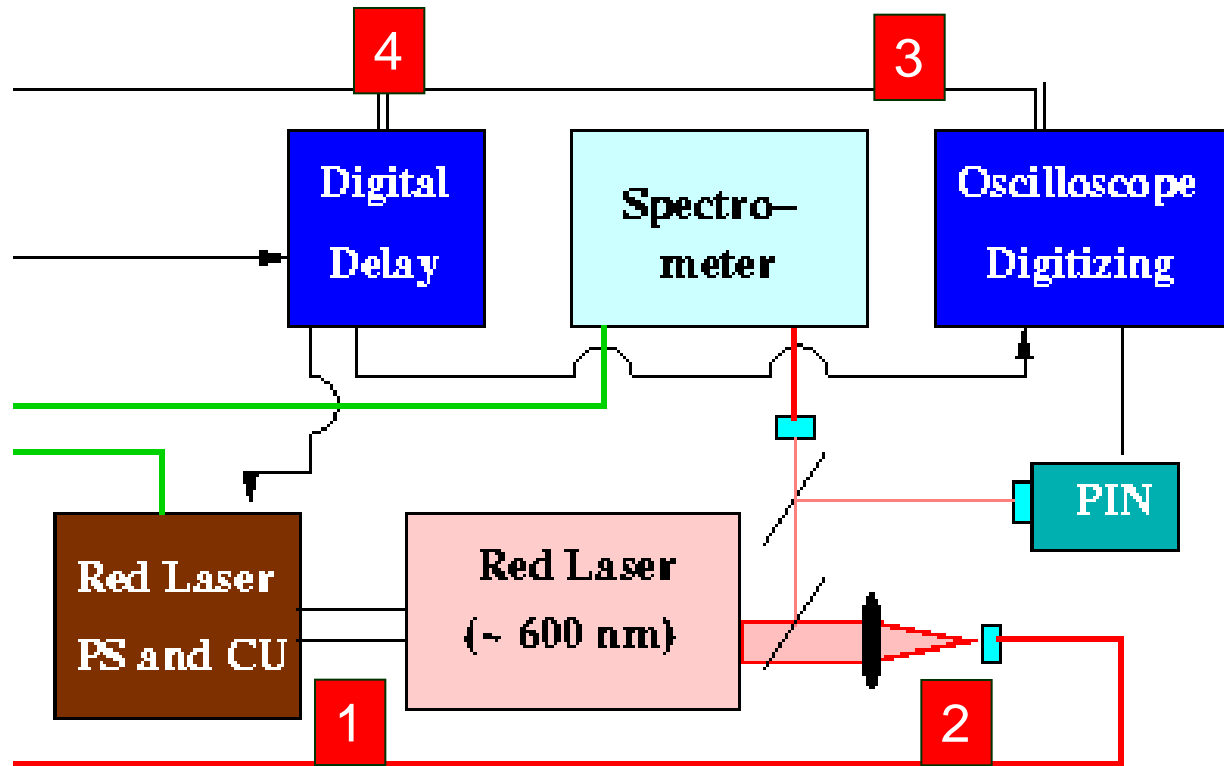
Caltech, Dec. 14, 2007



With the existing 5 x 1 switch an orange laser at 600 nm may be added into the existing system.

# Orange Laser Hardware Needed

- 1) Laser & Power Supply and Cooler Unit;
- 2) Optics for fiber coupling;
- 3) Diagnostics: DSO and Spectrometer;
- 4) Trigger Electronics: Digital Delay.





# Request for Quotation, Fall, 2010



- Pulse energy: 1 mJ at the vicinity of 600 nm
- **Pulse repetition rate: 0 – 100 Hz**
- Pulse width: < 30 ns
- Pulse jitter: < 3 ns
- **Pulse delay from external trigger: < 90  $\mu$ s**

The RFQ with above specifications was sent to more 20 laser vendors. Three positive responses were received:

- 1) Opotek: flash lamp pumped Nd:YAG + OPO
- 2) Photonics Industries: Pulsed or DC diode pumped Nd:YLF + intra-cavity OPO + THG
- 3) Spectra-Physics: DC diode pumped Nd:YLF + dye laser.

**A DC diode pumped Nd:YLF + intra-cavity OPO + THG from Photonics Industries meets all requirements.**



# Response to October RFQ



Parameters	Opotek OPO Opolette-HR355LD	Photo.-Ind. OPO+THG DP-OPO-600-1	Photo.-Ind. OPO+THG DS-OPO-600-1	Spec.-Phys. Dye laser Credo-YHP
Wavelength ( nm, PE > 1 mJ)	Tunable 450 – 600	Fixed at 610 ±10	Fixed at 610 ±10	Tunable 570 – 670
Pulse energy: (mJ)	>1	>1	>1	>1
Pulse repetition rate (Hz):	<b>Fixed at 100</b>	0 – 1K	0 – 1K	0 -1K
Pulse width (ns)	5	< 20	< 20	~35
Pulse jitter (ns, rms)	1	3	3	3
Delay (µs) (Ext. trigger->Output)	<b>~200</b>	<b>~500</b>	< 5	<b>~200</b>
Pulse to Pulse Instability (% , rms)	10	3	3	<5
Quoted Cost	\$83K	\$150K	\$200K	\$130K



# Photonics Industries OPO



## OPO Series

### High Repetition Rate OPO Optical Parametric Oscillator



Laser Head  
22"(L) x 7.5"(W) x 3.75"(H)

Control Unit  
13.5"(L) x 19"(W) x 5.25"(H)

This system is more compact than the Quantronix lasers. Two lasers may be accommodated on a 3' x 5' optical table in a laser room at USC55

#### OPO Series

Photronics Industries OPO series of diode-pumped, intra-cavity frequency conversion, Q-switched Optical Parametric Oscillator (OPO) produces stable, high repetition rate pulses in a compact, industry rugged design. An air cooled version is also available.

#### Applications

- Chemical Detection
- Eye-Safe Illumination
- NIR Spectroscopy
- MID-IR Spectroscopy
- LIDAR
- IR-MALDI
- Rangefinder, Designator
- Material Processing Research & Production

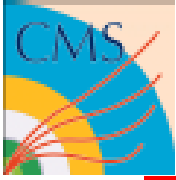
#### Features

- Diode Pumped Technology
- Wavelength: 1.5µm to 2.0µm (signal)  
2.2µm to 3.4µm (idler)
  - Fixed Wavelength or Tunable Versions Available
- Pulse Rates from Single Shot to 50kHz
- TEM<sub>00</sub> Beam with M<sup>2</sup> ~ 1.3
- mJ Pulse Energy at kHz Repetition Rates
- Field Replaceable Diode
- Compact, Rugged Design
- Patented OPO Generation Technology
- External TTL Triggering and Gating Input
- Air Cool Version Available



**Photronics Industries**  
International, Inc.

The Pioneer of Intra-Cavity Solid-State Harmonic Lasers



# User References



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

## 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.

## Oakridge National Lab

Dr. Yuan LIU commented on the Nd:YLF pumped Ti:Sapphire laser system of Photonics Industries procured about one 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.





# Summary: Proposed Actions



Laser system plays a crucial role in providing a precision PWO calorimeter *in situ*. The existing laser system performs as designed. The system, however, needs an upgrade to continue function with improved performance.

1. Procure two Dicon switches: 5 x 1 and 1 x 100.
2. Procure a Quantronix Darwin-Pro-527-40-M diode pumped Nd:YLF laser to replace one existing DC Kr Lamp pumped 527DQ-S Nd:YLF laser so that the laser system will continue function, and have a better stability and less maintenance requirement.
3. Procure a Photonics Industries DS-OPO-600-1 laser if the 2<sup>nd</sup> wavelength is needed for the endcaps.
4. Look also for spare IR and orange lasers if the 2<sup>nd</sup> wavelength is also required to be 100%.