Red Laser for Monitoring Light Source

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- A Brief History.

- Red Laser Specification.

- Result of Market Survey.

A Brief History of Red Laser Discussion

- The red/IR laser was first discussed in the ECAL Monitoring Workshop at Saclay on September 19, 2000. Basic specification, such as **wavelength choice and intensity requirement**, to the red/IR light source was discussed.

- Following Saclay Workshop, various scenarios of modifying the 2nd and the 1st lasers to provide an additional pulsed IR (880 nm) light source were investigated. A **market survey** on the red laser was carried out, followed by a **field test** at the OPOTEK on May 3, 2001.

- The result of this investigation was reported during the ECAL week on May 31, 2001. The ECAL Technical Board reached the following two conclusions.

  1. The 1st and 2nd lasers should be identical providing monitoring wavelength of 440 and 500 nm.

  2. The red laser decision will be made after the I&C of the 1st laser.

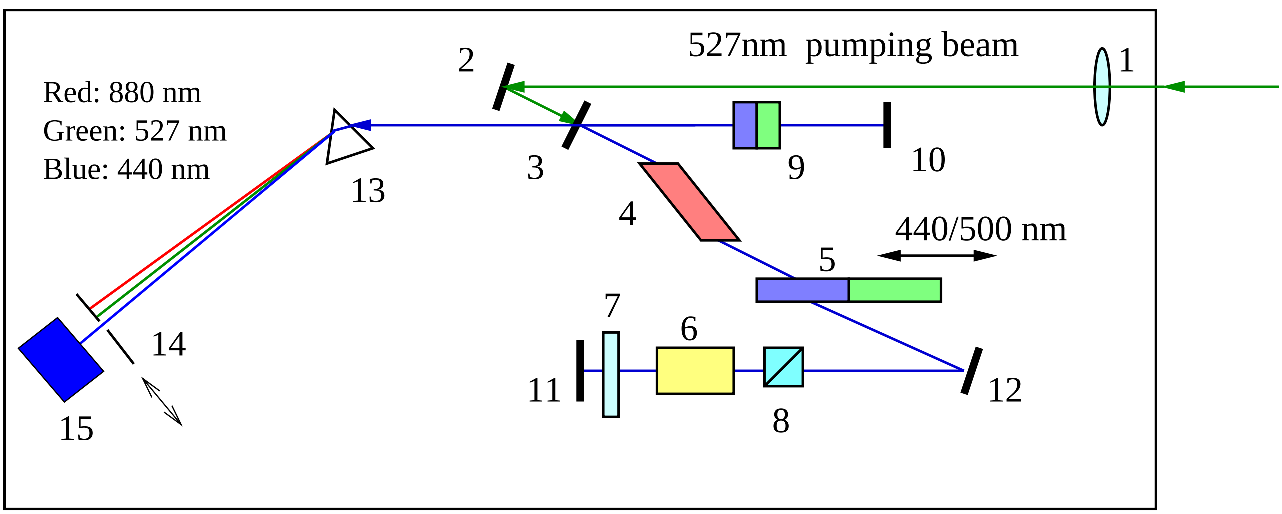
- The 1st laser was successfully installed and commissioned at the H4 test beam site in August, 2001, as reported on September 4, 2001, during the ECAL week. It is functioning, but not yet operative, pending on the completion of the installation of the heat exchanger and corresponding secondary piping for the chilled water supply.

- Remain issue: **Too Small Laser Barracks Area at H4**.

Extract IR from the 1st Quantronix Laser

Measured the Intensity of IR in Ti:S by Inserting a Prism

92.5±0.5/5.0±0.5 mw measured @ 440/880 nm with 23 A & 100 Hz

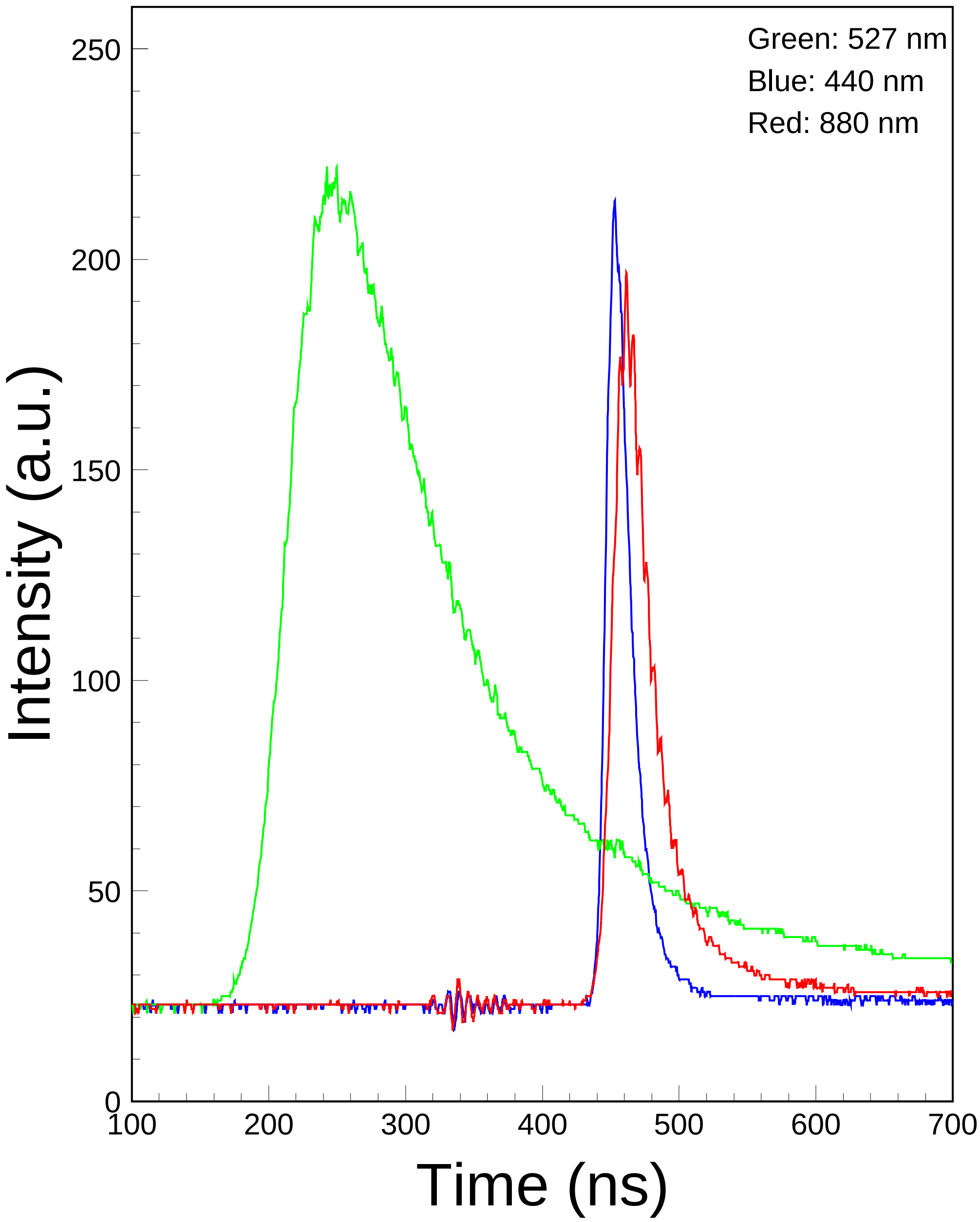


1: Pumping lens
2: Fold mirror
3: Pumping coupling and laser output mirror
4: Ti:Sapphire crystal
5: Birefringent filters (440/500 nm)
6: Pockel Cell
7: 1/4 waveplate
8: Polarizer
9: SHG crystals (LBO)
10, 11: Cavity mirrors
12: Cavity fold mirrors
13: Equilateral Prism
14: Aperture
15: Power detector

Extract IR from the 1st Quantronix Laser (Cont.)

Pulse Shape Recorded by HP54616C Digital Scope

Fundamental is 54% more wide than Second Harmonic



Various Scenarios of Modifying the 1st & 2nd lasers Cost Comparison for Extracting the IR Light Pulse

Compared to Baseline of 2 Lasers with 1/0.5 mJ @ 440/500 nm

1. Two Identical Laser Systems with 0.3/1 mJ @ 425/850 nm: **+50k**
    - Reduce cost for 2nd laser 425/850 nm: -1k.
    - Modify the 1st laser to 425/850 nm: 51k.
2. Allow two different lasers with 2nd laser of 0.3/1 mJ @ 425/850 nm: **-1k**
3. Add a 3rd IR laser from Quantronix: **+149k**
    - 3rd laser of 850 nm with 1 mJ/Pulse: 143k;
    - A 1 x 3 switch: 6k.

Red Laser Specifications

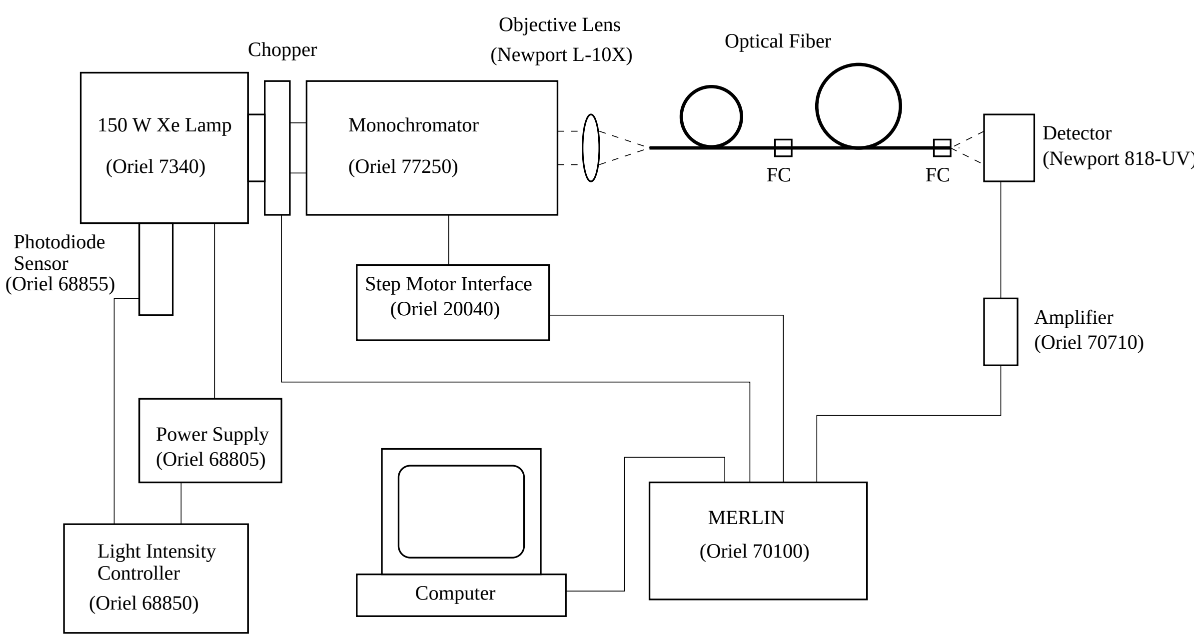
Conclusion Reached in Saclay Workshop

- Wavelength: **650 – 700 nm**
  1. fiber absorption: 650 – 700 nm or 750 – 850 nm;
  2. APD with significant QE $\times$ Gain: $<$ 800 nm;
  3. radiation induced color center in PWO crystals: $>$ 650 nm; and
  4. TIS requirement on laser safety: much more complicated at IR.

- Pulse intensity: $>$ **80 μJ** to reach calibration point at 75 – 80 GeV according to J. Rander.

- Pulse Width: **FWHM** $<$ **40 ns** to accommodate readout electronics.

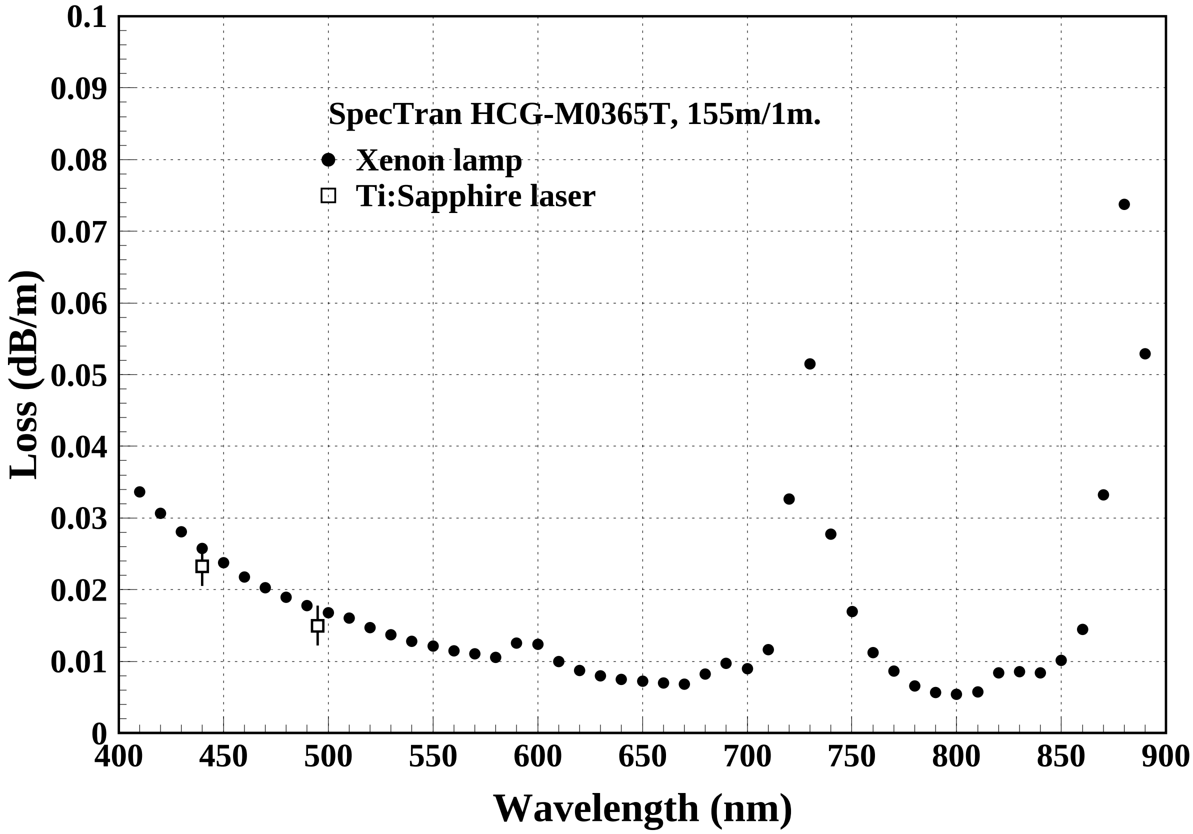
Setup for Fiber Loss Measurement



Result of HCG-M0365T Fiber Absorption

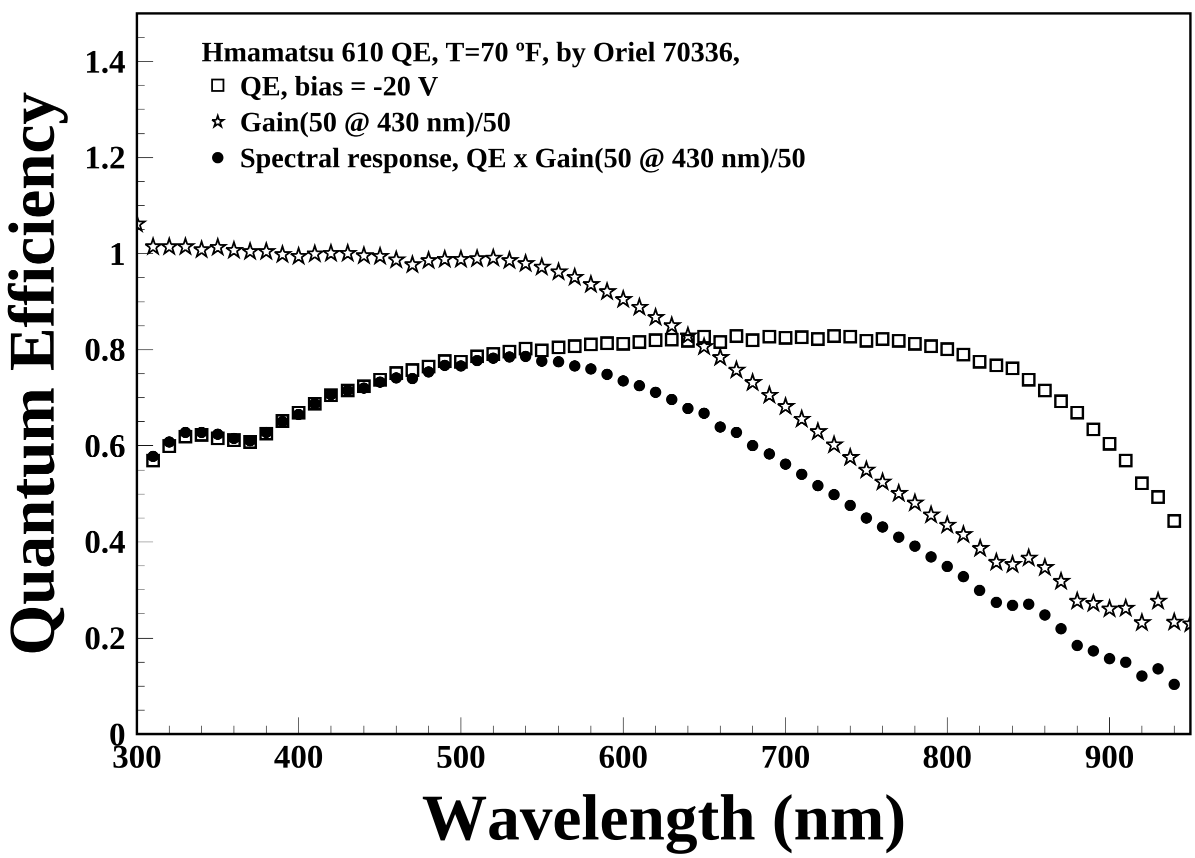
Two Allowed Wavelength Regions: 650 – 700 nm or 750 – 850 nm

Measured Attenuation @ 440 nm: 5 dB for 155 m fiber



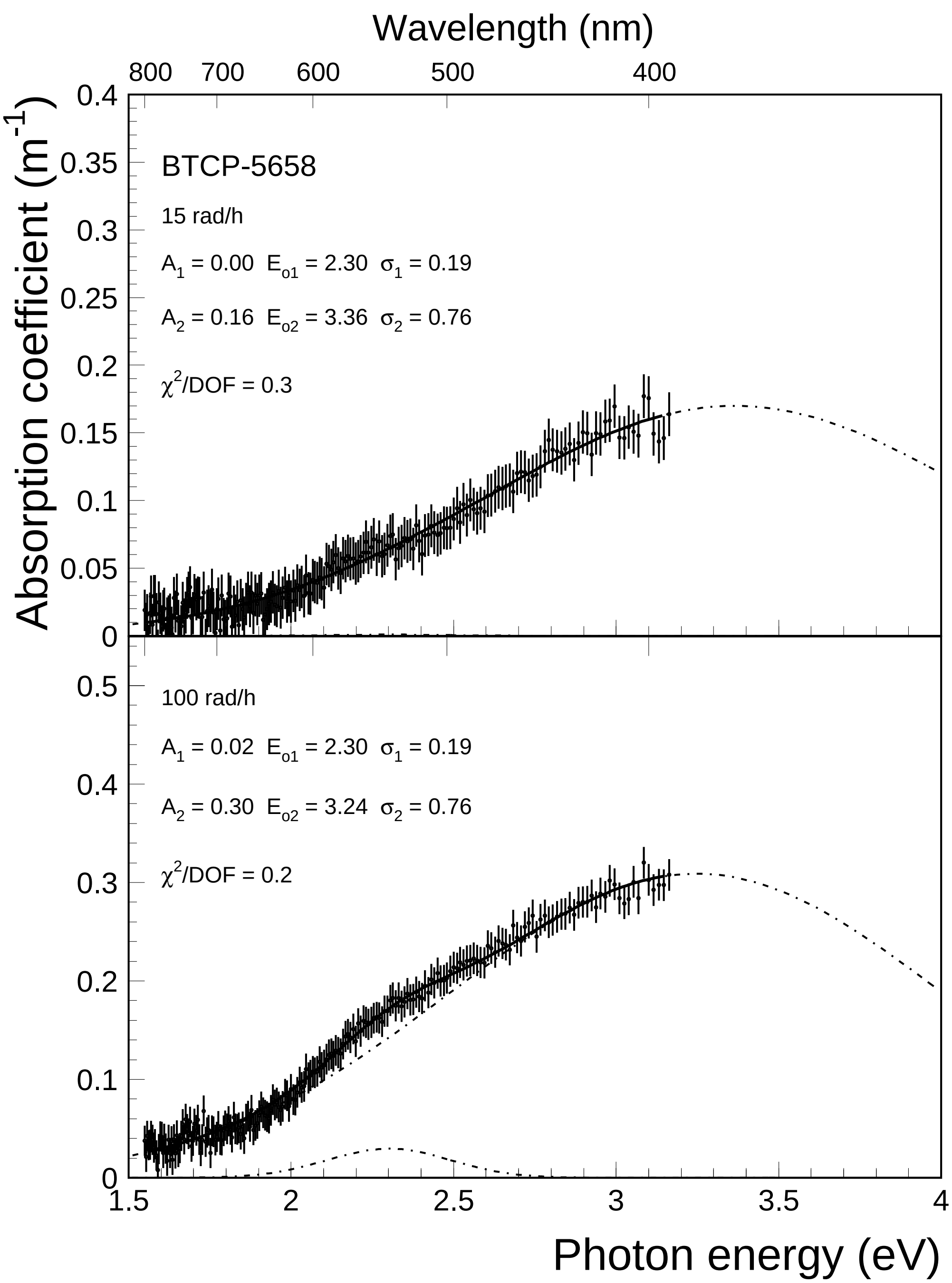
Quantum Efficiency & Gain of APD

Wavelength Constraint: $<$ 800 nm



Intensity of Radiation Induced Color Centers

Wavelength Constraint: > 650 nm

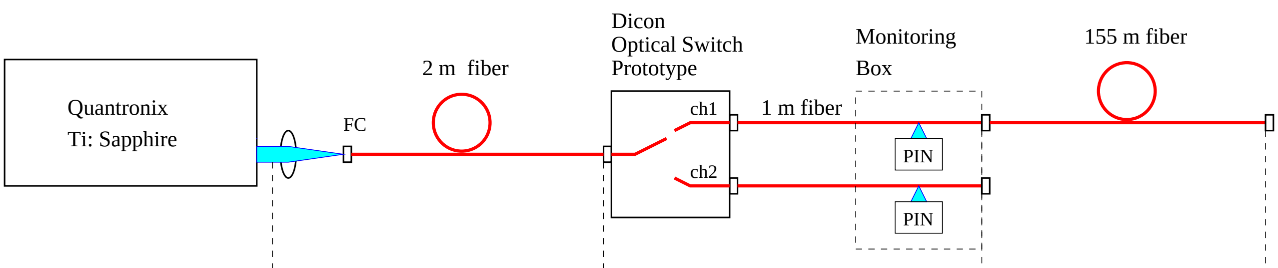


Result of High Level Attenuation

About 8 or 6 dB Loss @ 440 or 500 nm

6 or 4 dB Less than Budgeted 14 dB @ 440 nm

Loss Test , 06/02/2000



440 nm	0 dB	- 0.6 +- 0.1 dB	- 2.7 +- 0.1 dB	- 7.5 +- 0.3 dB
495 nm	0 dB	- 0.6 +- 0.1 dB	- 2.6 +- 0.1 dB	- 5.9 +- 0.3 dB

Summary of Monitoring Photon Budget

Original as Documented in CMS IN 1999/014

(Using Recent Data Measured at Caltech)

- Total Photon Attenuation: 72 dB:
  - High Level Optics & Connectors: 3 dB (3 dB);
  - DiCon Switch: 2 dB;
  - 150 m SpecTran HCG-M0365T Fiber: 9 dB (5 dB);
  - Level 2 Fanout: 17 dB;
  - Level 1 Fanout: 38 dB;
  - Fiber to back face of $PbWO_4$ crystal: 3 dB.
- 1 mJ/pulse ($2 \times 10^{15}\gamma$/pulse) $\Rightarrow$ 1.3×10^8/pulse at back face of crystal, with $PbWO_4$ light yield of 10 p.e./MeV, or 100 γ/MeV, 1 mJ/pulse $\Rightarrow$ 1.3 (3.3) TeV/pulse in crystal.
- For 425 nm, 1 mJ/pulse $\Rightarrow$ 1.2 (2.5) TeV/pulse in crystal.
- For 850 nm, **1 mJ/pulse** $\Rightarrow$ **0.89 (3.6) TeV/pulse** in crystal, or 1.1 (0.28) mJ $\Rightarrow$ 1 TeV.

Market Survey for Red Laser

- Specification
  1. Wavelength: 650 to 700 nm;
  2. Pulse Energy: $> 80\ \mu$J;
  3. Pulse Width: FWHM < 40 ns;

- 15 potential pulsed laser vendors were invited for quotation in April: AdvR, Inc., Anderson Laser Inc., Evergreen Laser Corp., Exitech, Lambda Physik, Melles Griot Laser Group, MWK Laser Products, **OPOTEK**, Photonics Industries, Physical Sciences Inc., Positive Light, Power Technology, **Quantronix**, Research Electro-Optics, Spectra-Physics.

- Only two vendors, Quantronix and OPOTEK, responded positively.

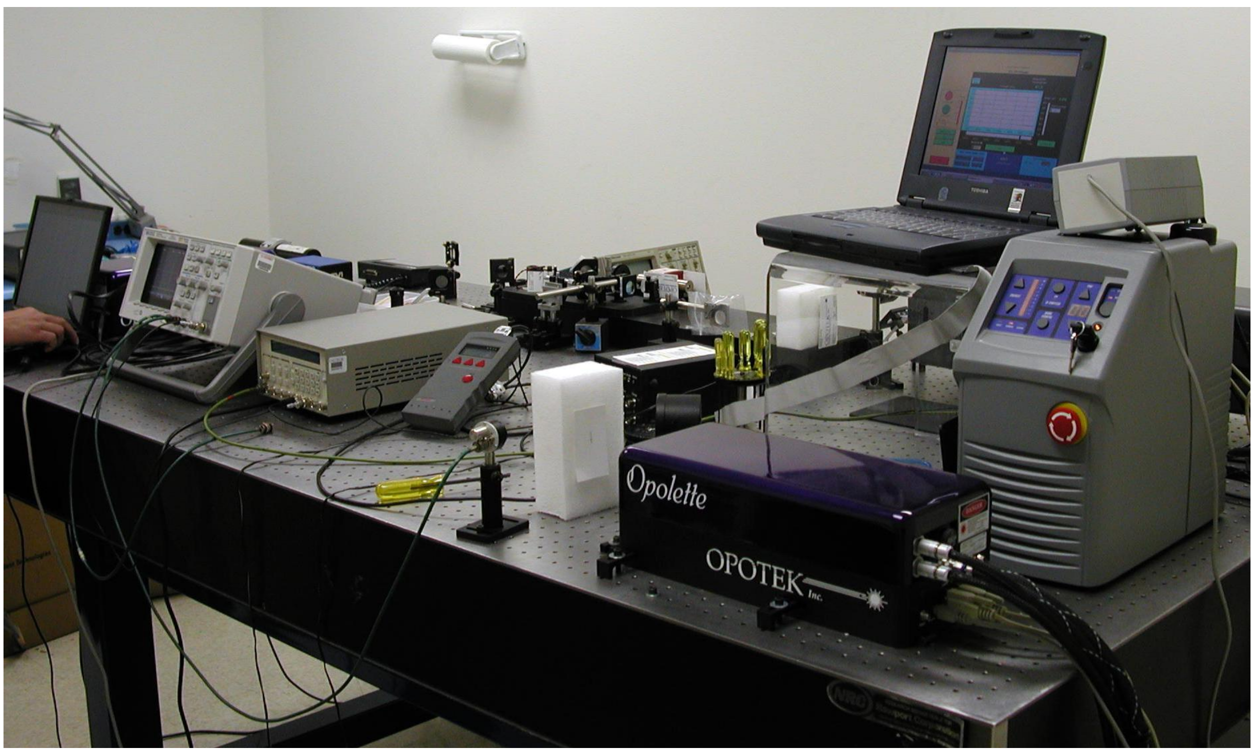
OPOTEK Lasers

OPOTEK was founded in 1993 at San Diego, California. It produces tunable laser systems based on Optical Parametric Oscillator (OPO) technology with its proprietary ring oscillator cavity design—the MagicPrism&trade. The QUANTEL Nd:YAG laser is used as the pump source.

Setup for OPOTEK Laser Evaluation

Carried out on May 3, 2001, at OPOTEK

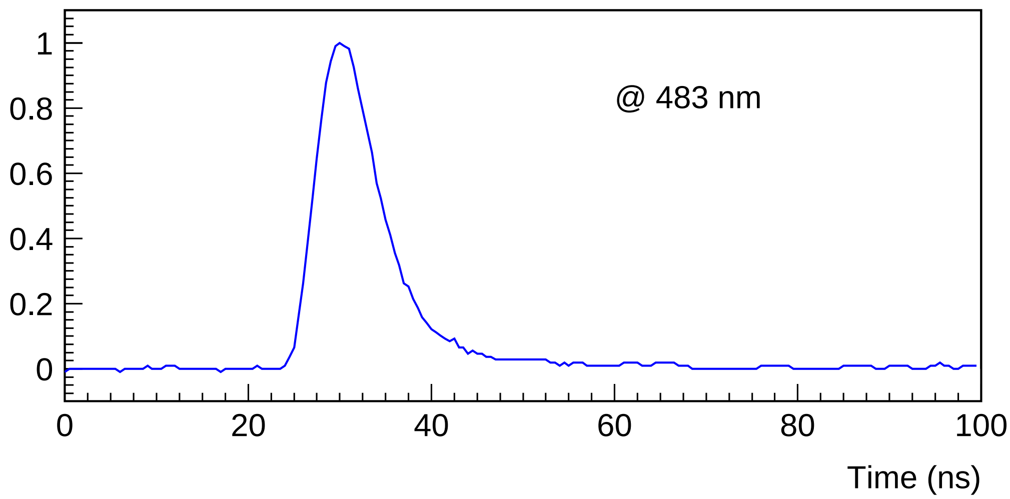
with Digital Delay, Digital Scope and Laptop

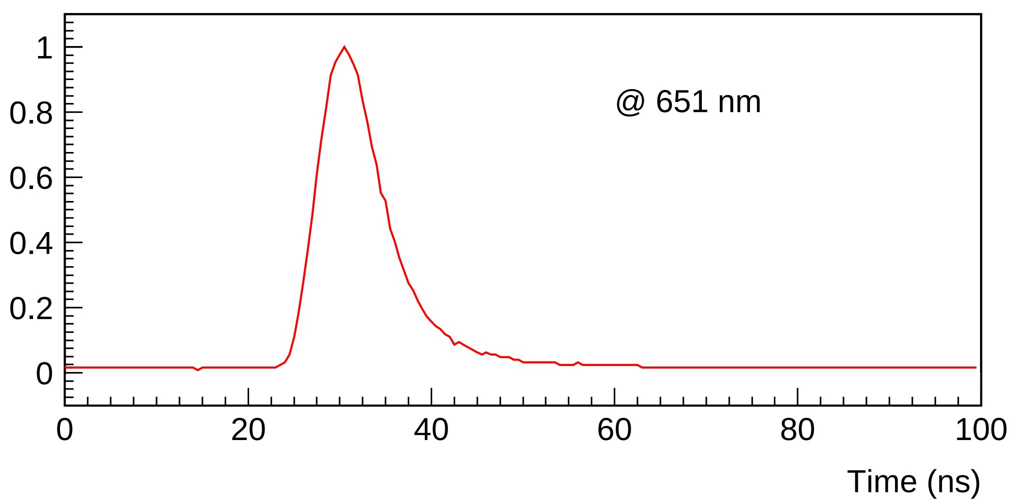


Pulse Shape of Opolette 355 Tunable Laser

Recorded by HP54616C Digital Scope

Pulse Width of 8 ns at 483 and 651 nm

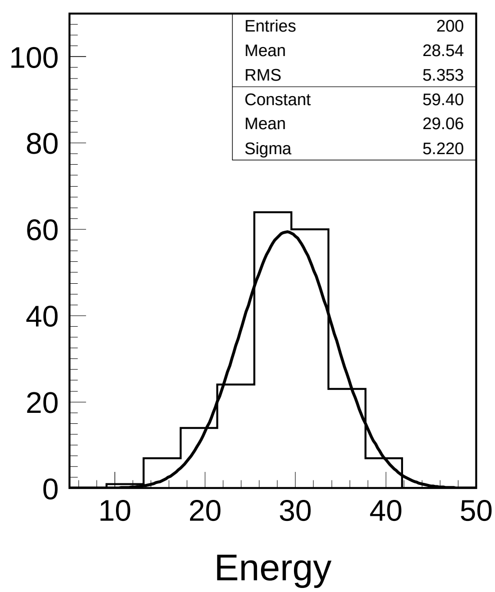


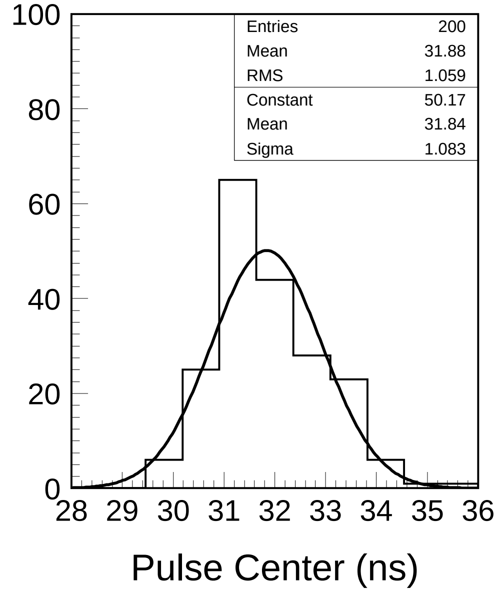


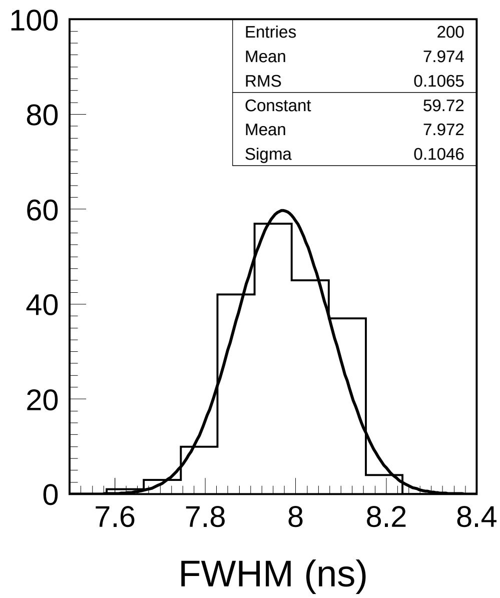
Energy Instability, Jitter and Width @ 651 nm

Recorded by HP54616C Digital Scope

19% Instability, 1 ns Jitter, 8 ns Width





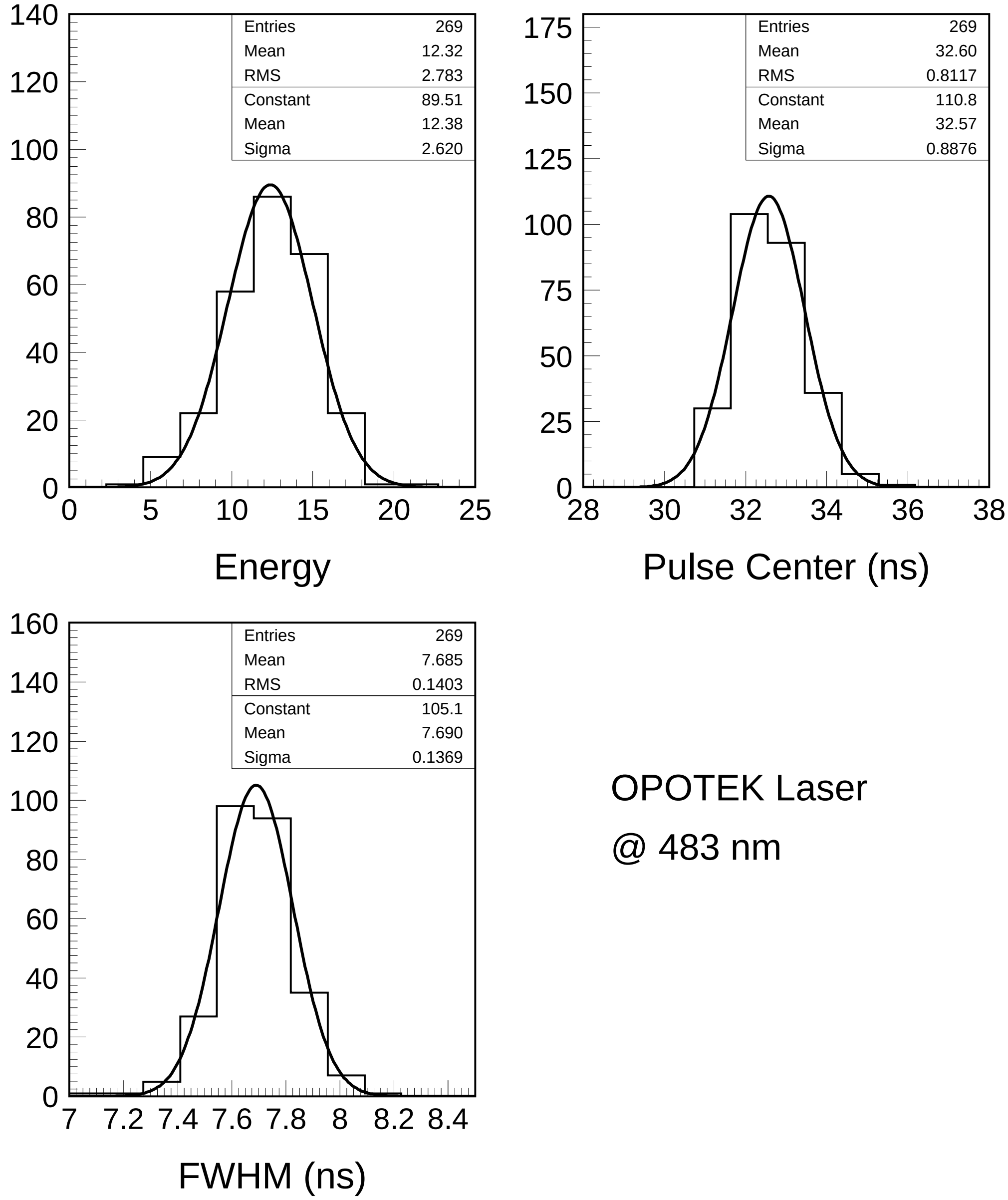


OPOTEK Laser
@ 651 nm

Energy Instability, Jitter and Width @ 483 nm

Recorded by HP54616C Digital Scope

21% Instability, 0.9 ns Jitter, 7.7 ns Width



OPOTEK Laser

@ 483 nm

Comparison of Quantronix and Opotek Lasers

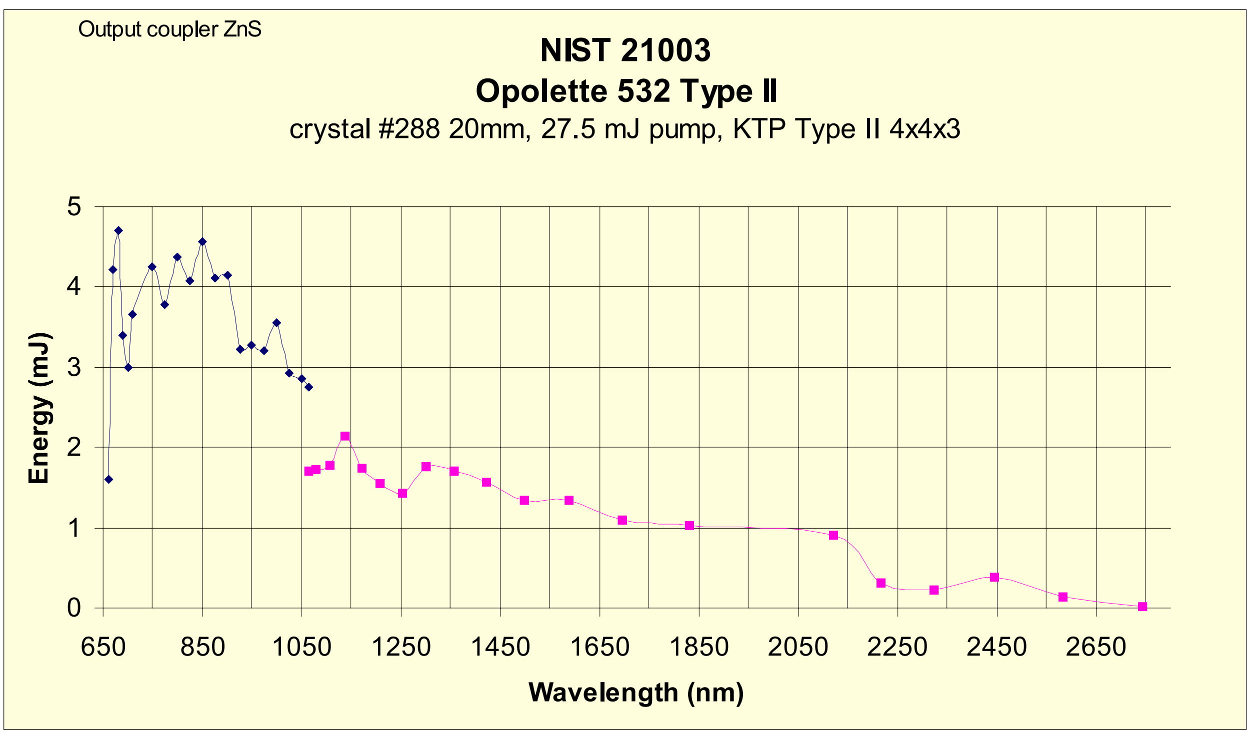
Vendor	Quantronix	Opotek
Technology	Nd:YLF + Ti:Sapphire	Nd:YAG + OPO
Pulse Energy	$>$ 80 μJ	$>$0.5 mJ
Power Instability	2%	**20%**
Pulse Width	$<$ 50 ns	$<$ 20 ns
Pulse Jitter	$<$ 3 ns	$<$ 2 ns
Pulse Rate	up to 1 kHz	$<$ **20 Hz**
History	30 years	8 years
# of Products	Thousands	Tens
Service at Europe	Yes	No
Cost ($)	135,000	45,000

The only two problems of the Opotek laser system are low repetition rate (20 Hz) and poor power instability (20%). Because of its significantly lower cost, the Opotek laser system is recommended to be the choice of the Red Light Source.

Pulse Energy of Opolette 532 Tunable Laser

> 1.5 mJ/pulse at 650 to 700 nm

Data Provided by OPOTEK



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