Red Laser for Monitoring Light Source

Liyuan Zhang, Kejun Zhu and Ren-yuan Zhu
Caltech
Duncan Liu
JPL

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- A Brief History.
- 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
Extract IR from the 1st Quantronix Laser (Cont.)

Pulse Shape Recorded by HP54616C Digital Scope

Fundamental is 54% more wide than Second Harmonic

Green: 527 nm
Blue: 440 nm
Red: 880 nm
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 × 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 $\mu$J 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

- **150 W Xe Lamp** (Oriel 7340)
- **Power Supply** (Oriel 68805)
- **Photodiode Sensor** (Oriel 68855)
- **Light Intensity Controller** (Oriel 68850)
- **Chopper**
- **Monochromator** (Oriel 77250)
- **Step Motor Interface** (Oriel 20040)
- **Objective Lens** (Newport L-10X)
- **Detector** (Newport 818-UV)
- **Amplifier** (Oriel 70710)
- **Computer** (MERLIN, Oriel 70100)
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

Hammatsu 610 QE, T=70 °F, by Oriel 70336,
□ QE, bias = -20 V
★ Gain(50 @ 430 nm)/50
● Spectral response, QE x Gain(50 @ 430 nm)/50
Intensity of Radiation Induced Color Centers

Wavelength Constraint: > 650 nm

Photon energy (eV)

Absorption coefficient (m$^{-1}$)

Wavelength (nm)

BTCP-5658

15 rad/h

$A_1 = 0.00$ $E_{o1} = 2.30$ $\sigma_1 = 0.19$

$A_2 = 0.16$ $E_{o2} = 3.36$ $\sigma_2 = 0.76$

$\chi^2$/DOF = 0.3

100 rad/h

$A_1 = 0.02$ $E_{o1} = 2.30$ $\sigma_1 = 0.19$

$A_2 = 0.30$ $E_{o2} = 3.24$ $\sigma_2 = 0.76$

$\chi^2$/DOF = 0.2
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
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) $\Rightarrow$ $1.3 \times 10^8$/pulse at back face of crystal, with PbWO$_4$ light yield of 10 p.e./MeV, or 100 $\gamma$/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;


- 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

@ 483 nm

@ 651 nm
Energy Instability, Jitter and Width @ 651 nm
Recorded by HP54616C Digital Scope
19% Instability, 1 ns Jitter, 8 ns Width

Energy

Entries 200
Mean 28.54
RMS 5.353
Constant 59.40
Mean 29.06
Sigma 5.220

Pulse Center (ns)

Entries 200
Mean 31.88
RMS 1.059
Constant 50.17
Mean 31.84
Sigma 1.083

FWHM (ns)

Entries 200
Mean 7.974
RMS 0.1065
Constant 59.72
Mean 7.972
Sigma 0.1046

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

Energy

Entries 269
Mean 12.32
RMS 2.783
Constant 89.51
Mean 12.38
Sigma 2.620

Pulse Center (ns)

Entries 269
Mean 32.60
RMS 0.8117
Constant 110.8
Mean 32.57
Sigma 0.8876

FWHM (ns)

Entries 269
Mean 7.685
RMS 0.1403
Constant 105.1
Mean 7.690
Sigma 0.1369

OPOTEK Laser
@ 483 nm
Comparison of Quantronix and Opotek Lasers

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Quantronix</th>
<th>Opotek</th>
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<tbody>
<tr>
<td>Technology</td>
<td>Nd:YLF + Ti:Sapphire</td>
<td>Nd:YAG + OPO</td>
</tr>
<tr>
<td>Pulse Energy</td>
<td>&gt; 80 µJ</td>
<td>&gt;0.5 mJ</td>
</tr>
<tr>
<td>Power Instability</td>
<td>2%</td>
<td>20%</td>
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<tr>
<td>Pulse Width</td>
<td>&lt; 50 ns</td>
<td>&lt; 20 ns</td>
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<tr>
<td>Pulse Jitter</td>
<td>&lt; 3 ns</td>
<td>&lt; 2 ns</td>
</tr>
<tr>
<td>Pulse Rate</td>
<td>up to 1 kHz</td>
<td>&lt; 20 Hz</td>
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<tr>
<td>History</td>
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<td>8 years</td>
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<tr>
<td># of Products</td>
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<td>Tens</td>
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<tr>
<td>Service at Europe</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Cost ($)</td>
<td>135,000</td>
<td>45,000</td>
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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
Pulse Energy of Opolette 355 Tunable Laser

> 0.5 mJ/pulse at 650 to 700 nm

Data Provided by OPOTEK