Yttrium Doped Lead Tungstate Crystals

Ren-yuan Zhu
California Institute of Technology

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Outline

- Segregation coefficient of the yttrium in PbWO$_4$ crystal.
- Performance of the yttrium doped PbWO$_4$ crystals.
- The transmittance and the birefringence.
The Glow Discharge Mass Spectroscopy (GDMS) was used to determine yttrium concentration in crystals.

A fit to the GDMS data extracts the yttrium segregation coefficient $k_e$ in PbWO$_4$.

$$ K_e = 0.91 \pm 0.04 $$
UV-excited photo luminescence and $\gamma$-excited radio luminescence.

- Decay kinetics.
- Radiation damage.
- Light response uniformity.
- Radiation Induced Color centers.

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Set-up for Luminescence Measurement

Photo-Luminescence

- Surface excited by UV
- No Internal absorption

Radio-Luminescence

- Whole body excited by $\gamma$-ray
- With internal absorption

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- 15-20 nm red shift of the peak of the radio luminescence to that of the photo luminescence.
- The shift is explained by internal absorption.
Both excitation and emission spectra are not affected by the \(\gamma\)-ray irradiation.

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Decay Kinetics

>85 and 95% of light in 50 and 100 ns

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Radiation Damage

5-15% and 15-30% light output loss under 15 and 500 rad/h

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## Summary of Light Output Measurements

<table>
<thead>
<tr>
<th>Sample</th>
<th>LO (1/MeV) p.e.</th>
<th>LO (1/MeV) γ</th>
<th>Fraction (%) 50ns/1μs</th>
<th>Fraction (%) 100ns/1μs</th>
<th>Fraction (%) 15</th>
<th>Fraction (%) 100</th>
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The response \((y)\) along the axis was fit to a linear function:

\[
\frac{y}{y_{mid}} = 1 + \delta \left( \frac{x}{x_{mid}} - 1 \right)
\]
Radiation induced color center density, or absorption coefficient:

\[ D = \frac{1}{LAL_{\text{equilibrium}}} - \frac{1}{LAL_{\text{before}}} \]

**LAL:**
light attenuation length
Color Center Decomposition

C_1: 3.07 eV (400 nm) / 0.76 eV,
C_2: 2.30 eV (540 nm) / 0.19 eV
Longitudinal Transmittance

Transmittance approaches theoretical limit: low intrinsic absorption

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Transmittance and Birefringence

Czochralski: grown along the **a axis**

Bridgman: grown along the **c axis**

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PWO Crystals Grown along c Axis

PWO crystals grown along the **c** axis are isotropic transversely.

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PWO Crystals Grown along c Axis (cont.)

Good longitudinal uniformity in the transverse transmittance

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PWO Crystals Grown along a Axis

Some longitudinal non-uniformity in the transverse transmittance.

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The concentration of yttrium ions in PbWO$_4$ crystals is rather uniform, the segregation coefficient is $0.91 \pm 0.04$.

The scintillation light of yttrium doped PbWO$_4$ crystals has a broad distribution with a peak at 420 nm, the luminescence spectra and longitudinal light response uniformity are not affected by the $\gamma$ – ray irradiations.

Yttrium doping is effective in reducing slow scintillation component, the ratio between light outputs integrated in 100 and 1000 ns is about 95%.

The yttrium doped PbWO$_4$ crystals have adequate radiation hardness for the barrel ECAL, but may fall short for the end caps.
The radiation induced absorption in all yttrium doped samples can be decomposed to two common color centers peaked at 400 nm (3.07 eV) and 540 nm (2.30 eV) with widths of 0.76 eV and 0.19 eV respectively.

Because of the birefringence PWO crystals grown along the c axis is isotropic transversely, while crystals grown along the a axis are optically not isotropic transversely.

Also because of the birefringence PWO crystals grown along the c axis have lower theoretical limit in longitudinal transmittance, which is significant in the short wavelength region.