Yttrium Doped Lead Tungstate Crystals

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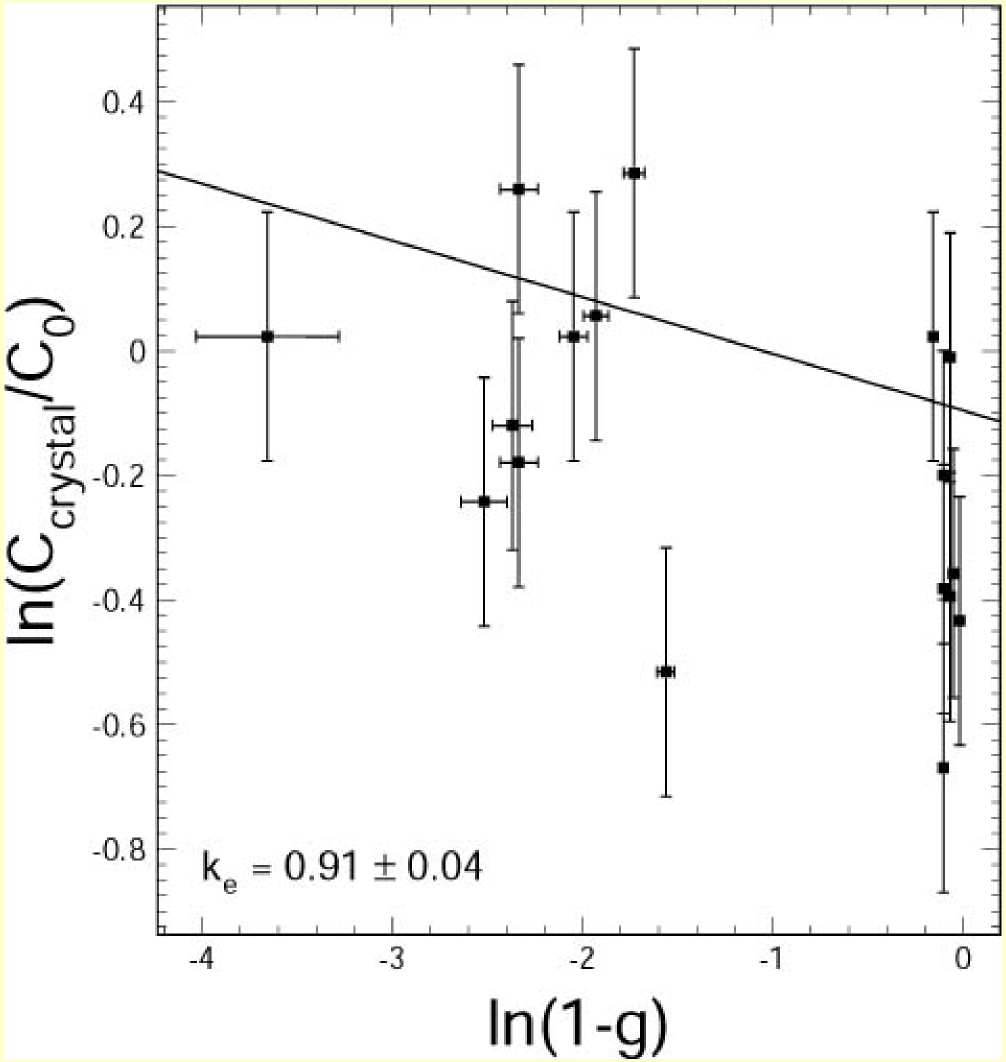
Outline

- Segregation coefficient of the yttrium in $PbWO_4$ crystal.
- Performance of the yttrium doped $PbWO_4$ crystals.
- The transmittance and the birefringence.

Yttrium Segregation Coefficient

- 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 $PbWO_4$.

$K_e = 0.91 \pm 0.04$

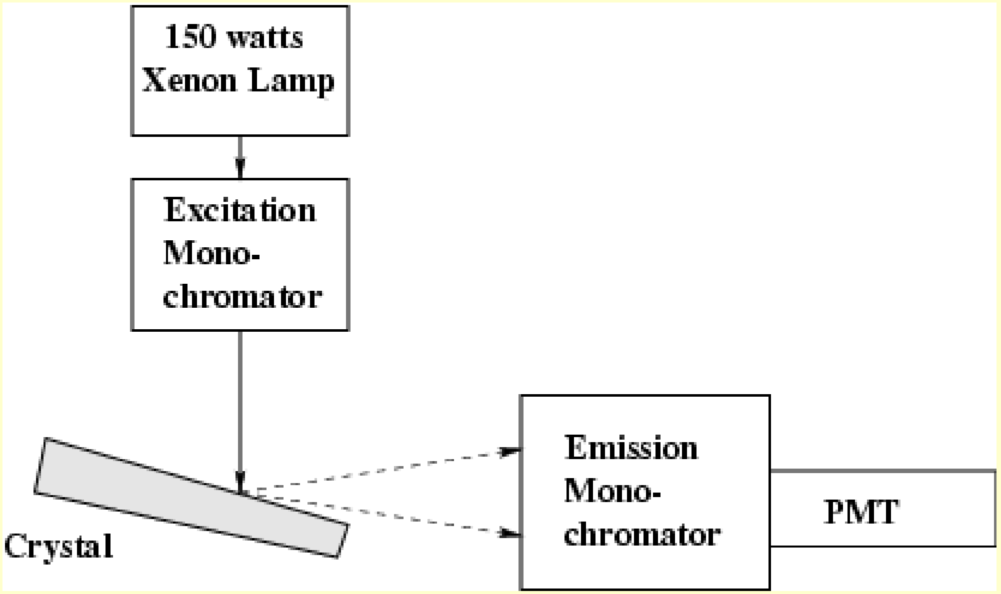


Properties of Yttrium Doped PWO Crystals

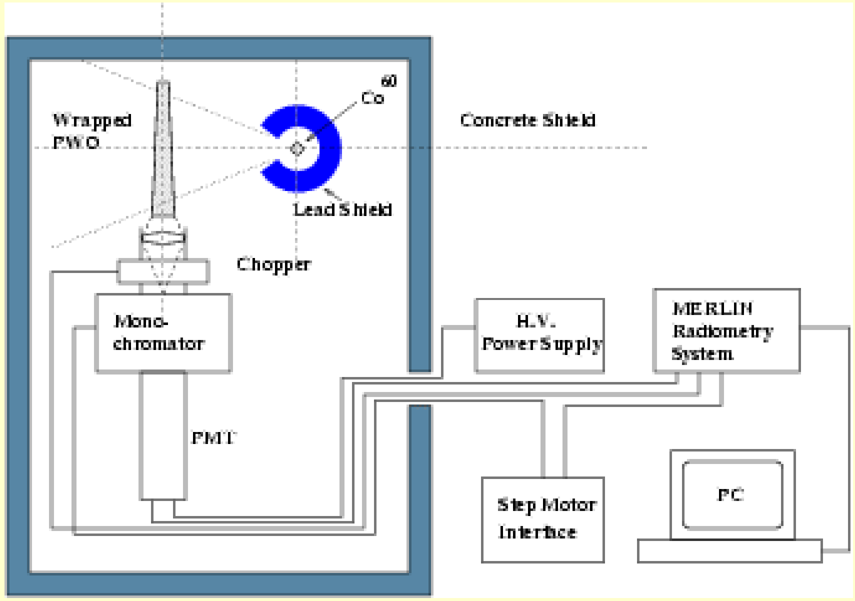
- UV-excited photo luminescence and γ–excited radio luminescence.
- Decay kinetics.
- Radiation damage.
- Light response uniformity.
- Radiation Induced Color centers.
- Published in NIM A480 (2002), 468.

Set-up for Luminescence Measurement

Photo-Luminescence



Radio-Luminescence

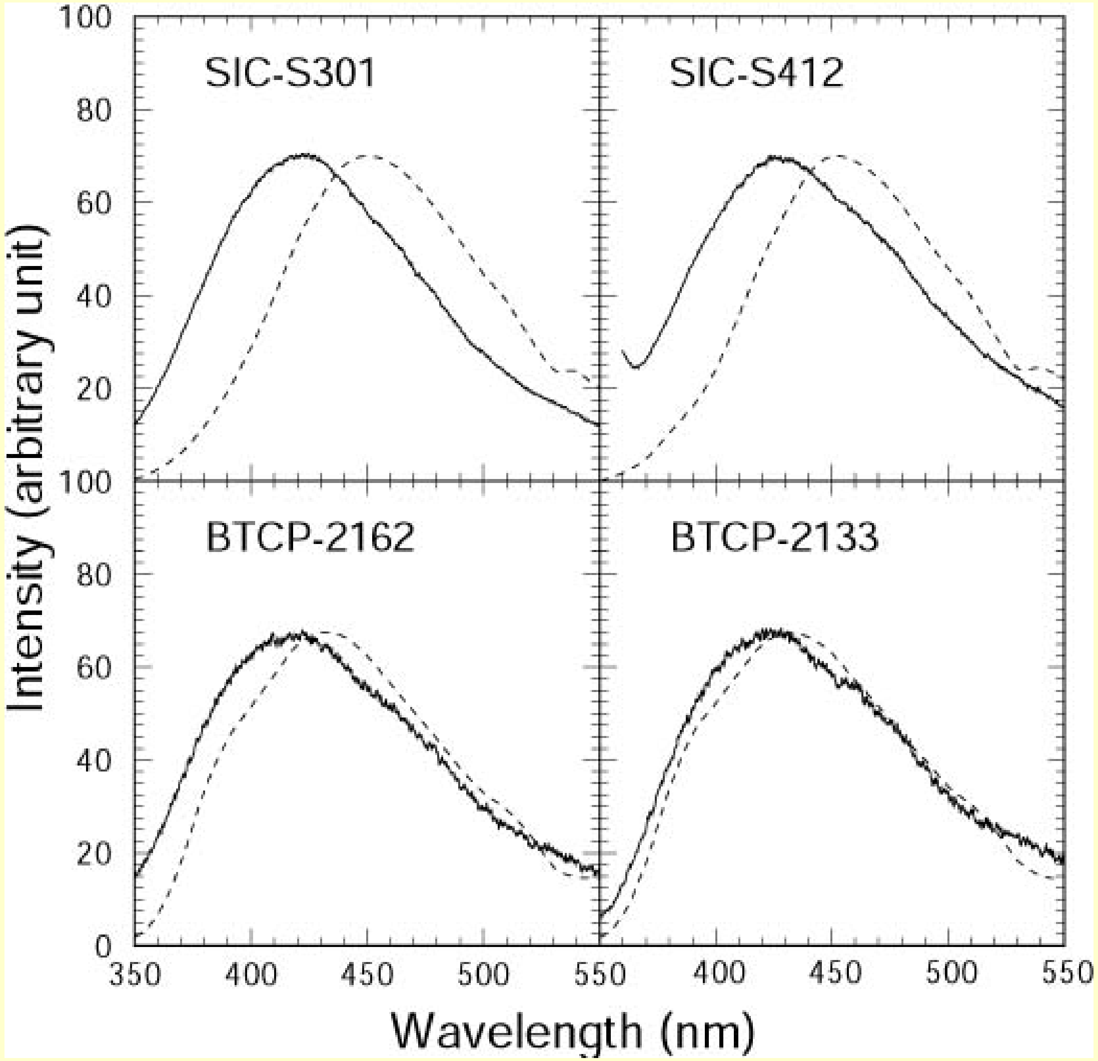


- Surface excited by UV
- No Internal absorption

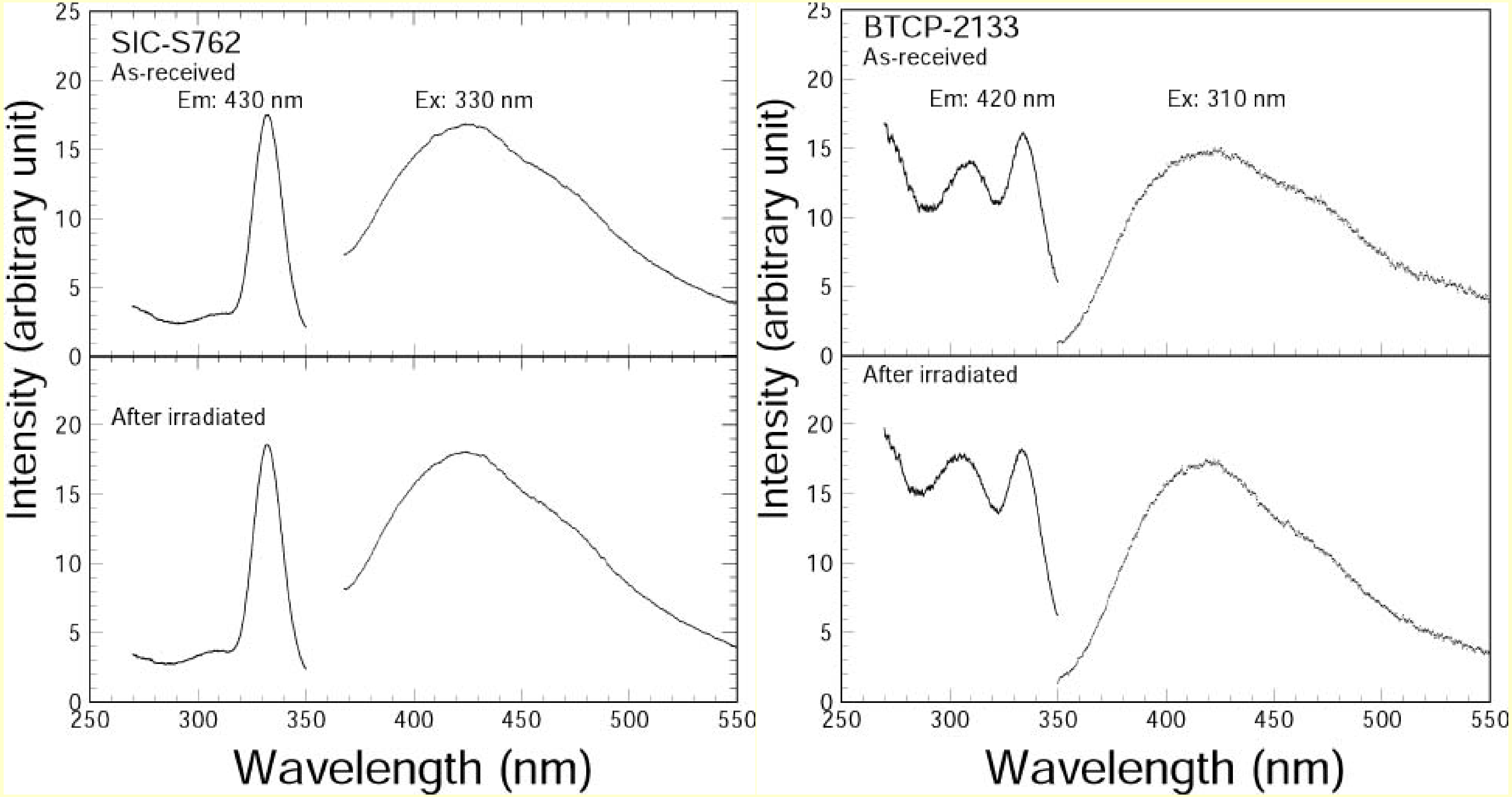
- Whole body excited by γ-ray
- With internal absorption

Photo and Radio Luminescence

- 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.

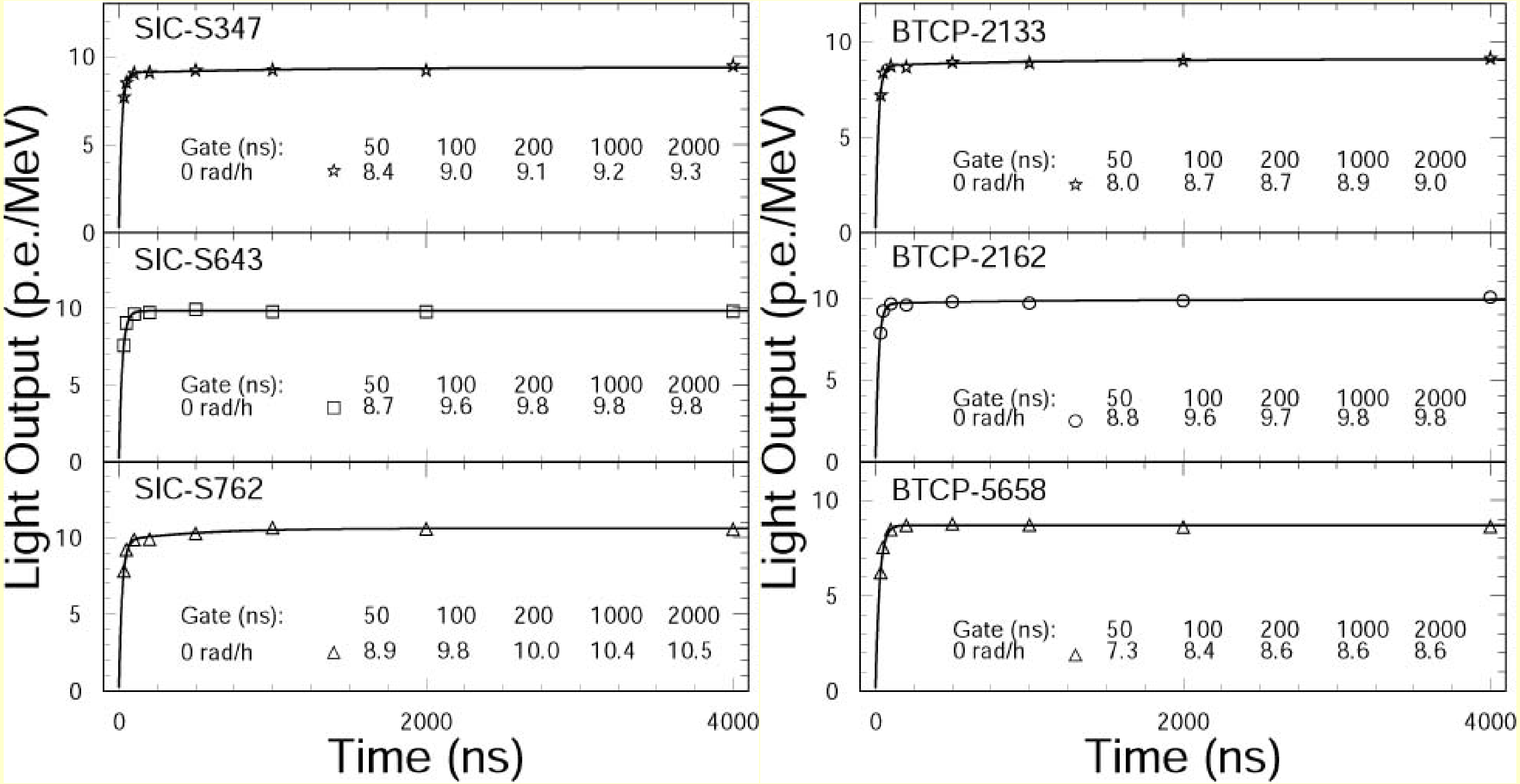


Luminescence before and after Irradiations



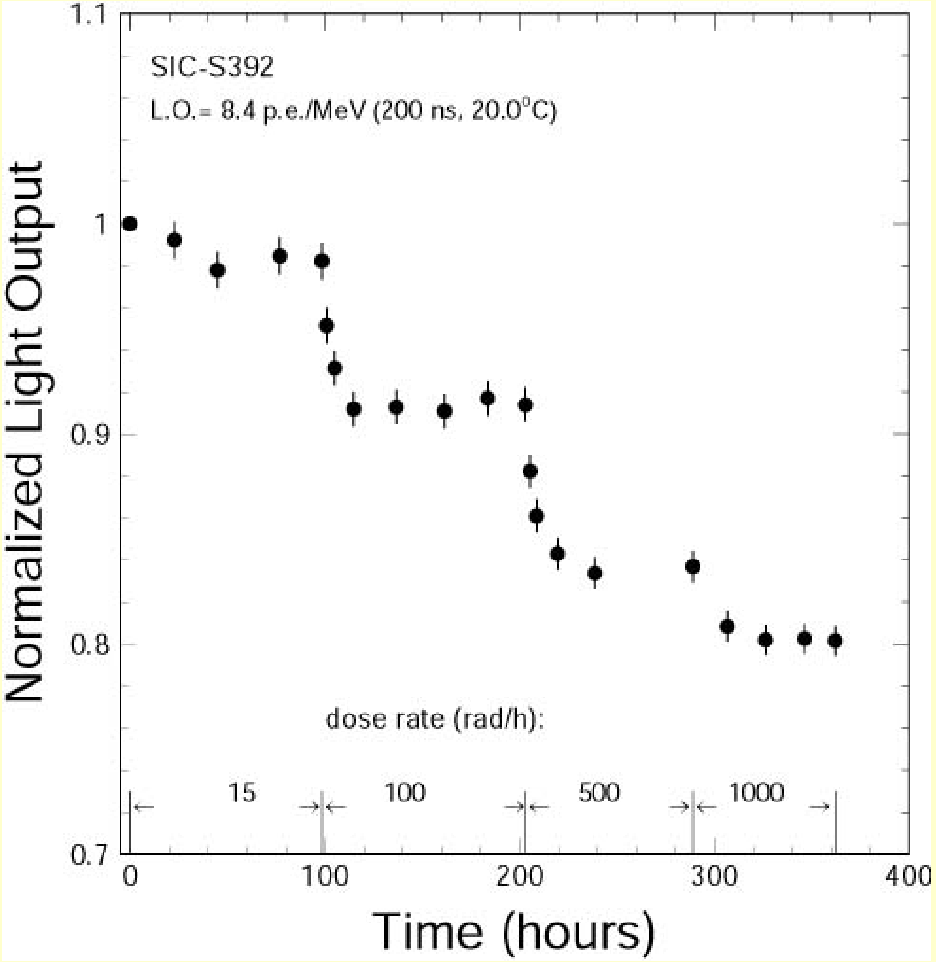
Both excitation and emission spectra are not affected by the γ-ray irradiation

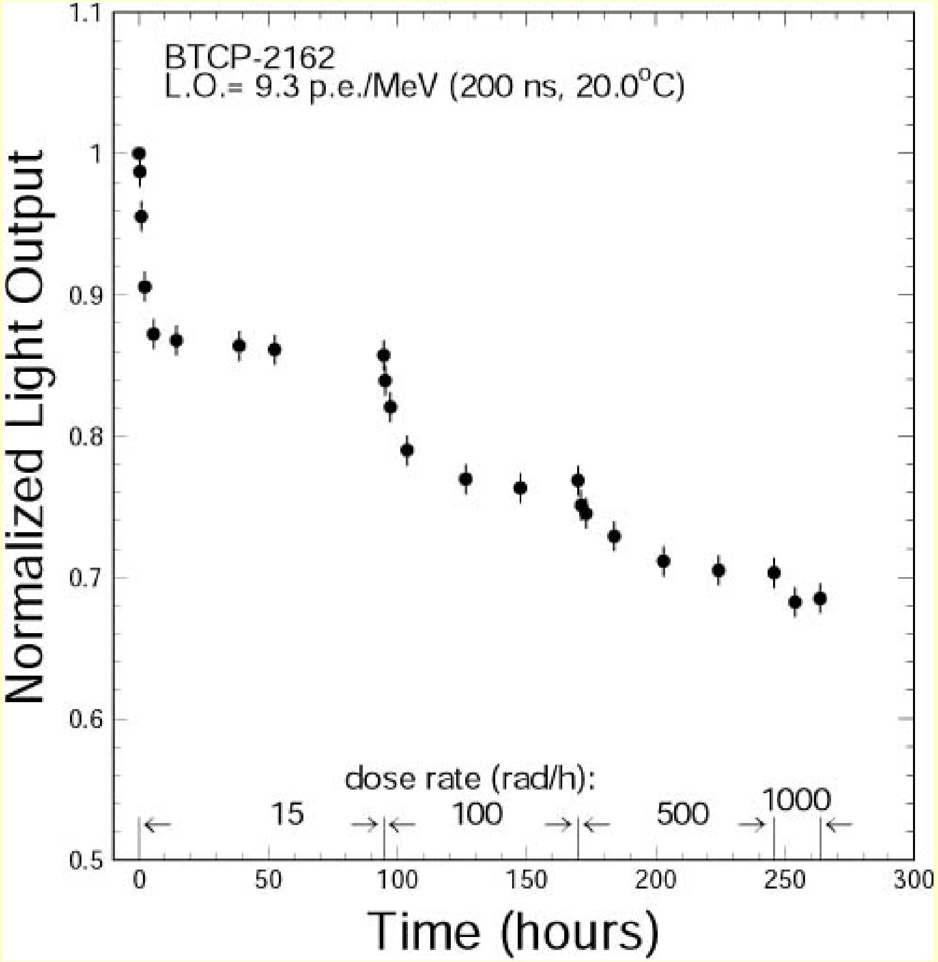
Decay Kinetics



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

Radiation Damage



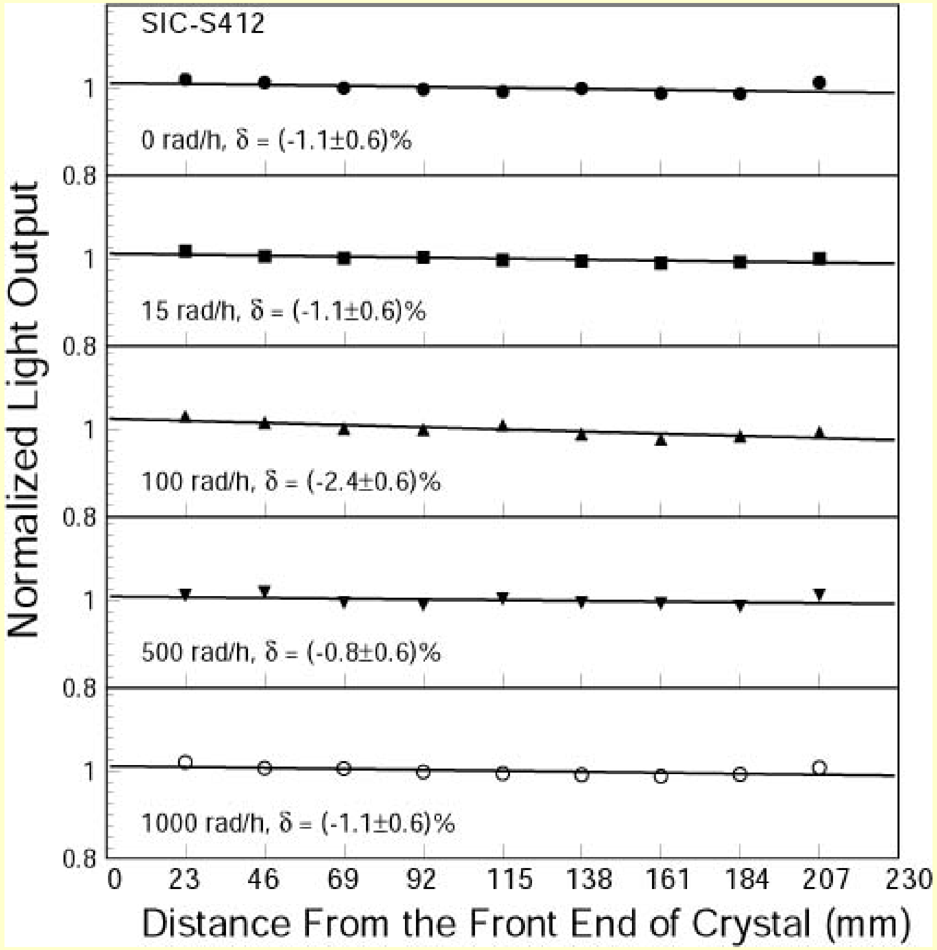


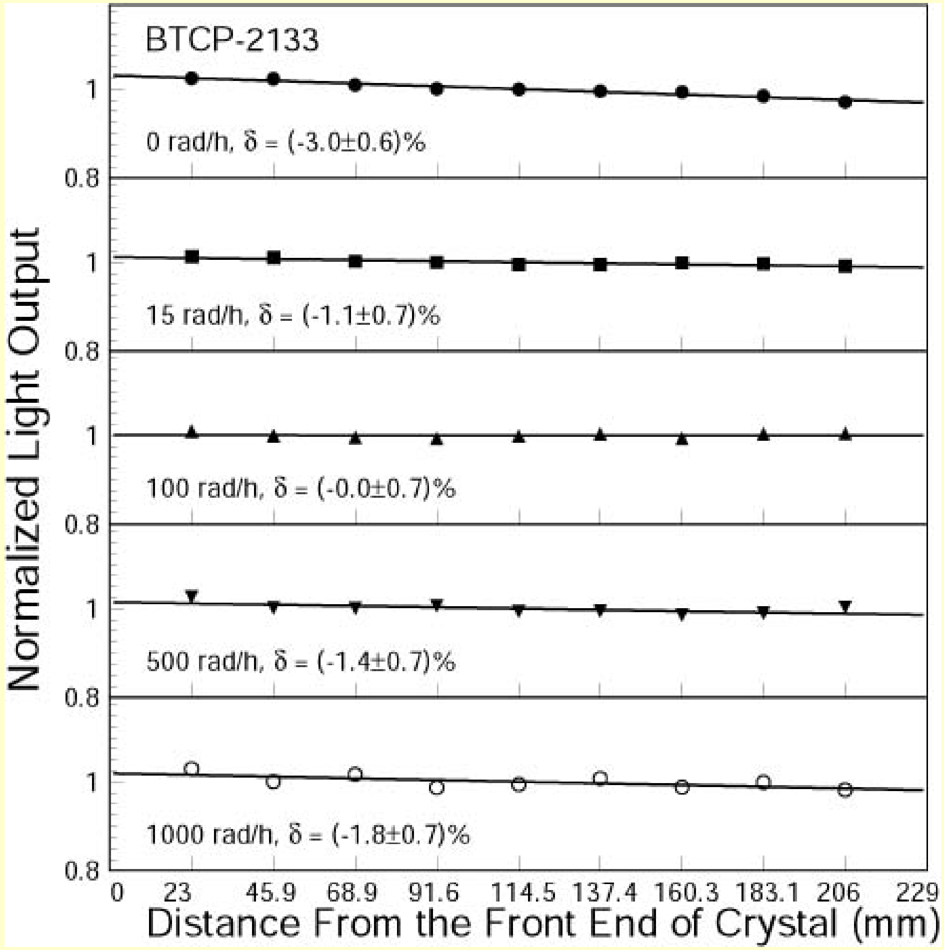
5-15% and 15-30% light output loss under 15 and 500 rad/h

Summary of Light Output Measurements

Sample	LO (1/MeV)		Fraction (%)		LO (%) at R (rad/h)			
ID	p.e.	γ	50ns/1μs	100ns/1μs	15	100	500	1000
SIC-S301	9.4	63.5	92.0	96.6	96.6	87.3	79.5	74.3
SIC-S347	9.9	66.9	91.3	97.8	95.1	88.6	82.1	78.0
SIC-S392	8.4	56.8	92.0	97.3	98.2	91.3	83.6	80.2
SIC-S412	8.3	56.1	94.6	98.6	98.2	91.2	85.9	85.3
SIC-S643	8.9	60.1	88.8	98.9	88.3	79.8	---	---
SIC-S762	10.6	71.6	85.6	94.2	91.5	84.2	81.4	---
SIC-606	10.4	70.3	88.3	98.4	91.7	79.3	---	---
SIC-678	10.4	70.3	85.2	93.5	94.2	76.0	59.6	---
SIC-679	10.8	73.0	85.0	94.7	93.5	73.5	57.3	---
BGRI-824	11.4	77.0	83.5	95.5	89.0	78.7	69.9	---
BGRI-826	11.2	75.7	84.4	96.7	86.0	74.7	62.2	---
BTCP-2133	8.2	55.4	89.9	97.8	89.2	78.6	72.3	70.5
BTCP-2162	9.3	62.8	89.8	97.9	86.1	76.8	70.3	68.2
BTCP-5615	7.2	48.6	86.6	98.5	82.9	---	---	---
BTCP-5618	7.2	48.6	86.8	98.5	77.4	---	---	---
BTCP-5658	8.8	59.5	83.9	97.7	76.1	63.6	---	---

Light Response Uniformity





The response (*y*) along the axis was fit to a linear function:

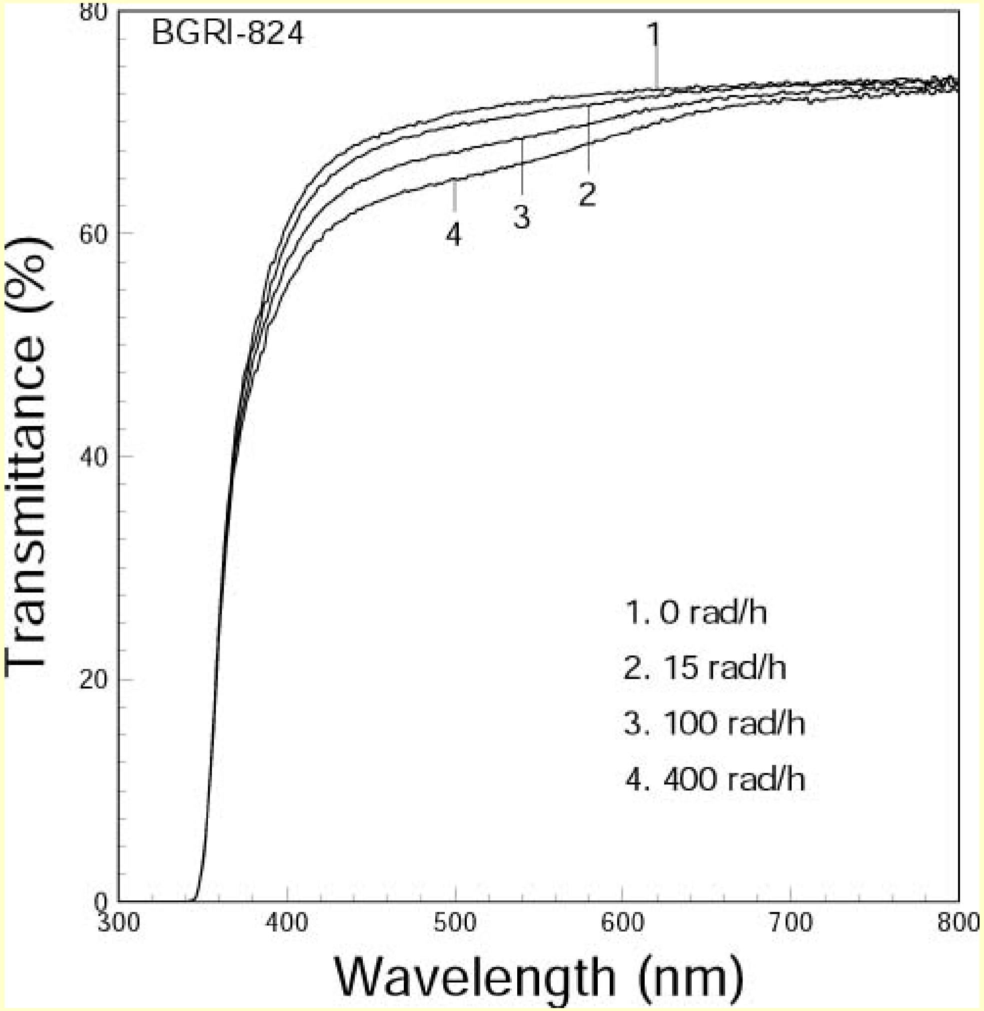
$$\frac{y}{y_{mid}} = 1 + \delta(x / x_{mid} - 1)$$

Color Center Density

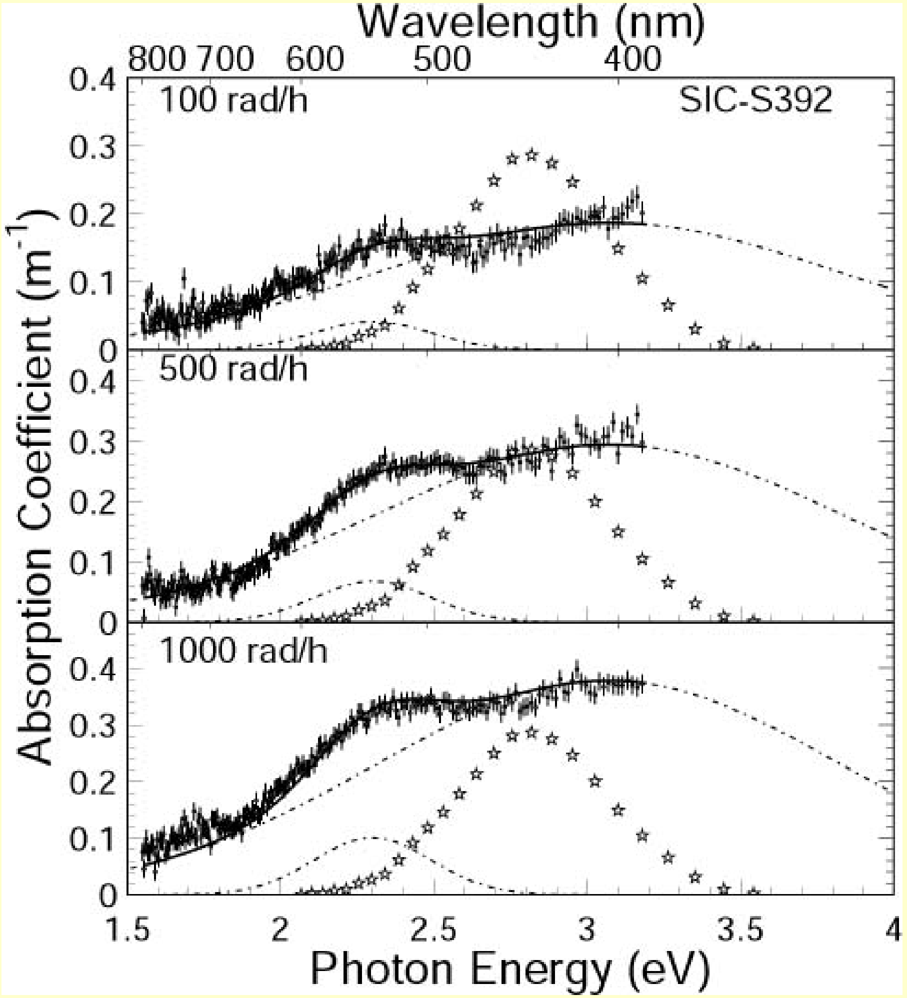
- Radiation induced color center density, or absorption coefficient:

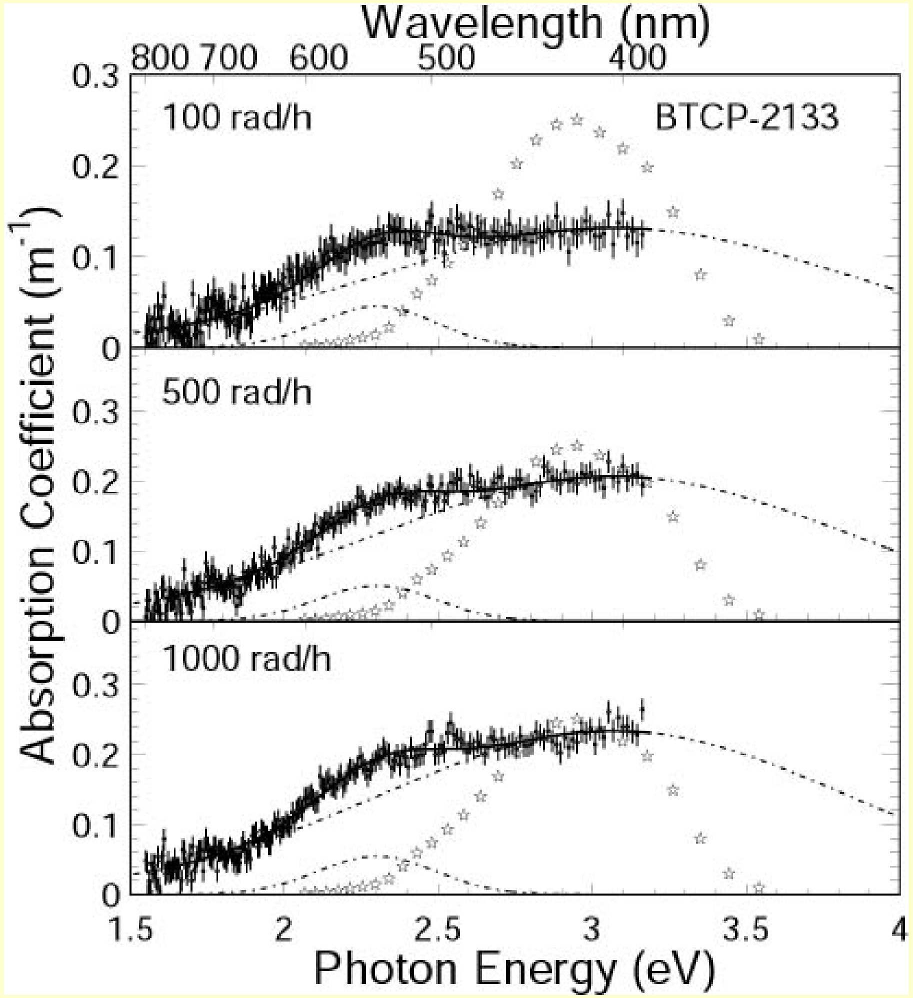
$$D = \frac{1}{LAL_{equilibrium}} - \frac{1}{LAL_{before}}$$

LAL:
light attenuation length



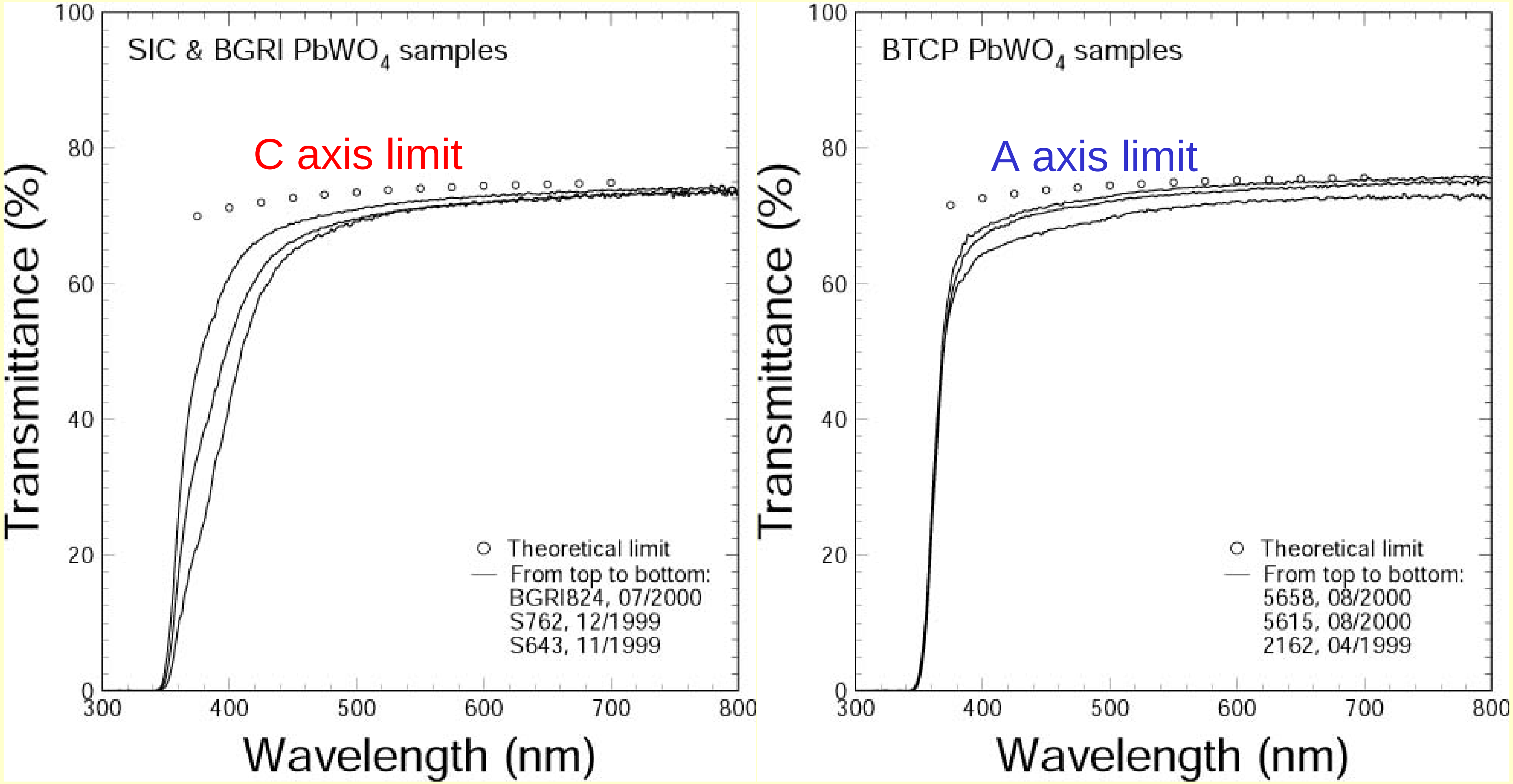
Color Center Decomposition





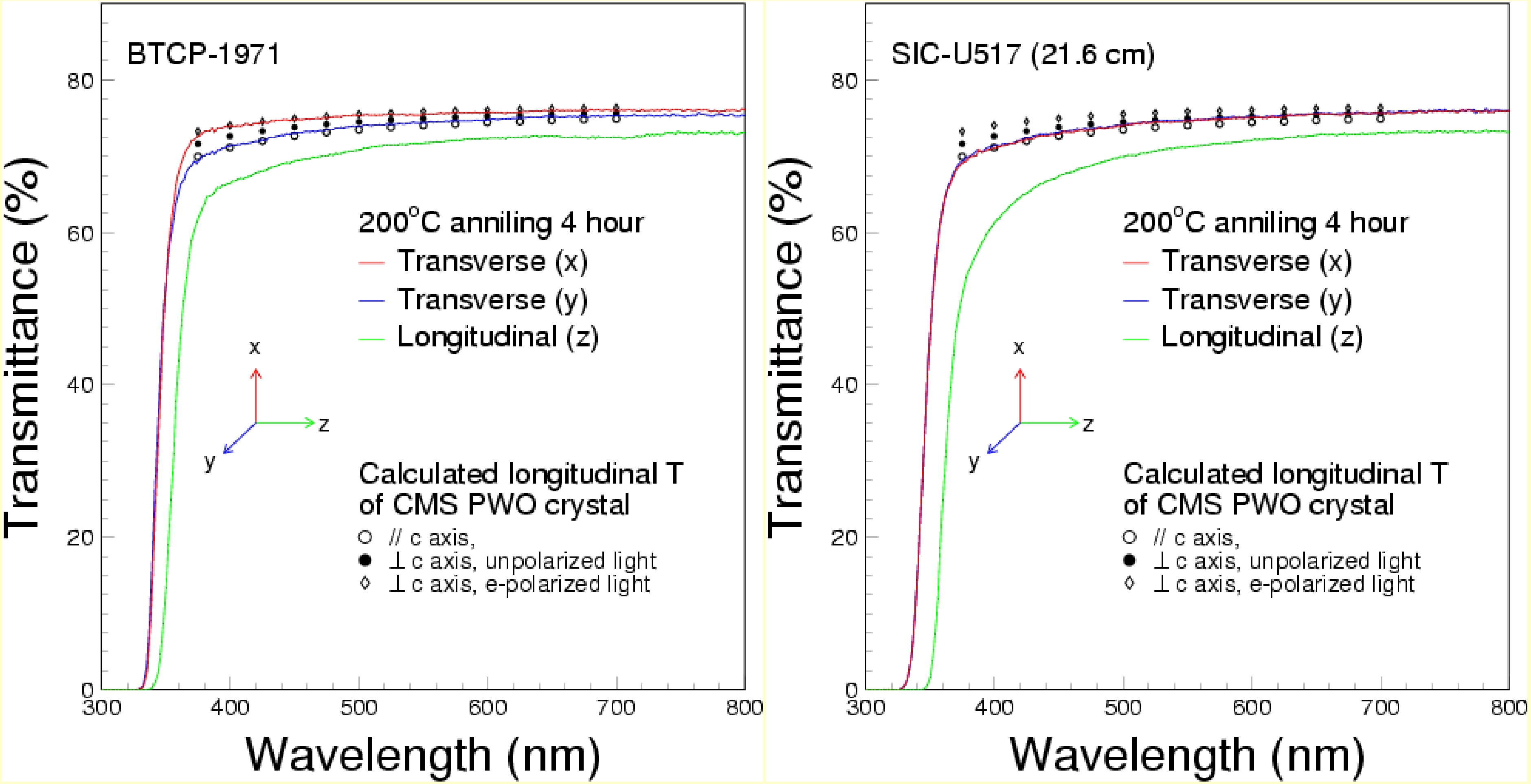
C_1: 3.07 eV (400 nm) / 0.76 eV, C_2: 2.30 eV (540 nm) / 0.19 eV

Longitudinal Transmittance



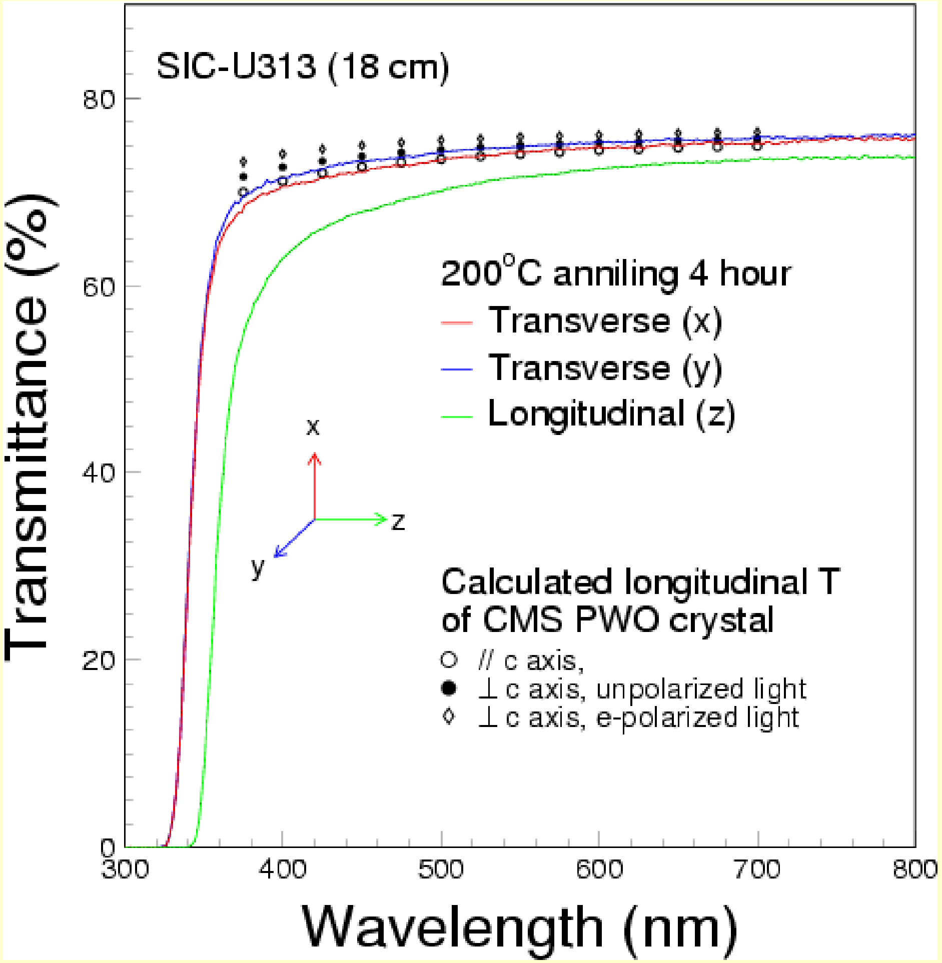
Transmittance approaches theoretical limit: low intrinsic absorption

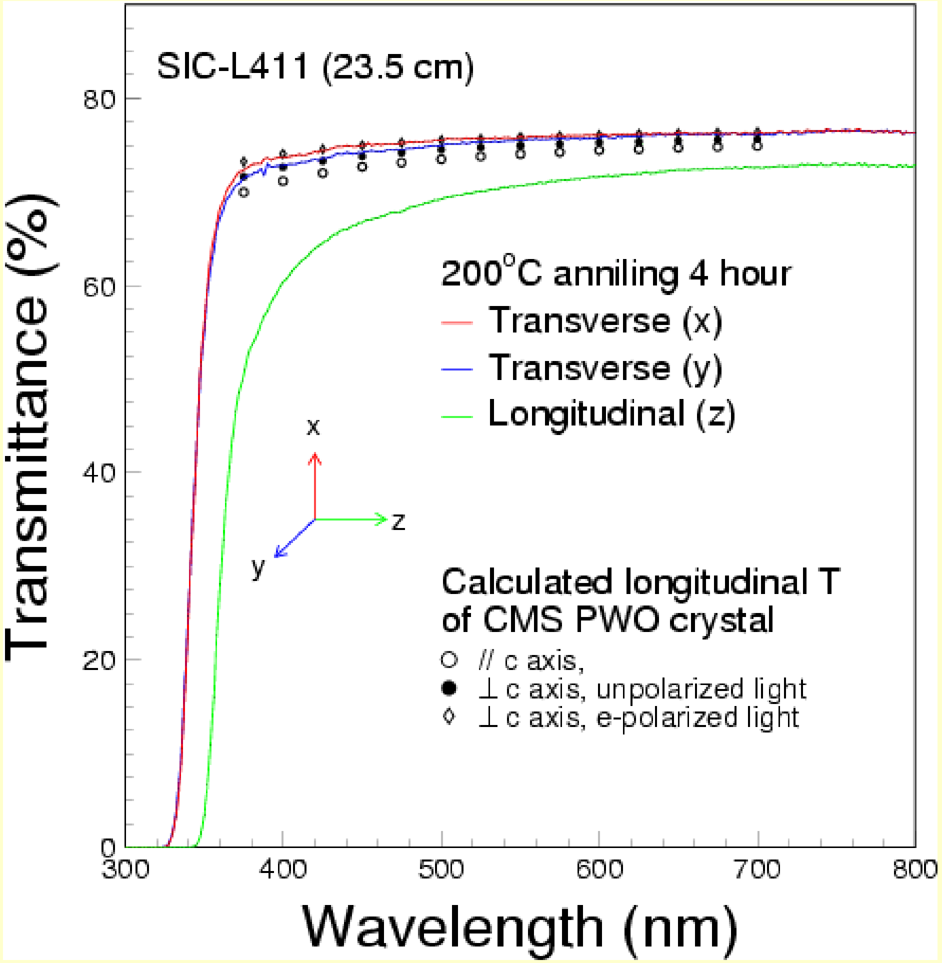
Transmittance and Birefringence



Czochralski: grown along the a axis   Bridgman: grown along the c axis

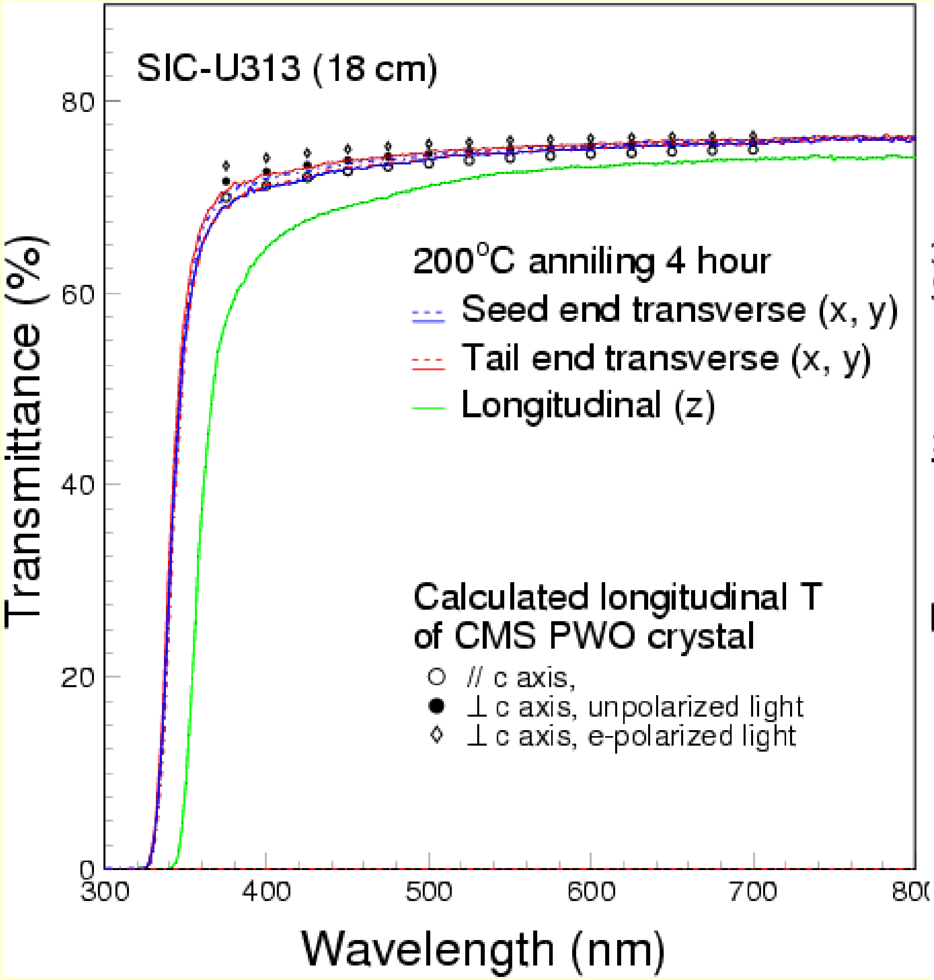
PWO Crystals Grown along c Axis

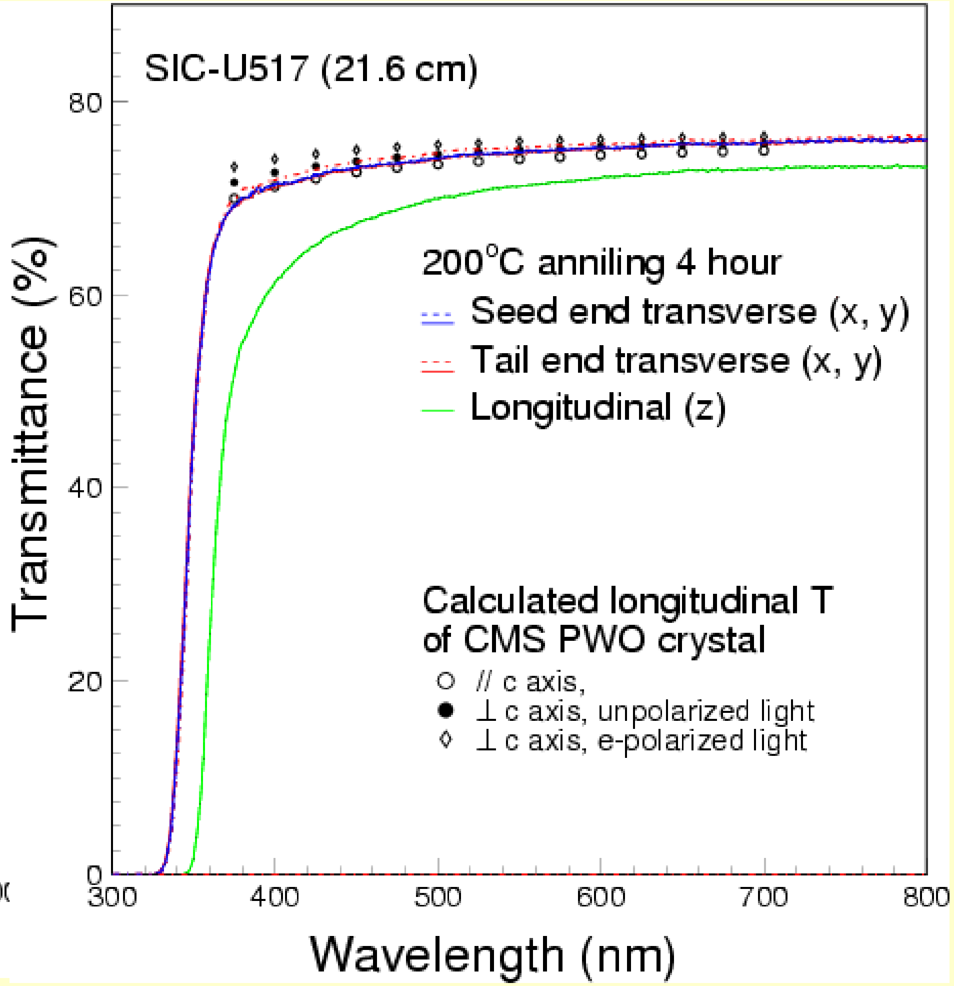




PWO crystals grown along the c axis are isotropic transversely

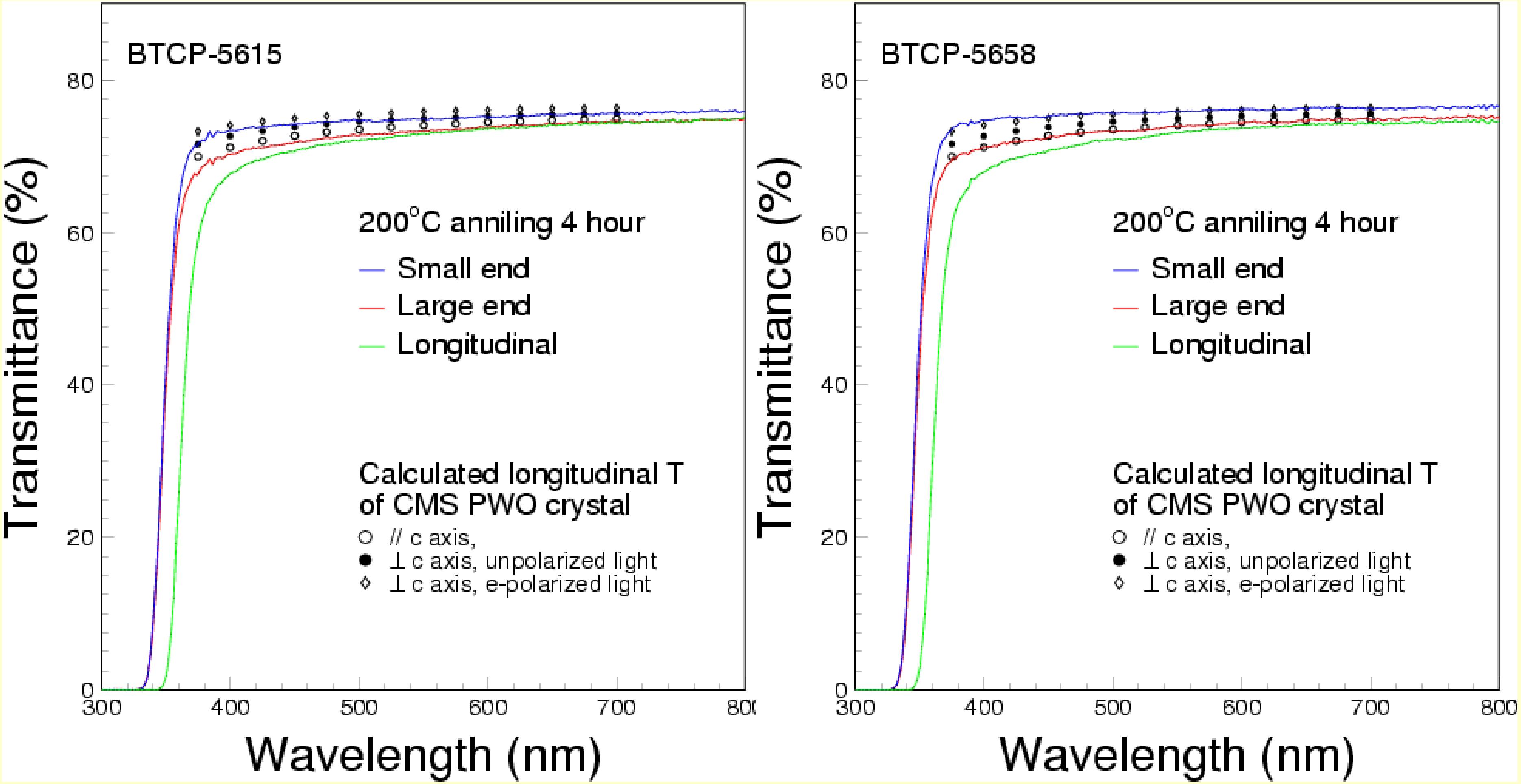
PWO Crystals Grown along c Axis (cont.)





Good longitudinal uniformity in the transverse transmittance

PWO Crystals Grown along a Axis



Some longitudinal non-uniformity in the transverse transmittance.

Summary

- The concentration of yttrium ions in $PbWO_4$ crystals is rather uniform, the segregation coefficient is 0.91±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 γ – 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.

Summary (Cont.)

- 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.