

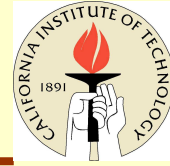
Results on 8 Endcap Crystals

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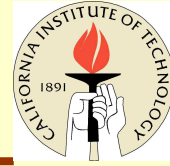
Introduction



- 20 endcap PWO crystals arrived Caltech by the end of October.
- 8 crystals went through a test procedure under γ -ray irradiation at 15, 100, 400 and 9k rad/h, following by recovery.
- All samples were annealed at 200 degree C for 3 hours before test, followed by irradiation under certain dose rate until equilibrium.
- The crystal performance is diverse. The 8 samples can be divided to 3 types.



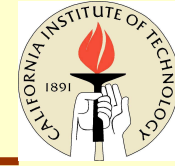
Crystal Property Measured



- UV-excited photo luminescence.
- Longitudinal transmittance.
- Light output and decay kinetics.
- Radiation damage.
- Radiation induced color centers.

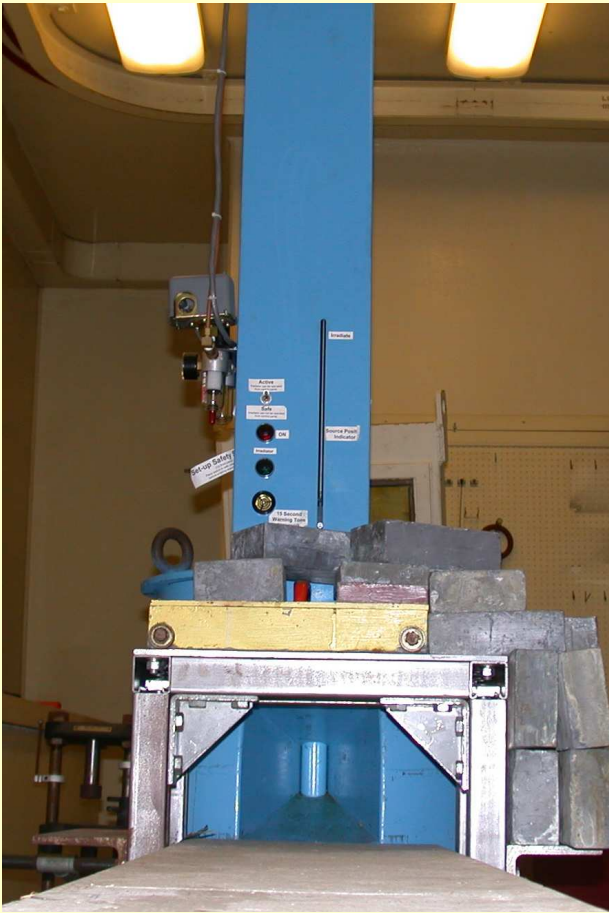


Caltech γ -ray Irradiation Facilities



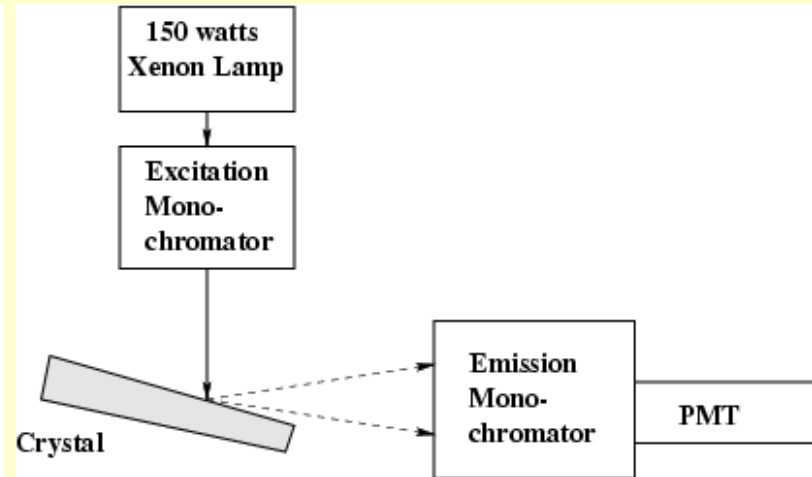
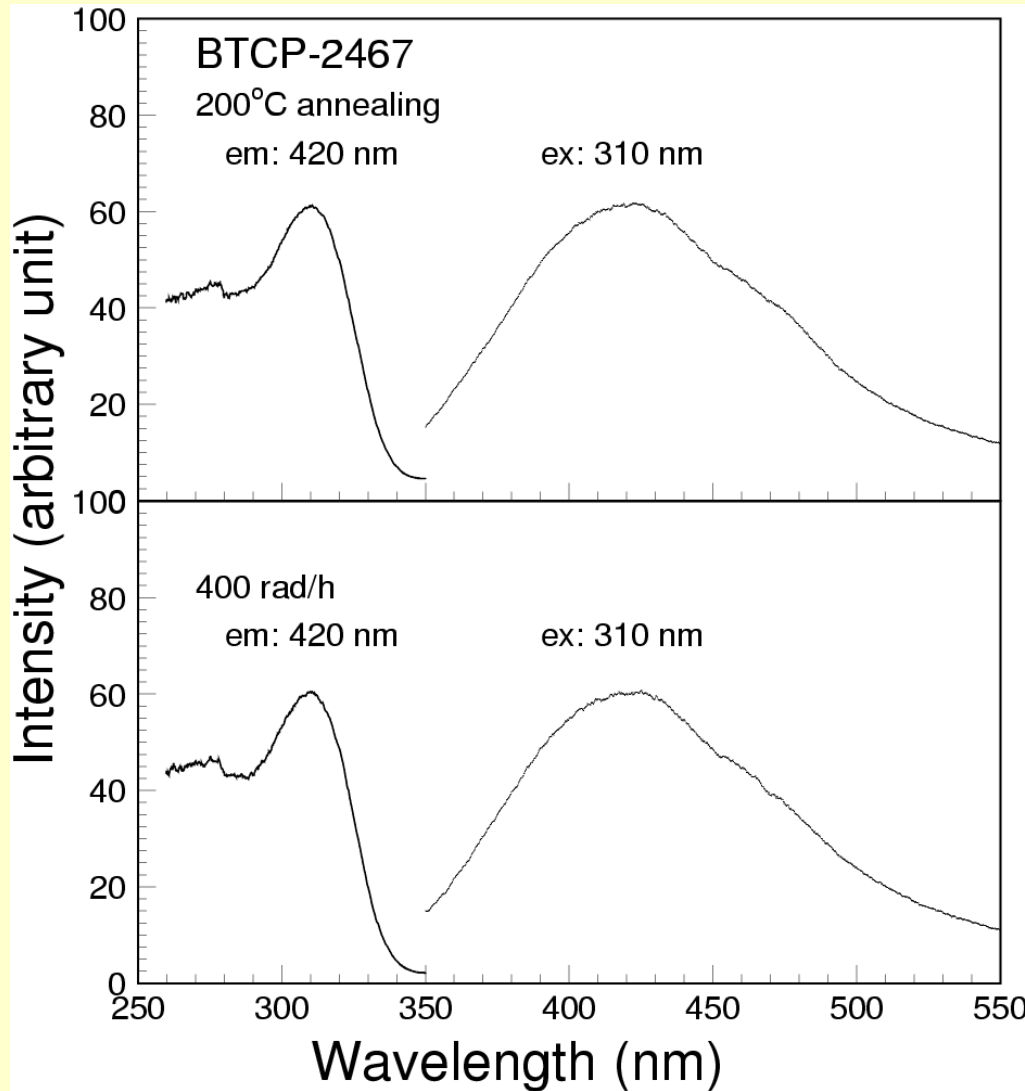
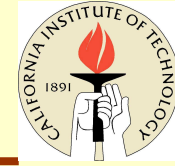
Open 50 curie Co-60:
15, 100 and 400 rad/h

Closed 2,000 curie Cs-137:
9k rad/h at center, up to 36k rad/h





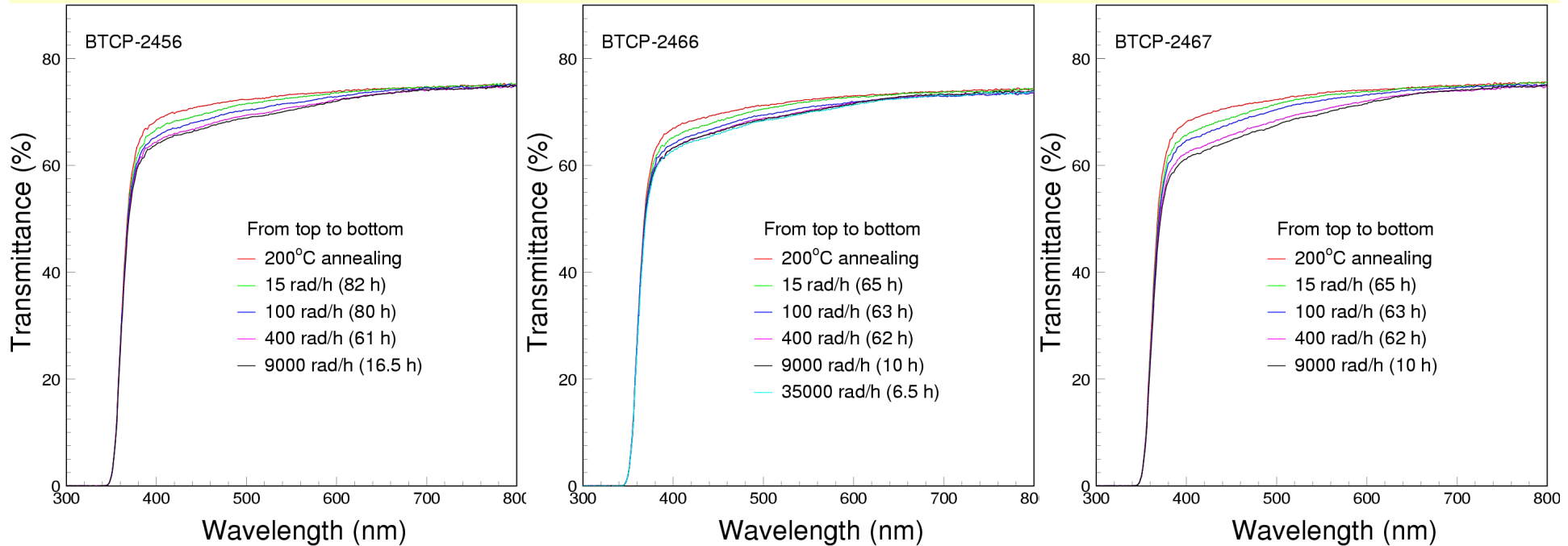
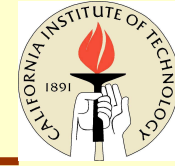
Photoluminescence



All 8 samples show no variation of either excitation or emission spectra.



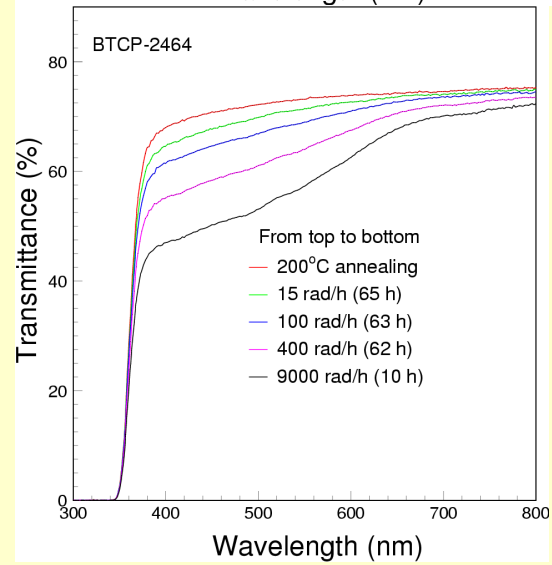
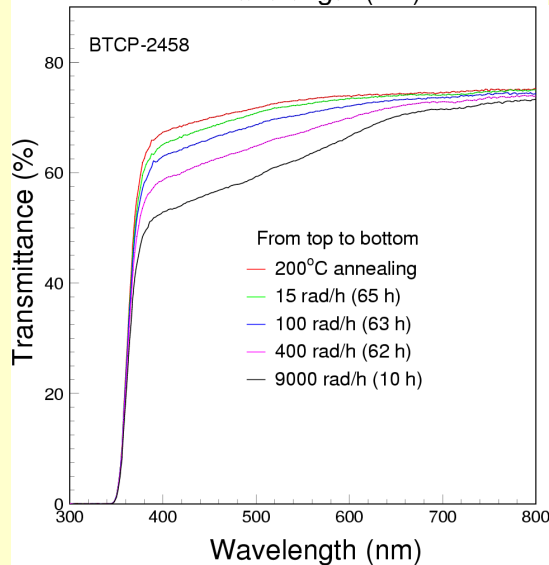
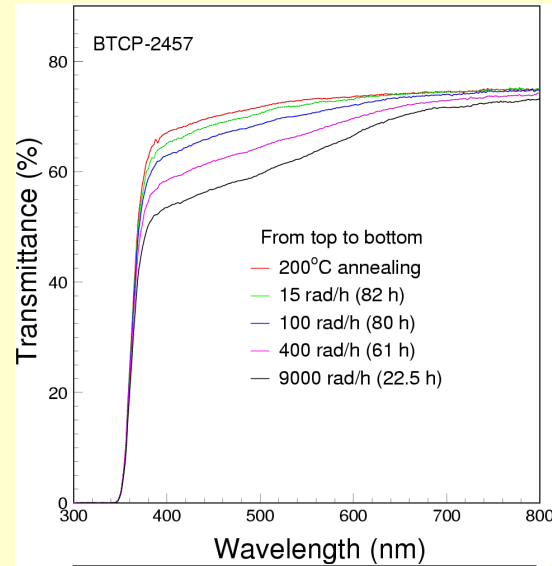
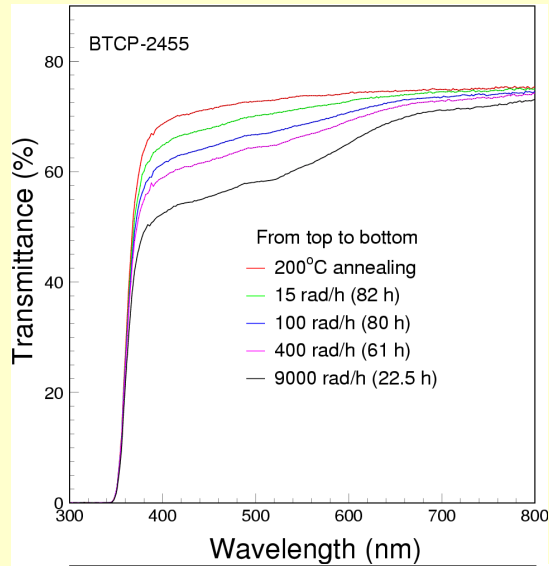
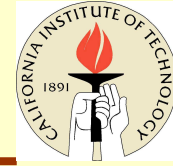
Longitudinal Transmittance (I)



Type I sample: relatively small degradation in longitudinal transmittance especially under high dose rates.



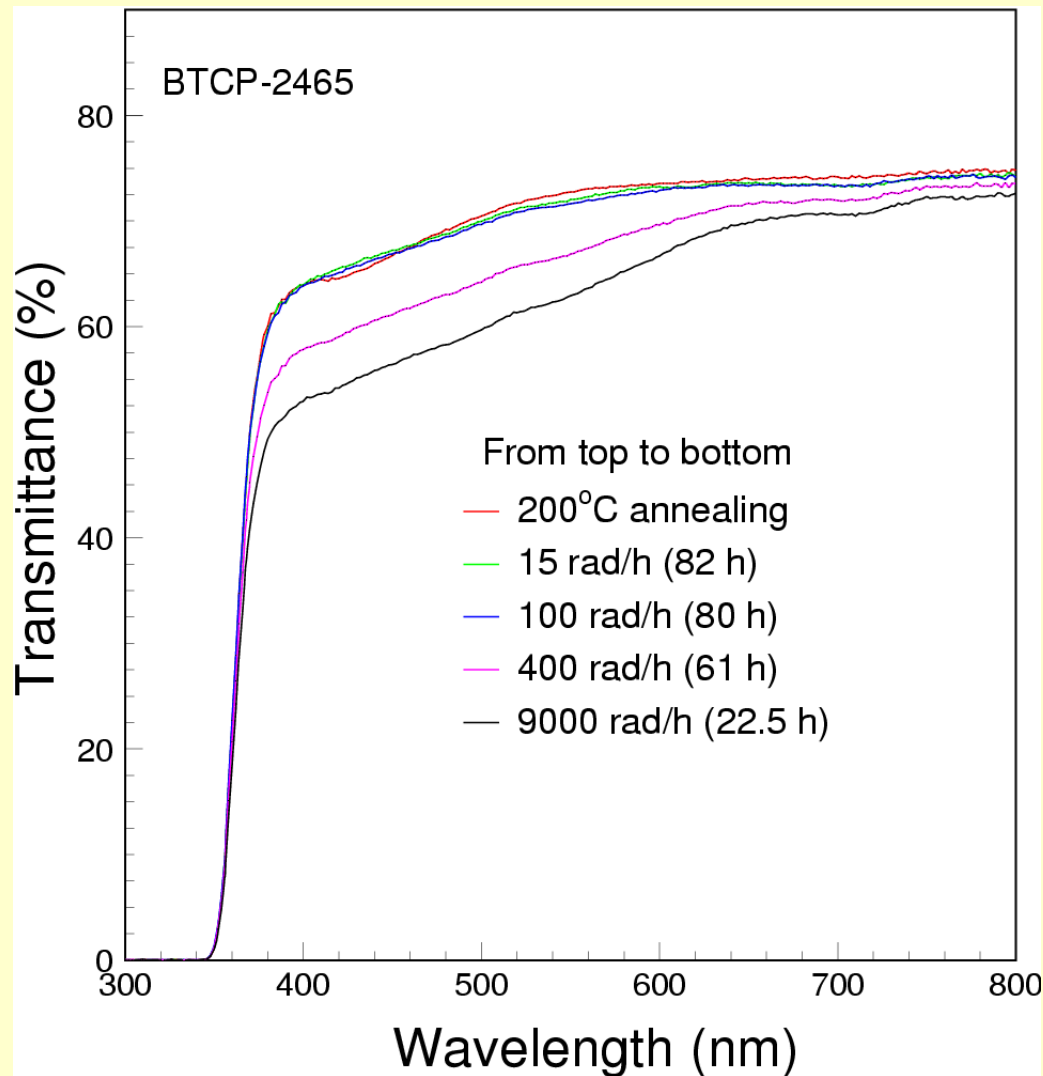
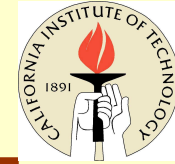
Longitudinal Transmittance (II)



Type II sample: relatively large degradation in longitudinal transmittance, especially under high dose rates.



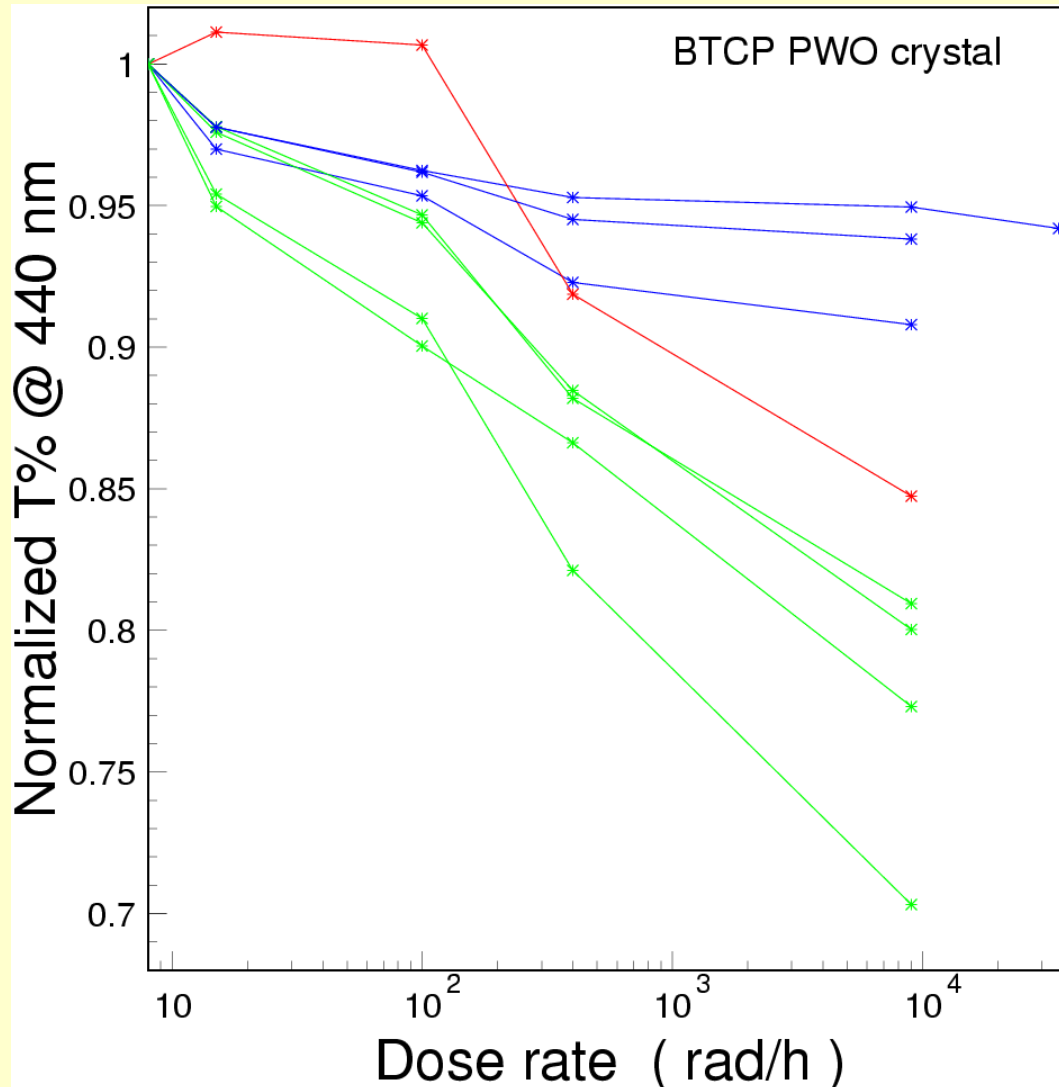
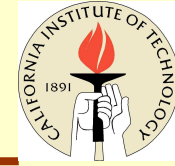
Longitudinal Transmittance (III)



Type II sample:
preexisting
intrinsic color
center at 420 nm
after 200 degree
annealing,
causing difficulty
for monitoring
with 440 nm light



8 Samples in Three Types



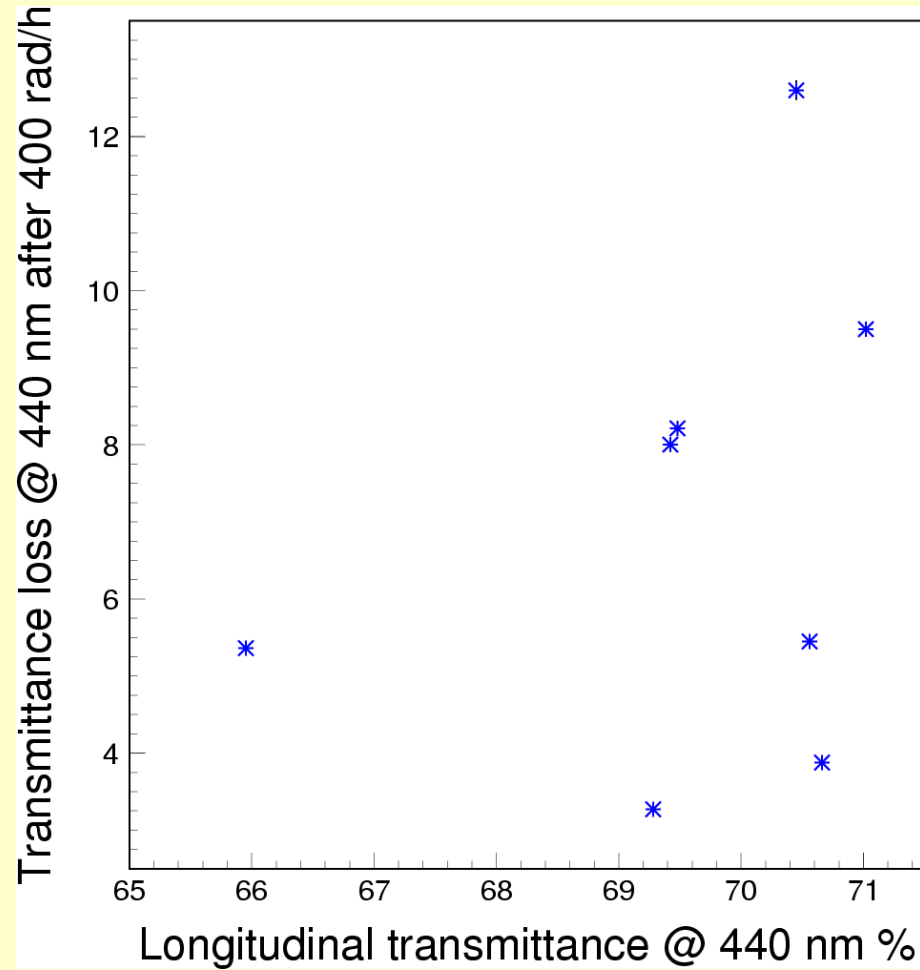
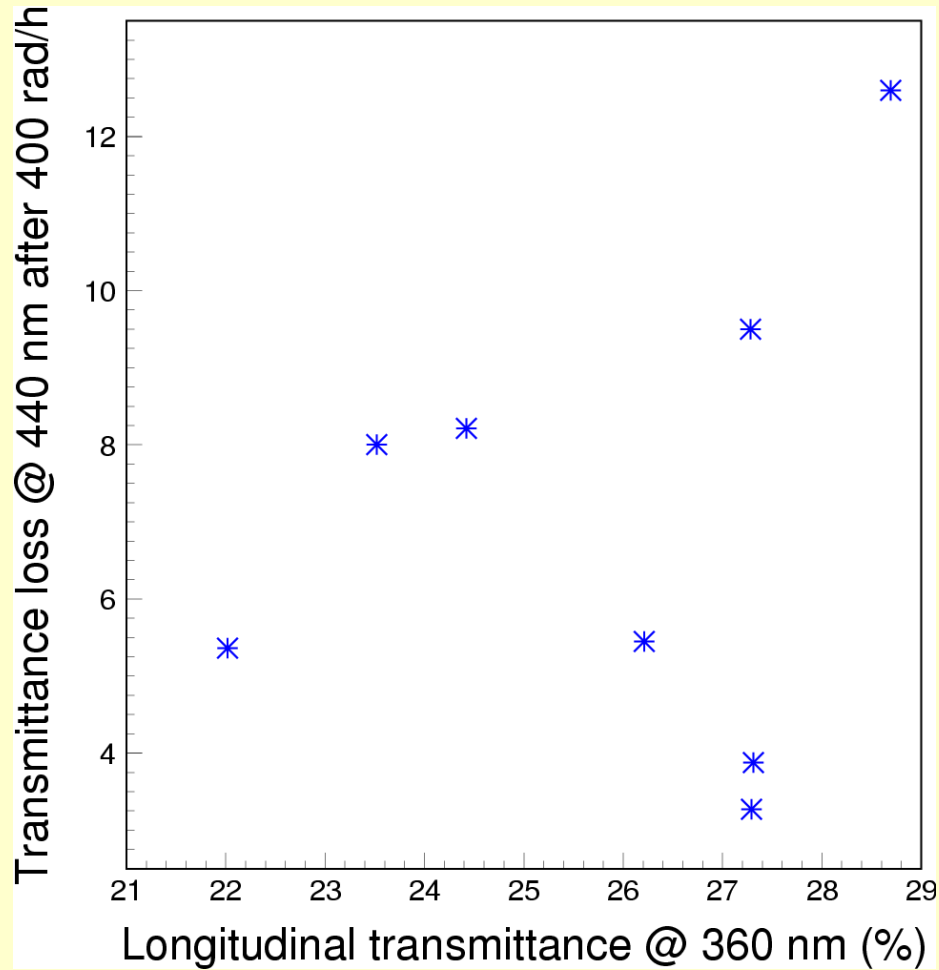
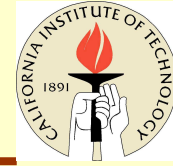
Type I: 2456,
2466 and 2467;

Type II: 2455,
2457, 2458 and
2464;

Type III: 2465.

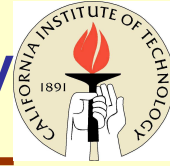


Longitudinal Transmittance versus Damage





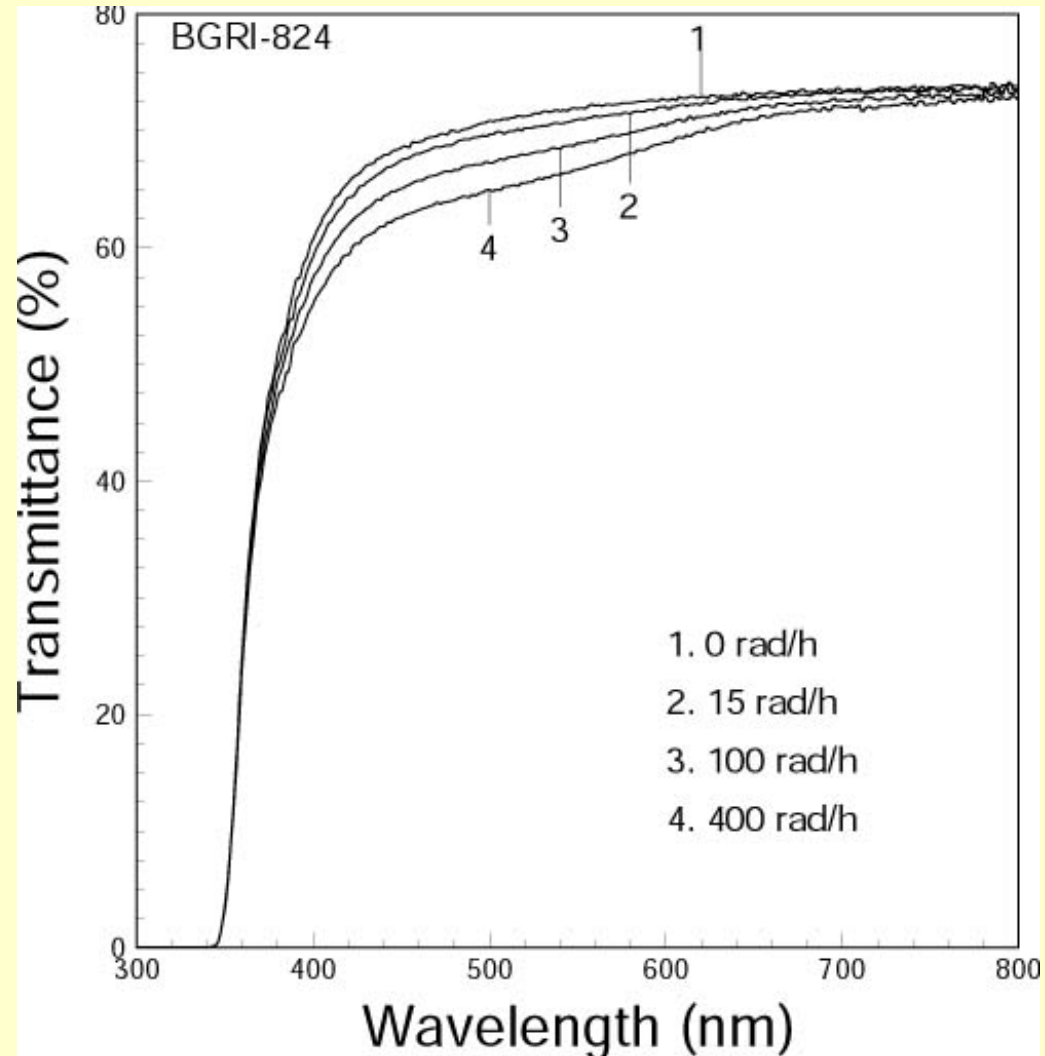
Radiation Induced Color Center Density



- Radiation induced color center density, or absorption coefficient:

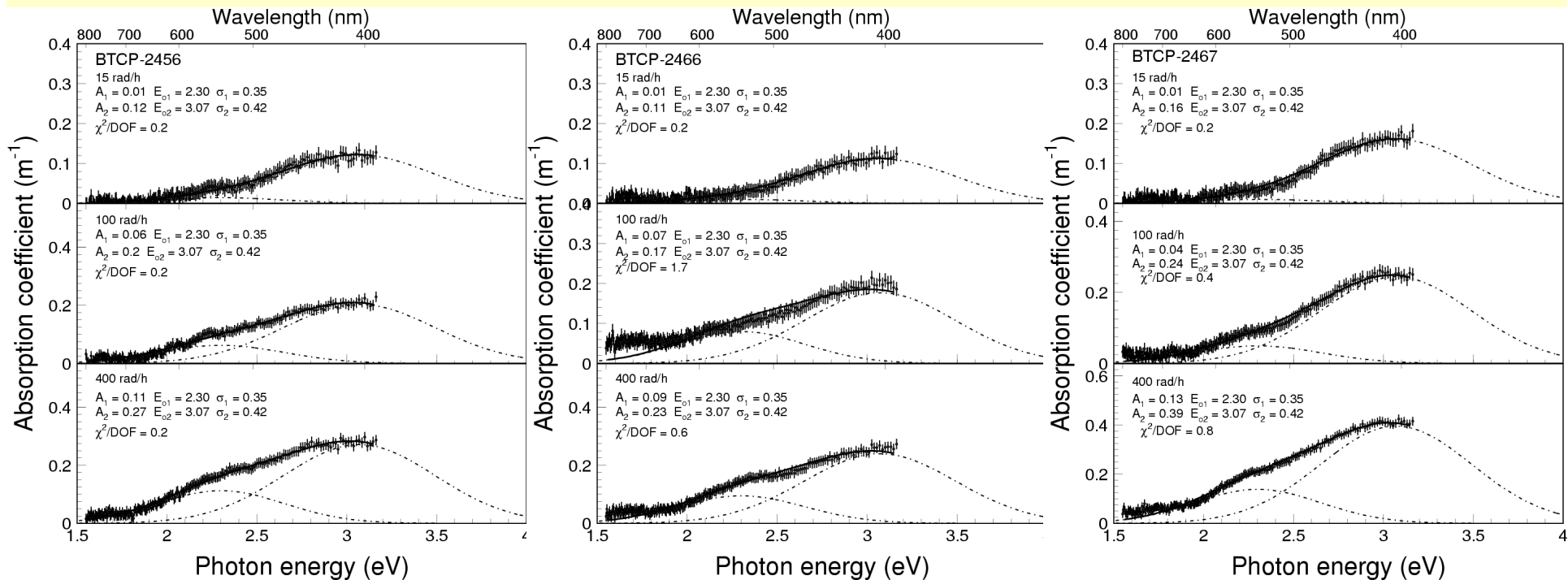
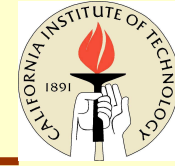
$$D = \frac{1}{LAL_{equilibrium}} - \frac{1}{LAL_{before}}$$

LAL:
light attenuation
length





Radiation Induced Color Centers (I)



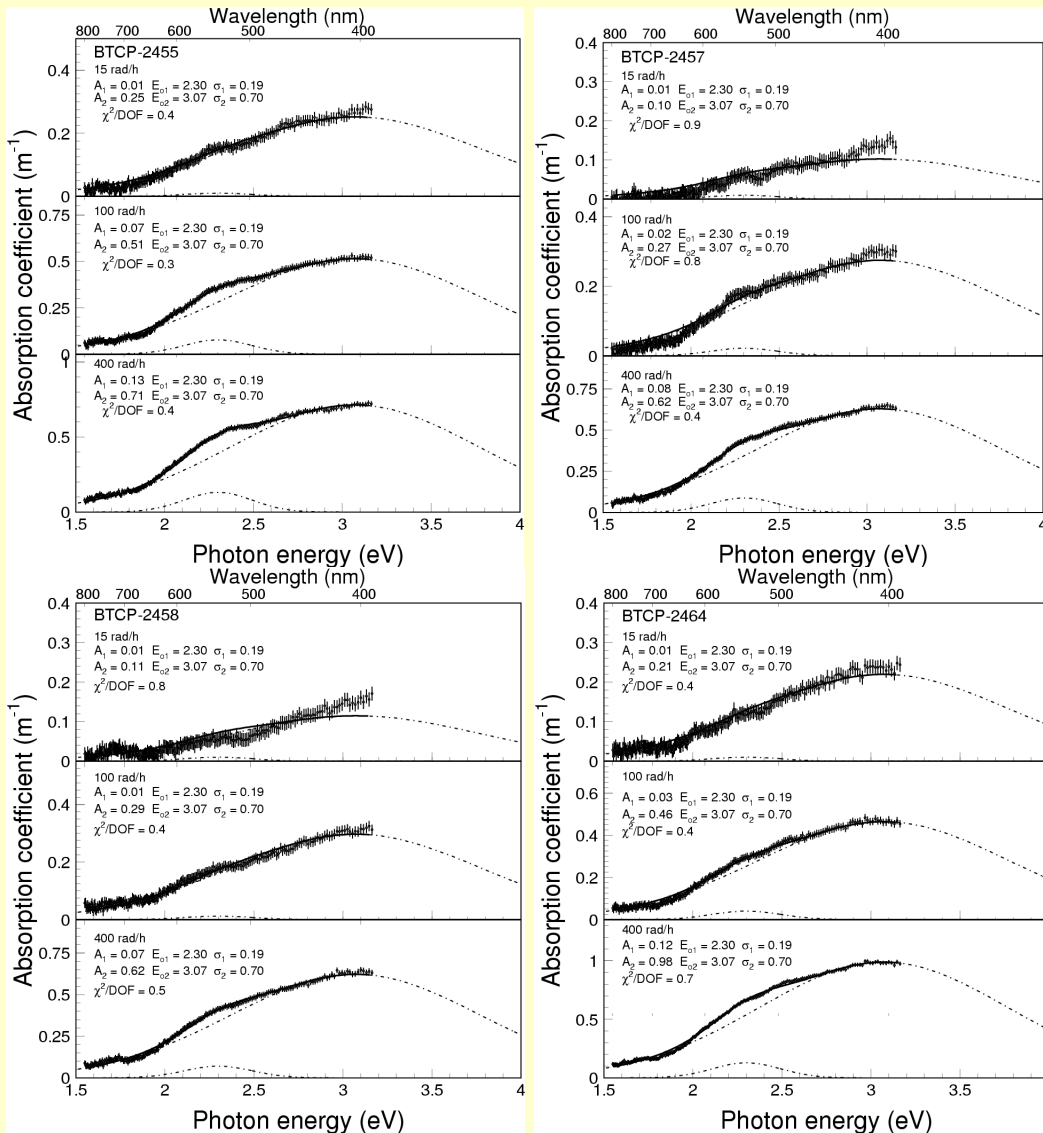
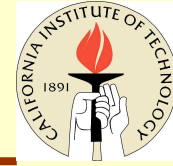
C₁: 2.30 eV (540 nm) with width of 0.35 eV

C₂: 3.07 eV (400 nm) with width of 0.42 eV

Radiation induced CC density <0.4/m



Radiation Induced Color Centers (II)



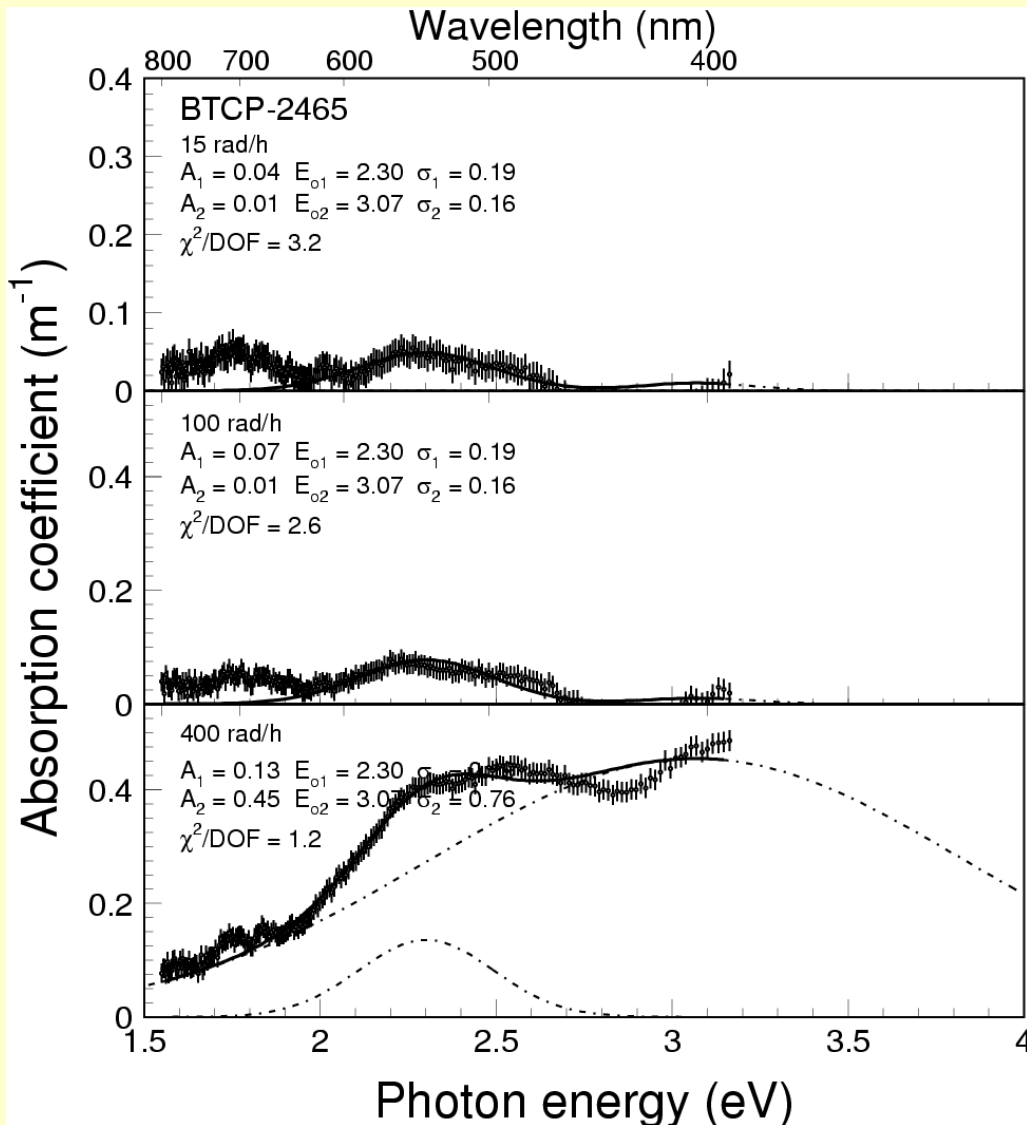
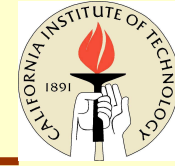
C_1 : 2.30 eV (540 nm)
with width of 0.19 eV

C_2 : 3.07 eV (400 nm)
with width of 0.70 eV

Radiation induced CC
density up to 1/m.



Radiation Induced Color Centers (III)



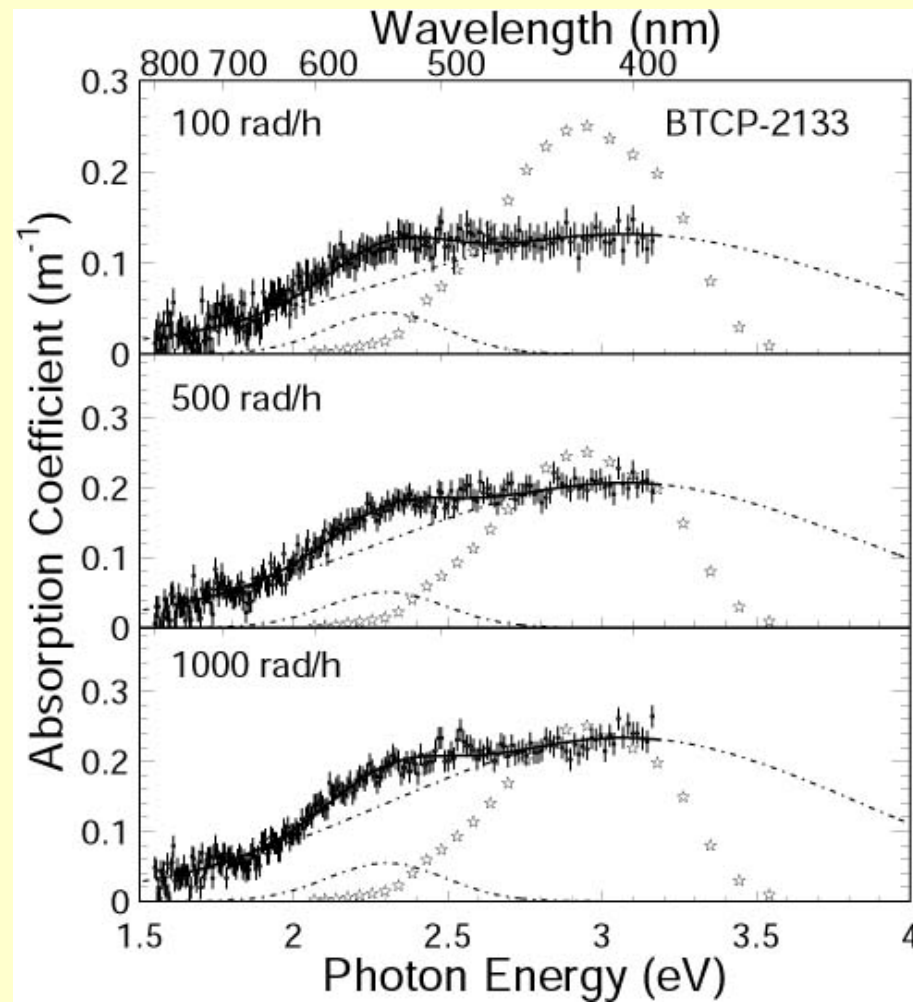
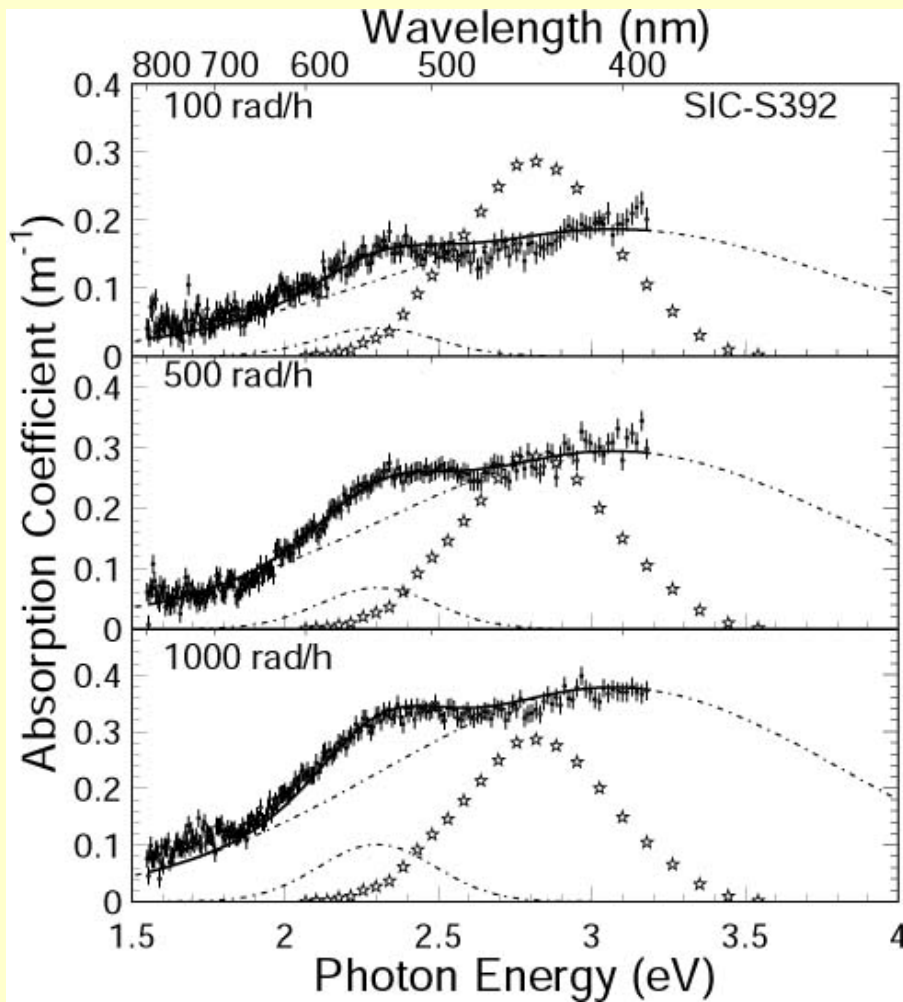
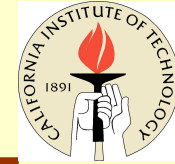
Different color centers under low and high dose rates: Poor Fit.

C_1 : 2.30 eV (540 nm) with width of 0.19 eV

C_2 : 3.07 eV (400 nm) with width of 0.16 and 0.76 eV



Previous Samples: Type II CC

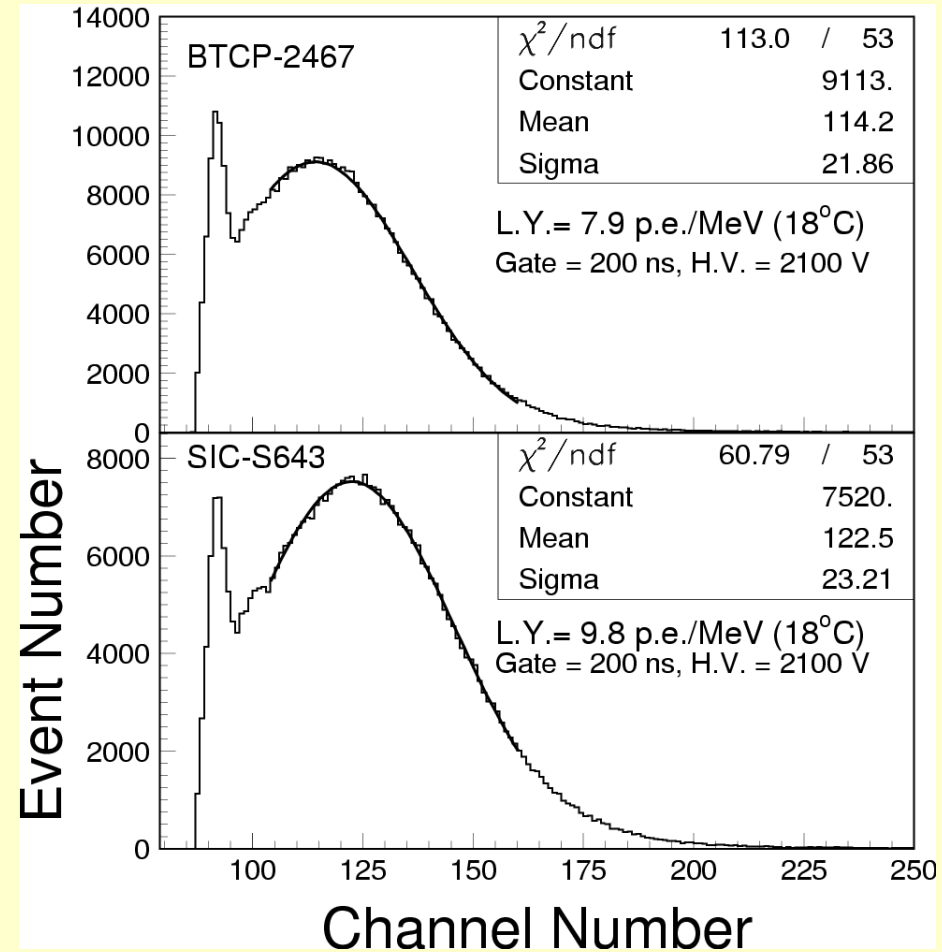
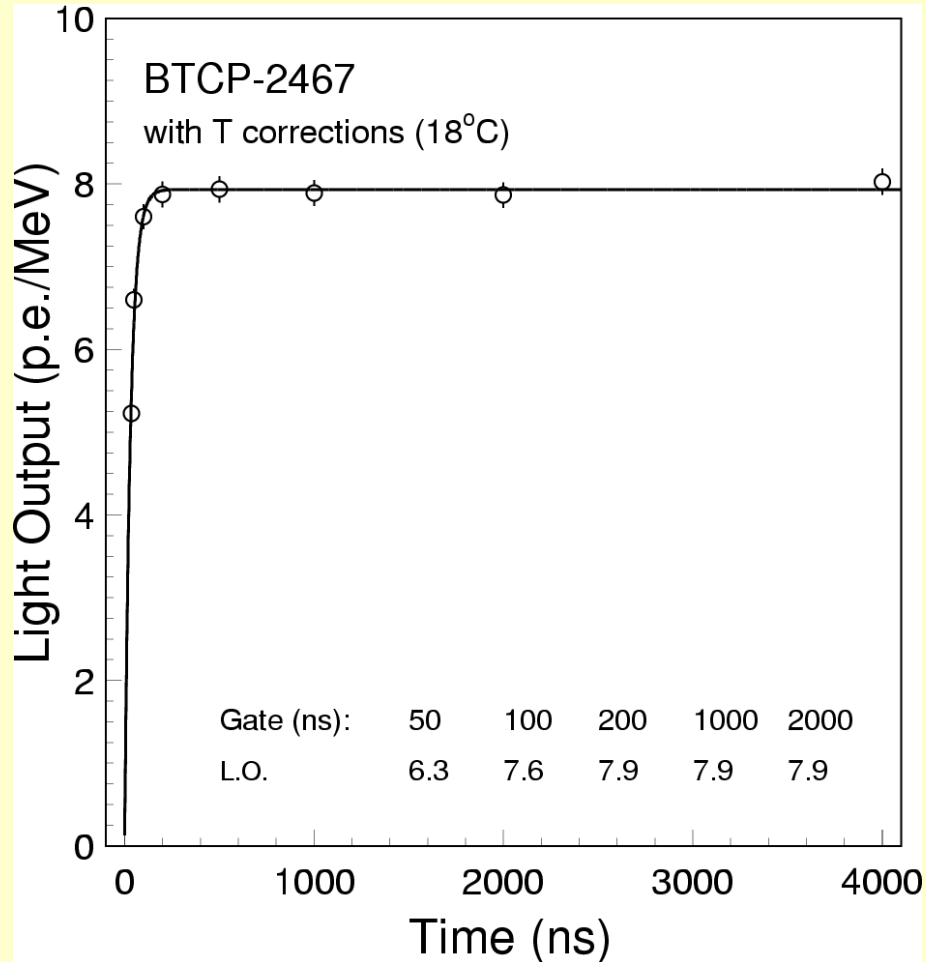
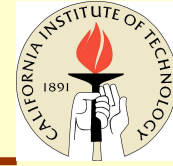


C_1 : 2.30 eV (540 nm) / 0.19 eV

C_2 : 3.07 eV (400 nm) / 0.76 eV



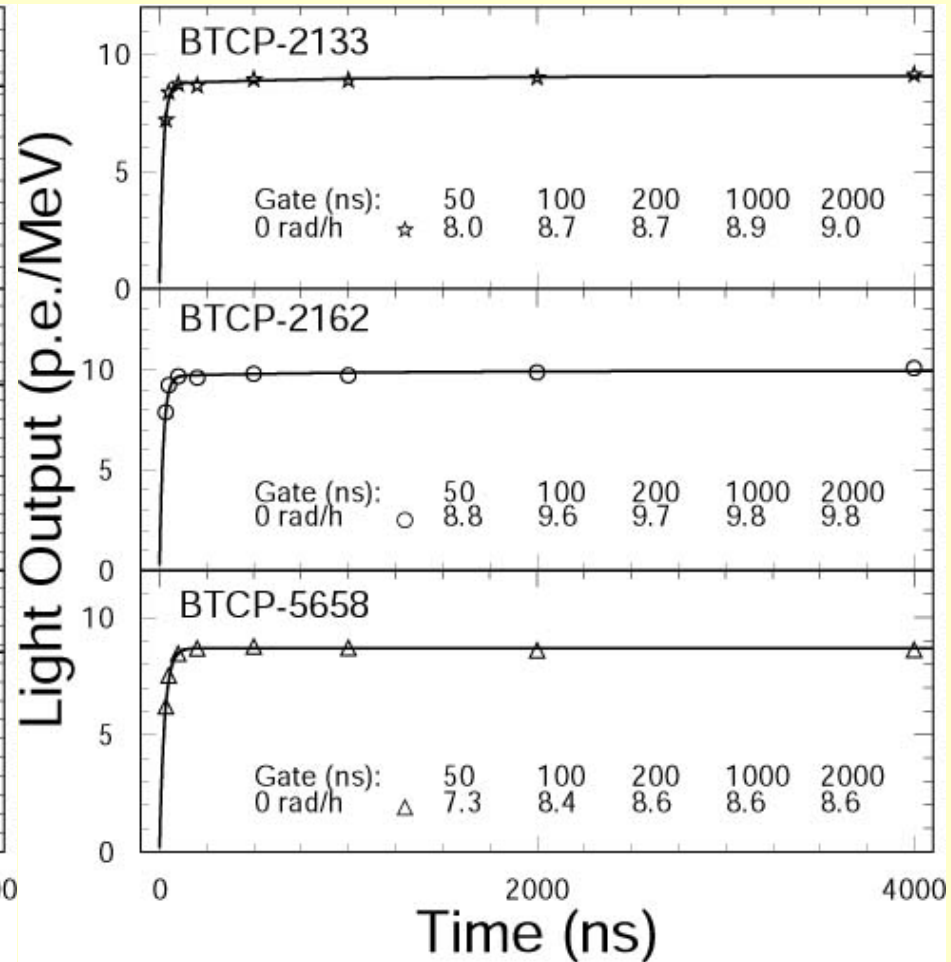
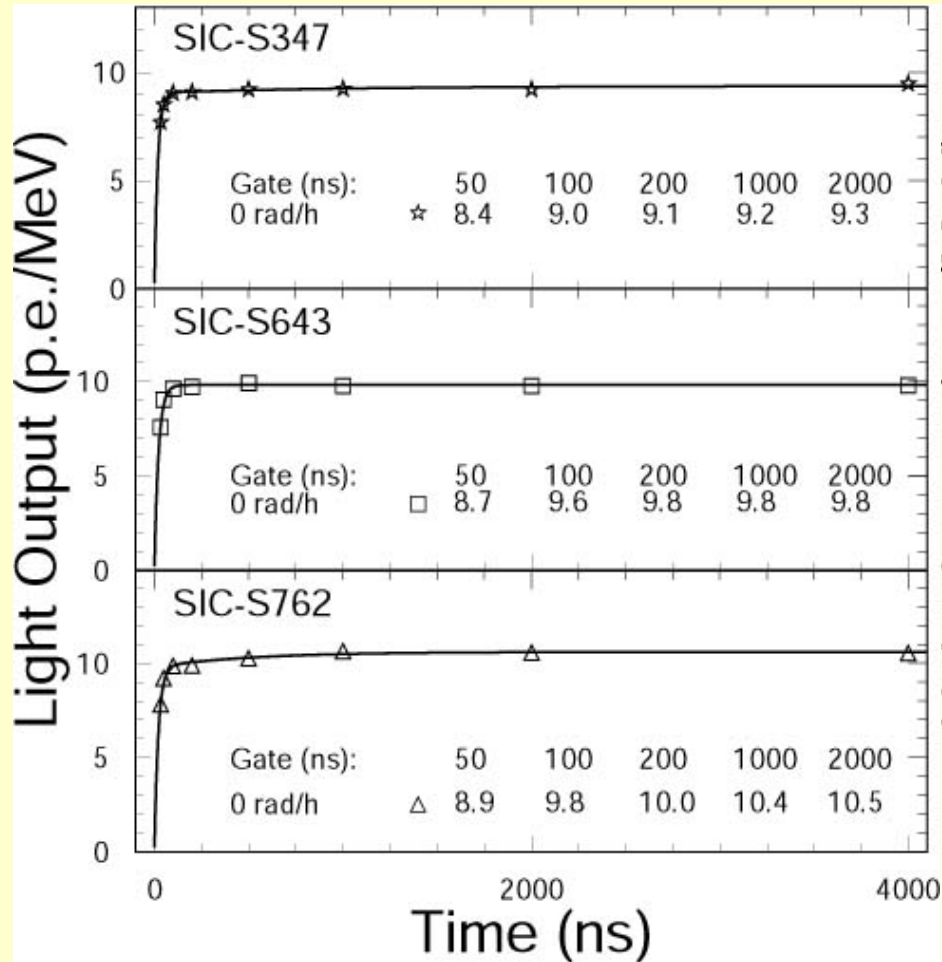
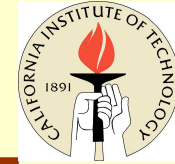
Light Output and Decay Kinetics



All samples have fast, but low, light output



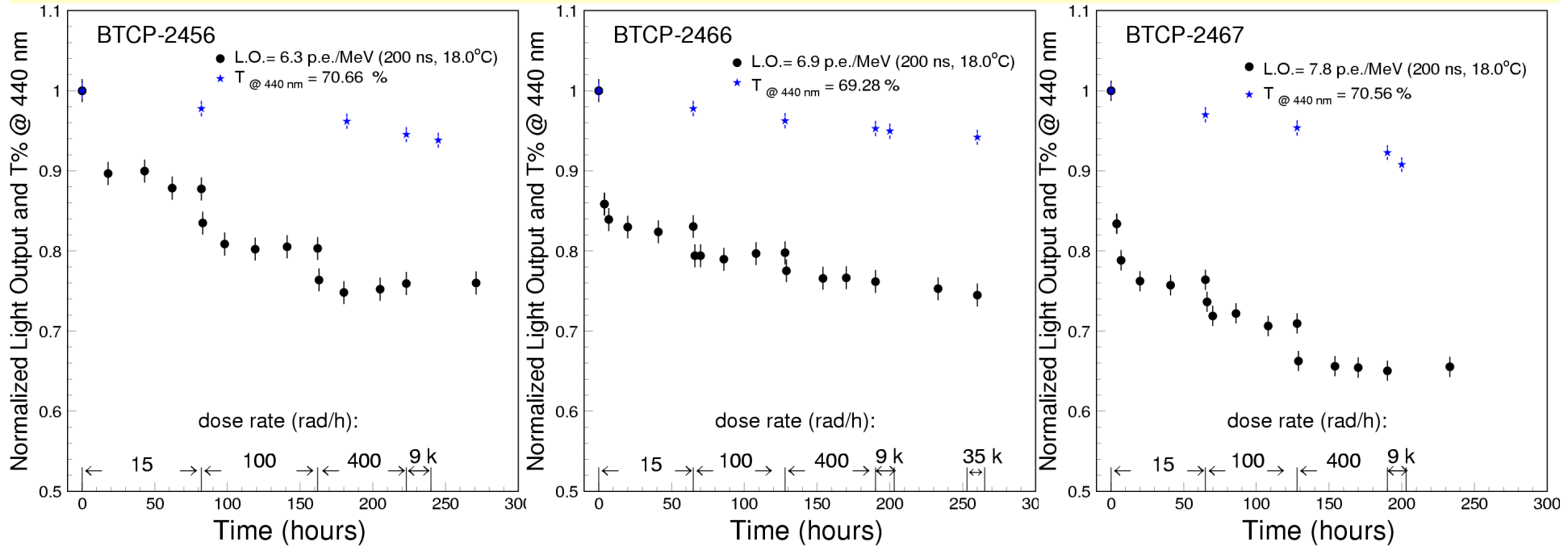
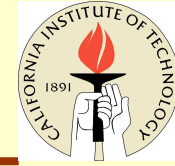
Previous Samples: Higher Light Output



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



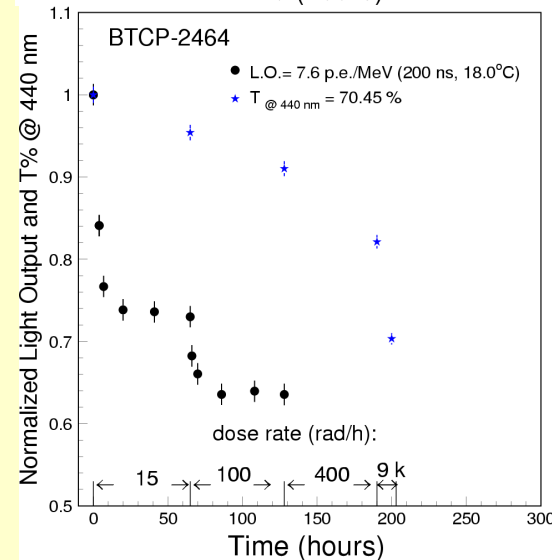
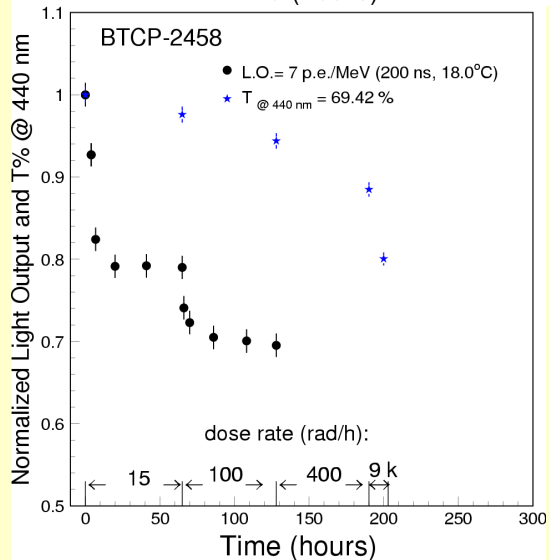
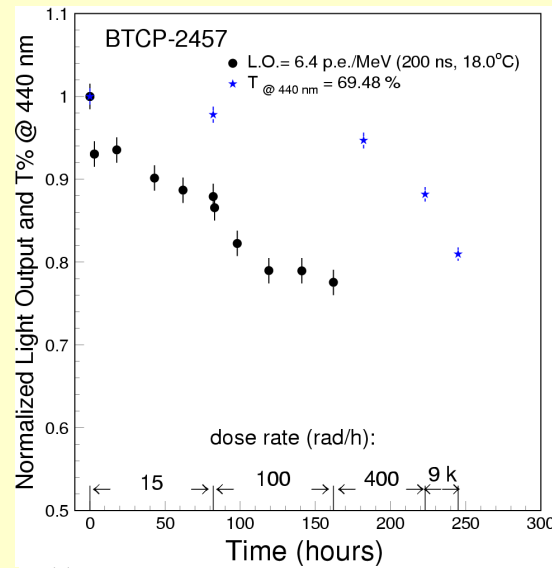
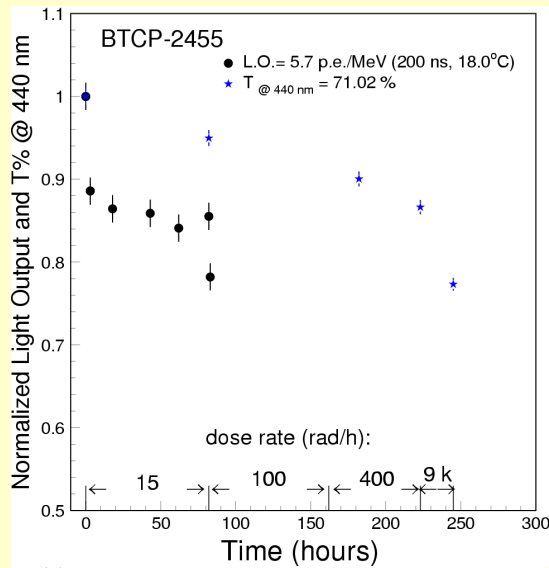
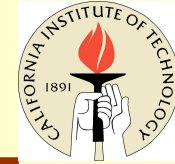
Light Output/LT Degradation (I)



Light output degradation of all samples show dose rate dependence. Type I crystals lose 10 – 20% light output under the barrel dose rate (15 rad/h) and 20—35% under the endcap dose rate (100—400 rad/h).



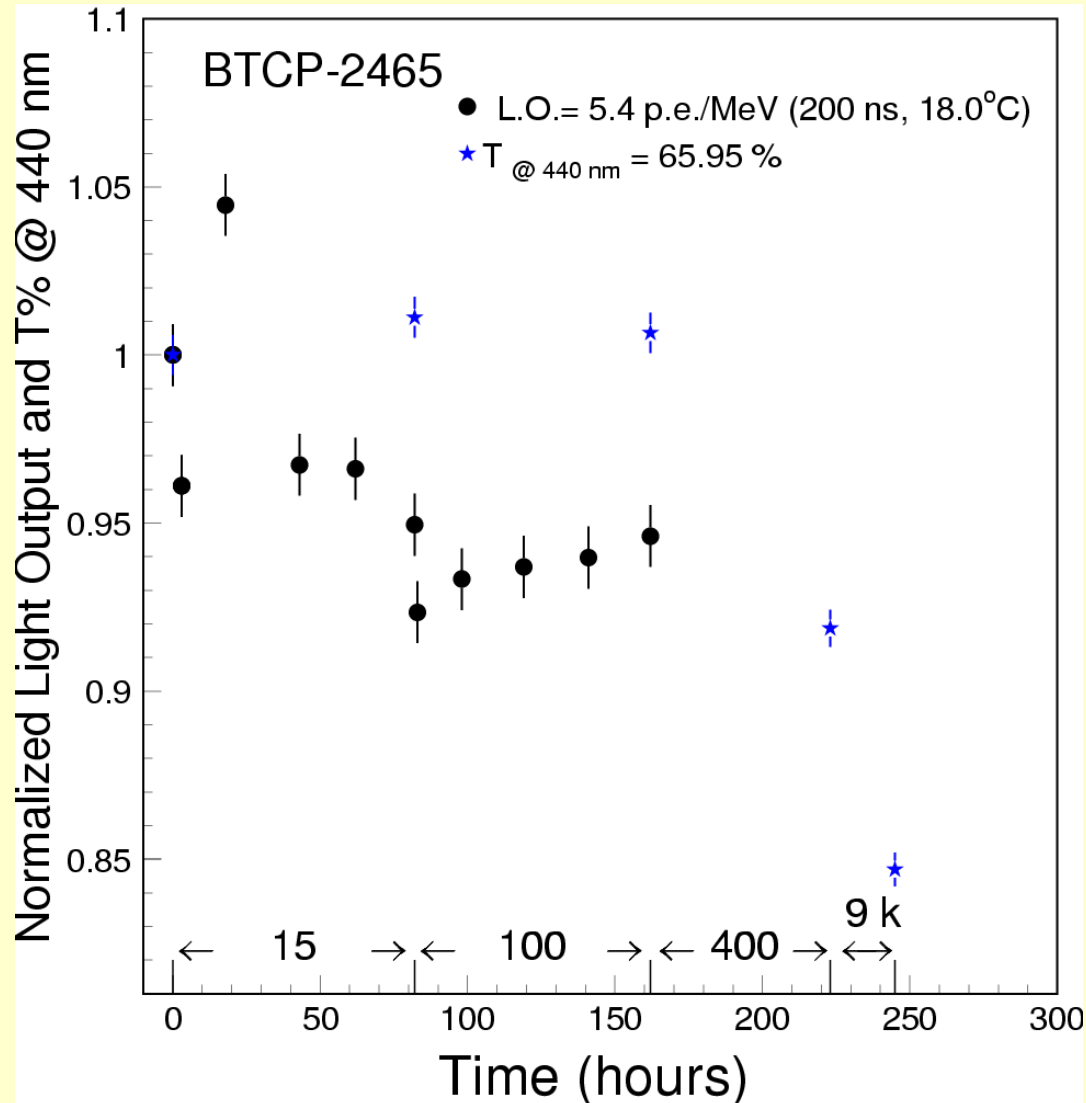
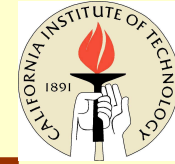
Light Output/LT Degradation (II)



Type II crystals lose 10 – 25% under the barrel dose rate and more than 30% under the endcap dose rate, which can not be determined by using source.



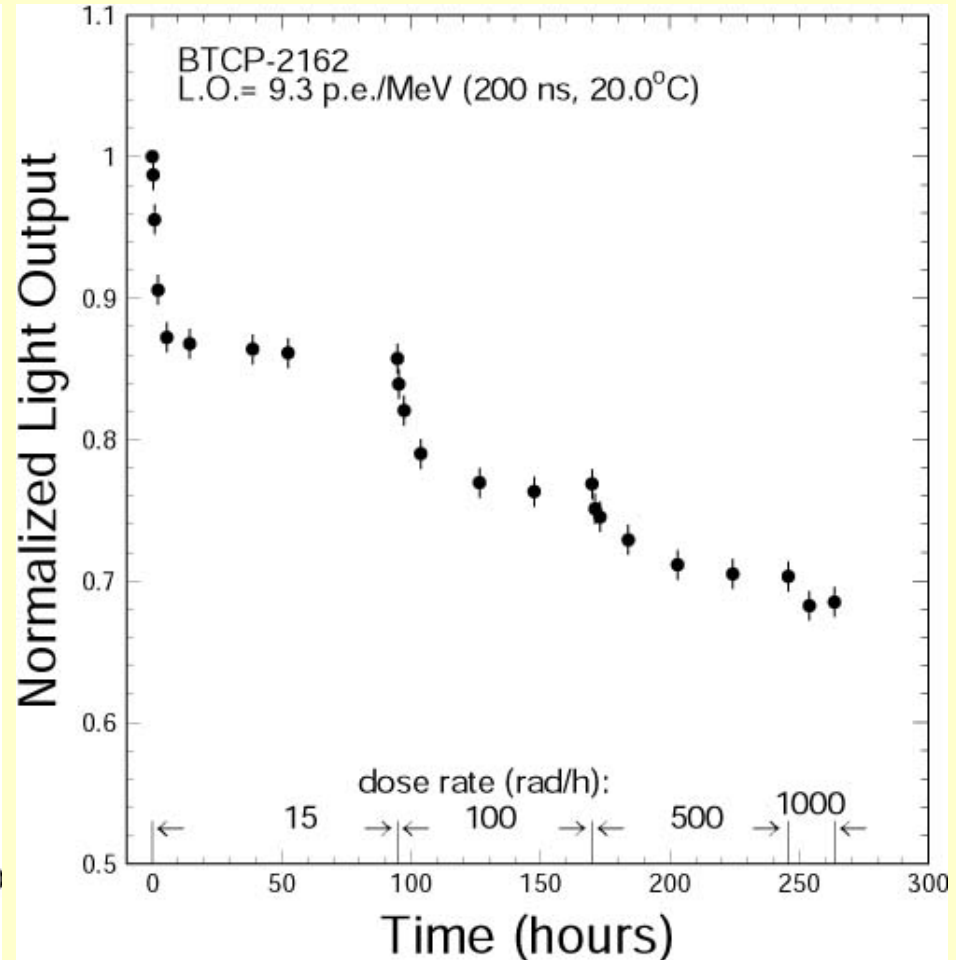
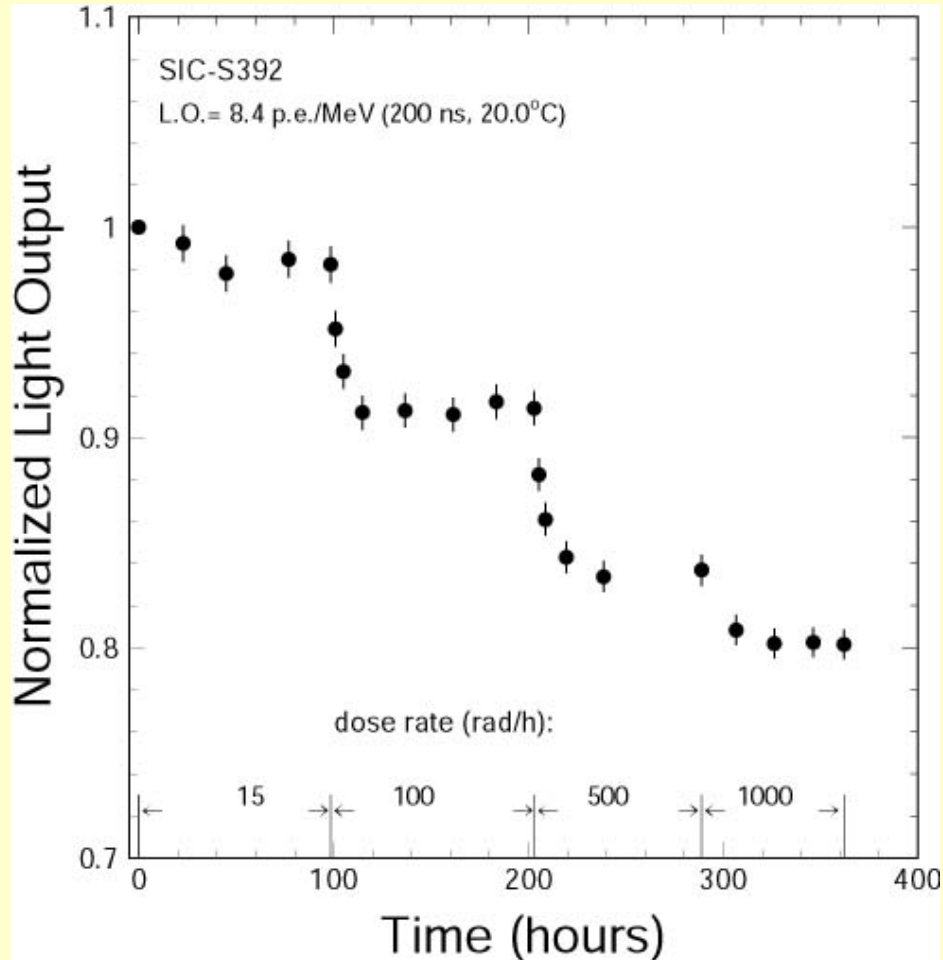
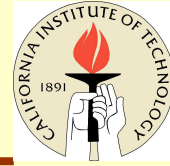
Light Output/LT Degradation (III)



Type III crystals lose a few percents under the barrel dose rate. Some confusion of monitoring at 440 nm.



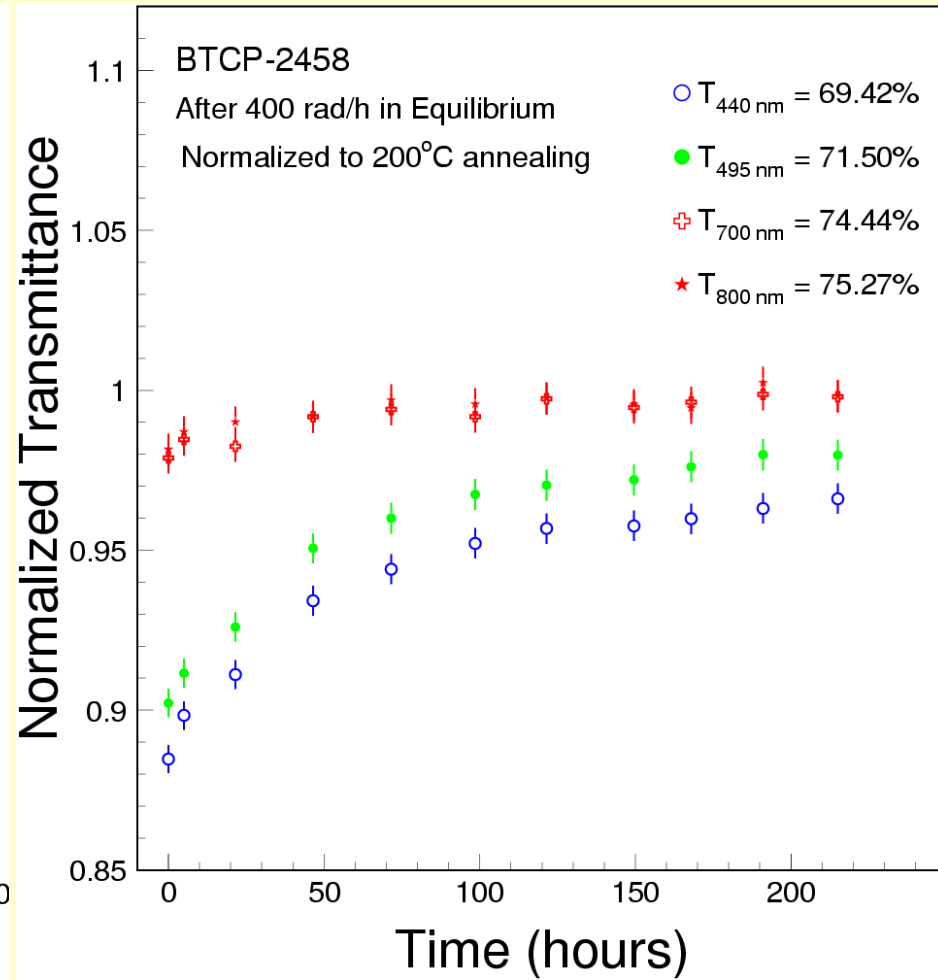
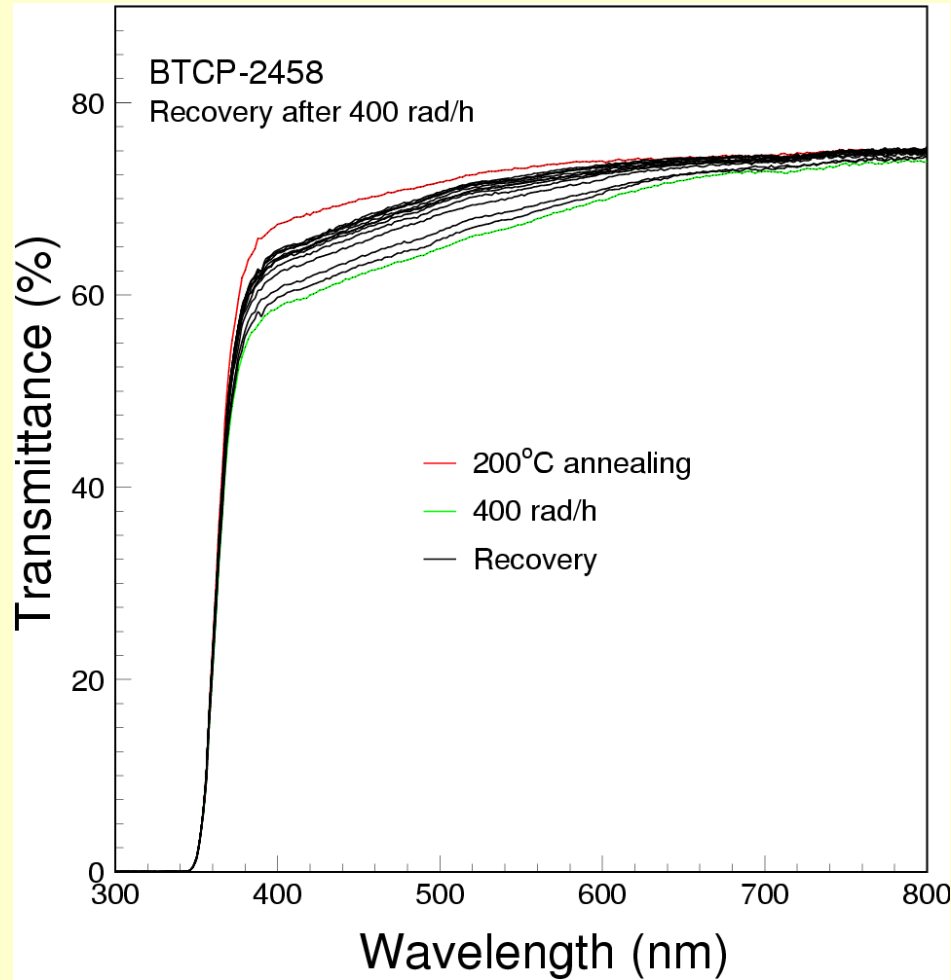
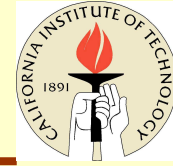
Early Samples Show less damage



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

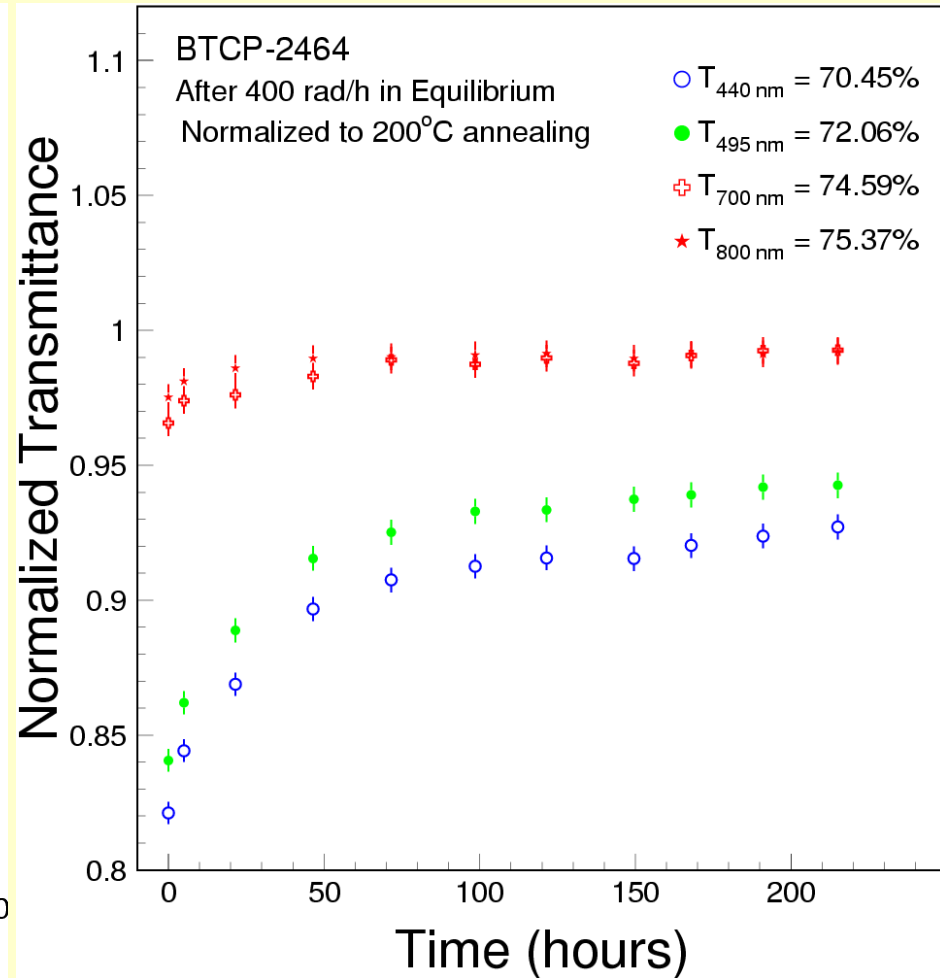
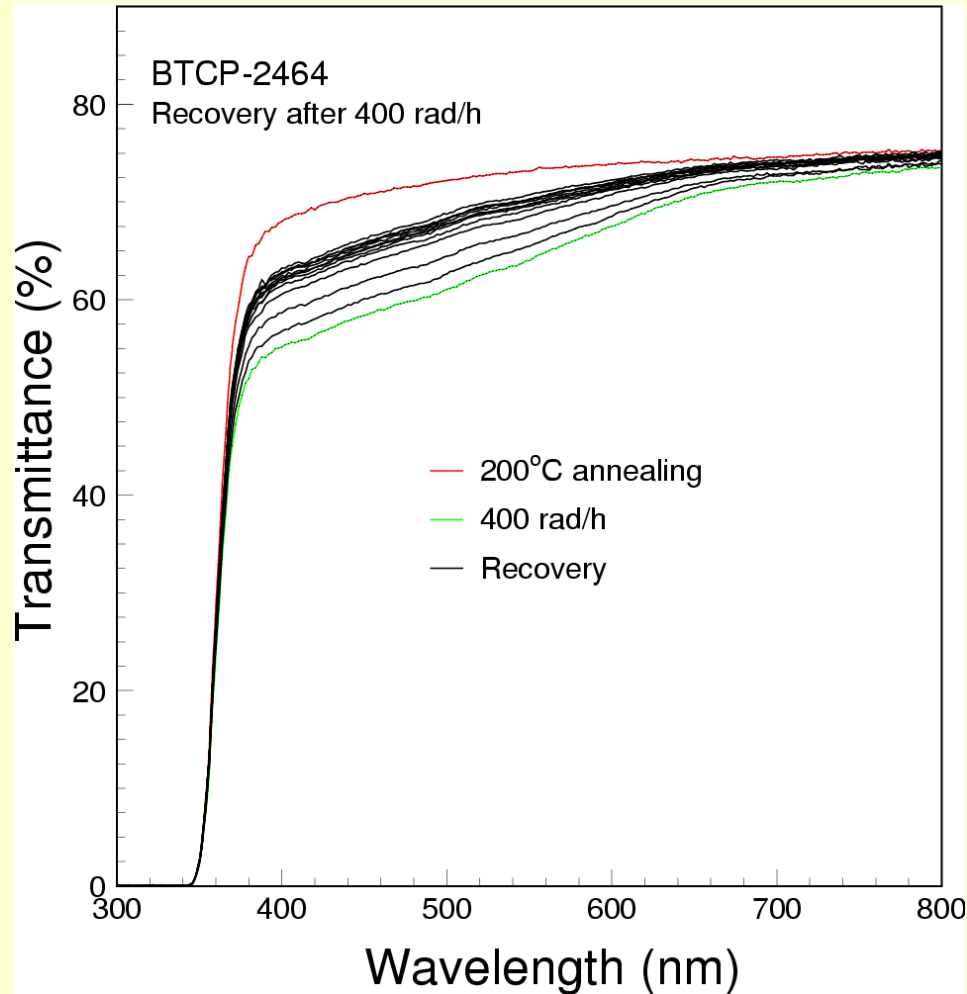
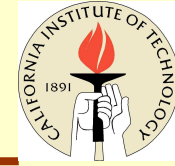


2458 Recovery after 400 rad/h



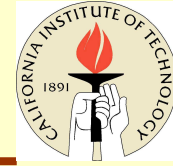


2464 Recovery after 400 rad/h





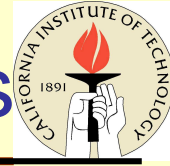
Summary



- 8 endcap PWO crystals can be divided to three different types with different level of radiation damage and radiation induced color centers.
- Type I crystals are different from previous samples, and are more radiation hard.
- Type II crystals are basically similar to previous samples.
- Type III crystals have problem for monitoring with 440 nm light, so should be rejected.
- All samples have fast, but low, light output.
- No correlations between radiation hardness and longitudinal transmittance was observed.



Summary of Light Output Measurements



Sample ID	LO (1/MeV)		Fraction (%)		LO (%) at R (rad/h)			
	p.e.	γ	50ns/1 μ s	100ns/1 μ s	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	---	---