A Study on Correlations and the Damage/Recovery under 100 rad/h for PWO Samples from BTCP and SIC

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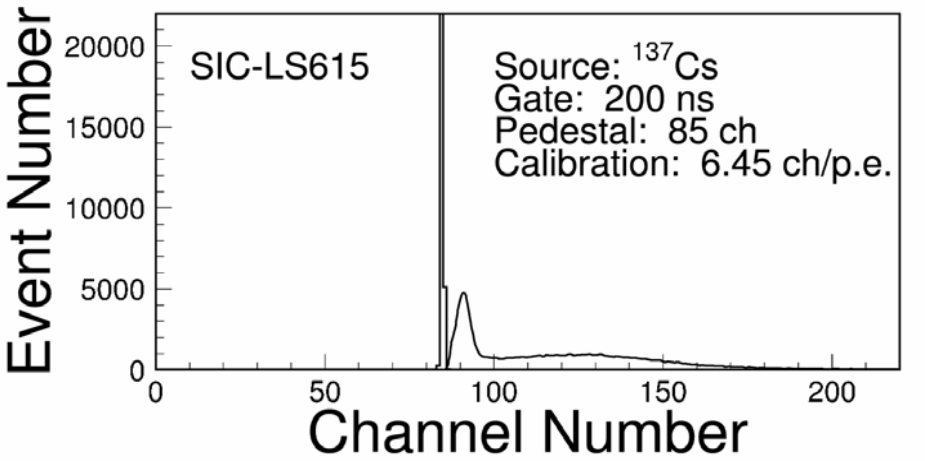
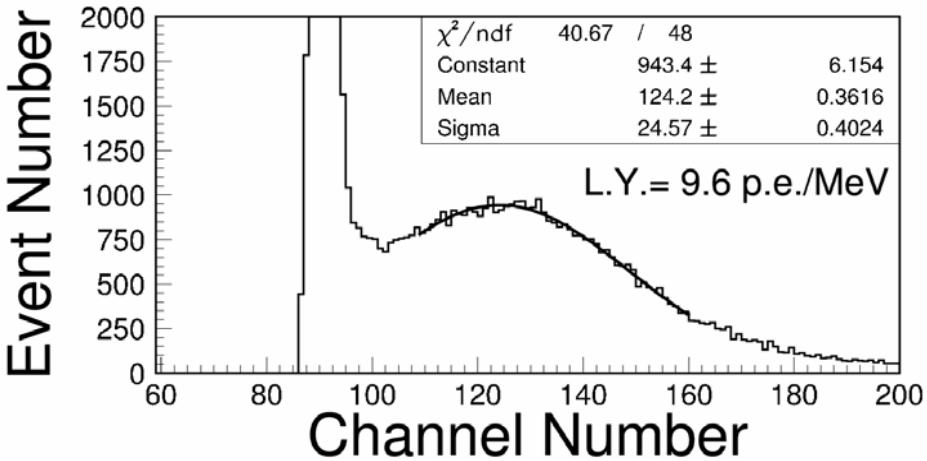
Introduction

- 54 PWO samples were studied at Caltech: 32 from SIC (20 of the 2002 batch and 12 of the 2004 batch) 22 from BTCP (20 2001 batch and 2 2003 batch).
- Properties measured: transmittance, emission and excitation spectra, light output, decay kinetics, light response uniformity and their degradation, as well as emission weighted radiation induced absorption coefficient (EWRIAC).
- Correlations between measured optical properties and their radiation damage were investigated for all samples, except one BTCP 2001 sample (type III).
- 2 SIC samples (2570 & 2572) and 2 BTCP 2003 samples (2482 & 2531) went through long term irradiation and recovery cycles @ 100 rad/h. They are now going through long term irradiation and recovery under 9 krad/h.

Light Output Measurement

Corrections must be implemented for time of less than one hour after irradiation if there is temperature change.





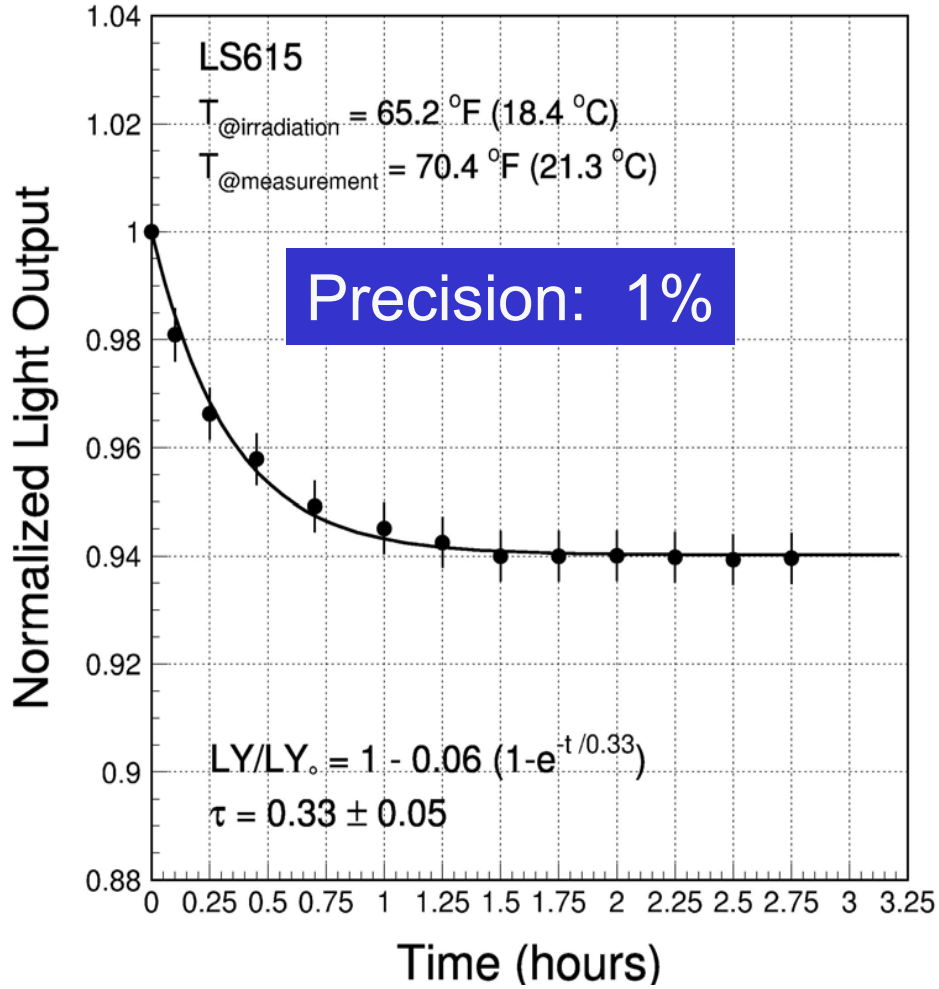
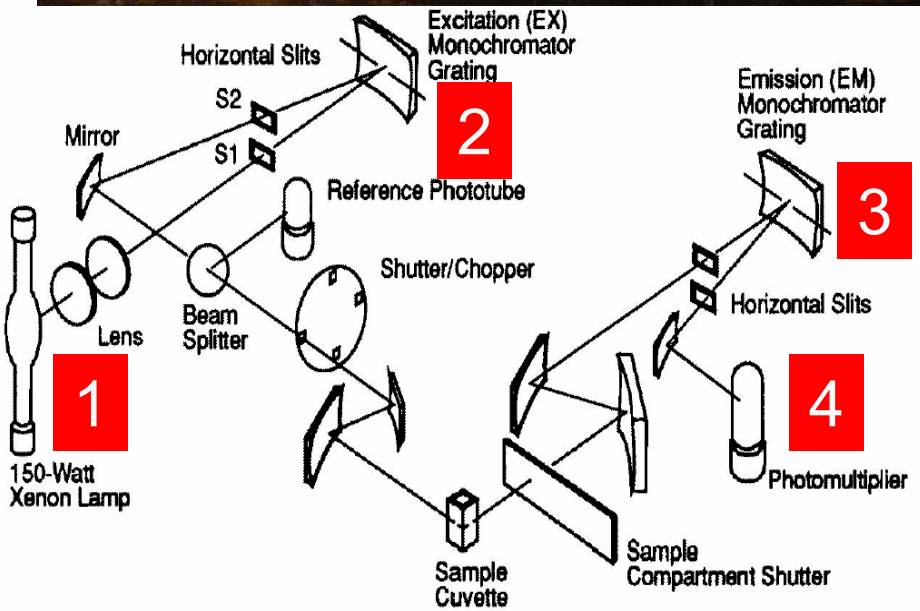
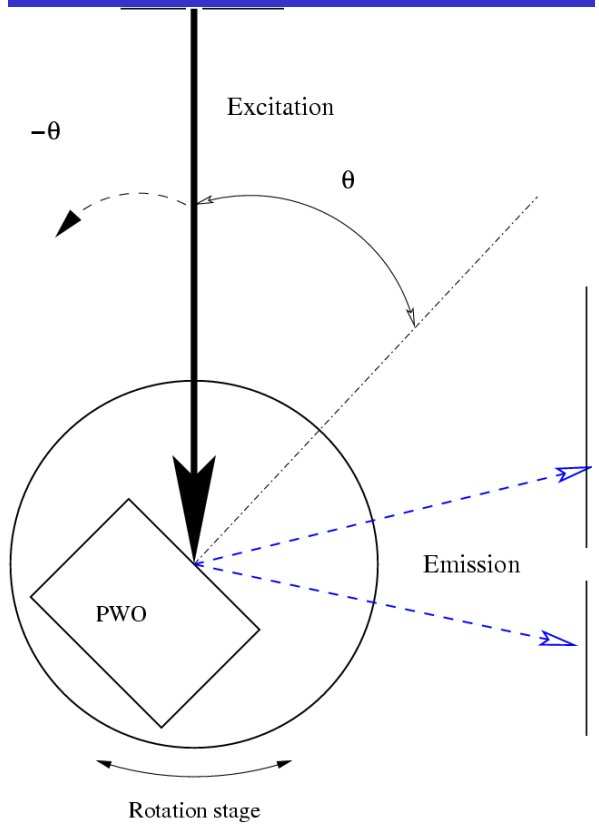


Photo Luminescence Measurement

HITACHI F4500 Fluorescence Spectrophotometer



Sample Orientation

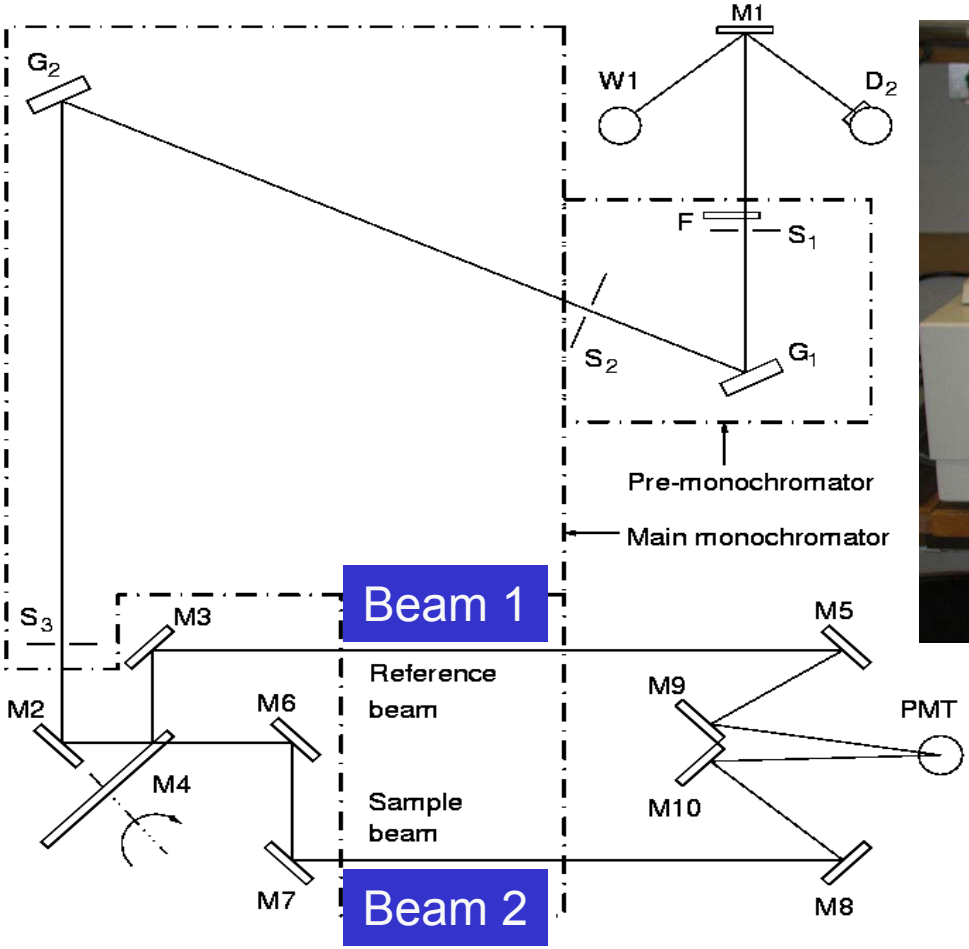


Corrections: Light Source (1), Gratings Efficiencies (2 & 3) & PMT QE (4)

Red-Extended Hamamatsu R928 PMT(4): 185 to 900 nm

Transmittance Measurement

HITACHI U-3210 UV/VIS spectrophotometer with double beam, double monochromator & a large sample compartment



Precision: 0.3%

$$T_s = (1-R)^2 + R^2(1-R)^2 + \ldots = (1-R)/(1+R), \text{ with}$$

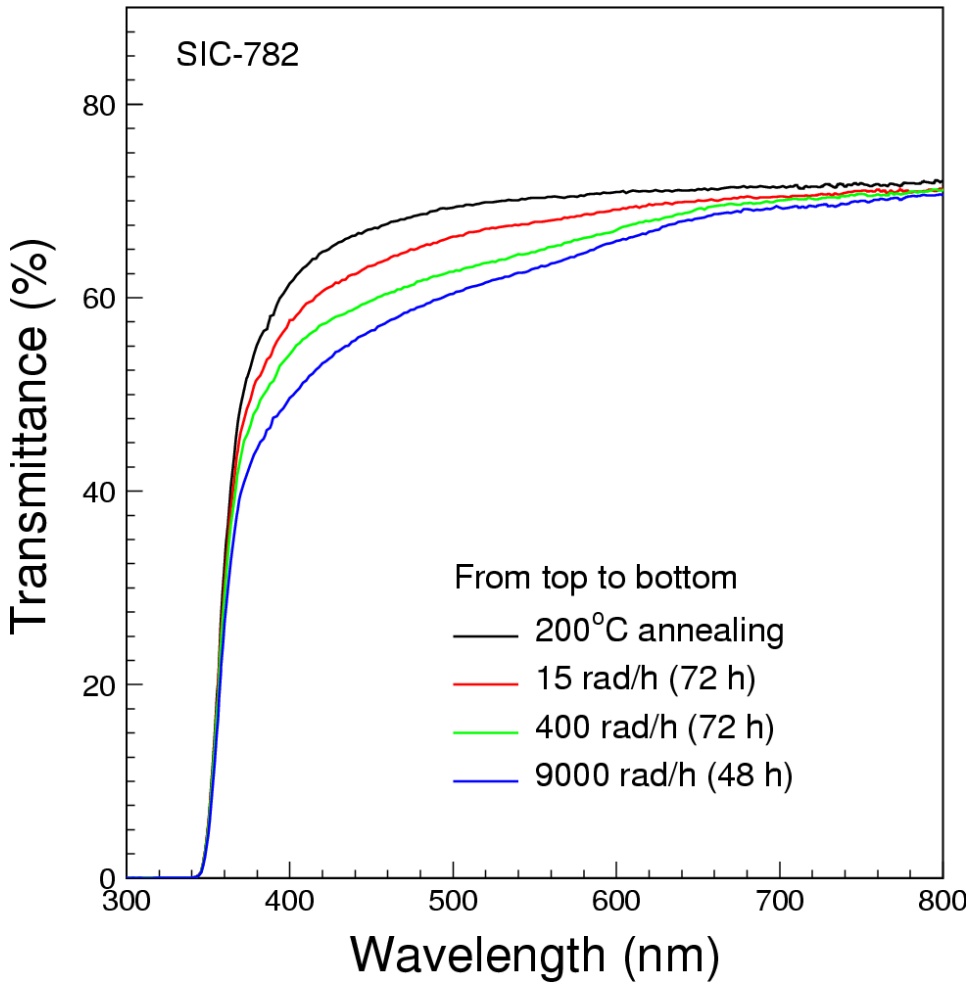
$$R = \frac{(n_{crystal}-n_{air})^2}{(n_{crystal}+n_{air})^2}.$$

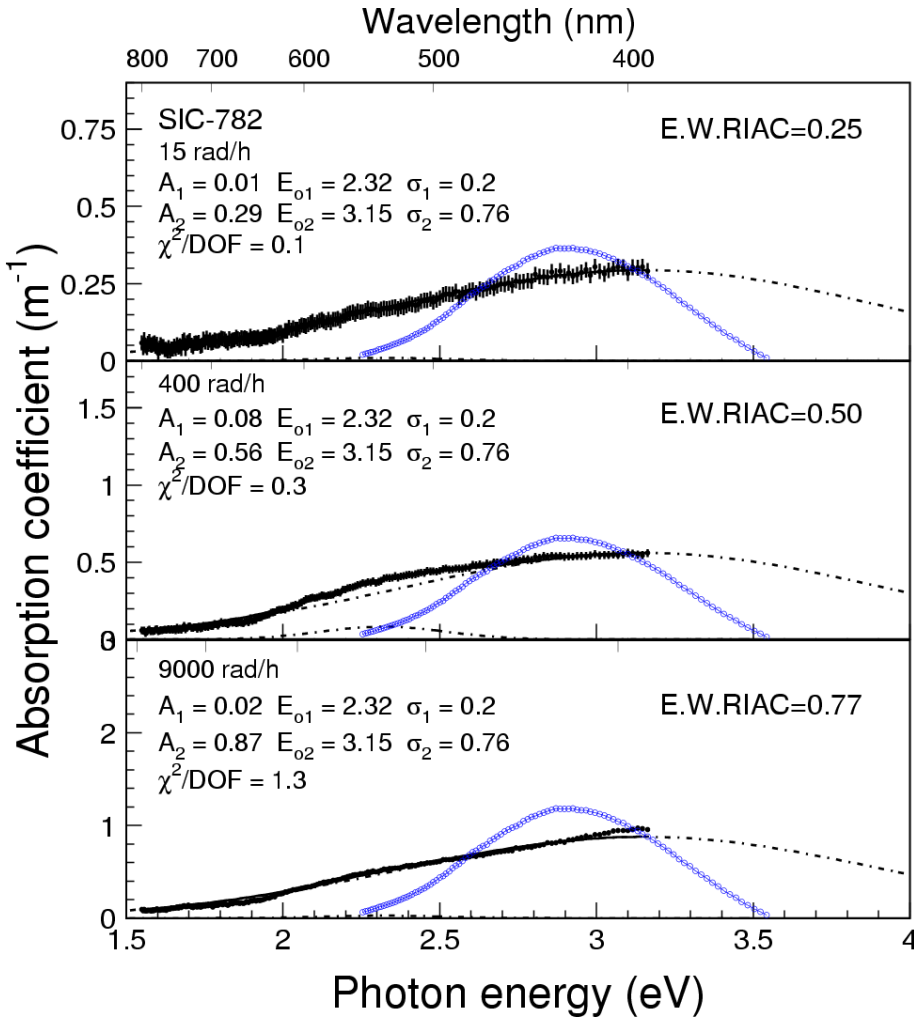
Theoretical limit of transmittance: NIM **A333** (1993) 422

EWRIAC Measured after Irradiations

Note: emission weighted and multiple bounces

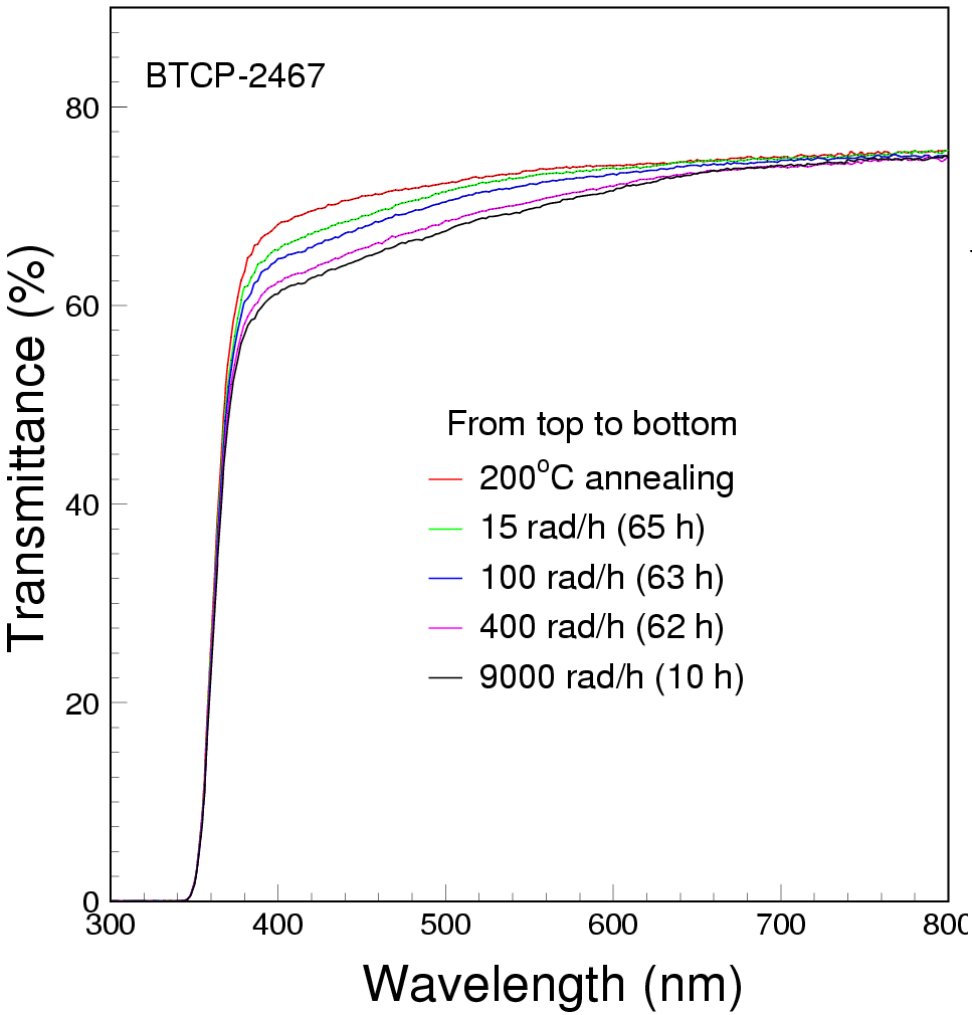
$$Riac = 1/LAL_{equilibrium} - 1/LAL_{before} \qquad LAL = \frac{\ell}{\ln\{[T(1-T_s)^2]/[\sqrt{4T_s^4 + T^2(1-T_s^2)^2} - 2T_s^2]\}}$$

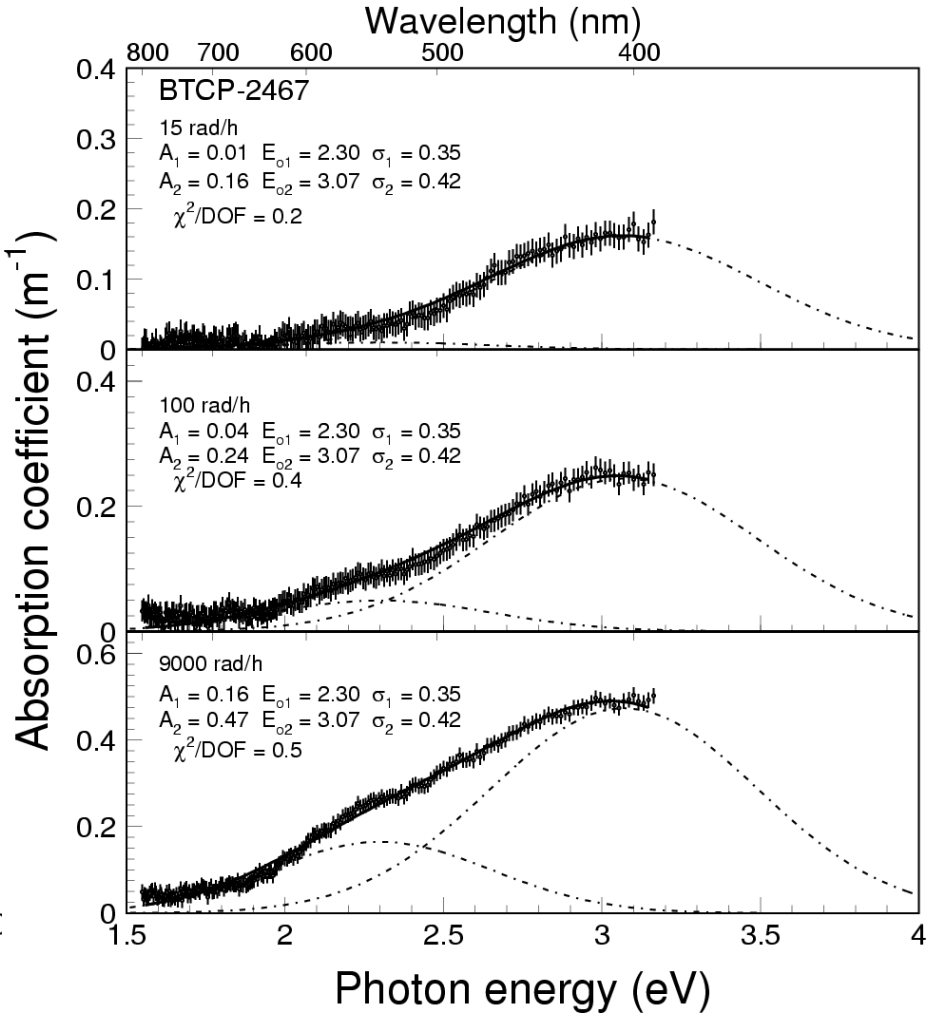




EWRIAC Measured after Irradiations

Both BTCP and SIC samples have two radiation induced color centers off emission peak, but SIC centers are deeper



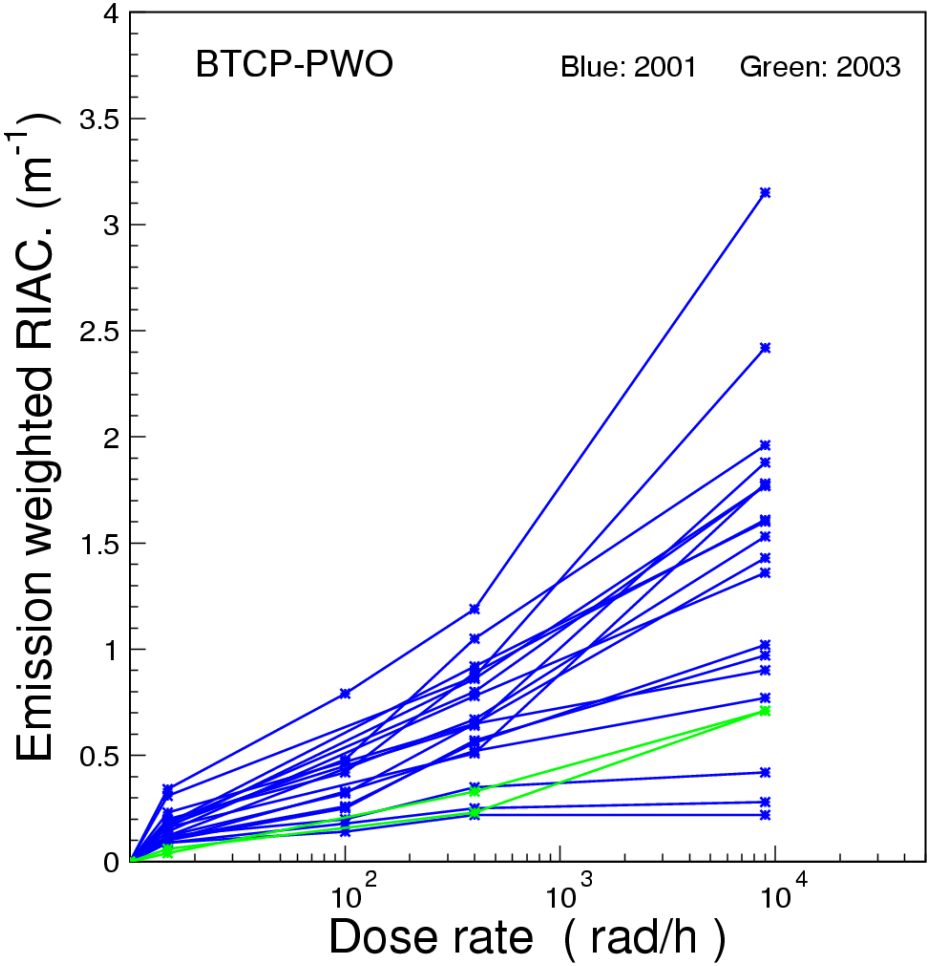


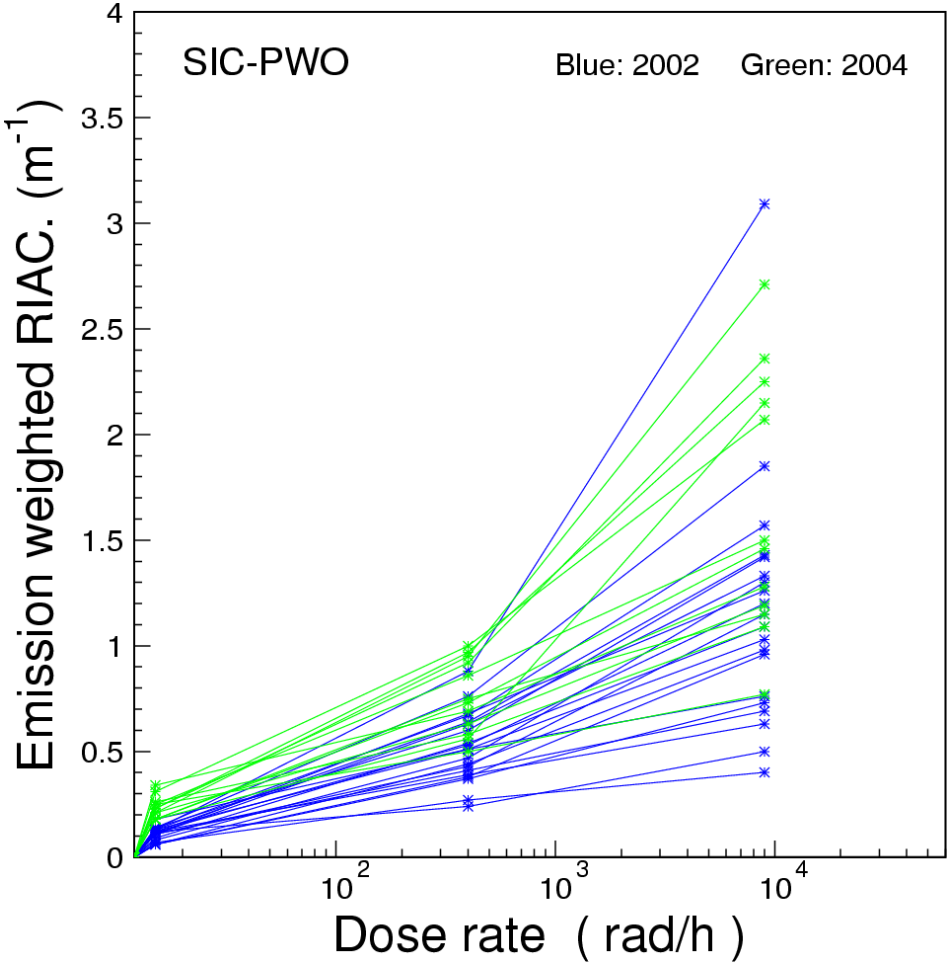
Emission Weighted RIAC

Radiation hardness is more divergent at high dose rate

All samples: EWRIAC < 1 m^{-1} up to 400 rad/h

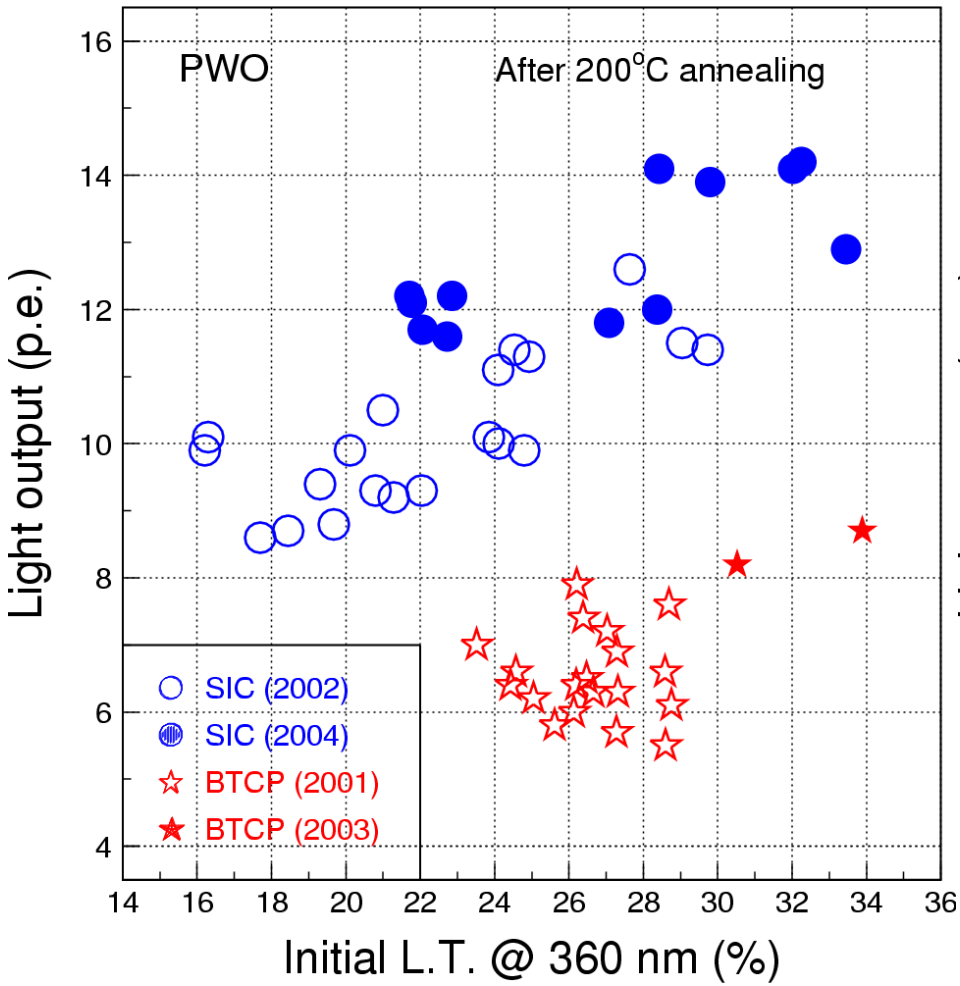
Rigorous QC required for the endcap crystals at SLHC

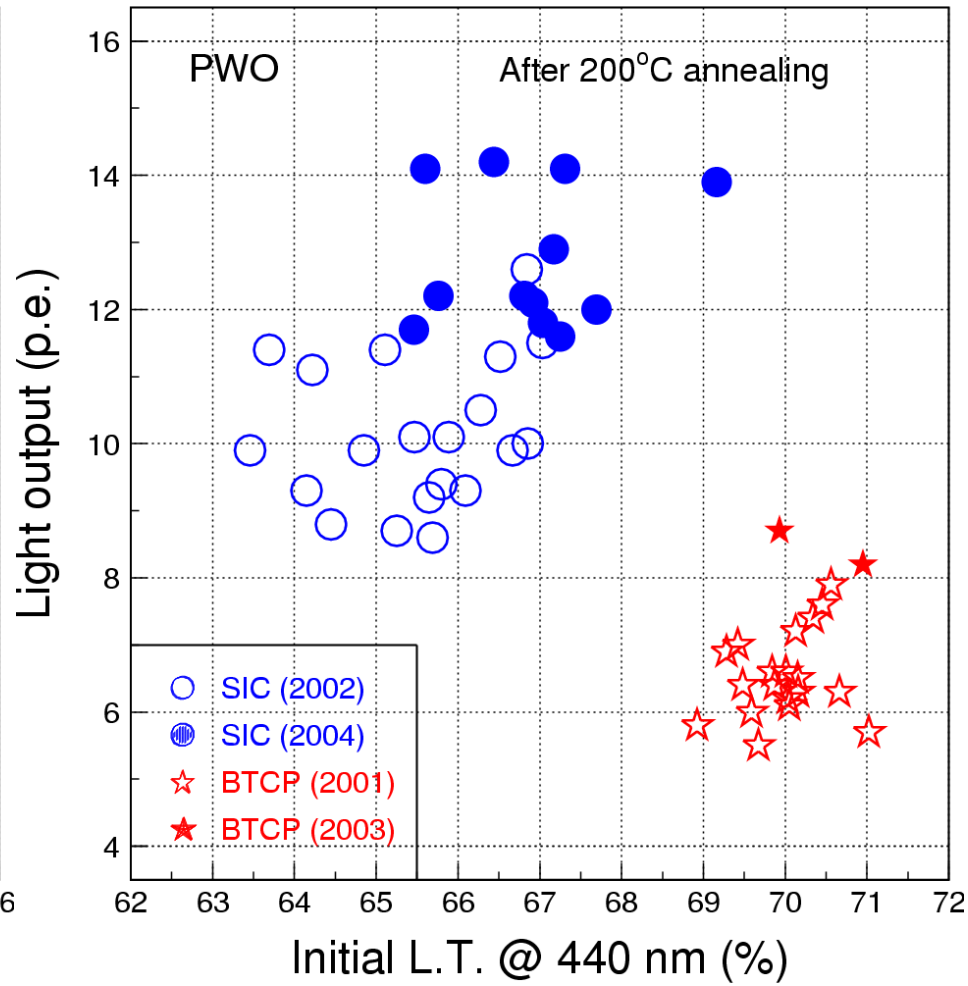




Initial LO versus Initial L.T.

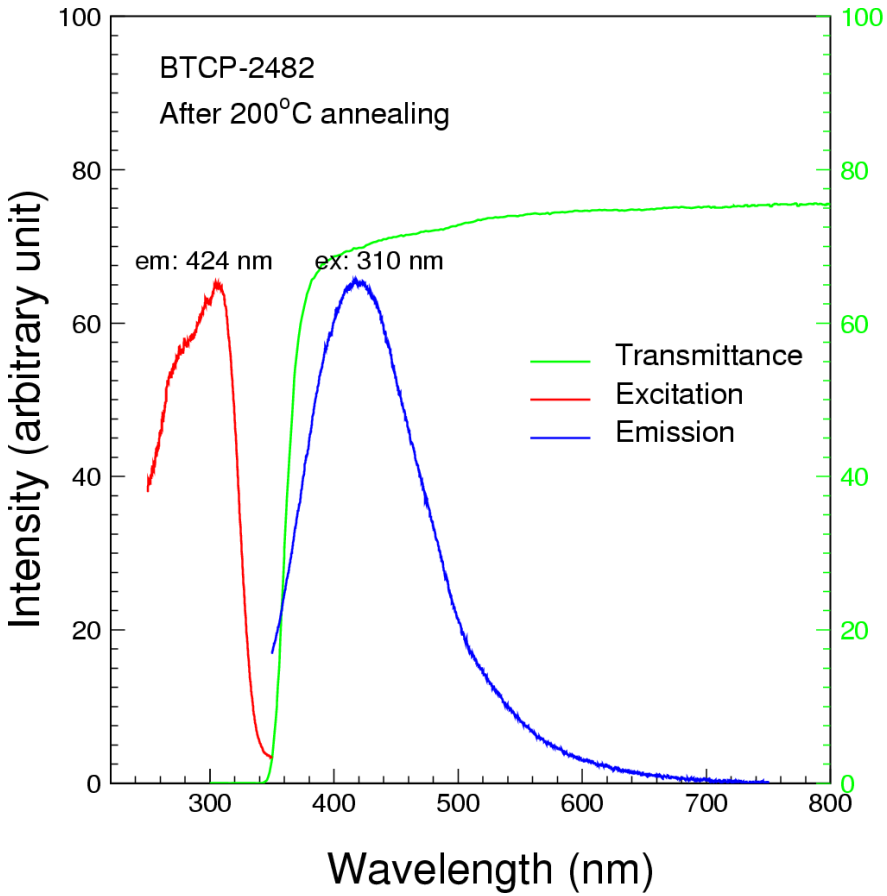
Some correlations exist, especially with 360 nm

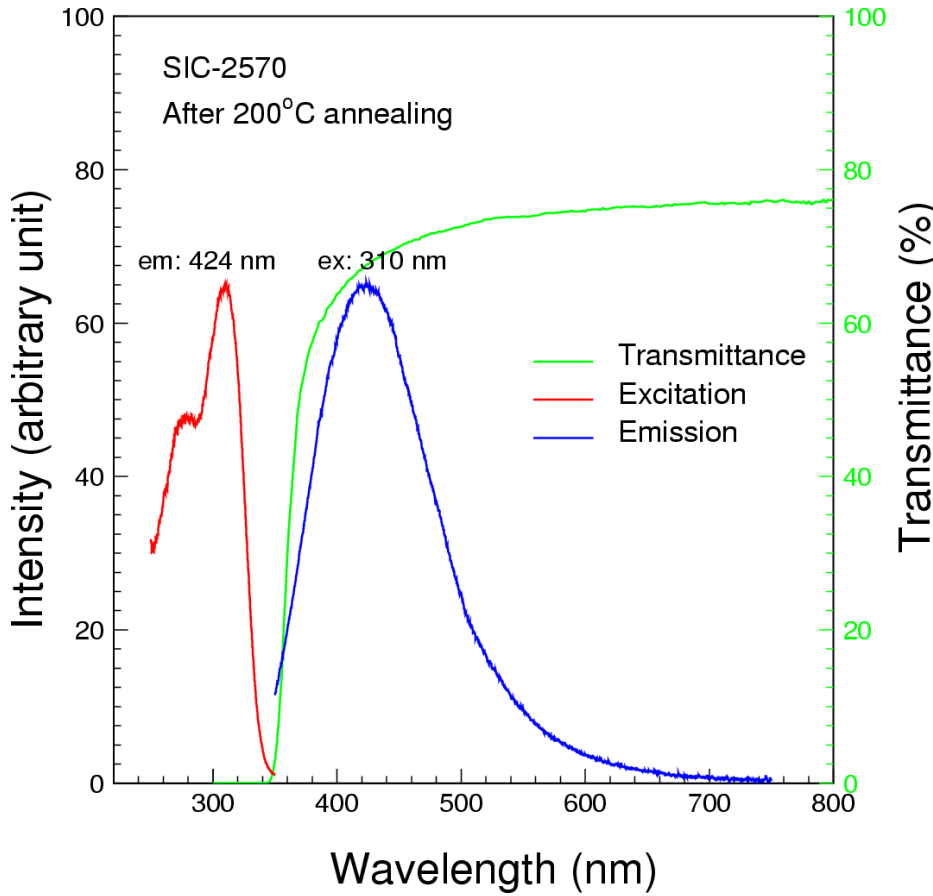




Possible Origin of this Correlation

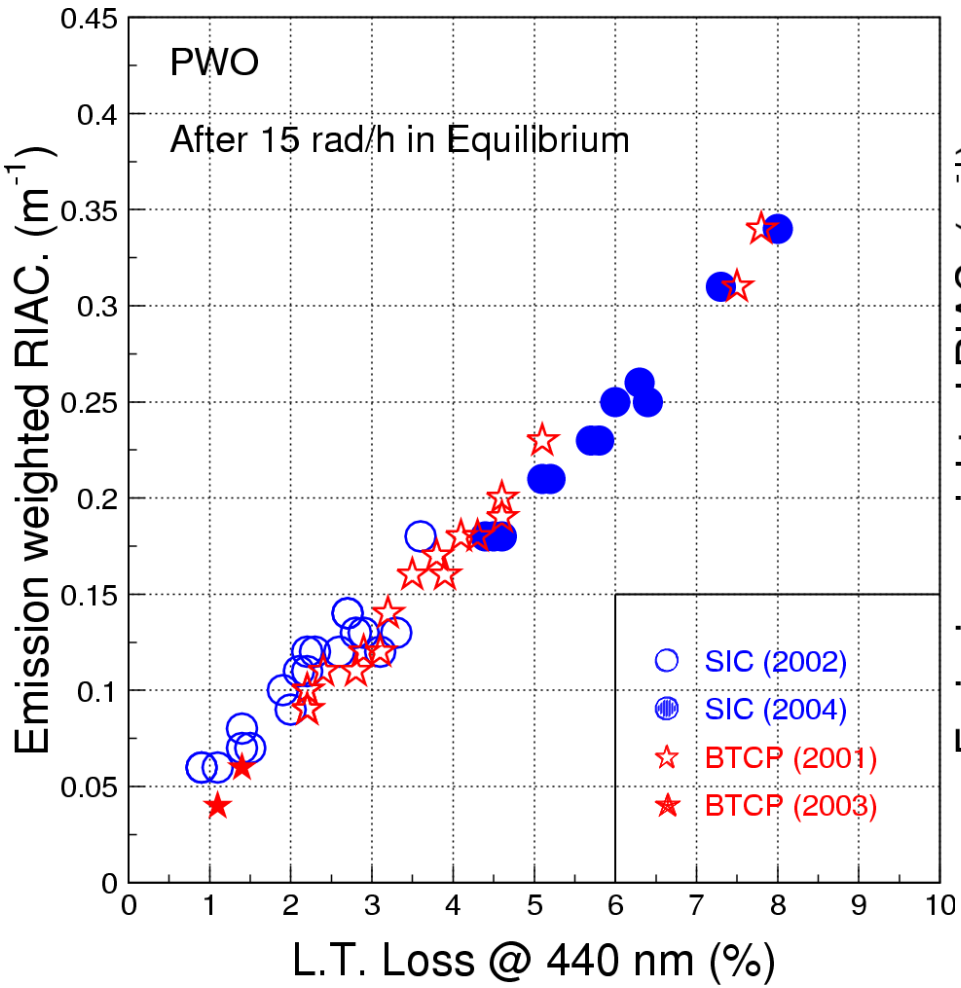
Part of emitted light may be self-absorbed

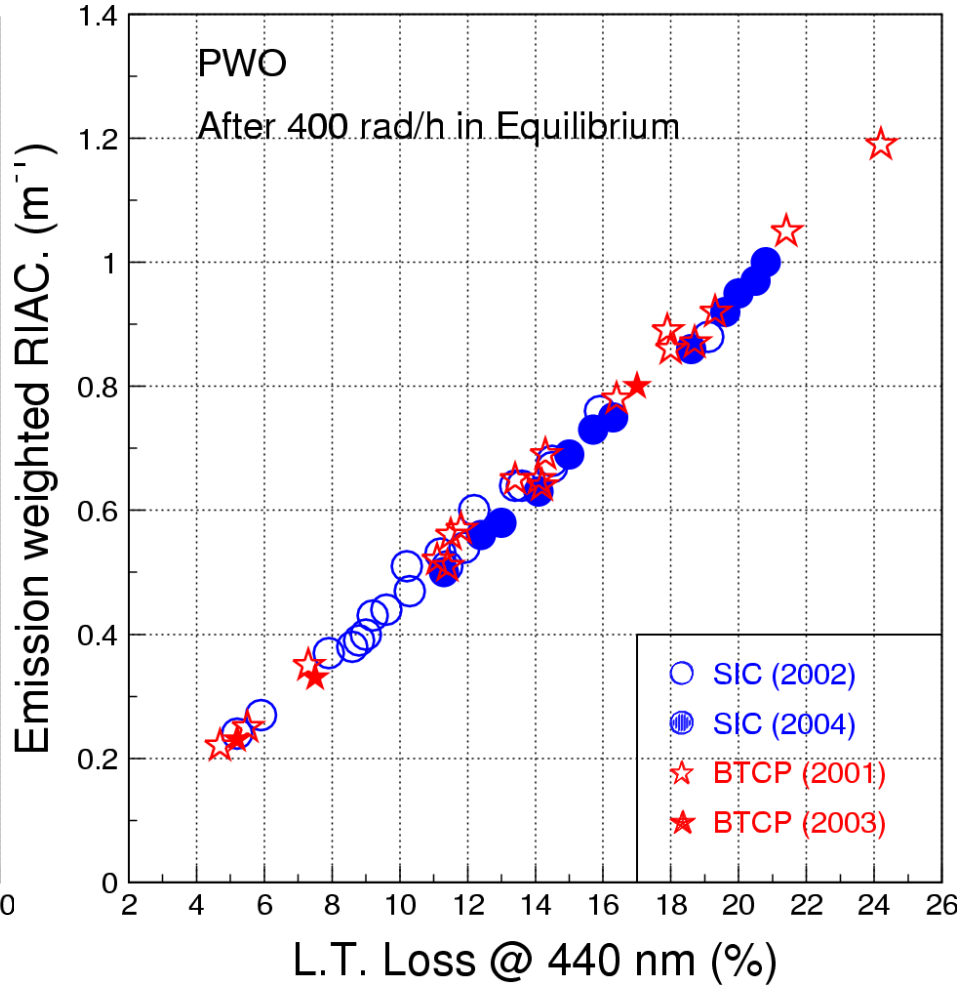




EWRIAC versus δLT/LT

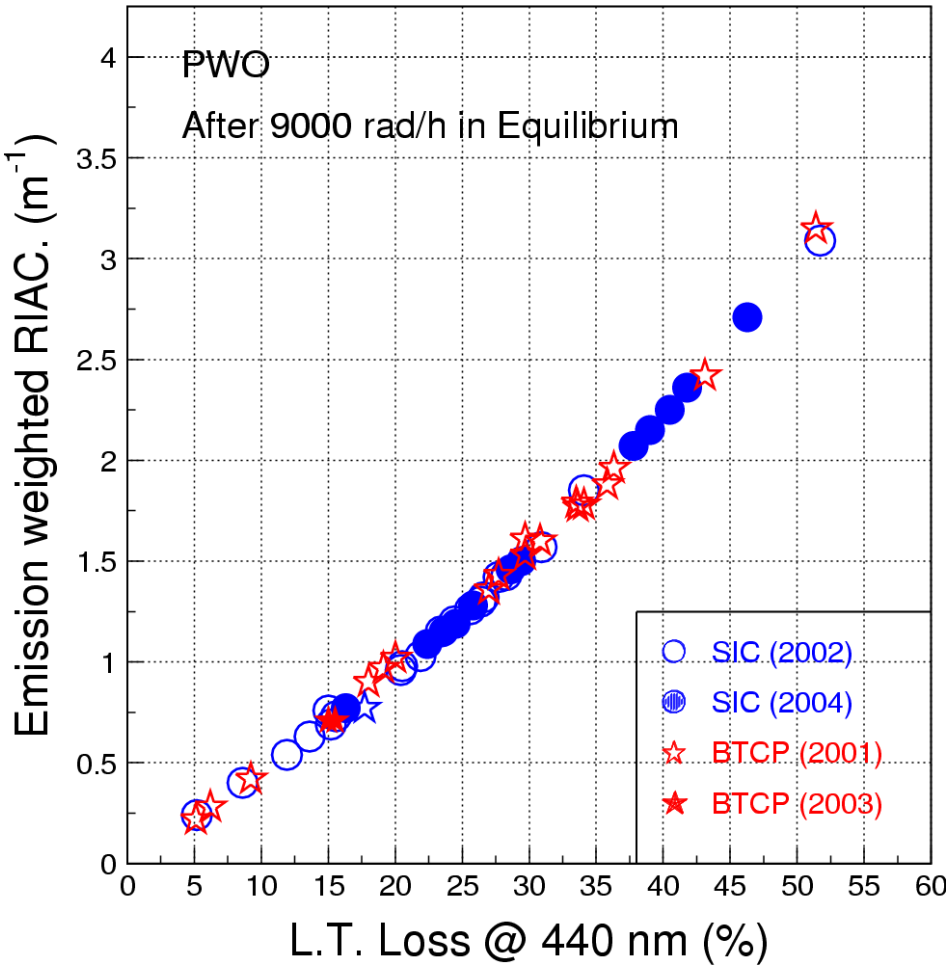
Linear correlation exists between the EWRIAC and the LT loss @ 440 nm at low dose rate

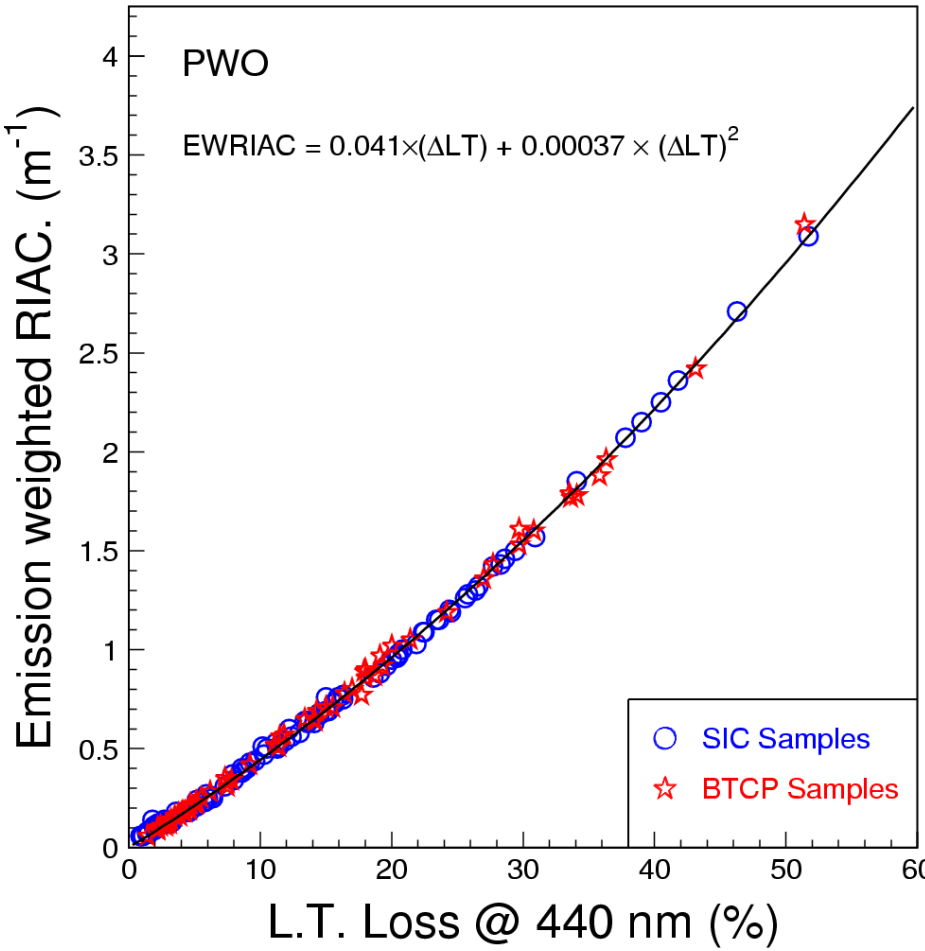




EWRIAC versus δLT/LT

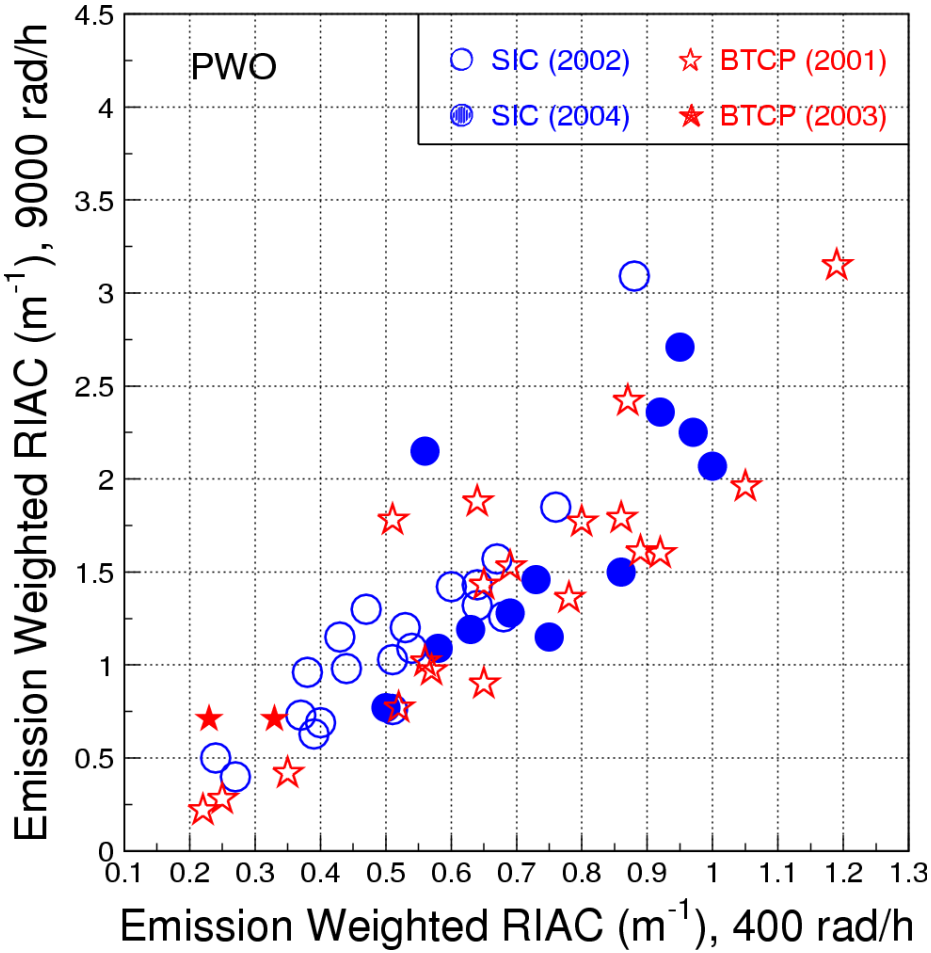
At high dose rate it is no longer linear. All BTCP/SIC data, however, are consistent with a 2nd order polynomial

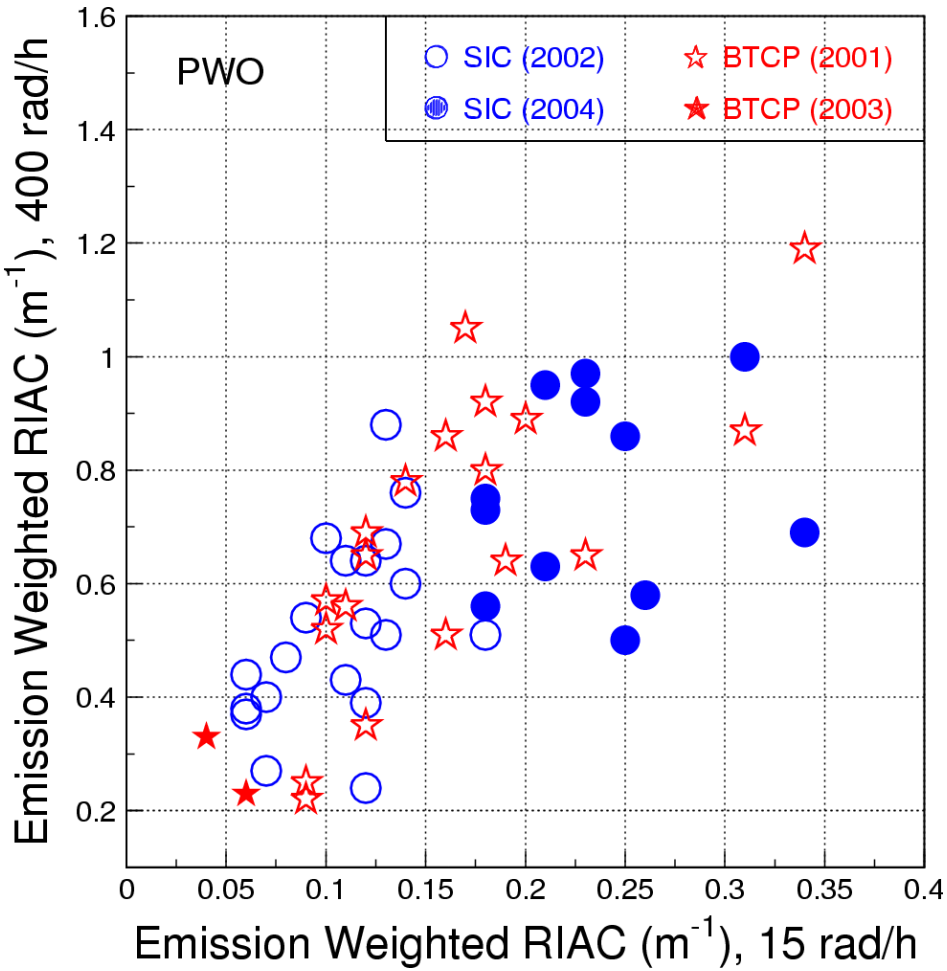




EWRIAC at Different Dose Rates

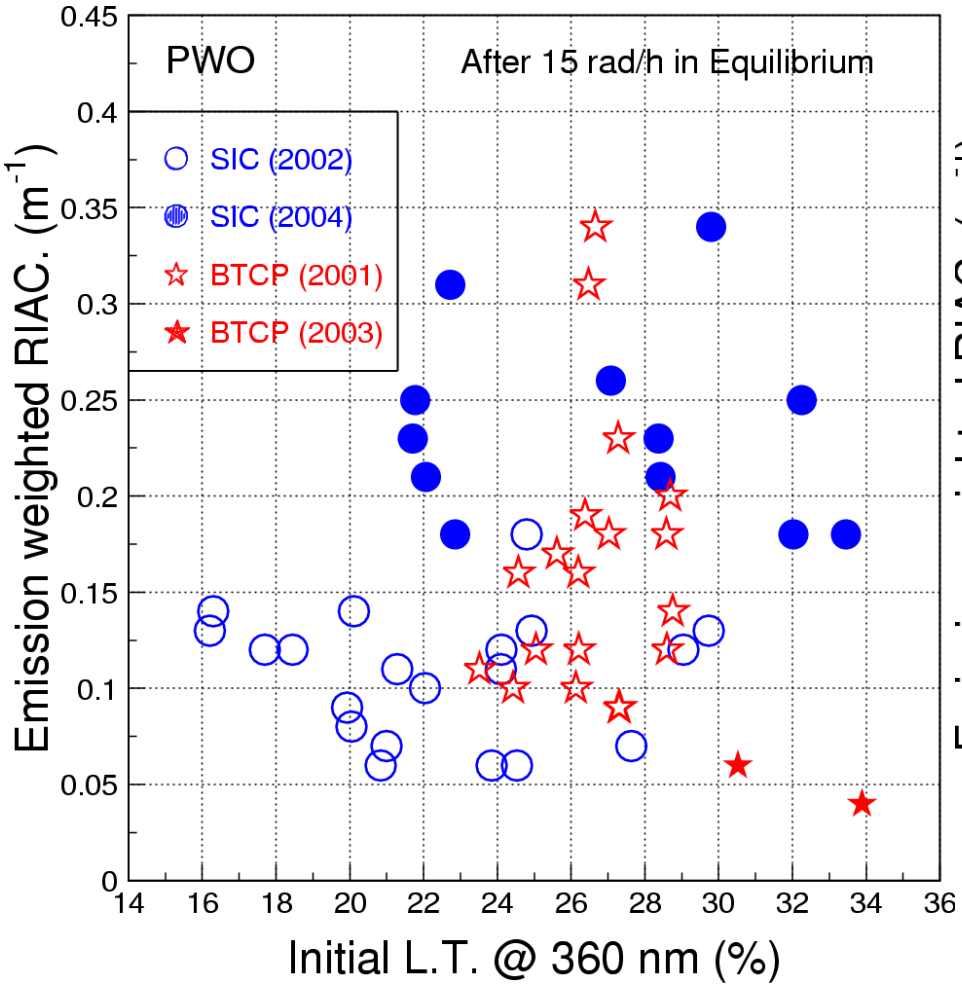
Correlations is weaker at lower dose rates because of different initial status (preexisting absorption)

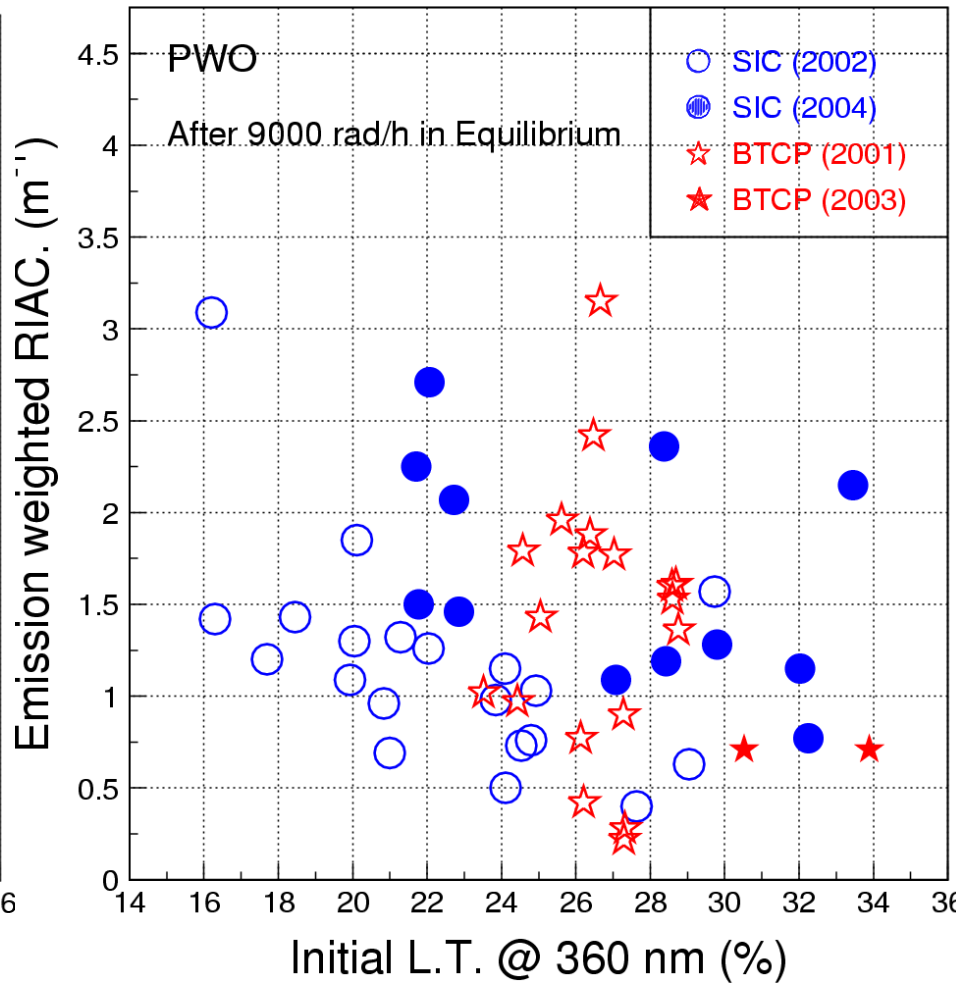




EWRIAC versus Initial LT

No correlation: preexisting absorption is not correlated with radiation induced absorption

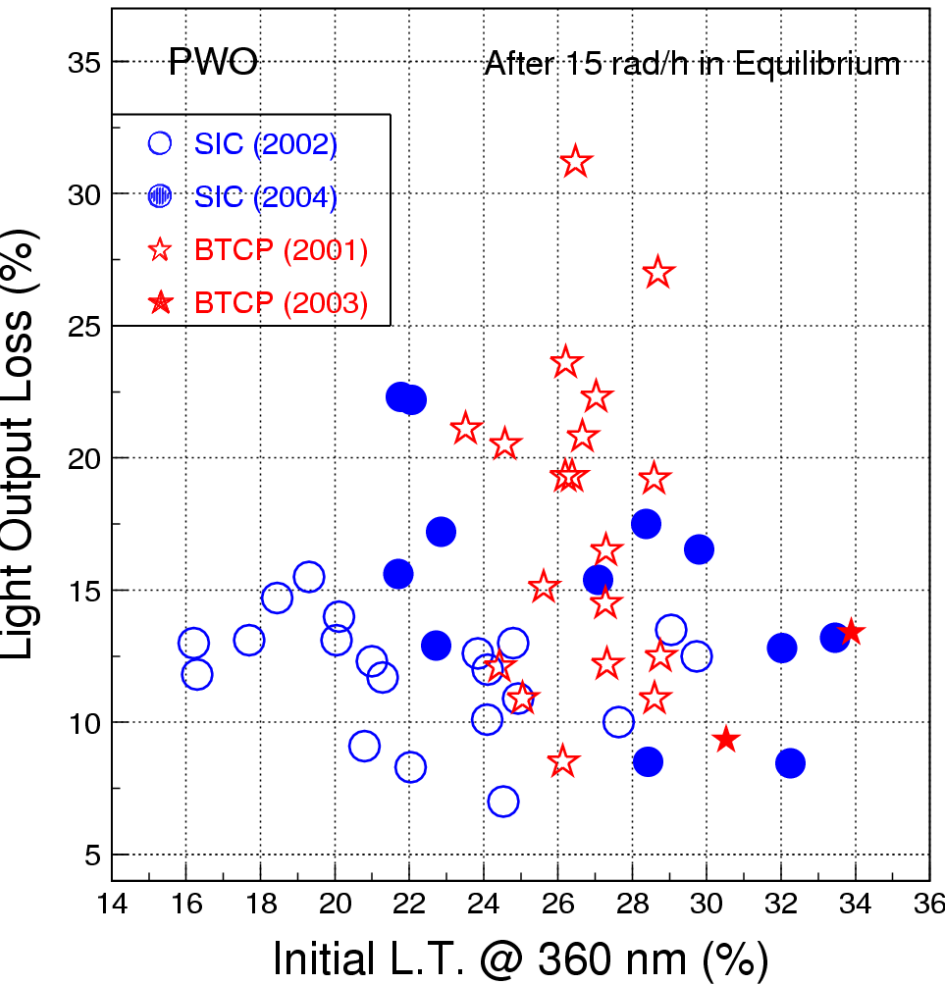


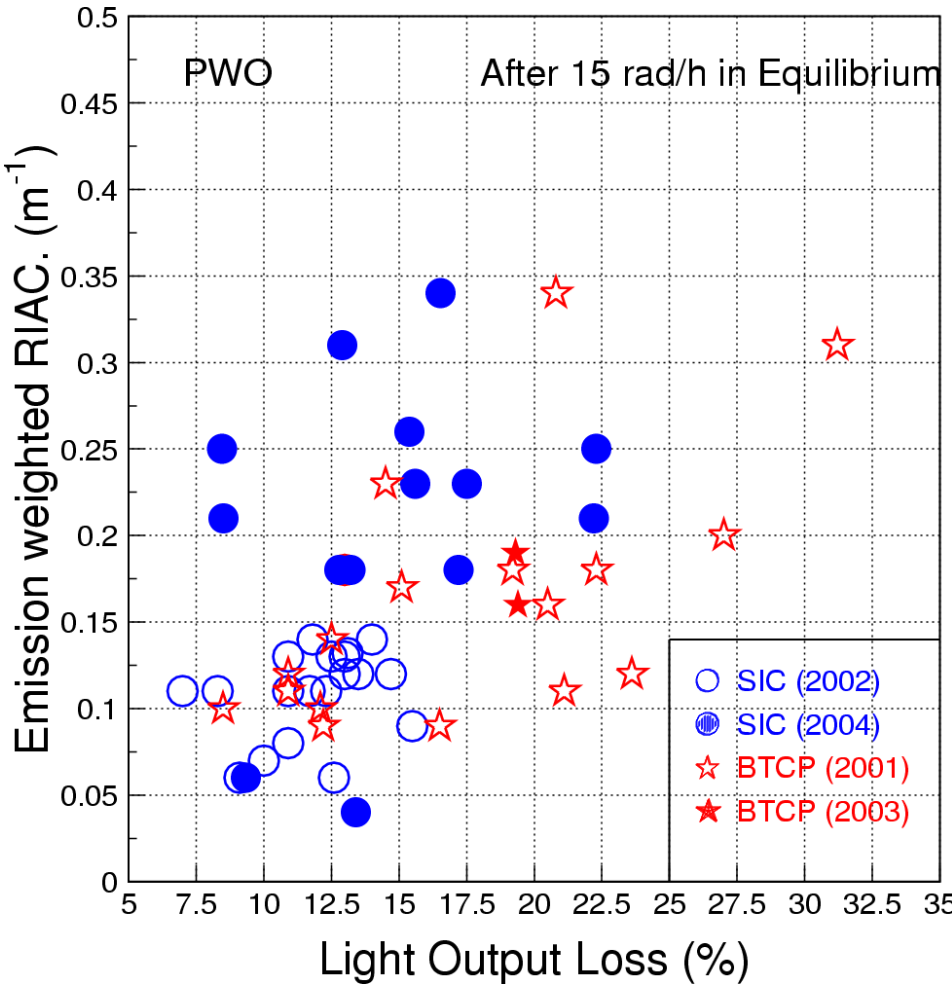


δLO/LO versus Initial LT or EWRIAC

No correlation between the δLO/LO and the Initial LT

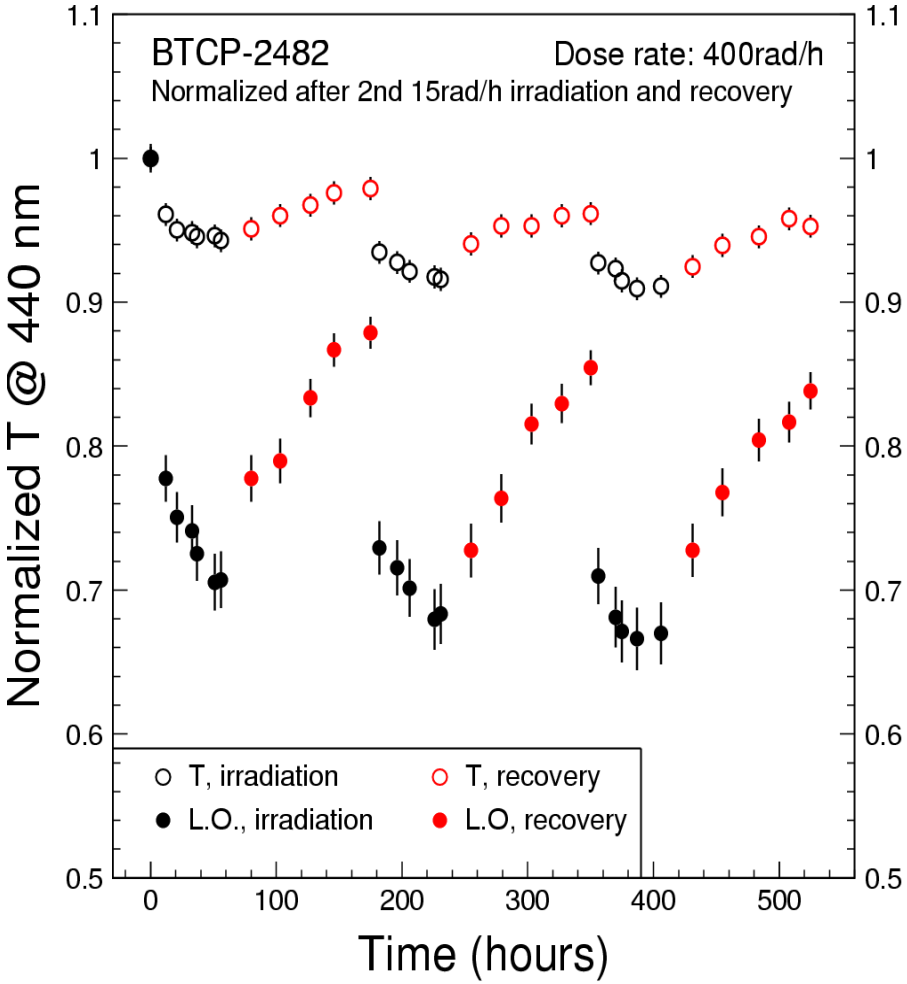
Weak correlation between the δLO/LO and the EWRIAC

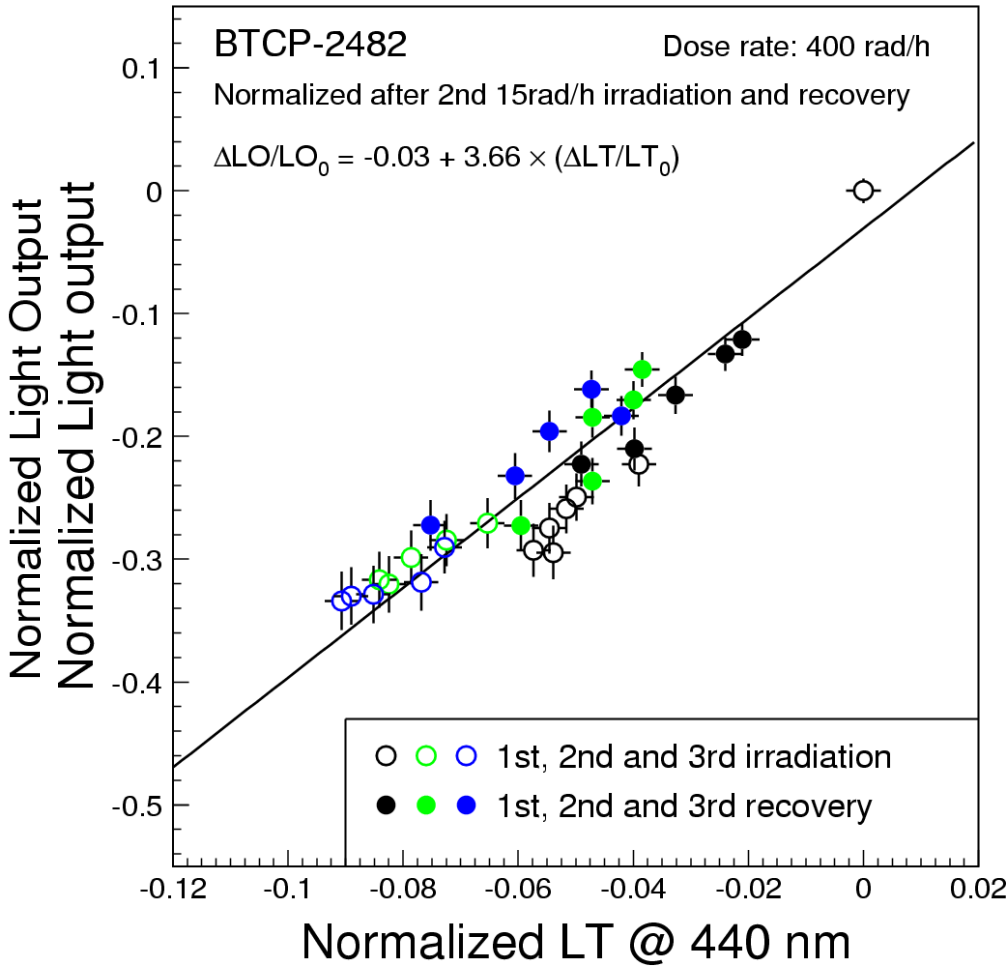




δLO/LO versus δLT/LT @ 400 rad/h

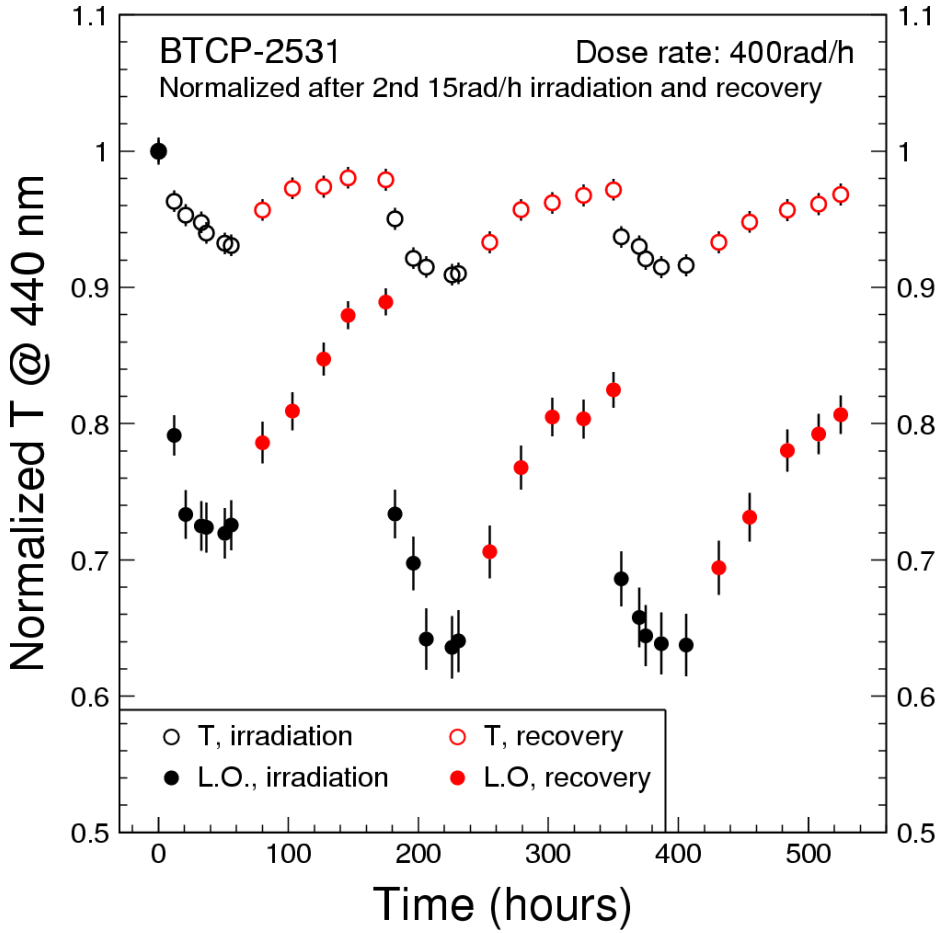
Strong correlation: R = 3.66

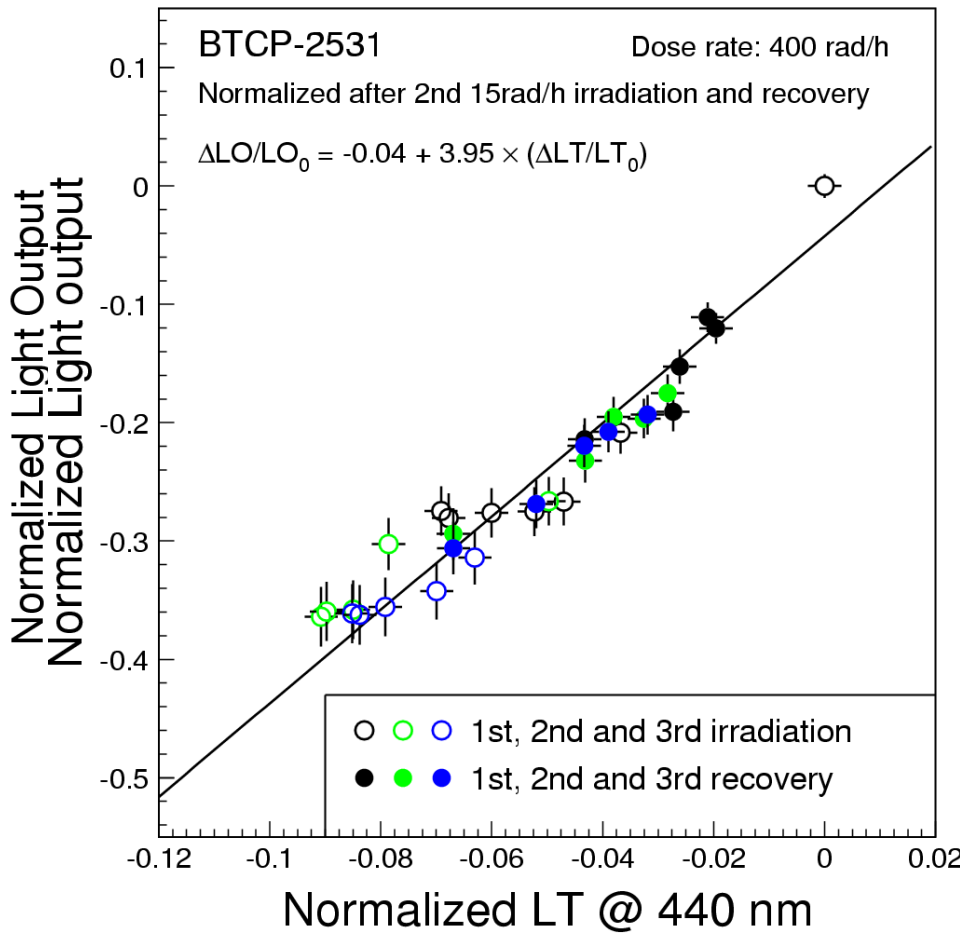




δLO/LO versus δLT/LT @ 400 rad/h

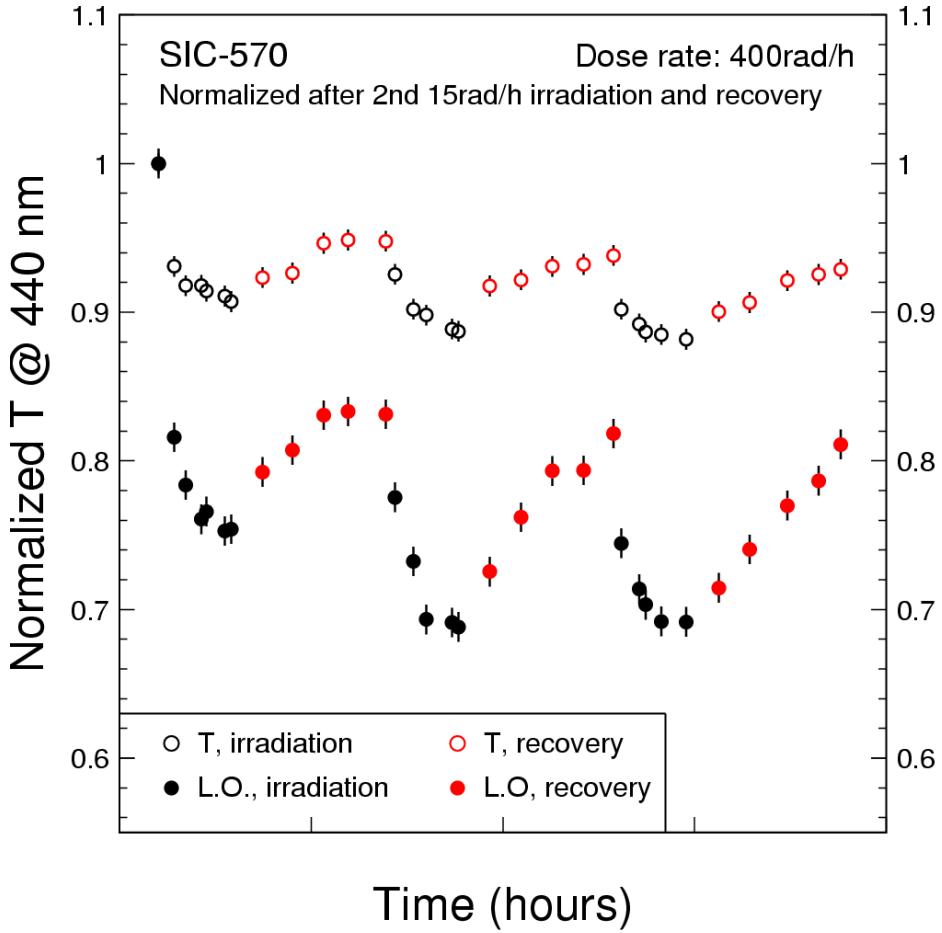
Strong correlation: R = 3.95

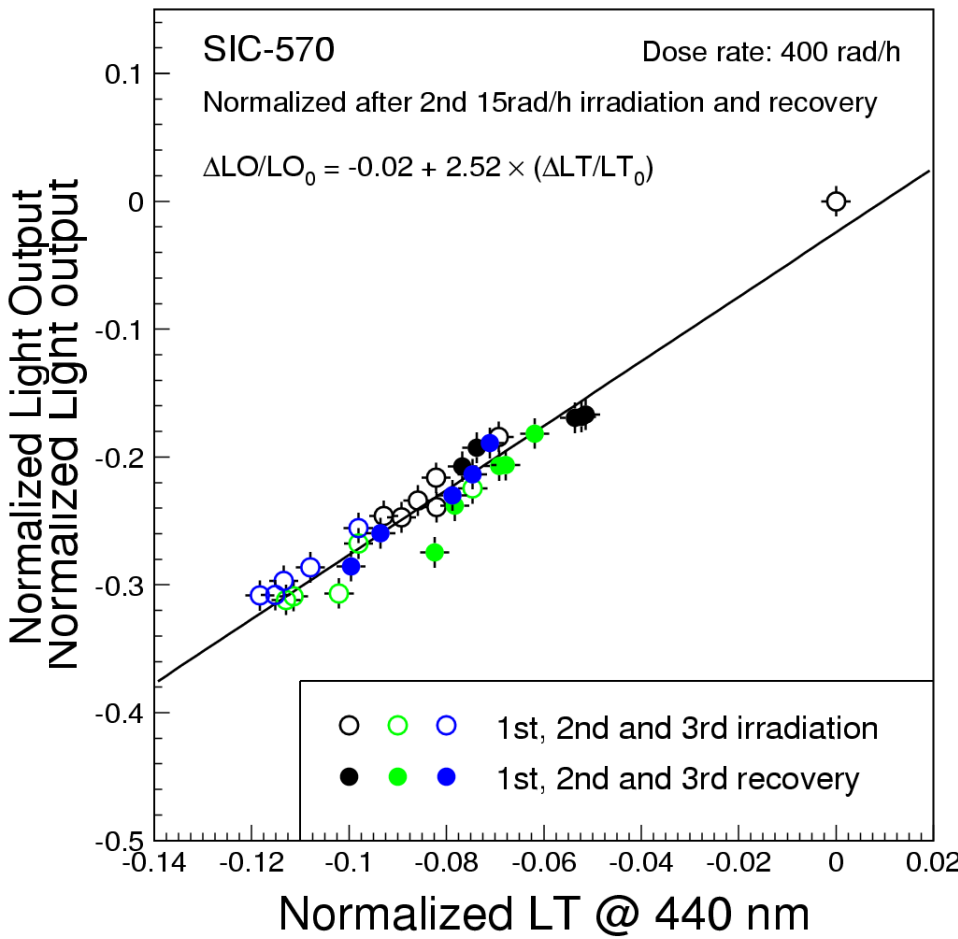




δLO/LO versus δLT/LT @ 400 rad/h

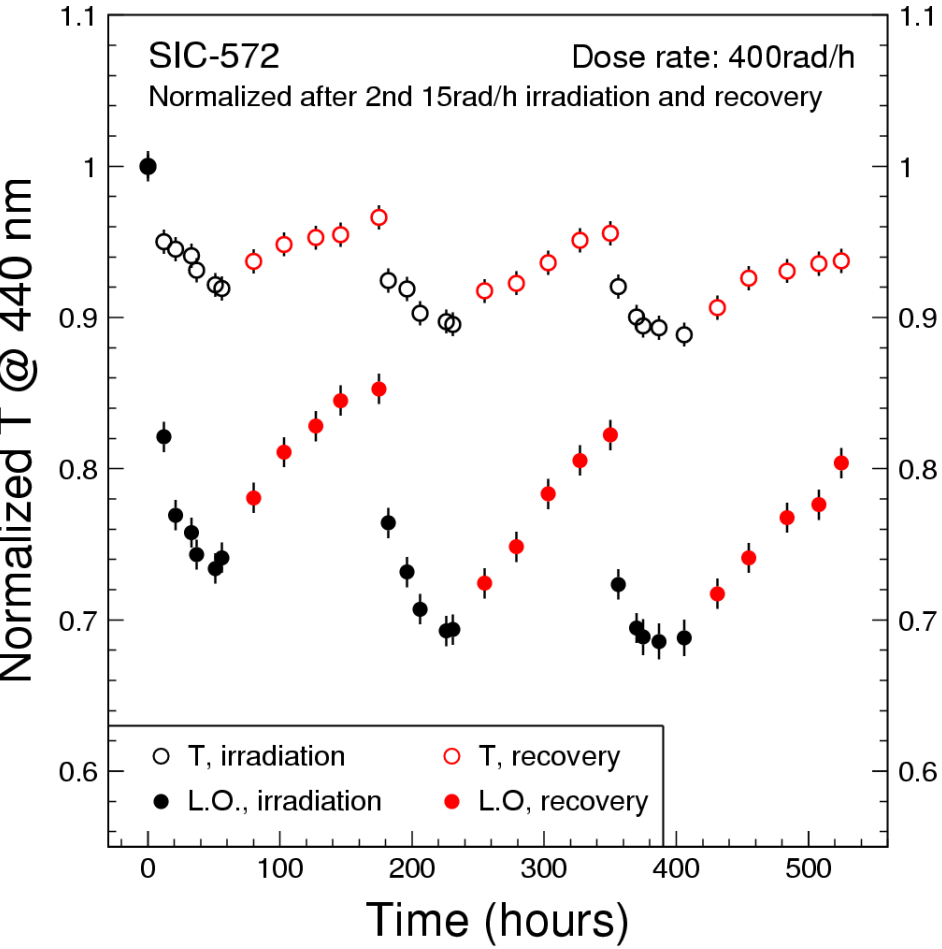
Strong correlation: R = 2.52

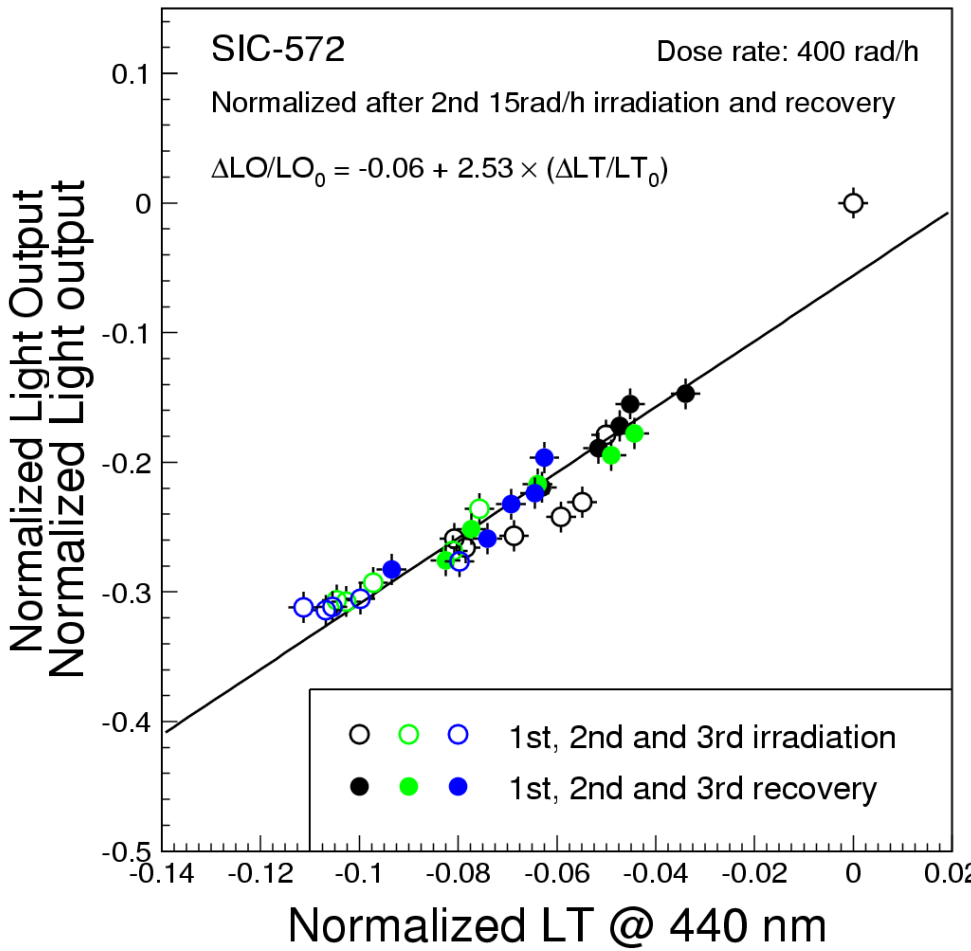




δLO/LO versus δLT/LT @ 400 rad/h

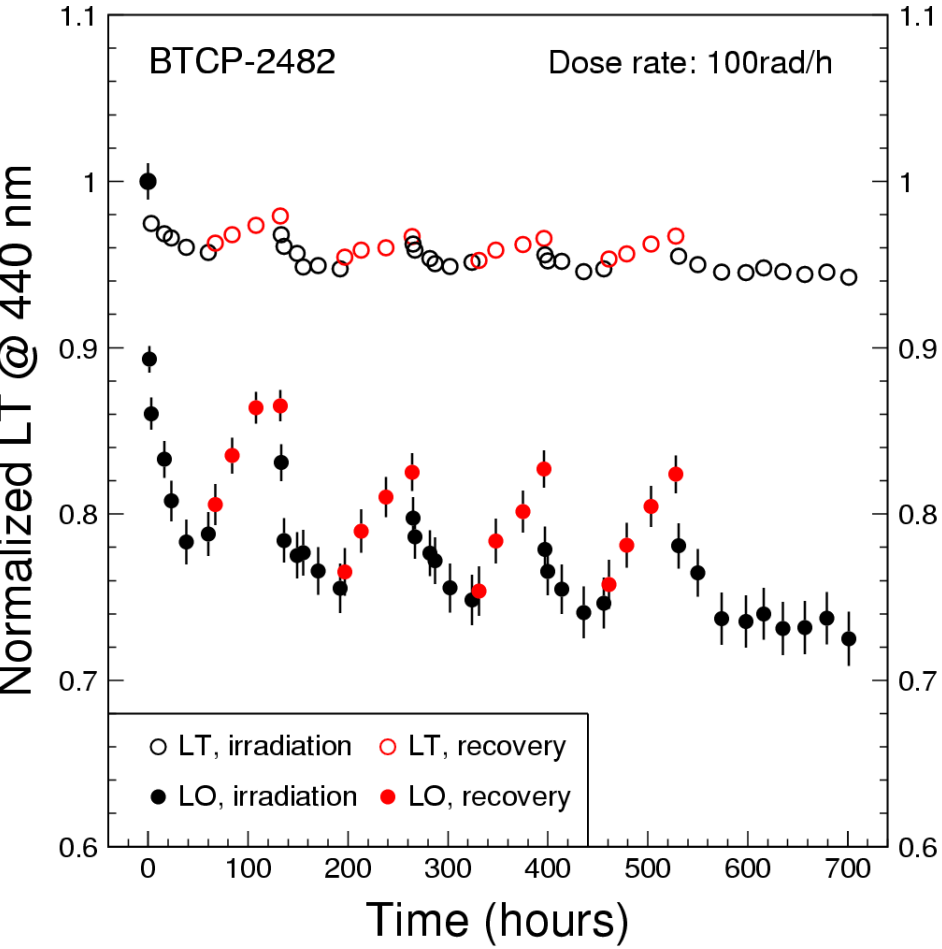
Strong correlation: R = 2.53

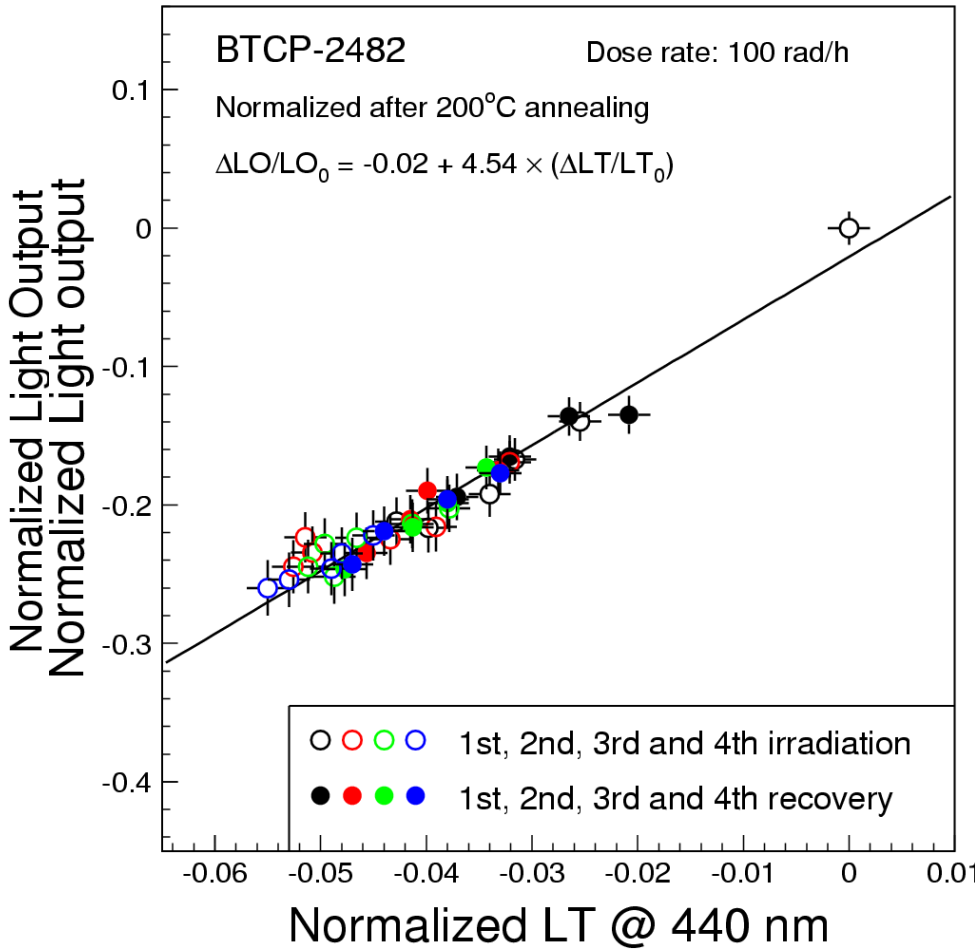




δLO/LO versus δLT/LT @ 100 rad/h

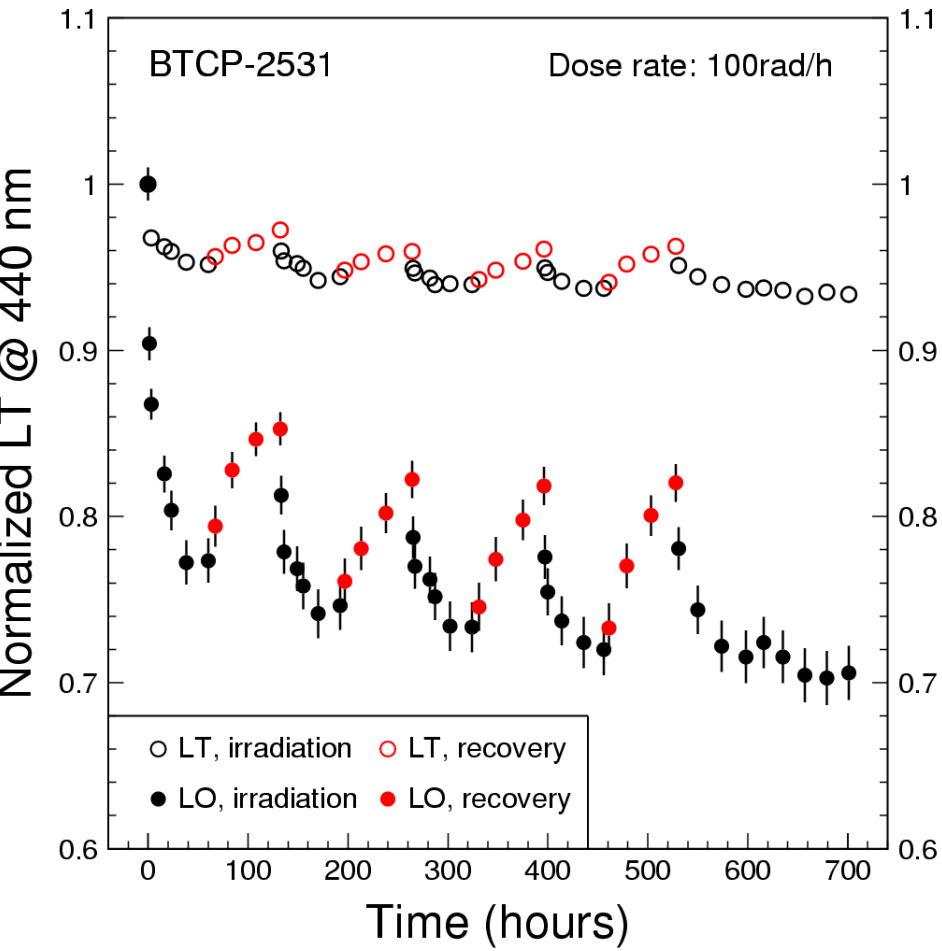
Strong correlation: R = 4.54

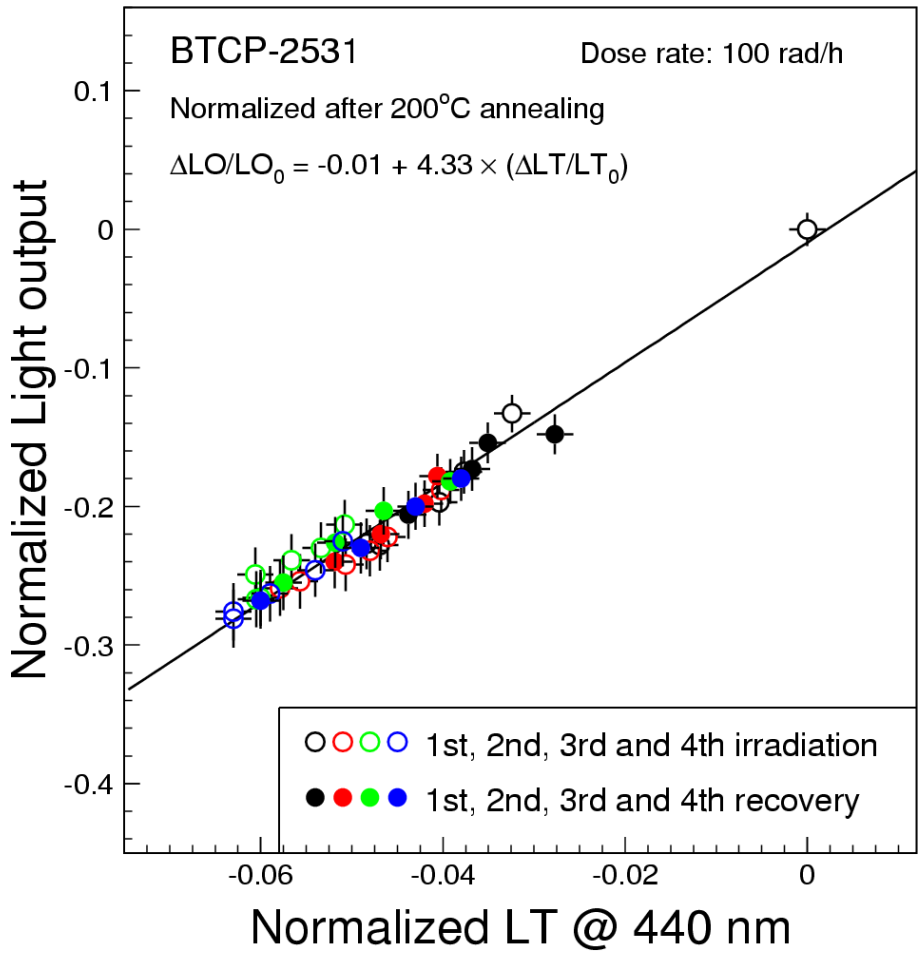




δLO/LO versus δLT/LT @ 100 rad/h

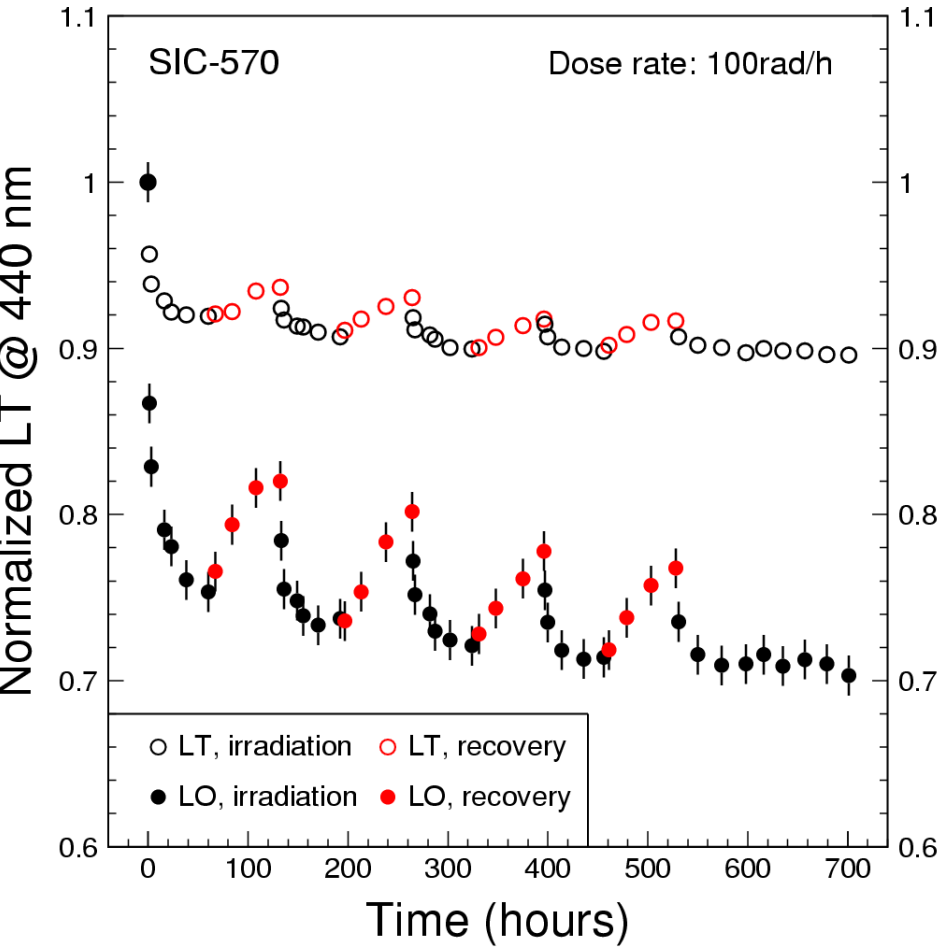
Strong correlation: R = 4.33

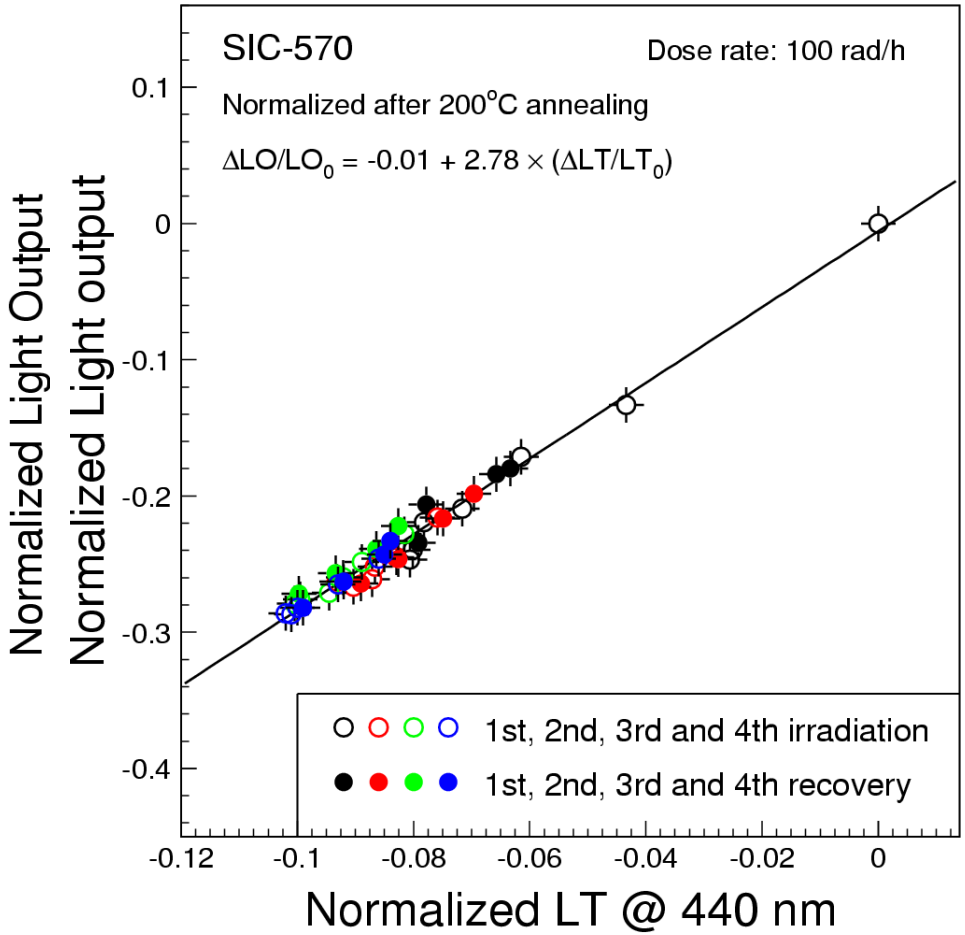




δLO/LO versus δLT/LT @ 100 rad/h

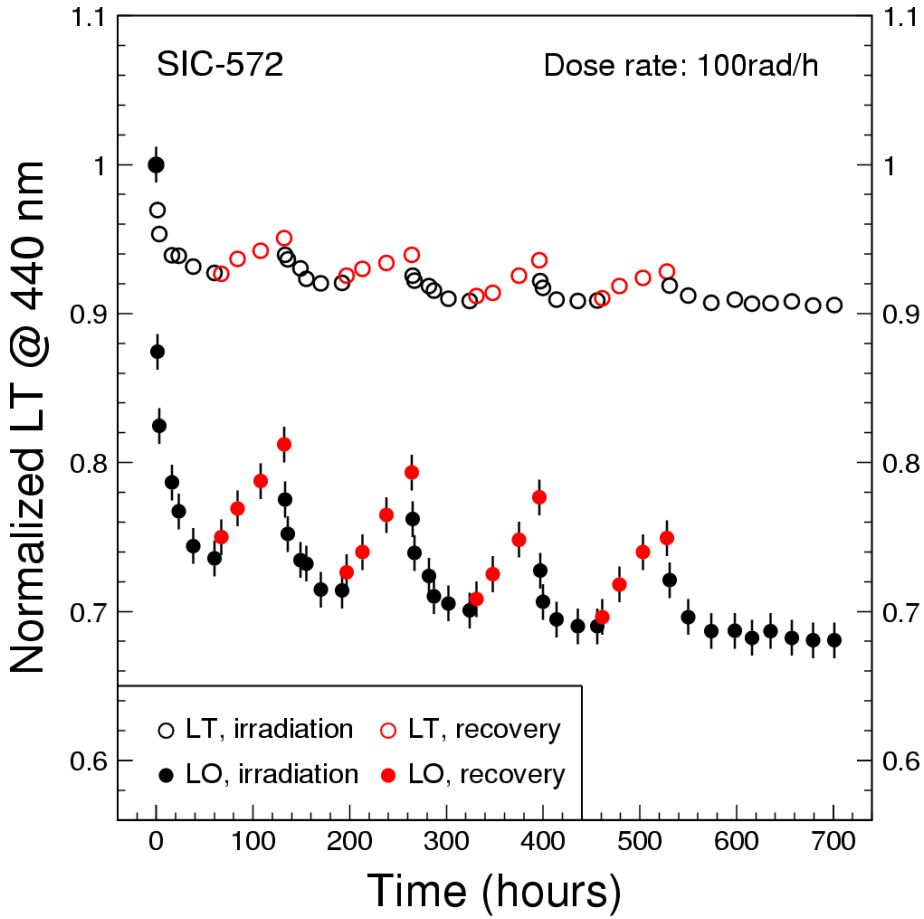
Strong correlation: R = 2.78

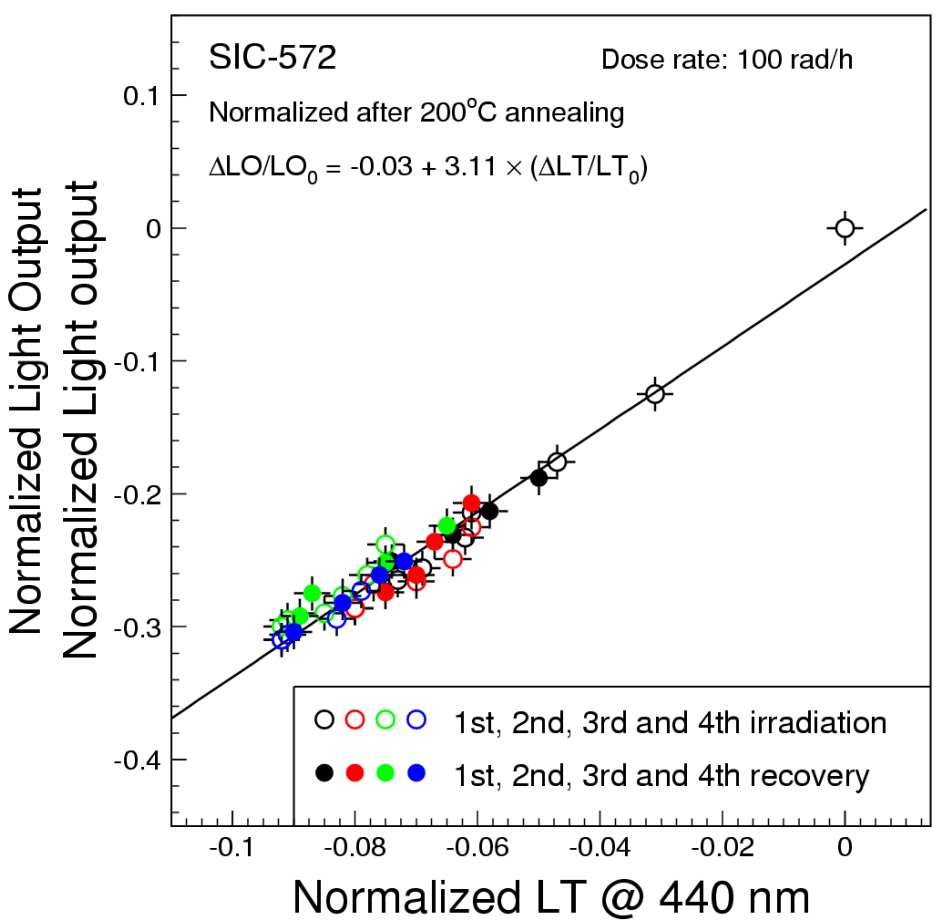




δLO/LO versus δLT/LT @ 100 rad/h

Strong correlation: R = 3.11





Summary

- Some correlations exist between the initial LO and the initial LT @ 360 nm, which may be due to that a part of the PWO emission spectrum is self-absorbed.
- There is a universal 2nd order polynomial relation between the EWRIAC and the δLT/LT@ 440 nm for all BTCP and SIC samples.
- The correlation between the EWRIAC measured at different dose rates is weaker at lower dose rates, where the consequence of the preexisting absorption is not negligible.
- The EWRIAC and the δLO/LO are not correlated with the initial LT indicating that the preexisting absorption is not correlated with the radiation induced absorption.
- The correlation between the EWRIAC and the δLO/LO @ 15 rad/h seems also diluted by the preexisting absorptions.
- A strong correlation exists between the δLO/LO and the δLT/LT @440 nm for each sample, which is the basis of our light monitoring. The R values obtained with a linear fit, however, is not a constant even for the same sample. To be studied: a polynomial or exponential fit.
- Main differences between the BTCP and SIC PWO samples are the initial LO caused by the different doping recipe and the different initial LT caused by the different crystal growth axis. To be understood: why BTCP samples lose 50% more light than that of SIC samples.