Ionoluminescence on α-quartz: Mechanisms and modeling

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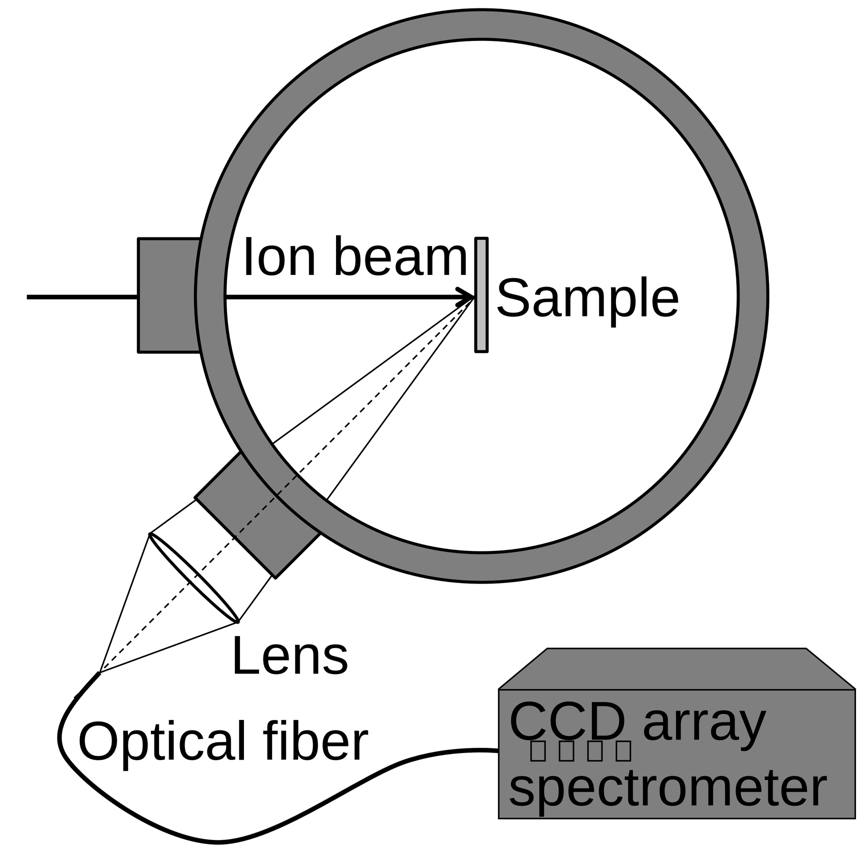
Introduction

Ionoluminescence of α-quartz exhibits two dominant emission bands peaking at 1.9 eV (NBOHCs) and 2.7 eV (STEs). The evolution of the red emission yield does not show a correlation with the concentrations of neither the NBOHC nor with that of other color centers. The blue emission yield closely follows the amorphization kinetics independently measured by RBS/C spectrometry. A simple theoretical model has been proposed; it assumes that the formation and recombination of STEs are the primary event and both, the light emissions and the lattice structural damage are a consequence this phenomenon. The model leads to several simple mathematical equations that can be used to simulate the IL yields and provide a reasonable fit to experimental kinetic data.

Experimental

- Samples: c-SiO_2
  - 6x6x1 mm^3
- Ions: B, O, F, Cl and Br
  - Beam inhomogeneity < 10 %
  - J ~ 10-30 nA (measured in real-time)
- Spectrometer: QE6500 (Ocean Optics Inc.)
  - 200-850 nm
  - t_{int} ~ 1-5 s

http://www.cmam.uam.es/



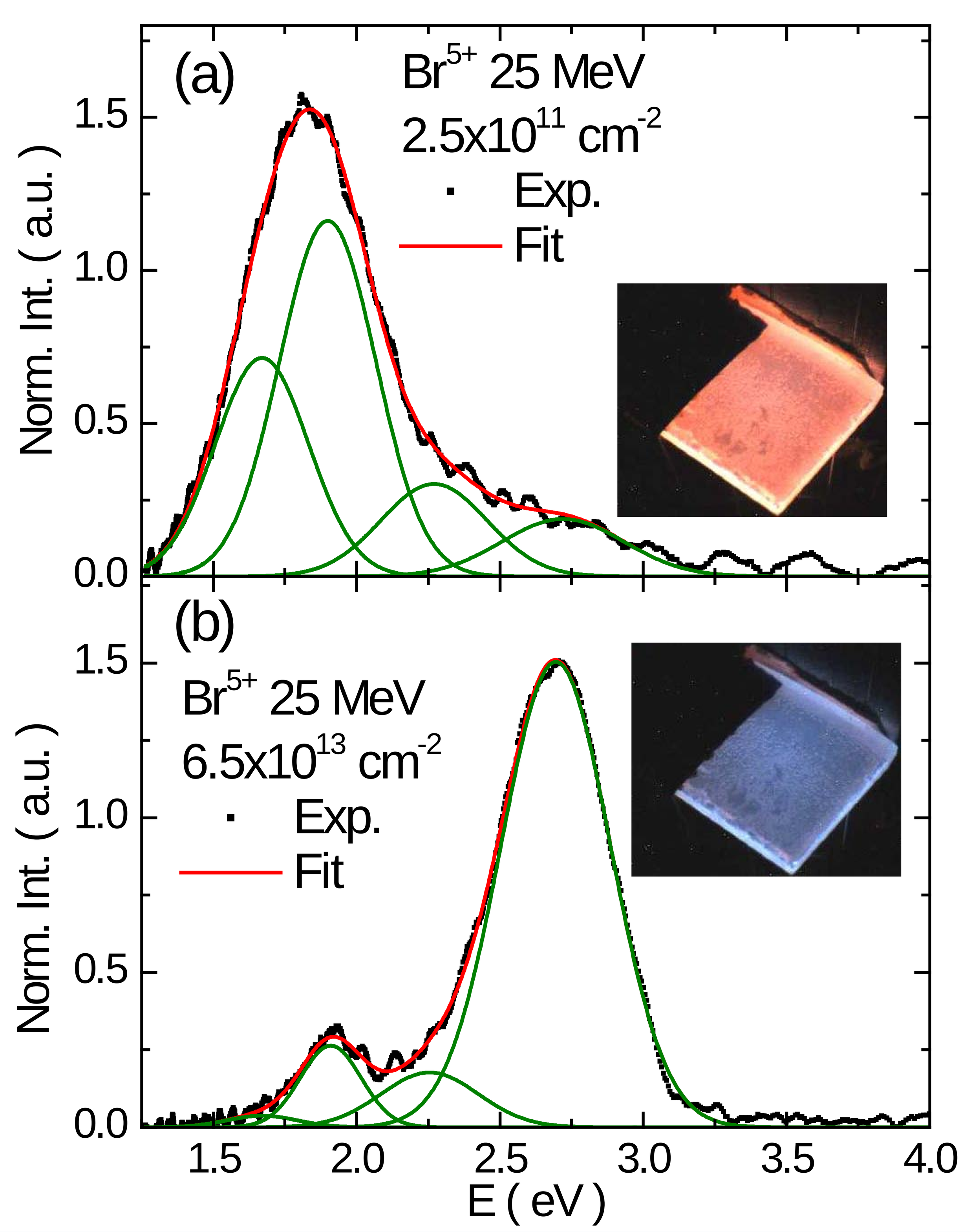


Figure 1. IL spectra for Br at 25 MeV. (a) Low fluence ($2.5x10^{11}$ cm^{-2}) and (b) high fluence ($6.5x10^{13}$ cm^{-2}).

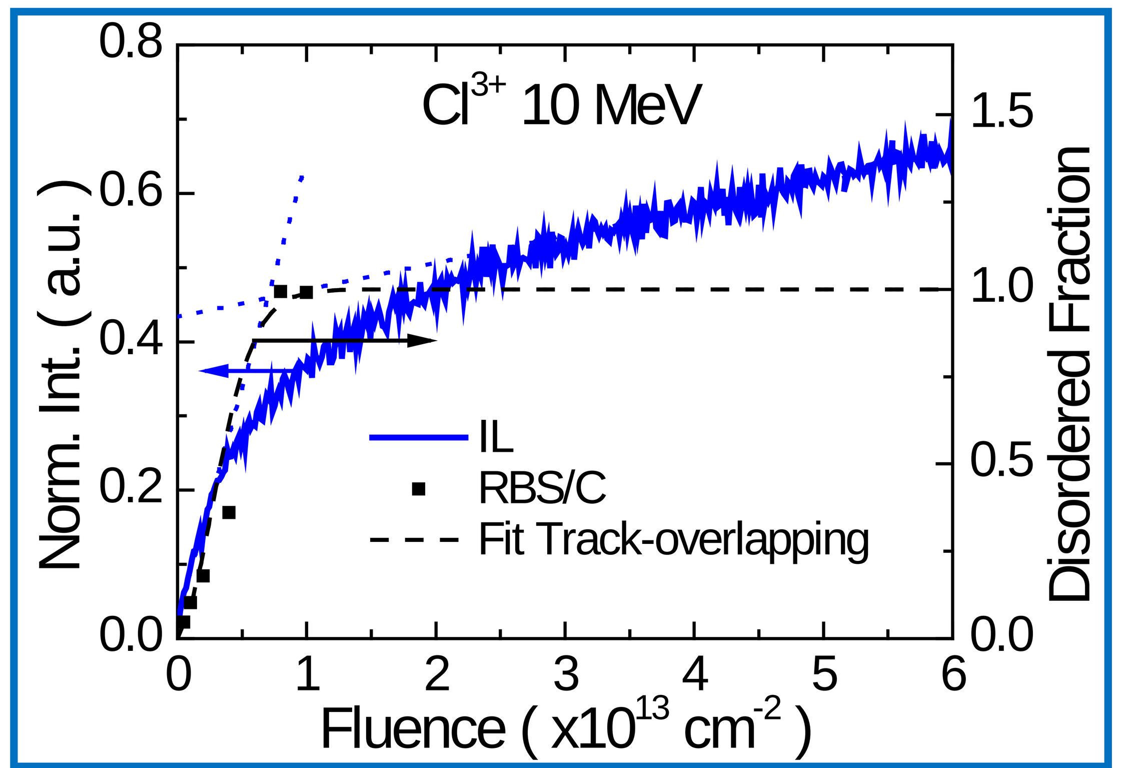
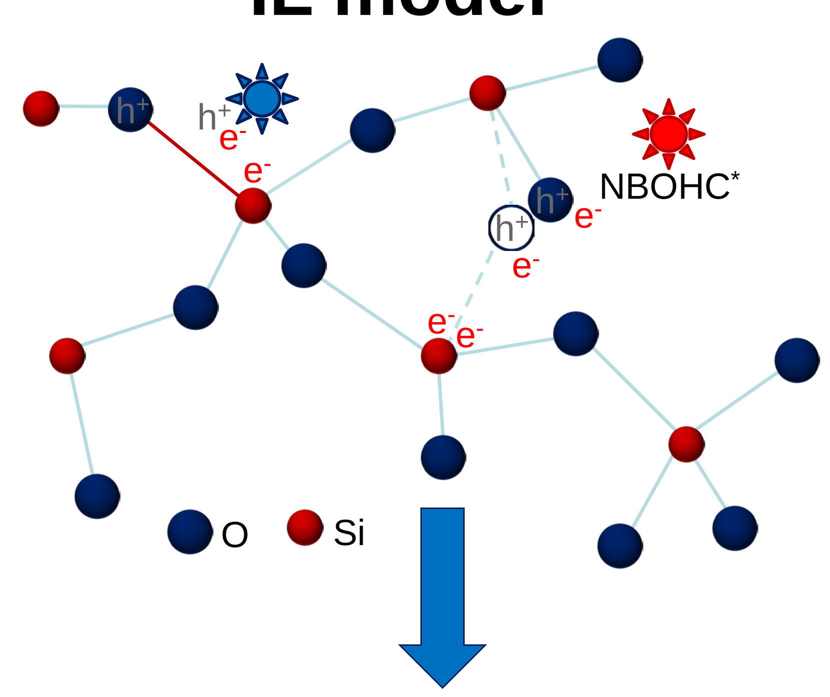


Figure 2. Blue IL and disordered fraction versus fluence for Cl at 10 MeV.

φ: Irradiation fluence, Φ: Irradiation flux, τ_{STE}: Lifetime of the self-trapped exciton, σ_{STE}: STE recombination cross-section, Y_B (Y_R): Luminescence yield for the blue (red) band, η_B (η_R): Efficiency of the blue (red) emission, f_U(f_S): Fraction of unstressed (stressed) bonds.

IL model



$$Y_R(\phi) = \eta_R f_U(\phi) \sigma_{STE} N_{STE}(\phi)$$
$$Y_B(\phi) = \eta_B f_S(\phi) \sigma_{STE} N_{STE}(\phi)$$
$$N_{STE}(\phi) = N_{STE}^{\infty}\{1 - \exp(-\phi/\Phi\tau_{STE})\}$$
$$= N_{STE}^{\infty}\{1 - \exp(-\sigma_{STE}\phi)\}$$
$$f_S(\phi) = 1 - \exp(-\sigma_S\phi)$$
$$f_U(\phi) = 1 - f_S(\phi)$$

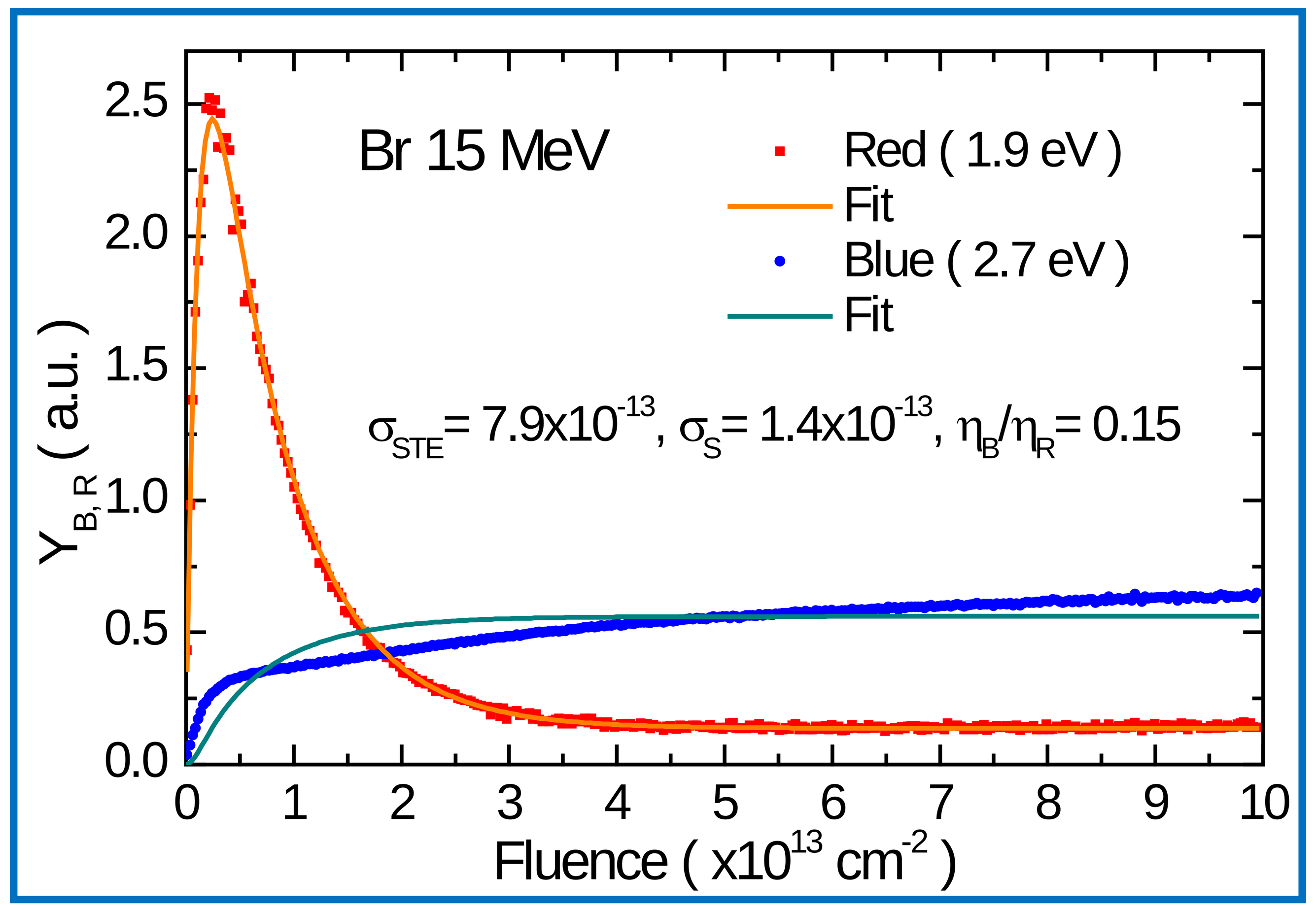


Figure 3: Fits for the kinetics of the red and blue emission yields with the equations of the model, for the samples irradiated with Br at 15 MeV .

Conclusions

- Our data support the assignment of the 1.9 and 2.7 eV emission bands to recombination of NBOHC and STE, respectively.
- We found an excellent correlation between the change of slope (Y_B) and the damaged fraction (RBS/C).
- At a qualitative level the agreement with the experiments is quite satisfactory.
- Even at the quantitative level the obtained fits appear very promising, although one is pending of further improvements and refinements of the model.

References

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Acknowledgements

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