

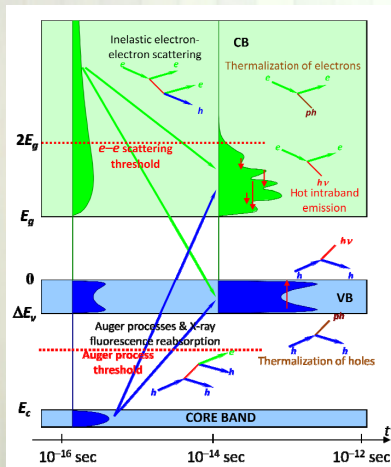
Hot intraband luminescence vs material band structure and excitation type

S.I. Omelkov, V. Nagirnyi, M. Kirm and others

Institute of Physics, University of Tartu, Estonia

Tartu FAST activity report, Prague, 14 June 2018

Intraband luminescence (IBL) mechanism



- Decay 10^{-12} s
- Broad structureless spectrum
- Yield determined by branching ratio (D. Vaisburd):

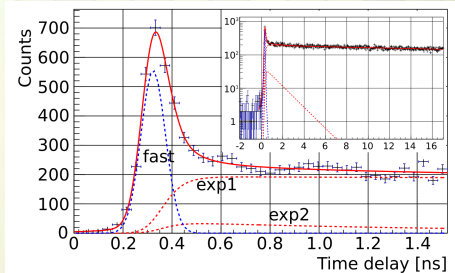
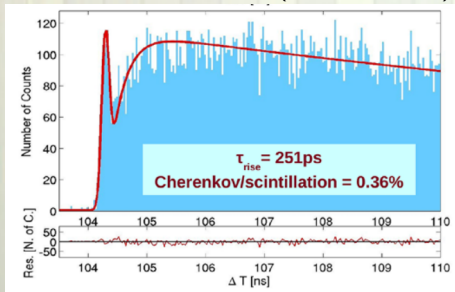
$$\eta = \frac{P_{rad}}{P_{nonrad}} \approx \frac{\tau_{nonrad}}{\tau_{rad}} \approx \frac{1ps}{10ns} \approx 10^{-4} \rightarrow 10 \text{ ph/MeV} \quad (1)$$

Figure: The mechanism of IBL (drawing by A. Vasil'ev)

Prompt photons concept

Scintillation under 511 keV γ -excitation (small crystals)

LuAG:Pr-CTR 205 ps ($2 \times 2 \times 10 \text{ mm}^3$) BGO-CTR 330 ps ($3 \times 3 \times 20 \text{ mm}^3$)

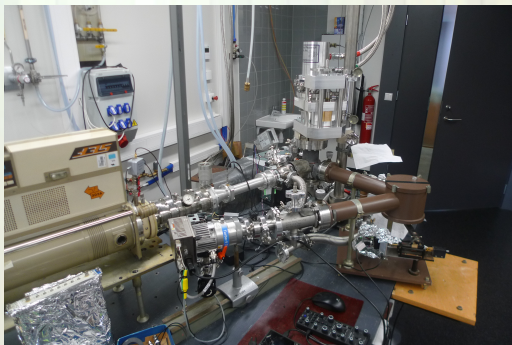
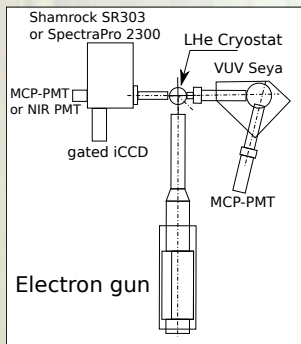


[1] S. Gundacker et al, Phys. Med. Biol. 61 (2016) 2802

[2] S E Brunner and D R Schaart
Phys. Med. Biol. 62 (2017) 4421

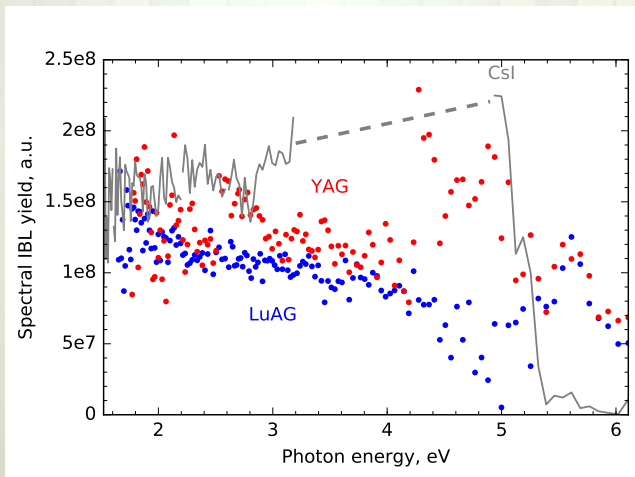
Not enough prompt photons!

The pulse cathodoluminescence setup in Tartu



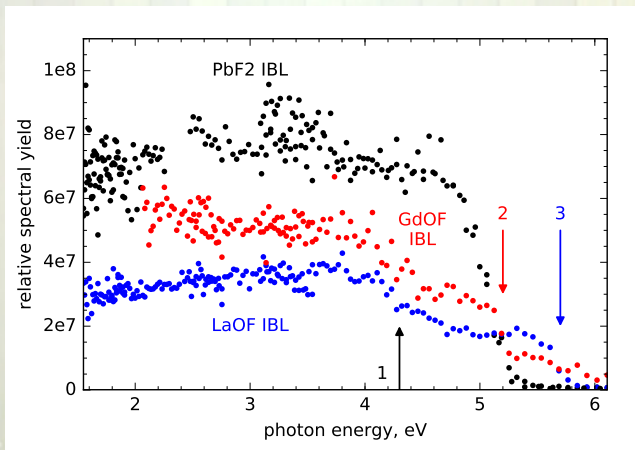
- Electron energy 100–200 keV, pulse current 10–50 A/cm²
- Time resolution <150 ps (rise time)
- **2017: High resolution mode: 55 ps FWHM**
- Fast to slow emissions ratio (up to seconds)
- Spectral range 0.75–10.6 eV (117–1650 nm)
- Temperature range 5.5–800 K

IBL and band structure: garnets

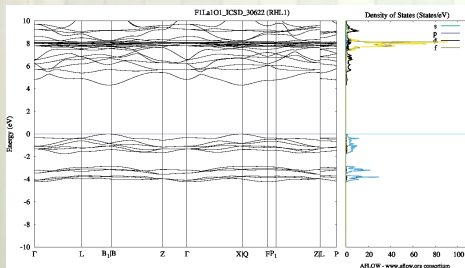


The IBL yield of YAG and LuAG is essentially the same
The band structures of YAG and LuAG differ only by Lu 4f states in VB

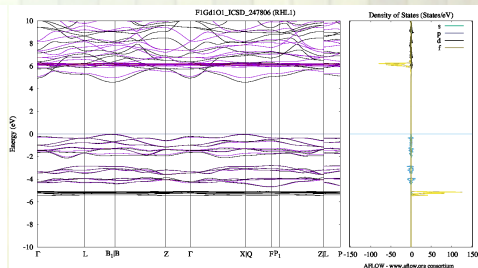
IBL and band structure: rare-earth oxyfluorides



LaOF and GdOF band structure (AFlowLIB.org)

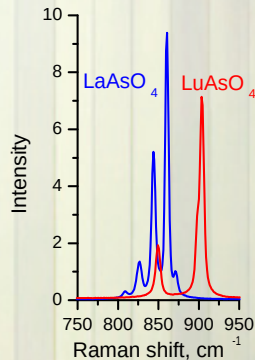
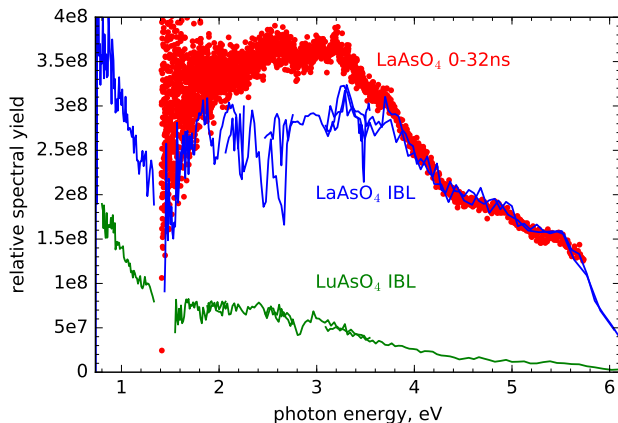


LaOF (R3m)



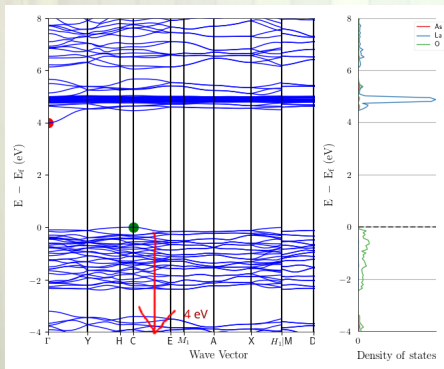
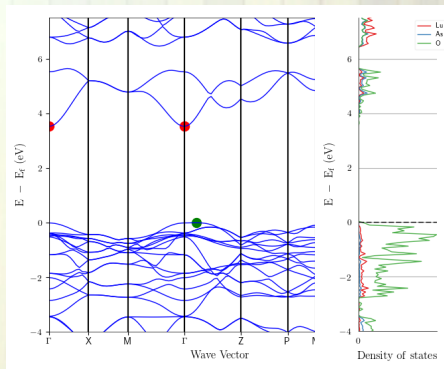
GdOF (R3m)

IBL and band structure: rare-earth arsenates



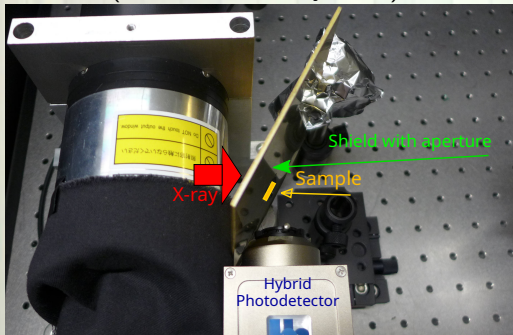
More on IBL and phonons: S. Omelkov et al, J.Lumin 198 (2018) p260

LaAsO₄ and LuAsO₄ band structure (MaterialsProject.org)

LaAsO₄ (P2₁/c)LuAsO₄ (I4₁/amd)

IBL under x-ray excitation: nonproportionality effects

XRL setup in CERN
(Laser-excited xray tube)



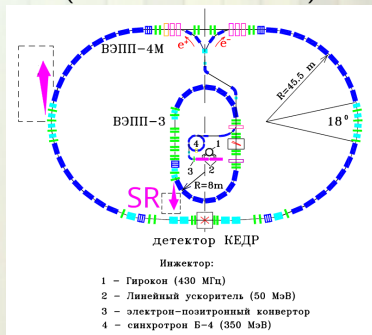
3–40 keV max 10 keV

Low power, no spectral resolution

2 MHz repetition rate

~100 ps FWHM time resolution

XRL setup on VEPP-3 ring
(2 GeV, Novosibirsk)



3–60 keV max 10 keV

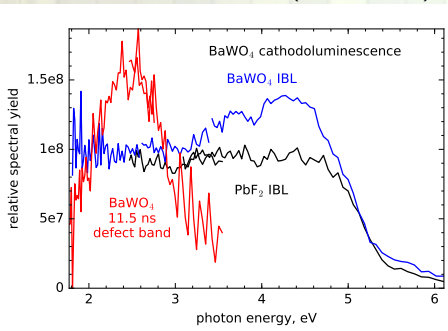
High power, used 55 μm Cu filter

8.06 MHz repetition rate

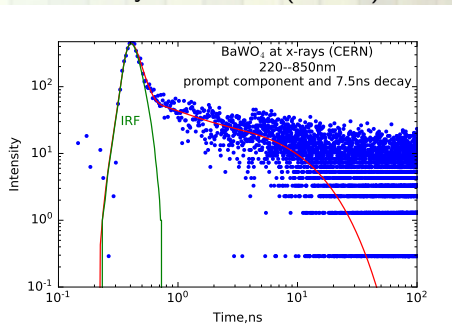
~1 ns FWHM time resolution

IBL in BaWO₄

Cathodoluminescence (≤ 100 keV)

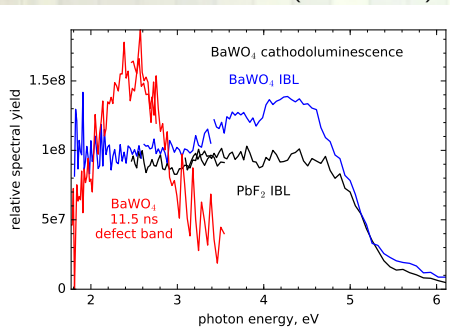


X-ray ≤ 40 keV (CERN)

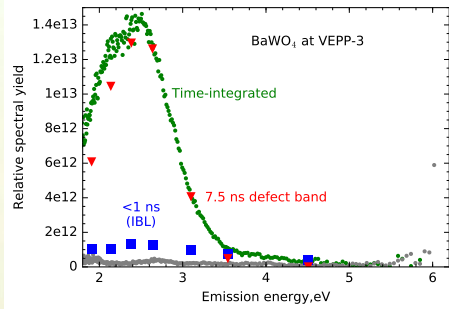


$$\text{Yield(IBL)} = 2.2 \times \text{Yield(defect)}$$

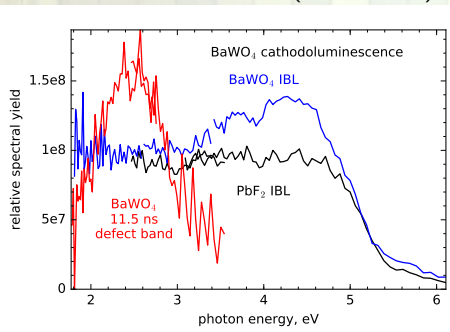
$$\text{Yield(IBL)} = 0.2 \times \text{Yield(defect)}$$

IBL in BaWO₄Cathodoluminescence (≤ 100 keV)

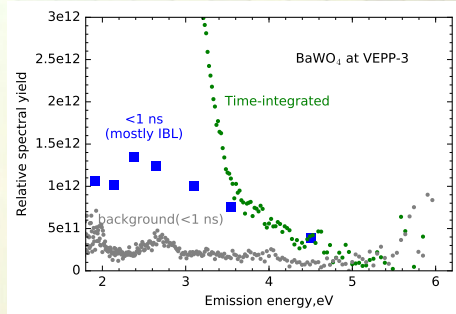
$$\text{Yield(IBL)} = 2.2 \times \text{Yield(defect)}$$

X-ray ≤ 60 keV (VEPP-3)

$$\text{Yield(IBL)} = 0.3 \times \text{Yield(defect)}$$

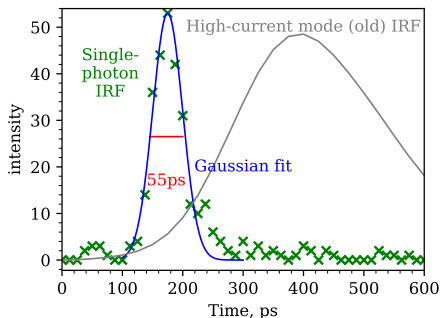
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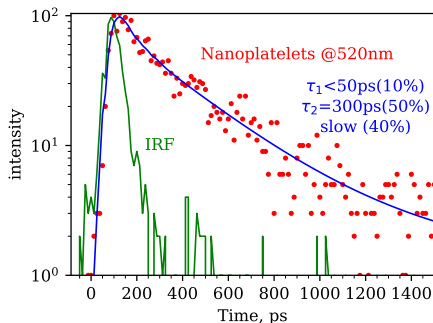
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Cathodoluminescence time resolution



Intraband luminescence of
PbF₂@275nm (aka IRF)



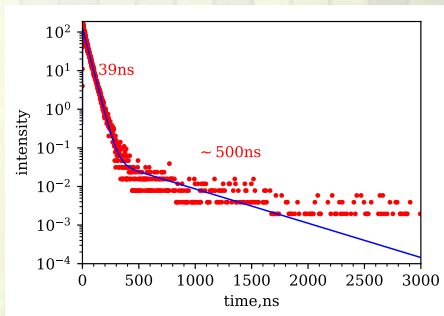
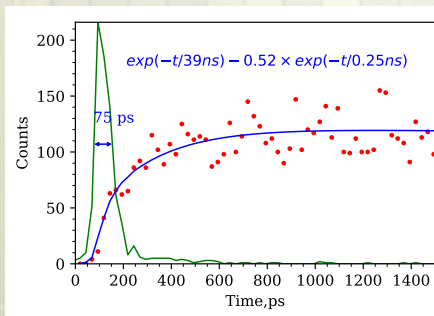
Cathodoluminescence of
nanoplatelets (1.35:1 aspect ratio)
In collaboration with Rosana M.
Turtos

Preparing for the future: cathodoluminescence time resolution

Acquisition time: 0.5–10 hours/decay curve

Background level is 10^{-5} counts/bin/hour

SNR is **limited by statistics**



Rise and decay of cathodoluminescence of LYSO:Ce@400nm

Conclusions

- The band structure seems to influence IBL yield and spectra
 - ... in some way, at least ... (more research needed)
 - The nonproportionality of IBL is very strong
 - The IBL spectra are changing with excitation energy
 - ... theoretical support is needed ...
 - VEPP-3 is an interesting x-ray source for studying IBL and density effects
 - New synchrotron radiation facility is being designed in Novosibirsk hard x-rays with **1 ps compressed bunch mode**
 - It will likely to have luminescence station as well!

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Acknowledgments



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FÜÜSIKA INSTITUUT



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Thank you for attention