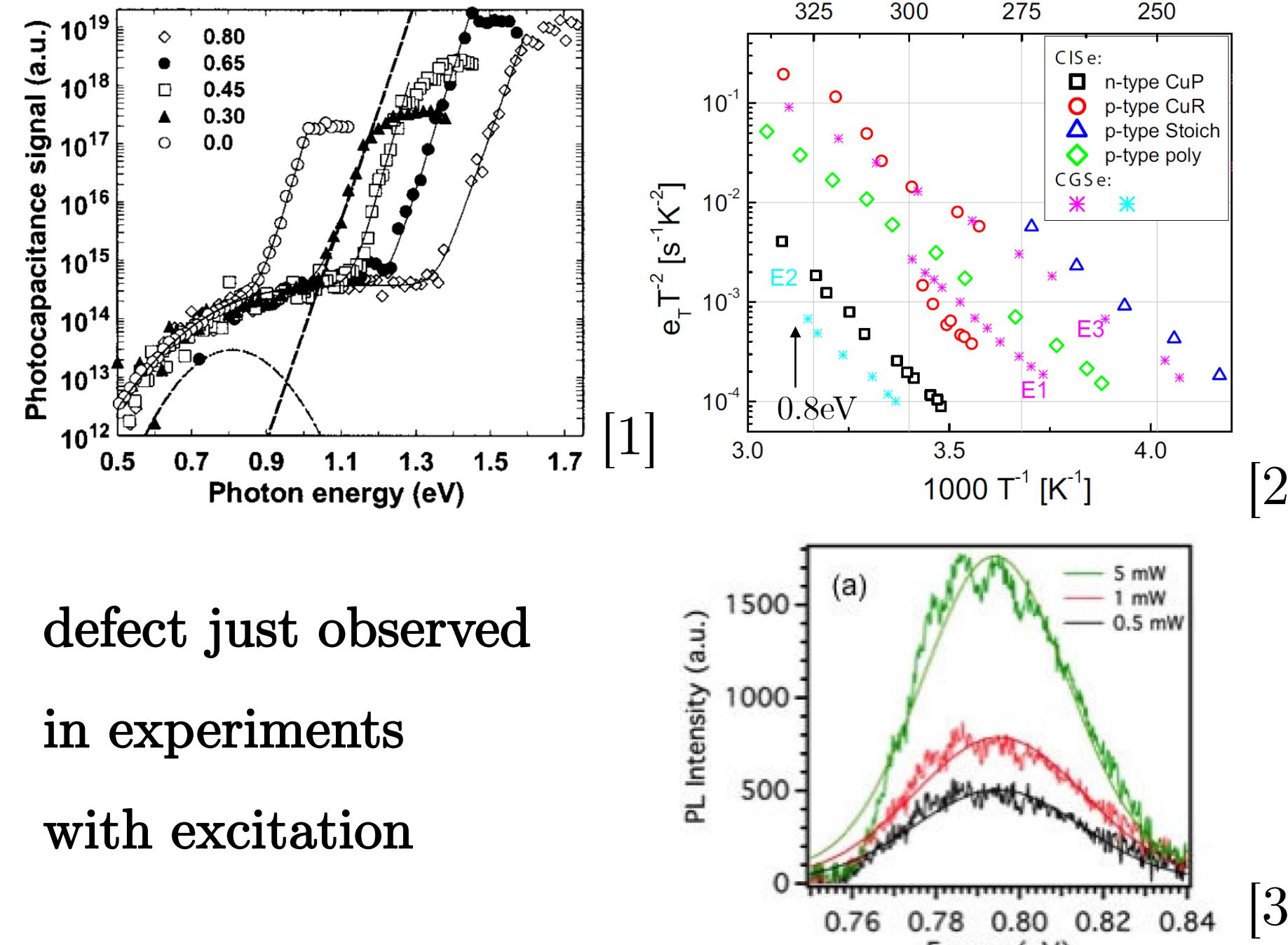


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Motivation

- photocapacitance measurements reveal defect signature at 800 meV above valence band [1]
- signal appears independent of Ga/(Ga+In) ratio and in ternary compounds CuInSe₂/CuGaSe₂
- if the signal is caused by defects, we should observe the levels in photoluminescence measurements
- by extending our setup we perform defect spectroscopy on thin films down to 400 meV

Literature: Experiment



- defect just observed in experiments with excitation

- 0.8 eV defect observed by photocapacitance [1]
- independent of Ga/(Ga+In) ratio in Cu(In,Ga)Se₂
- PICTS shows defect response around 0.8 eV in epitaxial/polycrystalline CuInSe₂ and CuGaSe₂ [2]
- recently PL transition shown at 0.8 eV [3]

Experimental details

- samples grown by MOVPE on SI-(100)-GaAs

	CuInSe ₂	CuIn _{0.7} Ga _{0.3} Se	CuIn _{0.5} Ga _{0.5} Se	CuIn _{0.2} Ga _{0.8} Se ₂	CuGaSe ₂
GGI	0	0.27	0.46	0.8	1
CGI	1.25	0.99	1.29	1.13	1.18

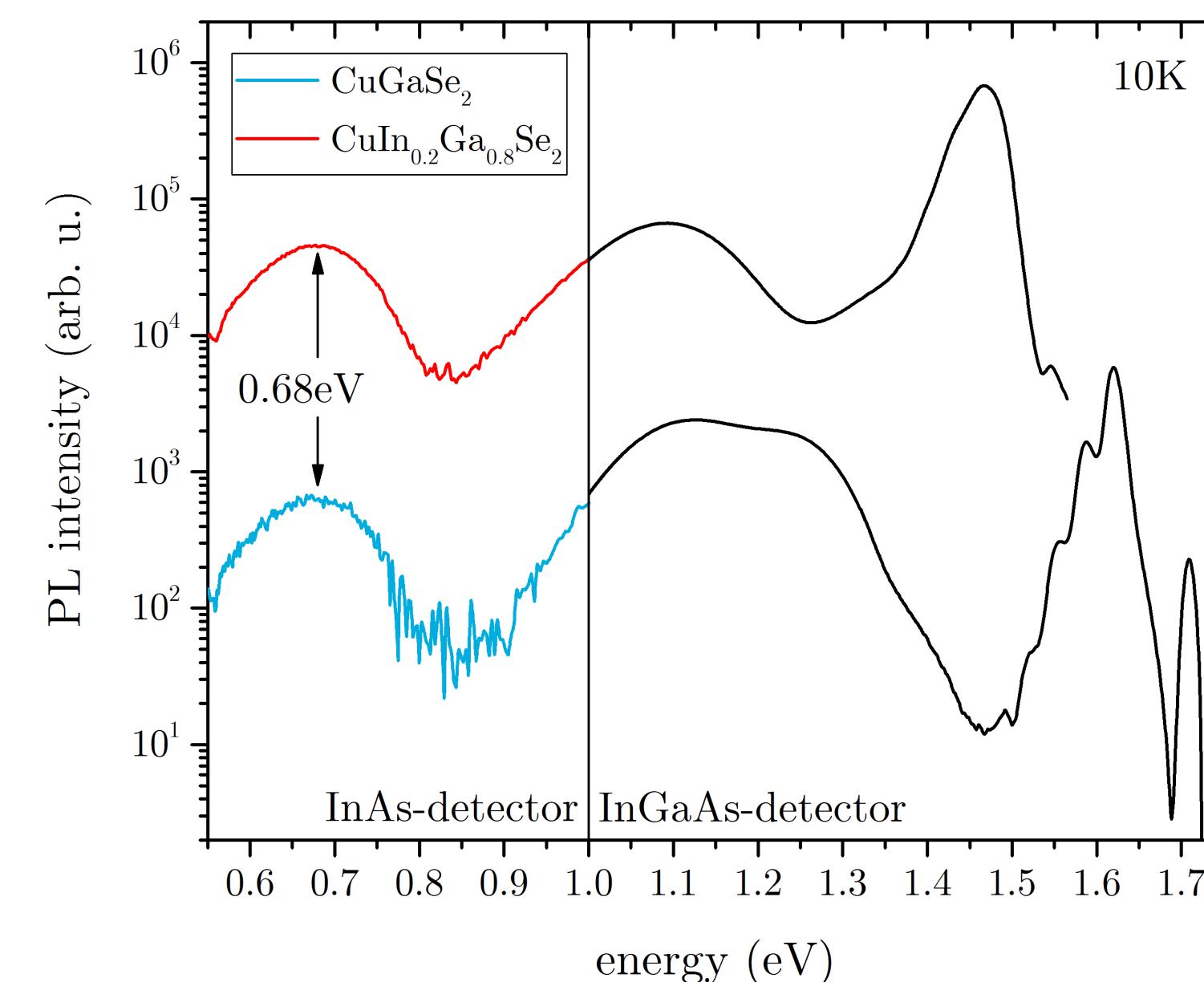
- InAs-detector, range down to 0.4 eV (3100nm)
- InGaAs-array, range down to 0.77 eV (1610nm)

Acknowledgements

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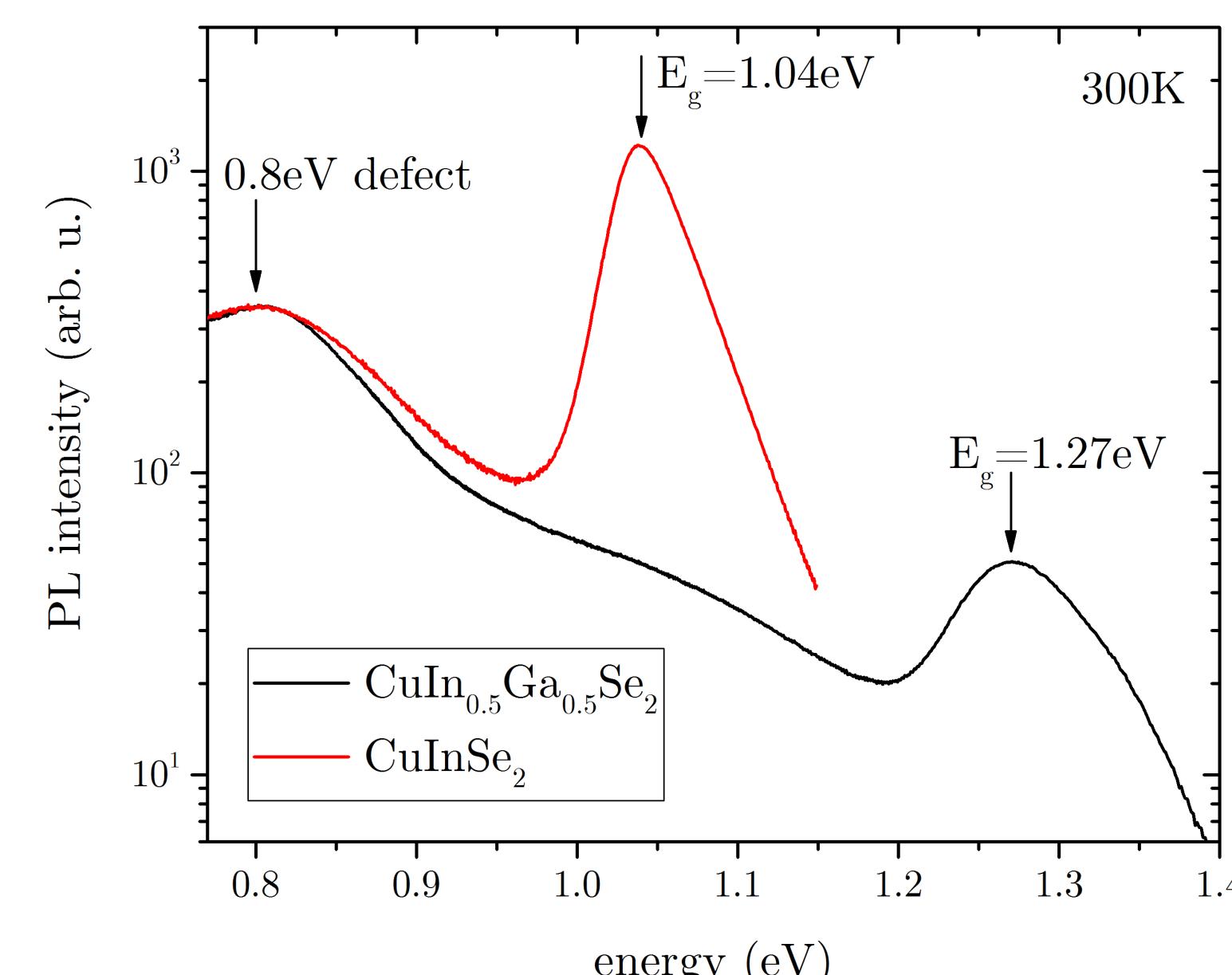
Photoluminescence 10K



- transition at 0.68 eV most likely DA-transition into dominant shallow acceptor at 100 meV
- deep level remains constant when adding Indium

⇒ defect level exists around 0.7 - 0.8 eV

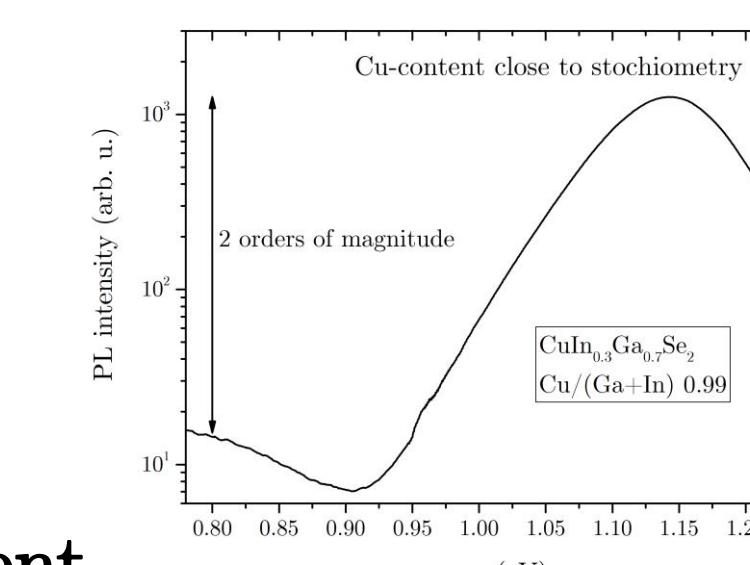
Deep defect observable at 300K?



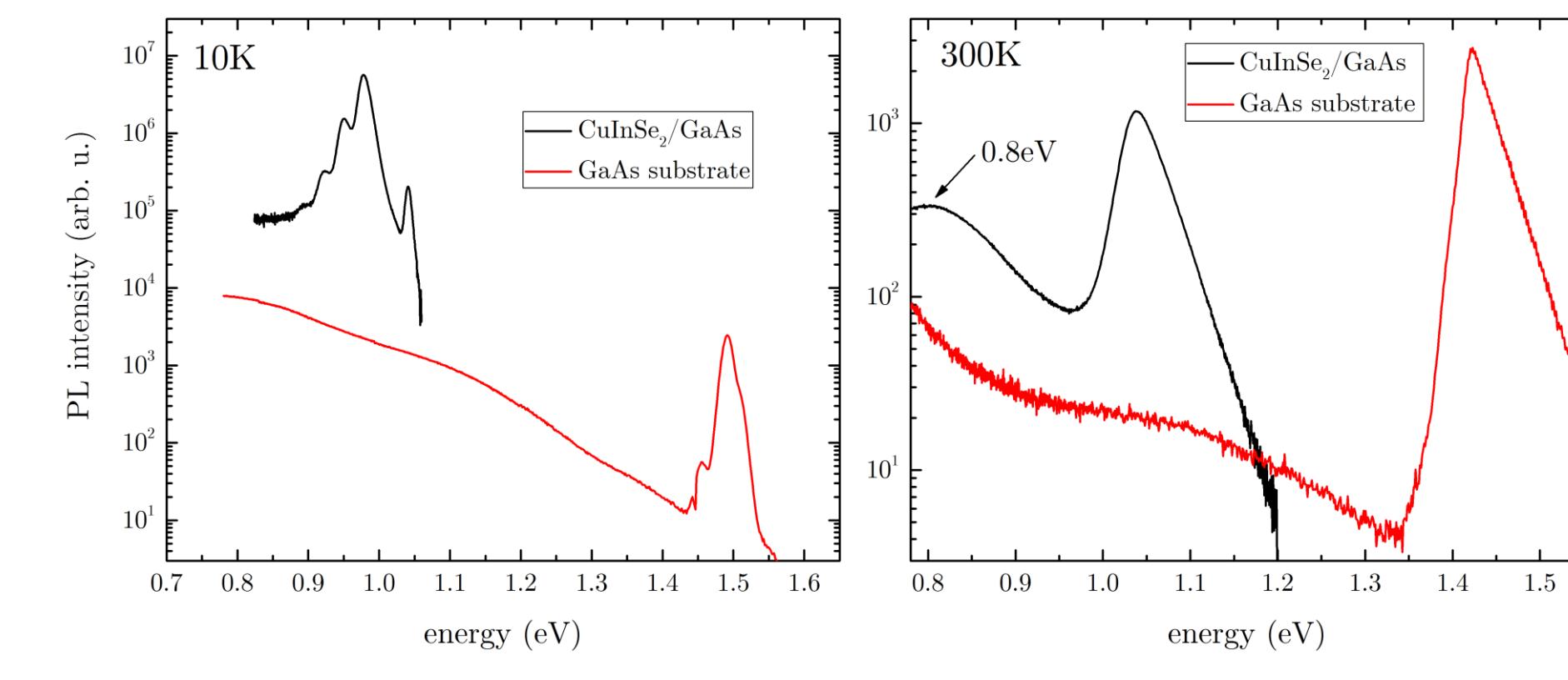
- defect transition at 0.8 eV for room temperature
- free-to-bound transition ⇒ defect level at 0.8 eV
- observed in Cu-rich CuInSe₂ and Cu(In,Ga)Se₂

What about lower Cu-contents?

- 0.8 eV defect peak not observed in state-of-the-art absorber with GGI approx. 0.3 and CGI approx. 0.9
- Sample B with CGI 0.99 shows smallest defect signal
- 0.8 eV signal decreases with respect to band-band transition for lower Cu-content



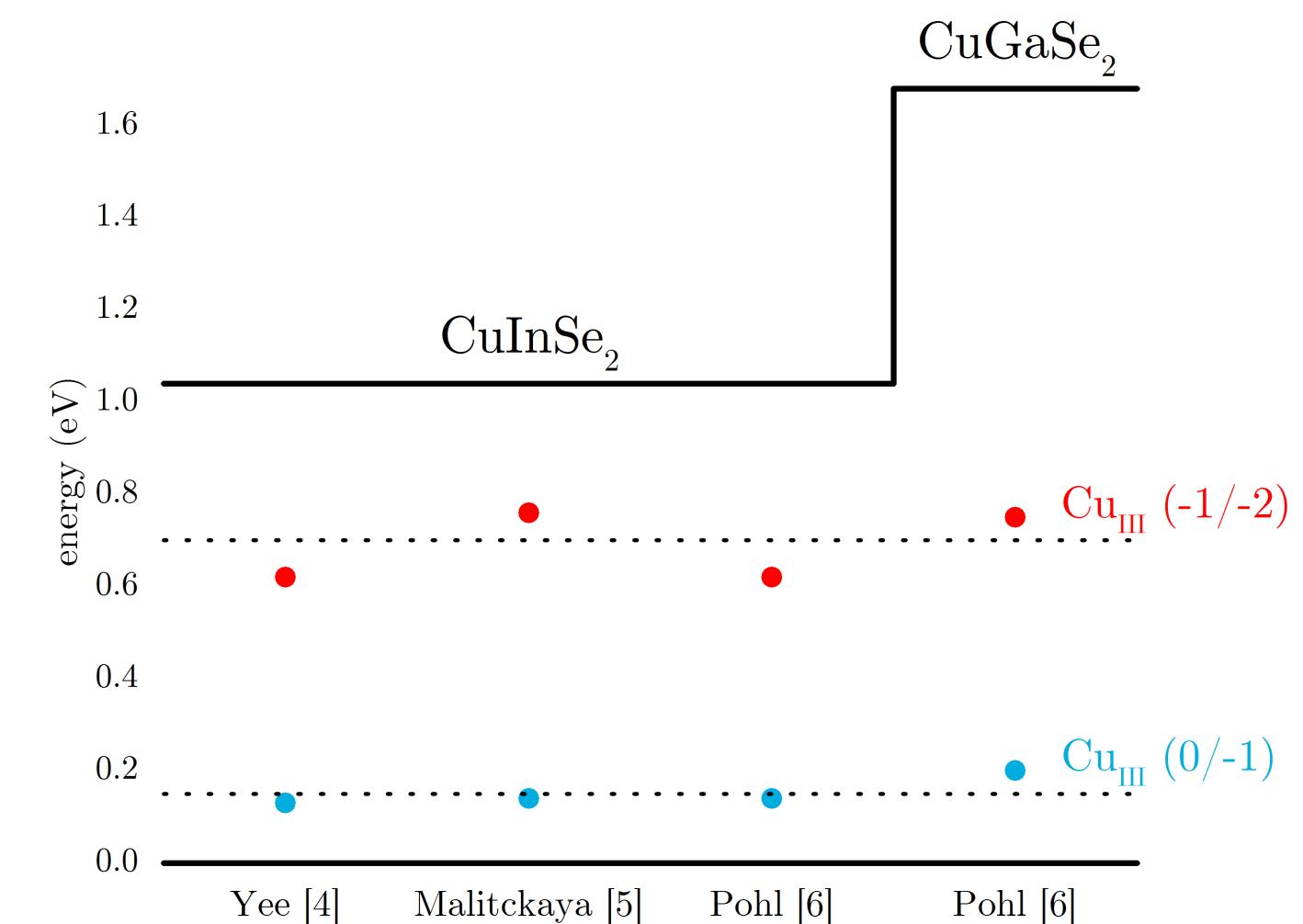
GaAs-substrate luminescence?



- GaAs has known EL2 defect (As_{Ga} antisite) with optical transitions around 0.7 eV
- PL signals with direct substrate-illumination have lower intensities than for CuInSe₂/GaAs

⇒ deep defect transitions not correlated to substrate

Literature: Theory



- calculations predict the charge transition Cu_{In}(-1/-2) at 0.6 - 0.8 eV above the VBM in CuInSe₂
- Pohl et. al. calculated Cu_{Ga}(-1/-2) at the same level
- under most preparation conditions E_f close to VB:

⇒ no direct formation of Cu_{III}⁻¹

⇒ photoexcitation needed to charge Cu_{III}⁻¹

Conclusion

- transition at 0.7 eV for 10K, at 0.8 eV for 300K
- deep defect level remains constant for varying GGI
- defect level not observed in Cu-poor compositions
- defect level attributed to Cu_{III}(-1/-2) antisite
- possible reason for loss of V_{OC} in Cu-rich solar cells