Unveiling nanoscale optical and structural properties of TMD monolayers using combined electron spectroscopies techniques

Noémie Bonnet[1] – RJP 2021

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REAL title:
Cathodoluminescence for nanoscale measurements

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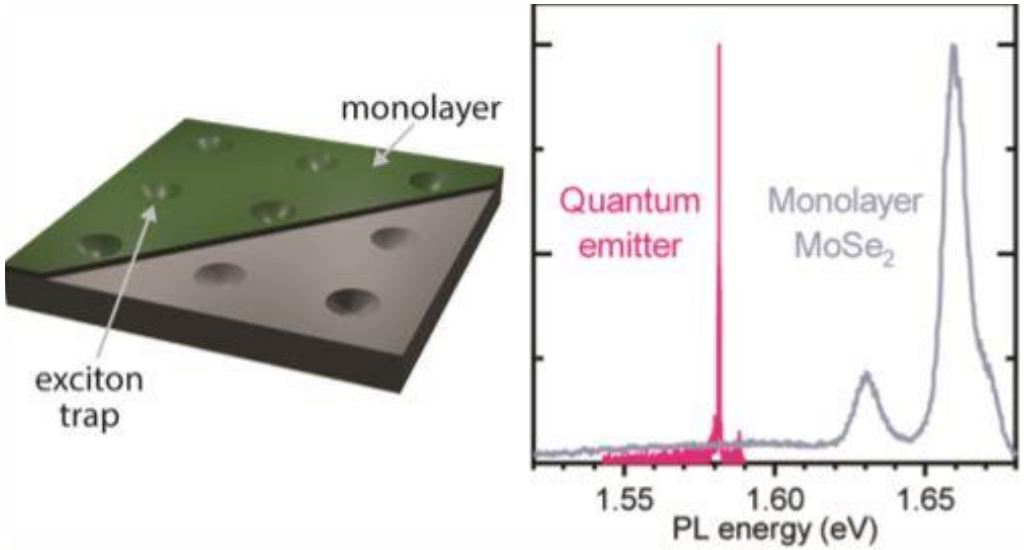
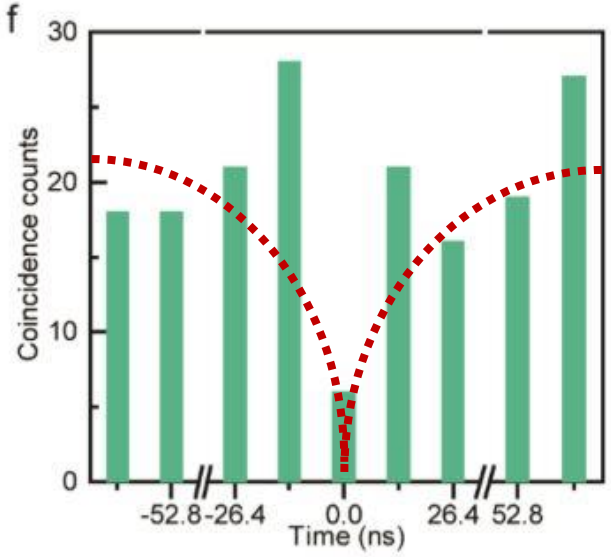
université PARIS-SACLAY

LPS ORSAY

Engineering of quantum emitters

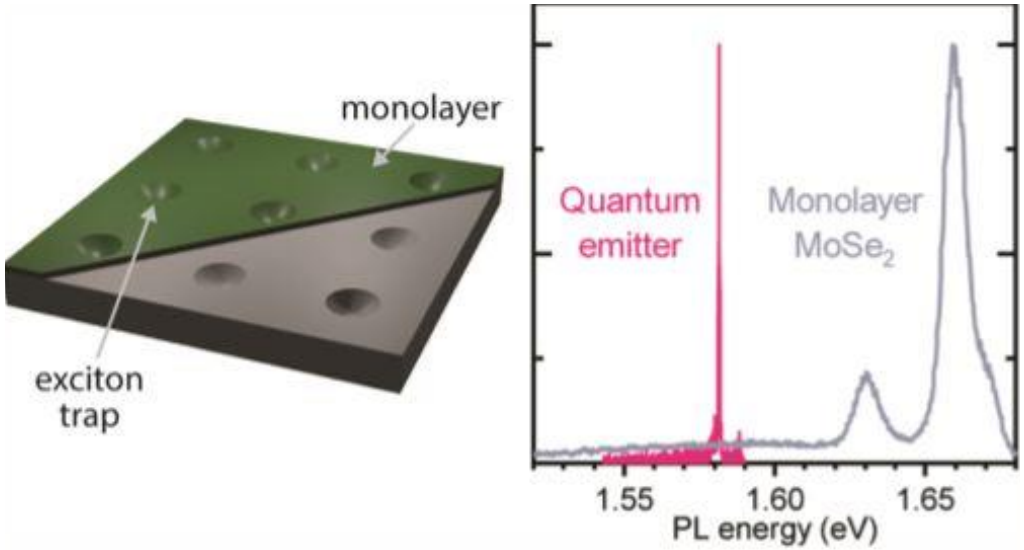


Autocorrelation function



L. YU et al. Site-Controlled Quantum emitters in Monolayer MoSe2, Nano Letters (2021)

Engineering of quantum emitters



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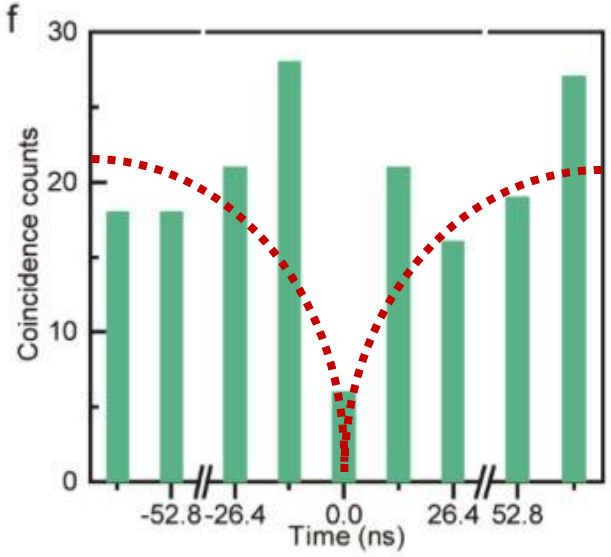

What is the origin of quantum emission in TMDs ?

L. YU et al. Site-Controlled Quantum emitters in Monolayer MoSe2, Nano Letters (2021)

Outline

1. What’s a TMD ?

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2. What is cathodoluminescence (CL) ?

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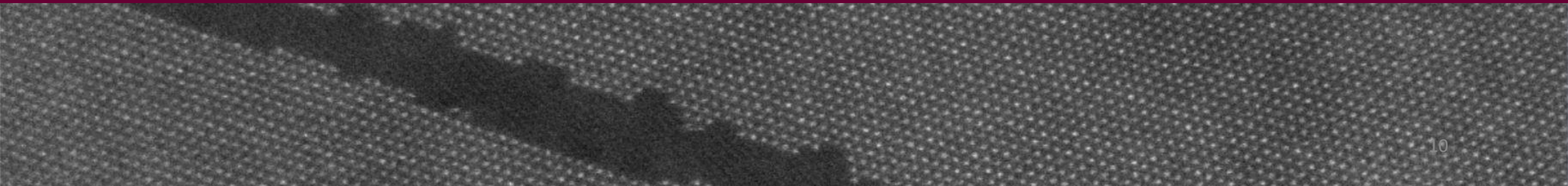
3. How to get CL from a monolayer ?
4. What does a CL measurement look like ?
5. Why is it interesting ?

1. What’s a TMD ?

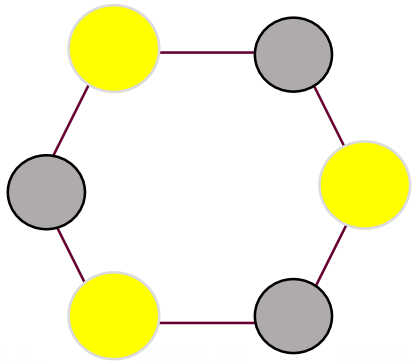


1. Transition Metal Dichalcogenides (TMD)

MX_2

Metal: W, Mo

Chalcogen X: S, Se, Te



Top view

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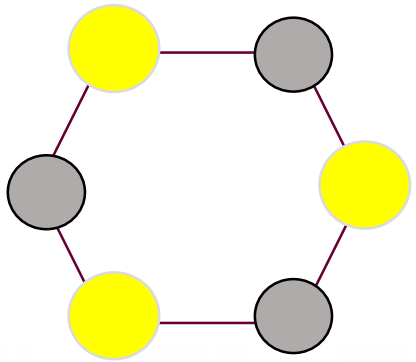

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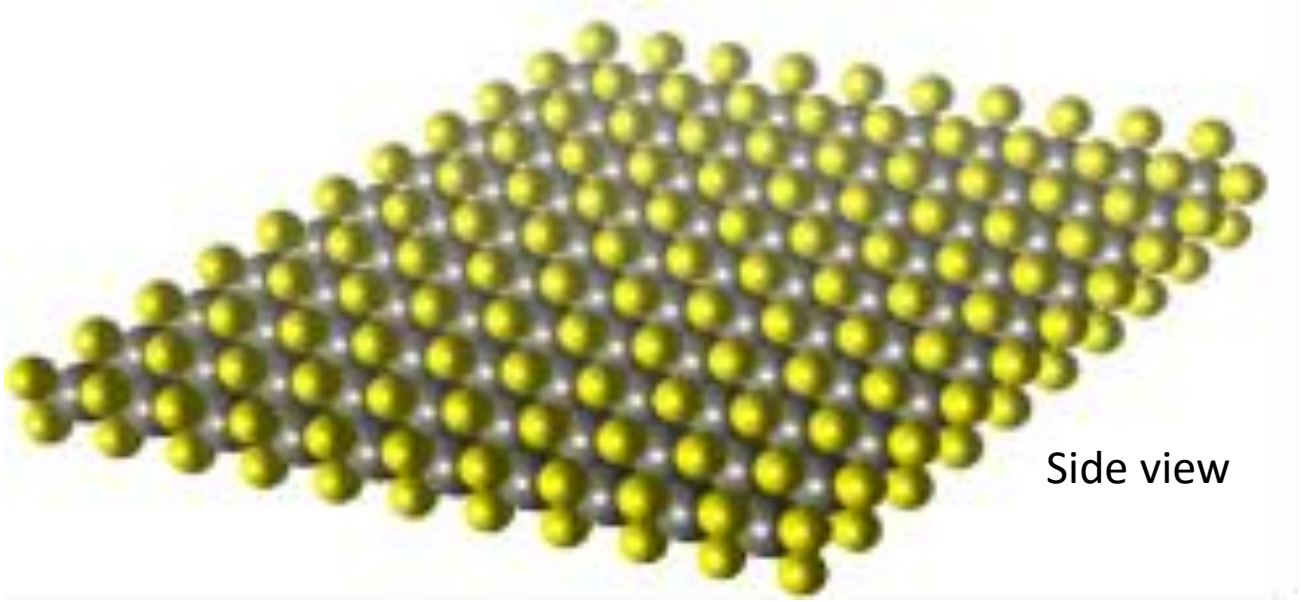

Side view

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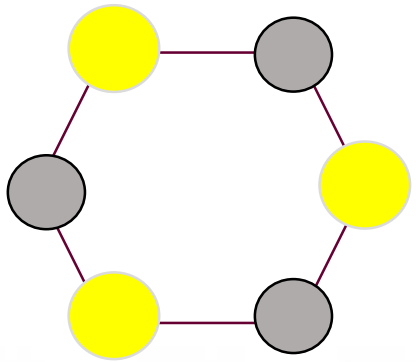
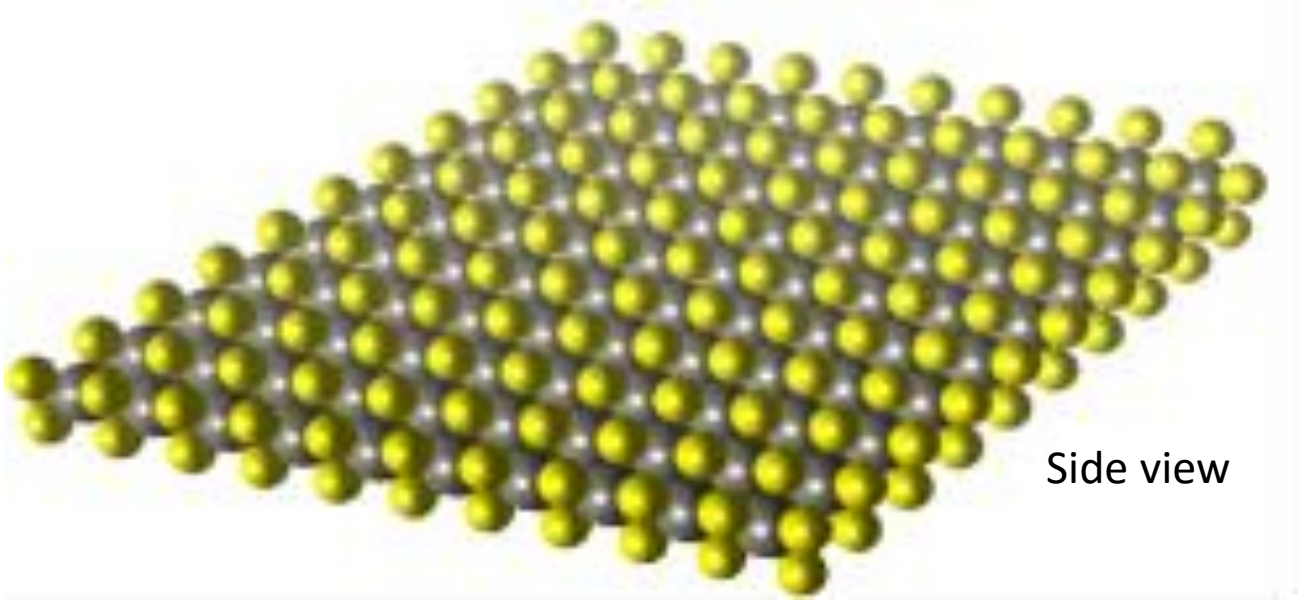


Top view

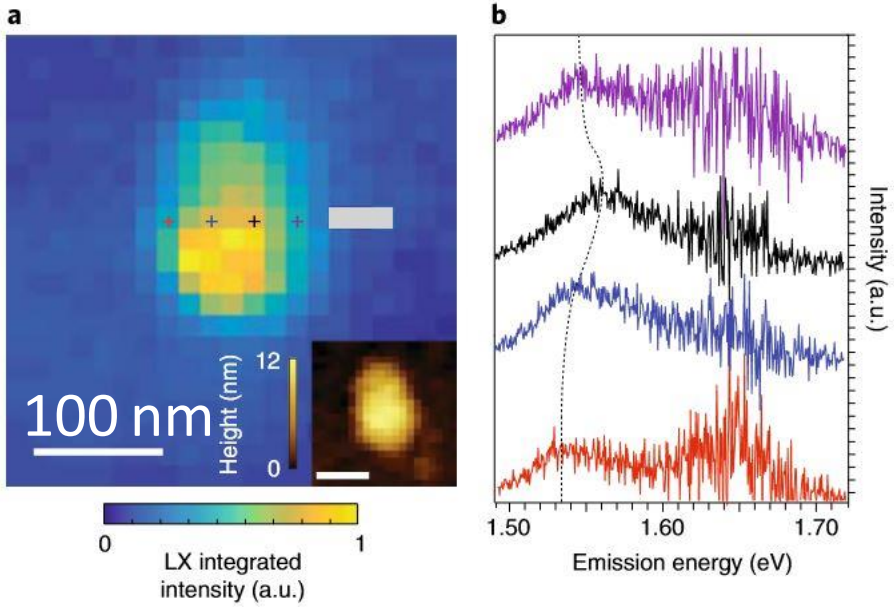


Side view

Here, we study **WS_2**

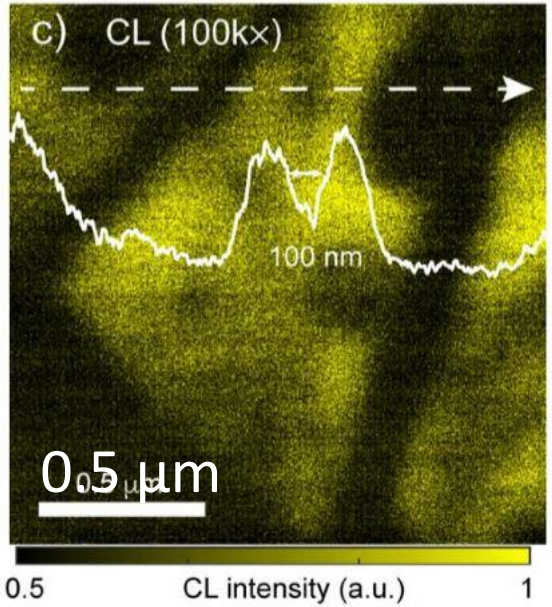
1. Spatial limitations

Photoluminescence



Darlington, Nat. Nanotech. , 15, 854–860 (2020)

Cathodoluminescence

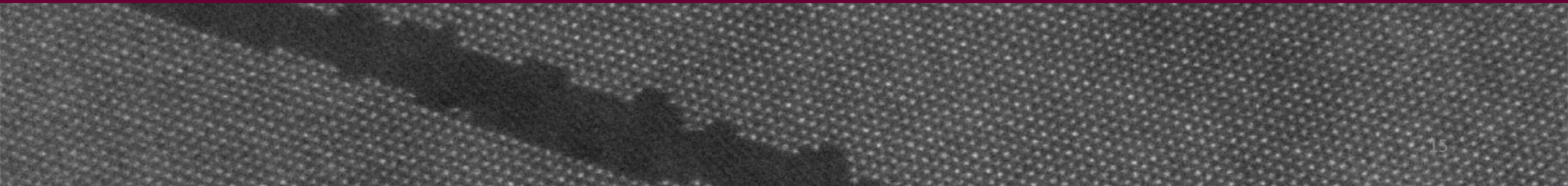


A. Singh, et al, Nano Research. (2020)

G. Nayak, et al, Phys. Rev. Mat. **3**, 114001(2019)

S. Zheng, et al, Nano Lett. **17**, 6475 (2017)

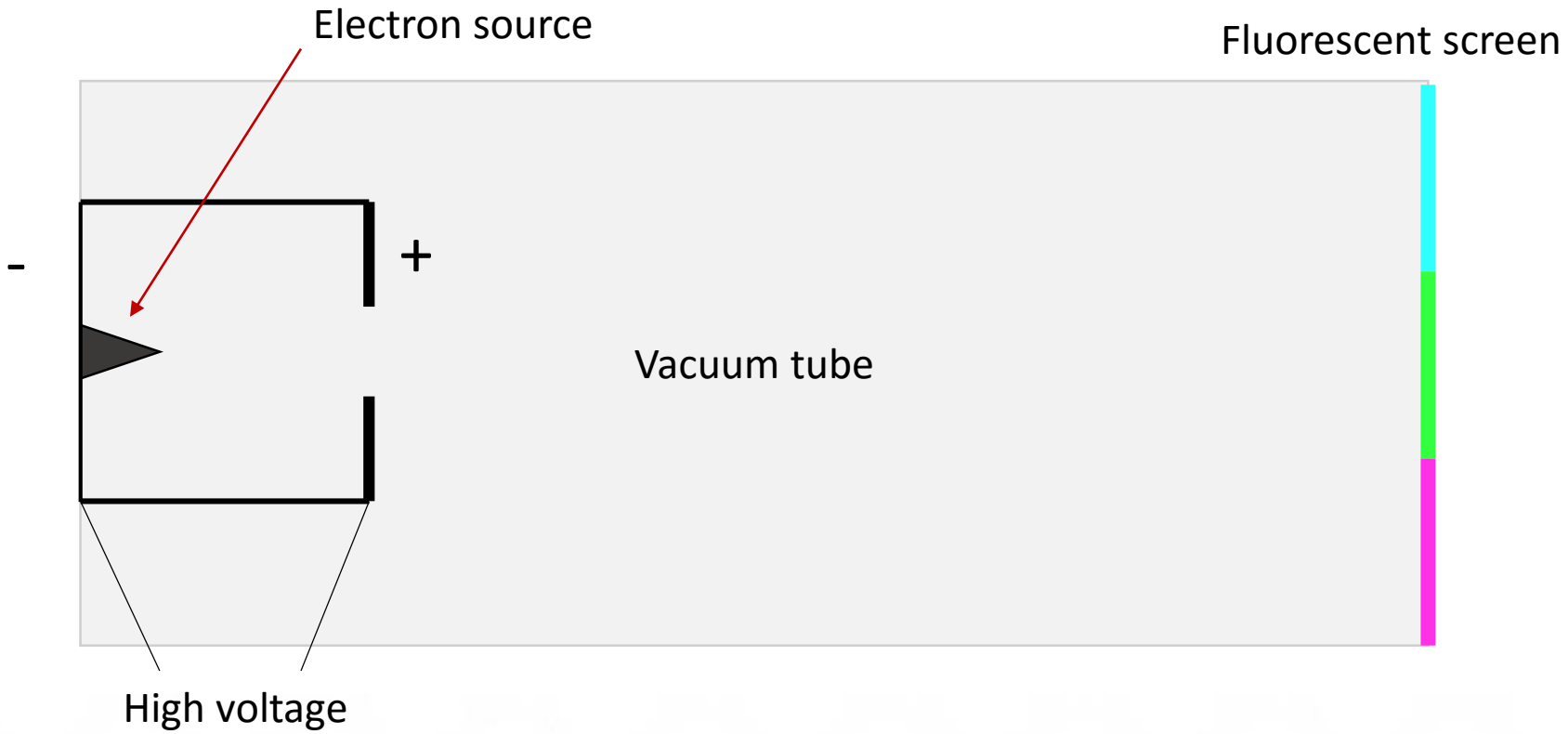
2. What’s cathodoluminescence ?



2. CL: light emission by electron excitation

Screen with cathode-ray tube:

2. CL: light emission by electron excitation



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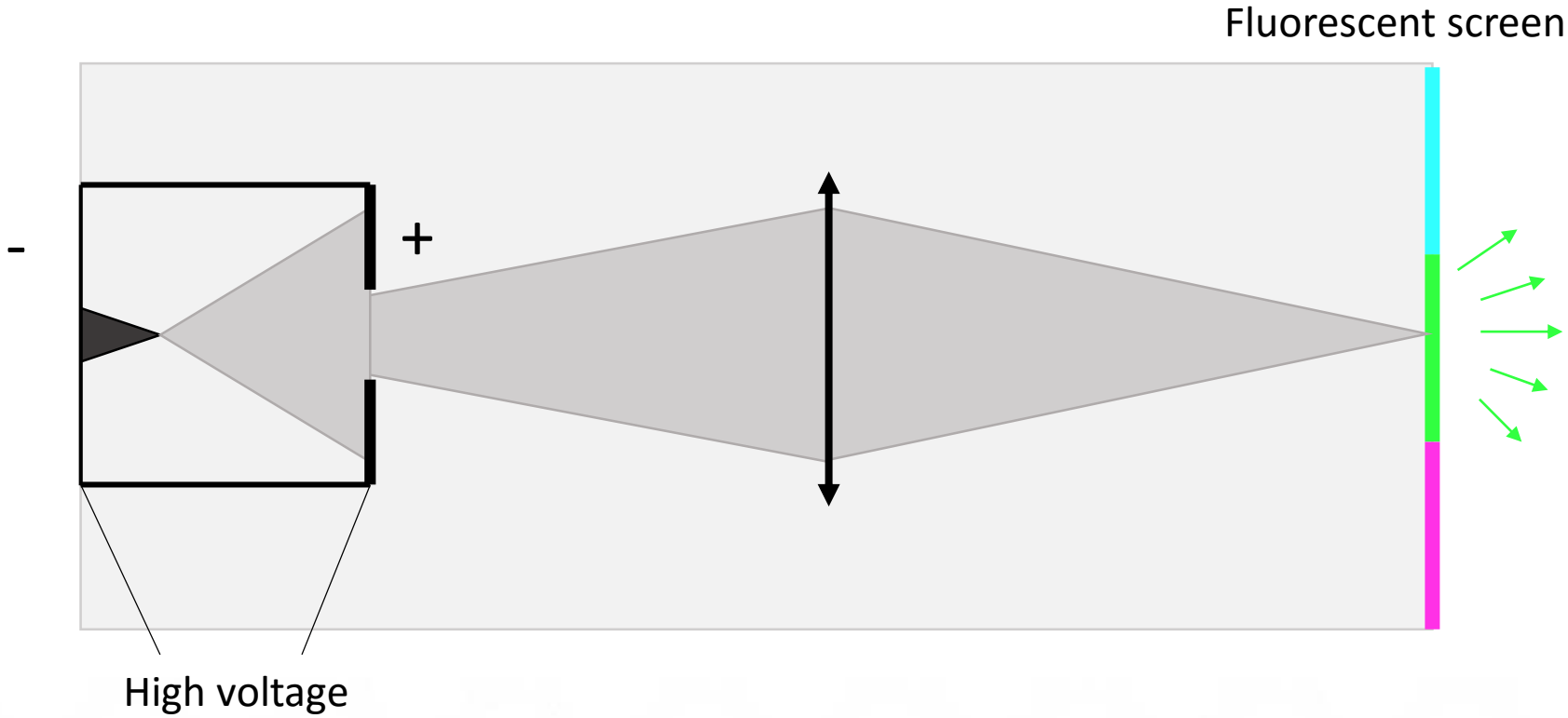
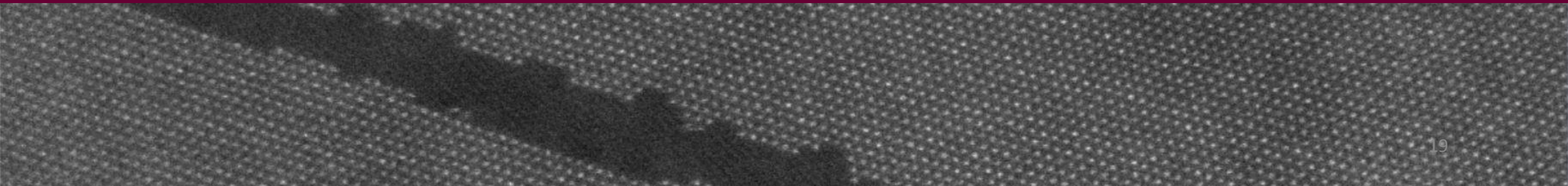
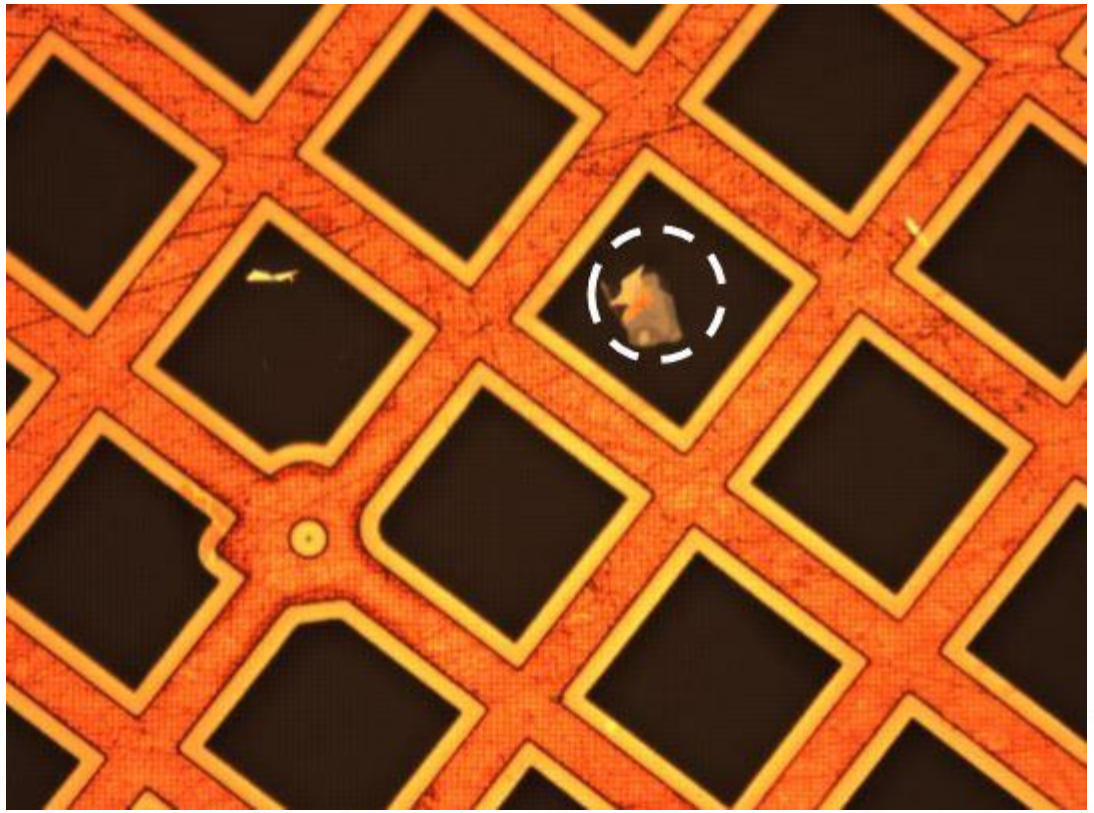
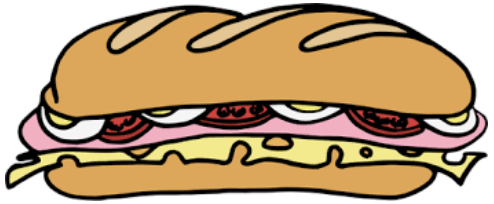


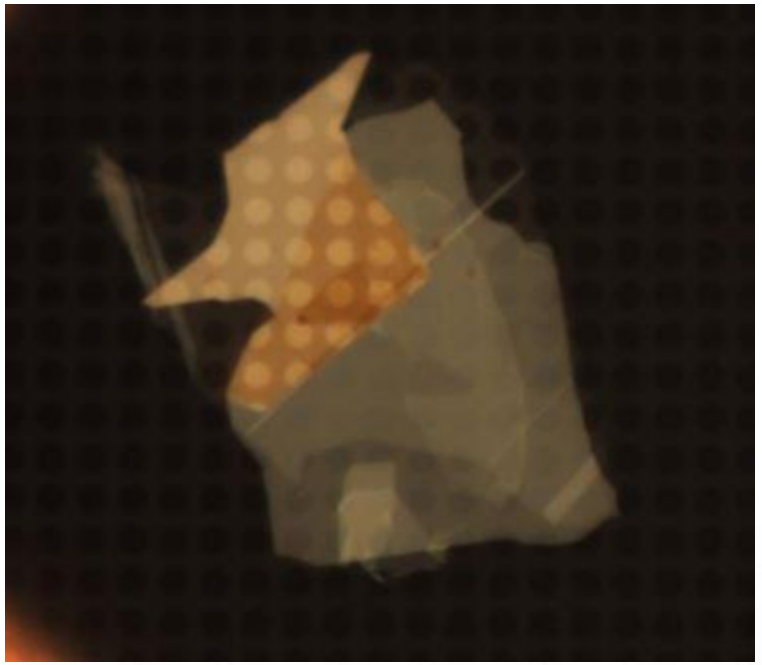
3. How to get it for a monolayer ?



3. Sample geometry: the sandwich !



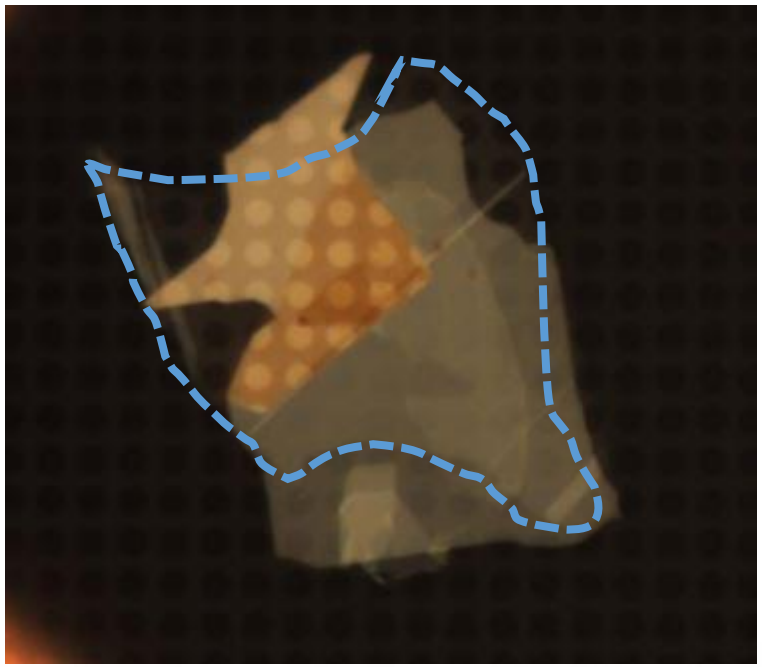




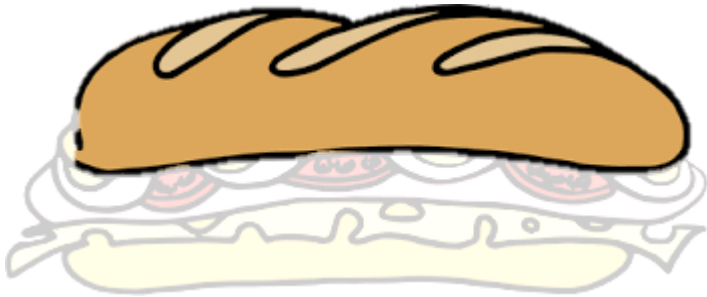
3. Sample geometry: the sandwich !

Hae Yeon Lee,
Silvija Gradečak
(MIT, USA)

Thin hBN 5 nm



h-BN from
Kenji
Watanabe
and Takashi
Taniguchi
(NIMS, Japan)



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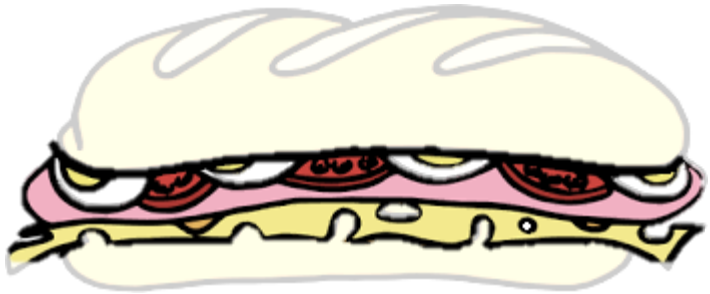
WS_2 monolayer



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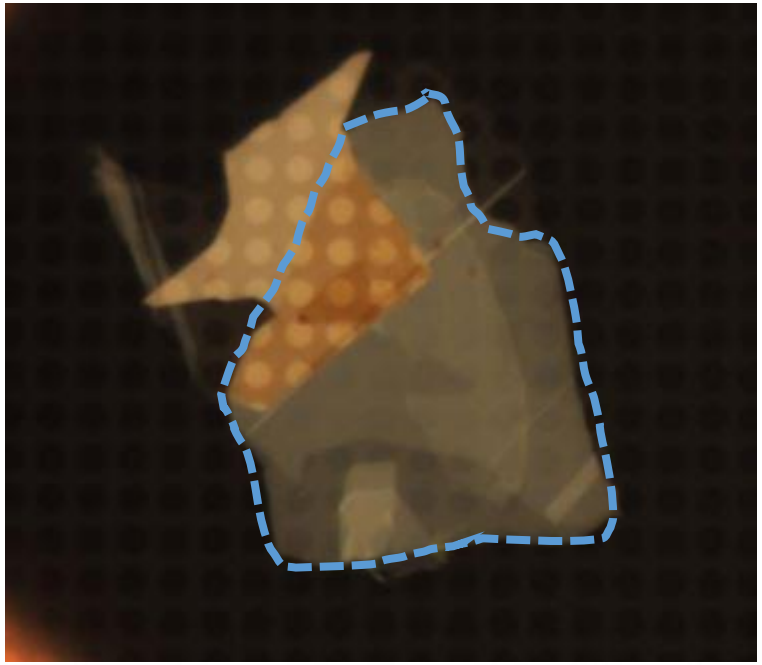
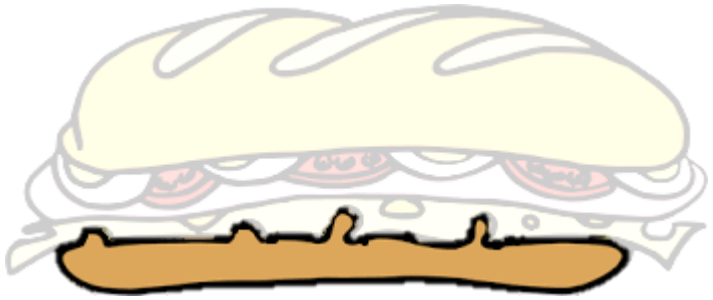
Thick hBN 25 nm





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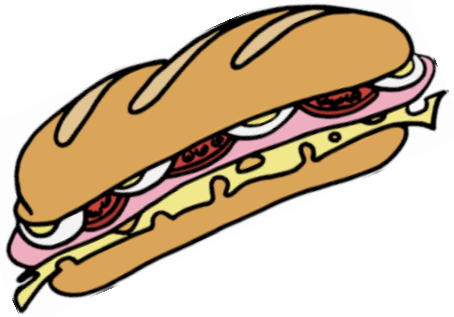

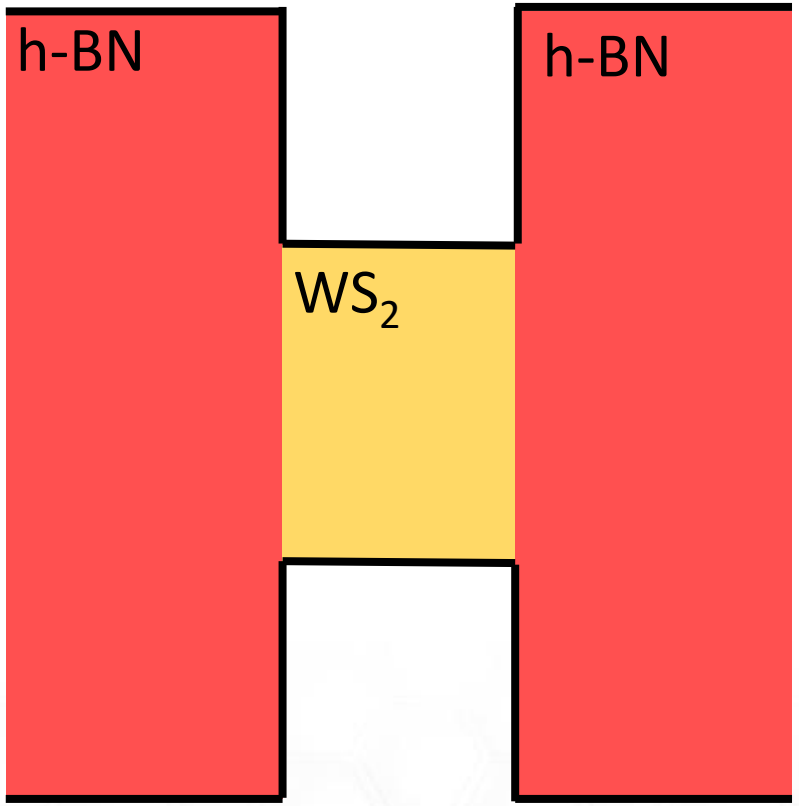

S. Zheng, et al, Nano Lett. **17**, 6475 (2017)

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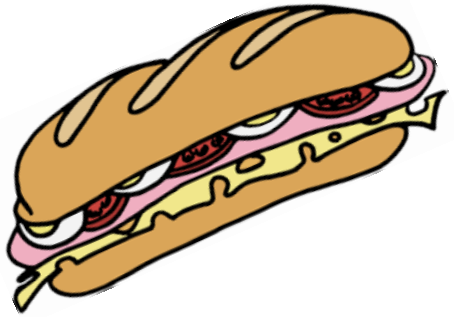

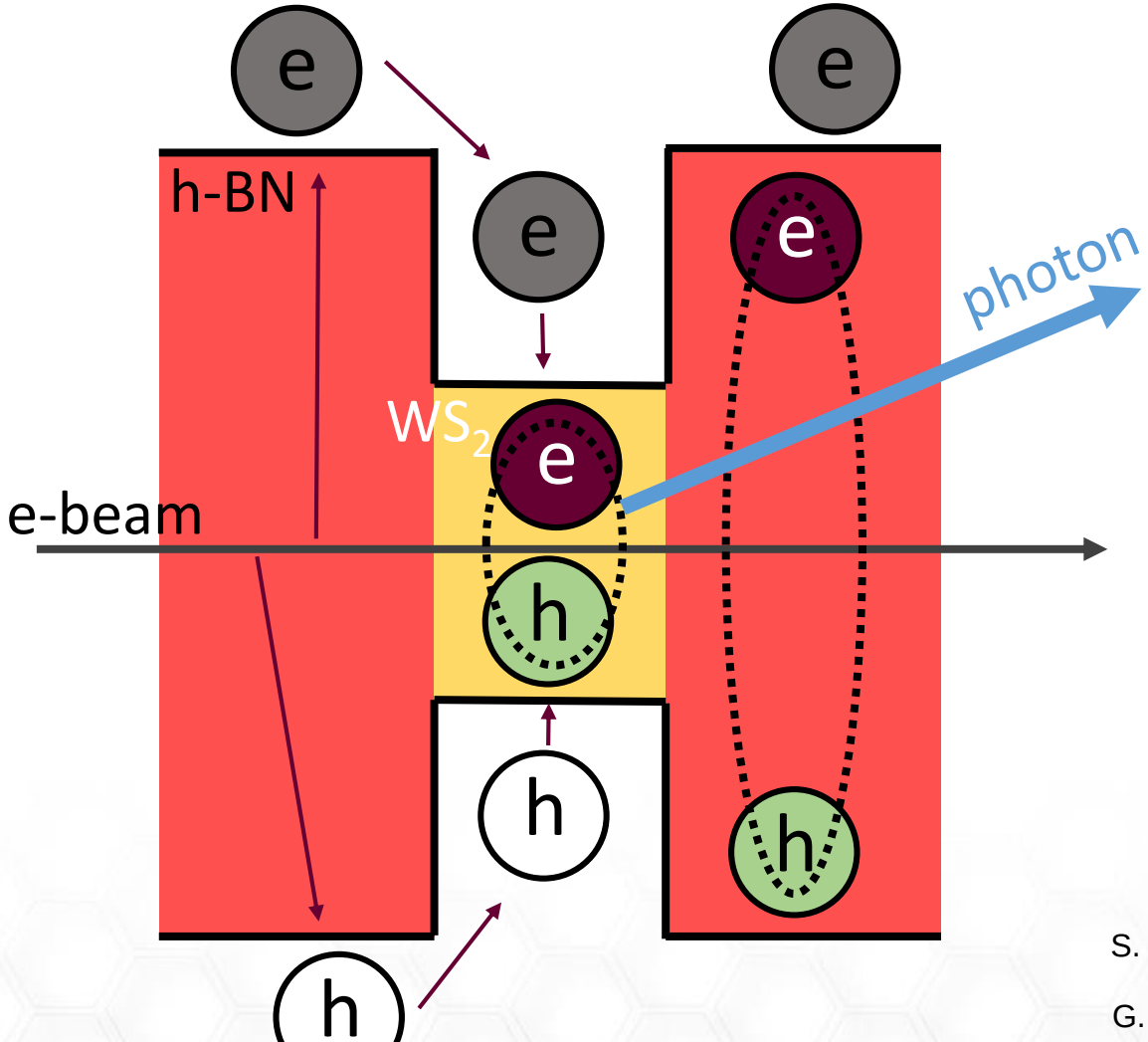

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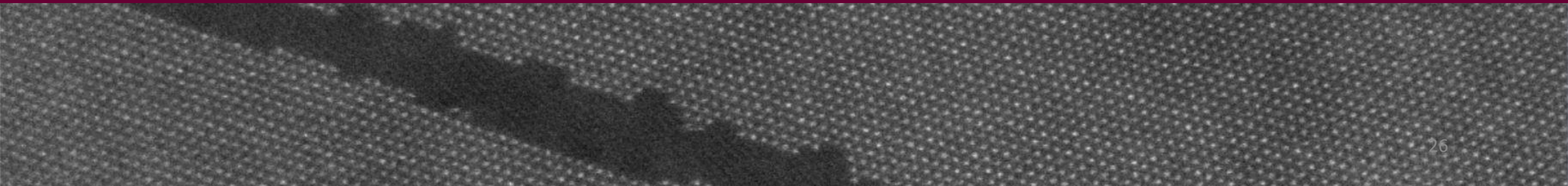
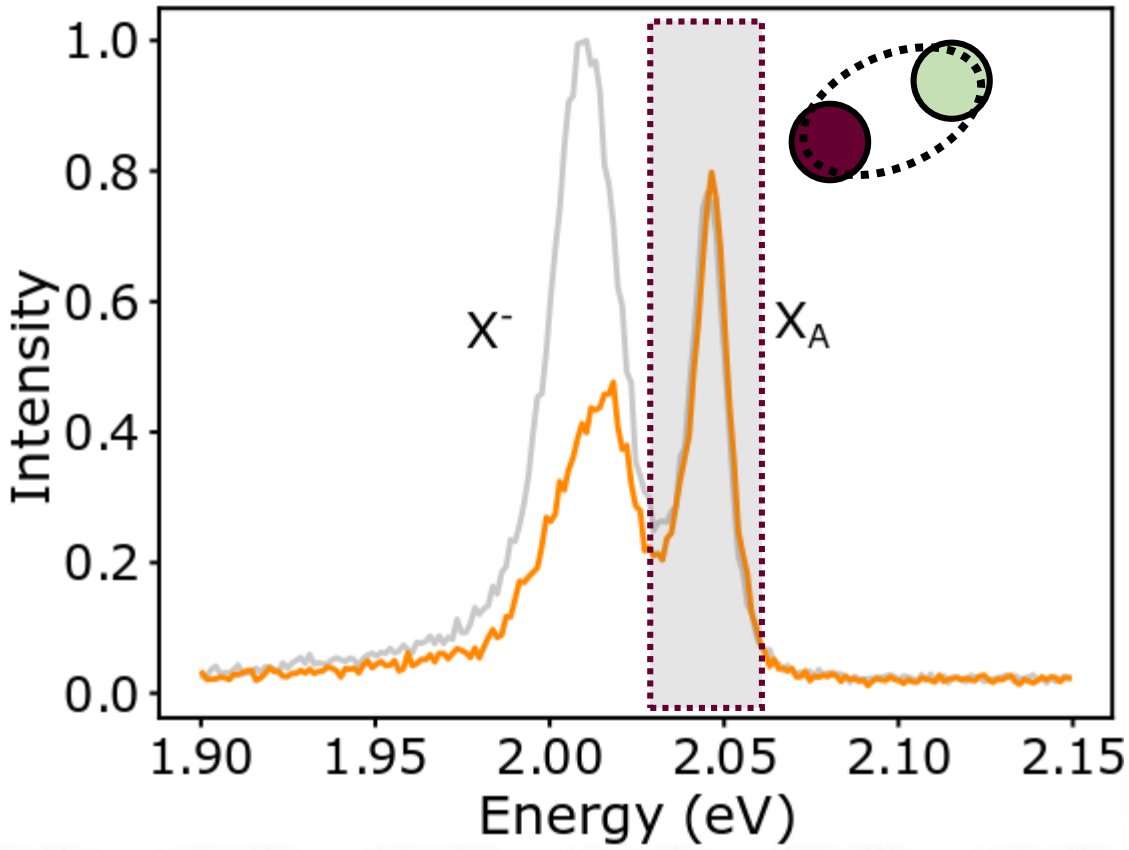
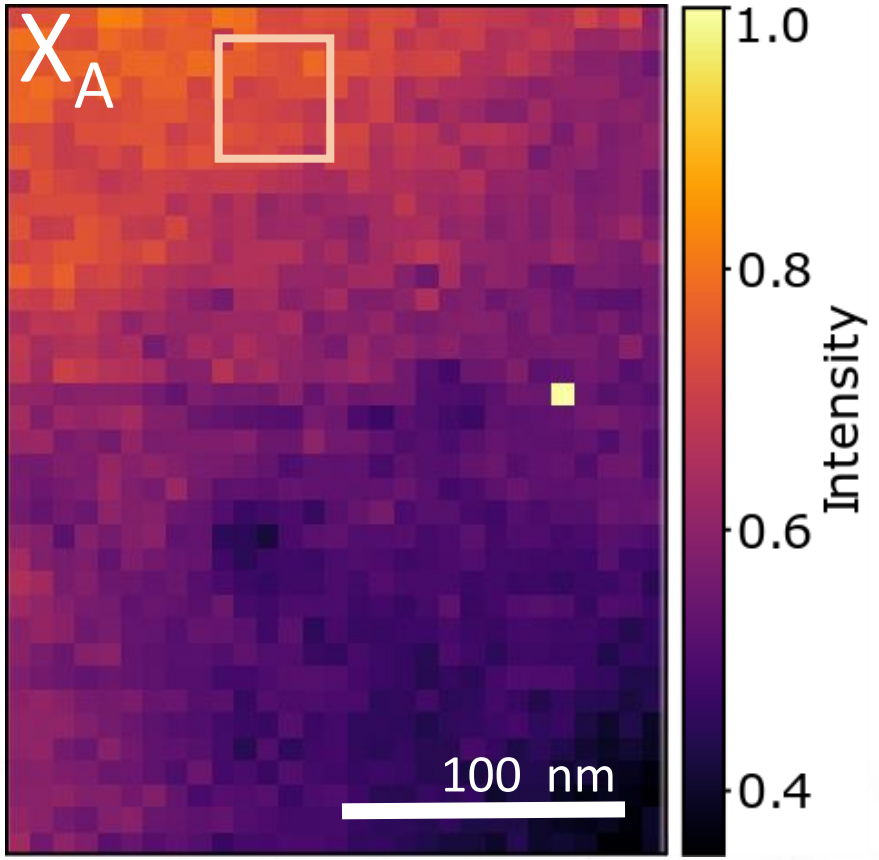
4. What does a measurement look like ?



4. CL





N. Bonnet *et. al,* in submission (2021)

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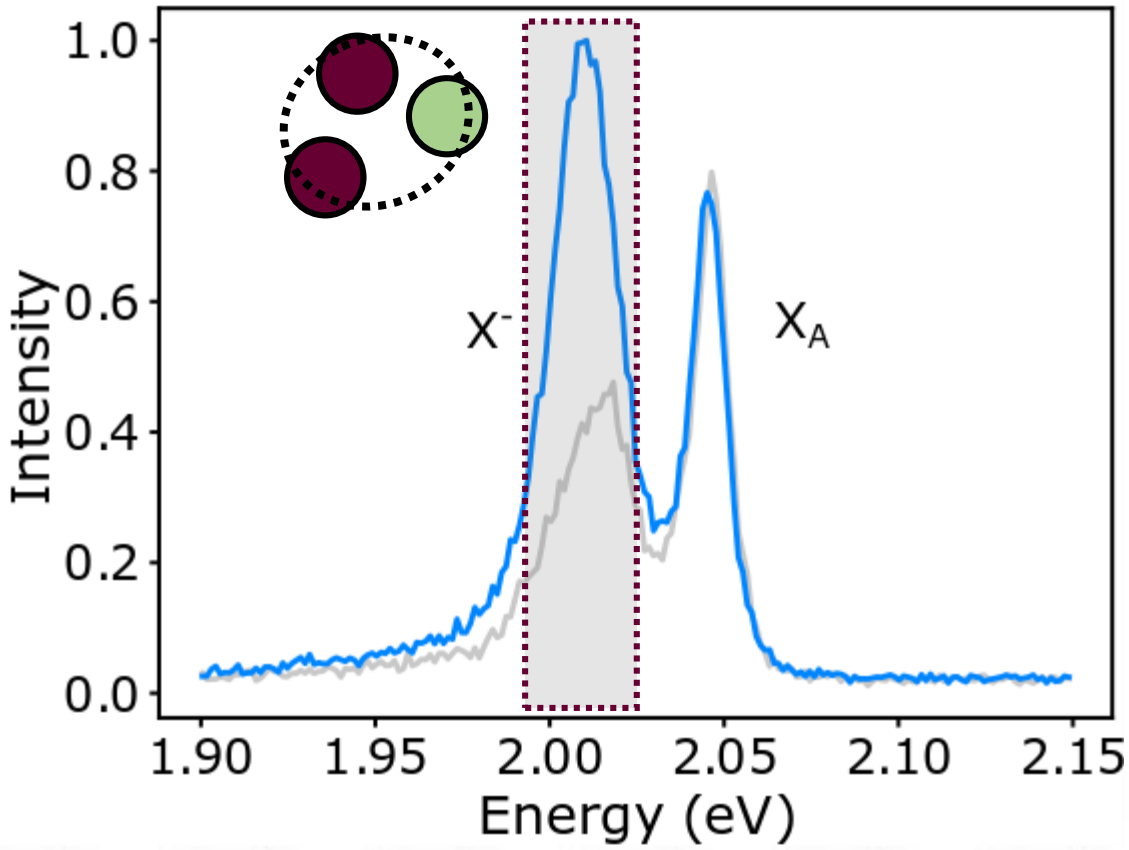

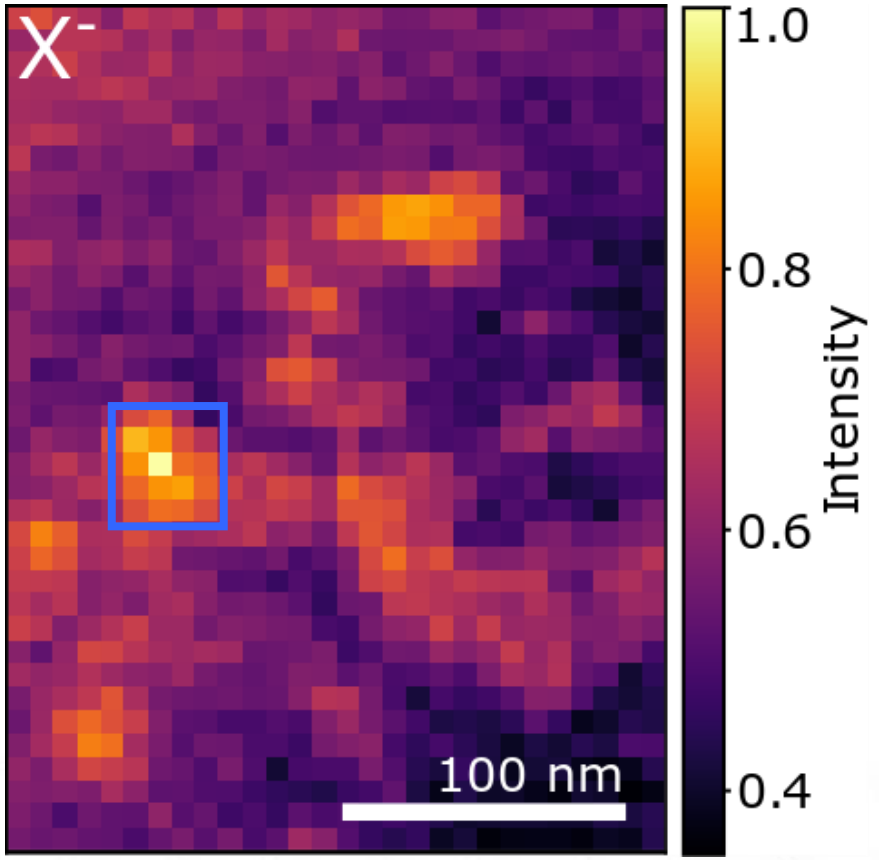

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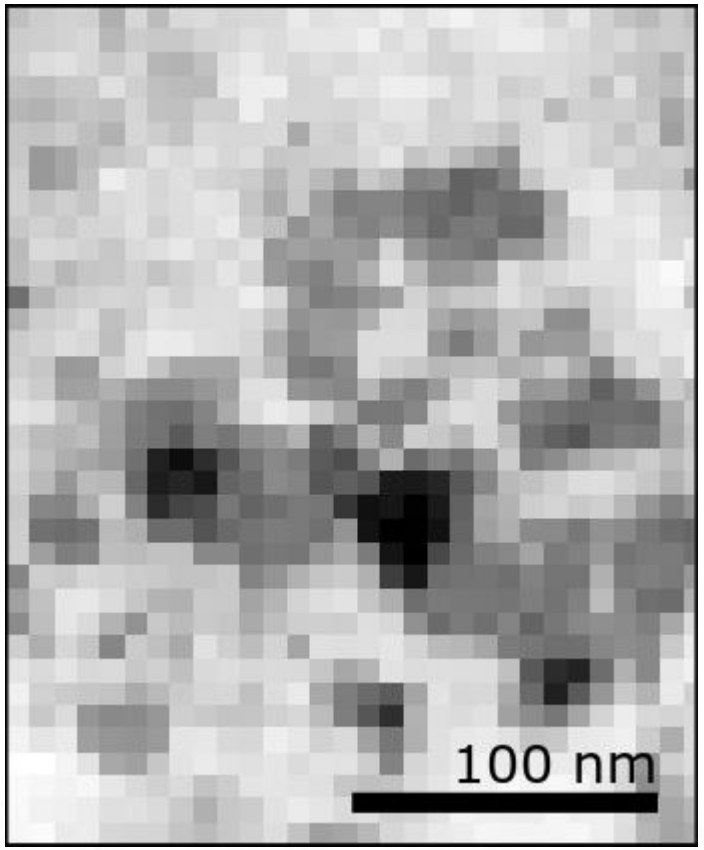
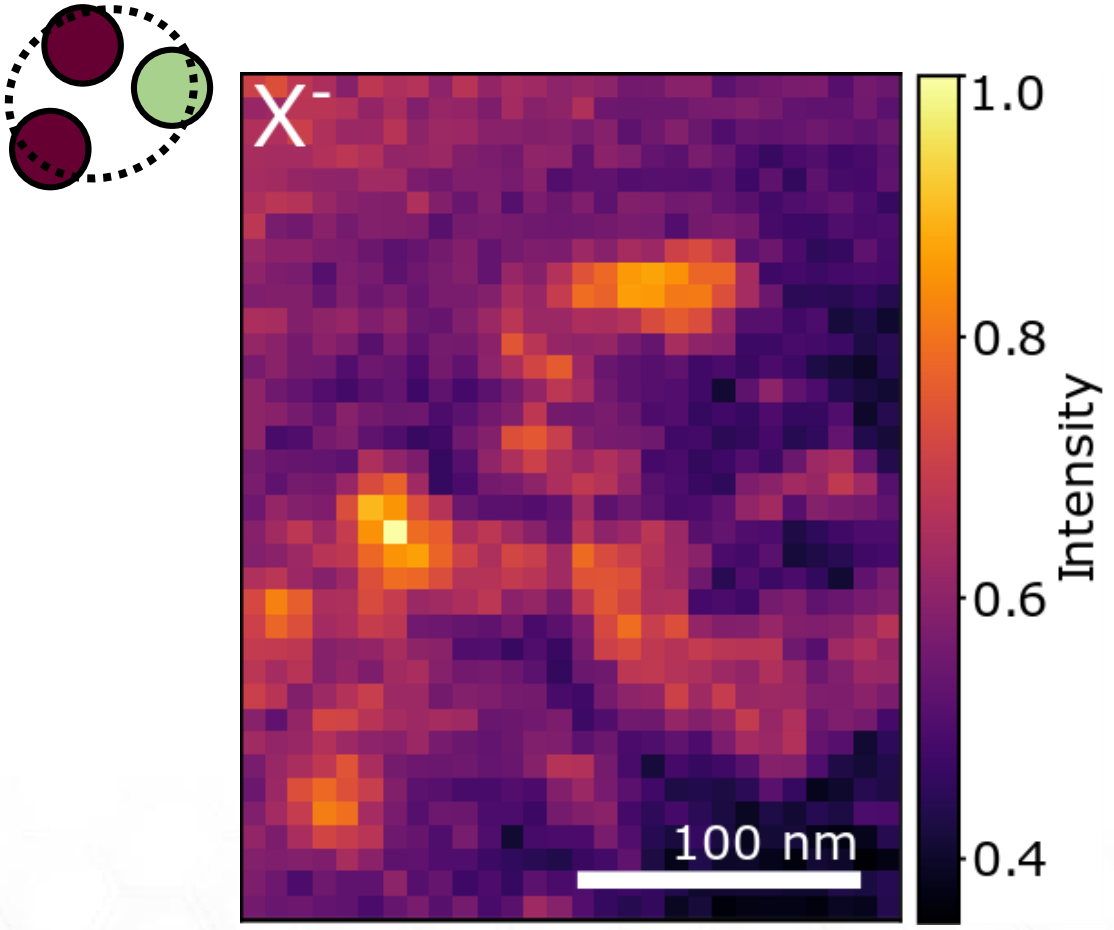
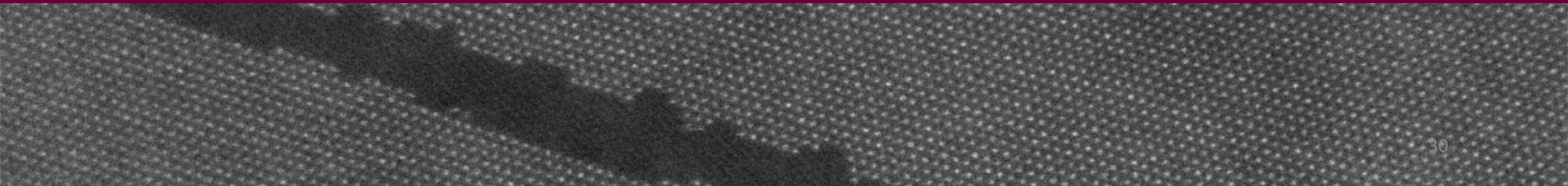




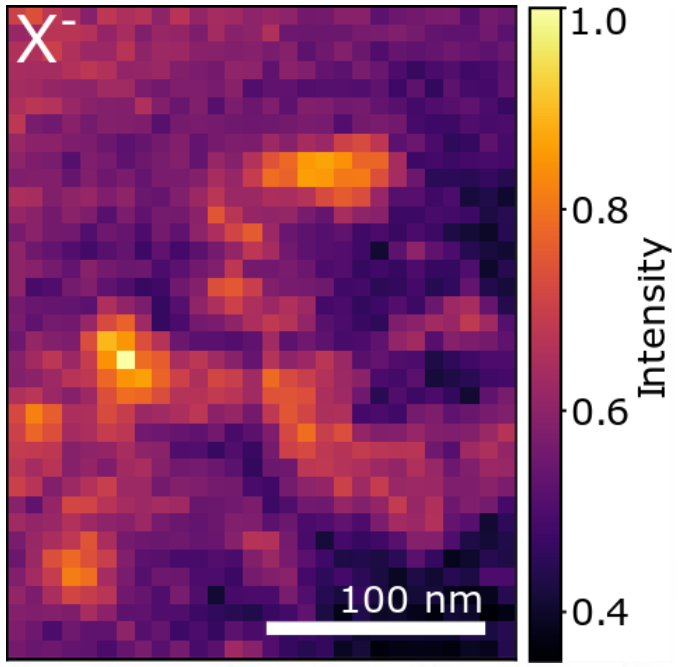
N. Bonnet *et. al,* in submission (2021)

5. Why is it intersting ?



5. Correlation with other measurements

CL



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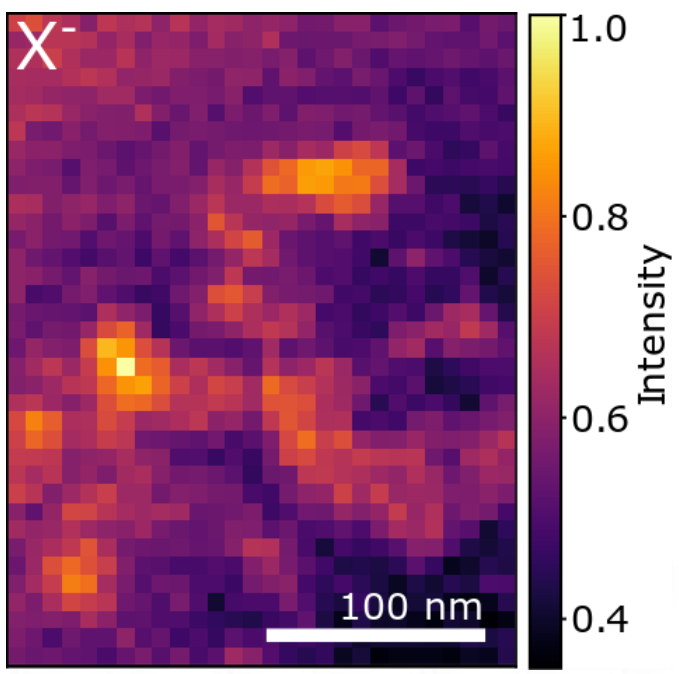
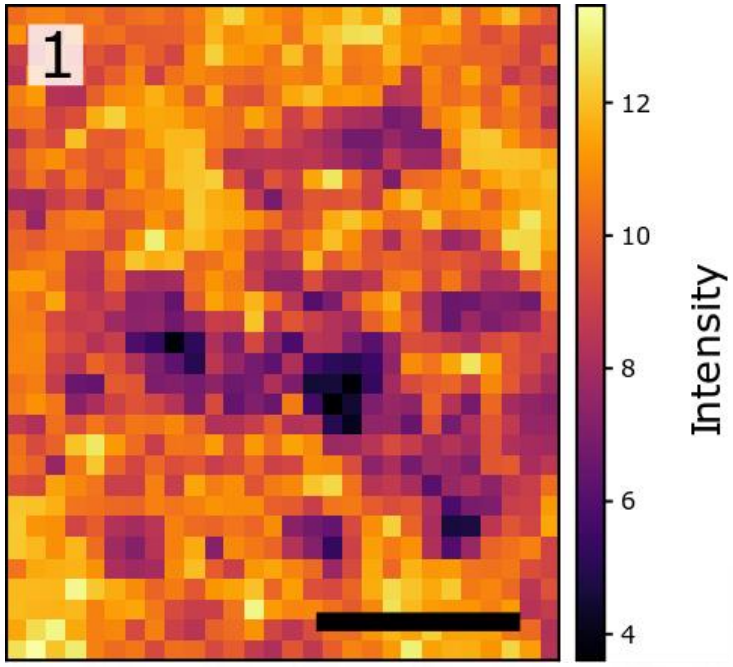


Element mapping



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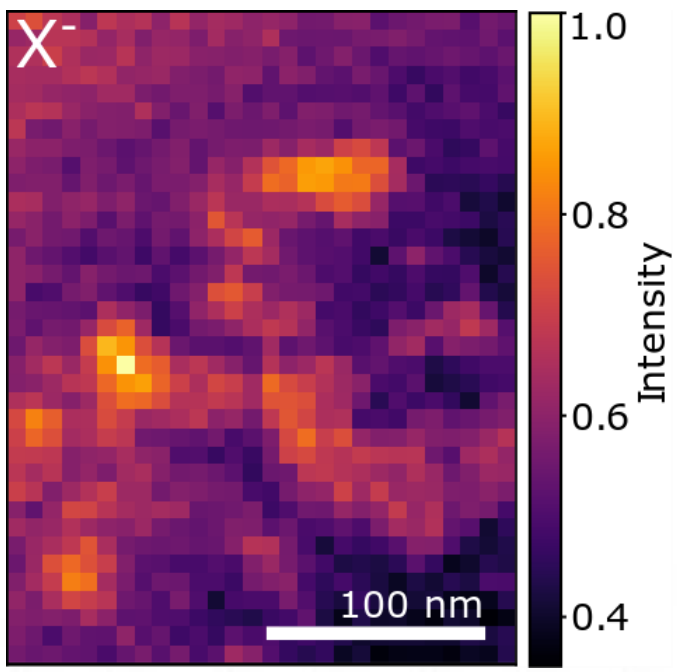

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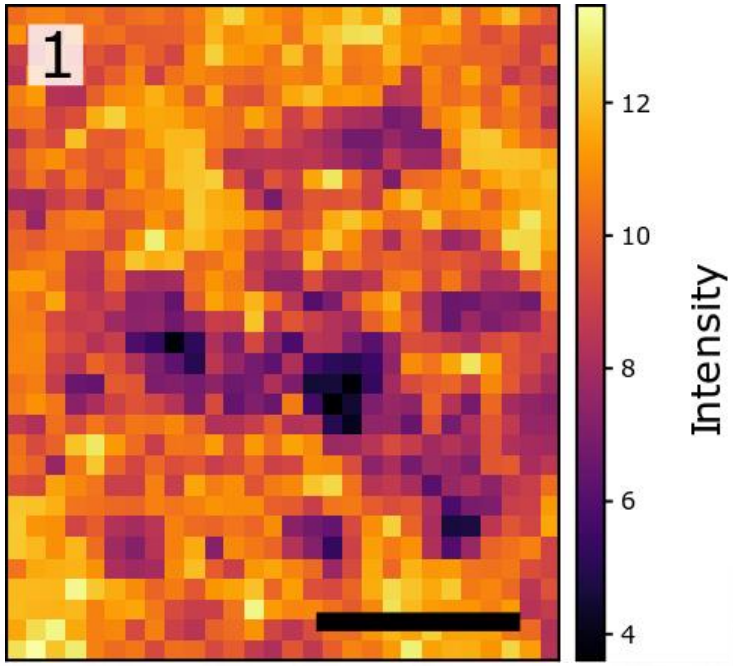
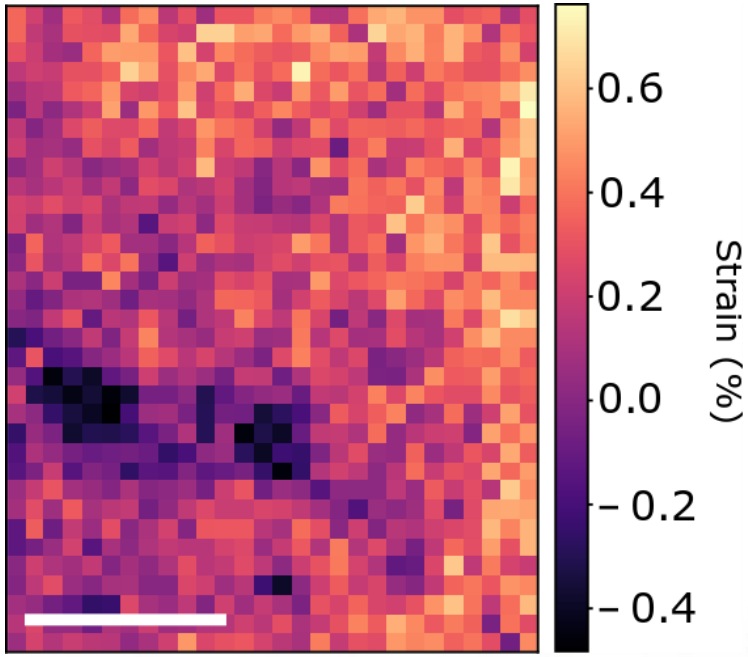


strain



Conclusion

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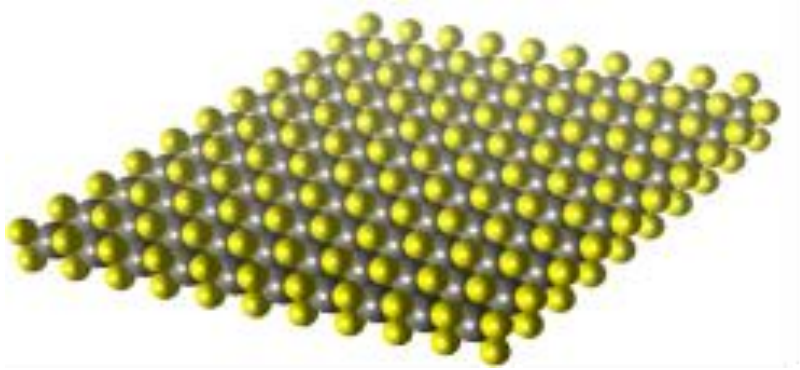

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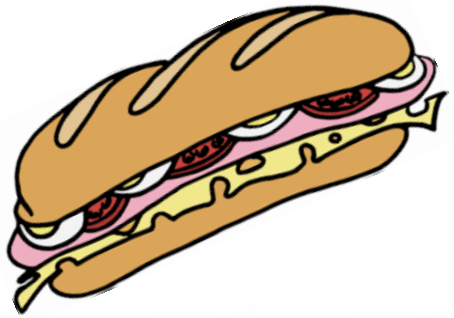
- To do CL measurement in an electron microscope, we used the **sandwich structure**



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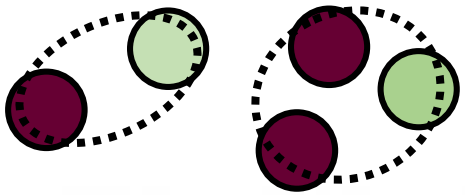
- We found **localized emission** at tens of nanomenters



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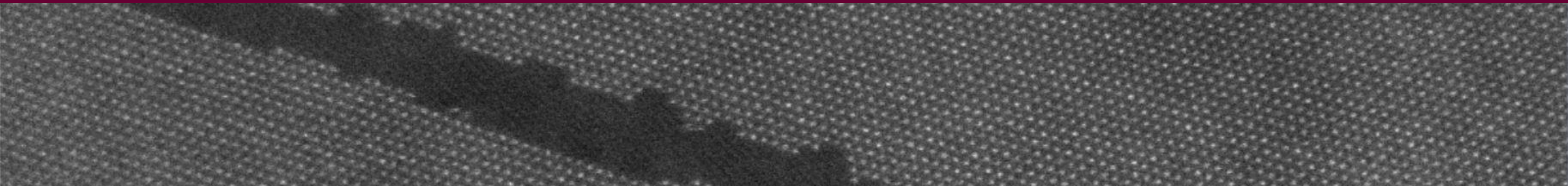
- We found **localized emission** at tens of nanomenters
- On the way to look at quantum emitters and find their structure !

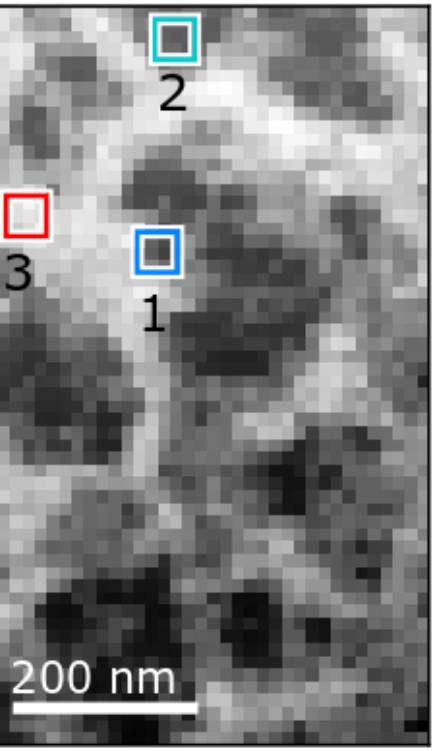
- **Noémie Bonnet[1] – RJP 2021 – noemie.bonnet@universite-paris-saclay.fr**
- H.Y. Lee[2], F. Shao[1], S.Y. Woo[1], K. Watanabe[3], T. Taniguchi[3], A. Zobelli[1], O. Stéphan[1], M. Kociak[1], S. Gradecak-Garaj[2], L.H.G. Tizei[1]

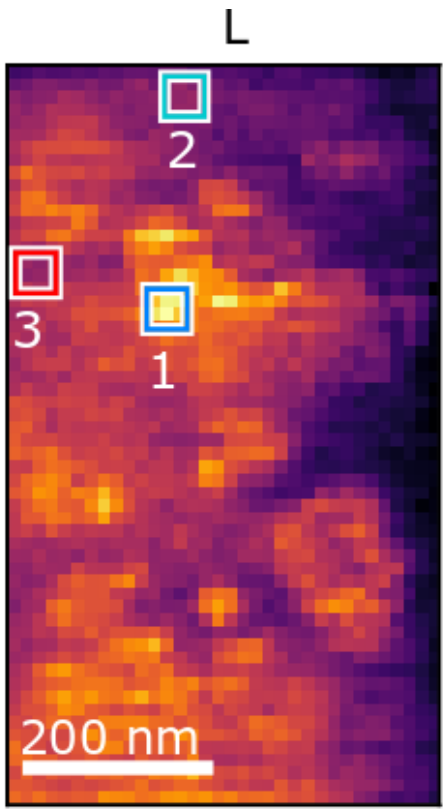
- **N. Bonnet *et. al*, arXiv:2102.06140 [cond-mat.mes-hall]**

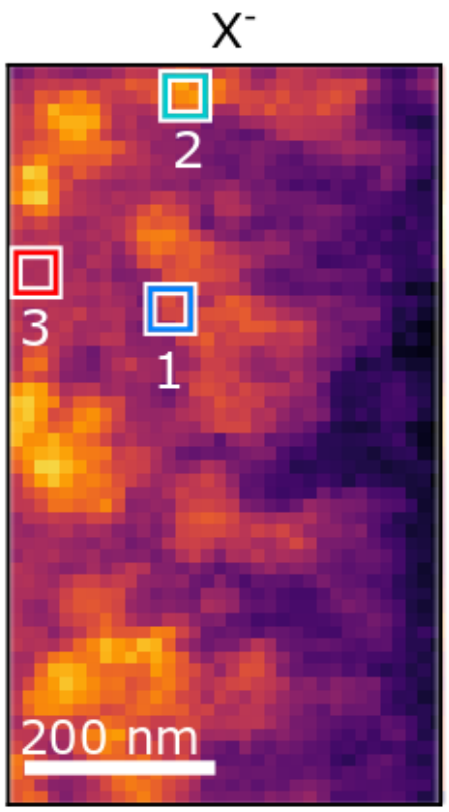
Thank you !

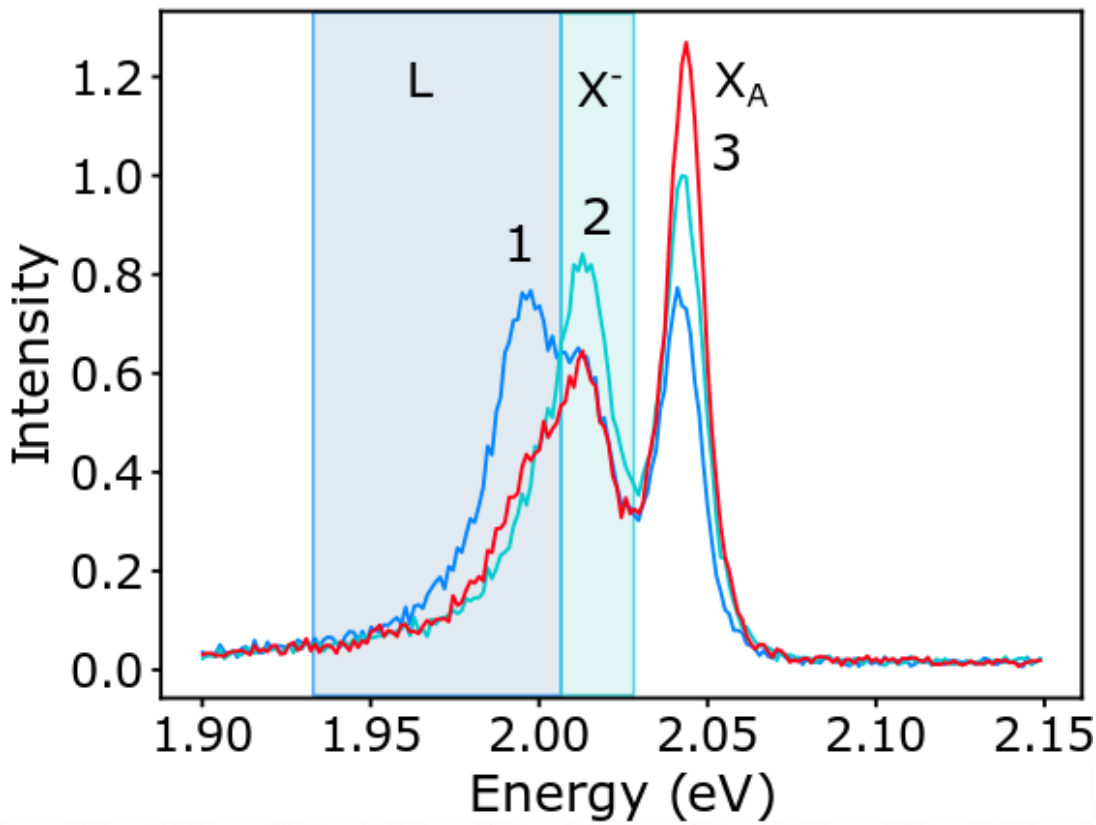


Perspectives – Localized excitons



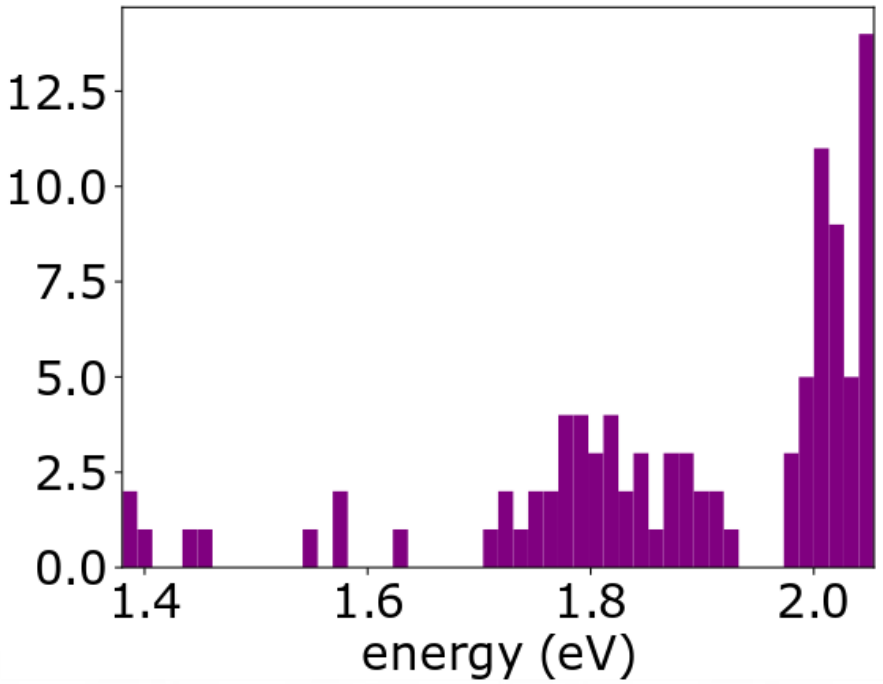


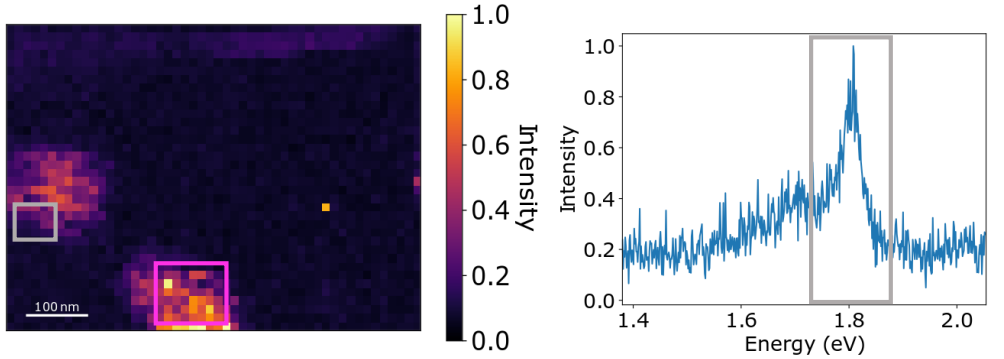


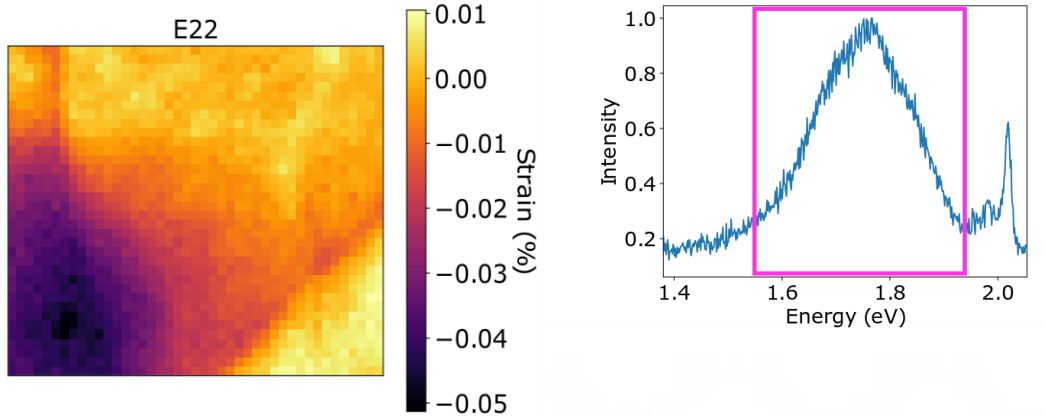


N. Bonnet *et. al,* in submission (2021)

Perspectives – Localized excitons

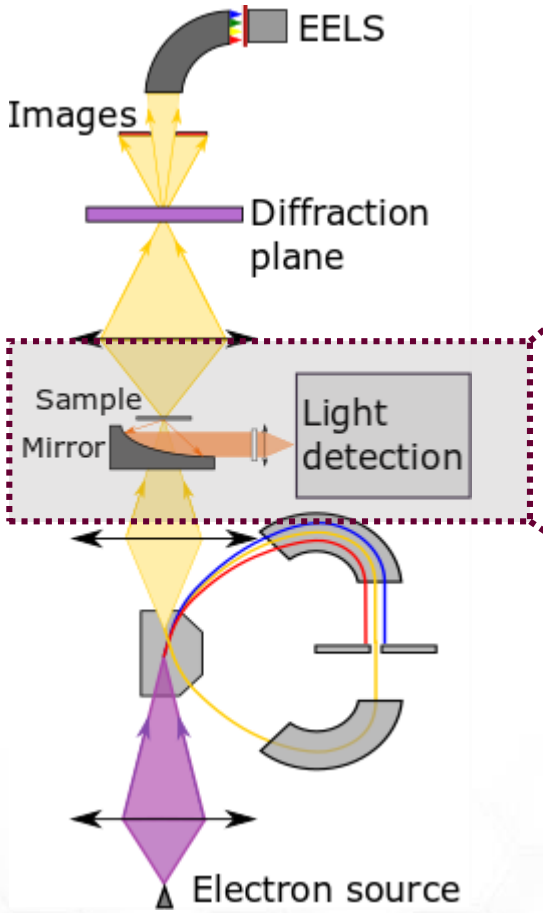


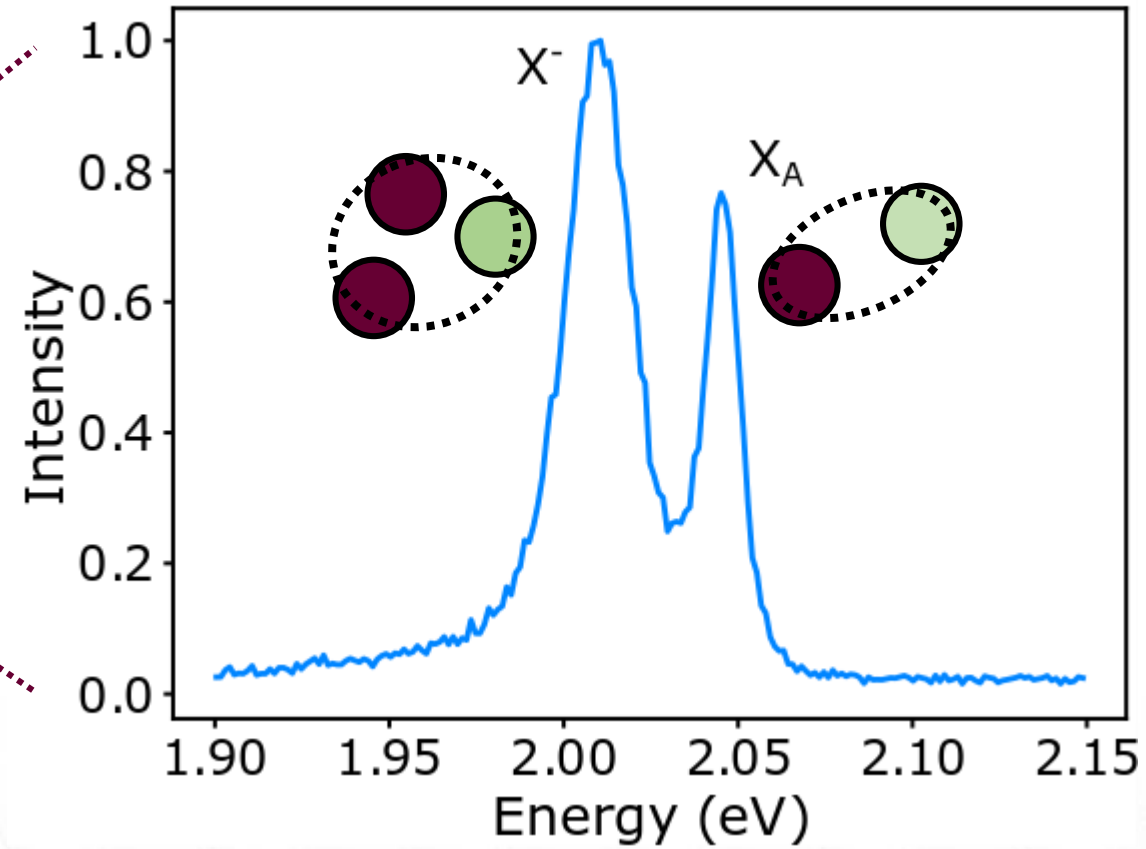




N. Bonnet *et. al,* unpublished (2021)

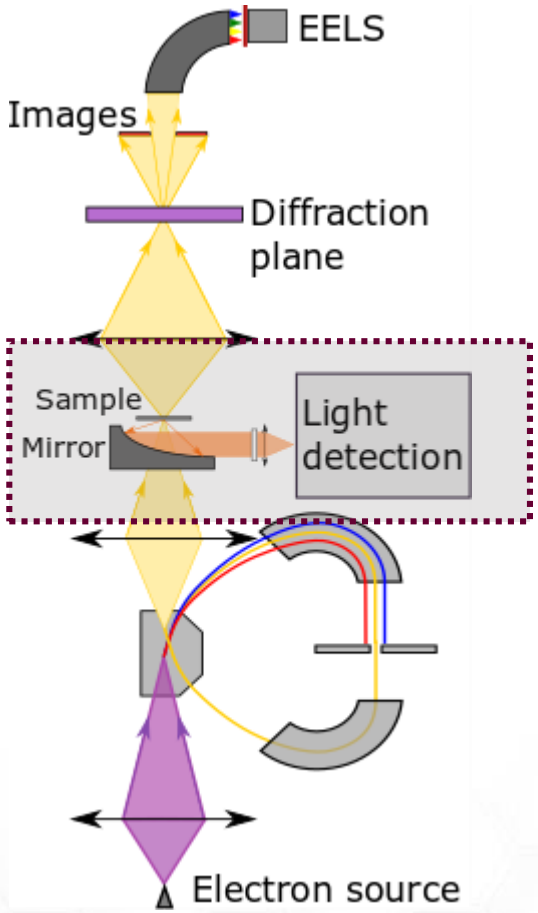
3. Cathodoluminescence measurements



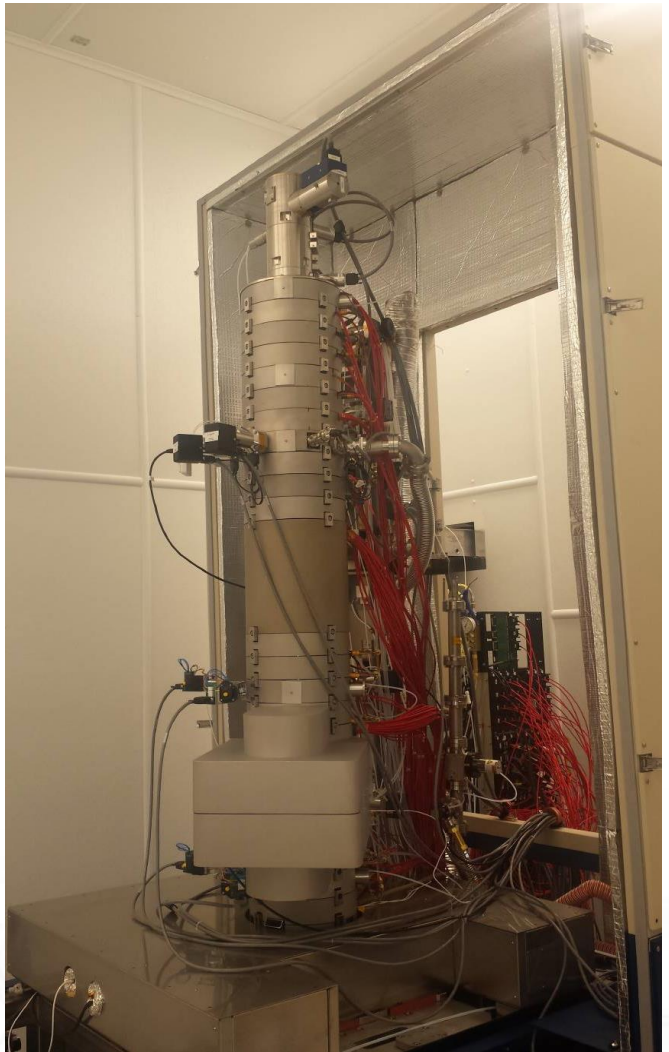


N. Bonnet *et. al,* in submission (2021)

Microscope used

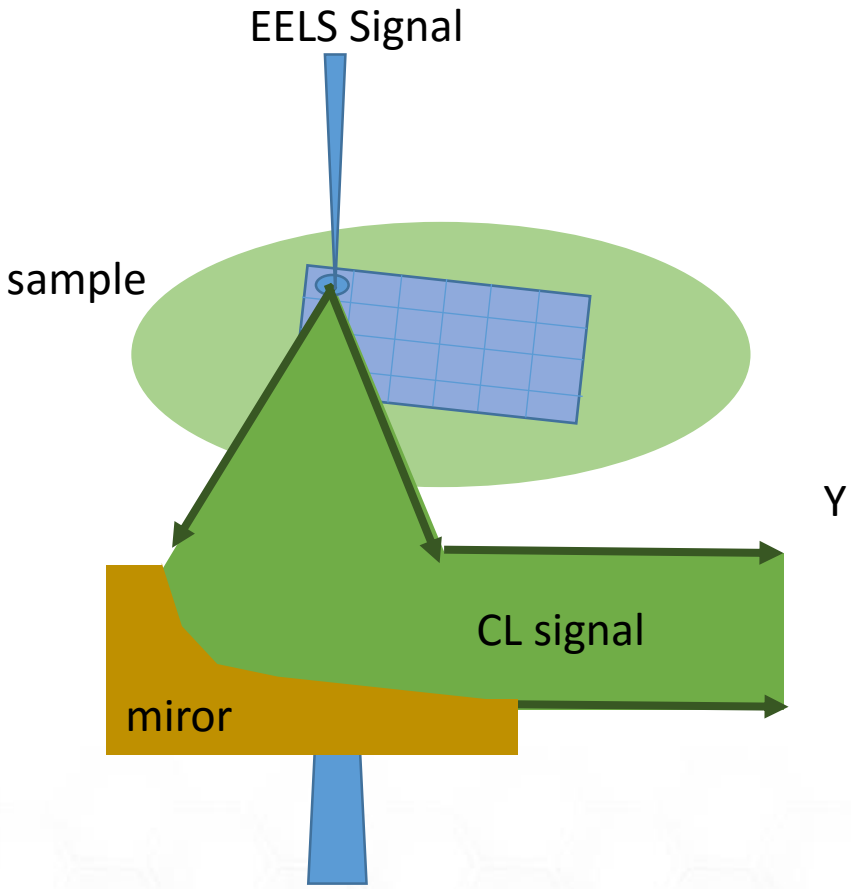


N. Bonnet *et. al,* in submission (2021)



Measured in ChromaTEM (Nion Hermes200)
60kV
Temp. 150K
10 mrad (conv.)
30-40 mrad (coll.)

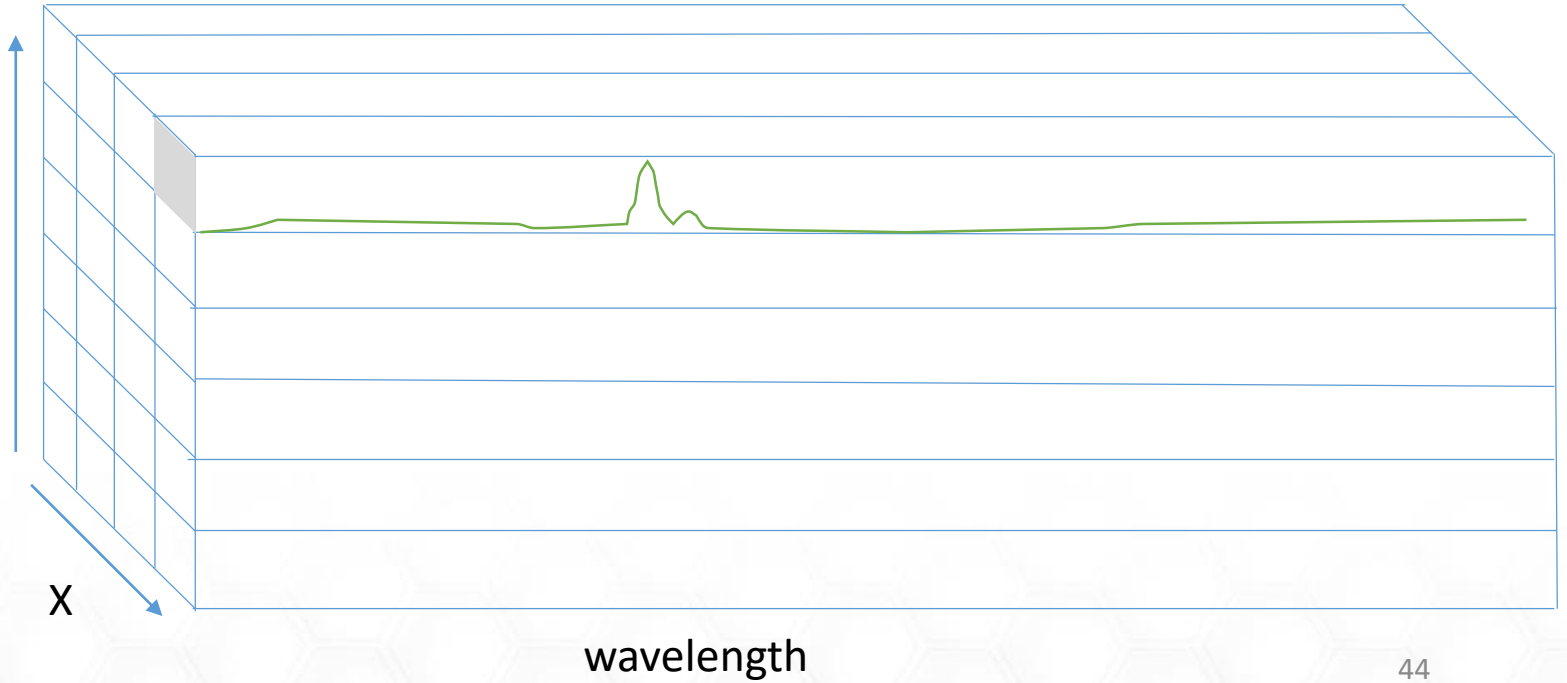
Spatial limitations



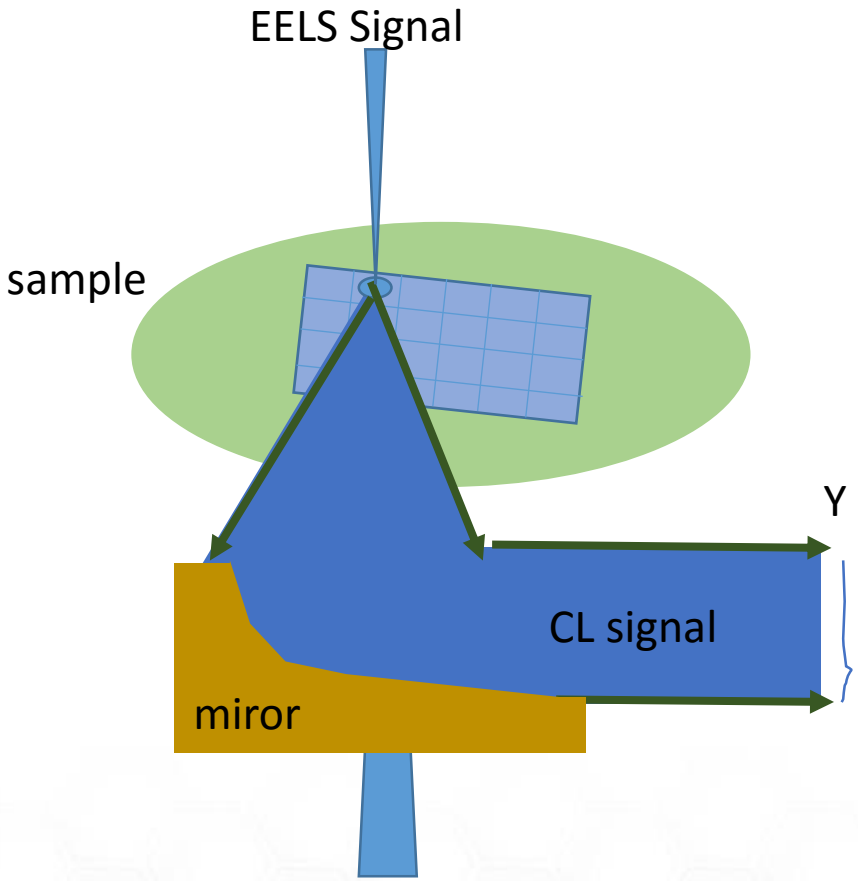
HYPERSPECTRAL IMAGING

Data analysis:

HyperSpy
multi-dimensional data analysis



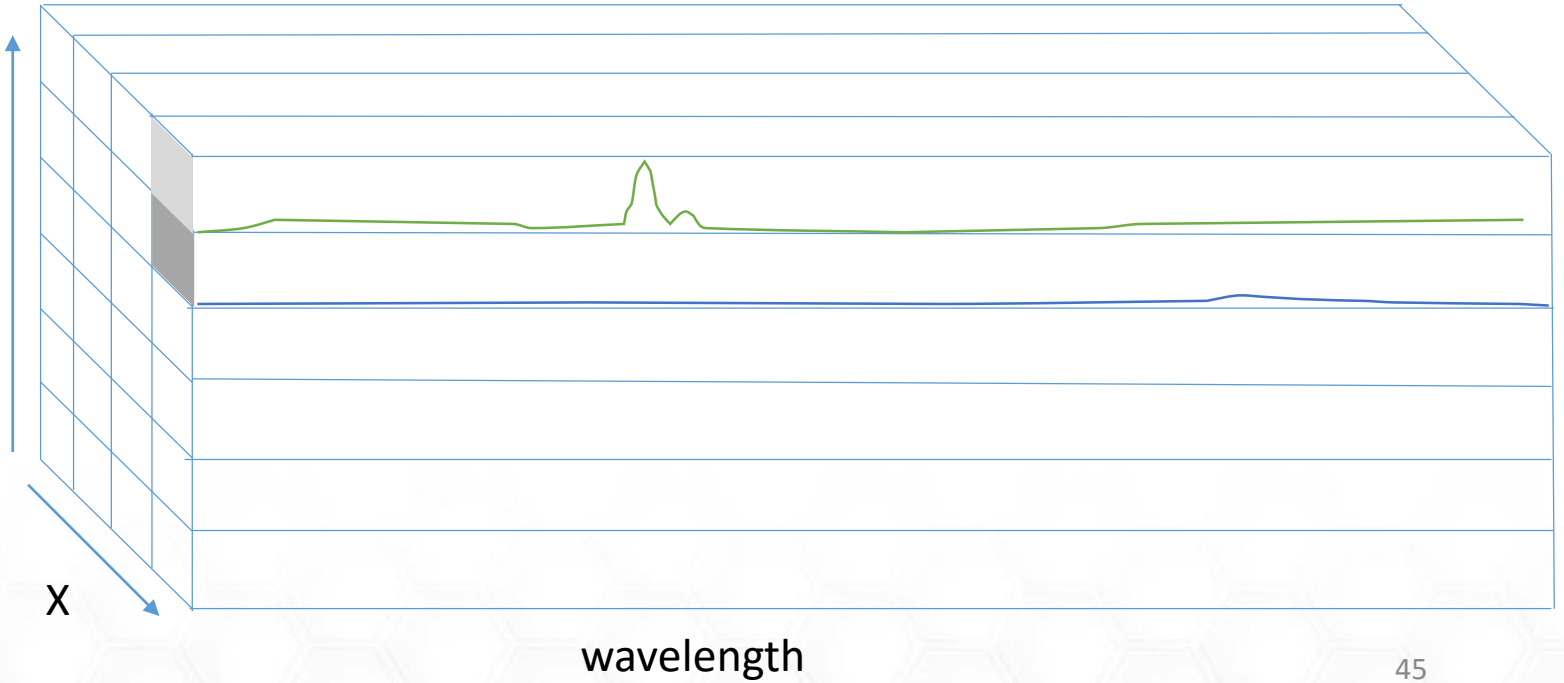
Spatial limitations



HYPERSPECTRAL IMAGING

Data analysis:

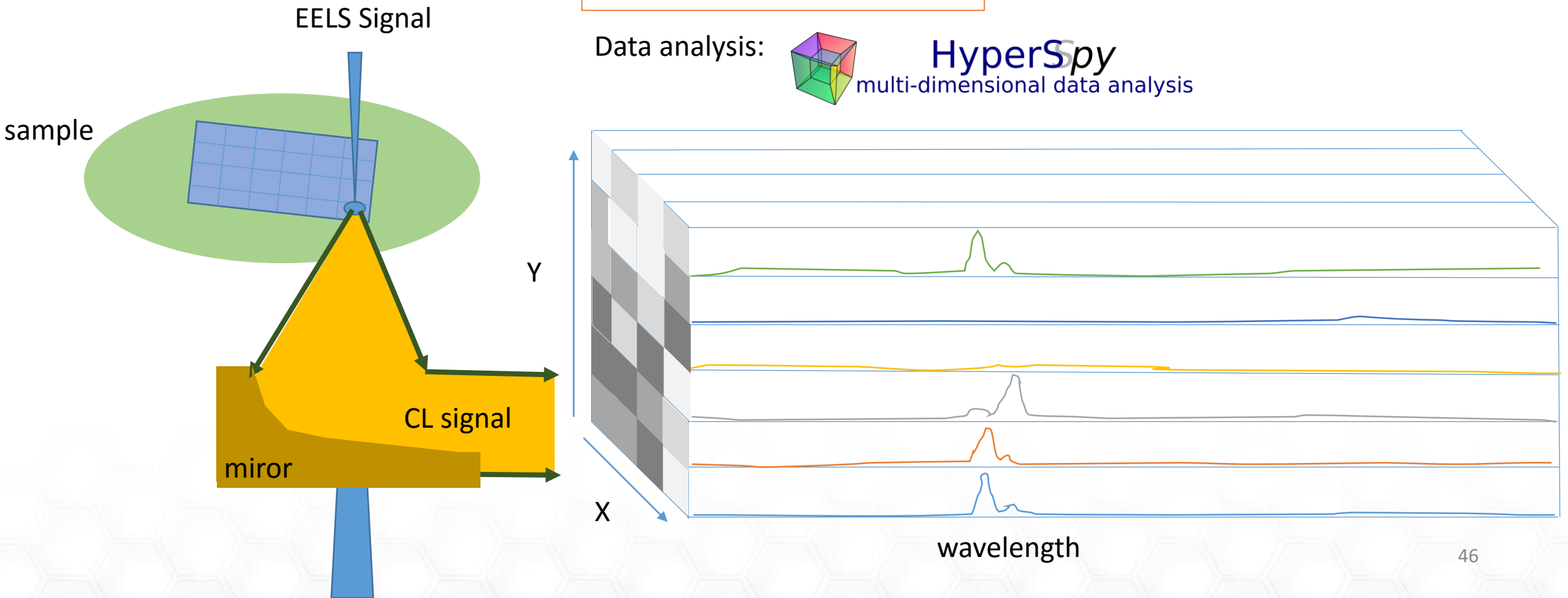
HyperSpy
multi-dimensional data analysis



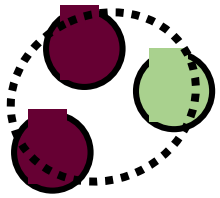
Spatial limitations

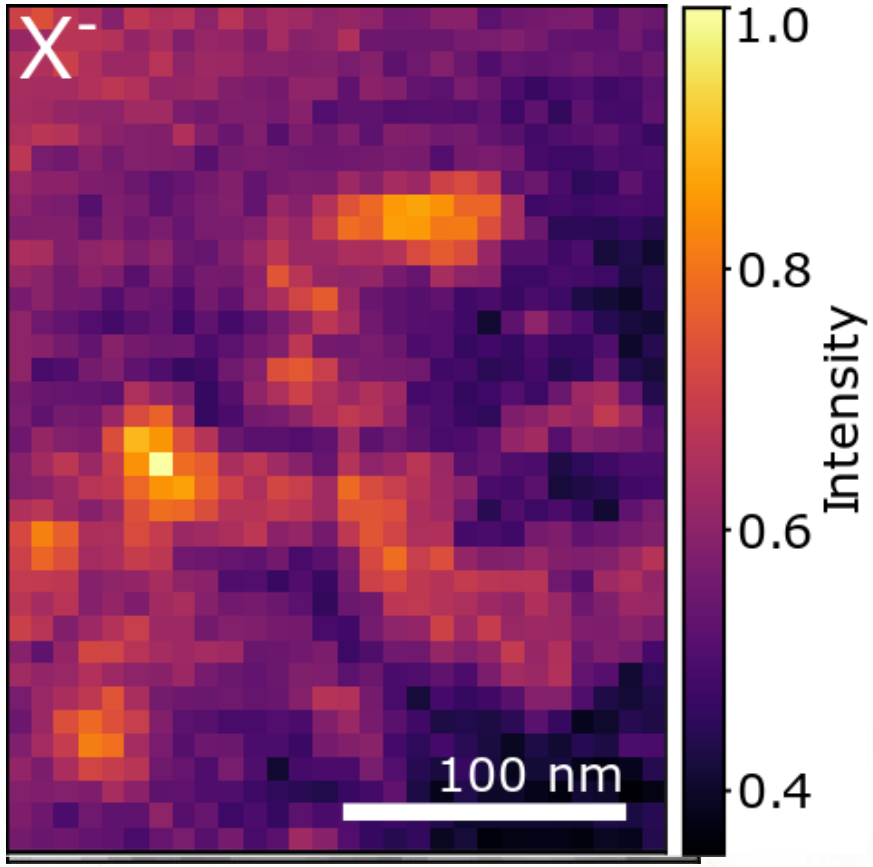
HYPERSPECTRAL IMAGING

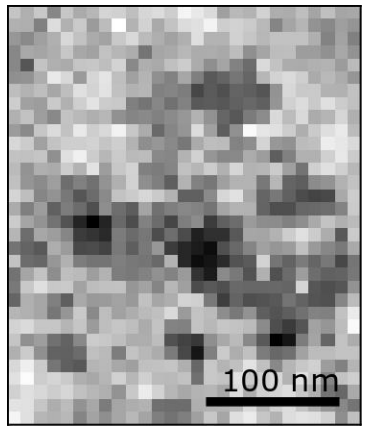
Data analysis: HyperSpy multi-dimensional data analysis

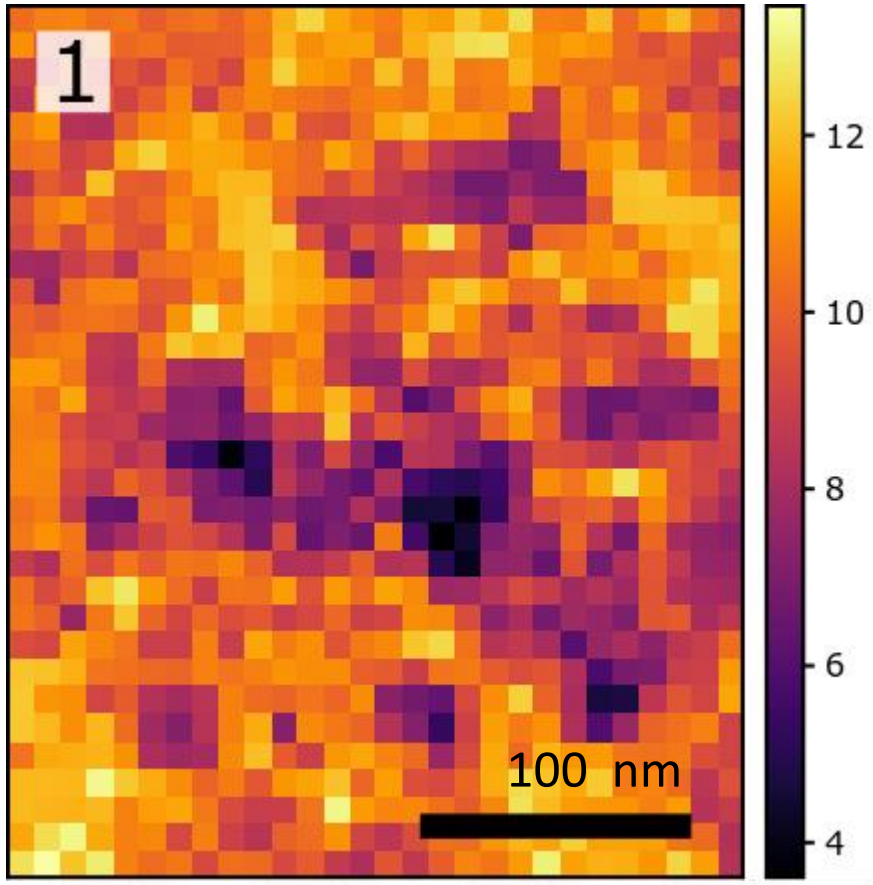


5. EELS core loss measurements









N. Bonnet *et. al,* arXiv:2102.06140 [cond-mat.mes-hall]

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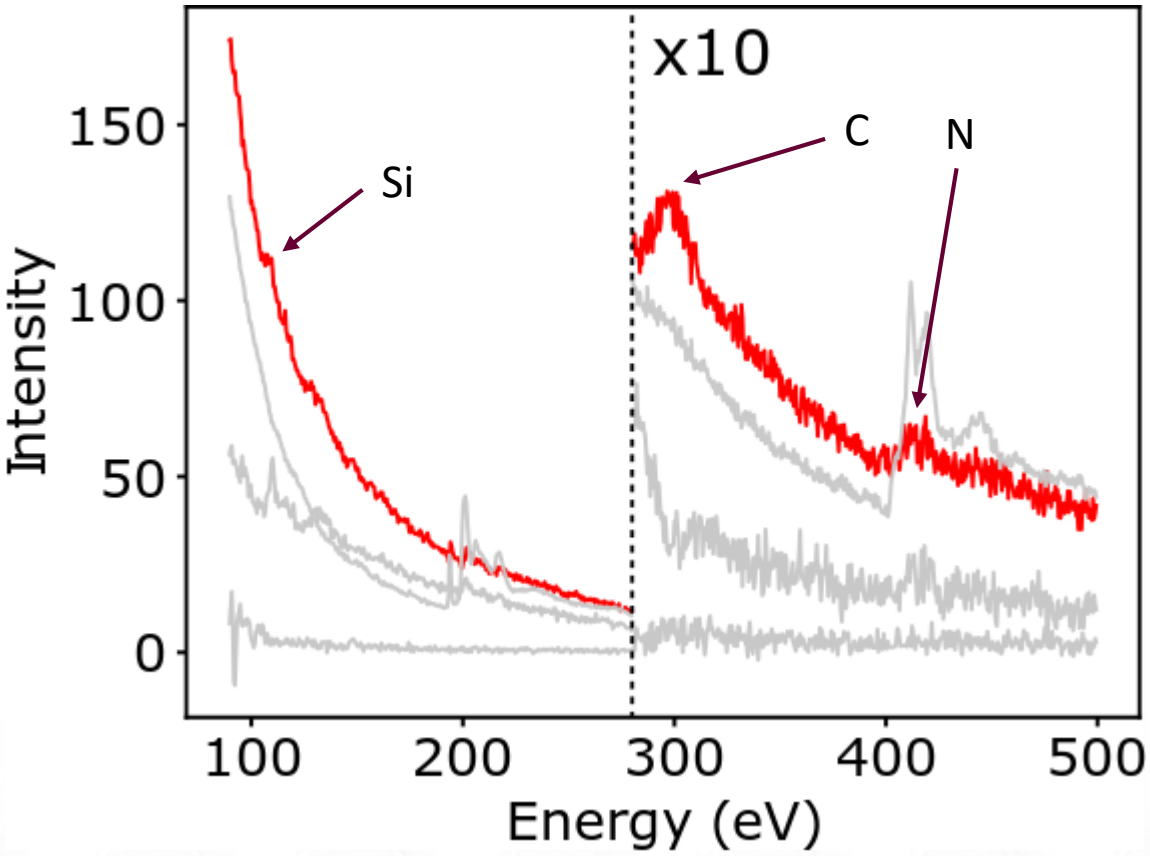

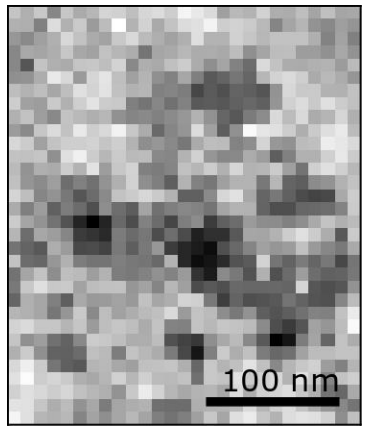

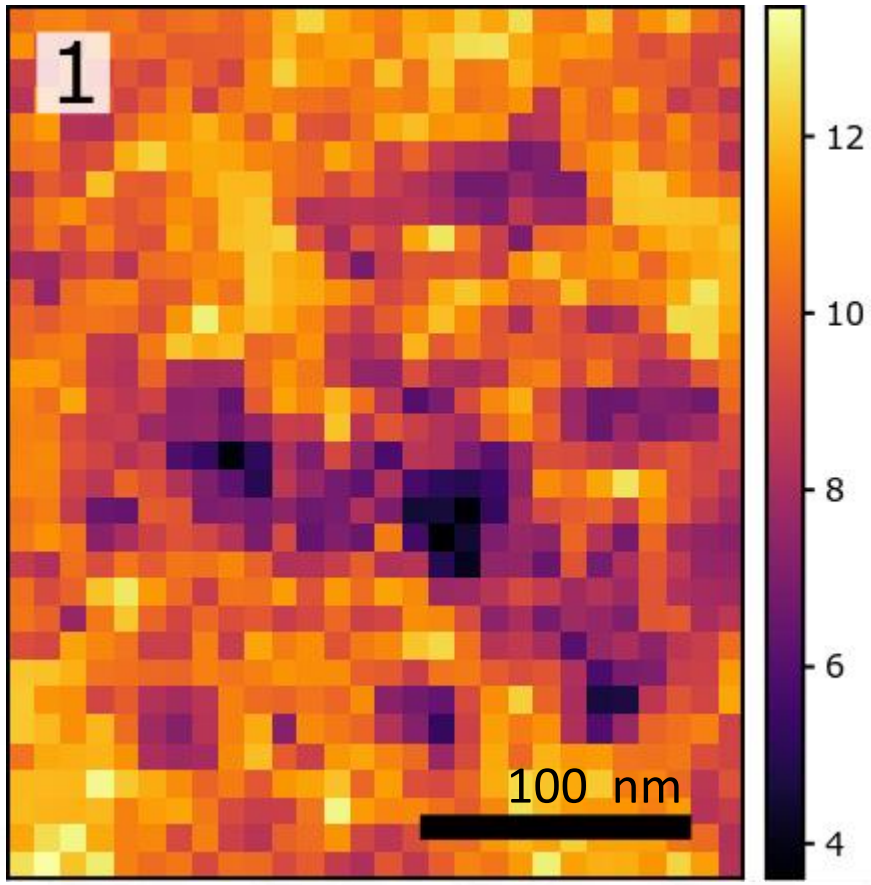

N. Bonnet *et. al,* arXiv:2102.06140 [cond-mat.mes-hall]

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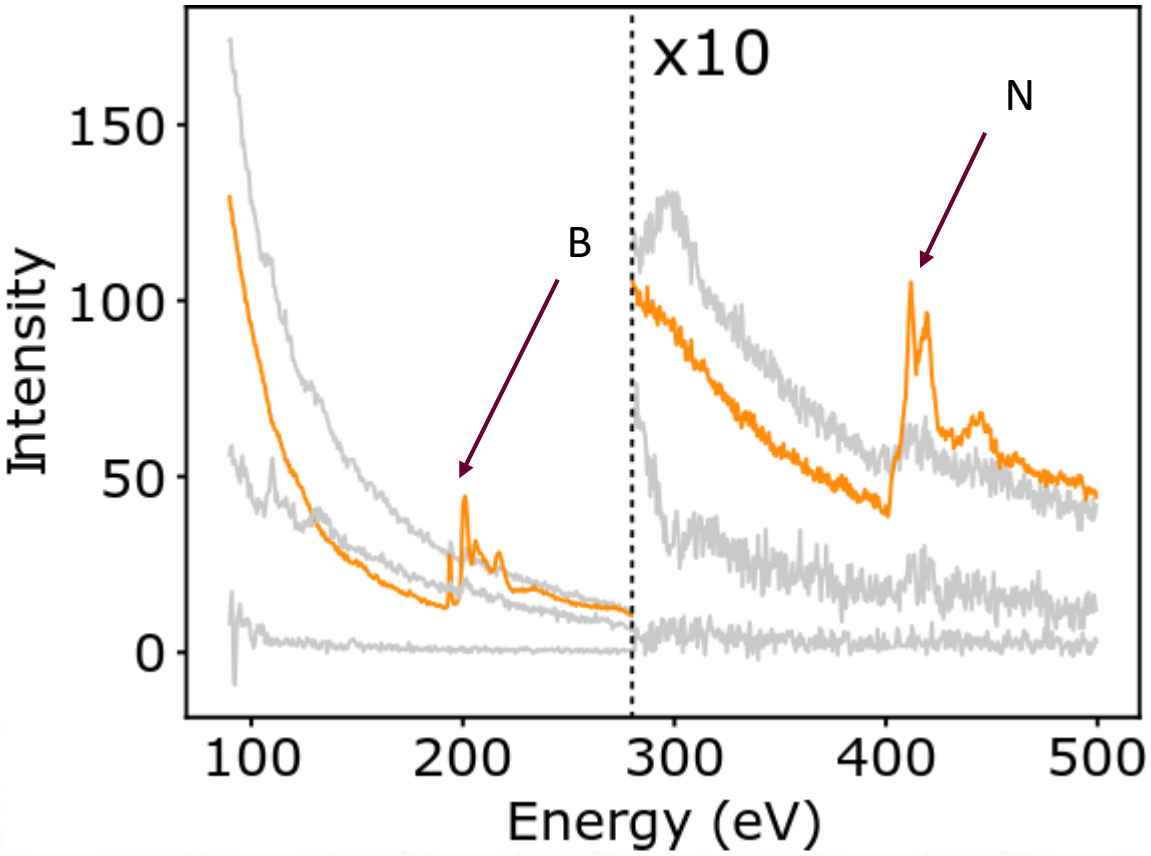

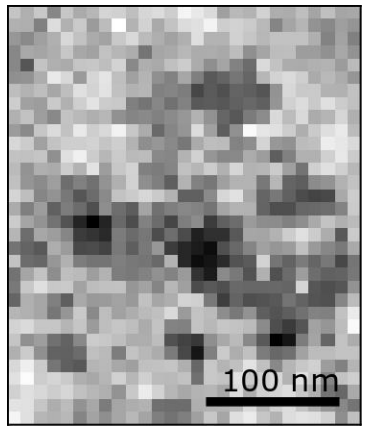

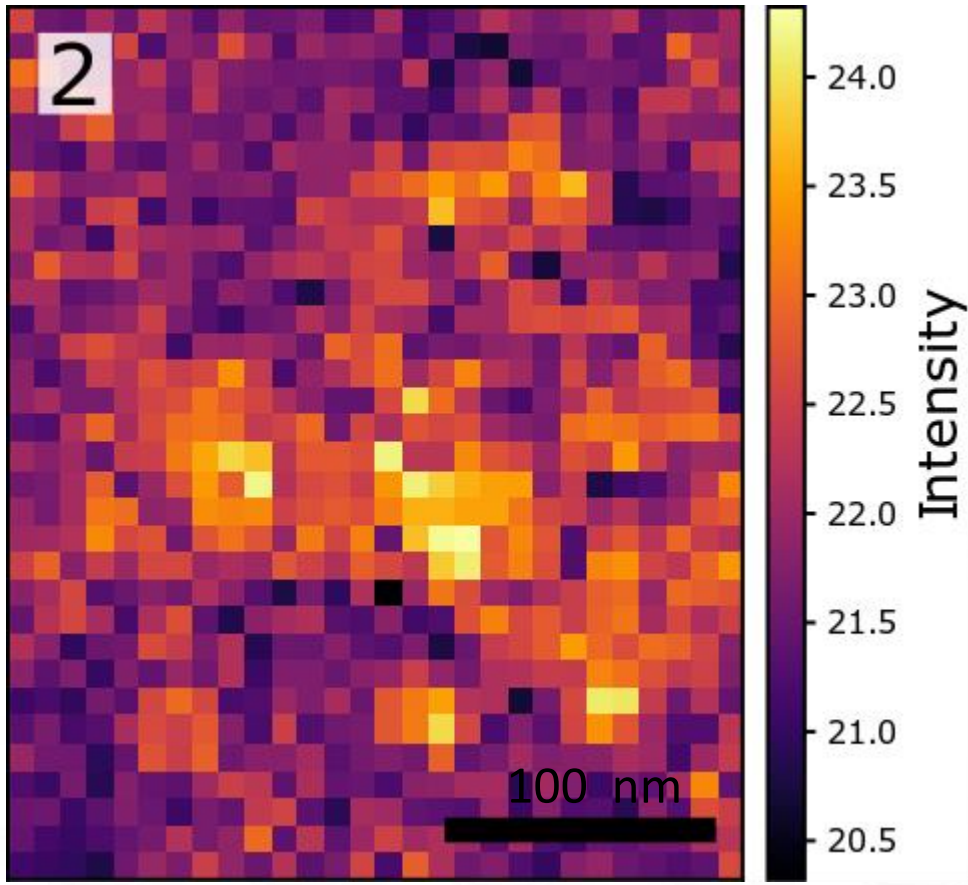

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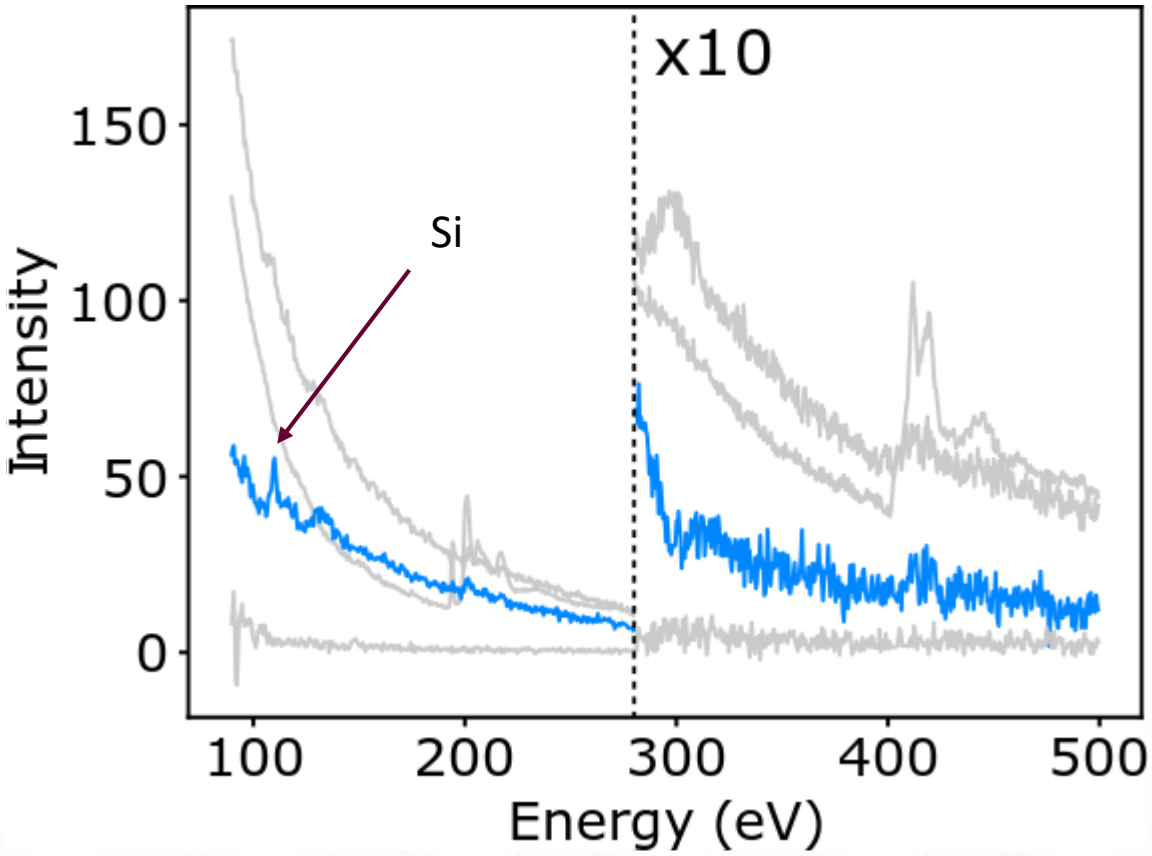

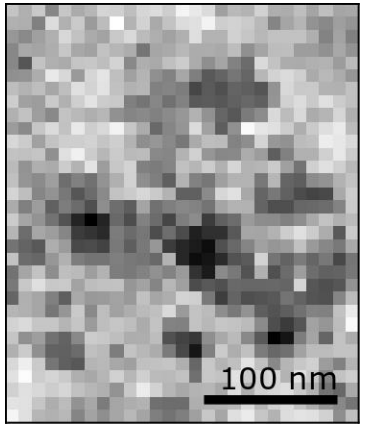

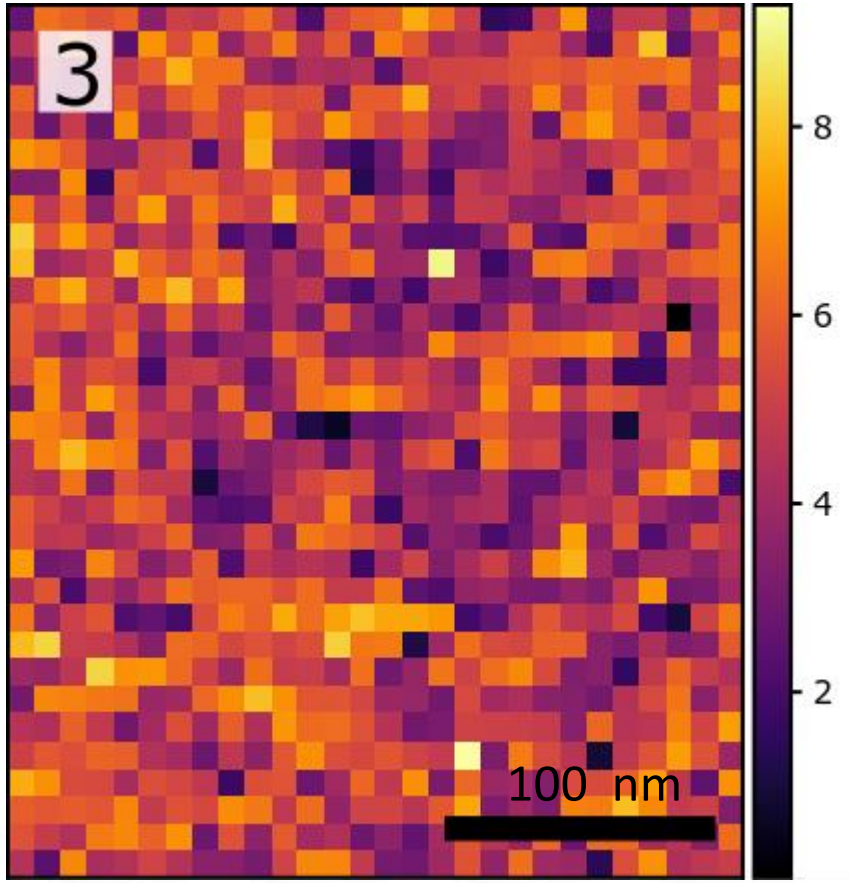

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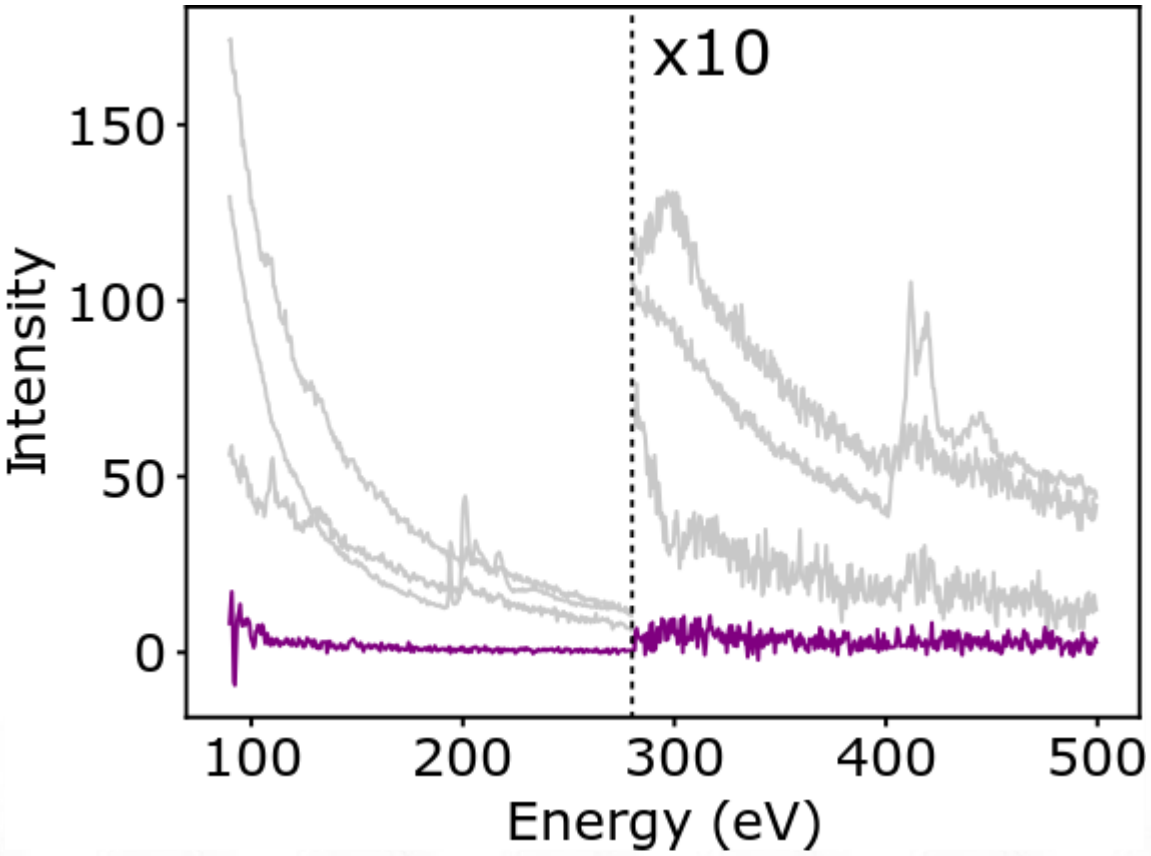

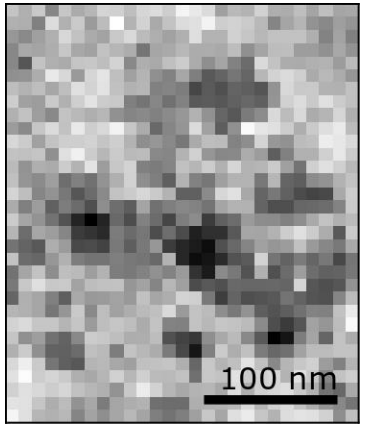

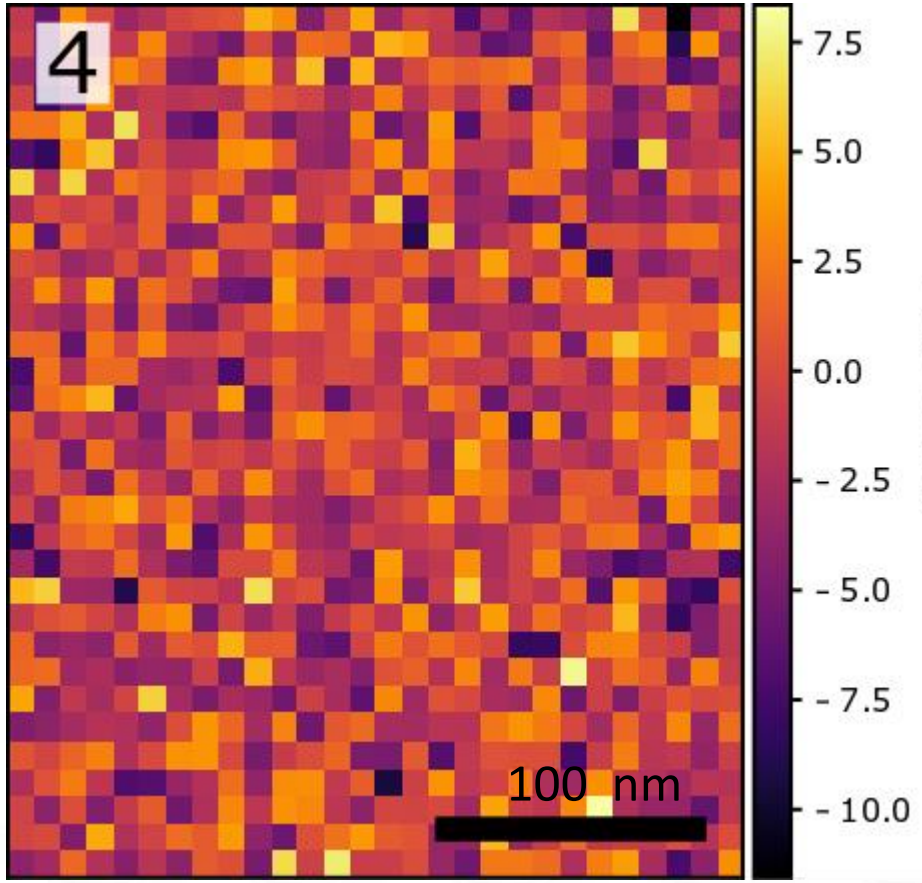

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High resolution images