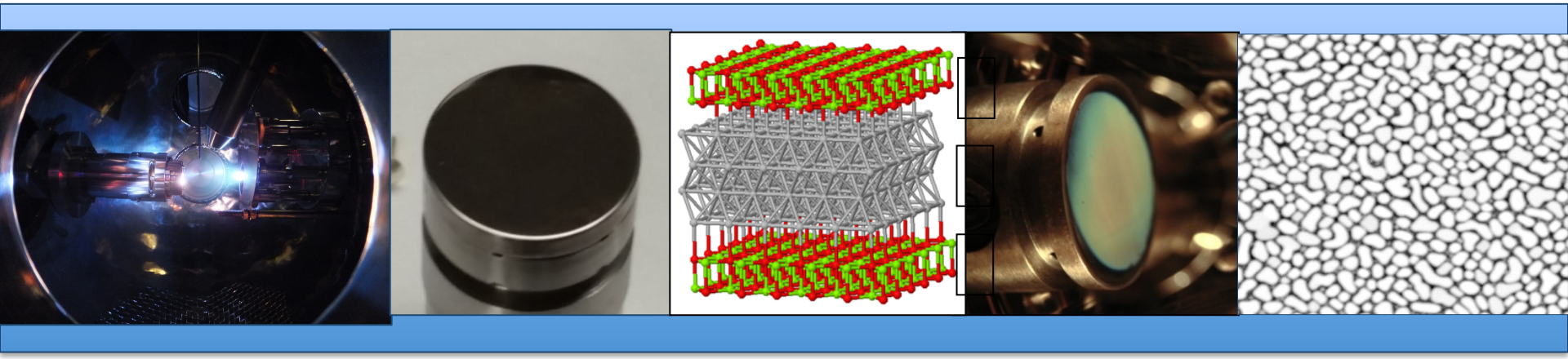
AWA Needs and Opportunities Workshop – 2019

Photocathode research – (N)UNCD Photocathodes



Gongxiaohui Chen, *Zhengrong Lee*, *Gowri Adikari, Shokoufeh Asaldzadeh*,
John Zasadzinski, Jeff Terry, Sergey Baryshev, Linda Spentzouris, Andreas Schroeder,
Jiahang Shao, Eric Wisniewski, and AWA group, Ani Sumant, Kiran Kumar Kovi,
Mark Warren, Daniel Velázquez, Katherine Harkay, Károly Németh, Noah Samuelson

Argonne NATIONAL LABORATORY

ILLINOIS INSTITUTE OF TECHNOLOGY

Onions have layers, ogres have layers, cathodes have layers…

Better living through material science

- Collaborate to get expertise of condensed matter scientists
- (and their instrumentation) to study
- surface morphology, work function, chemistry, QE, band structure, MTE
- And determine how PC figures of merit depend on fabrication, and what combinations of materials can improve them.

Fabrication of structured cathodes for improved performance

- MgO/Ag/MgO: Modify surface band structure with layered structure
- SC PC: Proximity effect / Plasmonic surfaces
- (N)UNCD: Diamond crystals with graphitic boundaries, H termination for QE

Finish with guns blazing

- Check lifetime and performance in an accelerator environment
- Investigate how cathode properties map to beam properties in a gun

Photocathode research in progress

Fundamental emission studies

Practical PC design for better performance

Multilayers continued:

- What's in an interface?

Lee, Terry

Ultra Nano Crystalline Diamond films (N)UNCD

- Nitrogen incorporation (into grain boundaries) to make films electrically conductive
- Investigating Hydrogen termination for better QE
- Interesting MTE

Chen, Baryshev, Schroeder, ***Adhikari***

Superconducting photocathode

- Multiple layers to achieve high QE

Zasadzinski, ***Asaldzadeh***

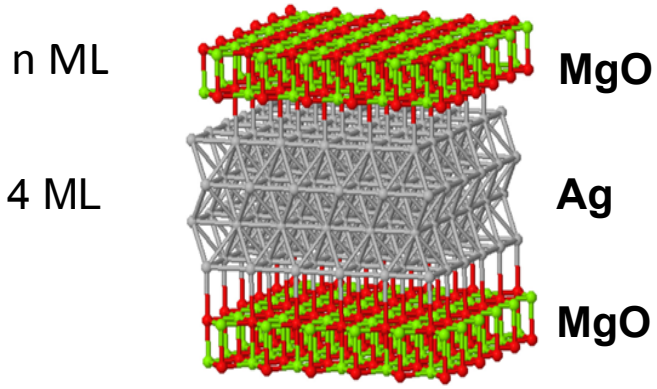
High gradient testing (all of the above)

Kelvin Probe data WF and QE

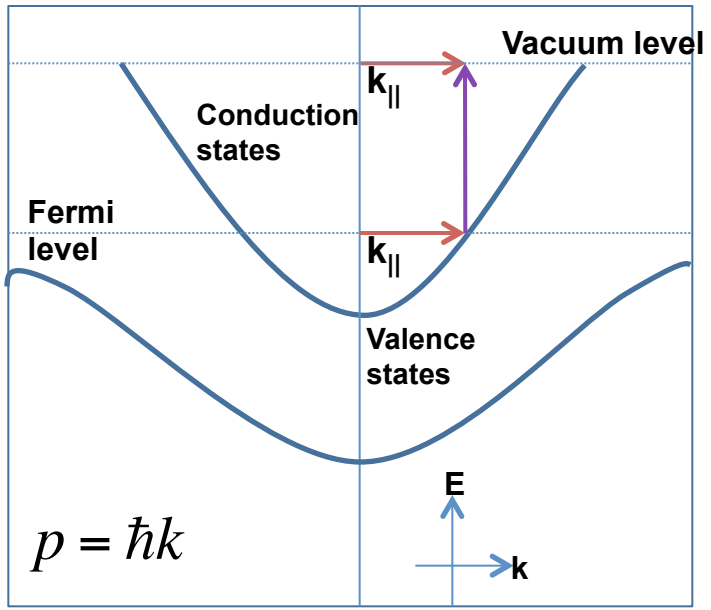
Shao, Wisniewski

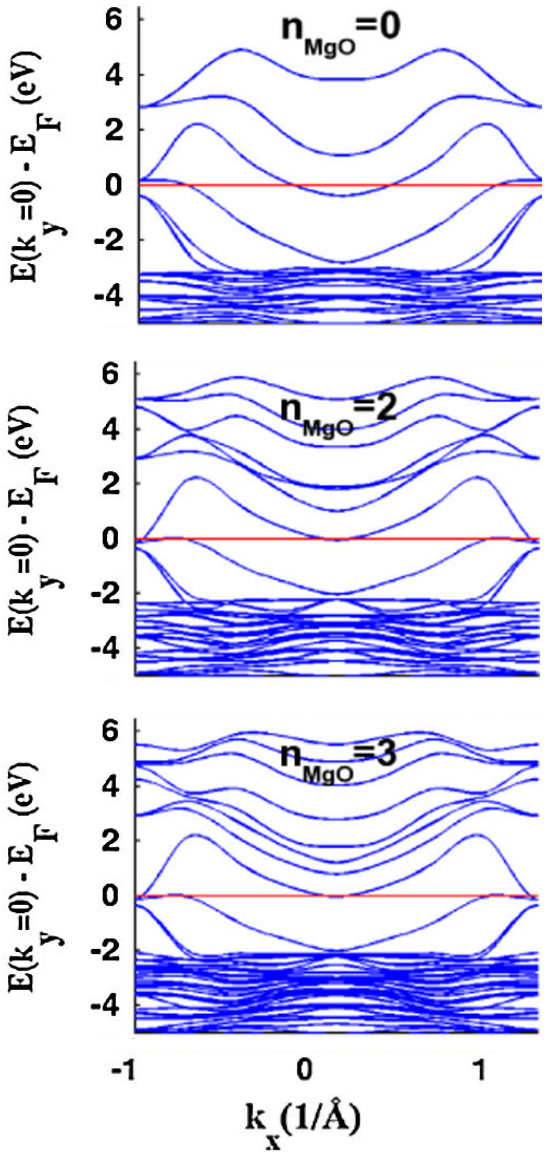
Multilayered MgO/Ag(001)/MgO structure

K. Nemeth et al.
Phys. Rev. Lett. 104, 2010.



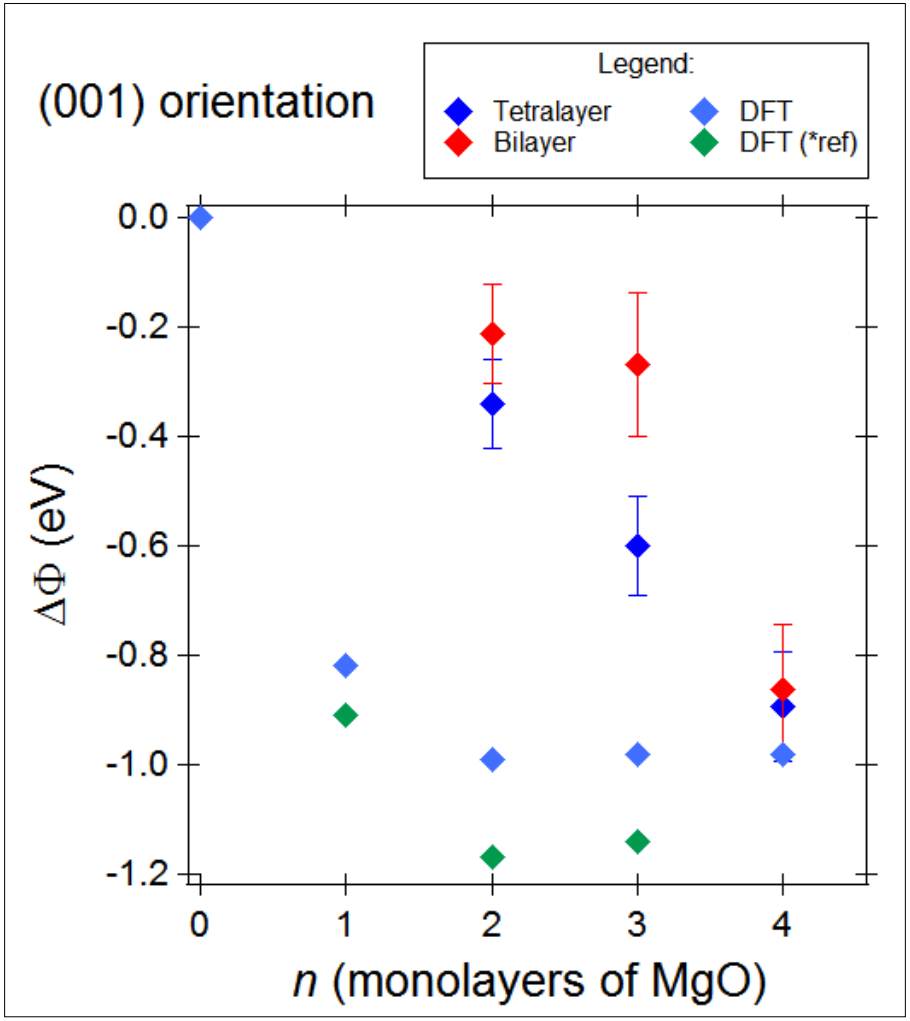
The number, n, of ML controls the location In k-space where the valence band crosses the Fermi level



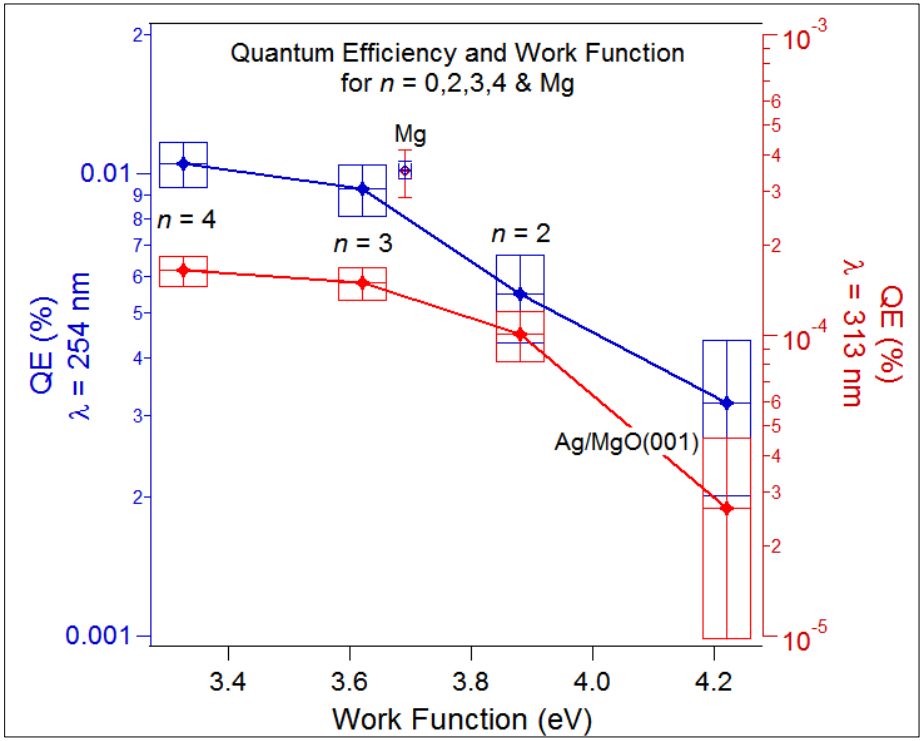


Measurements at AWA of work function and quantum efficiency versus MgO layer thickness

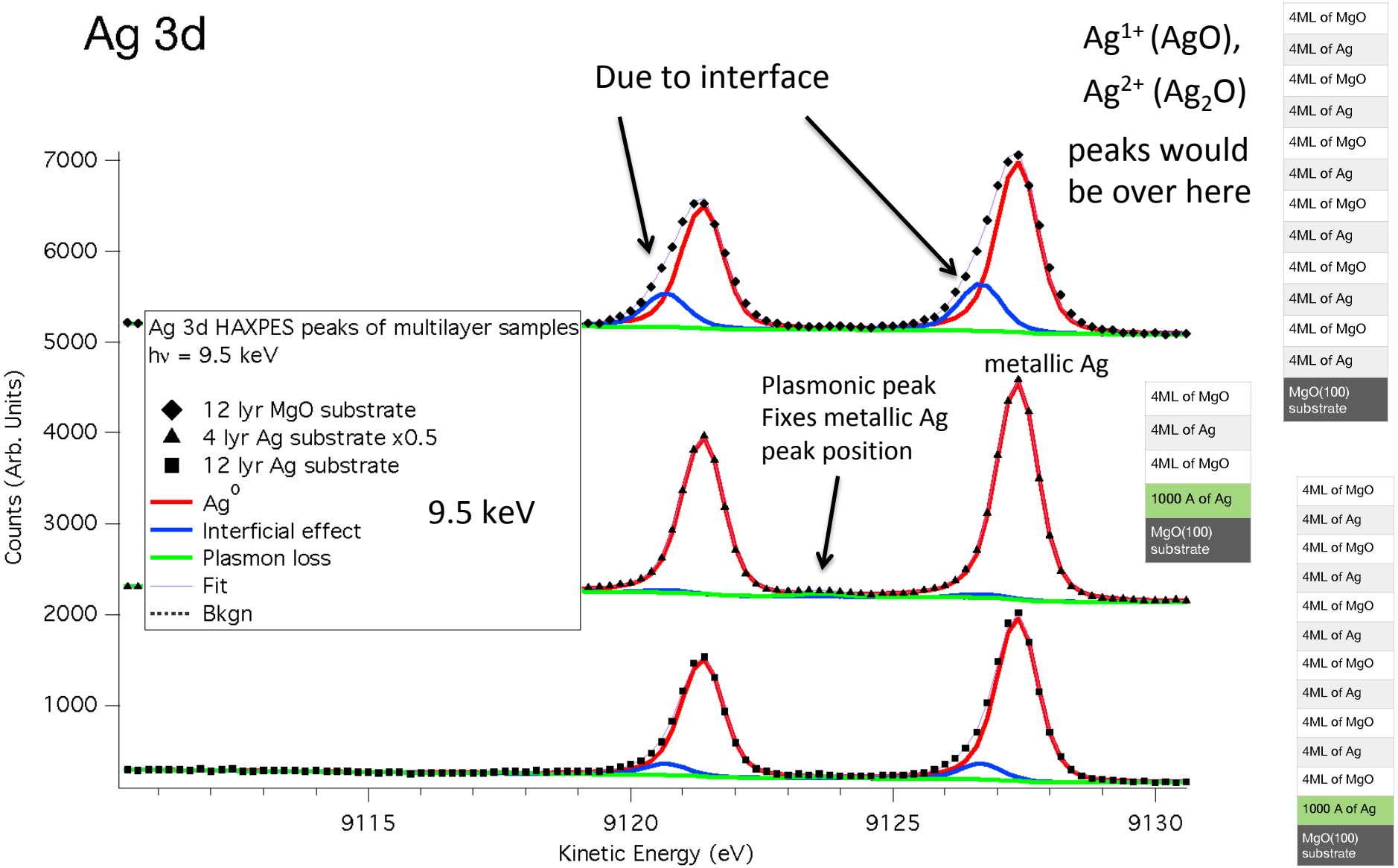
Kelvin probe data:
Work function vs. MgO thickness



QE and work function
for different MgO thickness



What's in an interface?



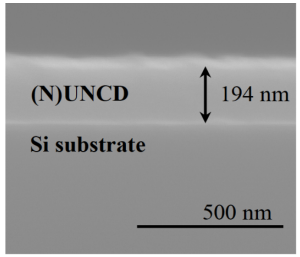
Taken at Scienta Omicron facility, Taunusstein Germany

Reflectance measurements of UNCD films

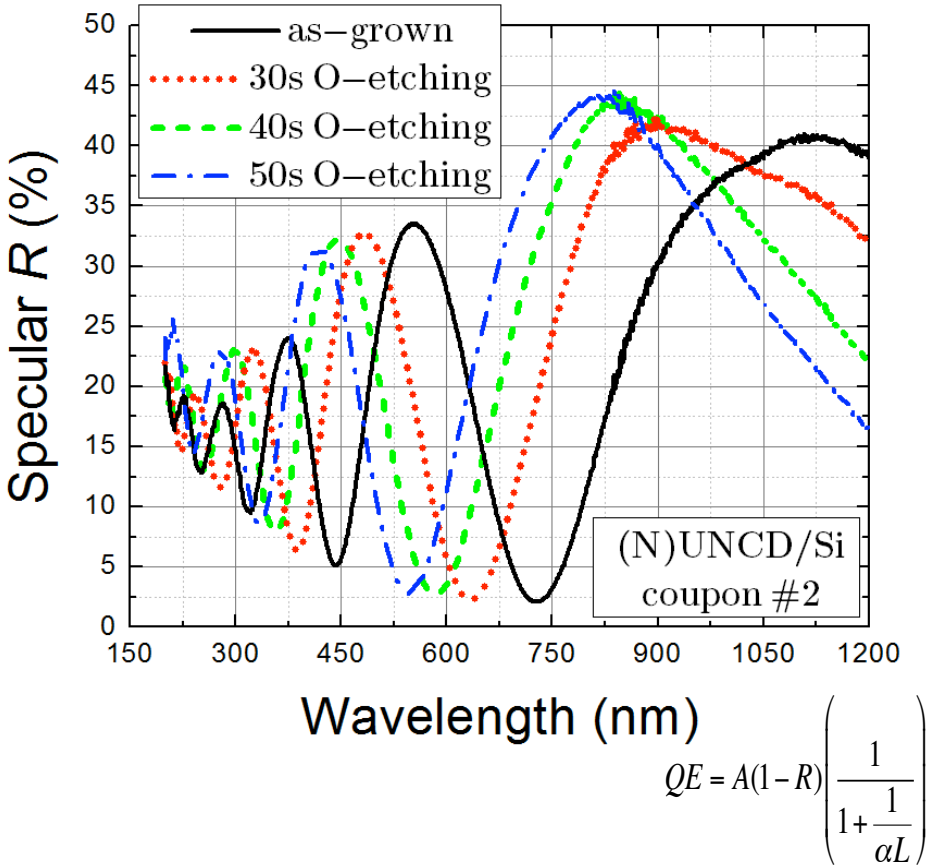
Interface pattern (R vs. λ) depends on film thickness

Calculation of thickness:
Use Snell's law + constructive/destructive interference condition to get thickness from adjacent peak positions

Experimental check:
Cross-sectional SEM



To do: Film thickness versus QE study
Improve QE at a specific λ



$$QE = A(1-R)\left(\frac{1}{1+\frac{1}{\alpha L}}\right)$$

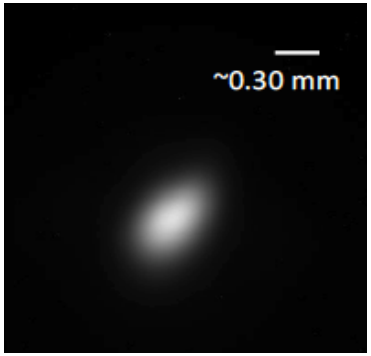
Desired capability: QE measurements at multiple wavelengths
We are developing this at IIT
QE measurement also possible at Kelvin Probe at AWA
Advantages: Concurrent WF measurements possible
Gun is nearby, enabling prompt transfer for high gradient testing

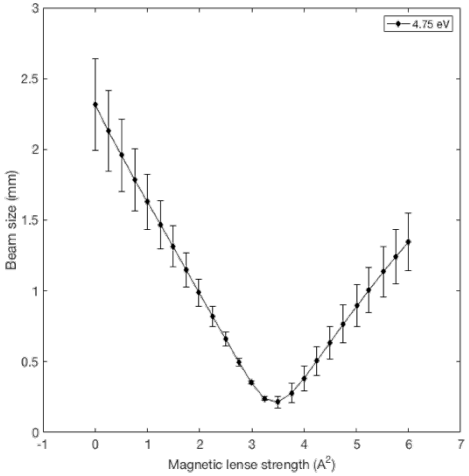
Mean Transverse Energy (MTE) of UNCD measured in Schroeder lab (UIC)

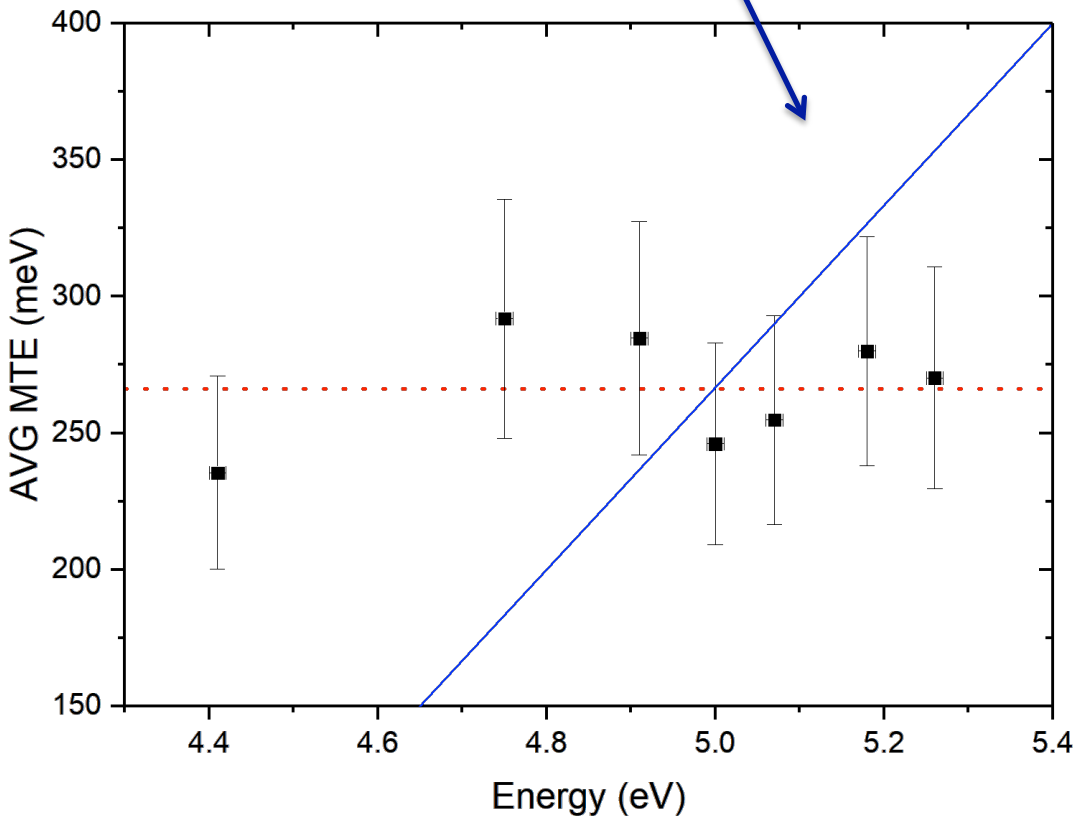
At UIC: Tunable laser, DC field, 2 solenoids, screen − MTE extracted from solenoid scan

$$\varepsilon \propto (laser\_spot)\sqrt{MTE}$$

Metals $MTE \propto \hbar\omega - \phi$

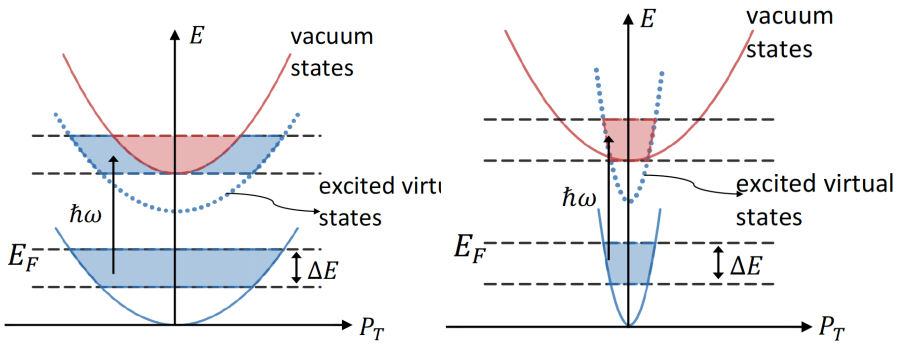




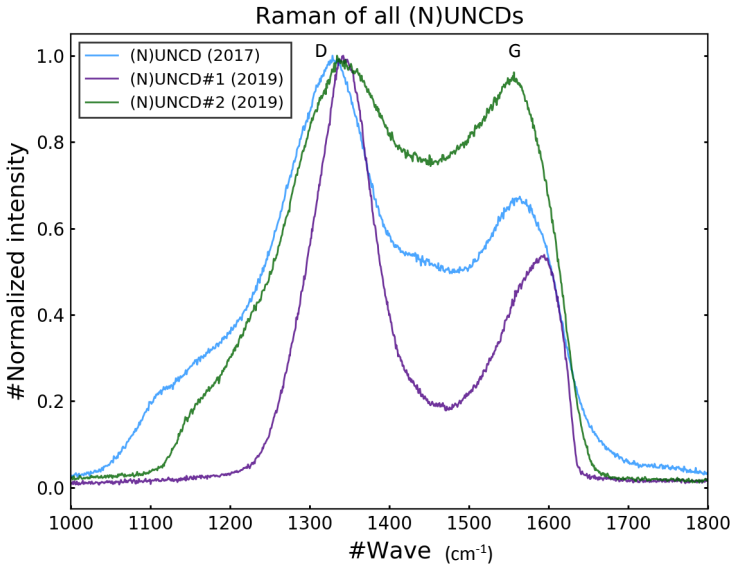


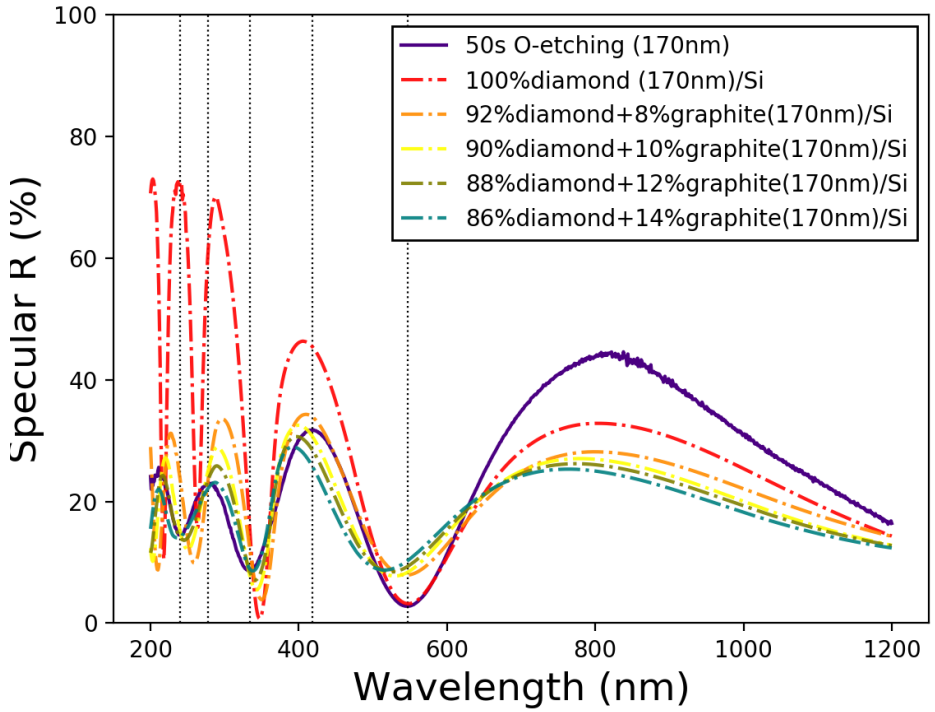
4.6 eV -> 270 nm
5 eV -> 248 nm
5.4 eV -> 230 nm

Is MTE due to one-step photoemission from low effective mass graphitic boundaries? Change the sp3/sp2 ratio (how much graphite) and look at MTE

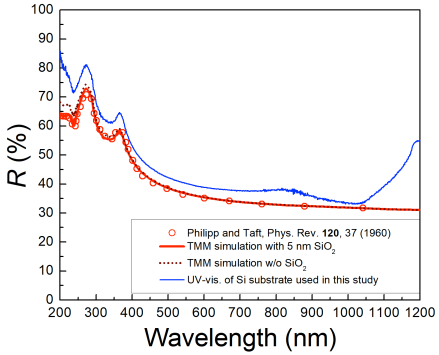


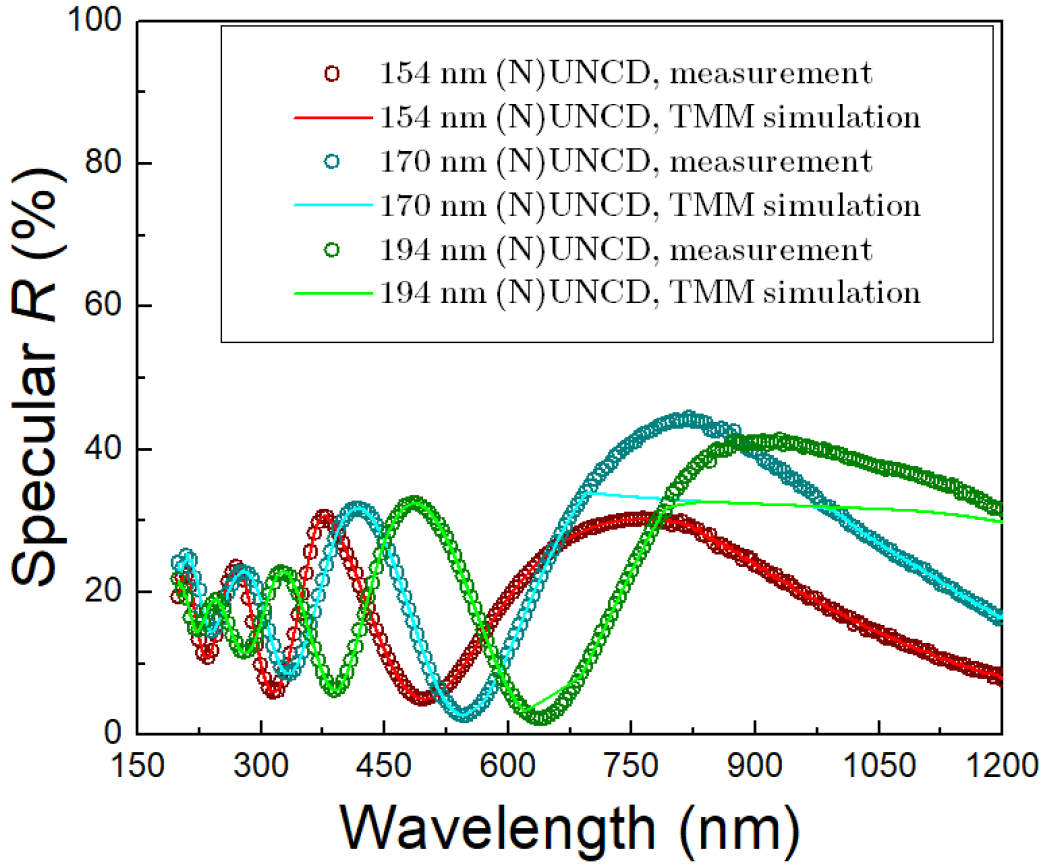
Reflectance calculations using TMM open source program (created by Dr. Steven Byrnes at the Charles Stark Draper laboratory)

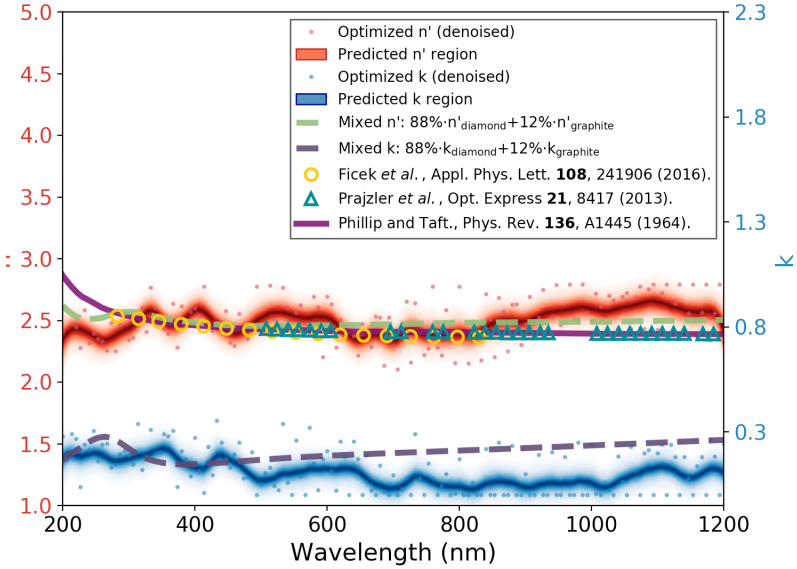


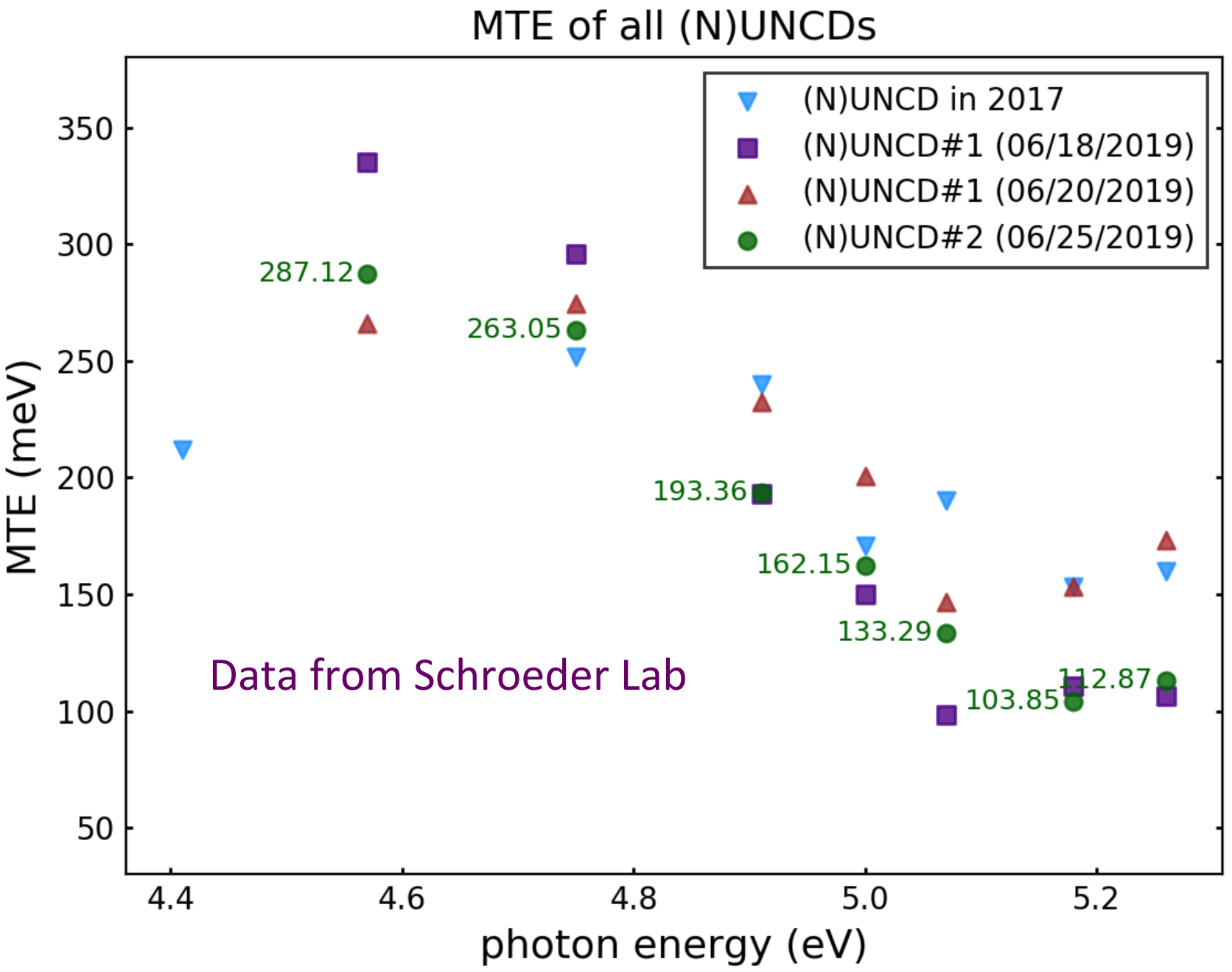


We trust (1) TMM code, (2) Thickness calculation
so .. we can extract the optical parameters, n, k for our complex material





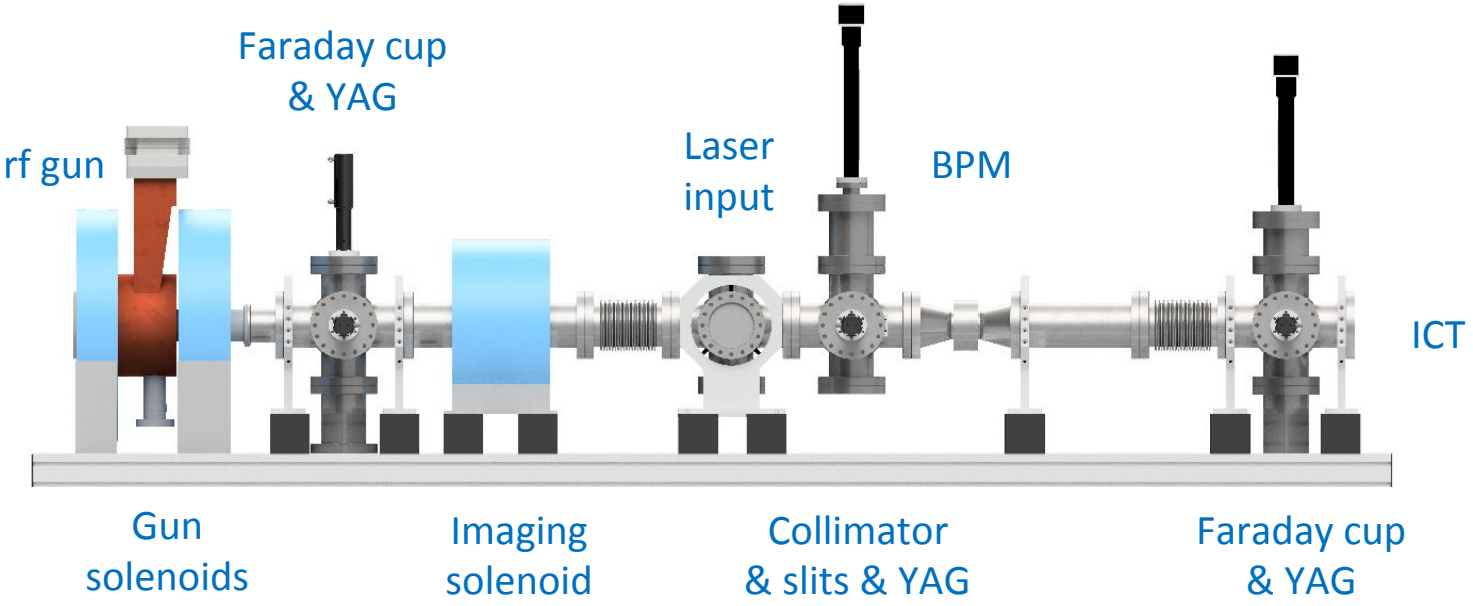


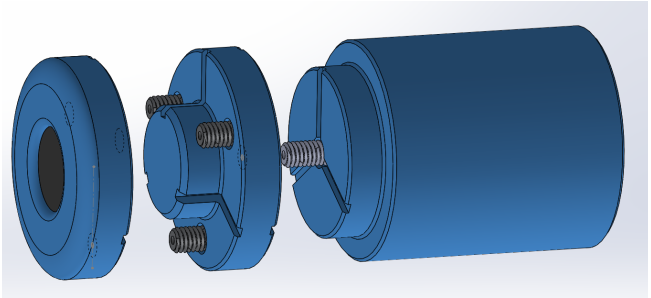

MTE of all (N)UNCDs
(N)UNCD in 2017
(N)UNCD#1 (06/18/2019)
(N)UNCD#1 (06/20/2019)
(N)UNCD#2 (06/25/2019)
287.12
263.05
193.36
162.15
133.29
112.87
103.85
Data from Schroeder Lab
MTE (meV)
photon energy (eV)
350
300
250
200
150
100
50
4.4
4.6
4.8
5.0
5.2

Put (N)UNCD in the test stand to find emittance and QE : Compare to MTE and KP/QE

Beam parameters <-> surface characterization

Survivability





Thanks Shao!

Wish list items ACT:

- Laser and ability to measure QE (need #photons)
- Continued help with plugs/insertion hardware for PC samples - ideally increased flexibility (fast turn around time)
- Keep those diagnostics and special devices coming!

Wish list items Kelvin Probe:

- KP officially maintained by AWA
- Photon sources for more wavelengths
- Possibly gun/KP standard transfer hardware

Superconducting Gun

THANKS!