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# *Ultra-Bright Photocathode Physics Study and Design*

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# *Ultra-Bright Photocathode Physics Study and Design*

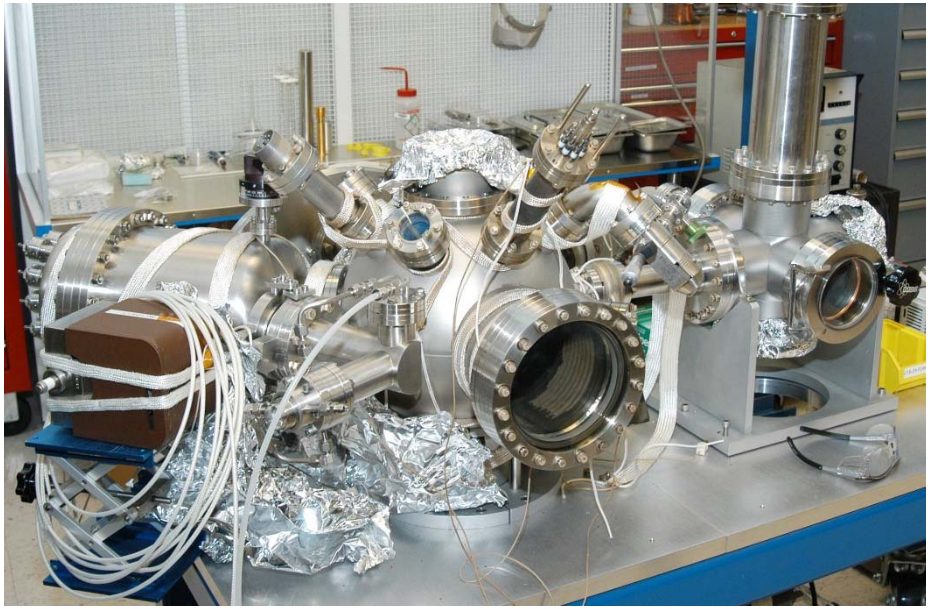
- Fundamental cathode emission properties determine lower bound on achievable electron source emittance
- Intrinsic emittance depends on:
  - Emission momentum distribution
  - Surface roughness, nonuniformity
  - Surface impurities (e.g., oxide layers)
  - Grain boundaries
  - Laser profile, energy, polarization
- Angle-resolved photoemission spectroscopy (ARPES), an important tool in surface science, is also promising as a tool to characterize photocathodes*

*E.g., see Fig 6. in A. Damascelli, Physica Scripta T109, 61 (2004).*

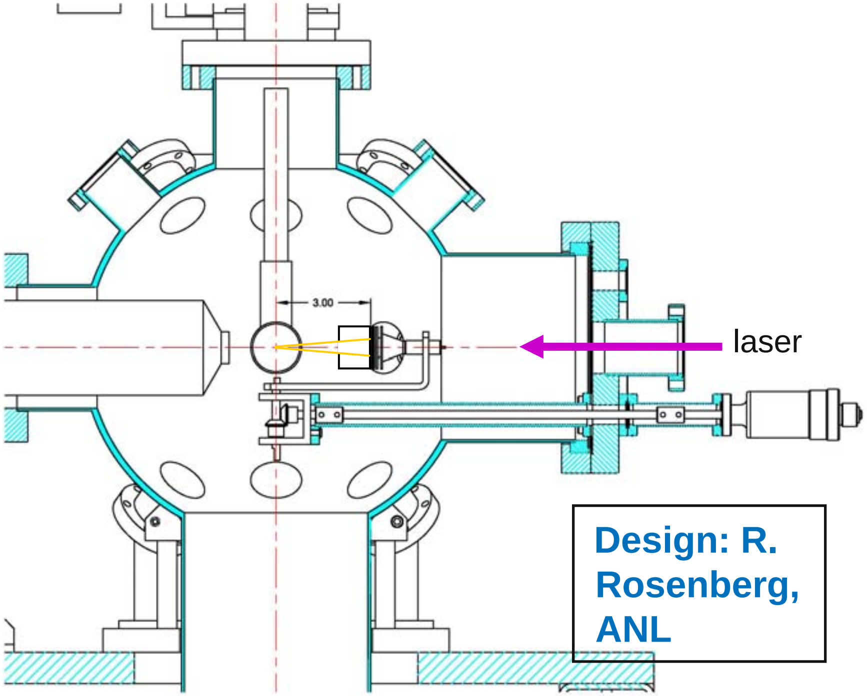
**Basic ARPES geometry**

* D. Sertore et al., Proc. 2004 EPAC;
W. Wan, CHBB Mini-workshop, DESY Zeuthen (2008).

# *Photocathode Surface Lab*



- Existing UHV surface analysis chamber being upgraded to add UV ARPES *
  - Nd:YAG laser, 3-ns pulse (1064, 540, 355, 266 nm); UV flash lamp (1-μs), spectrometer
  - MCP TOF electron detector



**Design: R. Rosenberg, ANL**

- Also available:
  - Heat/cool sample
  - XPS to study surface chemistry (dual-anode Al, Mg source)
  - Scanning EM (on 2nd chamber)

* K. Harkay et al., Proc. 2009 PAC (MO6RFP045)

# *Photocathode R&D*

- Plan to start with existing cathodes (Cu, $Cs_2Te$*, diamond**); no facilities for *in-situ* cesiation (GaAs)
- UV ARPES chamber assembly underway; first measurements this year. Opportunity to compare intrinsic emittance results with
  - BNL, PITZ (msr’d in injector)
  - INFN, LBNL (ARPES labs)
  - others
- Preliminary theoretical calculations underway; suggest a design method for ultra-high-brightness cathodes
- Novel material designs that predict small emittance to be investigated experimentally
- Procurement or fabrication of novel cathodes: Argonne Materials Science Division (ALD), APS X-Ray Science Division, others

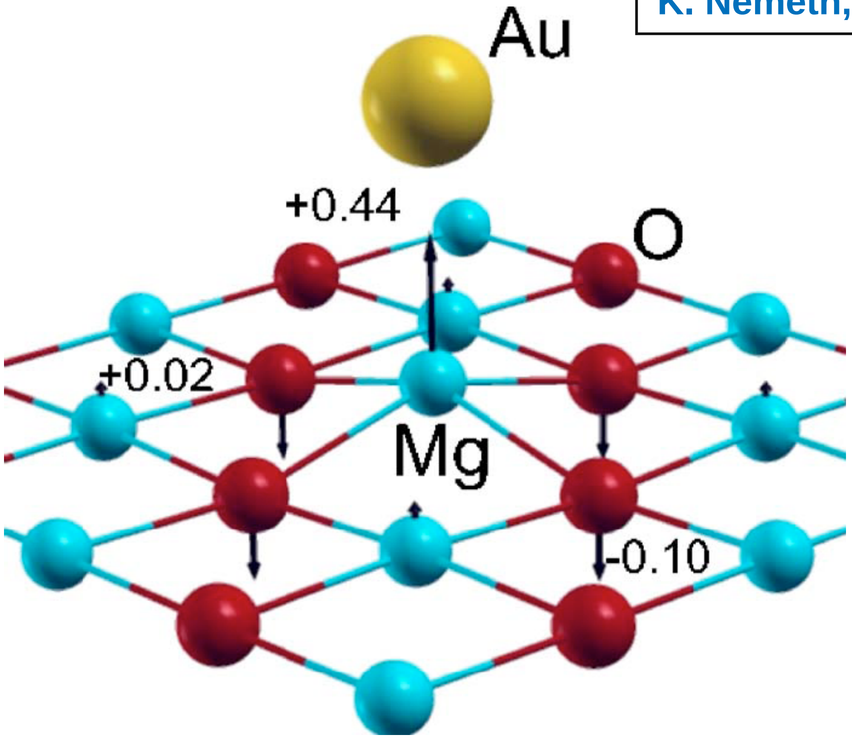
* Z. Yusof, http://www.hep.anl.gov/eyurtsev/psec

** J. Smedley, T. Rao, private discussion at ERL09

# *Preliminary ideas for low-transverse-emittance cathodes from surface catalysis systems*

**K. Nemeth, ANL**

**1. Analog of negative electron-affinity (NEA) cathode: Au on thin MgO layer over Ag(100) ***



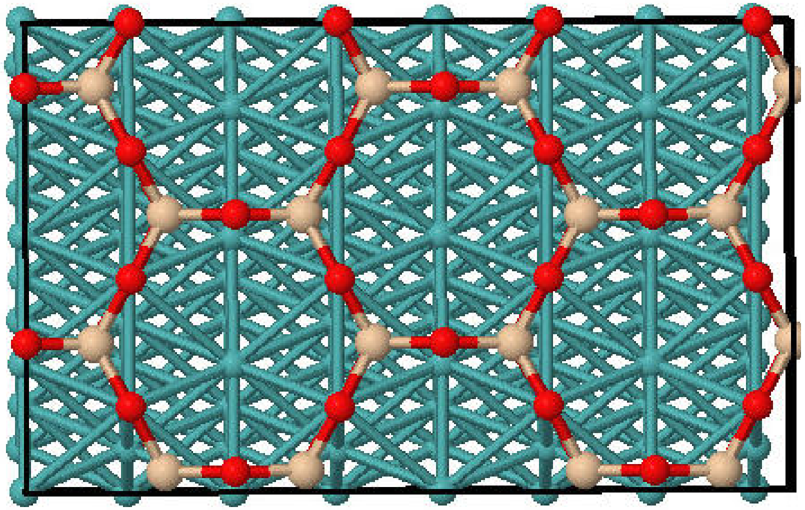
* J. Chem. Phys. 127, 144713 (2007)].

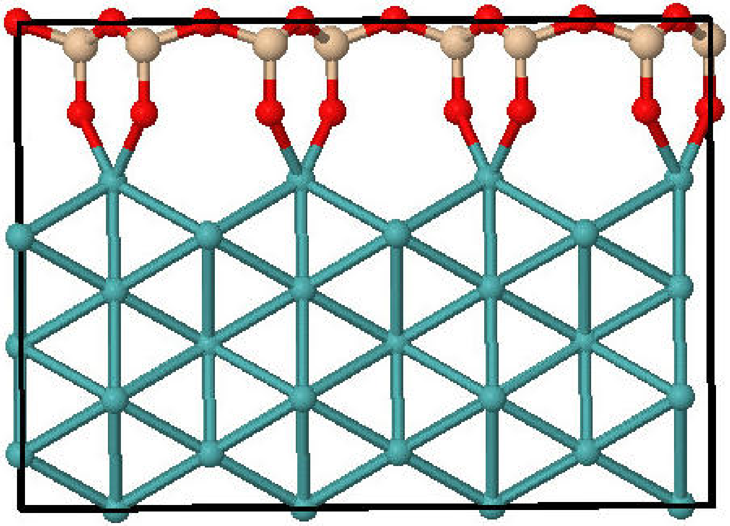
- Thin layer of MgO over Ag(100) dramatically reduces the work function of the Ag(100) surface
- System potentially useful as an analog of NEA cathodes
- NEA given by negative charge of Au atom (or other metal clusters) deposited on thin layer

# *Preliminary ideas (cont)*

**K. Nemeth, ANL**

**2. $SiO_2$ mono-layer on Mo(112) surface ***





*See Fig. 1A in Ulrich et al.*

STM images of Pd embedded in the $SiO_2$ monolayer (left), and Au atoms anchored to the embedded Pd atoms (right) Potential substitute for dispenser cathodes when Cs put into SiO2 honeycomb. Surface bands suggest small emittance.

*See Fig. 1C in Ulrich et al.*

* Ulrich et al., PRL 102, 016102, (2009).

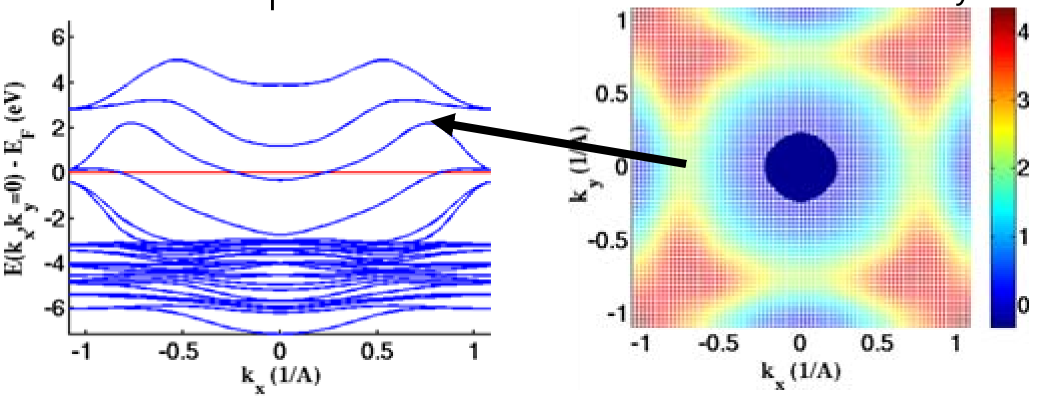
# ***Surface model analysis, ARPES spectra (DFT); emittance to be est. via 3-step model***

**K. Nemeth, ANL**

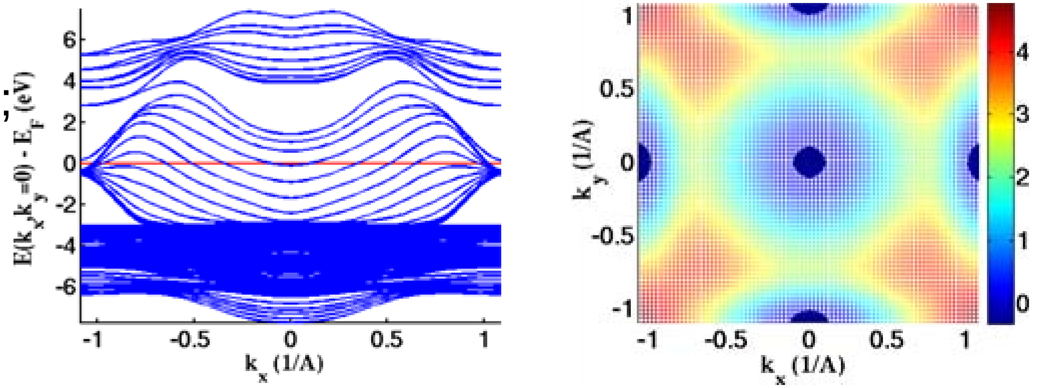
$k_x$ vs. energy bands relative to $E_f$

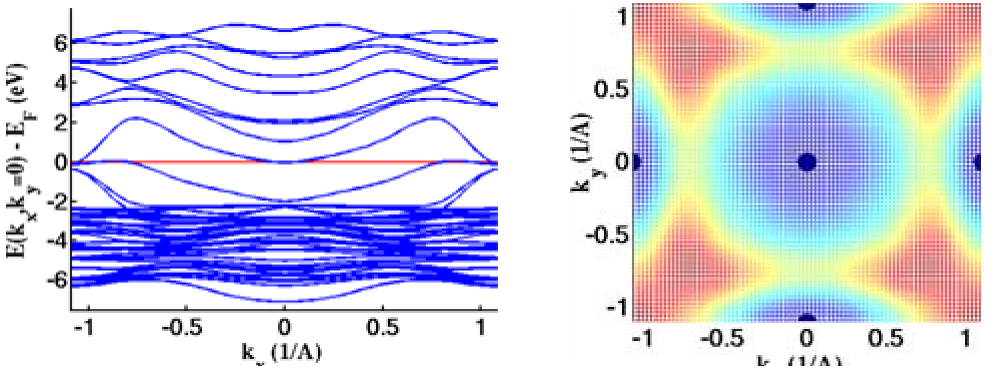
Lowest-energy (relative to $E_f$) surface bands in $k_x$ vs. $k_y$ space

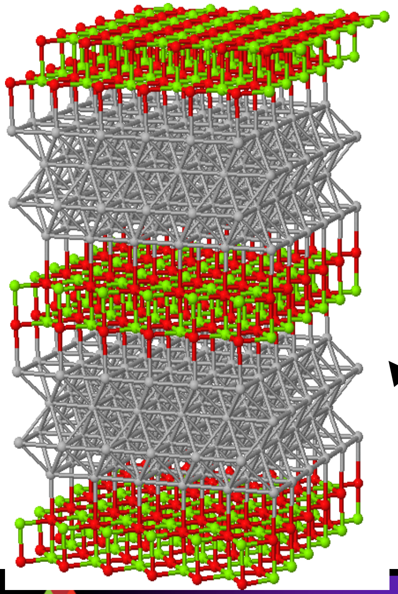
Ag(001)4L; DFT(PBE)



Ag(001)16L; DFT(PBE)







MgO(100)2L-Ag(100)4L-MgO(100)2L; DFT(PW91)
Work function reduced by ~1 eV relative to pure Ag(001)