Characterization of the GaAsSb Photocathode with the Micro-Mott Electron Polarimeter

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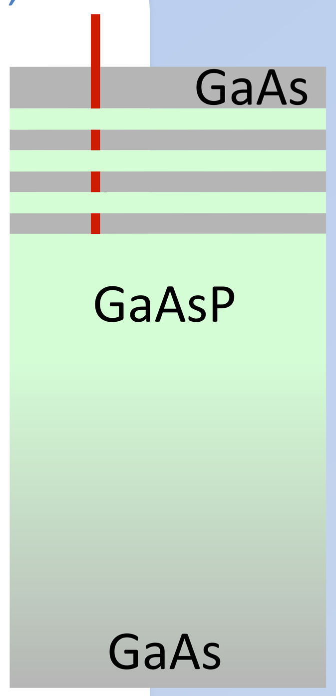
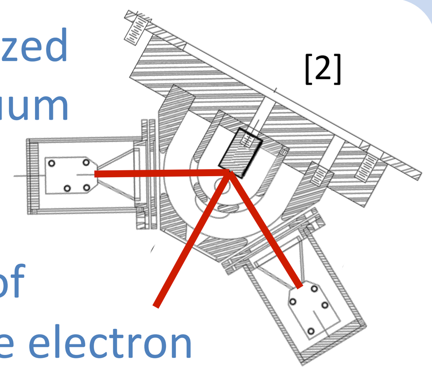
WE KNOW: GaAs:GaAsP

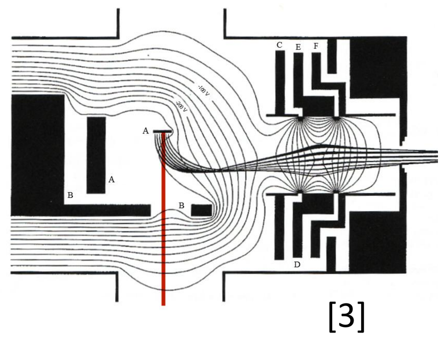
With respect to photocathodes for polarized applications, the ideal photocathode would have the following characteristics: (1) high resultant polarization, (2) ease and quickness of polarization reversal, (3) high quantum efficiency (QE), and (4) a long operational lifetime at high voltages[1]. Gallium arsenide (GaAs) cathodes produce reliably high QE, can easily reverse polarization, and have a relatively long lifetime. Pure GaAs has a theoretical maximum polarization of 50%. But, by growing GaAs on a substrate with a different crystal spacing, such as GaAsP, a superlattice structure with many thin alternating layers of GaAs:GaAsP is created. This introduces physical strain into the GaAs structure, which breaks a degeneracy and increases the theoretical maximum polarization to 100%. Using circularly polarized infrared light, electrons inside the GaAs:GaAsP sample can be excited to the conduction band such that only one polarization state is emitted at a time[1]. Although GaAs has a very high work function, adding Cs and NF_3 to its surface creates a negative-electron-affinity state, allowing surface electrons to escape with only a small electric field applied. However, GaAs is very sensitive to damage from ionized gasses striking its surface, requiring ultra-high vacuums and compromising its lifetime.



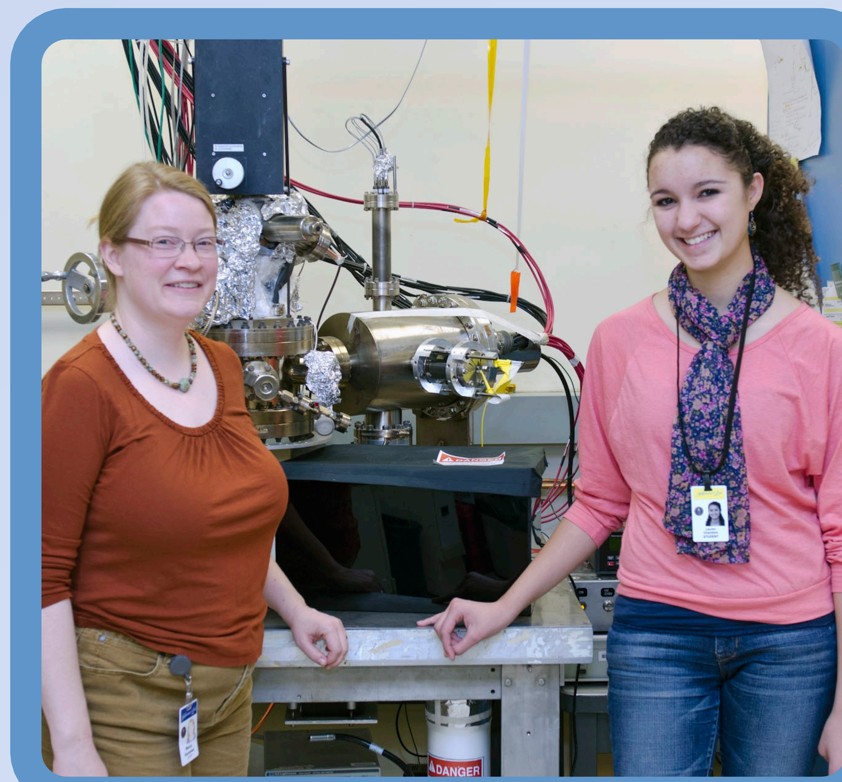
WE USE: Micro-Mott Polarimeter

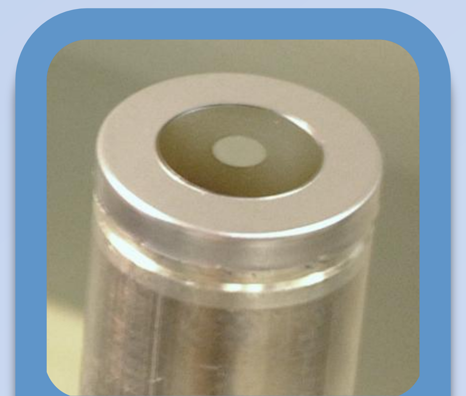


The micro-Mott electron polarimeter in EEL 118 is composed of a polarized source chamber connected to a polarimeter, kept under ultra-high vacuum conditions. Photocathodes are inserted into the source chamber via a stainless steel stalk and bellows, which operate as a load-lock system. Between the polarized source chamber and the polarimeter is a series of electrostatic lenses that, along with the electrostatic deflector, steer the electron beam into the target; transmission between them is around 20%. The micro-Mott polarimeter is a retarding-potential polarimeter, which means that it uses variable electric fields to analyze the electron energy loss during scattering off the target. When the electron beam enters the polarimeter itself, it accelerates due to a 20 kV difference and hits the gold target, scatters, decelerates, and is counted with two channel electron multipliers. Data acquisition and analysis are conducted using LabVIEW programming software.

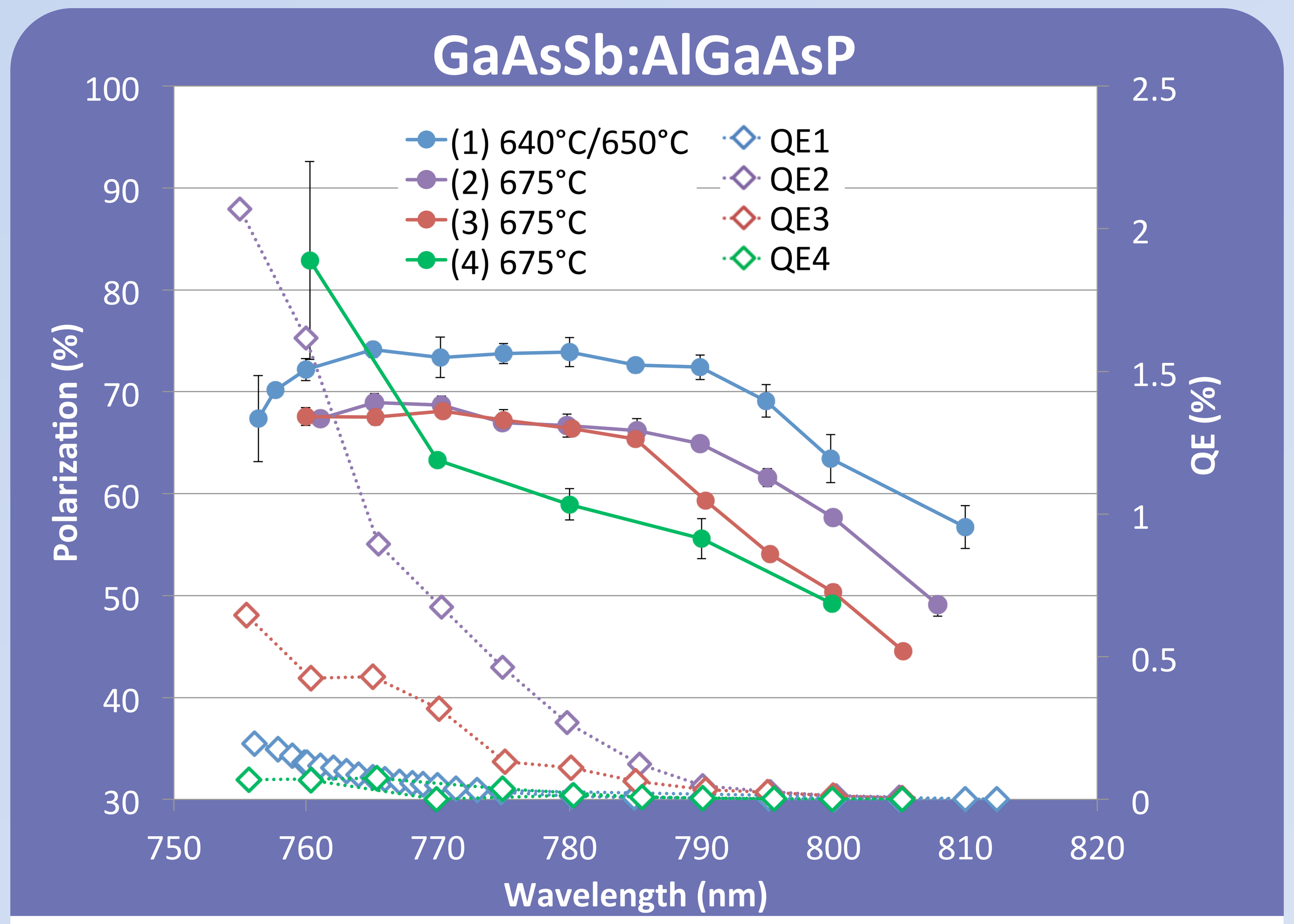


[3]

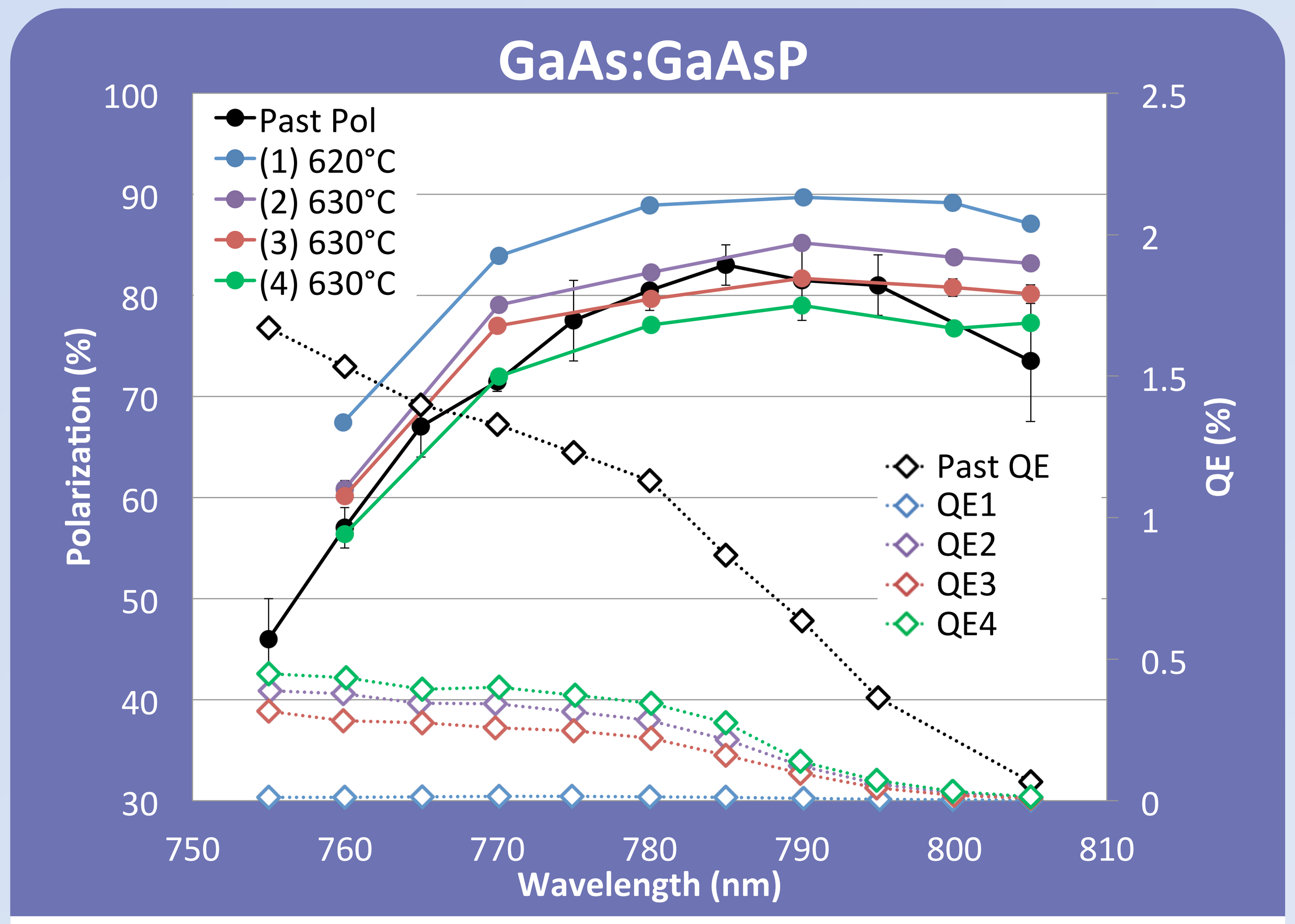




(Anodized) GaAs photocathode



The first heat cycle consisted of 30 minute heats at each temperature; the second, third, and fourth heats were two hour cycles.



All heat cycles lasted one hour.
Past QE/Pol values from McCarter 2010[3].

WE STUDY: GaAsSb:AlGaAsP

SVT Associates, a manufacturer of semiconductor photocathodes, recently began working with Jefferson Lab to characterize a new kind of GaAs superlattice: GaAsSb grown with AlGaAsP. This structure is anticipated to have comparable yield and polarization values to the established GaAs:GaAsP crystals, but with longer operational lifetime. By introducing antimony into the crystalline structure, the photocathode is theoretically less susceptible to degradation by ions and particles striking the surface. Such a photocathode could either yield more hours of operation before needing to be replaced, or allow for experimentation with higher-current sources; both are valuable options.

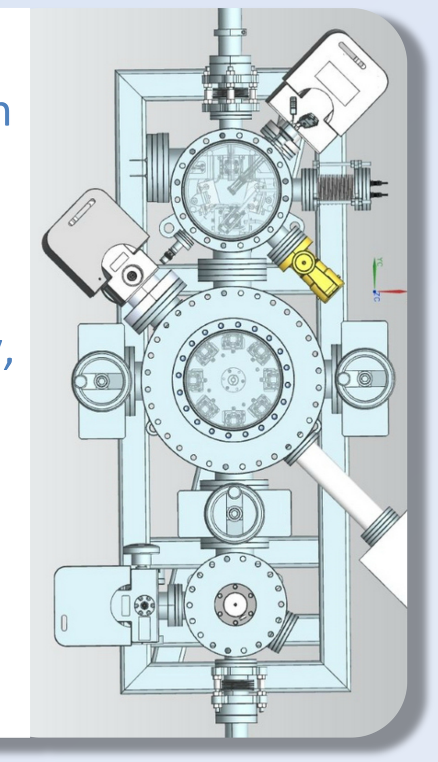
References:
[1] C. Hernandez-Garcia, P.G. O'Shea, M. L. Stutzman, Phys. Today 44 (2008) 61.2.
[2] H.M Al-Khateeb, B.G. Birdsey, T.C. Bowen, A.S. Green, T.J. Gay,,Rev. Sci. Instrum. 70 (1999) 3882.
[3] J.L. McCarter, M.L. Stutzman, K.W. Trantham, T.G. Anderson, A.M. Cook, T.J. Gay, Nucl. Instrum. Meth. A 618 (2010) 30.

RESULTS

Because polarization measurements for the GaAs:GaAsP photocathode agree with benchmark values, it can be concluded that our polarization values for GaAsSb are valid. Thus, GaAsSb yields polarization that is 15% lower than our current operating value, and that drops with continuing heat cycles. However, the QE values for GaAsP are abnormally low, indicating that our QE values for GaAsSb may be inaccurate. The micro-Mott should be vented and baked, and its cesiator should be replaced, before further testing for verification occurs.

THE FUTURE

The micro-Mott needs to be re-baked to allow for accurate QE measurements, then testing of the GaAsSb cathode will be able to continue. To verify the claims of increased lifetime, high current and high voltage runs will be performed. Ultimately, collaborations with Tim Gay from the University of Nebraska will lead to construction of a new micro-Mott (pictured at right), with a cathode puck carousel, a radiant heat system, and more accurate beam steering.



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