The Photocathode Program of the Large Area Picosecond Photo Detector (LAPPD) Project

The PC-group
(Klaus Attenkofer)
What are the Goals & Milestones:

- Goals: Bridging applied and basic sciences
  - Modern materials sciences approaches to tailor various properties of photocathodes
    - Wavelength response
    - Dark current
    - Timing response
  - Creating (using existing industrial capabilities if possible) appropriate production facilities
    - Proof of principle
    - Evaluating various recipes and approaches and selecting most cost-efficient processes
    - Creating prototype facilities which allows an industrial production (appropriate to the market conditions (~ 40,000 detector units of 8”x8” per year)
    - Understanding cost-quality relation ship (unit price versus QE, dark current....)
  - Creating new programs which build on expertise and know-how of the collaboration
What are the Goals & Milestones:

- 2010 (end of June)
  - Identify and characterize photo-emission properties of materials for photocathode development.
  - Upgrade existing vacuum transfer facility to match the 8”x8” square module assembly.
  - A design, including costing and interfacing with vendors of production sealed glass tubes, for a vacuum transfer/assembly facility for the 8” square module assembly.
  - Demonstration of an 8” square operational PC.

- 2011 (end of June)
  - Design and costing of a photocathode characterization facility.
  - Design and costing of an 8” glass tile assembly facility.
The Three Pillars of the Project

Photocathode Project

SSL
Basic Design
- Small Production Volume
- Moderate Specs
- Fully Integrated in Detector
- Future Production of One-of-a-Kind

ANL/WashU/UIUC
Theory Inspired Design
- Development of Novel Materials and Design Concepts
- Applying Principles of Modern Semiconductor Development
- Basis for Future Detector Development

ANL
Industrial Production
- Addressing Large Production Volume Issues
- Prototyping of Production Facilities
- Industry Contacts
- Compatibility with Assembly Process

Know-How and Lab Infrastructure of Four Institutions
The Photocathode Families

- Required spectral response still not clear (main application)
- Future applications (combination with scintillators) will require response optimization

<table>
<thead>
<tr>
<th>Suffix</th>
<th>Photocathode</th>
<th>Input Window</th>
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<tbody>
<tr>
<td>-71</td>
<td>GaAs</td>
<td>Borosilicate Glass</td>
</tr>
<tr>
<td>-73</td>
<td>Enhanced Red GaAsP</td>
<td>Borosilicate Glass</td>
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<tr>
<td>-74</td>
<td>GaAsP</td>
<td>Borosilicate Glass</td>
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<tr>
<td>-76</td>
<td>InGaAs</td>
<td>Borosilicate Glass</td>
</tr>
<tr>
<td>Non</td>
<td>Multialkali</td>
<td>Synthetic Silica</td>
</tr>
<tr>
<td>-01</td>
<td>Enhanced Red Multialkali</td>
<td>Synthetic Silica</td>
</tr>
<tr>
<td>-02</td>
<td>Bialkali</td>
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</tr>
<tr>
<td>-03</td>
<td>Cs-Te</td>
<td>Synthetic Silica</td>
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</table>
Why we had Planed a Large Cathode Effort?

- Multi-Alkali seems to have perfect cathode properties
  - Little understanding
  - Small community
  - No developed Industry
  - Problems with mass-production

- Existing III-V cathode have not the right properties
  - Excellent understanding
  - Large community
  - Excellent developed Industry
  - Easy mass-production

<table>
<thead>
<tr>
<th>Property</th>
<th>Multi-Alkali</th>
<th>GaAs-based</th>
<th>GaN-based</th>
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</thead>
<tbody>
<tr>
<td>Wavelength response</td>
<td>150nm-500nm</td>
<td>450nm-850nm</td>
<td>100nm-350nm</td>
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<tr>
<td>Typical efficiency</td>
<td>20%</td>
<td>20%</td>
<td>30-40%</td>
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<tr>
<td>Maximum efficiency</td>
<td>50%</td>
<td>60%</td>
<td>80%</td>
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<tr>
<td>Wavelength tunability</td>
<td>low</td>
<td>large</td>
<td>Very high</td>
</tr>
<tr>
<td>Dark current</td>
<td>~100cps/cm²</td>
<td>~10000cps/cm²</td>
<td>~100cps/cm²</td>
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<tr>
<td>Growth properties</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Single crystal substrate</td>
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<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Easy scalable</td>
<td>No</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>Large production volume</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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<td>Prefabrication possible</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Temperature sensitive</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
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<td>Existing Industry</td>
<td>No (besides</td>
<td>Yes (foundries available)</td>
<td>Yes (foundries available)</td>
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<td>Basic Physics</td>
<td>Good understanding</td>
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<td>Microscopic understanding</td>
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<td>2-D Fabrication tools</td>
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<td>3-D Fabrication tools</td>
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<td>Theoretical description</td>
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<td>Yes</td>
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<tr>
<td>Band-structure engineering</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Not Clear which will be the best for the project
The People and Places (details will be presented in the following talks)

- Integration of 4 partners
- Collaboration partners bring:
  - Growth expertise (III-V and multi-alkali)
  - World class growth facilities
  - Standard and unique characterization tools
  - Connection to industry
  - Connection to science community (future funding)
- Unique effort for cathodes
  - Size
  - Completeness (growth, macroscopic and microscopic characterization, theory/simulation)
Summary

- Project is based on three pillars:
  - proof of principle & small production volume (SSL)
  - Basic sciences approach to address important issues of PC-production and increase QE, production yield, tune wavelength response, and reduce production costs (mainly ANL)
  - Design and commissioning of large scale production facility (ANL/Fermi)

- Potential PC-materials:
  - $M_3Sb$ ($M$: K, Na, Cs and mixtures): mainly at SSL (polycrystalline) and ANL (amorphous)
  - Ga(In)N: amorphous growth on glass substrates at WashU
  - GaAs: crystalline growth with transfer and bonding technology at UIUC & ANL

- How does the group work?
  - Weekly teleconferencing meetings (Friday 3:30-chicago time)
  - Strong interaction during collaboration meetings and Godparent reviews (about every 3-4 months)
  - First successful test: investigations of interface effects of MgO (film growth at ANL, functionality test at SSL, optical tests and theory at ANL)

- Who works on this project:
  - SSL: ~3-4 staff
  - ANL: 2 staff (50% +30%); ~4 postdocs; additional 3 staff and 2 postdocs for characterization and theory, 1 student (UIUC)
  - WashU: 2 staff