The temperature management of photo cathodes at MAMI and MESA

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15th Sept, 2017

THE LOW-ENERGY FRONTIER OF THE STANDARD MODEL

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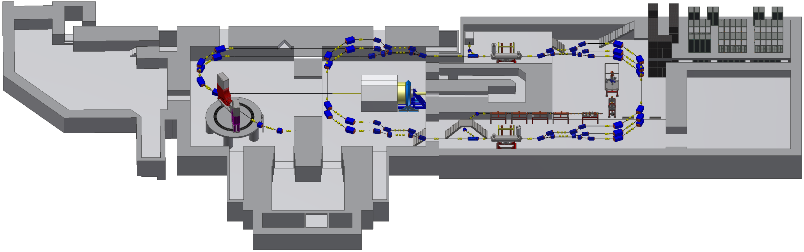
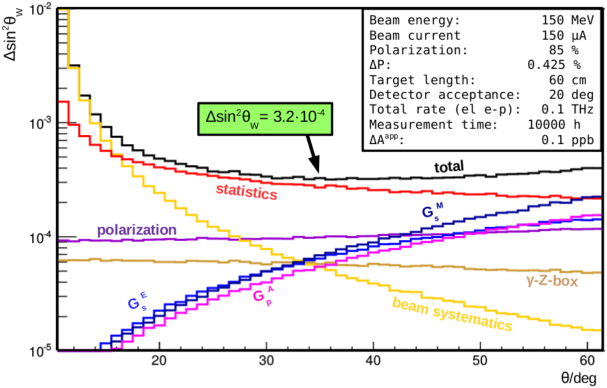
Contents

MESA



- P2-experiment: precision measurement of weak mixing angle
- Accelerator physics: multi-turn, superconducting ERL
- New technique for nuclear and particle physics PIT
- CW spin polarized beam
- Beam current $\sim 150 - 1000\,\mu\mathrm{A}$, beam energy $\sim 155\,\mathrm{MeV}$

P2 Experiment

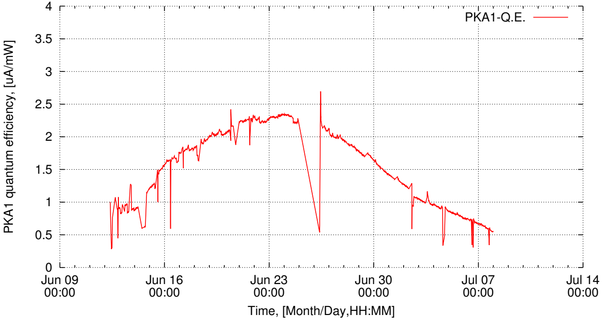


- Aim is to measure the weak mixing angle $\sin^2\theta_w$ in electron proton scattering to precision 0.13%
- Beam current $\sim 150 - 1000\,\mu\mathrm{A}$, beam energy $\sim 155\,\mathrm{MeV}$

Polarized Beam

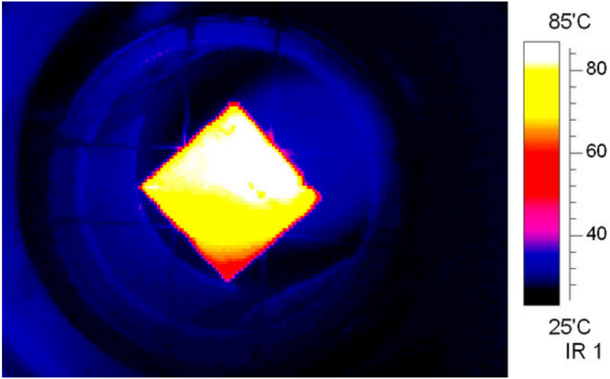
- P2-Experiment operates at 150 $\mu\mathrm{A}$, but (Cathode heating problem must be solved!)
- P2 needs 14 Coulomb per day
- Currently at MAMI photo cathodes charge life time $\sim 200\,\mathrm{C}$
- Currently dark life time 850 hours at PKA2
- Two weeks continuous operation at MAMI
- Cathode exchange every three hours possible (or necessary) to operate at $\sim 1.\,\mathrm{mA}$ polarized average current
- Life time improvement desirable! (STEAM project)

MAMI and MESA Photo cathodes



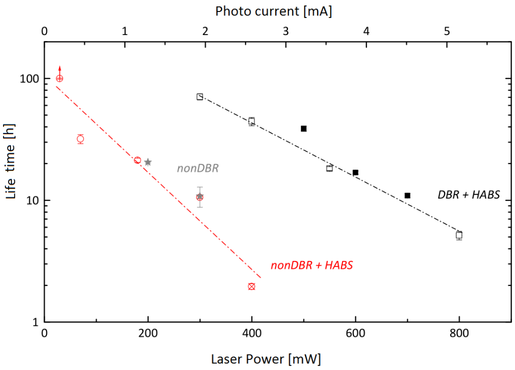
- $I_{\text{MAMI}} \sim 0.1 - 100.0\,\mu\text{A}$, $E_{\text{MAMI}} \sim 150.0 - 1500.0\,\text{MeV}$, $P_{\text{MAMI}} \sim 0.85$
- 7 days/24 hours
- MAMI & MESA similar photo cathodes SVT Associates
- Lot of laser power needed. Power eccent lied to heating of the cathodes and loss his efficiency

The problem itself



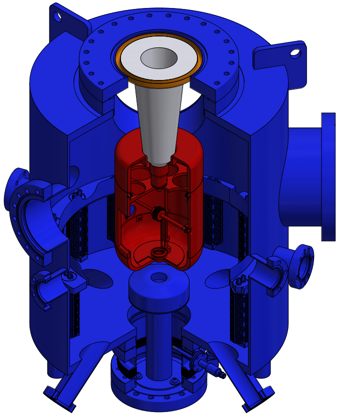
- Free cathode in vacuum at $\sim 0.1\,\mathrm{W}$ laser power
- Cathode life time is limited due to heating of incident laser light

Life time chart of photo cathodes



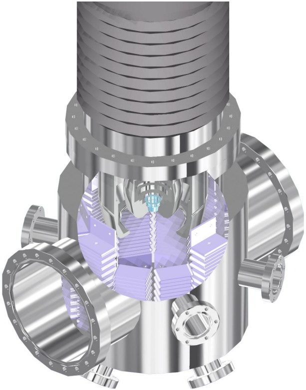
- Within DBR working range, laser power can be increased
- But untill now not enough
- Tenfold the current ⇔ tenfold the laser power
- Cathode is heating up, life time is reduced significantly

Polarized electron beam sources



Inverse source 200.0 kV STEAM,

Ph.D Thesis S. Friedrich 2018

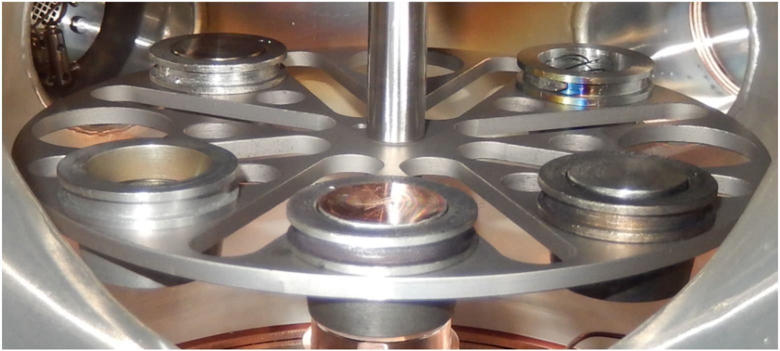


MAMI source 100.0 kV
PKA1 operation from 1998
PKA2 modified 2008

Thermal connection chain: materials and interfaces

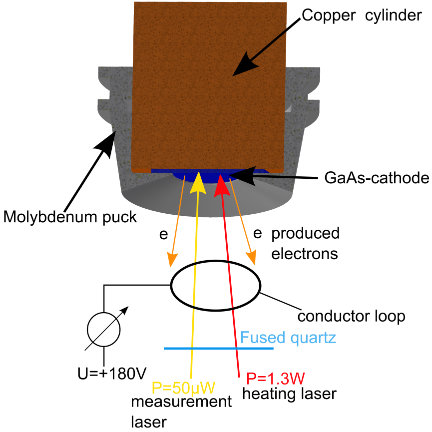
Parts	Connection PKA1	Connection STEAM
Cathode		
	In solder	In solder
Cathode holder		
	mechanical press	mechanical press
Electrode		
	copper rod	thermal problem
Outside		

Some cathodes in HABS chamber



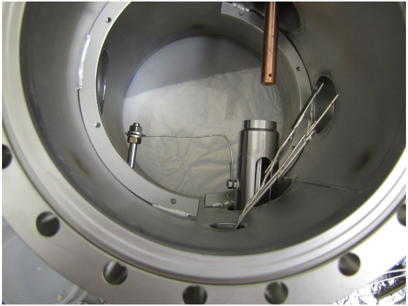
(GaAs cathodes have been soldered with puck)

Life time measurement



- The cathode is heated simulating continuous use
- A different laser is used for data collection
- To attract the electrons a conductor loop is used

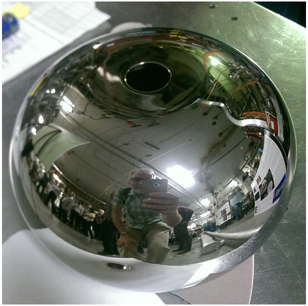
Life time measurement



- HABS chamber is to the left
- NEG pump at the bottom
- Copper shaft adjustable
- two sets of thermocouples to measure temperature

For PKA-X sources at $1.3\,\mathrm{W}$, keeping $T_{cathode} = 303\,\mathrm{K}$

Total emissivity of stainless steel surfaces



JLab cathode head, 14th Sept 2017

The cathode cooling using black body radiation
Polished ϵ_{in}=0.16-0.19
Unpolished ϵ_{out}=0.4
with $\phi_{12} = 1$, $\phi_{21} = 0.28$
$T_{in} = 293\,\mathrm{K}$, $T_{out} = 258\,\mathrm{K}$

$$\epsilon = \frac{1}{\left(\frac{1}{\epsilon_{in}} - 1\right)\phi_{12} + \left(\frac{1}{\epsilon_{out}} - 1\right)\phi_{21} + 1}$$

$$P_{irradiated} \sim \sigma\, \epsilon\, \phi_{12}\, S_{in}\, \left(T_{in}^4 - T_{out}^4\right) \sim 1.0\,\mathrm{W}$$

Conclusion and Outlook

- Reliable high current polarized beam operation at MAMI and MESA requires a significant improvement of heat transfer from photo cathodes
- The solution of cooling for actual MAMI sources (PKA1, PKA2 and PKAT) seems to be possible with modification
- The solution for future source STEAM at MESA has been proposed, has been estimated or measured soon

Thank you

Thank you for your attention.

Abstract

Production of highly polarized electron current is limited due to cathode heating which leads to the destruction of the active layer. For the new electron accelerator MESA a more efficient solution for the cathode cooling problem is required, with the goal to achieve acceptable temperatures at an incident power of about 1 Watt. The current status of temperature management of photo cathodes at MAMI and MESA is presented.