Polarized source and beam injection system for MESA

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presenting work of the MESA injector group
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MESA:
Mainz Energy-recovering Superconducting accelerator
- presently under construction,
- expected begin of operation 2020
- main experiments P2/MAGIX
- Hall for source not yet erected
- set up as many components as possible in available building

Further talks:
S. Baunack on P2 Tuesday
MESA overview tomorrow
STEAM
Small Thermalized Electron Source at MESA

New (wrt MAMI):
- higher current (MAGIX polarized *10) = 1 mA
- more sophisticated spin control (P2)
- 1300 MHz operation (instead of 2499)
- scientific project: explore high brightness near bandgap emission at "relevant" bunch charges for radiation sources
Comparison between STEAM ↔ PKA2 (existing source)

- PKA2: $E_{\text{acc}} \approx 1 \frac{\text{MV}}{\text{m}}$ @100 kV, STEAM: $E_{\text{acc}} \approx 2.5 \frac{\text{MV}}{\text{m}}$ @100 kV

Difference:

PKA2: $E_{\text{acc}} \approx 1 \frac{\text{MV}}{\text{m}}$ @100 kV, STEAM: $E_{\text{acc}} \approx 2.5 \frac{\text{MV}}{\text{m}}$ @100 kV

Down to $-200$ kV
Finished design concept of electron source

Preparation chamber
- Renewal of Cs:O layer for GaAs
- Insertion of new photocathodes w/o breaking vacuum

Photocathode electron source needs:
- UHV conditions
- Load-locked operation mode
- No field emission

beam line setup here only for demonstration

S. Friederich
Comparison between STEAM ↔ PKA2 @ 100 kV

Further simulation parameters

\[ U = 100 \text{ kV}, \quad k_B T = 200 \text{ meV}, \quad \sigma_0 = 0.5 \text{ mm}, \quad t_{\text{bunch}} = 2 \cdot t_{\text{cutoff}} = 200 \text{ ps} \]

Drift length = 200 mm + \( d_{\text{cathode, anode}} \)
Comparison between STEAM ↔ PKA2 @ 100 kV

Transverse Emittance simulated with CST

\[ \varepsilon_{x,n,rms} \text{ in mm mrad} \]

<table>
<thead>
<tr>
<th>q in pC</th>
<th>PKA2</th>
<th>STEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>15</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>20</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>30</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>40</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>50</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Desired value

Further simulation and calculation parameters

\[ U = 100 \text{ kV}, \quad k_B T = 200 \text{ meV}, \quad \sigma_0 = 0.5 \text{ mm}, \quad t_{\text{bunch}} = 2 \cdot t_{\text{cutoff}} = 200 \text{ ps} \]

Drift length = 200 mm + \( d_{\text{cathode,anode}} \)

\[ \varepsilon_{n,rms} = \beta \gamma \sqrt{\langle x^2 \rangle \cdot \langle x'^2 \rangle - \langle x \cdot x' \rangle^2} \]
Comparison between STEAM ↔ PKA2 @ 100 kV|200 kV

Further simulation and calculation parameters

\[ U = 100 \text{ kV}|200 \text{ kV}, \; k_B T = 200 \text{ meV}, \; \sigma_0 = 0.5 \text{ mm}, \; t_{\text{bunch}} = 2 \cdot t_{\text{cutoff}} = 200 \text{ ps} \]

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S. Friederich

Christoph Matejcek

ETC Workshop 2016 3rd August 2016
Comparison between STEAM ↔ PKA2 @ 100 kV|200 kV

Energy Spread simulated with CST

Improvement by > 50 %

Further simulation and calculation parameters

\[ U = 100 \text{ kV}|200 \text{ kV}, \ k_B T = 200 \text{ meV}, \ \sigma_0 = 0.5 \text{ mm}, \ t_{\text{bunch}} = 2 \cdot t_{\text{cutoff}} = 200 \text{ ps} \]

Drift length = 200 mm + \( d_{\text{cathode, anode}} \)

\[ \frac{\Delta E}{E} = \frac{E_{\text{max}} - E_{\text{min}}}{e \cdot U + m_e c^2} \]
Source assembling finished and ready for baking out and HV-processing
Working platform and beamline framework was finished recently and source was mounted.

Actual setup

Planned setup in autumn
Spinrotation System
Spinrotating system at MELBA (MESA low energy beam apparatus)
Working principle

Spin Rotating System

Source

Pump

1. Wien filter (constant $\phi = 90^\circ$)

Solenoid ($\theta = \pm 90^\circ$)

2. Wien filter (variable $\phi$)

3.7 m

Top view:

Side view:
Wienfilter
- 100 keV version exists and works
- Two in stock

Solenoid
- $\int B_\parallel ds = 0.10 \text{T m for } 100 \text{ keV, } 90^\circ$
- Under design
Laser System
Current Laser system at MAMI is a MOPA (Master Oszillator Power Amplifier)

- It is temperature stabilized and an external feedback loop is responsible for beam current stabilization
- 250 mW are available at the photocathode
- Quantum efficiency of GaAs/GaAsP superlattice at 780 nm is 2 $\frac{mA}{W}$
- With 150 µA we get $14 \frac{C}{d}$ or $4 \frac{mAh}{d}$
- We assume to get 200 C per lifetime of one cathode

⇒ Able to provide 14 days of continuous beam
⇒ Able to supply the P2 experiment with beam
Beamline Simulation
Use result particle distribution of one program as start distribution for the other.
Parmela simulation from second alpha magnet to the end of the first MAMBO section for a beam current of 1.3 mA.

<table>
<thead>
<tr>
<th>$\alpha_x$</th>
<th>$\beta_x$ in m</th>
<th>$\epsilon_{x,RMS,n}$ in $\mu$m</th>
<th>$\alpha_x$</th>
<th>$\beta_x$ in m</th>
<th>$\epsilon_{y,RMS,n}$ in $\mu$m</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.5</td>
<td>4.6</td>
<td>0.419</td>
<td>12.2</td>
<td>3.7</td>
<td>0.386</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>$\frac{\Delta E}{E_{RMS}}$ in %</th>
<th>$\Delta \phi_{RMS}$ in °</th>
<th>$\epsilon_{z,RMS}$ in °keV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7</td>
<td>1.3</td>
<td>1.576</td>
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Summary & Outlook
■ STEAM can provide P2 experiment
■ Backup source PKA2
■ Spinrotating system soon available
■ With current Laser system, source, cathodes we can provide sufficient beam current and beam availability for P2 experiment
■ Beamline can handle beamcurrent

■ Infrastructure (e. g. cooling water) is ready to use
■ Build up first part of beamline till autumn
■ Finish whole low beam energy transport within the next year
Thank you for your attention!
Backup Slides
- LASER diodes → cheap
- three available wavelengths (405 nm, 520 nm, 780 nm)
- @780 nm → QE = 0.5 %; pol. ≈ 80 %
- @405 nm → QE = 15 %; pol. ≈ 0 %
- DC- or pulsed mode → longer lifetime
- RF synchronized
- green laser diode
- $\lambda = 520 \text{ nm}$
- $P = 120 \text{ mW}$
- $I_{th} = 120 \text{ mA}$
- transmission @120° $> 95\%$
- low beam current $< 1 \mu\text{A}$
Recent Achievements in Synthesizing new Photocathodes

$K_2CsSb$ Photocathodes

V. Bechthold

Christoph Matejcek

ETC Workshop 2016 3rd August 2016

 QE / %

Wavelength / nm
Potassium Cesium Antimonid (PCA) versus GaAs photocathodes

PCA photocathodes promise **high quantum efficiency**, fast response time and **low thermal emittance** while being **100 fold** more robust.
Quantum efficiency and polarisation as function of the photon energy for p-doped bulk GaAs crystal. By Y. Yashin, 2006
**Principle**: Radiofrequency streak method

- **Conversion of the longitudinal profile into transversal profile by TM-110 RF Deflector Cavity**
- **Electron bunches must be emitted synchronously to RF Master** → stable spatial image of the bunch is generated
- **Pulse image shifted over slit by varying the phase of the laser pulse relative to RF**
- **Bunch profile sampled by measuring the dependence of the current or picture on YAG-screen**
- **TM110** cavity transforms longitudinal beam profile into a transversal one
- synchronization of electron bunches and RF cavity needed for observation
- resulting intensity distribution represents the time dependency of electrons in one bunch
- measured by YAG-screen and channeltron
blue laser diode
\( \lambda = 405 \text{ nm} \)
\( P = 200 \text{ mW} \)
\( I_{th} = 25 \text{ mA} \)
transmission @ 120° > 99%
\[ P_{\text{max}} < 300 \text{ mW} \]
\[ P_{\text{avr.}} < 300 \text{ mW} \]

Pulsed | \( 10 \mu\text{s} < t_p < 500 \mu\text{s} \)
\[ f = <50 \text{ Hz} \]

\[ P_{\text{max}} < 300 \text{ mW} \]
\[ P_{\text{avr.}} < 3 \text{ mW} \]

Pulse train | \( 100\text{ps} < t_p < 300\text{ps} \)
\[ f = <50 \text{ Hz und } f_{RF} = 1.3 \text{ GHz} \]

\[ P_{\text{max}} < 3000 \text{ mW} \]
\[ P_{\text{avr.}} < 3 \text{ mW} \]
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**Diagram:**
- **Phase spectrum**
- **Transvers particle distribution**
- **Long. phase space**