Polarized source and beam injection system for MESA

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presenting work of the MESA injector group
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L. Hein, B. Le Droit, P. Heil, Chr. Matejeck, C. Stoll)

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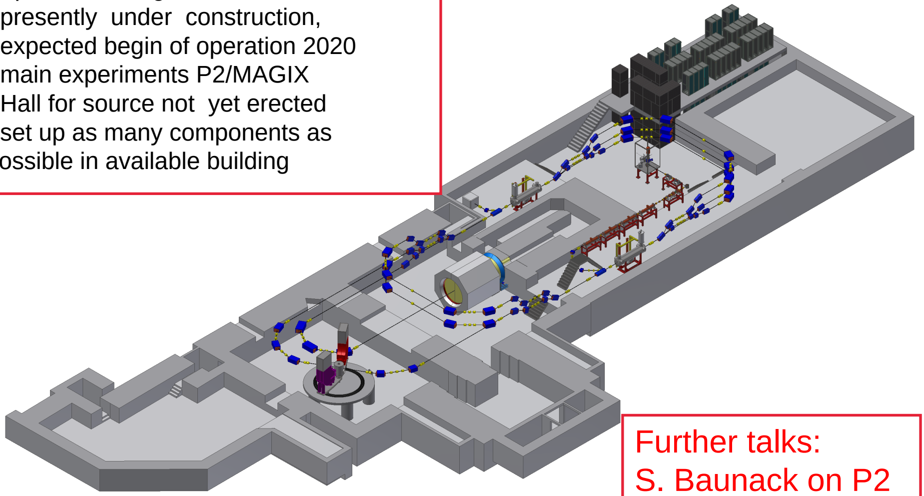
Bundesministerium
für Bildung
und Forschung

PRISMA

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



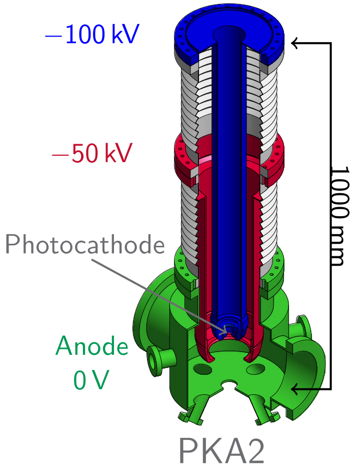
Further talks:
S. Baunack on P2 Tuesday
MESA overview tomorrow

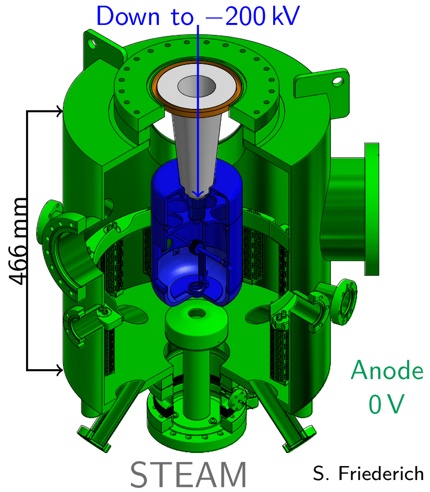
STEAM

Small Thermalized Electron Source at MESA

New (wrt MAMI):
-higher current (MAGIX polarized *10) =1mA
- 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)

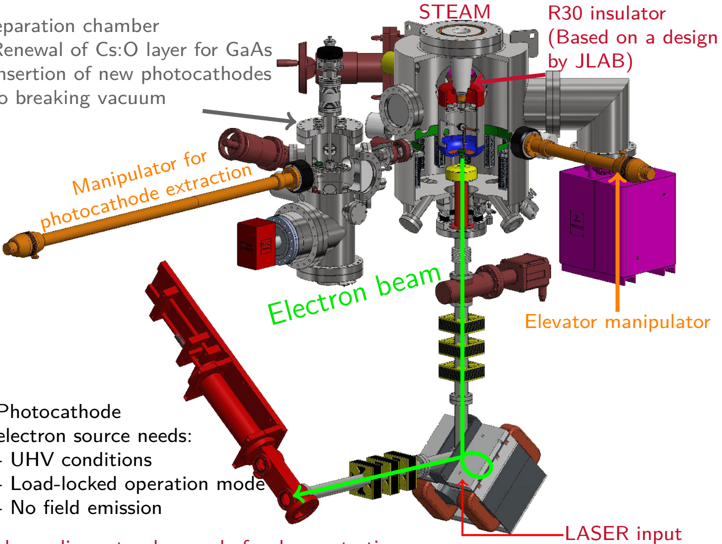




Difference: PKA2: $E_{\mathrm{acc}} \approx 1\,\frac{\mathrm{MV}}{\mathrm{m}}$ @100 kV, STEAM: $E_{\mathrm{acc}} \approx 2.5\,\frac{\mathrm{MV}}{\mathrm{m}}$ @100 kV

Finished design concept of electron source

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

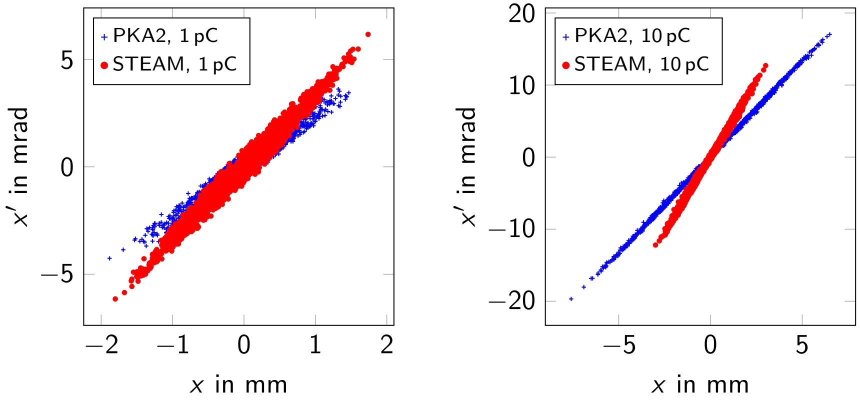


Photocathode electron source needs:
- UHV conditions
- Load-locked operation mode
- No field emission

beam line setup here only for demonstration

S. Friederich

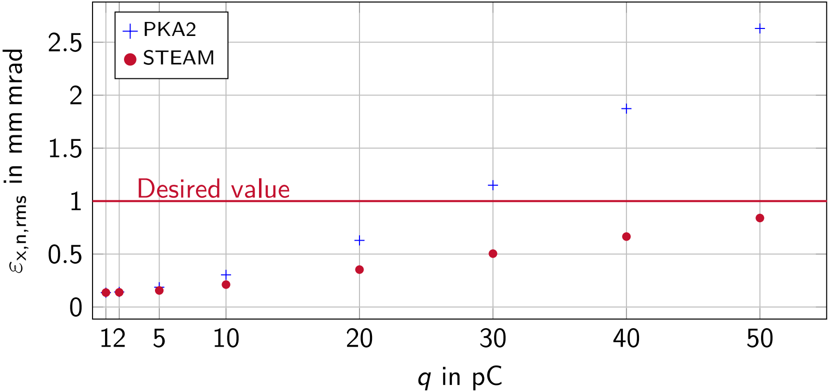
Comparison between STEAM ↔ PKA2 @ 100 kV



Further simulation parameters

$U = 100\,\text{kV},\ k_B T = 200\,\text{meV},\ \sigma_0 = 0.5\,\text{mm},\ t_{\text{bunch}} = 2 \cdot t_{\text{cutoff}} = 200\,\text{ps}$
Drift length $= 200\,\text{mm} + d_{\text{cathode,anode}}$

Comparison between STEAM ↔ PKA2 @ 100 kV

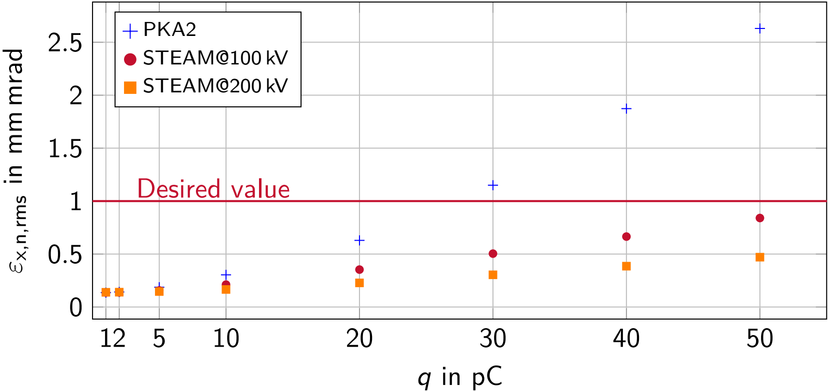


Further simulation and calculation parameters

$U = 100\,\text{kV}$, $k_B T = 200\,\text{meV}$, $\sigma_0 = 0.5\,\text{mm}$, $t_{\text{bunch}} = 2 \cdot t_{\text{cutoff}} = 200\,\text{ps}$
Drift length $= 200\,\text{mm} + d_{\text{cathode,anode}}$
$\varepsilon_{\text{n,rms}} = \beta\gamma\sqrt{\langle x^2\rangle \cdot \langle x'^2\rangle - \langle x \cdot x'\rangle^2}$

S. Friederich

Comparison between STEAM ↔ PKA2 @ 100 kV|200 kV

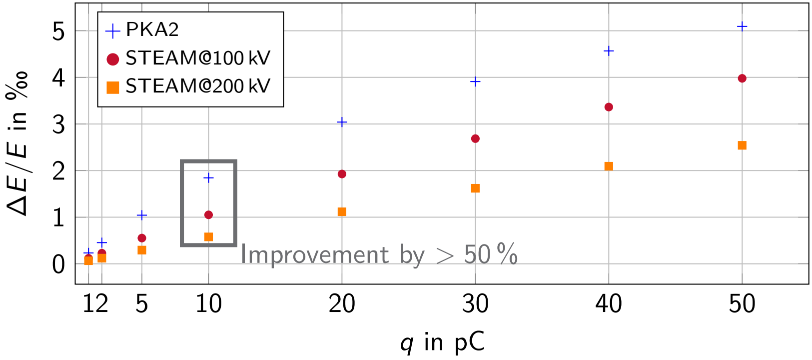


Further simulation and calculation parameters

$U = 100\,\text{kV}|200\,\text{kV}$, $k_B T = 200\,\text{meV}$, $\sigma_0 = 0.5\,\text{mm}$, $t_{\text{bunch}} = 2 \cdot t_{\text{cutoff}} = 200\,\text{ps}$
Drift length $= 200\,\text{mm} + d_{\text{cathode,anode}}$
$\varepsilon_{\text{n,rms}} = \beta\gamma\sqrt{\langle x^2\rangle \cdot \langle x'^2\rangle - \langle x \cdot x'\rangle^2}$

S. Friederich

Comparison between STEAM ↔ PKA2 @ 100 kV|200 kV



Further simulation and calculation parameters

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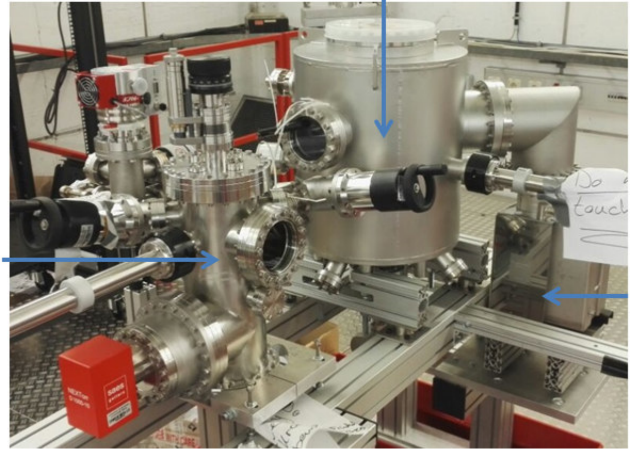
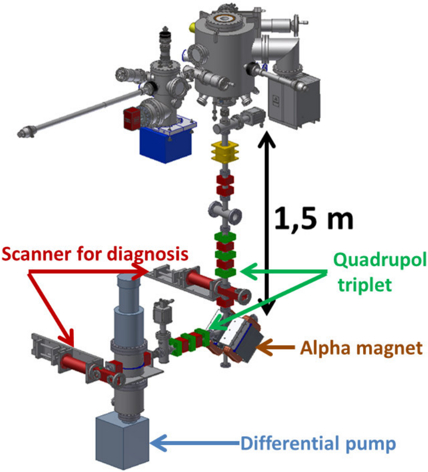
Drift length $= 200\,\text{mm} + d_{\text{cathode,anode}}$
$\frac{\Delta E}{E} = \frac{E_{\max} - E_{\min}}{e \cdot U + m_e c^2}$

Source assembling finished and ready for baking out and HV-processing



Working platform and beamline framework was finished recently and source was mounted

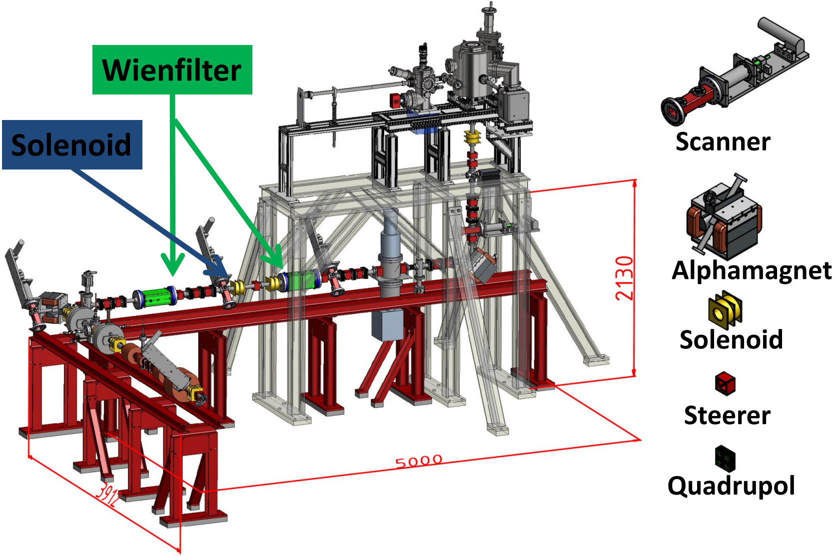
Actual setup



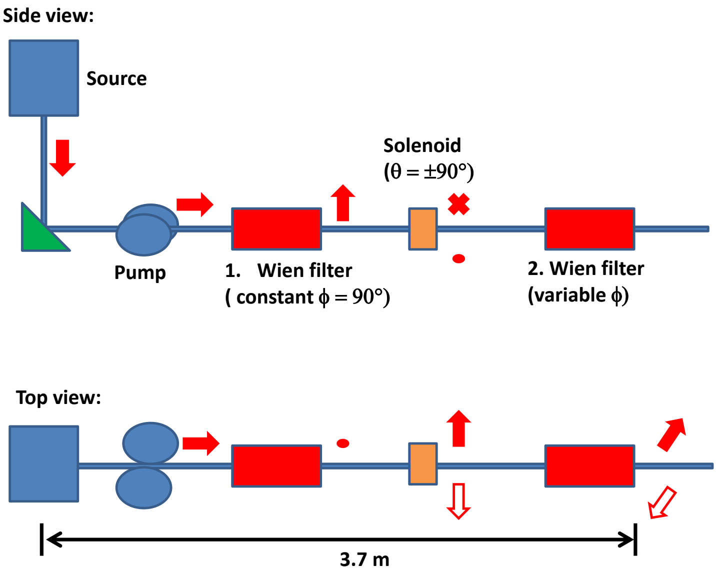
Planned setup in autumn

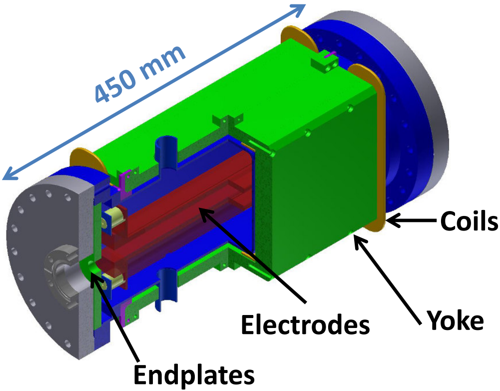
Spinrotation System

Spinrotating system at MELBA (MESA low energy beam apparatus)



Working principle





Wienfilter

- 100 keV version exists and works
- Two in stock

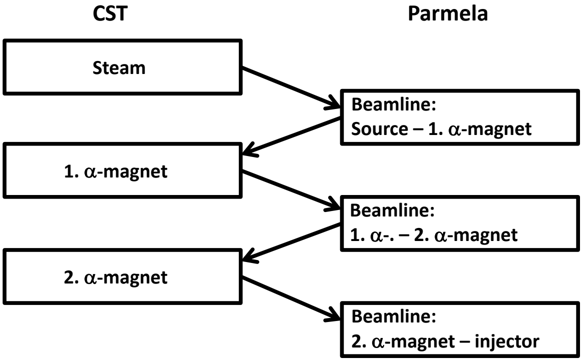
Solenoid

- $\int B_{\parallel} ds = 0.10\,\mathrm{T\,m}$ for 100 keV, 90°
- Under design

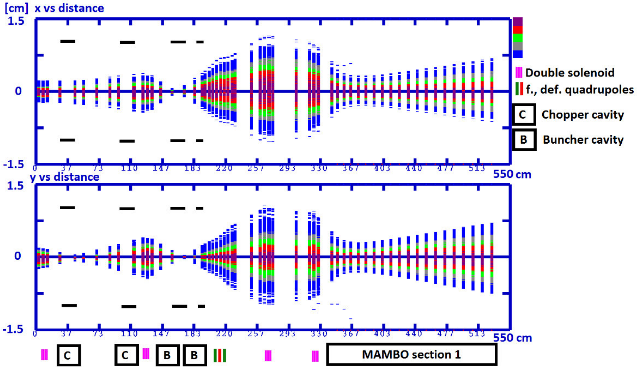
Laser System

- 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 $\frac{\text{mA}}{\text{W}}$
- With 150 µA we get 14 $\frac{\text{C}}{\text{d}}$ or 4 $\frac{\text{mA h}}{\text{d}}$
- We assume to get 200 C per lifetime of one cathode
- $\Rightarrow$ Able to provide 14 days of continous beam
- $\Rightarrow$ 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.

α_x	β_x in m	$\epsilon_{x,RMS,n}$ in µm	α_x	β_x in m	$\epsilon_{y,RMS,n}$ in µm
16.5	4.6	0.419	12.2	3.7	0.386

$\frac{\Delta E}{E}_{RMS}$ in %	$\Delta\phi_{RMS}$ in °	$\epsilon_{z,RMS}$ in °keV
1.7	1.3	1.576

Summary & Outlook

Summary & Outlook

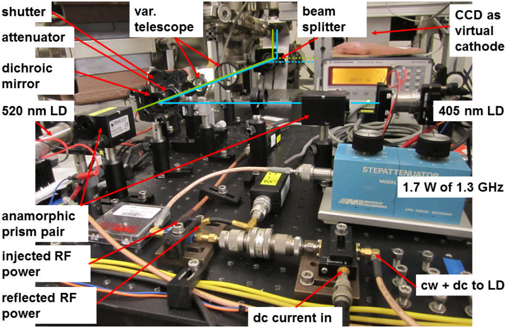
- STEAM can provide P2 experiment
- Backup source PKA2
- Spinrotating system soon available
- With current Laser system, source, cathodes we can provide sufficent beam current and beam availability for P2 experiment
- Beamline can handle beamcurrent

- 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!

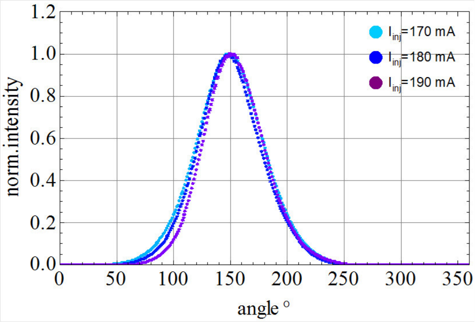
Backup Slides

- LASER diodes $\rightarrow$ cheap
- three available wavelengths (405 nm, 520 nm, 780 nm)
- @780 nm $\rightarrow QE = 0.5\,\%$; pol. $\approx 80\,\%$
- @405 nm $\rightarrow QE = 15\,\%$; pol. $\approx 0\,\%$
- DC- or pulsed mode $\rightarrow$ longer lifetime
- RF synchronized

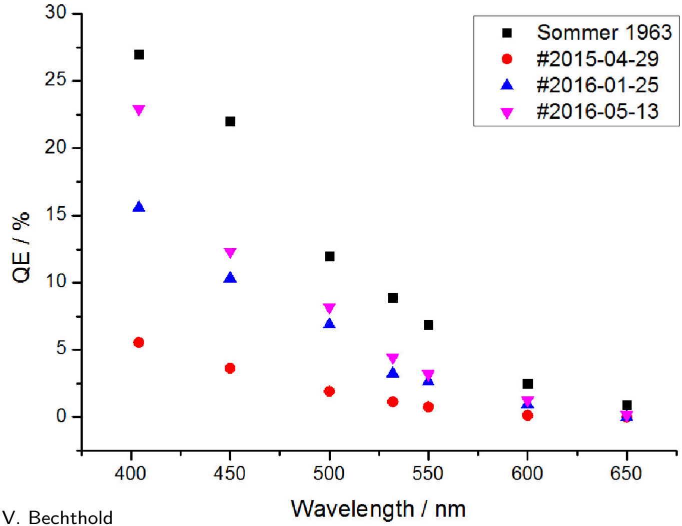


I. Alexander

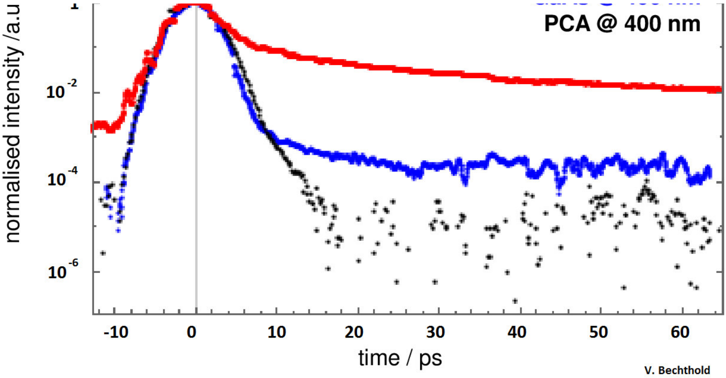
- green laser diode
- $\lambda = 520\,\text{nm}$
- $P = 120\,\text{mW}$
- $I_{th} = 120\,\text{mA}$
- transmission @$120^\circ > 95\,\%$
- low beam current $< 1\,\mu\text{A}$



I. Alexander

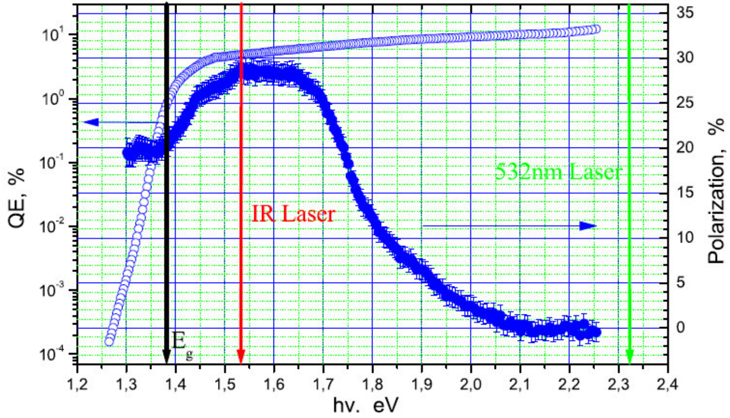


QE / %
30
25
20
15
10
5
0
400
450
500
550
600
650
Wavelength / nm
Sommer 1963
#2015-04-29
#2016-01-25
#2016-05-13



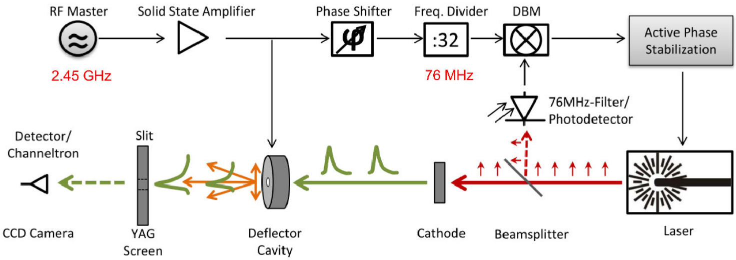
Potassium Cesium Antimonid (PCA) versus GaAs photocathodes

PCA photocathodes promise **high quantum efficiency**, **fast response time** and **low thermal emittance** while being **100 fold** more robust.

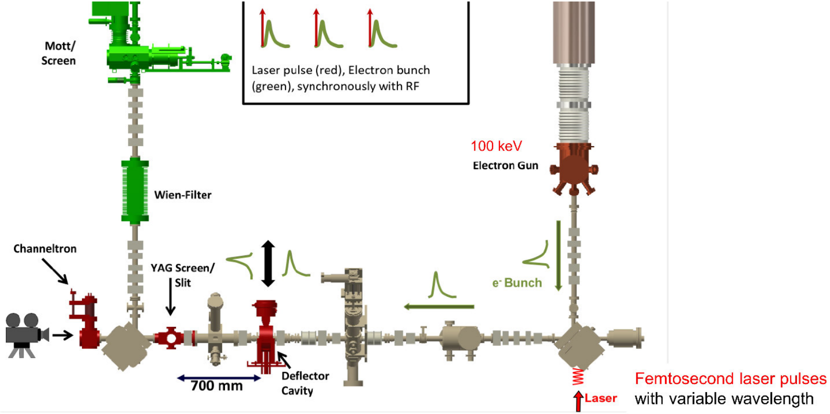


Quantum efficiency and polarisation as function of the photon energy for p-doped bulk GaAs crystal. By Y. Yashin, 2006

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



- TM_{110} 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

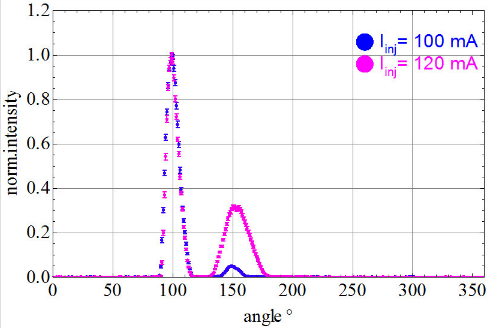
blue laser diode

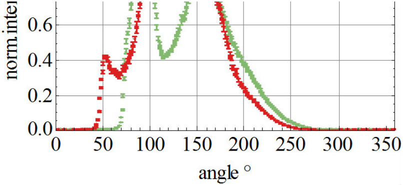
λ = 405 nm

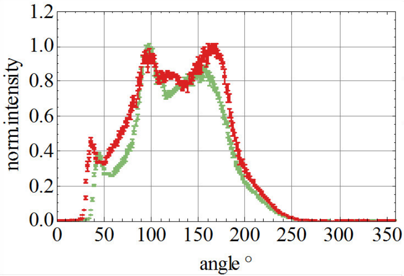
P = 200 mW

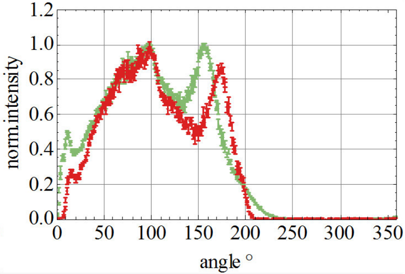
I_{th} = 25 mA

transmission @ 120° > 99%




norm.inte
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
350
angle °


norm.intensity
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
350
angle °


norm.intensity
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
50
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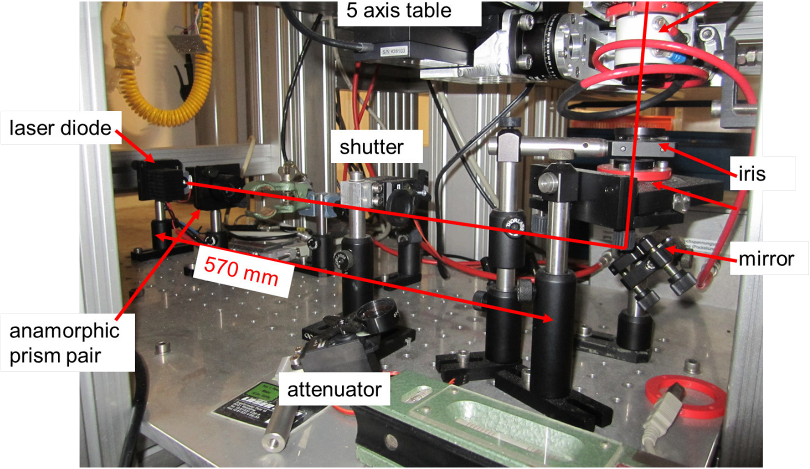
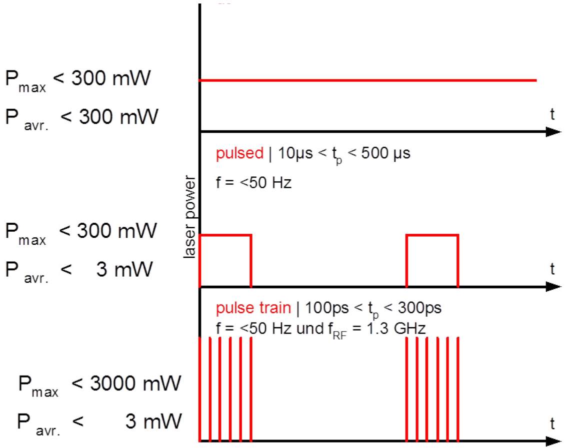
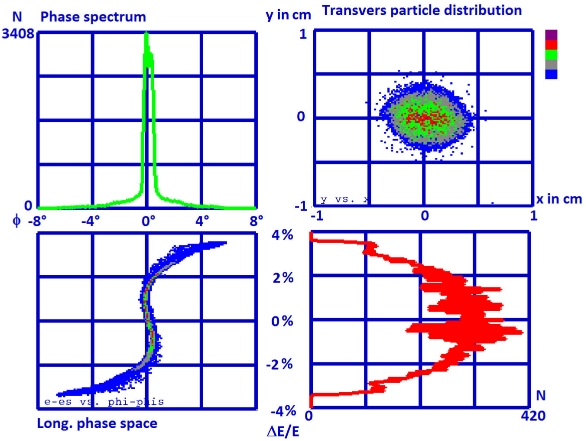
200
250
300
350
angle °


5 axis table
laser diode
shutter
iris
mirror
570 mm
anamorphic
prism pair
attenuator


P max < 300 mW
P avr. < 300 mW
t
pulsed | 10µs < tp < 500 µs
f = <50 Hz
laser power
P max < 300 mW
P avr. < 3 mW
t
pulse train | 100ps < tp < 300ps
f = <50 Hz und fRF = 1.3 GHz
P max < 3000 mW
P avr. < 3 mW
t



$\frac{\Delta E}{E}_{RMS}$ in %	$\Delta\phi_{RMS}$ in °	$\epsilon_{z,RMS}$ in °keV
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