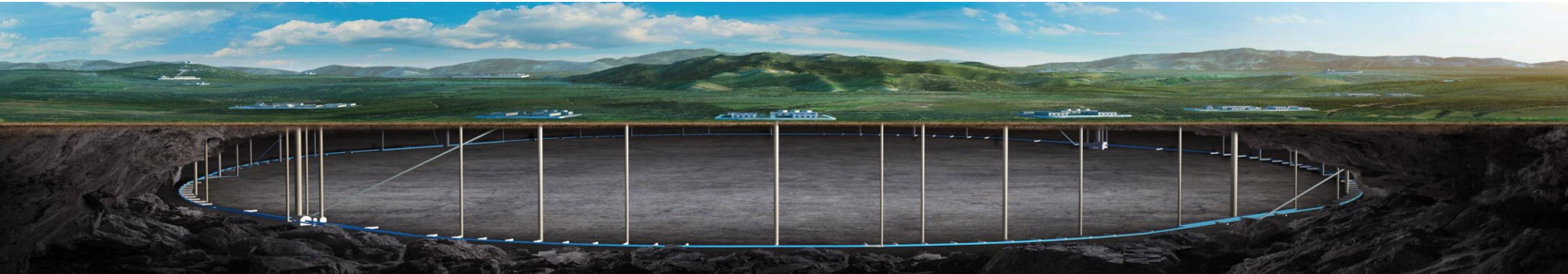
中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

CEPC 环形正负电子对撞机
Circular Electron Positron Collider

CEPC polarized electron source R&D in EDR

Xiaoping Li, Zhe Duan, Valery Tyukin, Wei Liu, Yaqi Pu, Jie Gao



Content

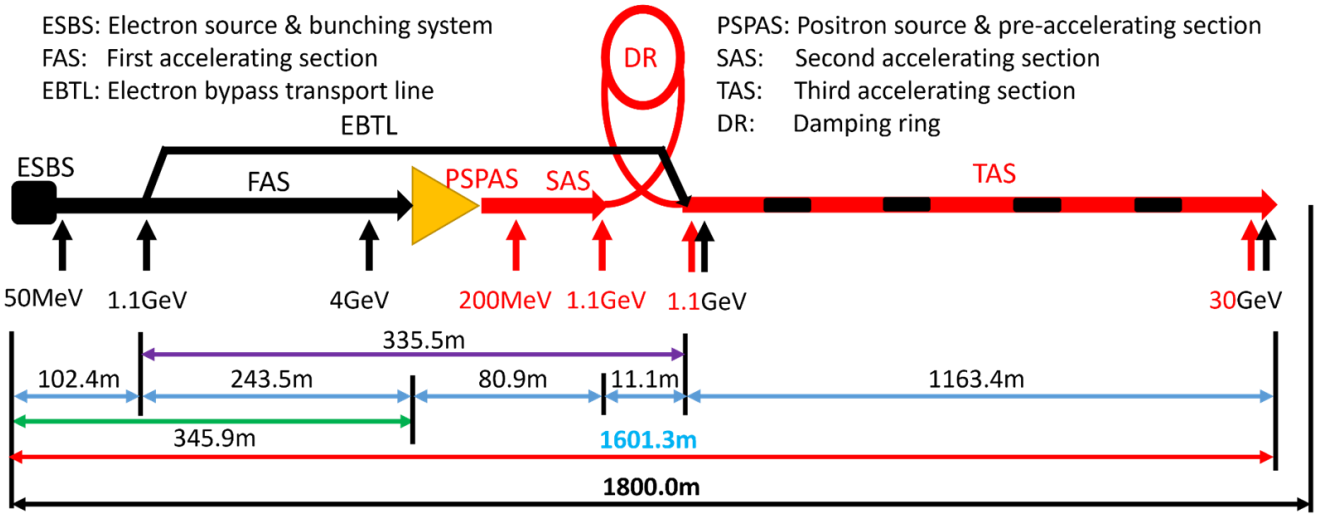
- **CEPC Electron Source**
- **Generation of polarized electron beams**
- **Polarized electron source related R&D**
  - Domestic R&D on the superlattice GaAs photocathode
  - Test results of the superlattice GaAs photocathode
  - A test platform for superlattice GaAs photocathode
  - A polarized electron gun design for CEPC
- **Summary**

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CEPC Linac

- **Baseline design of the CEPC Linac**
  - A **30GeV** room temperature Linac
  - A combination of **S-Band (2860MHz)** and **C-Band (5720MHz)**
  - FAS+PSPAS+SAS：S-Band
  - TAS：C-Band（Higher gradient → Shorter linac tunnel length）
  - The Linac tunnel length is **1.8km**

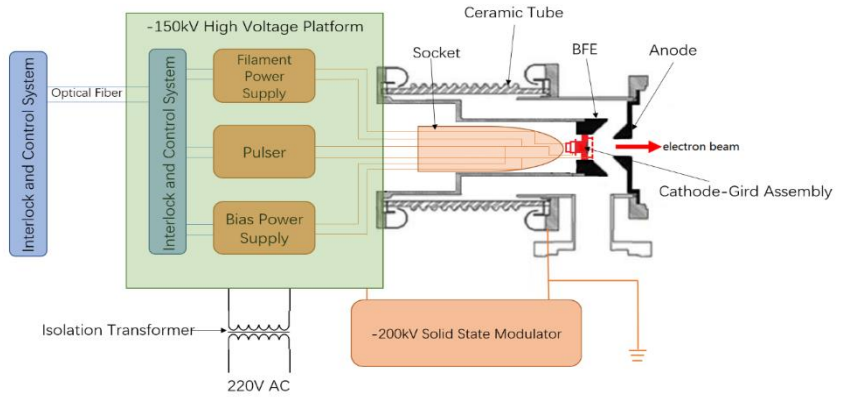


Parameter	Symbol	Unit	Baseline
Energy	E_{e-}/E_{e+}	GeV	30
Repetition rate	f_{rep}	Hz	100
Bunch number per pulse			1 or 2
Bunch charge		nC	**1.5**
Energy spread	σ_E		1.5×10^{-3}
Emittance	ε_r	nm	6.5

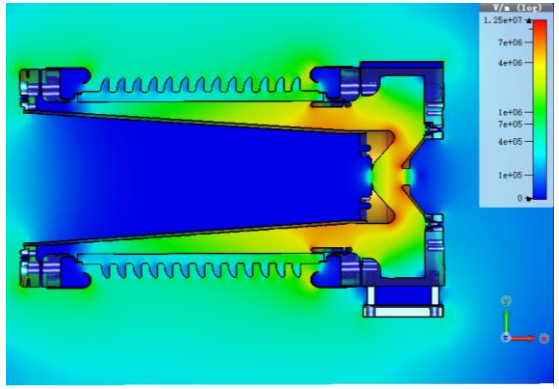
CEPC Electron Source

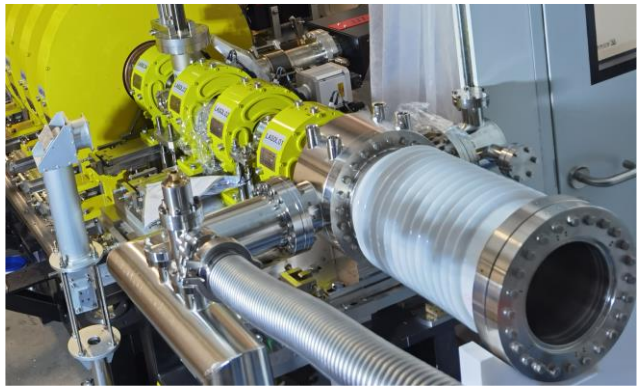
The electron source is used for generating an electron beam with a specific longitudinal distribution that can be accelerated for injection and positron production.

- **Electron Gun (Baseline design)**
  - A traditional thermionic triode gun with two operation modes
  - **1.5nC** for electron injection
  - **10nC** for positron generation
- **Has been verified at BEPCII and HEPS Linac**



Parameter	Unit	Value
Type	-	Thermionic Triode Gun
Cathode	-	Dispenser cathode
Beam current	A	> 10
High voltage of anode	kV	150
Bunch charge 1	nC	1.5 (e^- injection)
Bunch charge 2	nC	10 (e^+ production)
Repetition	Hz	100





CEPC electron source parameters and its design

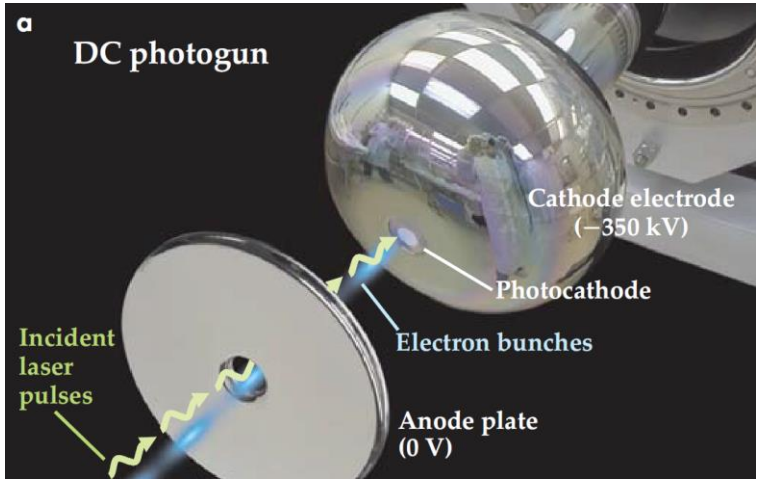
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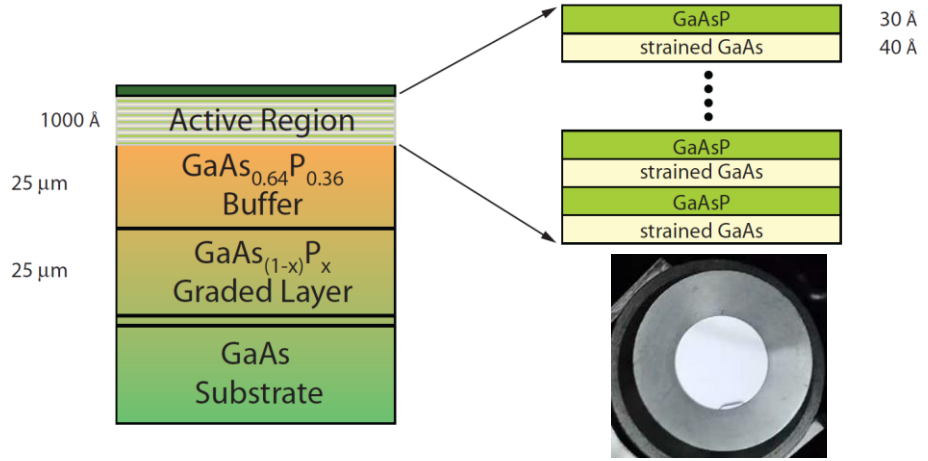
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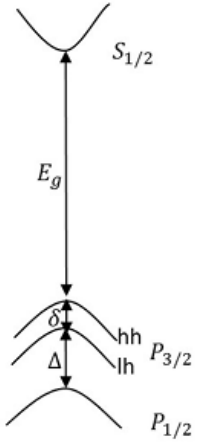
Generation of polarized electron beams

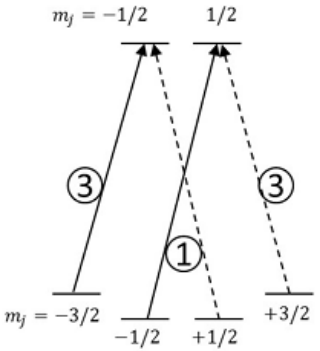
Polarized electron generation

- One effective method for generating polarized electrons is using GaAs photocathode in a **HV photocathode gun** (**Extremely high vacuum**) and recently also demonstrated in a **SRF-Gun**
- For a common bulk GaAs, polarization is about 30%-35%. For a strained GaAs, a maximum polarization in theory is 100%, considering depolarization effect it usually is about **85%** at around **780nm** of laser wavelength (Determined by its special band structure)
- Constructing **superlattice** structure is an effective way to obtain strained GaAs
- This type of photocathode is usually be grown on a substrate using MBE









$$P = \left|\frac{3}{3}\right| = 100\%$$

Polarized electron generation from superlattice GaAs

Content

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Polarized electron source related R&D

Domestic R&D on the superlattice GaAs photocathode

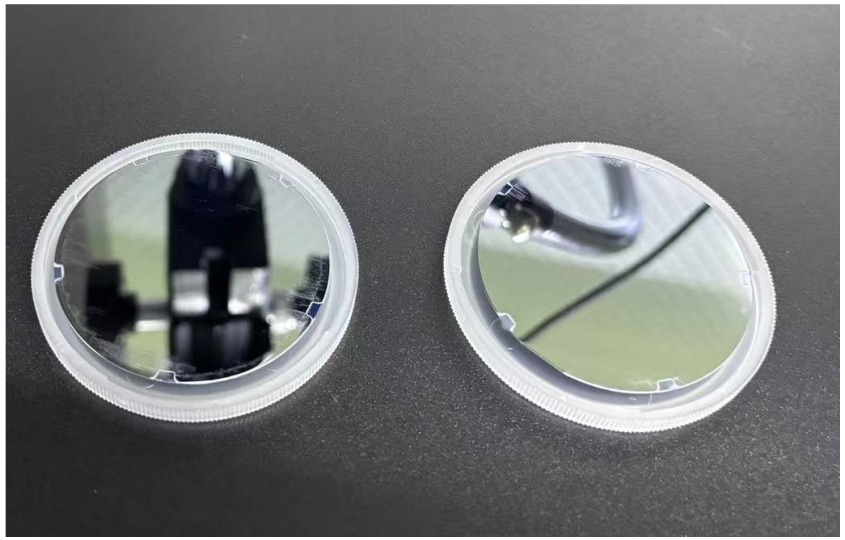
- One of **the most important** part for PES is Superlattice GaAs Photocathode
- Since the beginning of 2025, we have been starting the R&D of Superlattice GaAs
- In collaboration with a domestic company Acken Optoelectronics Ltd. @ Suzhou
- Superlattice GaAs photocathode produced by MBE system
- The first the batch of photocathodes have been produced

GaAs	**5 nm**	**$p=5\times10^{19}$ cm^{-3}**
GaAs/GaAsP SL	(4/3 nm) $\times$14	$p=5\times10^{17}$ cm^{-3}
$GaAsP_{0.35}$	2750 nm	$p=5\times10^{18}$ cm^{-3}
Graded $GaAsP_x$ (x = 0~0.35)	5000 nm	$p=5\times10^{18}$ cm^{-3}
GaAs buffer	200 nm	$p=2\times10^{18}$ cm^{-3}
p-GaAs substrate ($p>10^{18}$ cm^{-3})		

Structure of Superlattice layers



MBE system in Acken

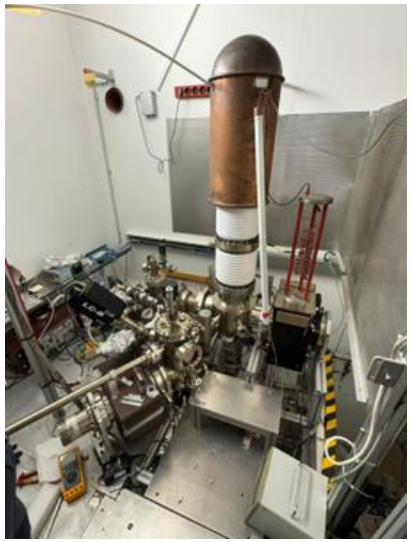


Samples of superlattice GaAs/GaAsP

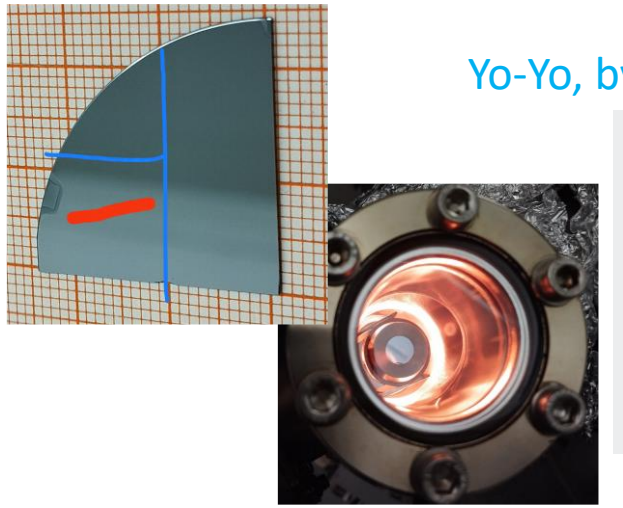
Polarized electron source related R&D

Test results of the superlattice GaAs photocathode

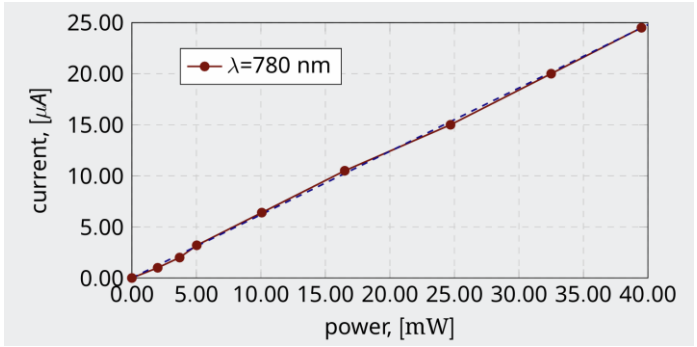
- Collaboration with Inst. of Nuclear Physics, JGU Mainz on SL GaAs (Valery Tyukin, **PIFI 2024-2026**)
- A sample of SL GaAs wafer had been cut and a quarter delivered to Mainz
- Activation experiment for QE of the SL GaAs and beam polarization measurement experiment has been carried out in Mainz. The beam polarization was measured by **Mott at 3.5MeV** and **Moller 855.0MeV polarimeters**
- As a very important experimental data for our Mott polarimeter calibration in future



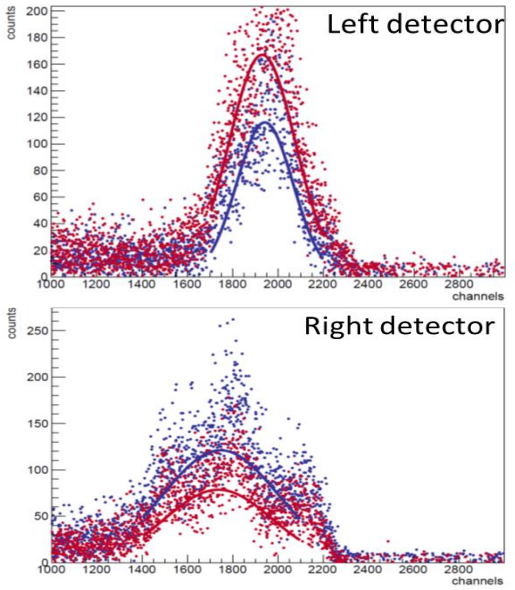
Polarized e- gun at Mainz



Yo-Yo, by using $Cs+NF_3$ activation



Activation and photo-current measurement at Mainz

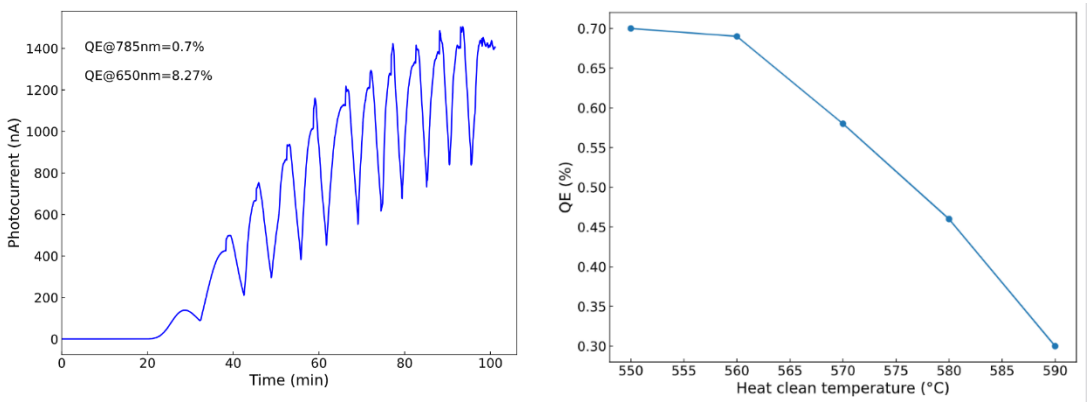


Asymmetry of polarized e-

Polarized electron source related R&D

Test results of the superlattice GaAs photocathode

- Cross check of activation experiment based **on the same wafer sample** was carried out on the platform of Chongqing University in China (only activation experiment and QE measurement) .
- Yo-Yo method by using $Cs+O_2$ activation
- QE is **0.7% @785nm** and **8.27%@650nm**, and QE of decreasing with the increase of heat clean temperature
- Performance test results show promising results in polarization and QE



Activation on SL GaAs at Chongqing University

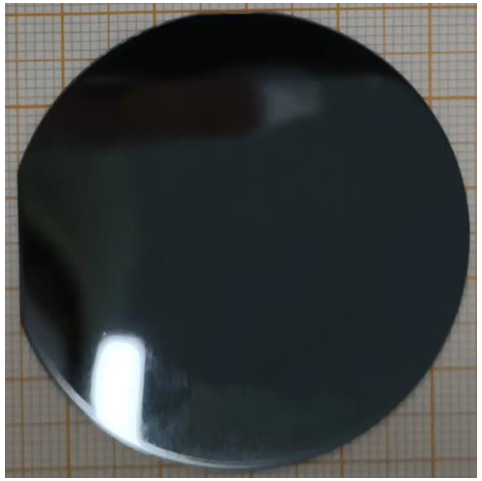
Summary of the First Batch of Wafer Testing

Parameter	Valery Tyukin @ JGU Mainz	Wei Liu @ Chongqing University
Polarization	**80%~82%**, slightly higher or comparable to SVT SL wafer	–
Activation	Yo-Yo, Cs + NF_3	Yo-Yo, Cs + O_2
Quantum efficiency	0.1% @ 780 nm	**0.7% @ 785 nm**

Polarized electron source related R&D

Test results of the superlattice GaAs photocathode

- Based on the test results of the first batch of SL wafers, a second batch of samples was grown in Aug 2026.
- Acken improved the MBE process for SL wafers, **including optimization of the gradient process for buffer layer growth, reduction of the GaAsP component amplitude, and surface uniformity**
- Higher polarization and QE can be expected
- The second batch of SL wafer will be delivered to Mainz for testing soon



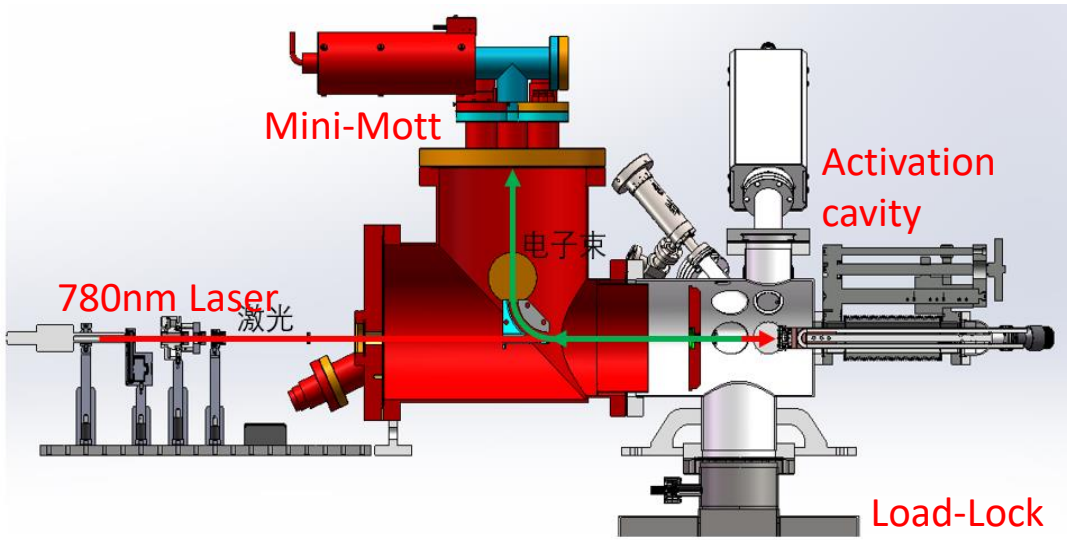


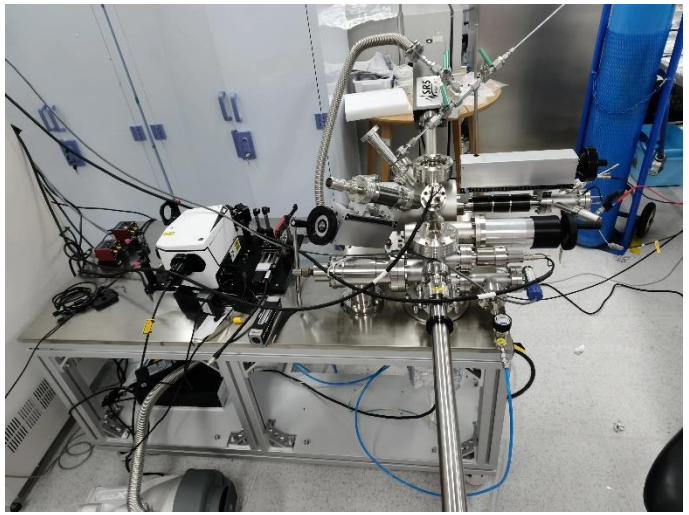
Second batch of SL GaAs and its cutting in clean room @Acken

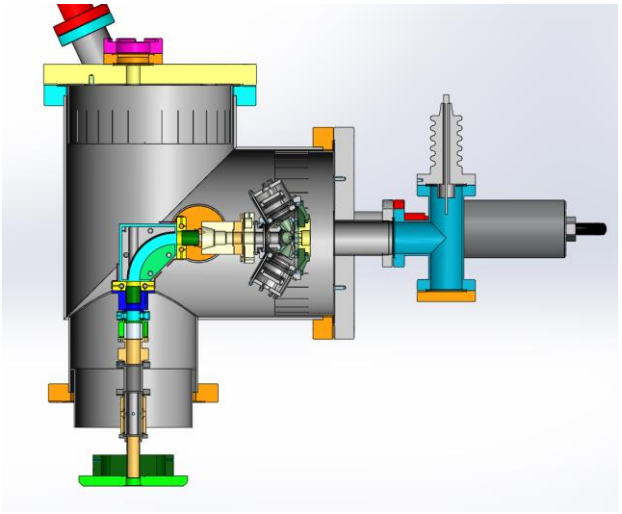
Polarized electron source related R&D

A test platform for superlattice GaAs photocathode

- A platform Including a photocathode load-lock chamber, an activation chamber, a Mini-Mott and a testing laser system for SL GaAs photocathode performance test (both pol & QE) has been designed.
- Up to now, this platform had been fabricated (except for Mini-Mott) and is currently under vacuum baking, expected to start activation experiment study on SL GaAs before the end of this year
- A Mini-Mott polarimeter for a low energy electron beam has been designed





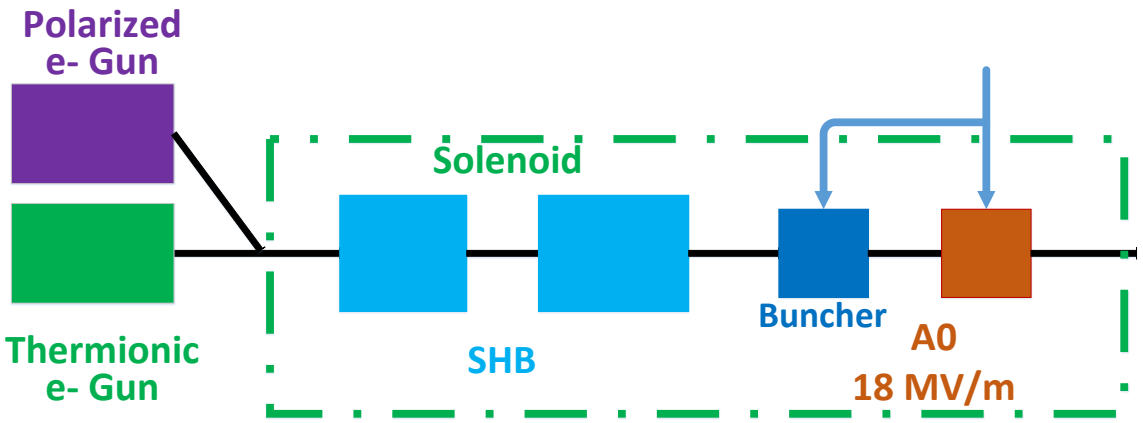


Platform for photocathode performance test

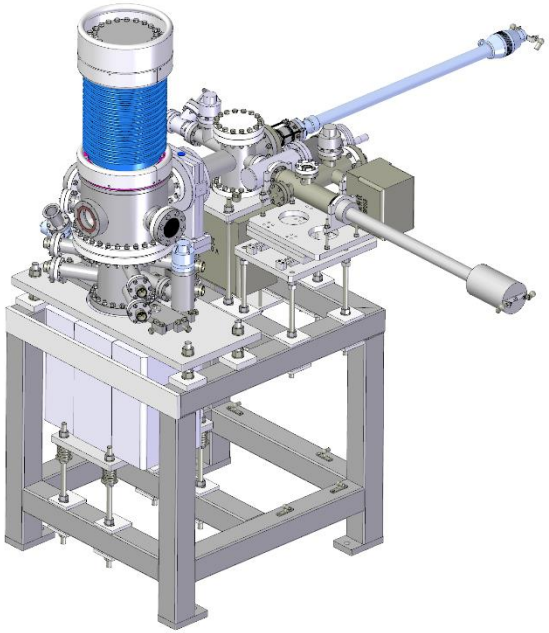
Polarized electron source related R&D

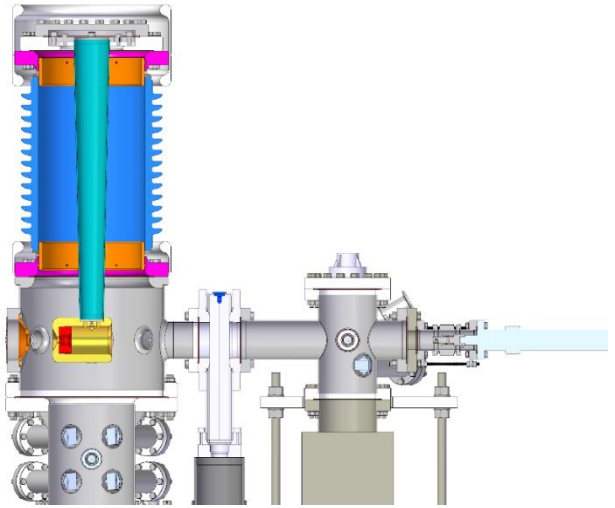
A Polarized electron gun design for CEPC

- A 150kV HV photocathode electron gun has been designed (Parameters are consistent with the thermionic gun)
- Two electron guns scheme and do not change the layout of the injector, share the bunching system
- As an alternative solution for CEPC electron source
- It can also be adopted in BEPCII as a polarized electron source



Two electron guns scheme for CEPC



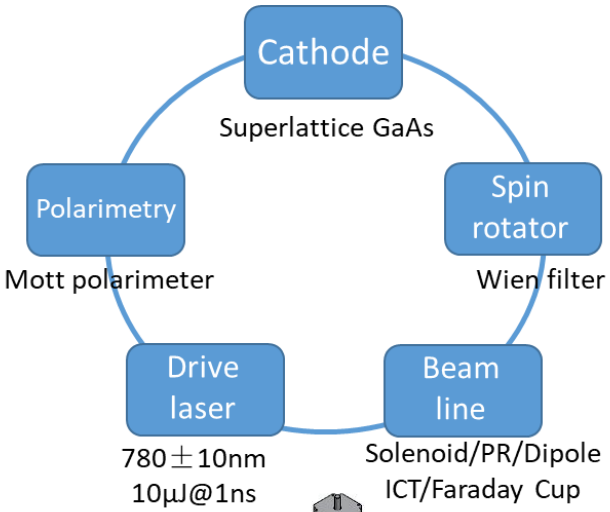


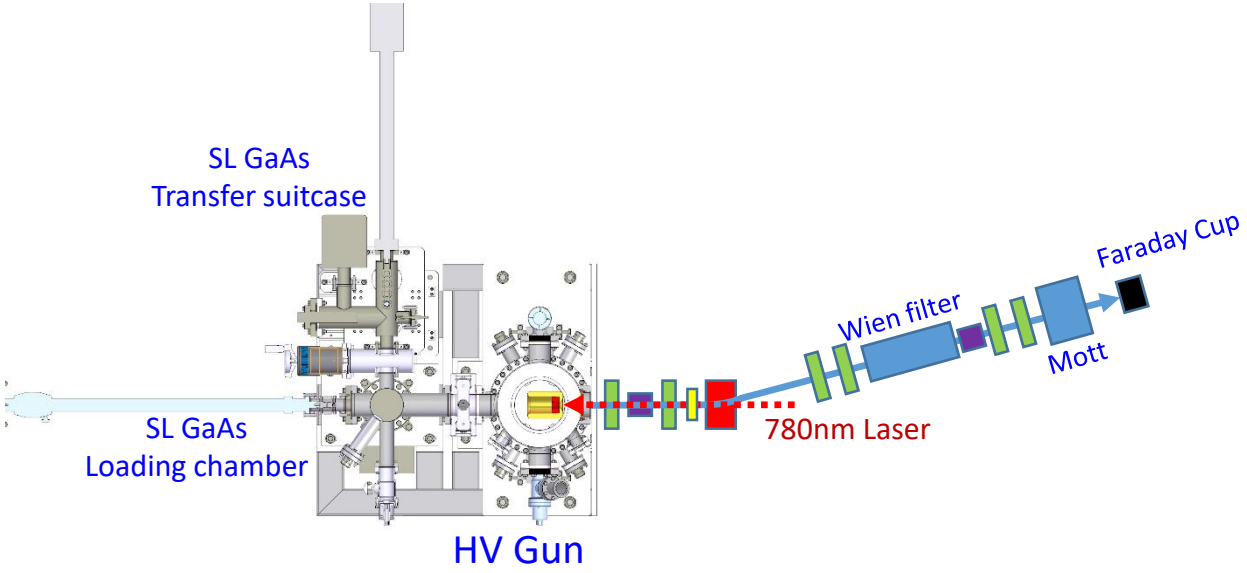
A 150kV HV photocathode electron gun

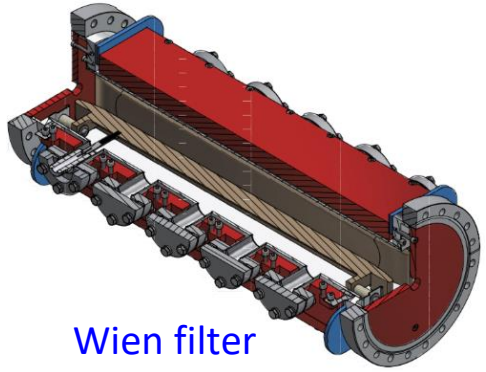
Polarized electron source related R&D

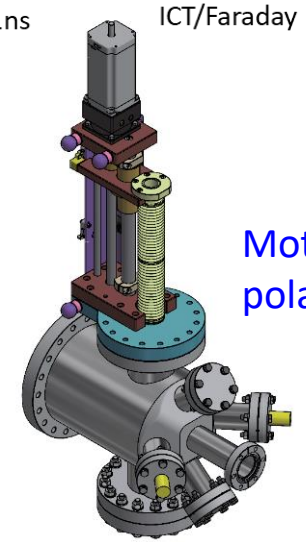
Next step for polarized electron source R&D

- Test of the second batch of SL GaAs wafer
- Start to design a polarized electron source prototype and its test beam line (150kV Gun, Laser, Wien filter, Mott polarimeter and a short test beam line, electron beam with nC bunch charge and 85% polarization)
- As an alternative solution for CEPC electron source and also BEPCII









A polarized electron source prototype development

Content

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Summary

- Introduction of electron source for CEPC.
- A brief introduction on the method of generating polarized electrons.
- Introduced progress of polarized electron source related R&D, including domestic R&D on the SL GaAs photocathode, progress of the platform for SL GaAs performance test and research plan of a prototype polarized electron gun for CEPC.