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

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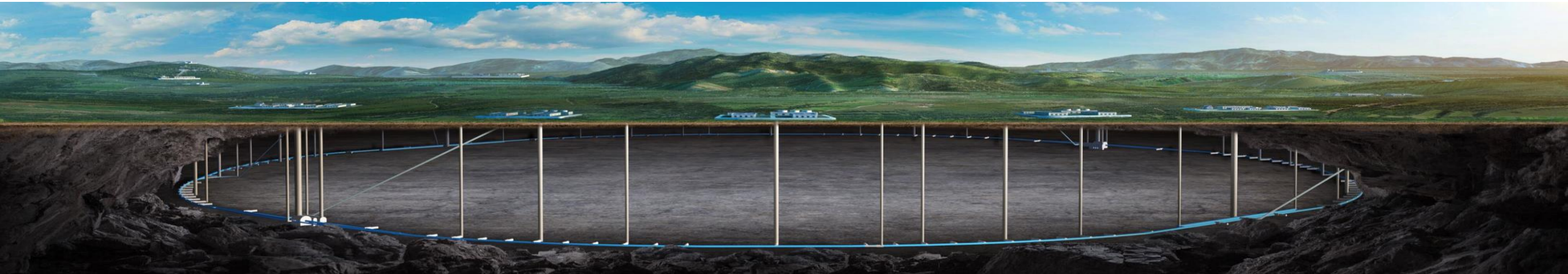

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- **CEPC Electron Source**
- **Generation of polarized electron beams**
- **Polarized electron source related R&D**
  - Polarized electron source R&D plan for CEPC at IHEP
  - Domestic R&D on the superlattice GaAs photocathode
  - Preliminary test on the 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)**
  - The Linac tunnel length is **1.8km**

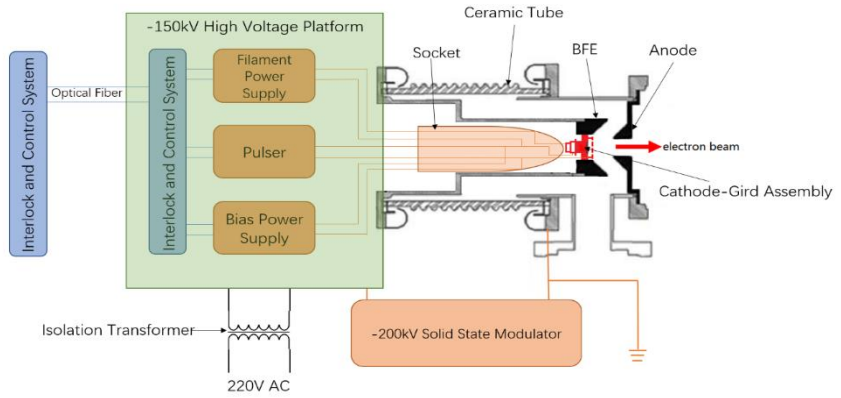
Parameter	Symbol	Unit	Baseline
Energy	E_{e-}/E_{e+}	GeV	30
Repetition rate	f_{rep}	Hz	100
Bunch number per pulse			1 or 2
Bunch charge		nC	**1.5**
Energy spread	σ_E		1.5×10^{-3}
Emittance	ε_r	nm	6.5

CEPC Electron Source

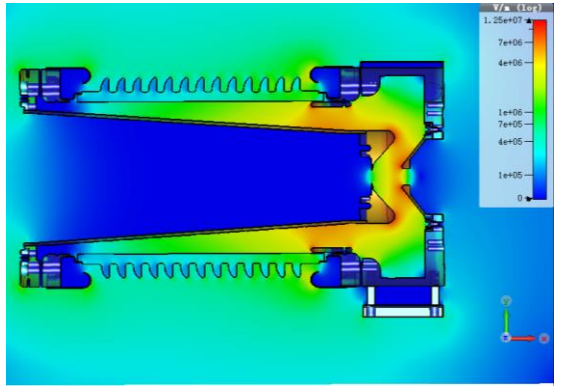
Introduction to CEPC Electron Source

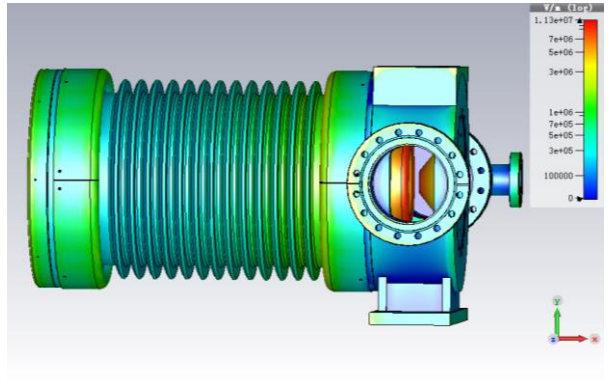
The electron source is used for generating an electron beam with a specific longitudinal distribution that can be accelerated for injection and positron production.

- **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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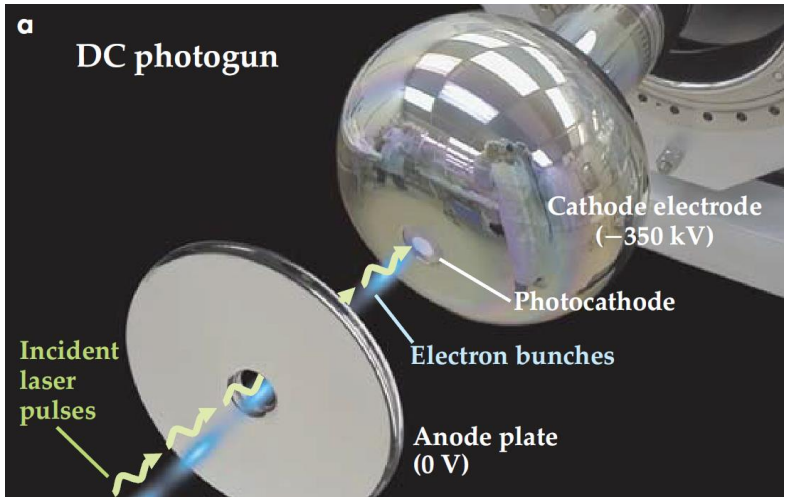
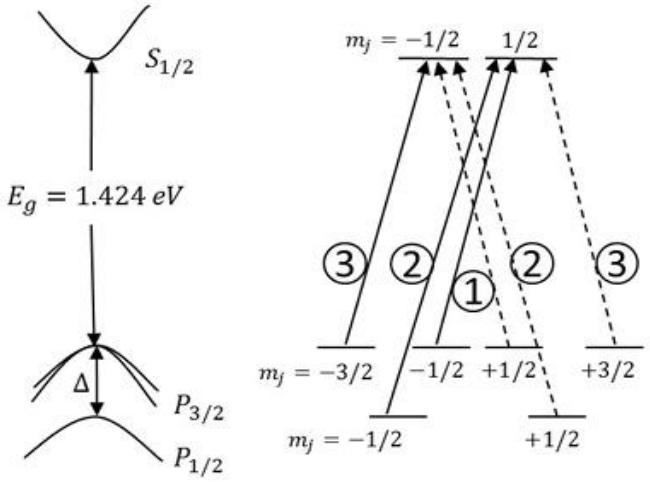
Generation of polarized electron beams

Polarized electron generation

- One effective method for generating polarized electrons is using GaAs photocathode in a photocathode HV electron gun (**Extremely high vacuum**)
- The unique band structure of GaAs determines that electron beams with a certain polarization can be generated under the driving of circularly polarized laser at a specific wavelength
- For a common bulk GaAs, a maximum polarization in theory is 50%, considering depolarization effect it usually is about **30-35%** at **780nm** laser wavelength





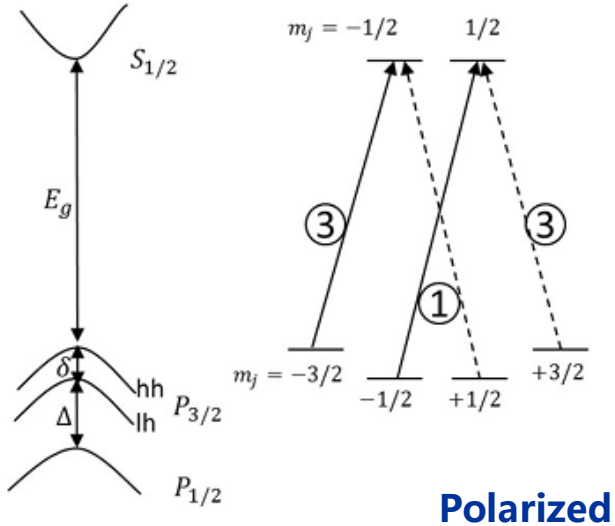
$$P = \left|\frac{1-3}{1+3}\right| = 50\%$$

Polarized electron generation from a common bulk GaAs

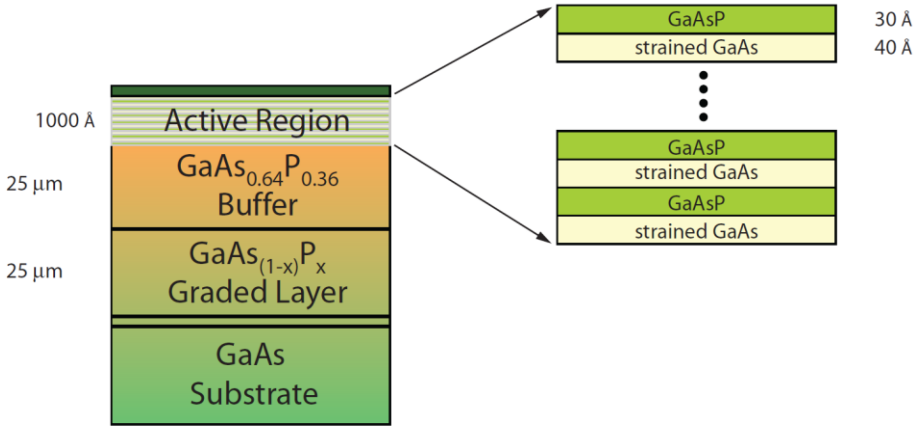
Generation of polarized electron beams

Polarized electron generation

- Strained GaAs and its energy band structure
- For a strained GaAs, a maximum polarization in theory is 100%, considering depolarization effect it usually is about **85%** at 780nm
- Constructing **superlattice** structure is an effective way to obtain strained GaAs
- This type of photocathode is not easy to obtain and needs to be grown on a substrate using MBE equipment



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



Polarized electron generation from superlattice GaAs

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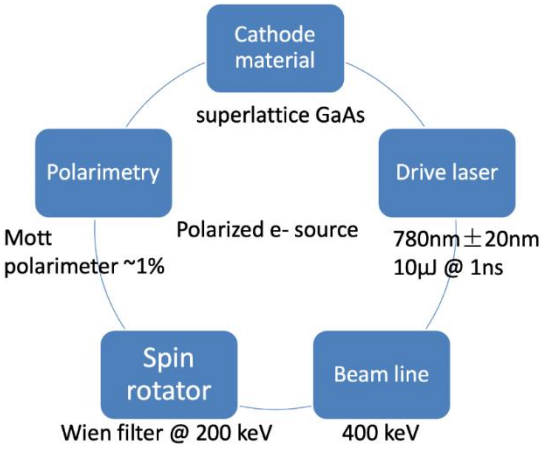
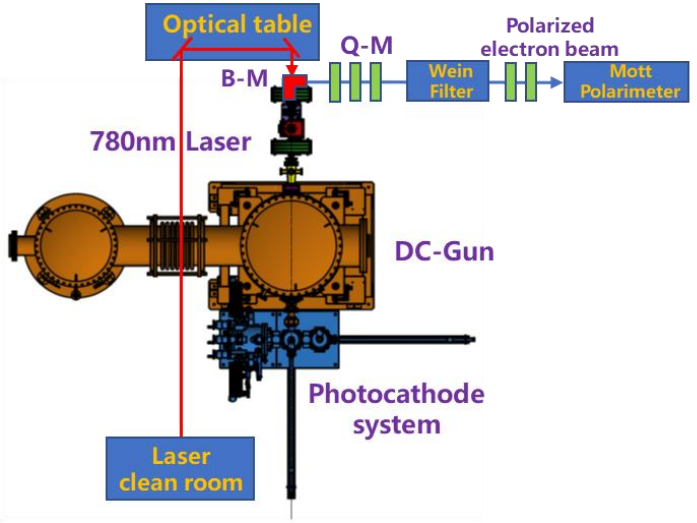
Polarized electron source related R&D

Polarized electron source R&D plan for CEPC at IHEP

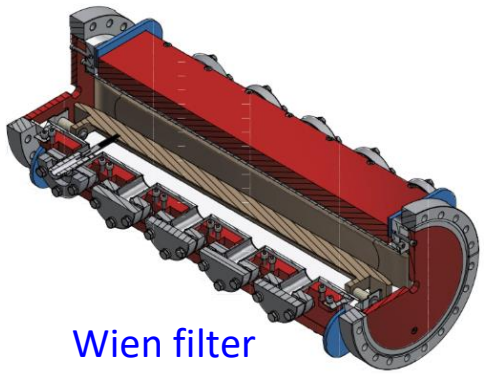
- Goals: Generation of electron beams with a bunch charge (**≥2nC**) and high polarization (**≥85%**)
- Based on a photocathode DC gun developed by IHEP with an extremely high vacuum (**10^{-10}Pa**)
- Beam line setup and beam dynamics study has been carried out
- Key components such as Wien filter and Mott polarimeter has been designed
- We expect a beam commissioning scheduled in 2027



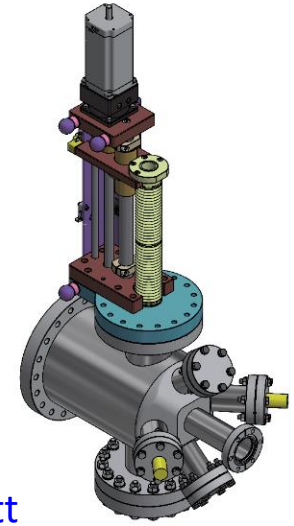
A photocathode DC gun @IHEP



Scheme of PES R&D based on DC gun



Wien filter



Mott polarimeter

Polarized electron source related R&D

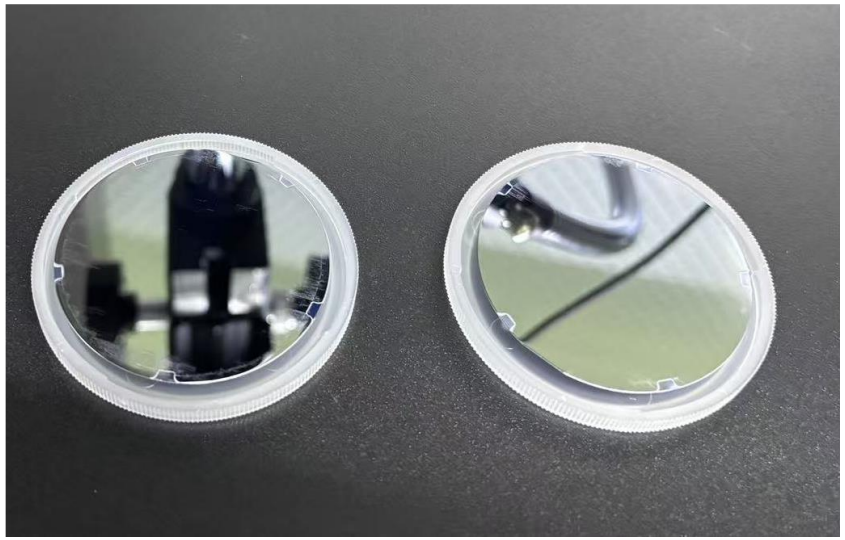
Domestic R&D on the superlattice GaAs photocathode

- 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, main requirements are Polarization > 85% and QE > 1%
- 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

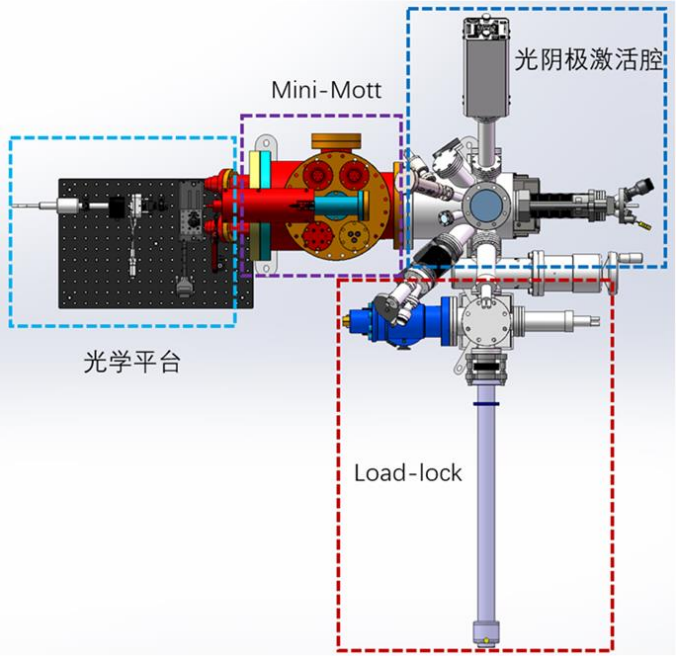


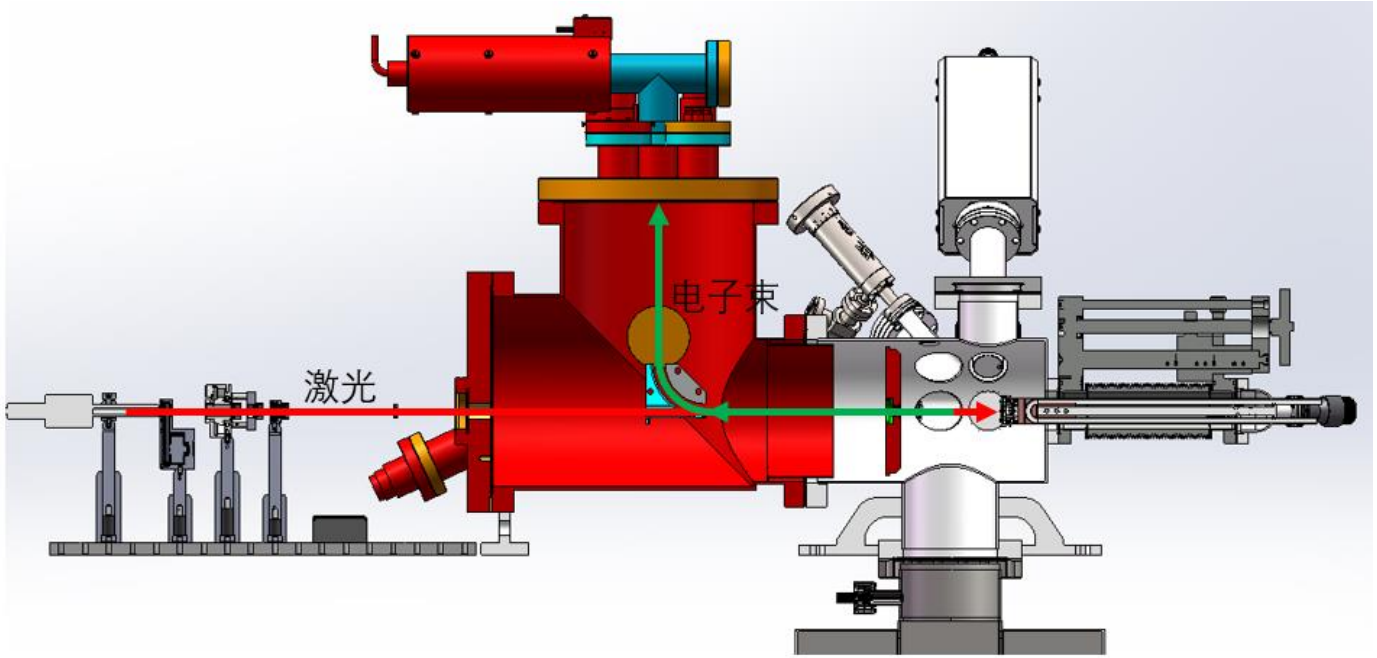
Samples of superlattice GaAs/GaAsP

Polarized electron source related R&D

Domestic R&D on the superlattice GaAs photocathode

- Build a platform for photocathode performance test (both pol & QE), this platform has been designed and is currently under development, expected to start experimental study on superlattice GaAs next year
- Including a photocathode load-lock chamber, an activation chamber, a Mini-Mott and a testing laser system





Platform for photocathode performance test

Polarized electron source related R&D

Preliminary test on the superlattice GaAs photocathode

- From 2024, Valery Tyukin from Inst. of Nuclear Physics, JGU Mainz participated in research on PES (**PIFI 2024/2025**)
- A superlattice GaAs wafer has been cut, and a quarter had been delivered to the Inst. of Nuclear Physics, JGU Mainz
- Activation experiment of the SL GaAs has been carried out in JGU Mainz
- To test the performance of SL GaAs (both QE and polarization)
- As a very important experimental data for our Mott polarimeter calibration in future

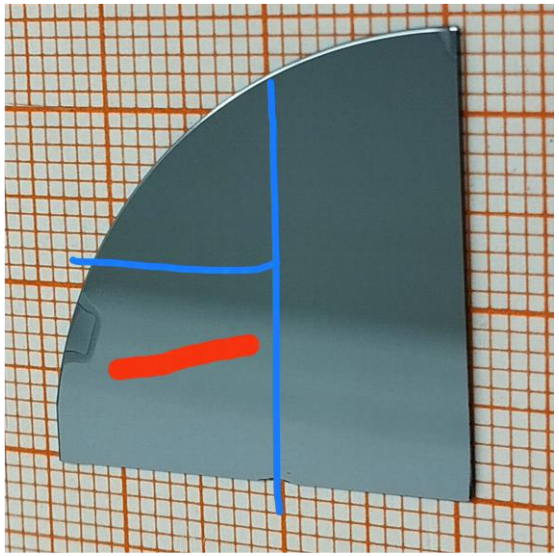
Valery Tyukin

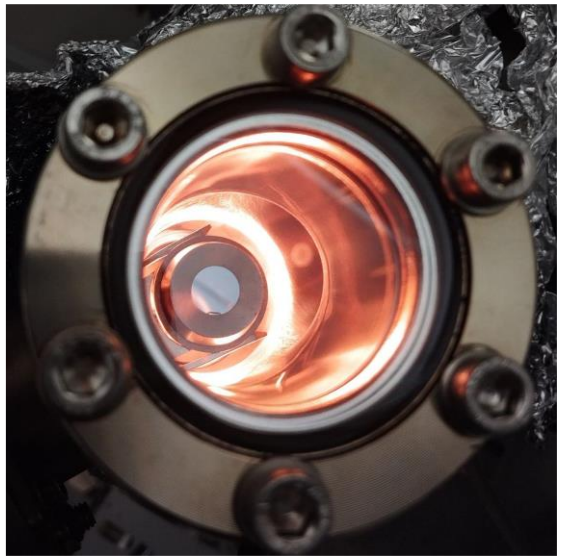
Superlattice GaAs wafer cut in Acken

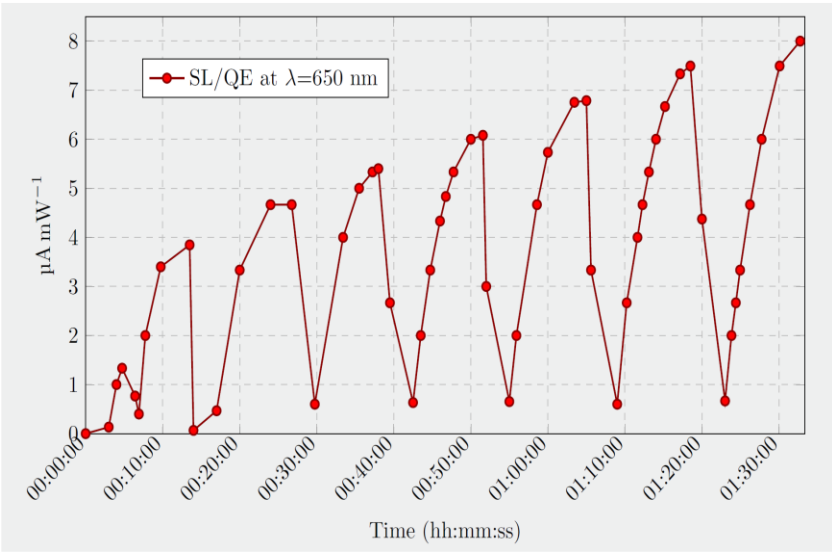
Polarized electron source related R&D

Preliminary test on the superlattice GaAs photocathode

- The QE is two to three times lower than that of bulk material structures
- The lifetime of the SL GaAs in sample preparation chamber is a few hundred hours, which is a good indicator
- Polarization measurements will be carried out in the near future (after repair work on the beamline)







- The SL structure is cut along blue lines
- Piece on the right is for main accelerator
- Piece on the left bottom is tested

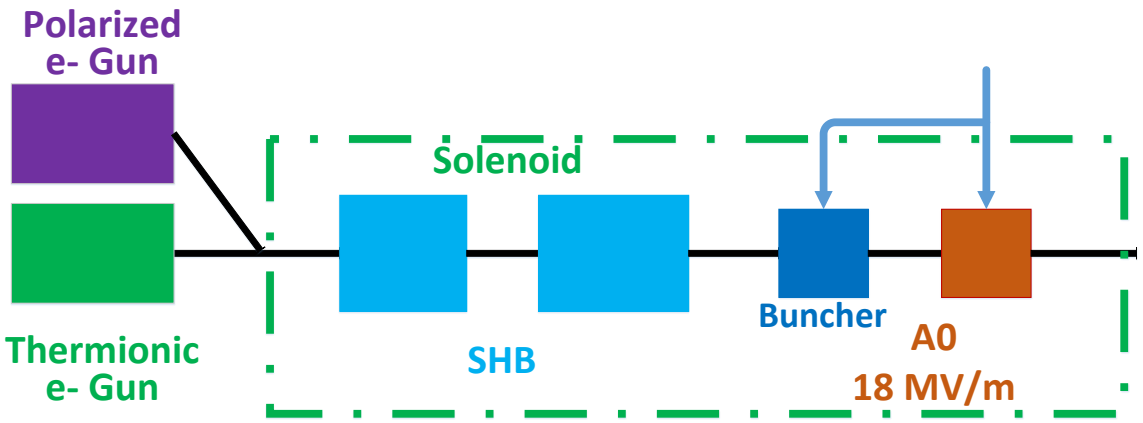
- SL in loadlock chamber
- Preheating in loadlock chamber

- Yo-Yo method, Cs + NF3
- Maximal QE=1.5% @650nm

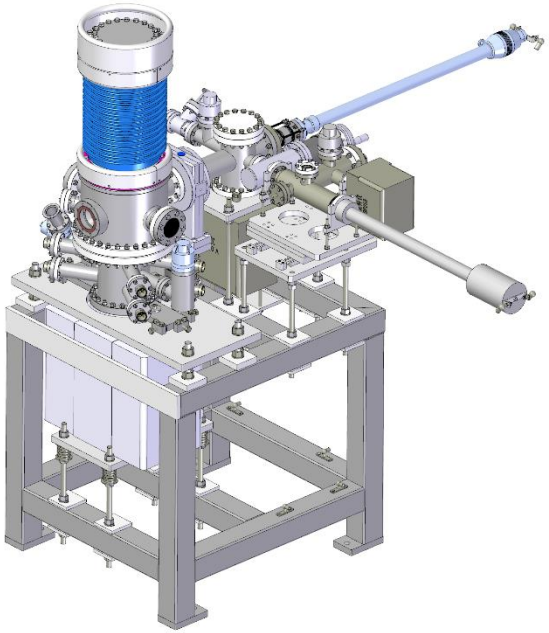
Polarized electron source related R&D

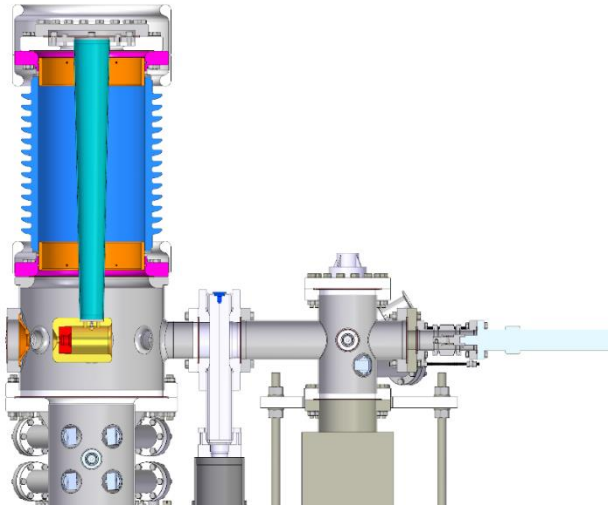
A Polarized electron gun design for CEPC

- A 150kV HV photocathode electron gun has been designed (Beam 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

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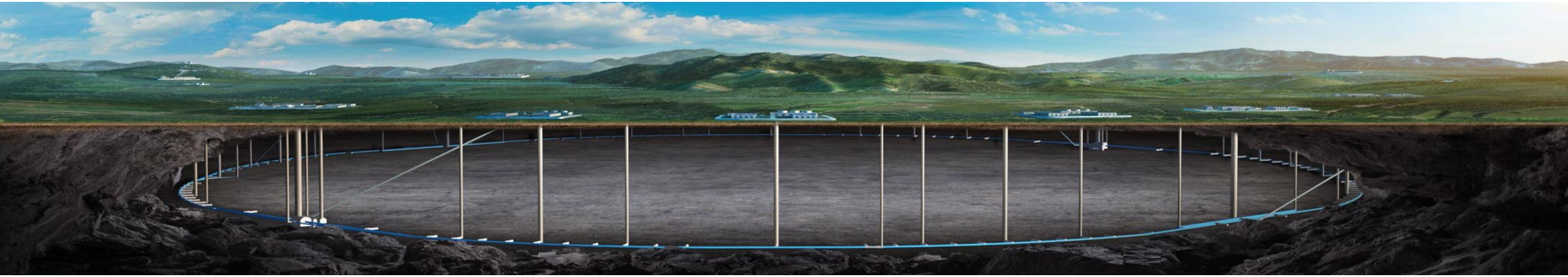
Summary

- Introduction of electron source for CEPC.
- The method of generating polarized electrons.
- Introduced progress of polarized electron source related R&D, including R&D plan, domestic R&D on the superlattice GaAs photocathode, preliminary test results about the superlattice GaAs photocathode in Mainz and a polarized electron gun design for CEPC.

Thank you for your attention!



CEPC Electron Source

CEPC Electron Source R&D

- A prototype of electron gun and its test platform had been built up
  - Used for **domestic** cathode-grid assembly R&D
  - The cathode emission capacity had been tested up to **12A@150kV**
  - The emission capacity does not decrease within 7000 hours operation