

Jochen Teichert for the Rossendorf SRF gun collaboration

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T. Kamps, J. Rudolph (HZB)
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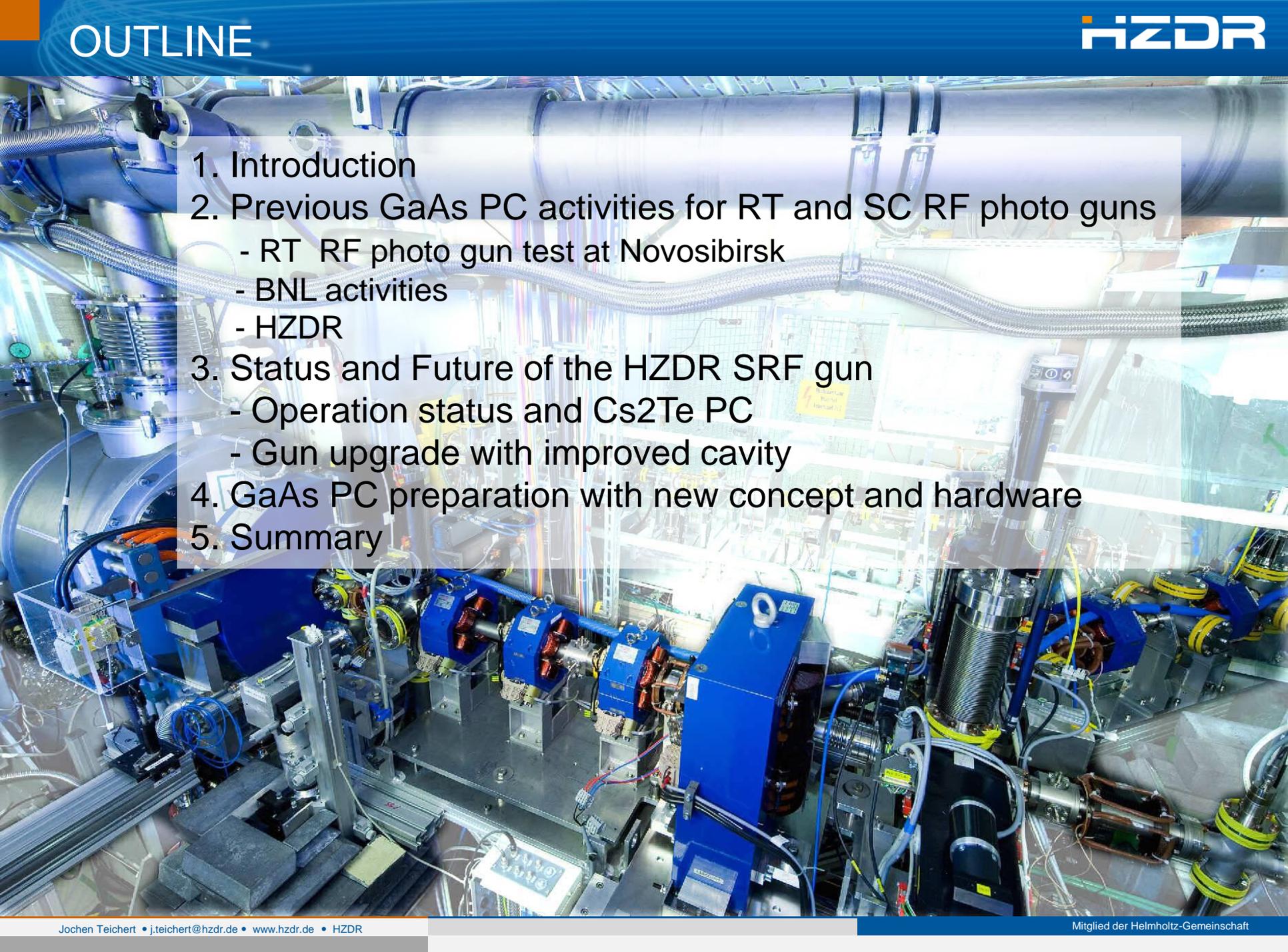
Polarized Photocathode SRF Guns



EuCARD'13

June 10-14, 2013, CERN, Geneva, Switzerland



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1. Introduction
 2. Previous GaAs PC activities for RT and SC RF photo guns
 - RT RF photo gun test at Novosibirsk
 - BNL activities
 - HZDR
 3. Status and Future of the HZDR SRF gun
 - Operation status and Cs₂Te PC
 - Gun upgrade with improved cavity
 4. GaAs PC preparation with new concept and hardware
 5. Summary

Why GaAs Photocathodes ?

**cesiated GaAs
is a NEA
(negative electron affinity)
material
with high quantum efficiency
>15 % @ green light
for **high currents****

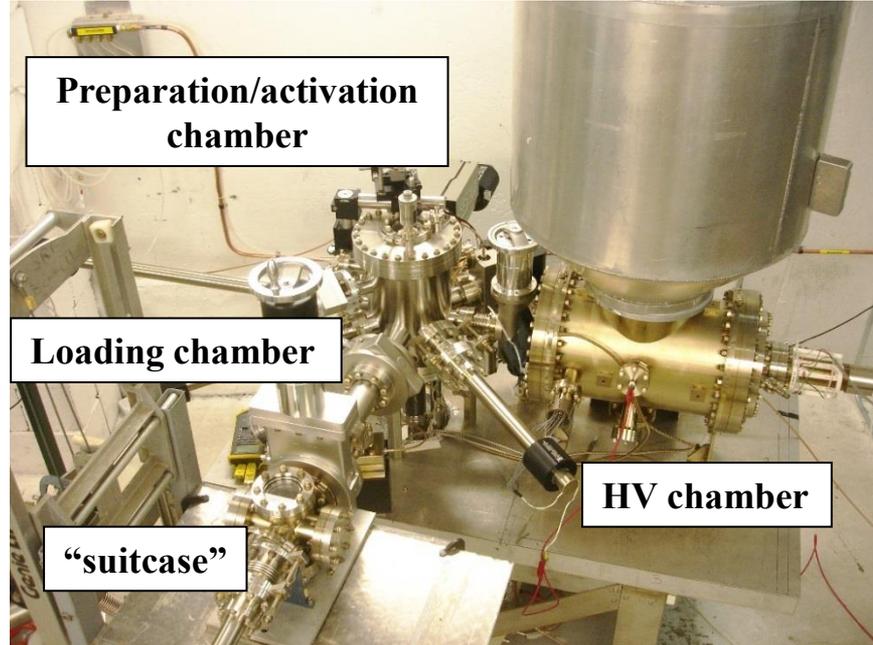
One candidate for ERL guns
JLab FEL: 10 mA
Cornell Univ.: 50 mA
Other high-current cathodes:
CsK₂Sb
Diamond Amplifier

**cesiated GaAs
is the only material
for
polarized electrons
with
GaAs/GaAsP
superlattice crystals
95 % polarization**

Used at
CEBAF (Jlab),
MAMI Mainz,
ELSA Bonn, etc.
in DC photoguns

Up to now all the guns of polarized electrons are **DC guns** since GaAs PCs need excellent ultra-high vacuum $p < 10^{-11}$ mbar

example: CEBAF load-locked gun (100 kV)



M. Poelker, ERL '07, Daresbury

ADVANTAGES OF SRF GUNS

superconducting: low RF losses -> high rep. rates in CW

laser and RF field: short pulses & high gradient -> high brightness

very good vacuum: GaAs -> polarized electrons?

MOTIVATION up to now: for Future Light Source (ERLs):
 Cs₂Te (UV) -> GaAs (green) in SRF guns:
 allows higher currents and simplifies the drive laser



**SRF gun of
 high-brightness,
 high bunch charge,
 polarized electron beams
 for
 particle physics**

ILC, eRHIC, ...

SAPPHiRE: a Small $\gamma\gamma$ Higgs Factory

S. A. Bogacz¹, J. Ellis^{2,3}, L. Lusito⁴, D. Schulte³, T. Takahashi⁵, M. Velasco⁴,
 M. Zanetti⁶ and F. Zimmermann³

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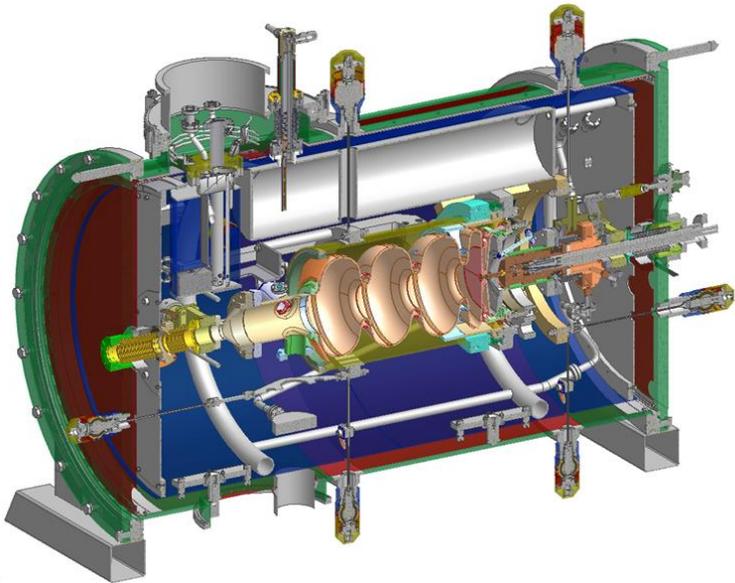
⁶ Laboratory for Nuclear Science, MIT, Cambridge, MA 02139, USA

Abstract

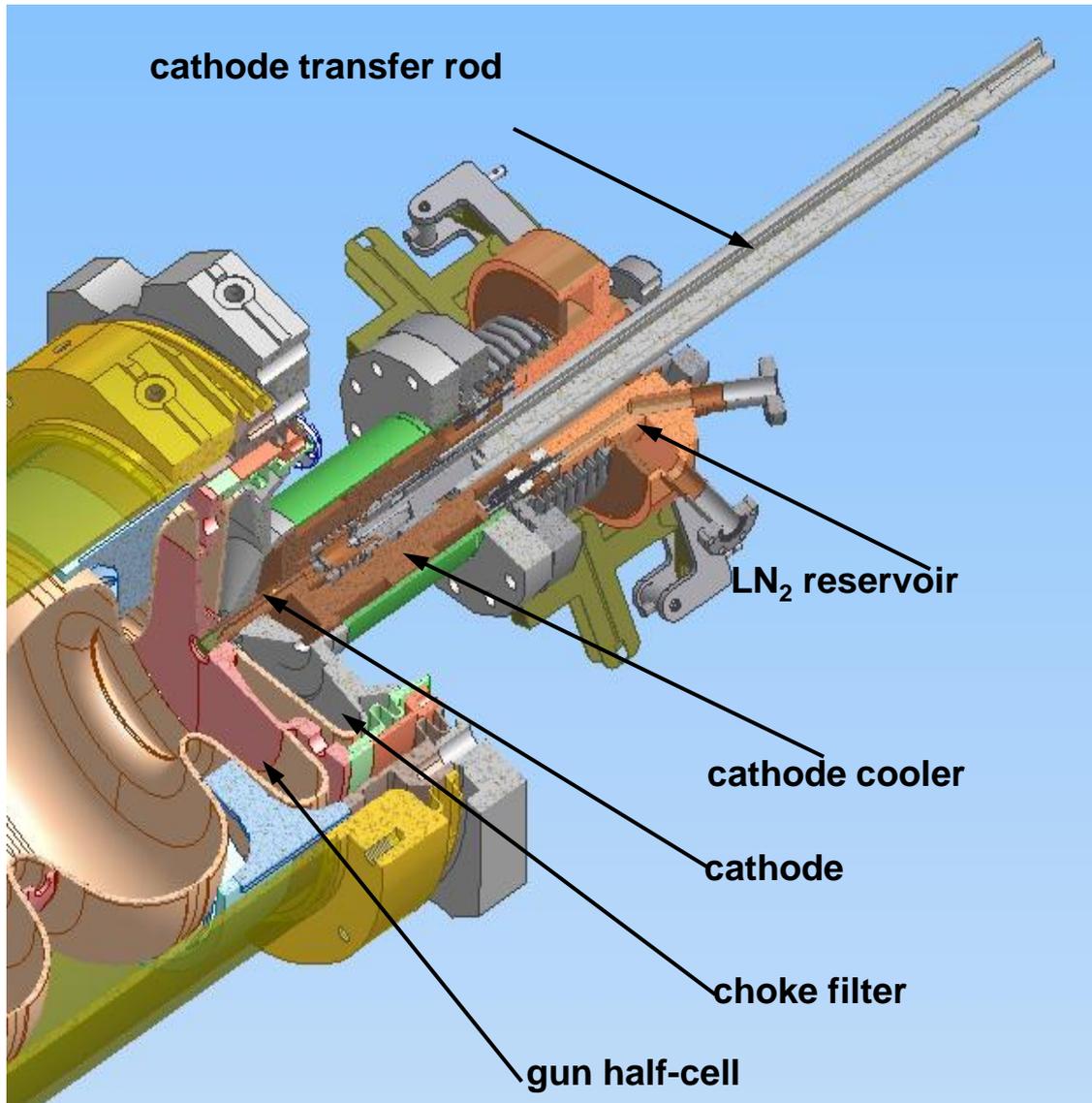
A new particle with mass ~ 125 GeV that resembles the Higgs boson has recently been discovered by ATLAS and CMS. We propose a low-energy $\gamma\gamma$ collider as a cost- and time-efficient option for a Higgs factory capable of studying this particle in detail. In the past, this option

Application of the ELBE SRF Gun

- high peak current operation for CW-IR-FELs with 13 MHz, 80 pC
- high bunch charge (1 nC), low rep-rate (<1 MHz) for pulsed neutron and positron beam production (ToF experiments)
- low emittance, medium to high charge with short pulses for THz-radiation and x-rays by inverse Compton backscattering

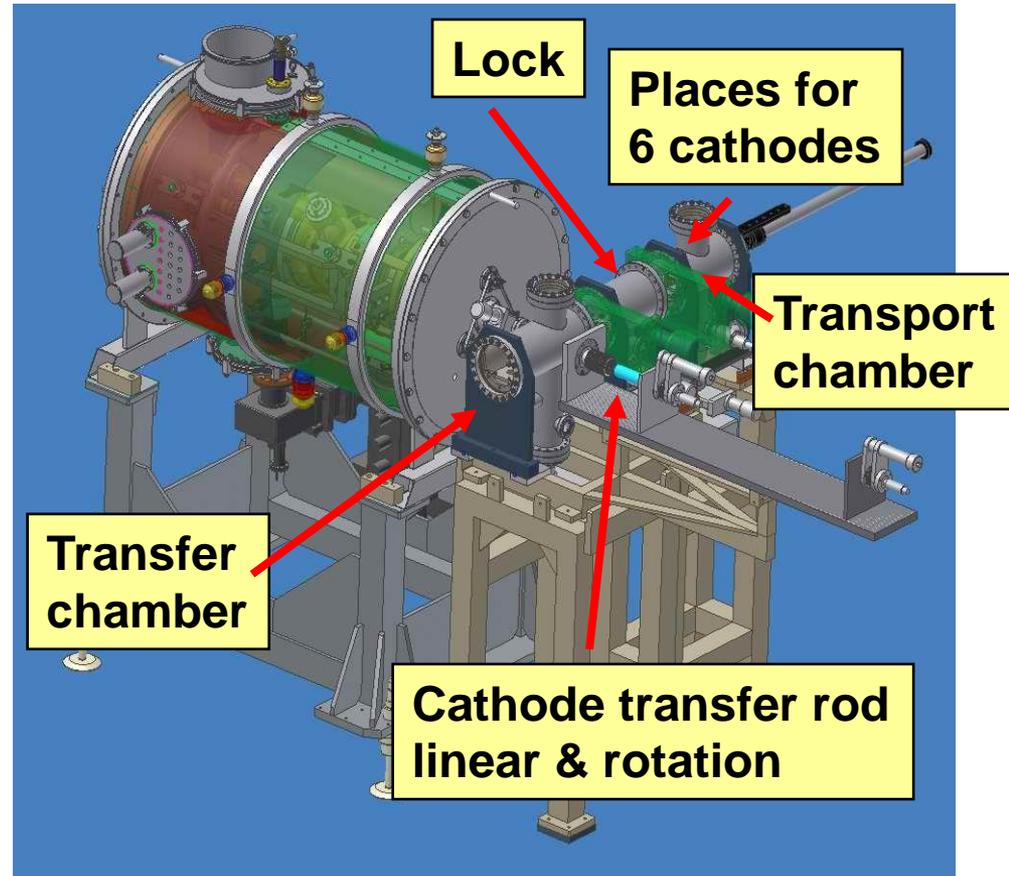
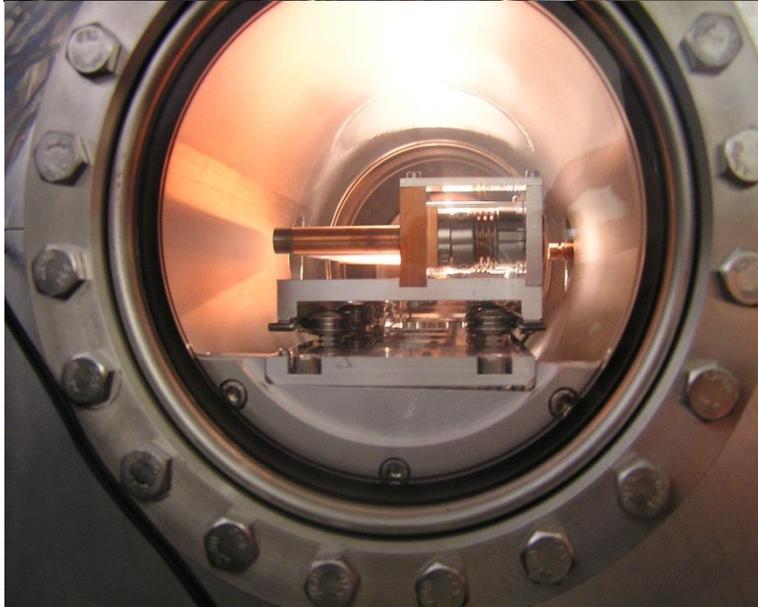
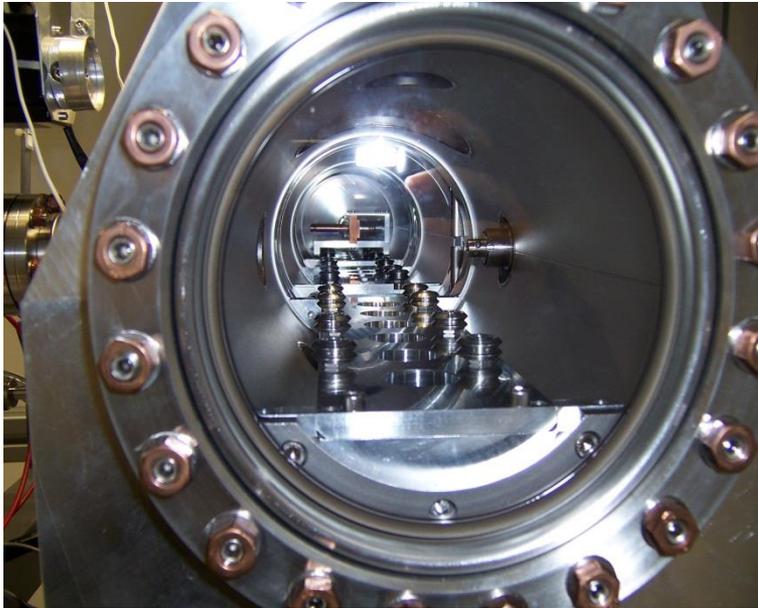


Parameter	<i>SAPPHiRE</i>	High Charge
final electron energy		MeV
RF frequency		Hz
operation mode		
Photo cathode	<i>GaAs</i>	e
bunch charge	<i>1.6 nC</i>	1 nC
repetition rate	<i>200 kHz</i>	500 kHz
laser pulse (FWHM)		15 ps
transverse rms emittance	<i>1.5 μm</i>	2.5 mm mrad
average current		0.5 mA



Normal-conducting photocathode in superconducting cavity

- Photo cathodes must be exchangeable without
- breaking the vacuum
 - warming-up the gun
- no particle generation During exchange
- Separate support and cooling with liquid N₂
 - Vacuum gap, electrically and thermally isolated



Use of semiconductor photo cathodes like Cs_2Te requires a UHV ($<10^9$ mbar) exchange system

BINP activity with a copper (RT) RF photo gun

Proceedings of the 1999 Particle Accelerator Conference, New York, 1999

EXPERIMENTAL STUDY OF GaAs PHOTOCATHODE PERFORMANCE IN RF GUN*

A.V.Aleksandrov, N.S.Dikansky, R.G.Gromov, P.V.Logatchov, BINP, Novosibirsk, Russia

Abstract

A prototype of S-band RF photogun with GaAs photocathode has been built and tested at Novosibirsk. The main goal of this prototype is to check a possibility of long time operation for GaAs photocathode in a strong accelerating field of RF cavity. The first experimental results concerning dark current and lifetime of GaAs photocathode in NEA condition under high RF power are

decreasing of cathode lifetime from 200min in absence of RF power to about 30 min in 30MV/m accelerating field. This effect could be explained by vacuum worsening in the cavity due to dark current. After experiment we observed significant damage on the cathode surface.

2.2 GaAs photocathode with large quantum efficiency.

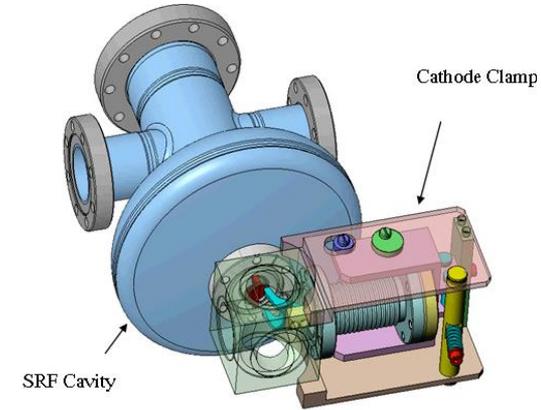
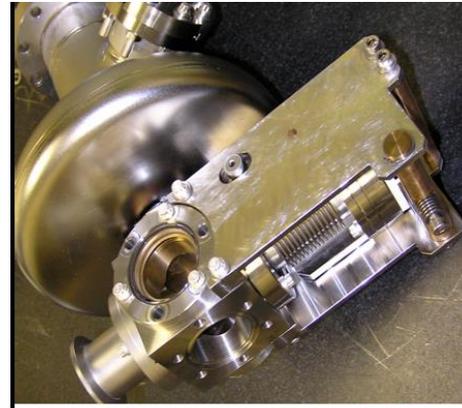
New cathode was installed at the end of 1997. 100 hours of baking at 300°C pressure $2 \cdot 10^{-10}$ torr established. Only ion pumps were used at this stage. Cathode was activated following usual “vo-vo” algorithm.

Problems with GaAs Photocathodes: experiment failed due to

- worse vacuum of $> 10^{-9}$ mbar,
- high dark current,
- electron backbombardment

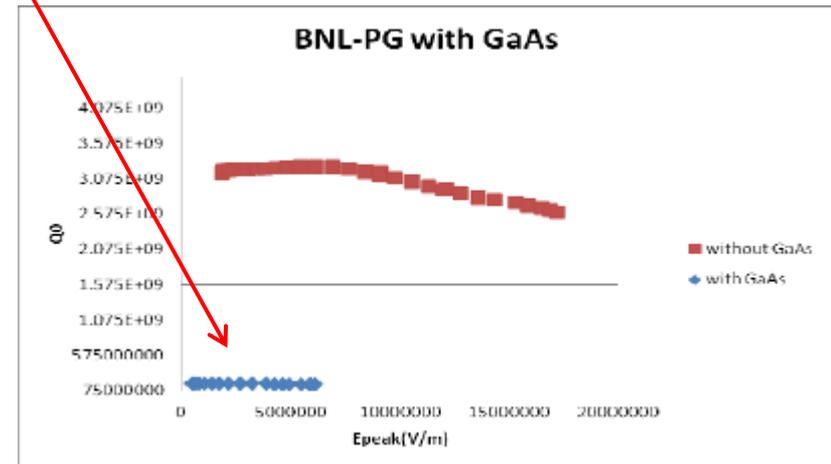
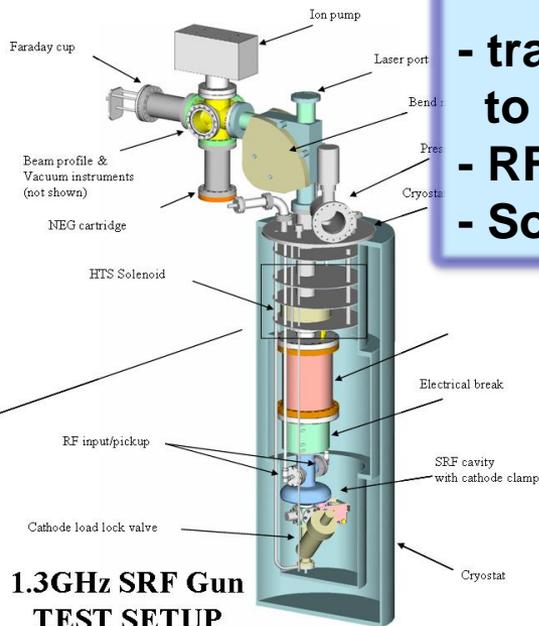
GunBNL Polarized SRF Photocathode

Test set-up with 1/2-cavity installed,
 GaAs (Cs,O) preparation system exists,
 NEA GaAs PC prepared, QE=10%,
 First tests with cavity,
 Experiments ongoing



Problems:

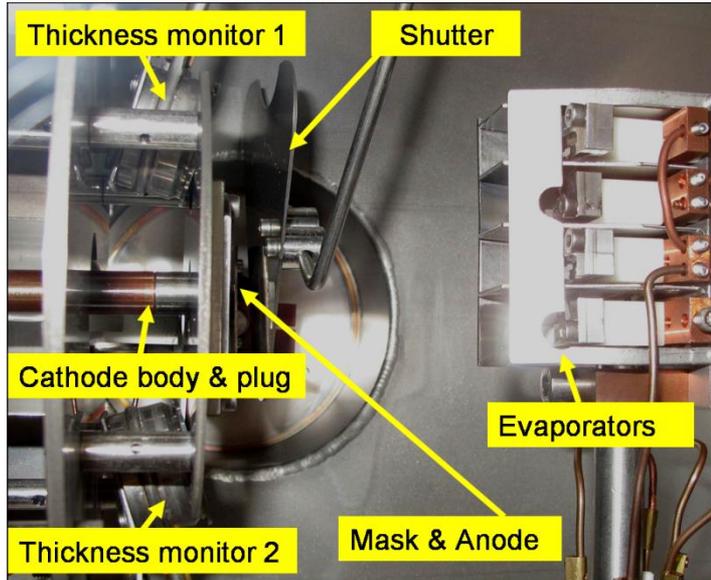
- transport of PC from preparation chamber to gun: vacuum only $\sim 10^{-9}$ mbar
- RF heat load in the GaAs crystal
- Solution to prevent e⁻ back bombardment



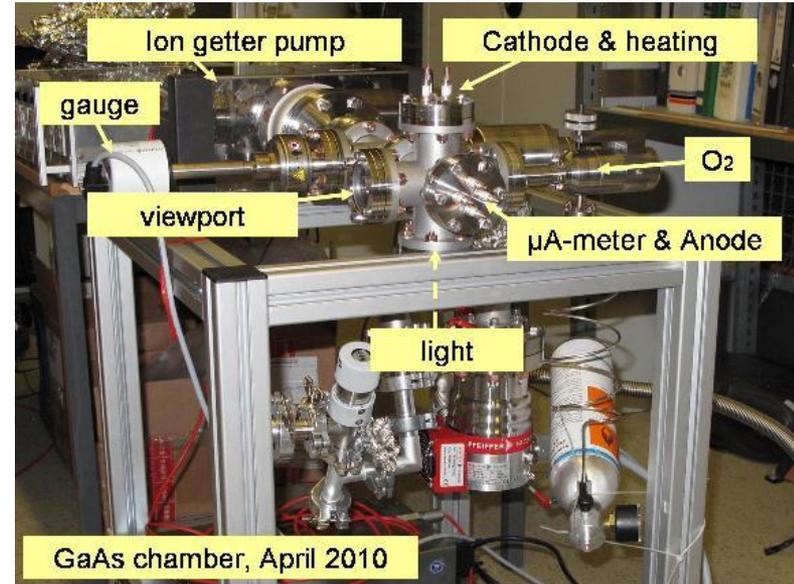
J. Park, et al., PAC'11, New York, p.385
 E. Wang, et. al., PAC'11, New York, p. 388

HZDR GaAs PC preparation system for ELBE SRF Gun

Inside view of the Cs₂Te preparation system



Compact GaAs preparation system (developed within EuCARD)

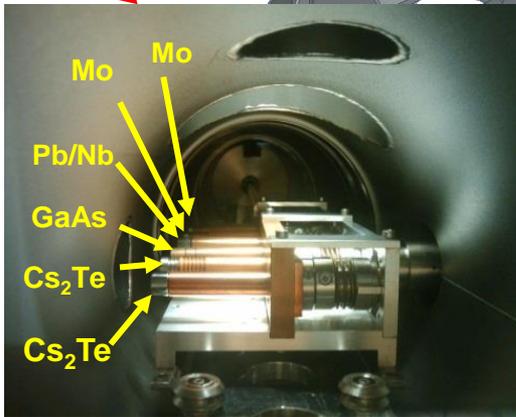
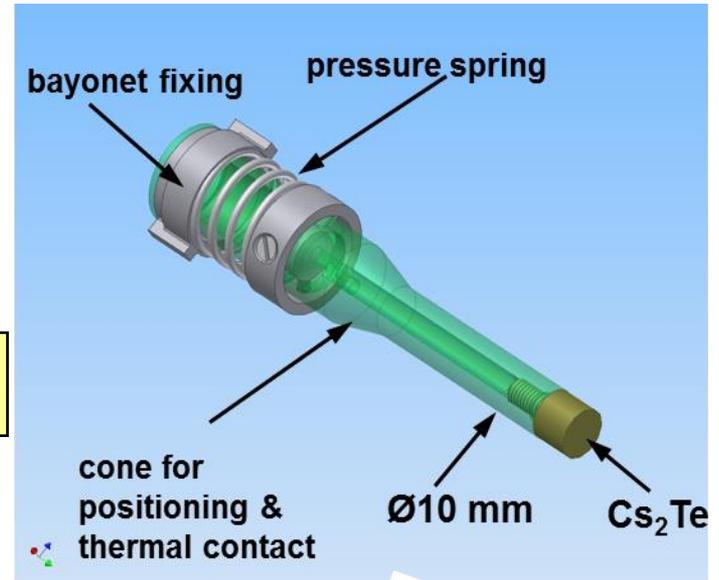
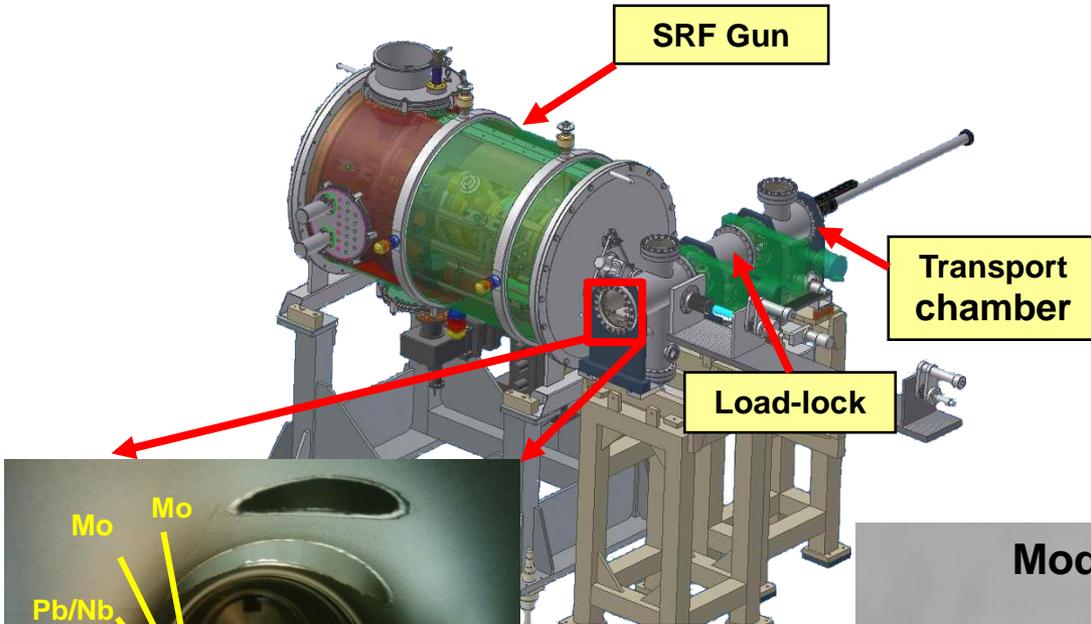


R. Xiang, et al., FEL'10, Malmö, p. 449
 R.Xiang, et al., IPAC'12, New Orleans, p. 1524

should be later integrated in the existing Cs₂Te chamber

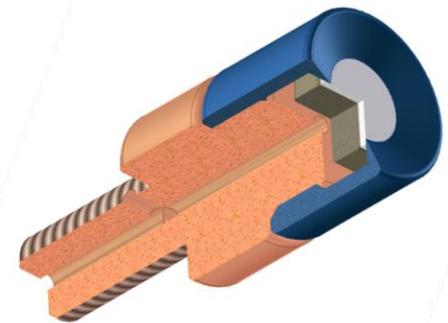
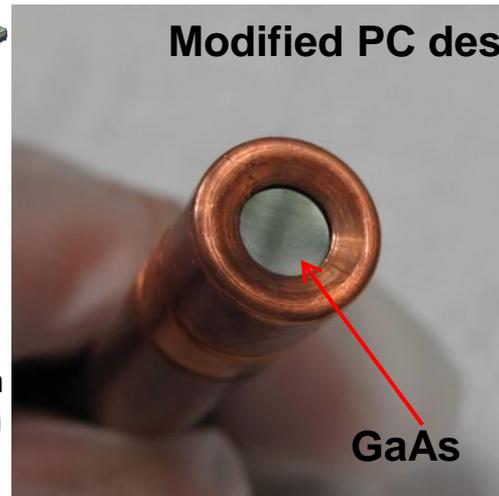
Problems:
Preparation of GaAs failed
 - To many compromises in design
 - Low QE, very short storage time

Test of non-activated GaAs PC



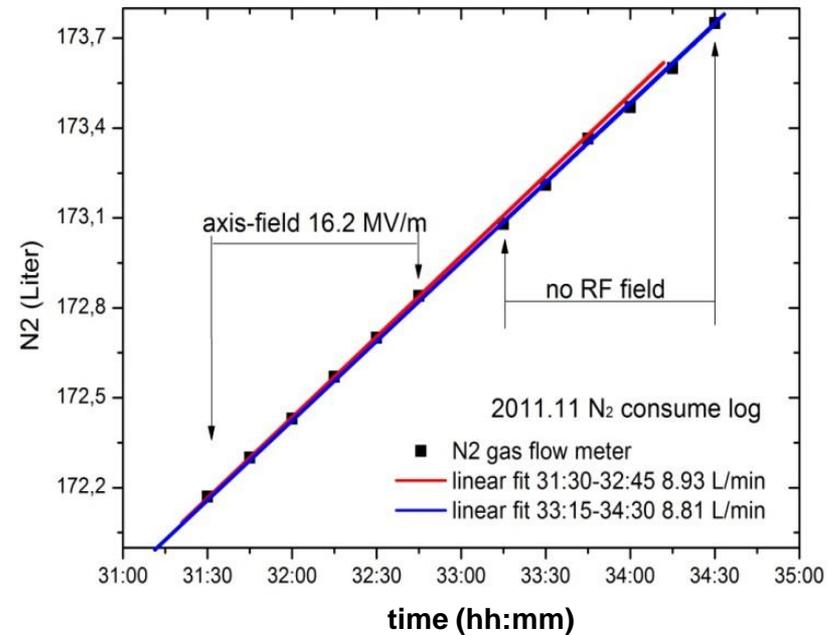
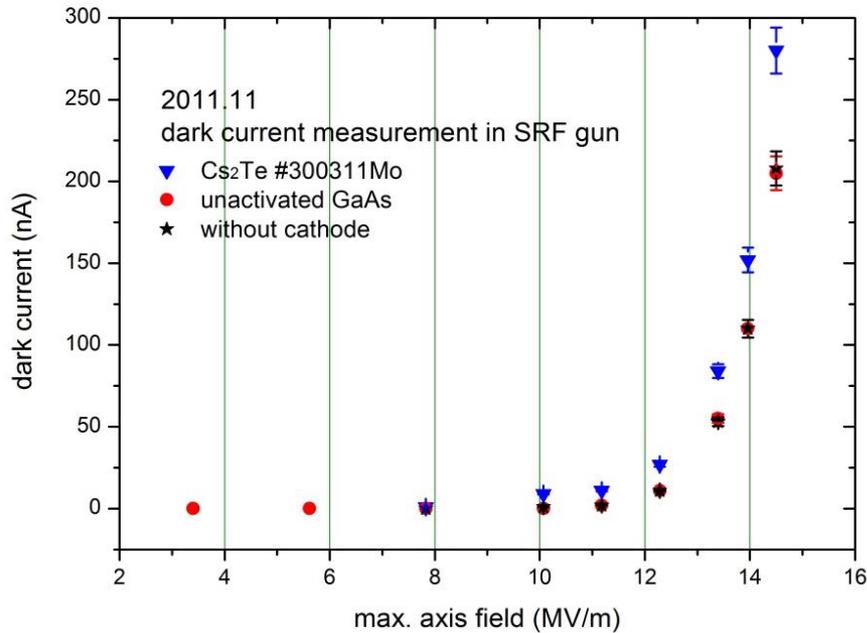
With Pierce cone
 Inside ϕ 4.75 mm
 Outside ϕ 10 mm

Modified PC design for GaAs



HZDR design:

Higher RF field than at BNL, but no dark current or heat load problems



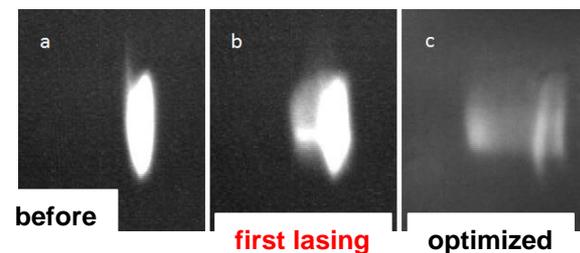
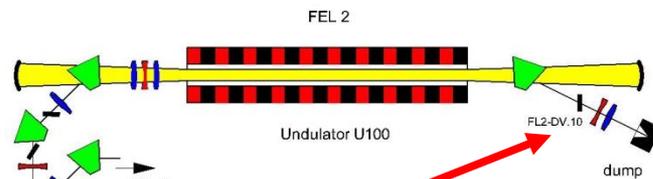
No detectable dark current from GaAs-crystal.

Gun with GaAs crystal (0.35mm) and holder
Without RF, P_{N₂}=34.52W
With RF_{max}=5.5MV/m on surface , P_{N₂}=35 W

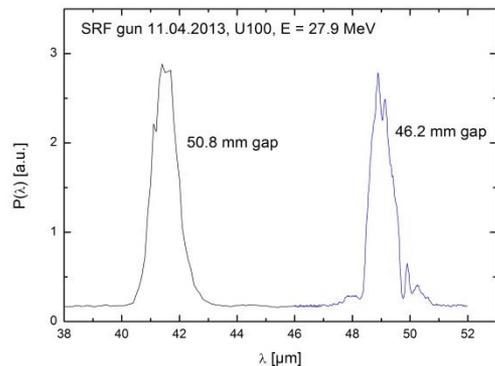
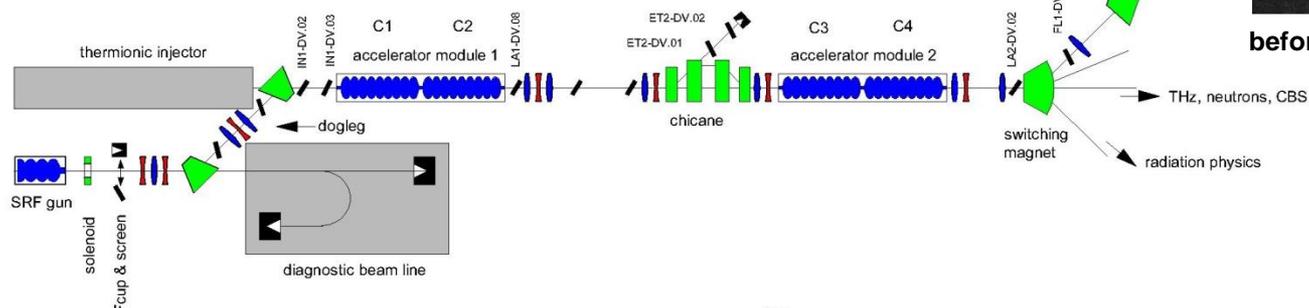
First lasing with the SRF Gun at ELBE – Successful proof of the basic design

E_{kin} at gun exit	3.3 MeV
Micro pulse repetition rate	13 MHz
Macro pulse repetition rate / length	1.25 Hz / 2 ms
Beam energy at FEL	27.9 MeV
Bunch charge / beam current	20 pC / 260 μ A
Photo cathode	Cs ₂ Te
RMS bunch length	1.6 ps
Normal. RMS emittance	1 mm mrad

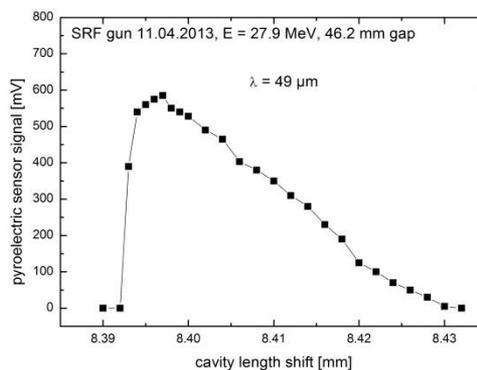
ELBE infrared FEL (20 – 250 μ m)



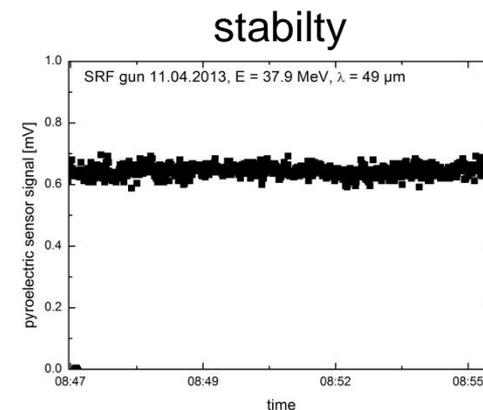
April 11, 2013



FEL spectra



FEL detuning curve

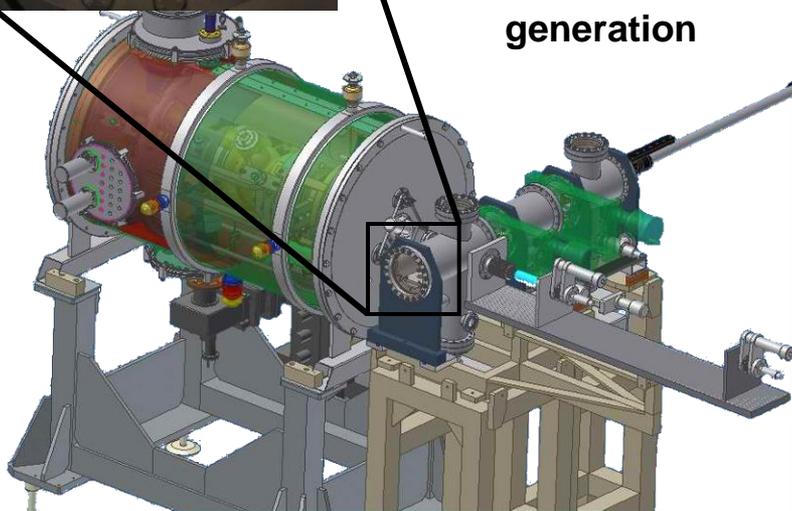
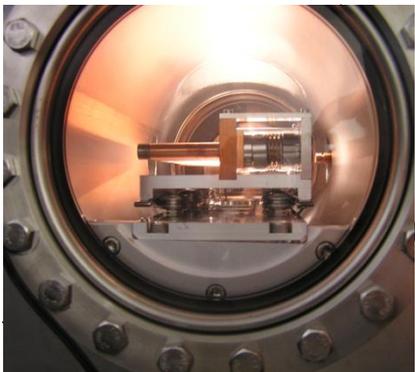
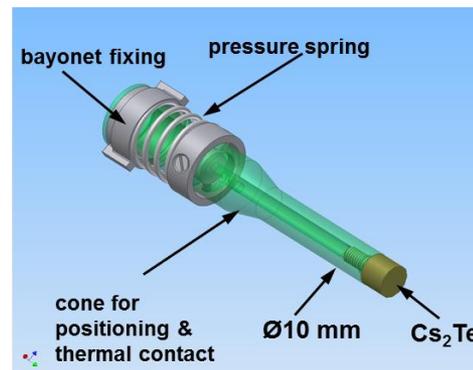


stability

Excellent lifetime of Cs₂Te PC in SRF gun

Requirements for Transfer:

- Load lock system with $< 10^{-9}$ mbar to preserve $QE \geq 1\%$
- Exchange w/o warm-up & in short time and low particle generation



Cathode	Operation days	Extracted charge	Q.E. in gun
#090508Mo	30	< 1 C	0.05%
#070708Mo	60	< 1 C	0.1%
#310309Mo	109	< 1 C	1.1%
#040809Mo	182	< 1 C	0.6%
#230709Mo	56	< 1 C	0.03%
#250310Mo	427	35 C	1.0%
#090611Mo	65	< 1 C	1.2%
#300311Mo	76	2 C	1.0 %
#170412Mo	From 12.05.2012	236 C	~ 0.6 %

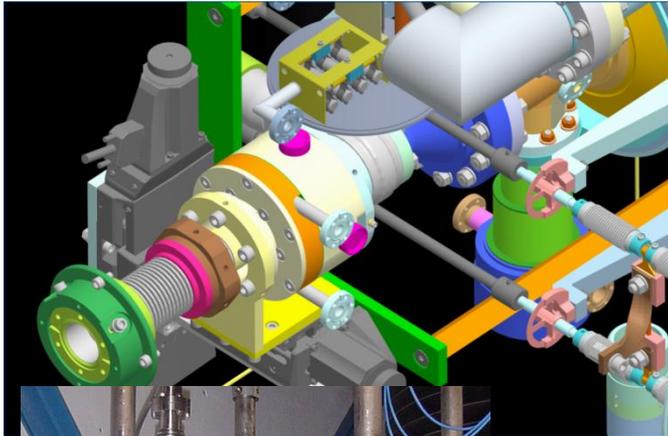
- fresh QE 8.5%, in gun 0.6%
- total beam time **575 h**
- extracted charge **236 C**

05.06.2013

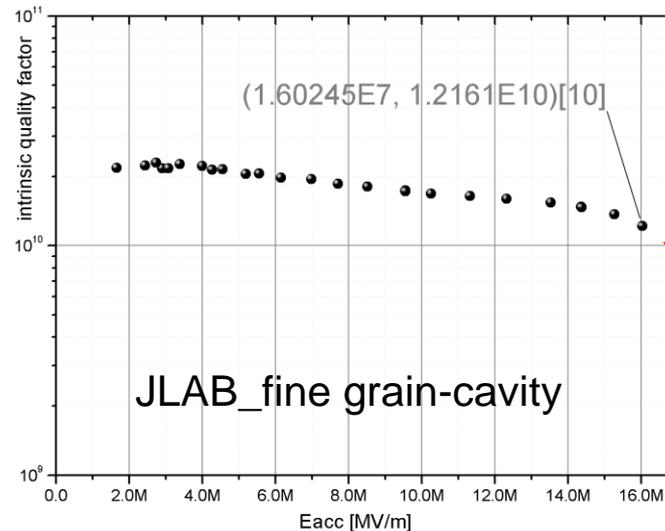
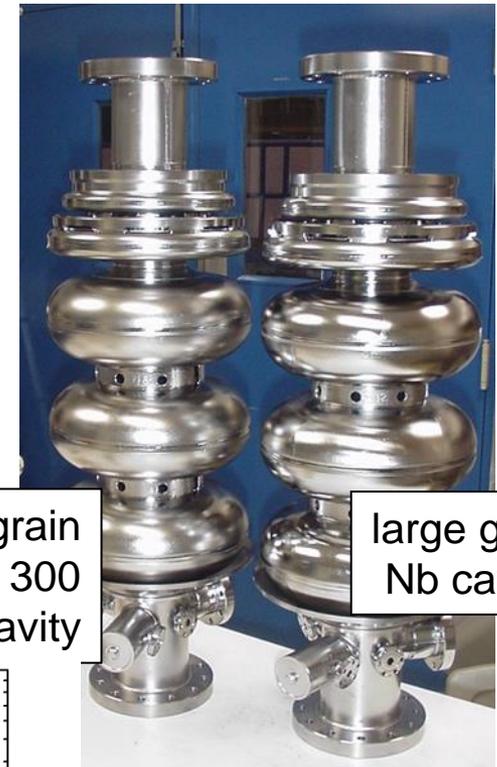
problems: multipacting, QE drop-down during storage

Version II gun with high-performance cavity & SC solenoid

Fabrication of two new cavities in collaboration with Jlab
(fabrication, treatment and tests)



- New cryomodule with
 - SC solenoid (2 K)
 - Niowave Inc. (NPS, HZB)
 - remote controlled xy-table for alignment (77 K)



43 MV/m peak field in vertical test @ JLab after He tank welding

- Preparation has to be performed near the gun
- movable system, commissioning and tests in preparation lab
connected to gun during GaAs PC beam time
- design of the system based on existing successful systems
(BNL, Daresbury Lab, Univ. Mainz)
- in the prep. system only small plug is handled
(new unified cathode/plug design of HZB, HZDR, Uni Mainz)

financial support of GaAs project: (not by EuCARD2)

German Helmholtz Society / ARD program:

> 100 k€ investment/year since 2012

new photo cathode laboratory (class 100 clean room)

BMBF collaboration project “photocathodes”

HZB, HZDR, Uni. Mainz, MSU Moscow, SPSPU St. Petersburg

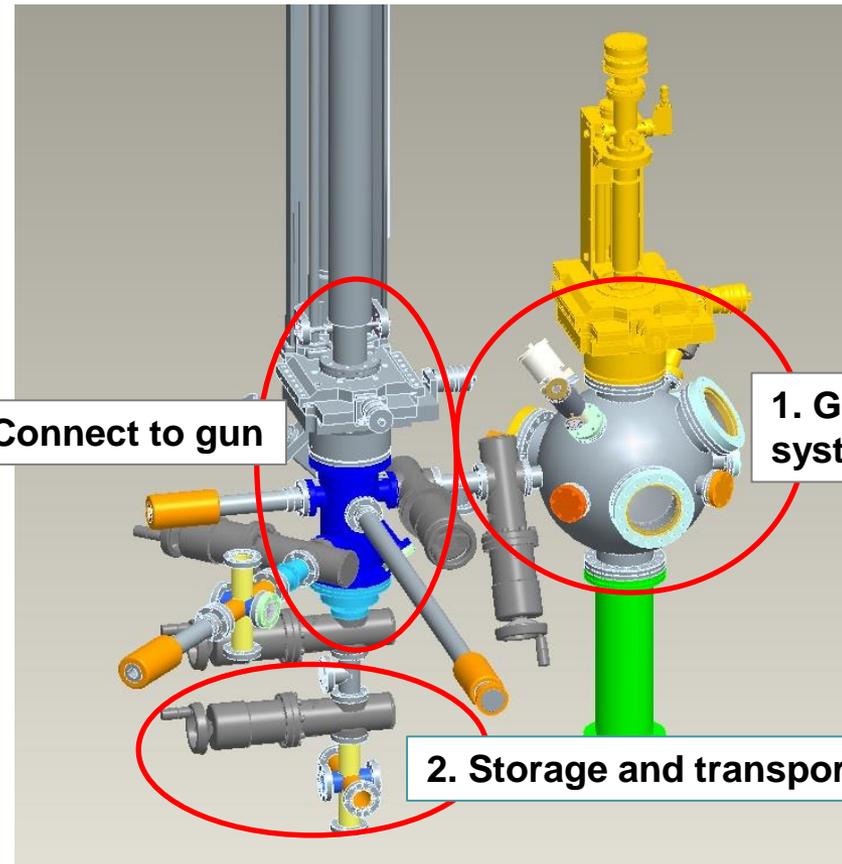
GaAs supper lattice supplier

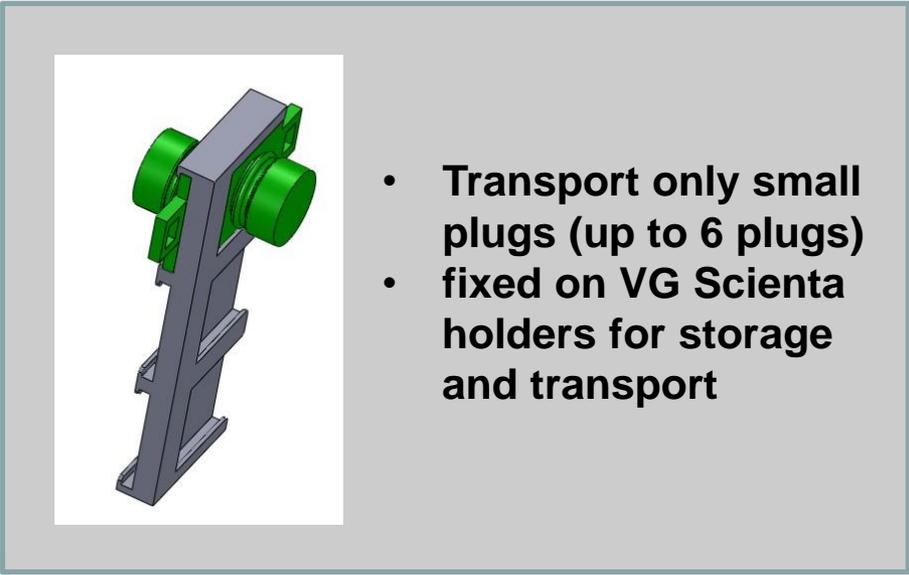
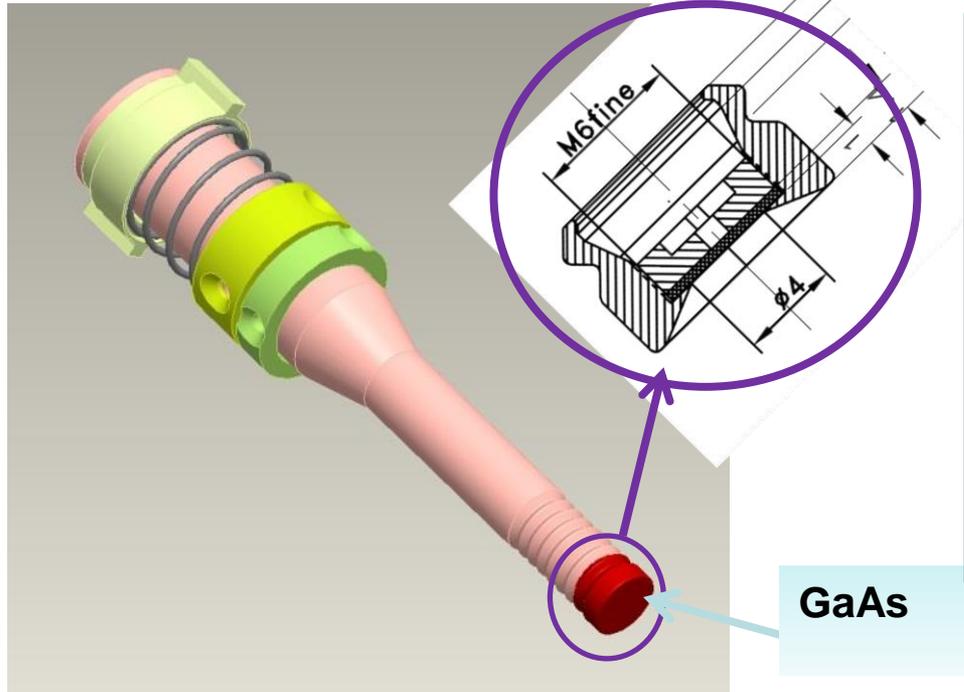
preparation and transfer system for GaAs (Cs,O)

- Close to SRF gun
- XHV chamber 10^{-11} mbar
- Green light
- Commissioning planned in 2013

Interesting points:

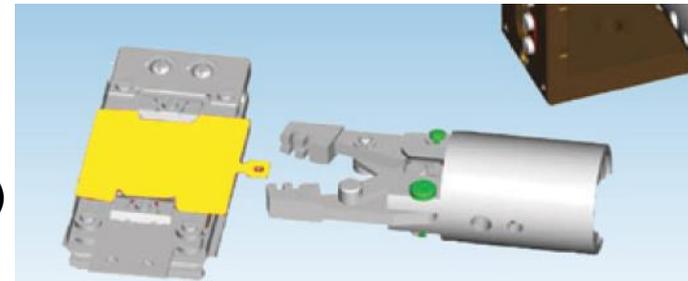
- QE / lifetime
- dielectric loss on crystal
- temporal response
- thermal emittance
- potential field emission
- dark current





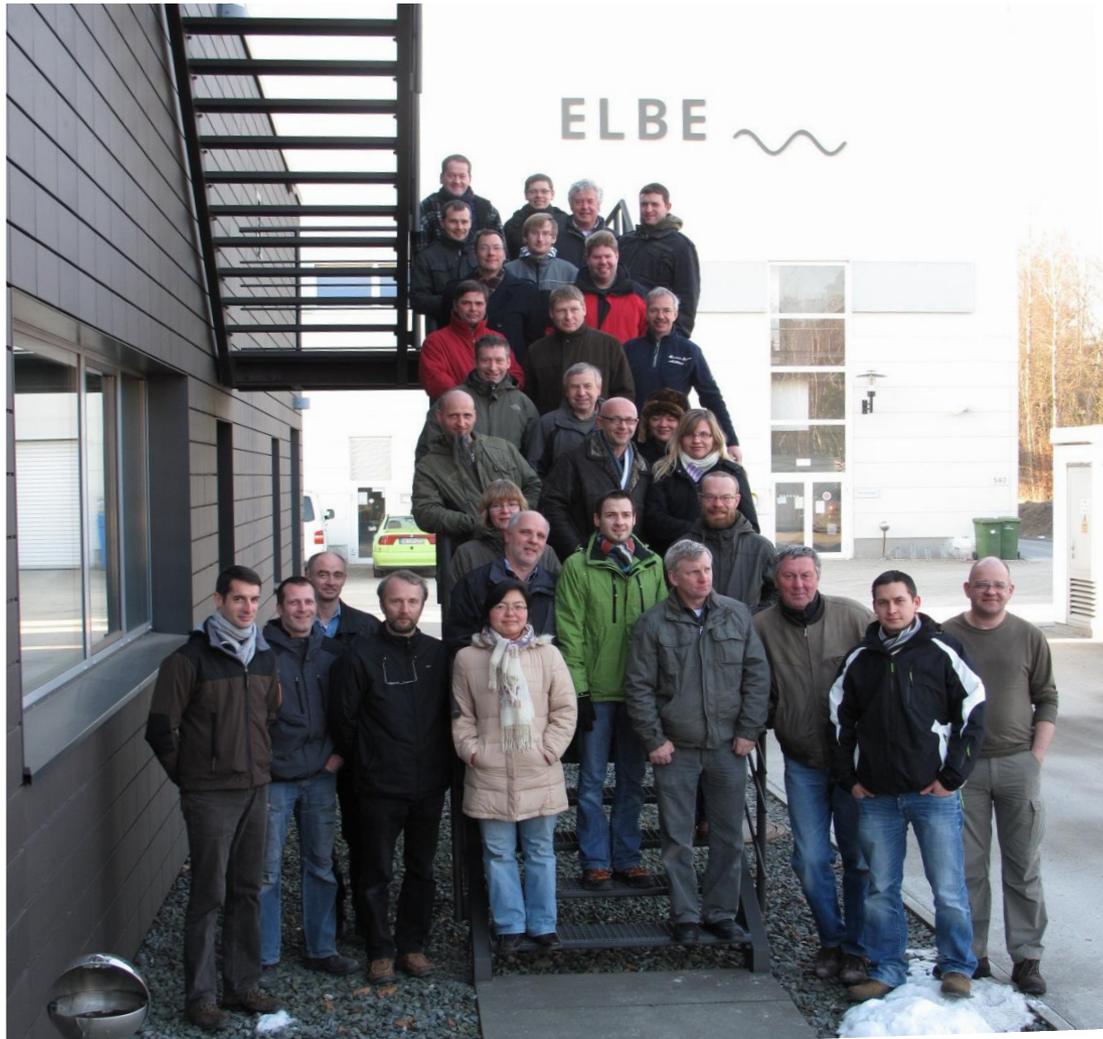
**Cathode 106 mm long
plug $\phi 10\text{mm} \times 6\text{mm}$ (HZB, HZDR, Mainz standard)**

- Easier for transport
- Easier for heat-cleaning



VG Scienta sample handling

topic	discussion	risk
GaAs cathode preparation	successfully demonstrated at many places	low
e-polarisation	using GaAs super lattices	low
SRF gun concept	demonstrated at HZDR/ELBE	low
PC lifetime in gun	vacuum ok; ion back bombardment low new unexpected problems?	medium
PC compatible with SC RF field	dark current, RF losses etc. degradation of cavity performance	medium
Beam brightness, emittance	high performance cavity Laser shaping, advanced emittance compensation	medium
QE, thermal emitt. time response, etc.	Experiences and solutions from DC guns	low



Acknowledgement

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