Study of Magnesium Photocathodes for Superconducting RF Photoinjectors

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Motivation

Superconducting RF photoelectron gun
- compact solution: injector + booster
- high current, high brilliance
- NC photocathode in SRF cavity
- perfect vacuum environment

Semiconductor photocathodes

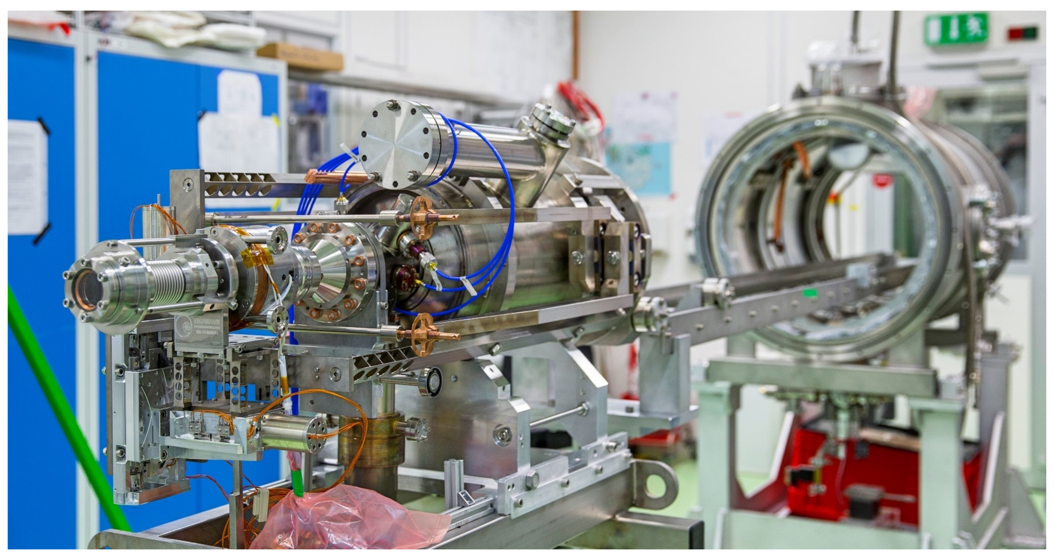
high quantum efficiency (QE)
less laser power required
high risk of contamination
required vacuum ~10^{-11} mbar

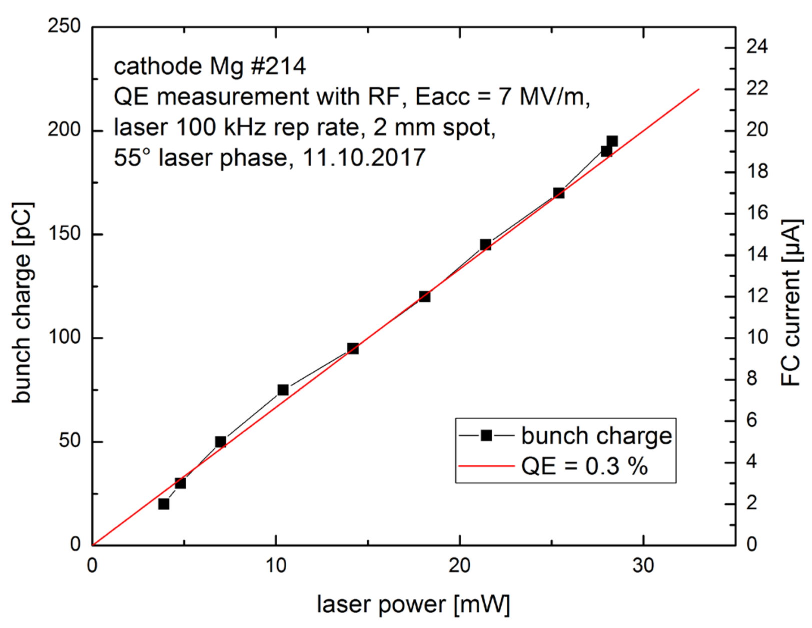
Metallic photocathodes

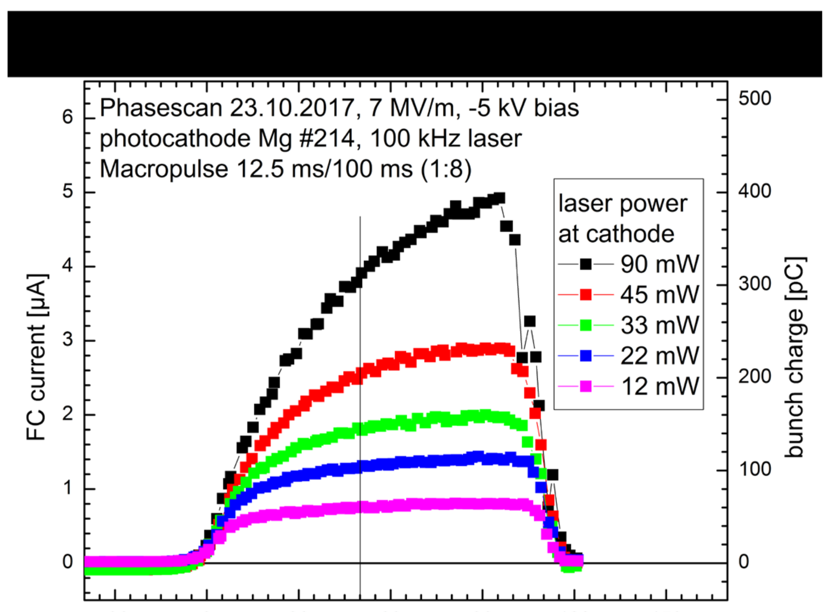
long lifetime, fast response
good compatibility with Nb cavity
Cu cathode 2 x 10^{-5} @ 258 nm
Mg cathode QE~10^{-3} @ 258 nm

SRF Gun II with Mg cathode

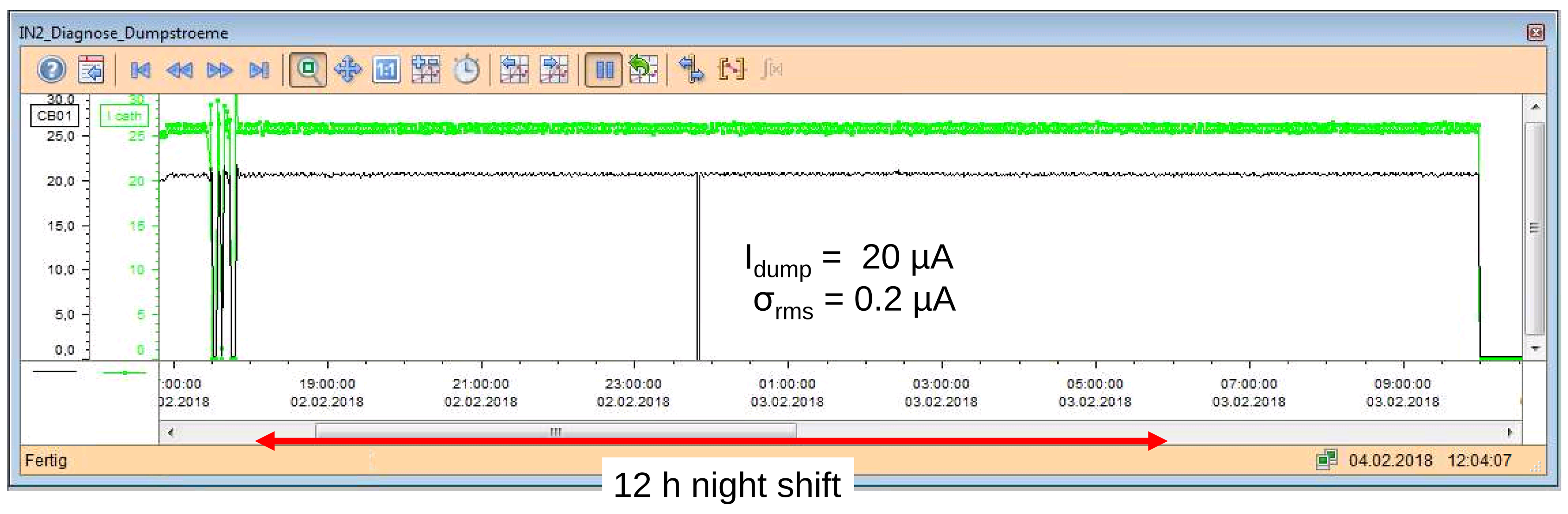
- 1.3 GHz 3½ cell cavity
- I_{dark} < 50 nA @ 7 MV/m
- drive laser: 258 nm, 100 kHz, Gaussian
- DC bias on cathode





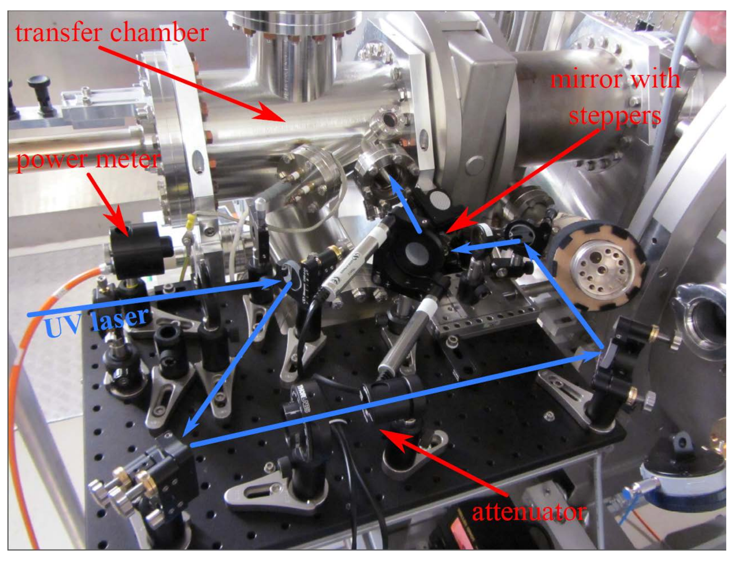


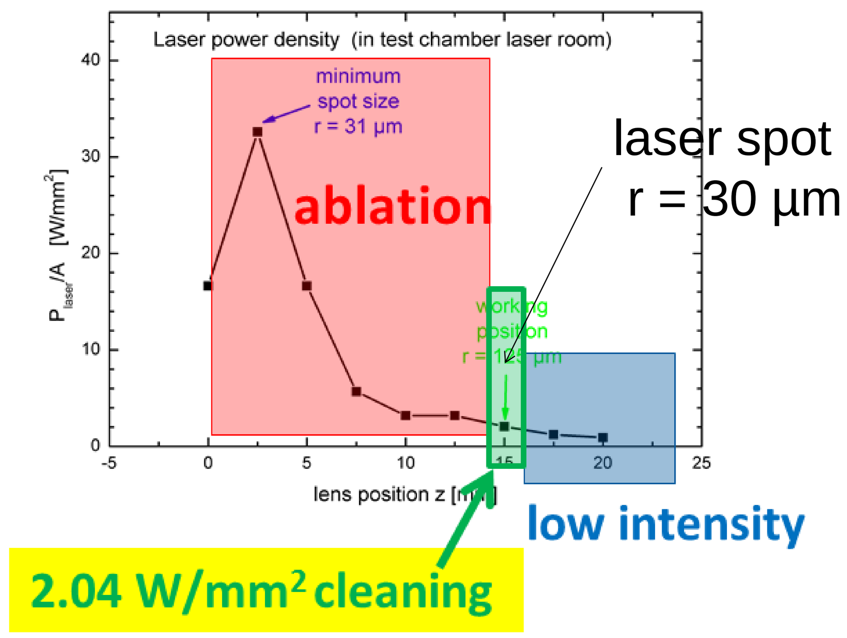
- QE~10^{-3} @ 258nm, stable, long lifetime in SRF gun
- small dark current, about 40 nA @ 7 MV/m
- low thermal emittance



- with current stabilization – compensation of long-term drifts
- Cathode current -> NI cRIO -> laser polarizer

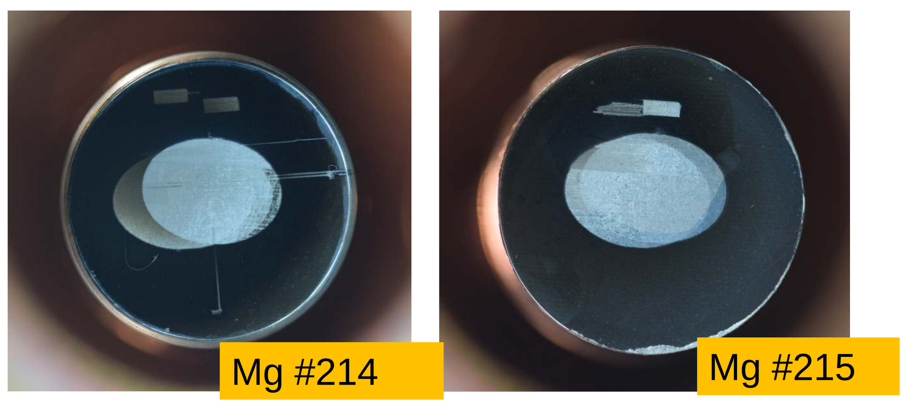
Laser cleaning

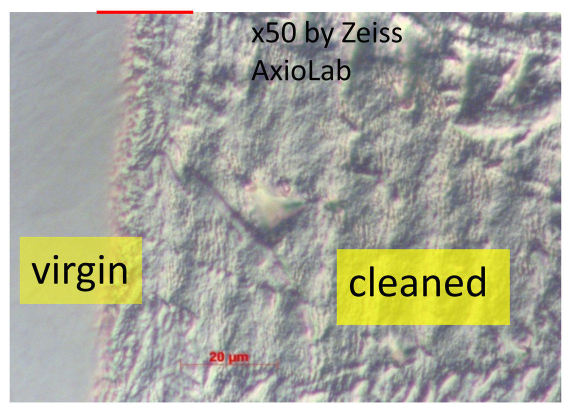




(photoemission in gun 0.1 W/mm²)

cleaning with UV drive laser in transport chamber
special optical set-up for focusing and scanning





- excellent QE, reaches 0.3 %
- experiment very well repeatable
- cleaned Mg is very sensitive, stable if p ≤ 10^{-9} mbar
- increase of roughness due to local surface melting
- very time consuming, ca. 5 h for 4 mm spot

Alternatives

Mg cathode cleaning
- heat treatment (✓)
- Ar^{+} ion beam sputtering
- KrF excimer laser cleaning

GaN photo cathodes
highest QE of 40 %
robust
collaboration with Univ. Siegen

Cs2Te photo cathodes
QE > 10 % (✓)
in prep lab
but:
- transport problems
- lifetime in gun overheating !

Photocathodes in SRF Gun II

Type	Time	QE	Q / I_{CW}	Remarks
Cu	June 14 – Feb. 15	2x10^{-5}	3 pC / 300 nA	Inserted during clean-room assembly of the gun
Cs_2Te	Feb. 15	2 % ↓ 0 %		**strong multipacting** & field emission cavity polution
Cu	Mar. 15 – Feb. 16	2x10^{-5}	3 pC / 300 nA	high dark current from cavity, no multipacting
Mg (#201)	Mar. 16 – Aug. 16	0.2 %	200 pC / 20 µA	no multipacting, no dark current from Mg, stable (user) operation, no QE decrease
Mg (#207)	Nov. 16 – Dec. 16	0.1 %	80 pC / 8 µA	no multipacting, no dark current from Mg, stable (user) operation, no QE decrease
Cs_2Te	Feb. 17	1.7 %	300 pC / 30 µA	no multipacting, no dark current from PC, **QE drop down after 2 weeks**, overheating!
Mg (#207)	Mar. 17 – May 17	0.2 %	150 pC / 15 µA	cathode laser cleaned 3rd time, stable beam operation
Cs_2Te (#2017.3.10)	June 17	1.3 %	15 pC / 200 µA	13 MHz CW ,no multipacting, no dark current **again QE drop down after 2 weeks**, overheating! showed same behavior as Cs2Te in Febr. 2017
Mg (#214)	August 17 – now	0.3 %	300 pC/ 30 µA	no multipacting, no dark current from Mg, stable operation up to **300 pC / 100 kHz gradient 8 MV/m (20.5 MV/m peak) Ekin = 4 MeV**

Acknowledgement

We would like to thank the whole ELBE team for their help with this project. The work was partly supported by the European Community under FP7 program (EuCARD-2, contract No.312453), and the German Federal Ministry of Education and Research (BMBF) grant 05K2016-HOPE II, and DFG grant HI²PE 4033122102..

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