Photocathodes Update at FLASH and European XFEL

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European Workshop on Photocathodes for Particle Accelerator Applications
20th - 22nd September, 2022
Milano

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

INFN LASA Istituto Nazionale di Fisica Nucleare Laboratorio Acceleratori e Superconduttività Applicata

FLASH Free-Electron Laser in Hamburg

European XFEL

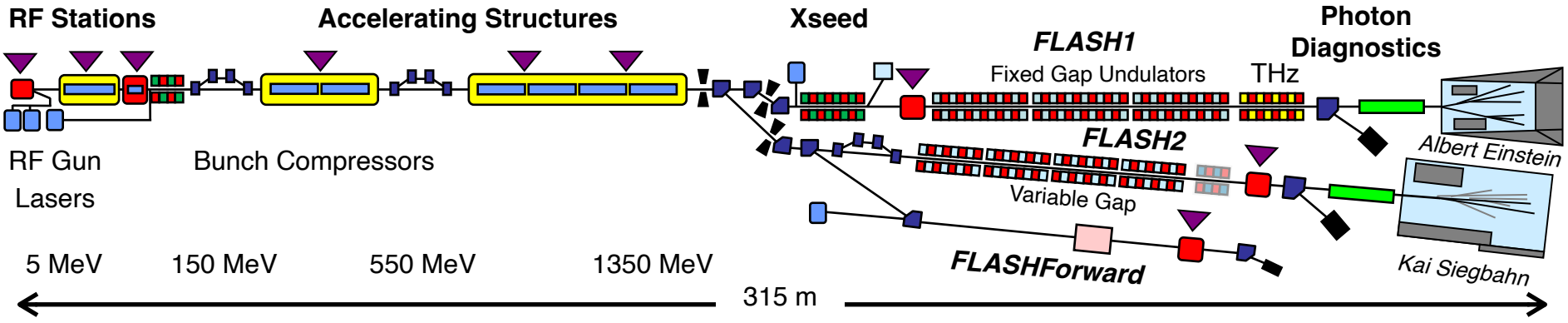
DESY.

FLASH – The Free-Electron Laser in Hamburg (Germany)

FLASH Layout 2022

FLASH: the first soft X-ray FEL user facility operating two undulator beamlines simultaneously

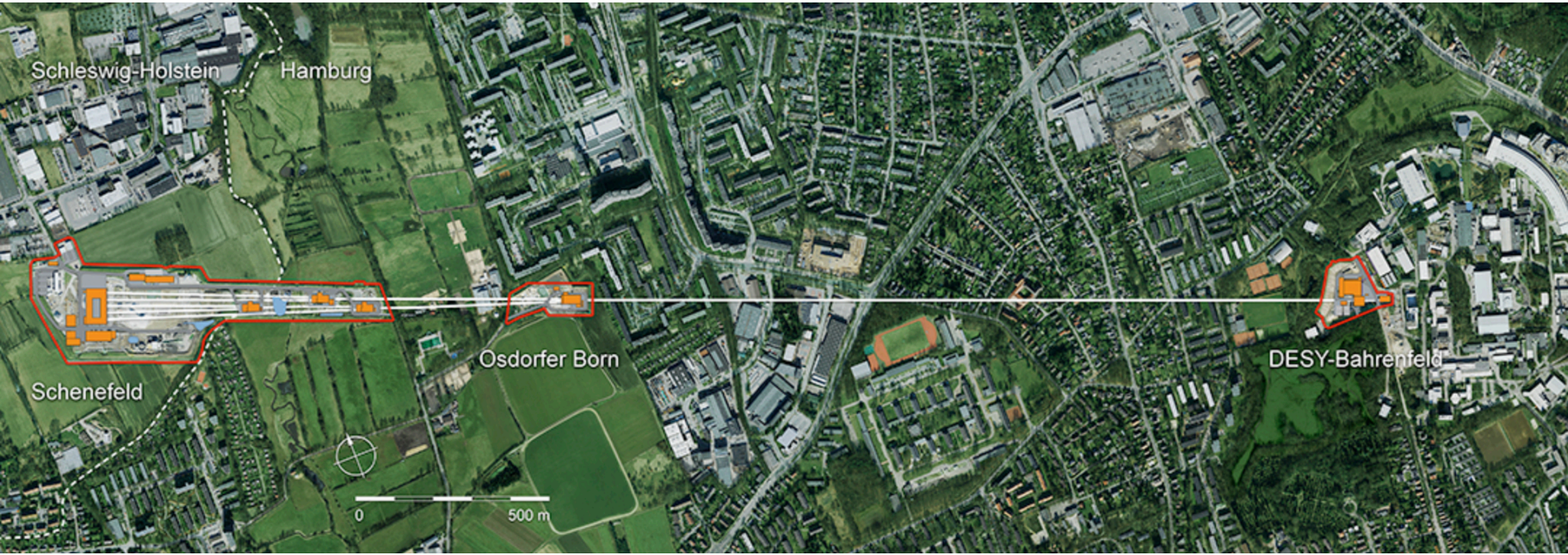






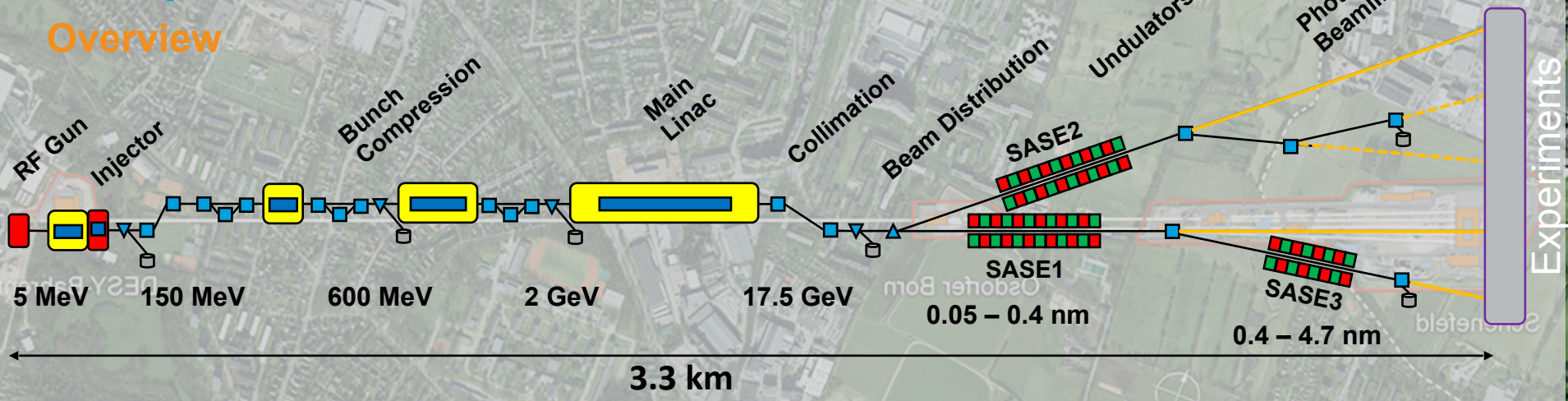
European XFEL

Overview



European XFEL

Overview

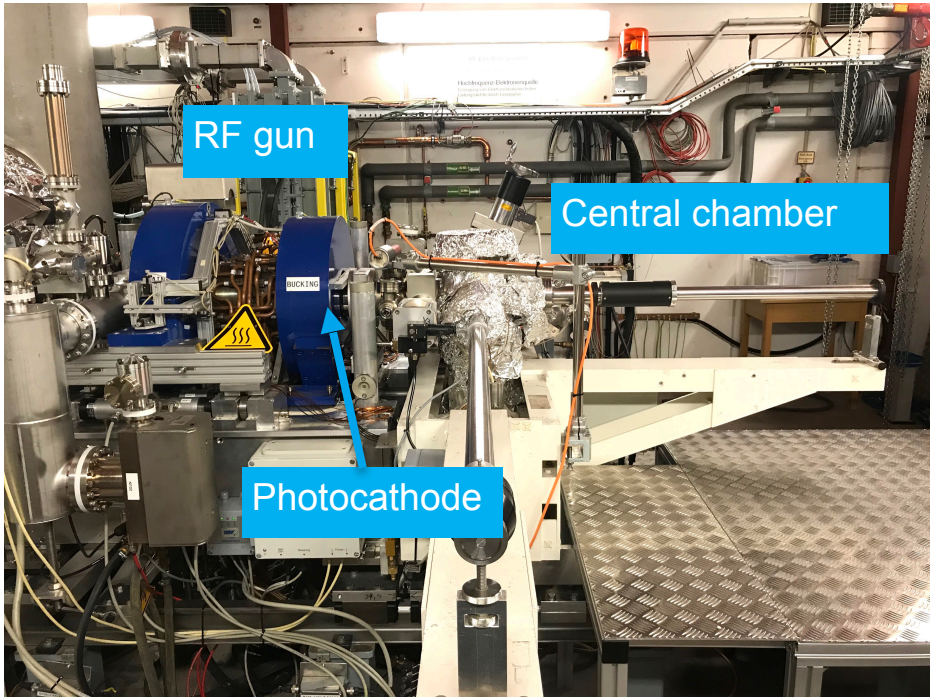


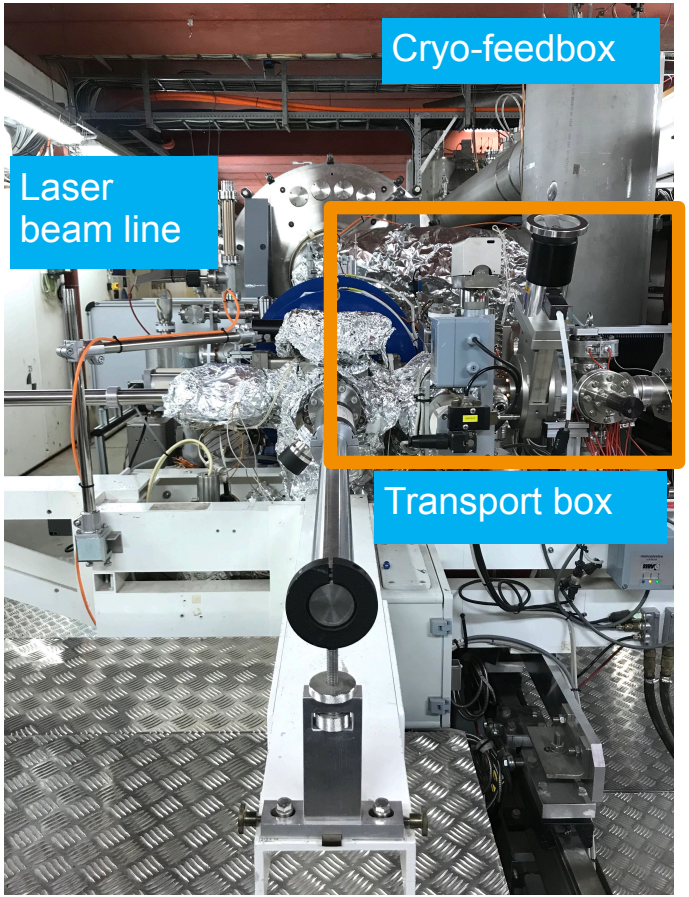
- 3 bunch compressors
- 97 1.3 GHz superconducting accelerator modules
  - Maximum beam energy 17.5 GeV
- Up to 600 kW beam power

- SASE1 and SASE2
  - 175 m magnetic length
  - 0.05 – 0.4 nm wavelength (25 keV – 3 keV)
- SASE3
  - 105 m magnetic length
  - 0.4 – 4.7 nm wavelength (3 keV – 0.26 keV)

FLASH photoinjector

FLASH – transfer system

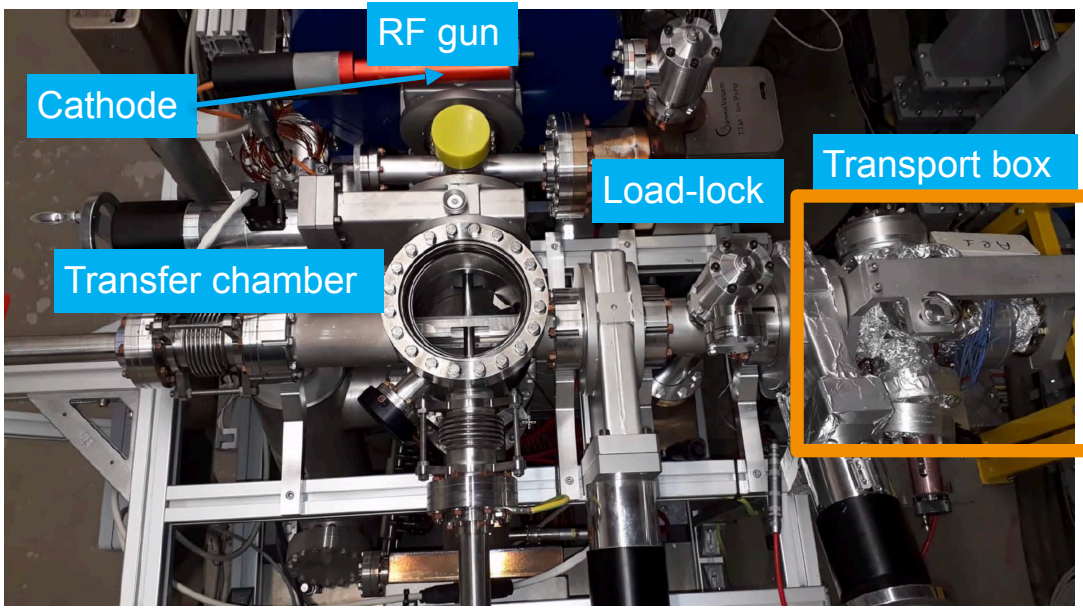




European XFEL photoinjector

European XFEL – transfer system

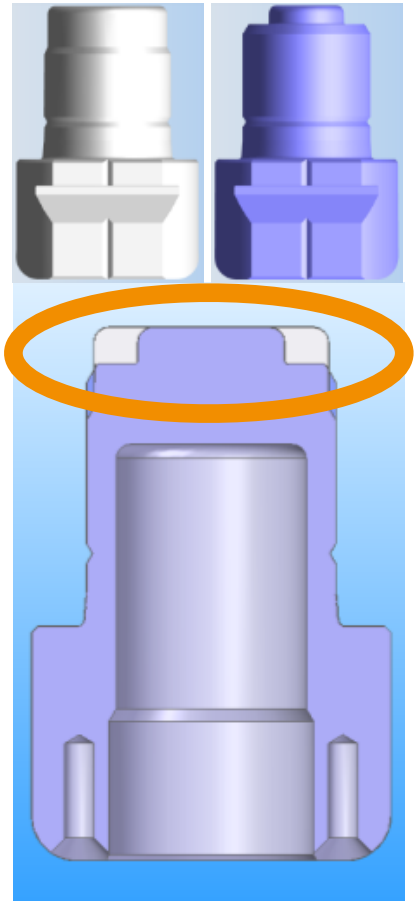
- System 100 % compatible to FLASH
- Improvements
  - Easier alignment between chambers (rails)
  - Improved visibility in the central chamber by means of a side view port
    - Positioning of the pincer much easier
  - Rails exchangeable



Cathodes for FLASH & EuXFEL

Cathode Plug
Comparison

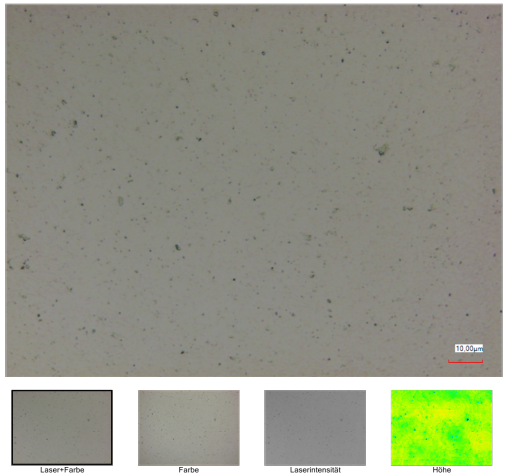
- Original INFN cathode plug design, used at European XFEL and FLASH
- For comparison, new INFN/Fermilab cathode plug design
  - used e.g. at APEX-gun @ LBL, CLARA @ STFC Daresbury, LCLS II @ SLAC, REGAE and SINBAD @ DESY
- Differences only in the front region, therefore
  - 100 % compatibility in preparation and transfer systems



Plugs fabrication and polishing

Done at DESY in Hamburg

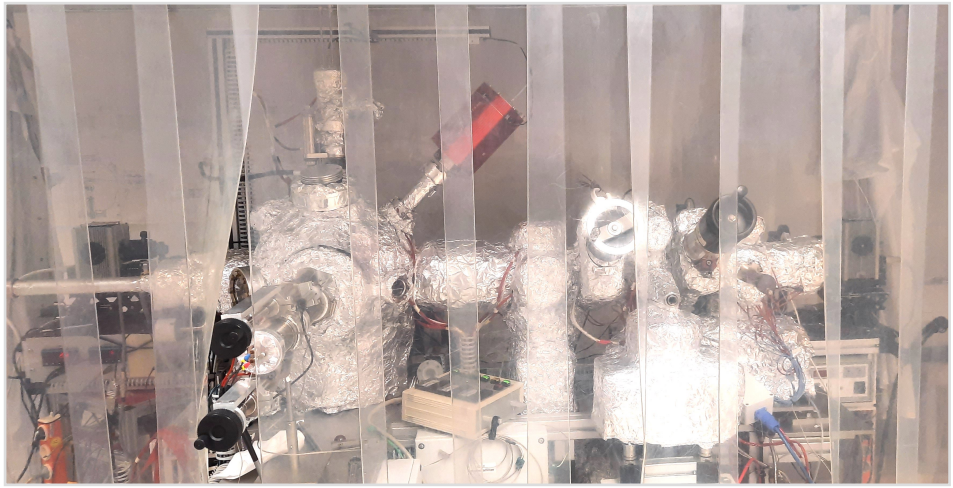
- Mo-Plugs are produced at DESY Hamburg
- Polishing recipes for different materials and designs
- Reflectivity at 532 nm around 60 %
- Surface-roughness Ra ~ 20 to 30 nm

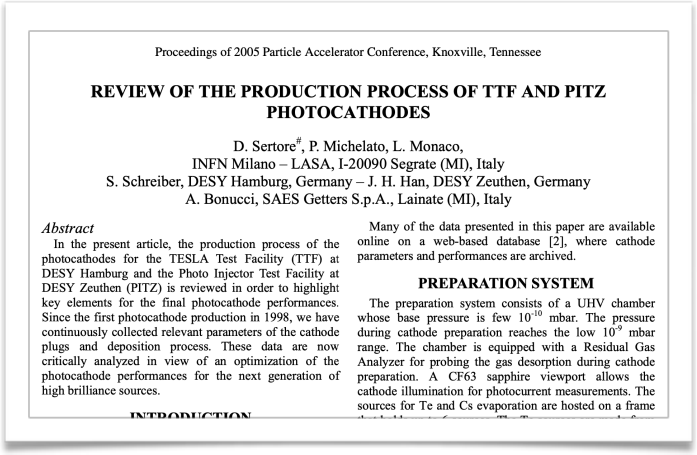


Cs_2Te Photocathodes

DESY deposition system // LASA's recipe

- INFN-Milano and LASA deposition system design
- Assembled by LASA in close collaboration with DESY
- All components are 100 % compatible to the Milano system





Proceedings of 2005 Particle Accelerator Conference, Knoxville, Tennessee

REVIEW OF THE PRODUCTION PROCESS OF TTF AND PITZ PHOTOCATHODES

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Abstract

In the present article, the production process of the photocathodes for the TESLA Test Facility (TTF) at DESY Hamburg and the Photo Injector Test Facility at DESY Zeuthen (PITZ) is reviewed in order to highlight key elements for the final photocathode performances. Since the first photocathode production in 1998, we have continuously collected relevant parameters of the cathode plugs and deposition process. These data are now critically analyzed in view of an optimization of the photocathode performances for the next generation of high brilliance sources.

Many of the data presented in this paper are available online on a web-based database [2], where cathode parameters and performances are archived.

PREPARATION SYSTEM

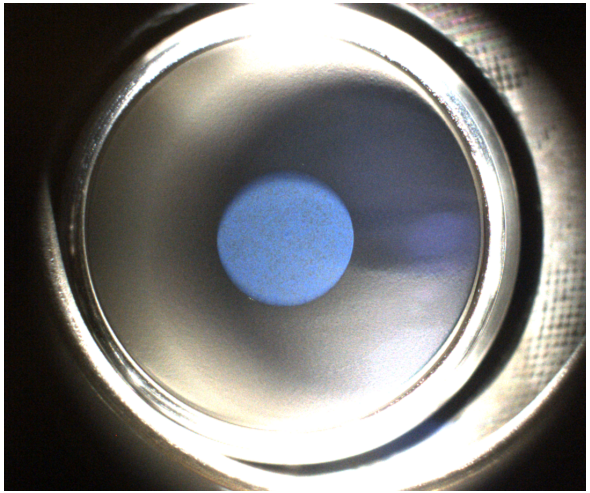
The preparation system consists of a UHV chamber whose base pressure is few 10^{-10} mbar. The pressure during cathode preparation reaches the low 10^{-9} mbar range. The chamber is equipped with a Residual Gas Analyzer for probing the gas desorption during cathode preparation. A CF63 sapphire viewport allows the cathode illumination for photocurrent measurements. The sources for Te and Cs evaporation are hosted on a frame

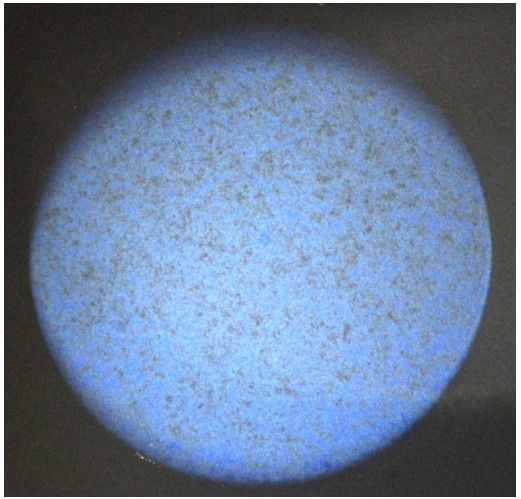
- Plug is heated to 450 °C then kept to 120 °C
- Tellurium source starts
  - Rate of 1 nm/min ~ 10 nm thickness
- Followed by Caesium source
  - Rate of 0.5-1.0 nm/min
  - Until the QE maximum is reached
- Photocurrent monitored during the process
- The cathode is cooled down to room temperature after deposition
- QE measured at 254 nm in its transport box

Cs_2Te Photocathodes

DESY deposition system // LASA's recipe

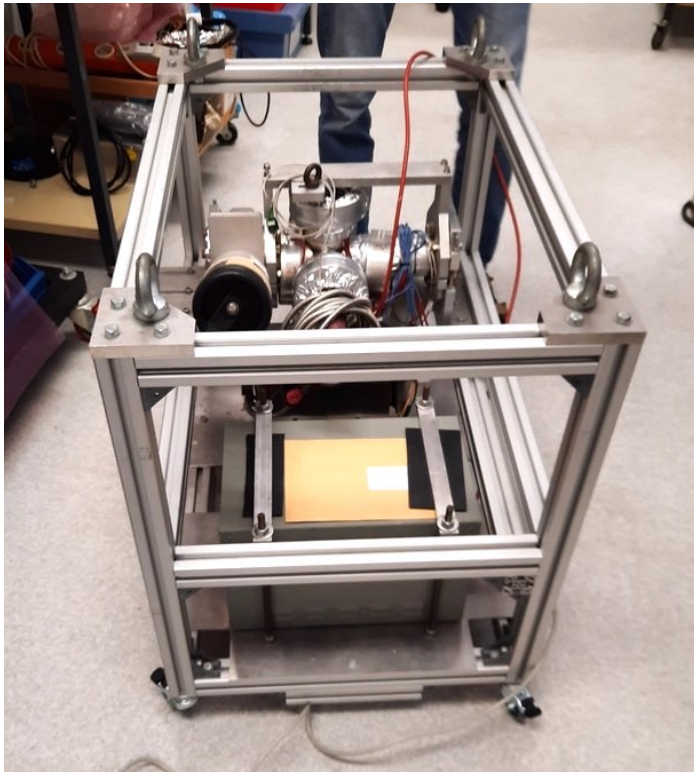
- Mo Cathode 722.1 polished and inserted in the system
- Cs_2Te deposition



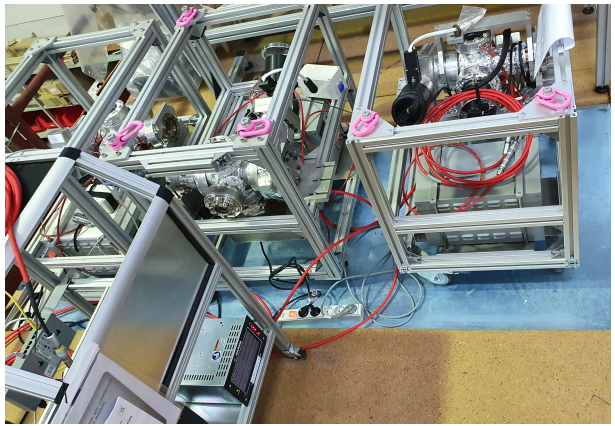


Cathode's transport box

From Hamburg to PITZ and Milano to Hamburg



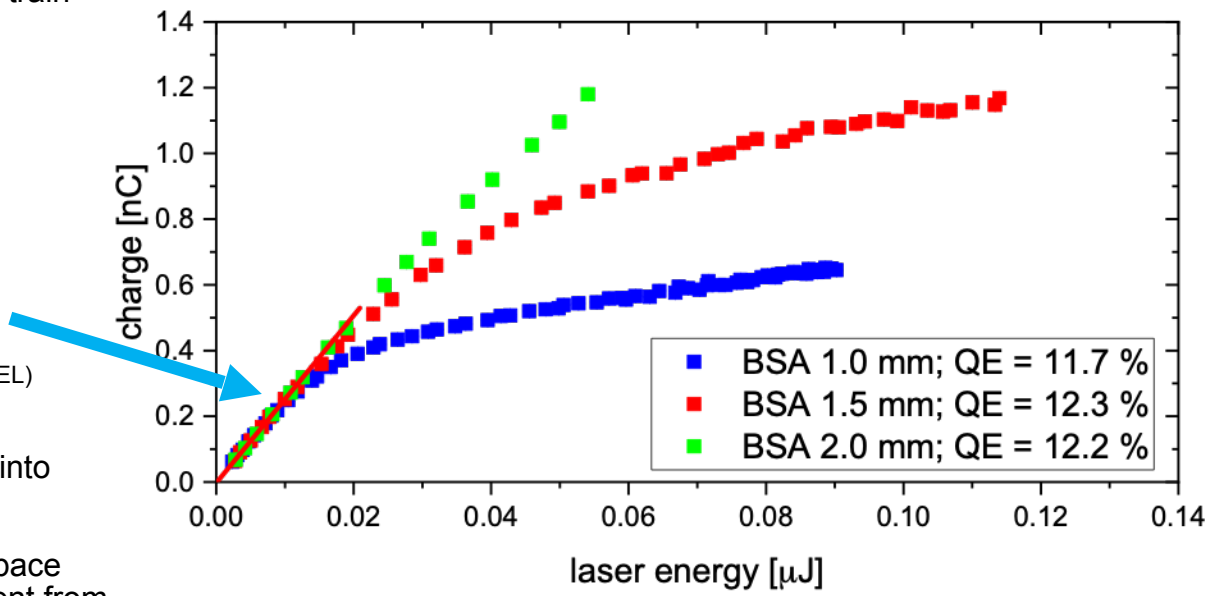
- Portable transport box
- 3 different designs boxes that are available to serve several facilities
- Powered through a DC/DC converter by a car battery
- The vacuum is in the low 10^{-10} mbar range
- The vacuum level is monitored continuously
- The 4 cathodes stored can stay alive for a long time



QE measurement procedure

At FLASH photoinjector

- Laser No. 2, 1 MHz, 30 Bunches, flat train with apertures 1.0, 1.2 and 2.0 mm
- Gun phase scan with max 200 pC
- Gun phase to 38 deg off zero
- Different laser apertures
- Laser energy measured by
  - Calibrated joulemeter (FLASH)
  - Cross-calibrated photo diode (European XFEL)
- Transmission of vacuum window and reflectivity of in-vacuum mirror taken into account
- QE is obtained from linear fit in not space charge dominated regime (independent from laser spot size for homogeneous cathodes)



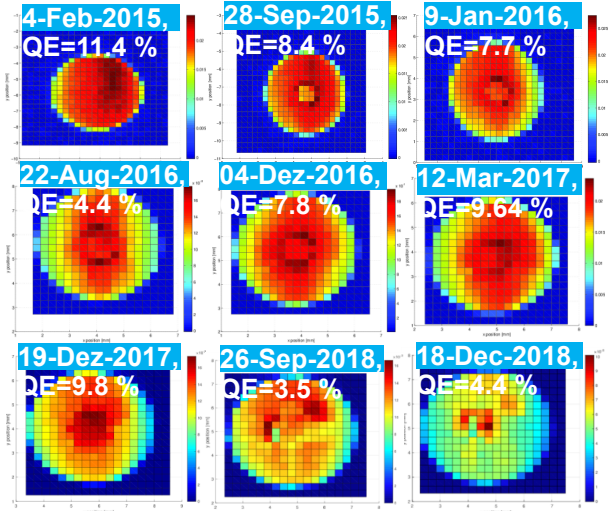
Current photocathode lifetime

FLASH cathodes comparison

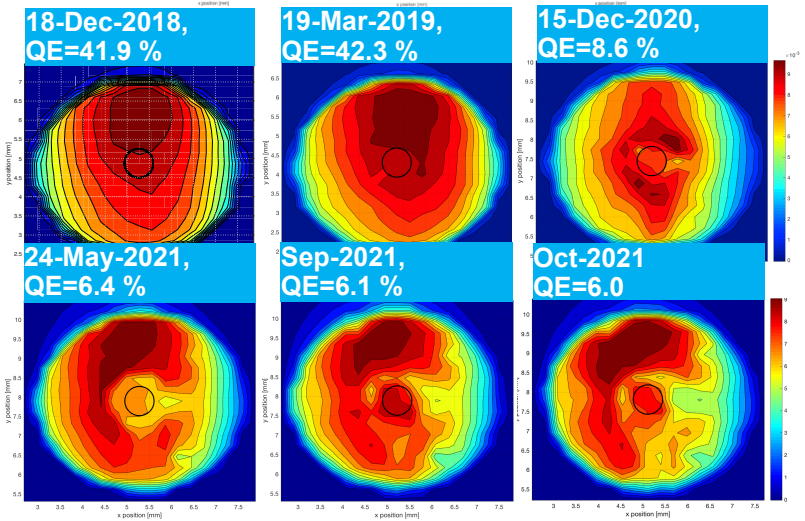
- Cathode # 73.3 Operated from Feb-2015 to Dec-2018 for **1413 days**
- Cathode # 105.2 Operational since Dec-2018 until shutdown **with 1065 days**

Both cathodes were produced at LASA

FLASH – cathode 73.3



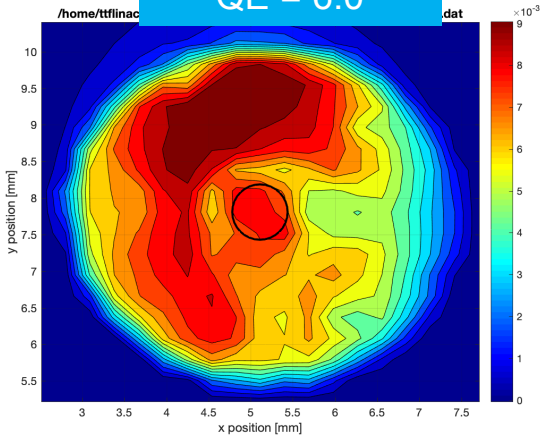
FLASH – cathode 105.2



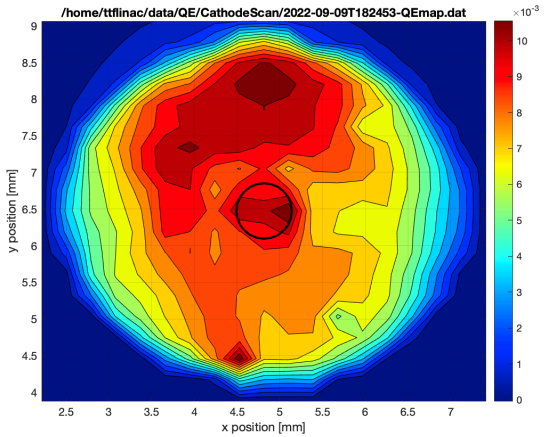
Cathode life time at FLASH

Cathode 105.2

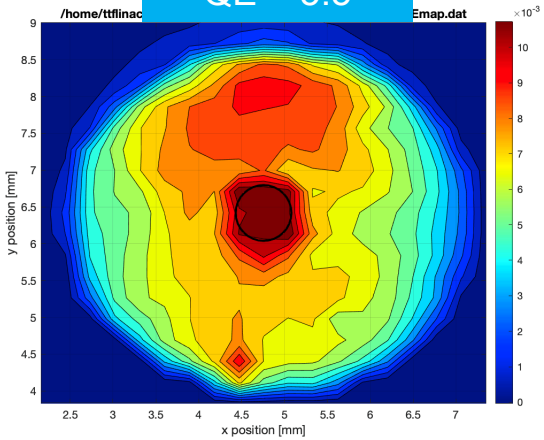
Oct-2021
Before shutdown
QE = 6.0



9th-Sep 2022
After shutdown



16th-Sep 2022
After shutdown
QE = 5.5



Cathode life time at FLASH

Cathode 105.2

cathode 105.2

laser 2

BSA=1.0 mm

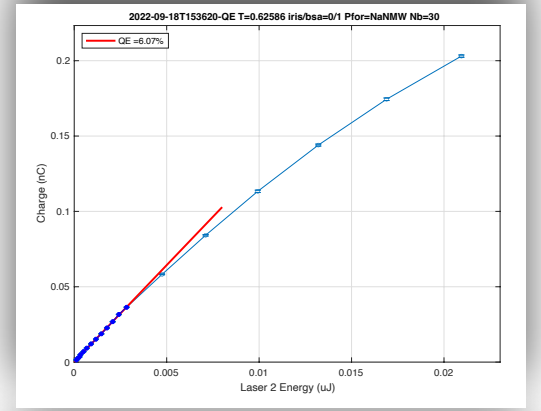
phase 38 dg off zero

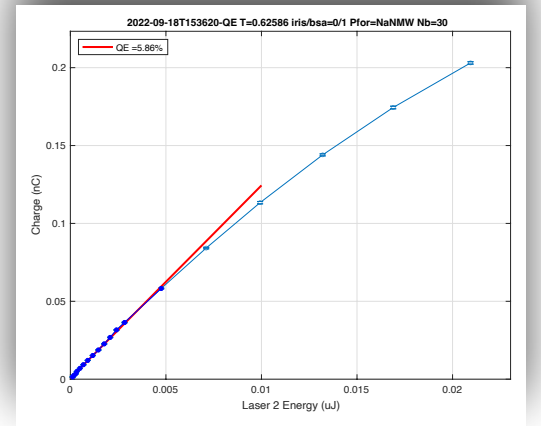
QE=5.5%

= we have confirmation:

gun phase at 45 dg -> QE=6.6 %

gun phase at 38 dg -> QE=5.5 %

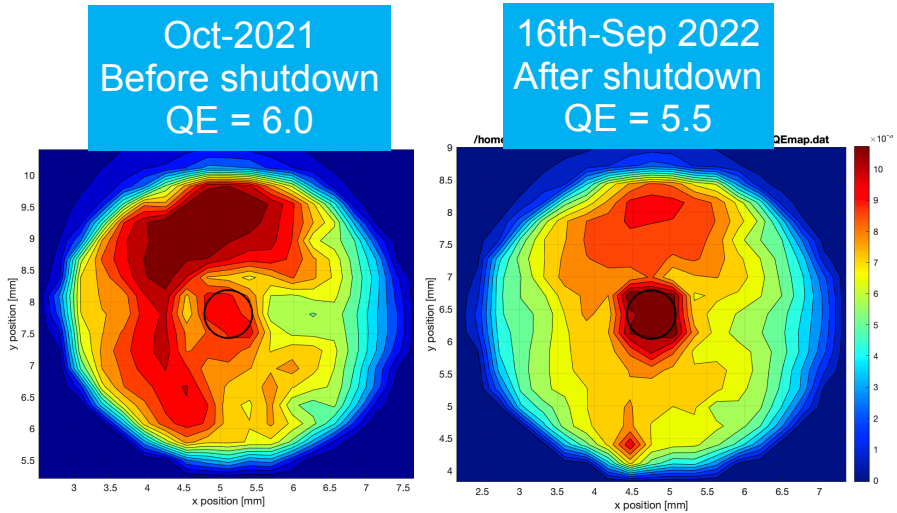


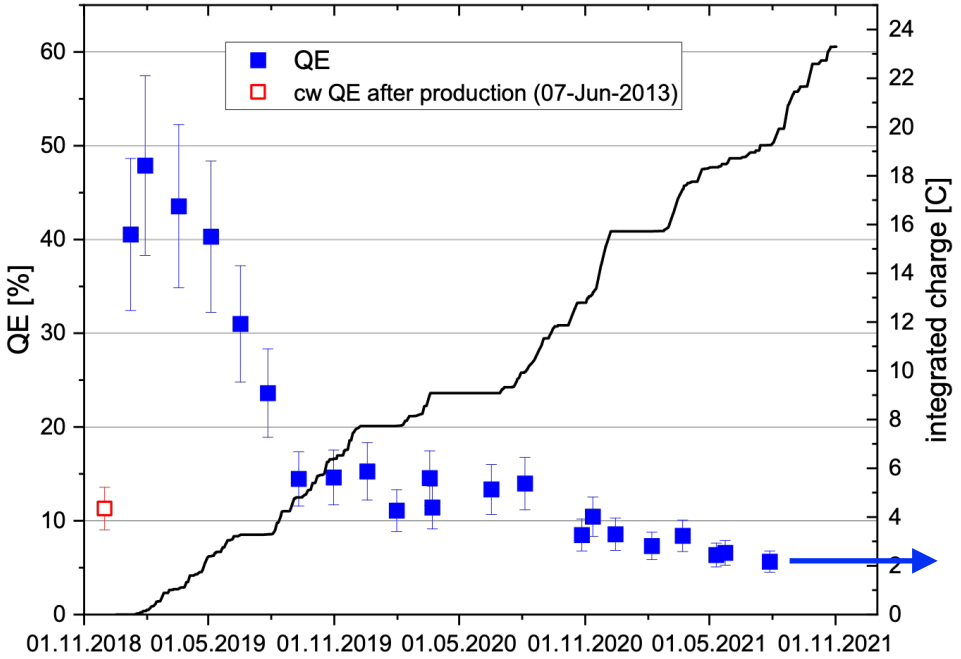


Cathode life time at FLASH

Cathode 105.2

- Cathode prepared 03-Jul-2013 at INFN-LASA
- In operation since 18-Dec-2018
- Operation time of 1065 days
- Total charge extracted 23.3 C

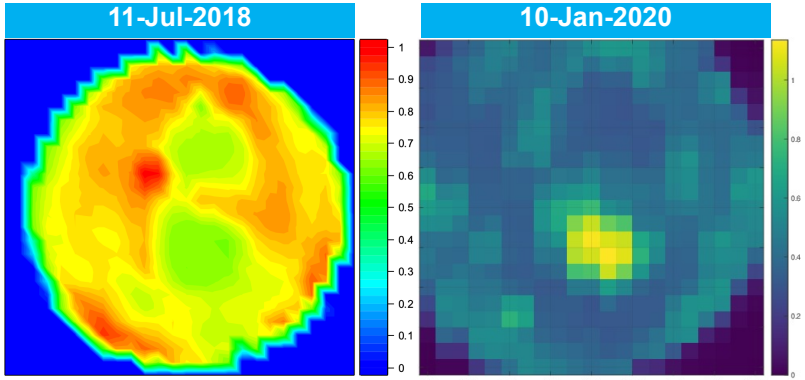


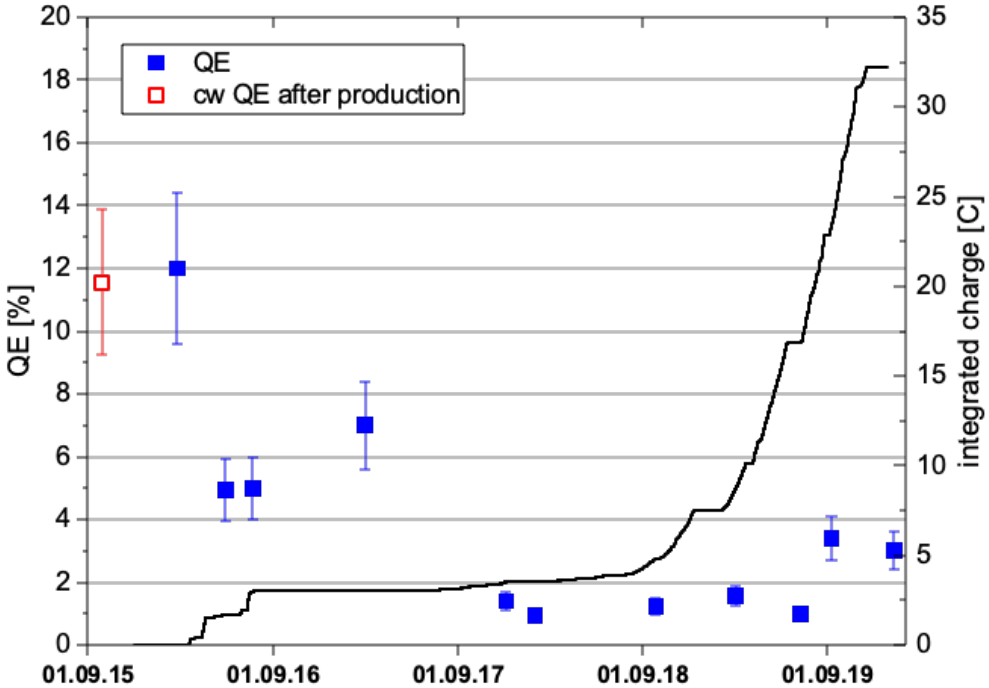


Cathode life time at European XFEL

Cathode 680.1 - Previous one

- Cathode prepared 01-Sep-2015 at DESY
- **Operation record time of 1452 days (previous one)**
- Total charge extracted 32.2 C

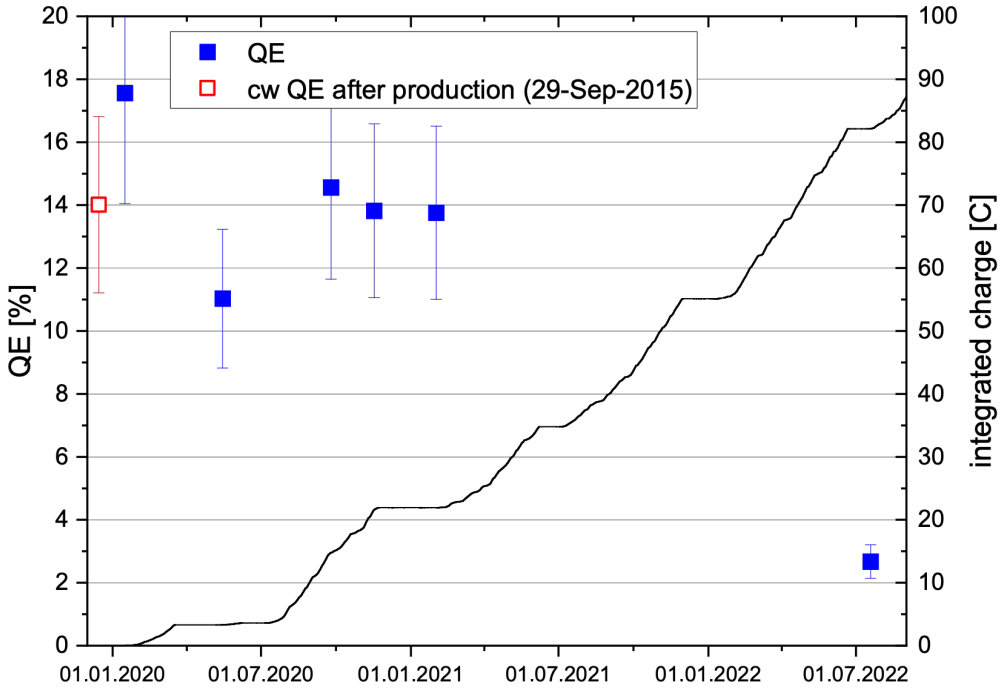




Cathode life time at European XFEL

Cathode 681.1 - Current photocathode

- Cathode prepared 08-Sep-2015 at DESY
- In operation since 14-Jan-2020
- **Operation time of 951 days**
- Total charge extracted 87.3 C
- 22nd-Jul-2022 re-inserted and rotated 180 DEG

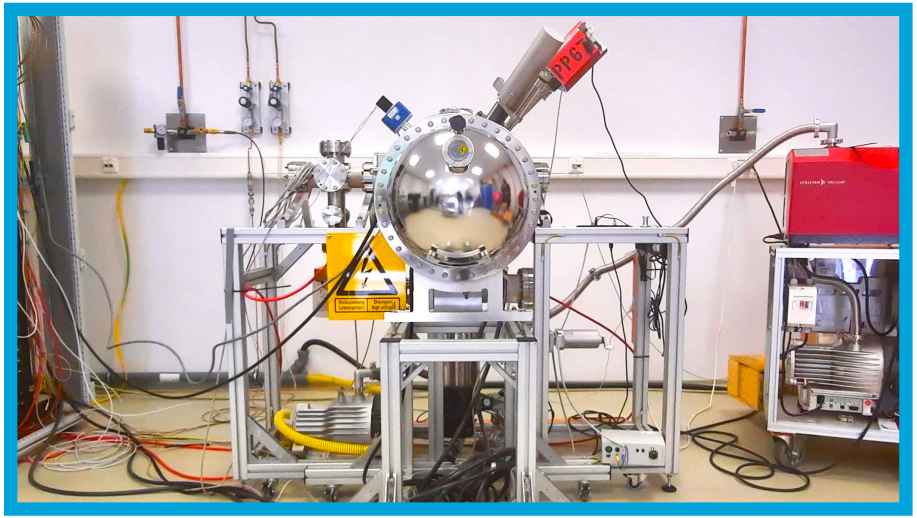


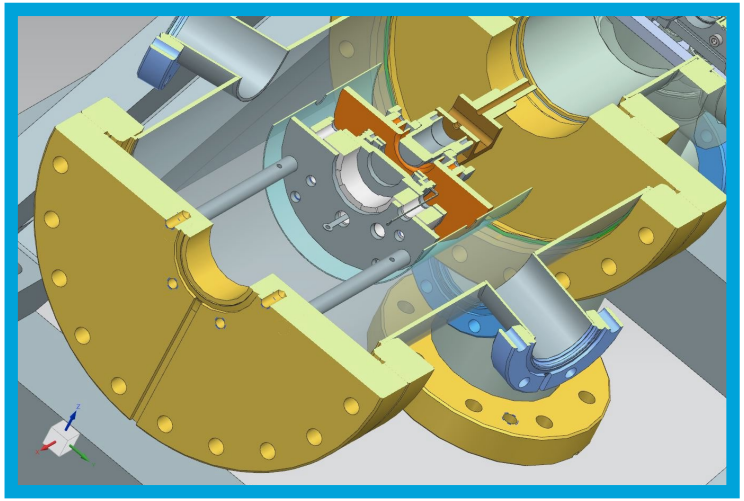
New characterisation system

Blue Lab at DESY

- Building a characterisation system (XPS and AES).
- Build an electron transverse momentum spectrometer. (Grant awarded!)

Check poster session





Summary

Summary

- Cathode handling and transfer at FLASH and European XFEL works reliable but is continuously improving.
- At FLASH and European XFEL currently no cathode's life-time issues of Cs_2Te photocathodes
- Cs_2Te fits well for FLASH and European XFEL as a user facility with its high QE and long lifetime
- Collaboration with PITZ and INFN-LASA in order to investigate green cathodes
- TEMA system light-source is under commissioning and components already ordered
- FLASH shutdown has finished -longest shutdown at FLASH, still using the same cathode with QE = 5.5 %

Thanks

Questions?