Evaluation of Photo-Cathode Port Multipacting in the SRF Photo-Injector Cryomodule for the LCLS-II High-Energy Upgrade

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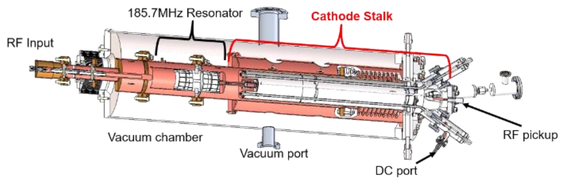
Introduction

- FRIB, HZDR, Argonne, and SLAC are developing a 185.7 MHz superconducting radio-frequency photo-injector cryomodule for a low emittance injector proposed for the high-energy upgrade of the Linac Coherent Light Source (LCLS-II-HE).
- Cathodes must be maintained at the **desired temperature**, **precisely aligned**, and operated **without multipacting (MP)**; to avoid field emission, **cathode exchange** must be **particulate-free**.

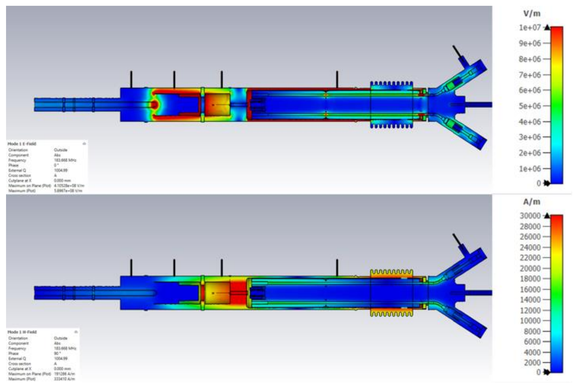


- An RF/DC test was developed to evaluate the cathode stalk performance as a subsystem and to identify and correct issues before assembly into the full cryomodule.

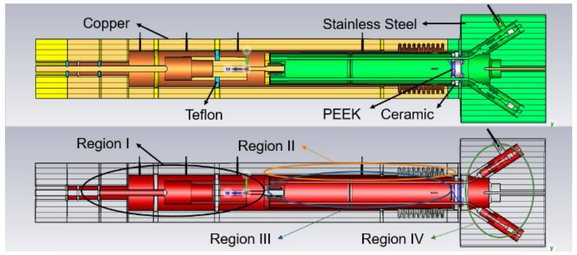
Multipacting Simulation

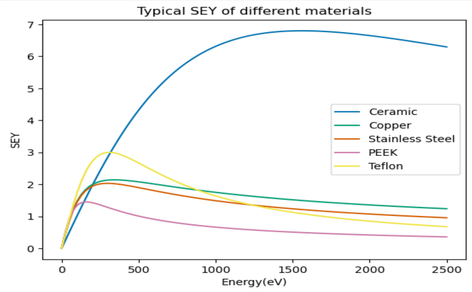
- CST Microwave Studio (CST)
- ❑ **Eigenmode** Solver -- generate RF/DC field
- ❑ **PIC** Solver -- MP simulation

- Simulation Sequence
  - Without DC Bias
  - Various DC Bias
  - Various Surface Conditions

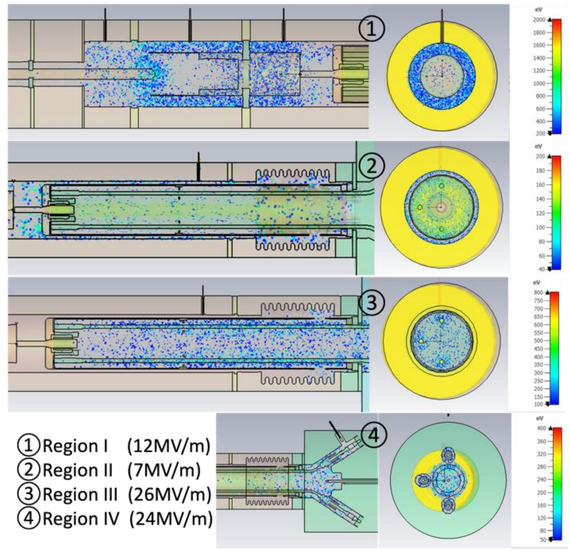


Simulation Results without DC Bias



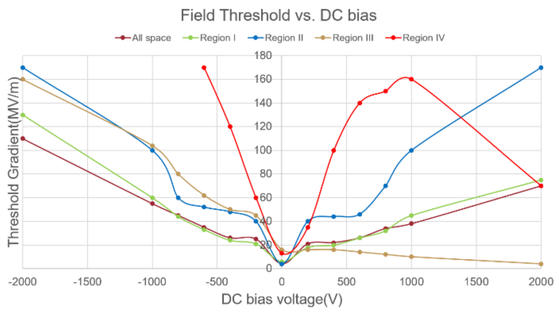


- MP is an important **resonance process** that can lead to detrimental effects such as elevated temperature and vacuum pressure, thereby **impacting photocathode stability and lifetime**.
- The occurrence of MP in RF structures relies on both the **electromagnetic field distribution** and the **secondary emission yield (SEY)** of the materials.
- **Initial particle sources** are divided into four regions, distributed in a Gaussian manner over time.
- MP happens in **Region II** at **low gradients** and in **Region IV** at **high gradients**. Besides, it is observed that MP activity is relatively weak in Region I and even more subdued in Region III.

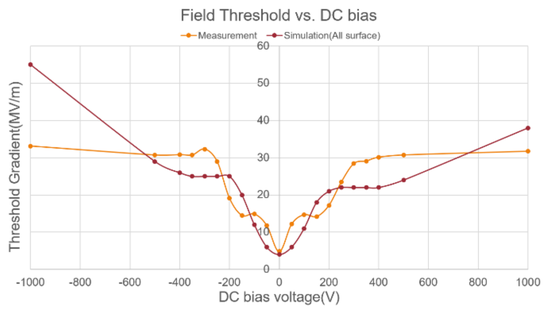


Simulation and Experimental Results for Various DC Bias

- (**Simulation**) Threshold gradient exceeds **30 MV/m** when the magnitude of DC bias exceeds approximately **600 V**.
- (**Simulation**) Positive and negative bias have different influence on **region III and IV**.



- (**Experiment**) When DC bias is under 500V, **only FPC current** occurs; when DC bias is over 500V, **only cathode current** appears.
- (**Experiment**) After **RF processing**, there is no MP when input power reaches its maximum value (**44MV/m at cathode**).

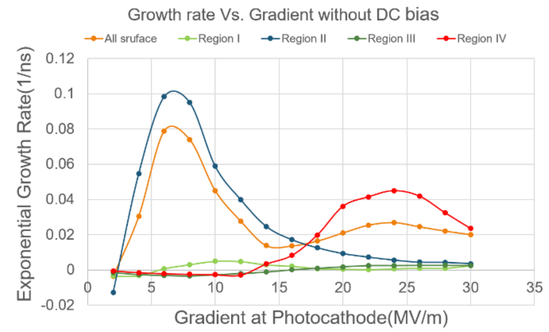


Exponential Growth

- In general, the number of electrons exhibits an **exponential increase** when the space charge effect is not considered.

$$N = A * e^{B*t}$$
$$\ln(N) = \ln(A) + B * t$$

- B is the **Growth Rate** we defined. N is the number of electrons and t is the time.



Summary & Outlook

- From **simulation**, a -1 kV bias effectively suppresses MP when the electric field at the photocathode reaches 30 MV/m.
- From **measurement**, MP threshold gradient saturates at 30 MV/m for DC bias levels exceeding 400 V.
- **RF field** used to simulate may **differ**. For instance, **high voltage wire** was not introduced in the simulated module.
- **Mesh density** may be insufficient in certain locations.
- Measurement at both **room temperature** and **liquid nitrogen temperature** after **rinsing** and **baking** the setup.

Acknowledgement

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