Field Emission Array (FEA) for electron/hole emission into liquid xenon

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INTRODUCTION

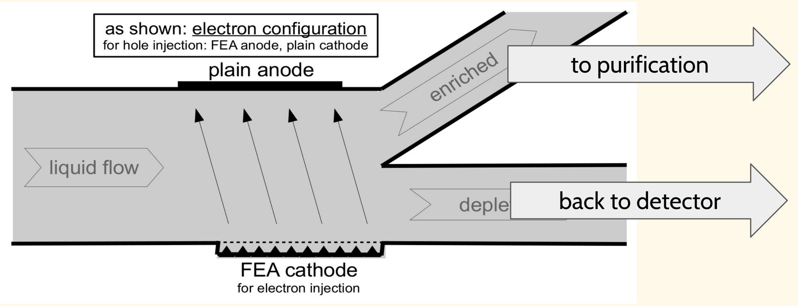
Radon is the main impurity in the current liquid xenon based detectors. We have methods that consists on distillation for example to get rid of Rn. However, next generation detector will require higher purification rate, which may not be satisfied by current purification methods.

What we want to do ultimately:

- use field emission arrays (FEAs) to inject electron/hole current into LXe.
  → electron/hole will then attach to Rn so that we can drift it inside the liquid and remove it

Objective of the first tests:

- observe current injection using FEA
- see what happens to tips after current discharge



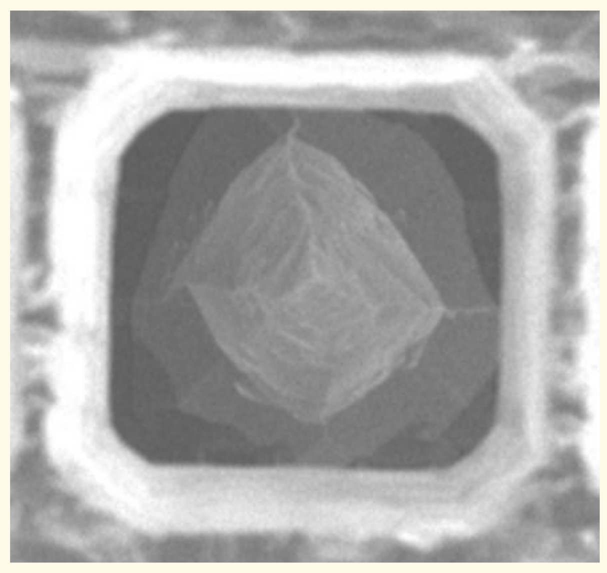
FEA

We are using FEAs provided by Prof. Rupert's group from OTH Regensburg. Some properties of FEAs:

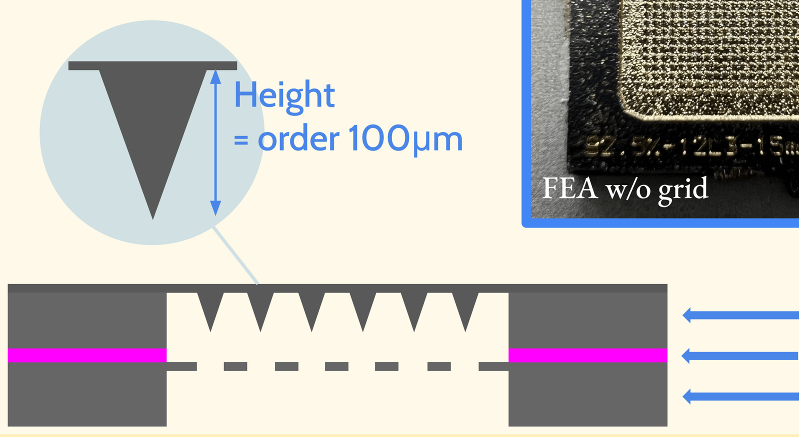
- made of silicon (gold plated for better conductivity)
- they were laser "chiseled" (both tips and grid)

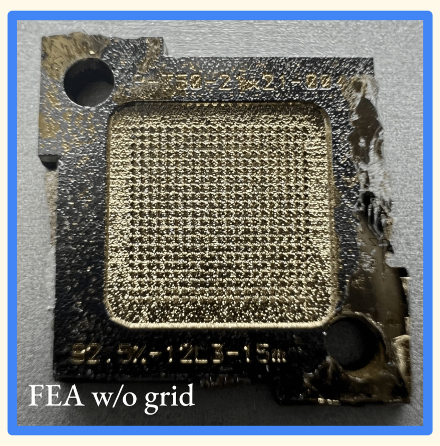
The imaging of the tips were conducted using the scanning electron microscope (SEM) and the Keyence digital optical microscope (VHX) with 3D reconstruction software.

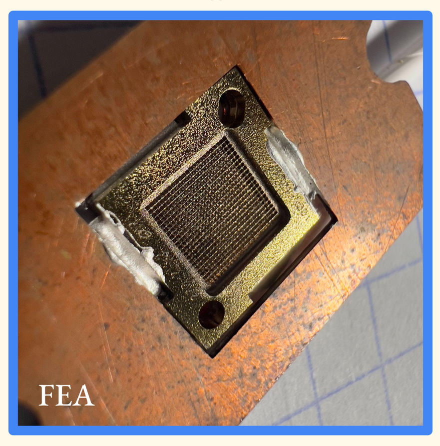
→ biggest advantage of VHX are colors and time consumption

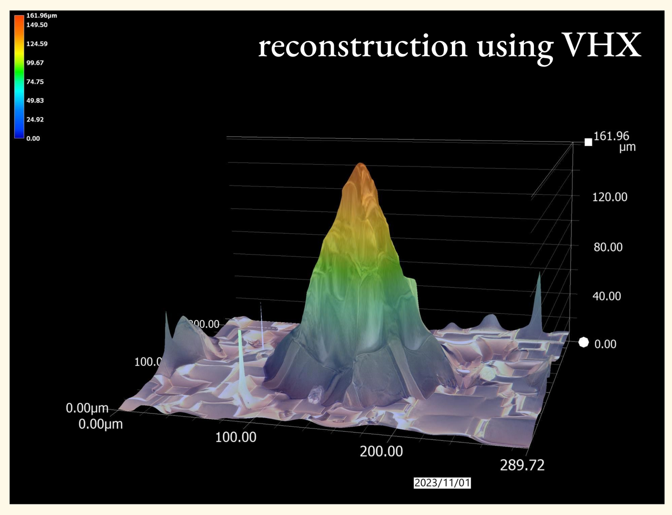


picture taken by SEM



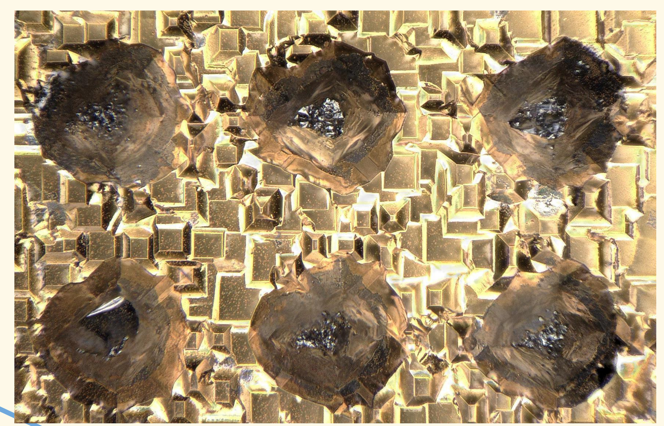


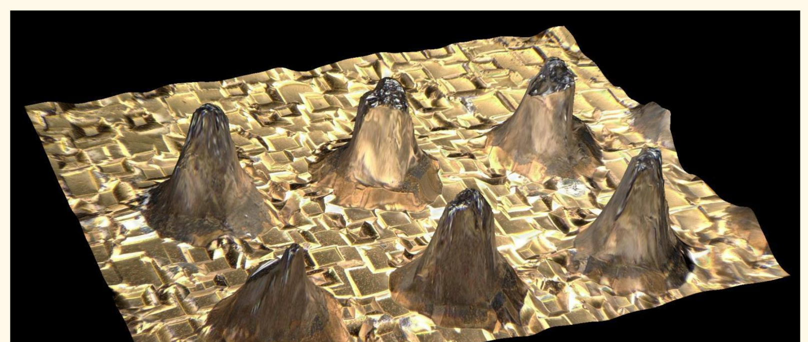




RESULTS

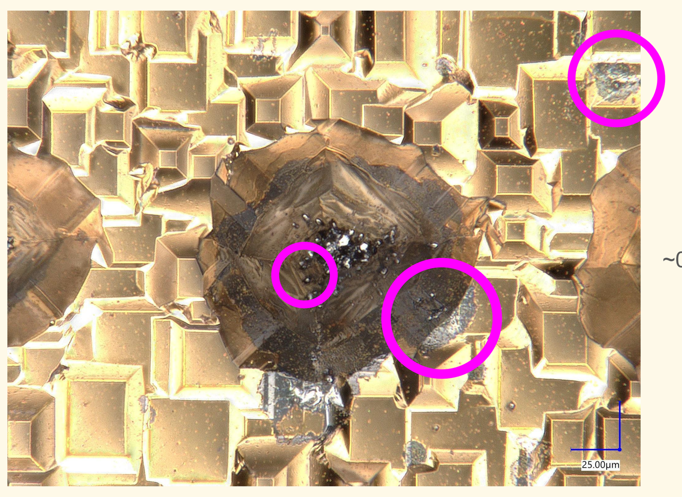
- Got current emission, but observed deformation of the tips.
  → deformations seems to depend on the current that flowed through the tip
- Grid misalignment is evident, and it is a systemic, not a simple shift (see this picture).
  → difficult to fix it, making the current from FEA uneven and difficult to simulate.
- damage in the grids also appeared after the current tests (see green highlight).



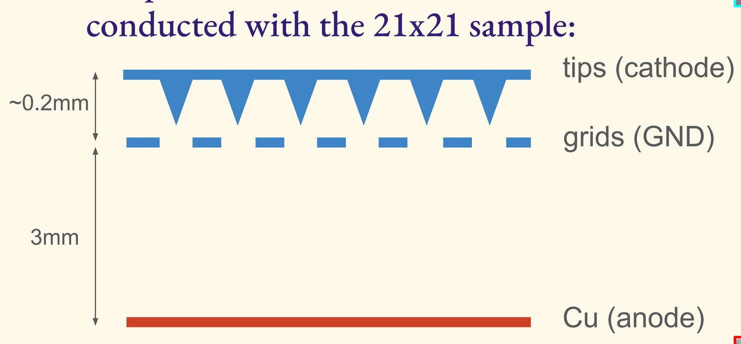


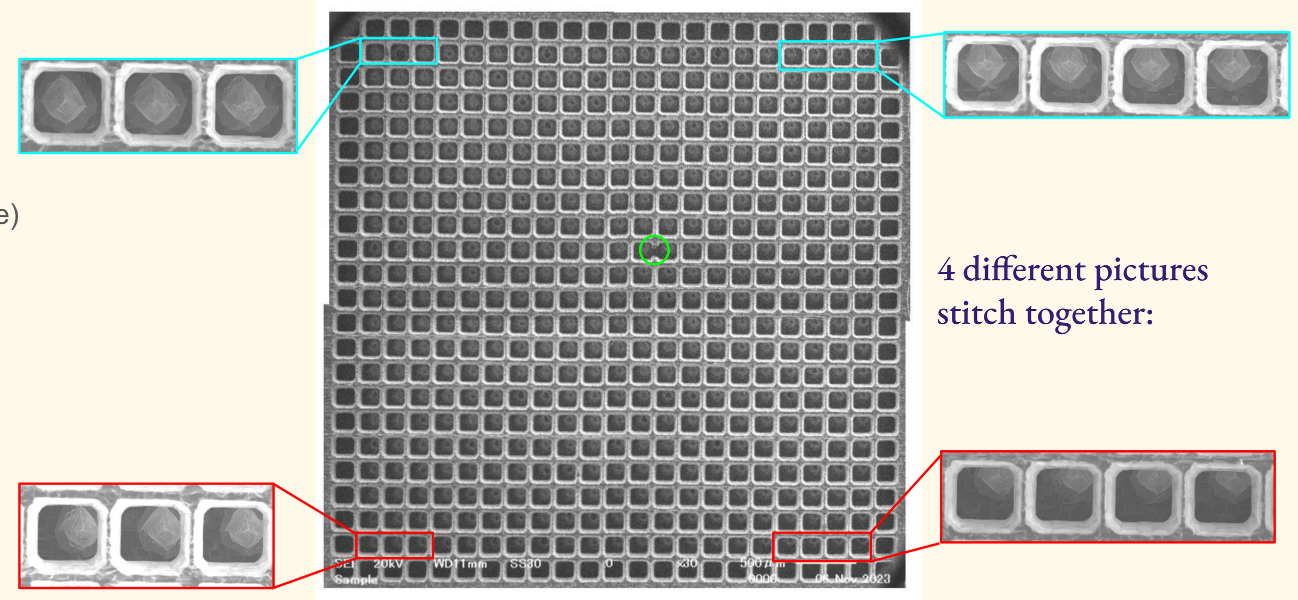
same picture stack as on the left via 3D software

- observed some droplets in the picture taken with VHX.
  → these droplets might be molten Si (pink highlight) from the tips.
- current plot of the tests conducted for the 21x21 FEA sample
- 1st plot showing the applied voltage in the anode (blue) and in the FEA (red)
- 2nd plot showing the output currents in the FEA (purple) and in the anode Cu (greenish blue).
- we got currents of max order μA from the cathode (FEA).
- interpretation is difficult due to the large number of the tips, grid misalignment... and lack of understanding of tips

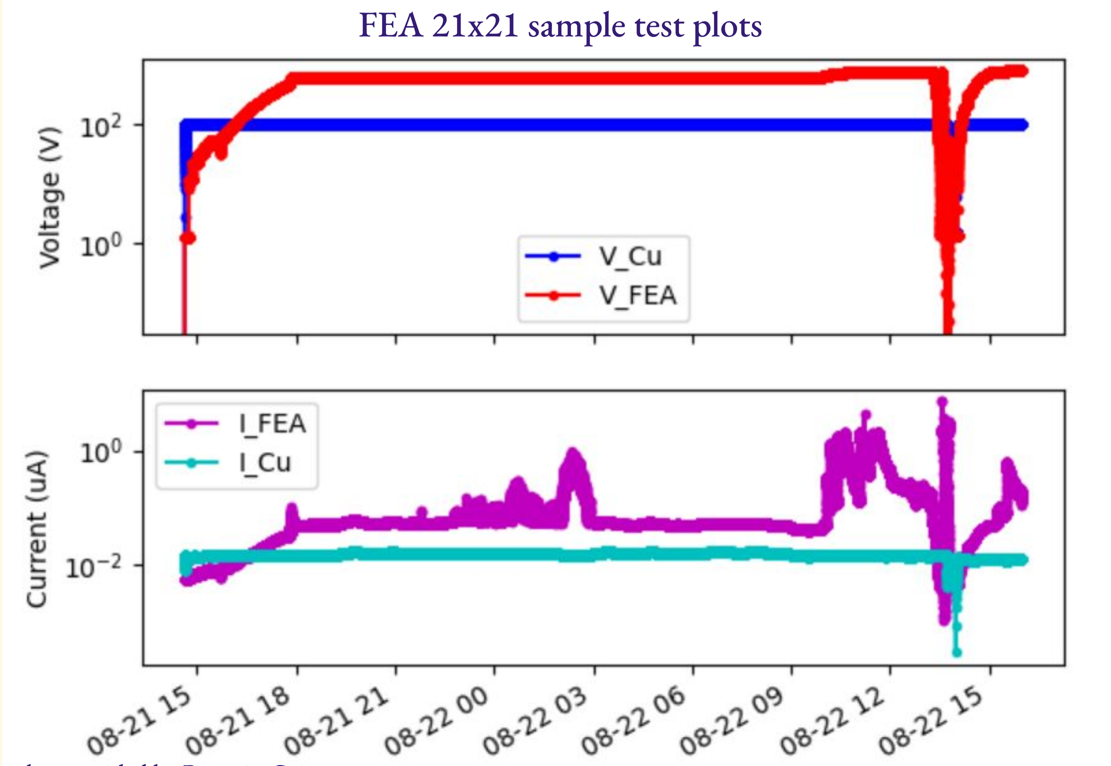


setup of the electrodes for the test conducted with the 21x21 sample:

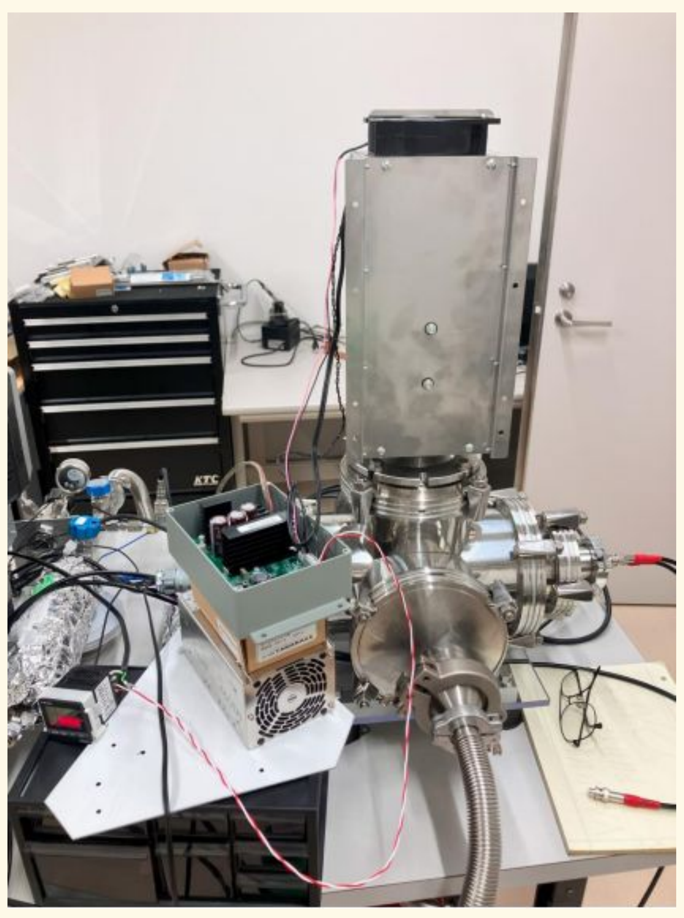


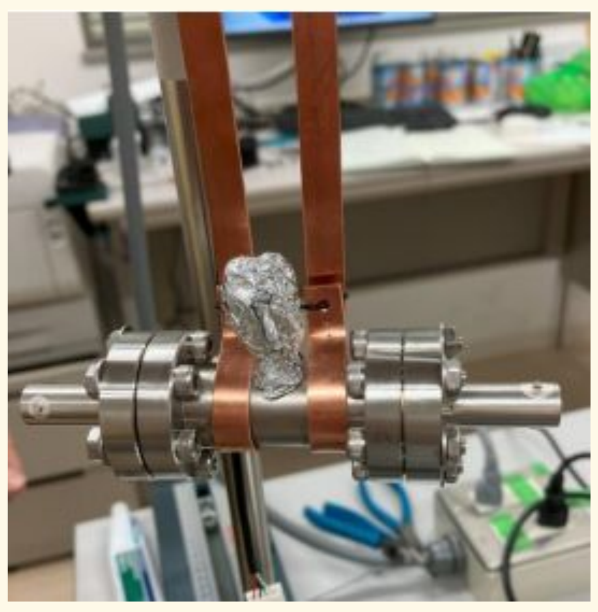


4 different pictures stitch together:



plot provided by Romain Gaior





pictures provided by Romain

CONCLUSION + FUTURE

We got currents! We have the logs, but interpretation will be difficult:

- uneven offset of grid and anode pair
- black carbon bridge in the insulator surface from epoxy

For next tests:

- Important to work with samples without the grids
- Essential to study a "FEA" with a single tip, so that we can measure the current output of only this one tip
- Need to study FEAs to know the limits (total charge, maximum current) and if they stabilize at some point, so that we do not see material ejection.
- interesting to test other materials to build FEAs, such as copper, tungsten, ...

Future:

verify if drifting Rn is possible and measure charge, current necessary to Rn drifts using this method

References

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