Experiment summary of Cs_2Te cathodes of different thickness

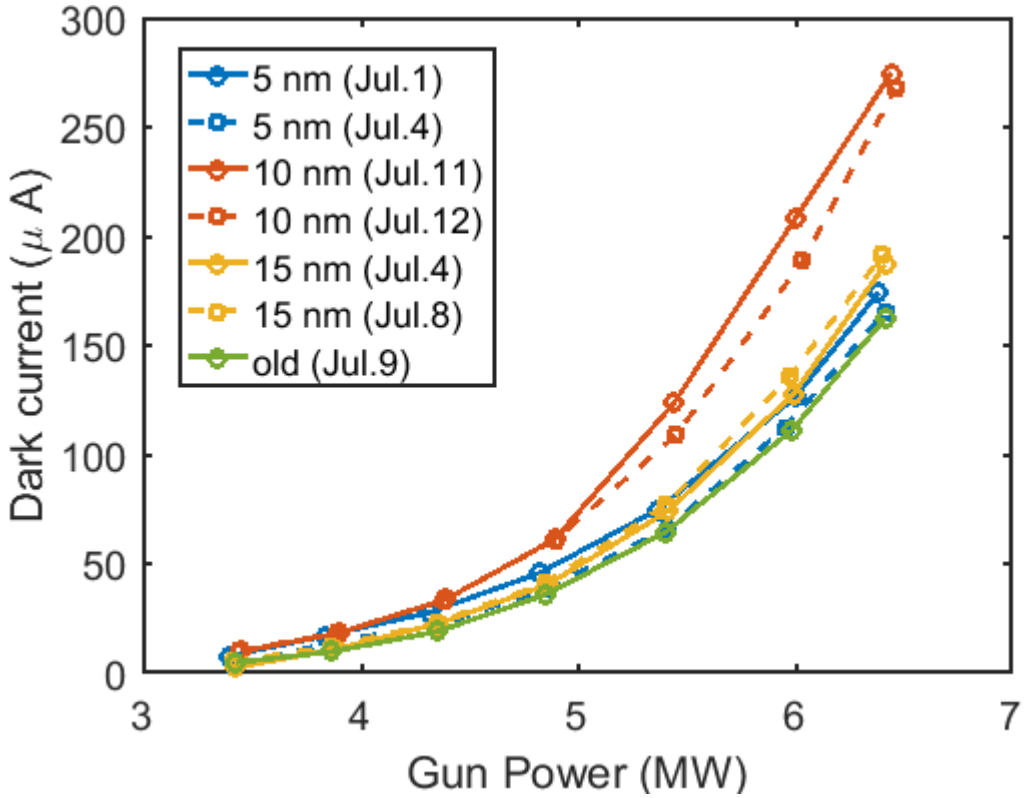
Pengwei Huang, 30.07.2019

Experiment

- Dark current: twice for each cathode. One is when the cathode is newly inserted. The other is after days' operation.
- QE vs E : 10 ~ 50 MV/m
- QE map at night shifts: BSA 0.25 mm, step size 0.2 mm.
- Thermal emittance vs E: 10 ~ 50 MV/m
- Thermal emittance map: BSA 0.5 mm, step size 0.5 mm
- 250 pC beam emittance at XFEL working point

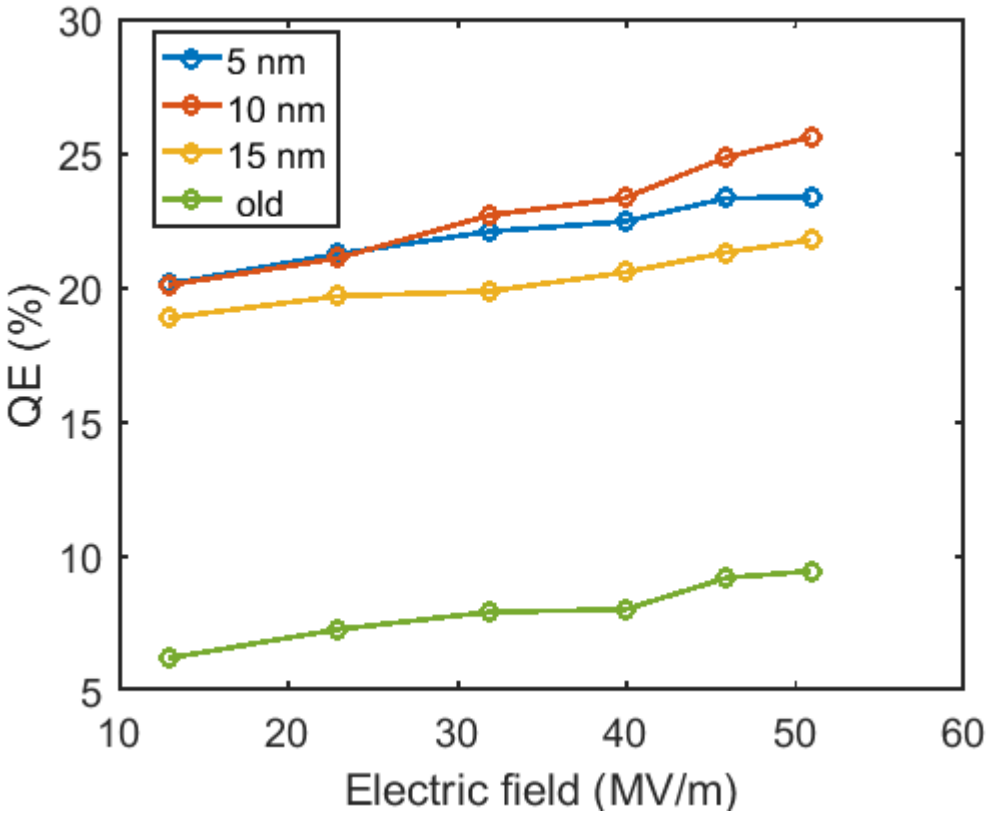
Dark current

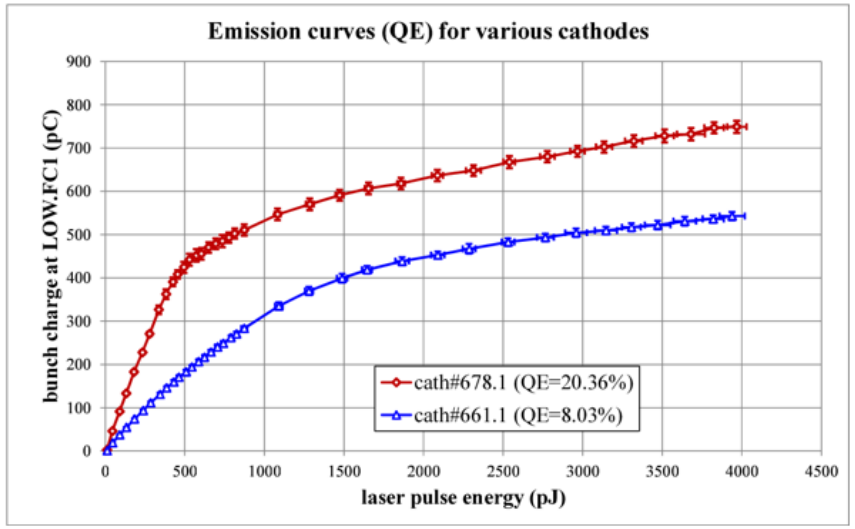
- The 10 nm Te cathode has significantly higher dark current than the 5 nm Te cathode and 15 nm Te cathode.
- After day's operation, the remeasurements are roughly consistent with the results when newly inserted. Slightly lower value are obtained at high field for the 5 nm and 10 nm Te cathode.



QE vs Electric field

The QE of these three cathodes are generally higher than most of the reported value, around 20 %.

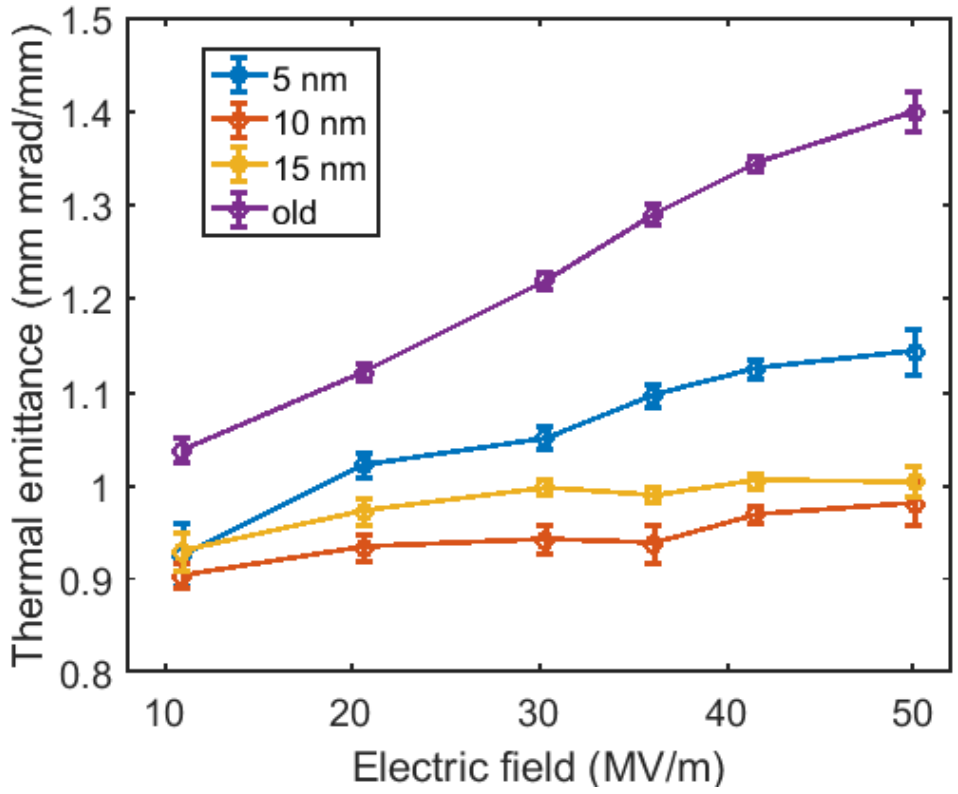


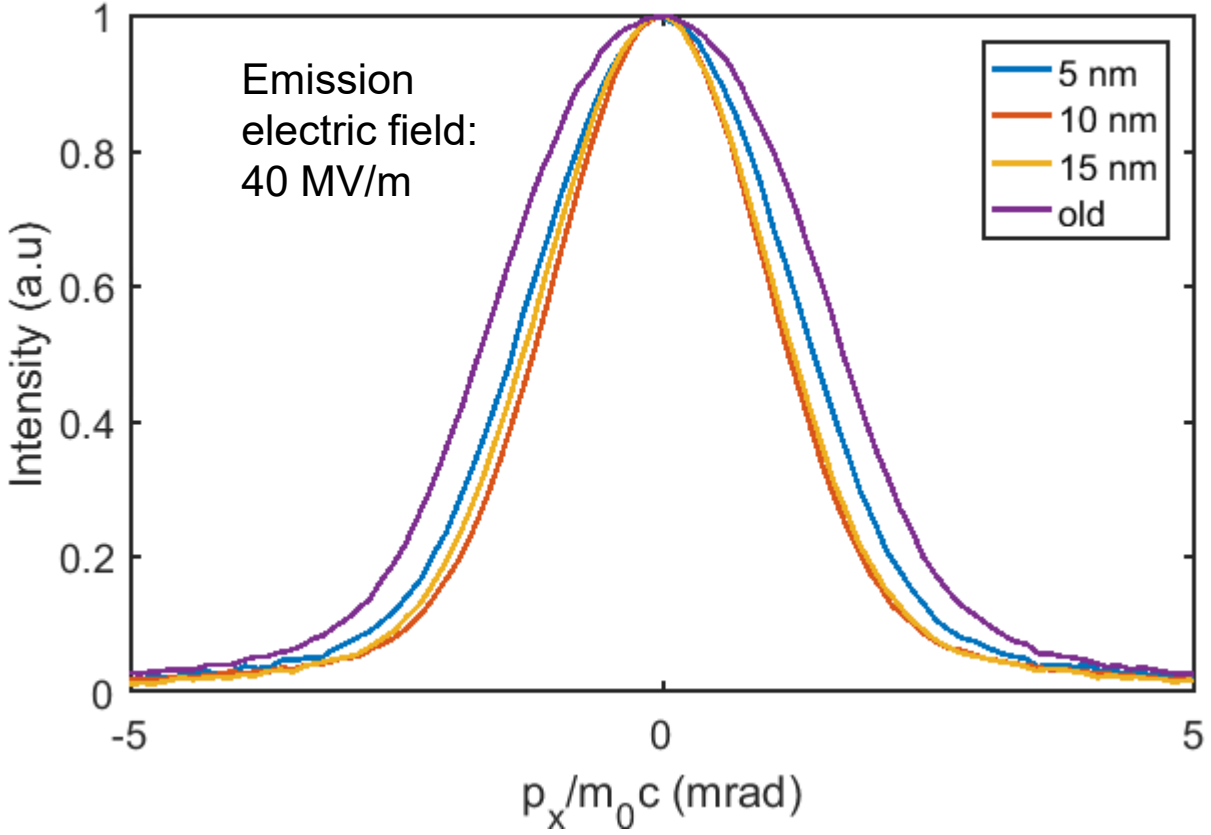


Cathode (thickness of Te)	Relative change against electric field (QE(50)-QE(10))/QE(10)
5 nm	16.0 %
10 nm	27.3 %
15 nm	15.3 %
10 nm (old)	52 %

Thermal emittance vs Electric field

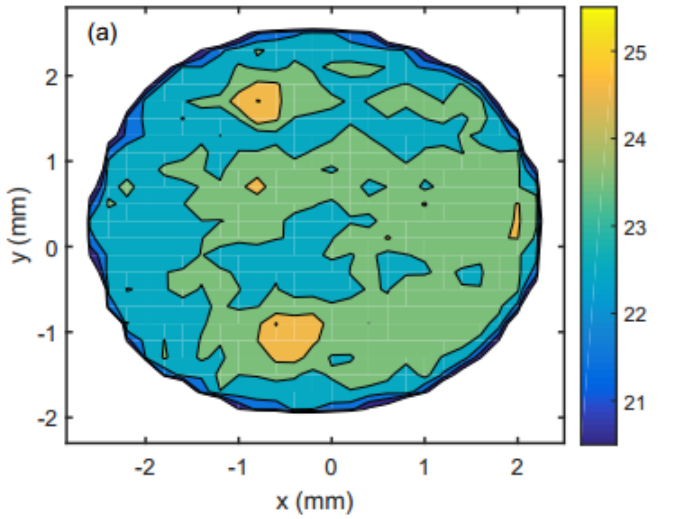
At low field, three new cathodes have similar thermal emittance. The 5 nm Te cathode has relatively higher thermal emittance, which can also be observed from the momentum profile.

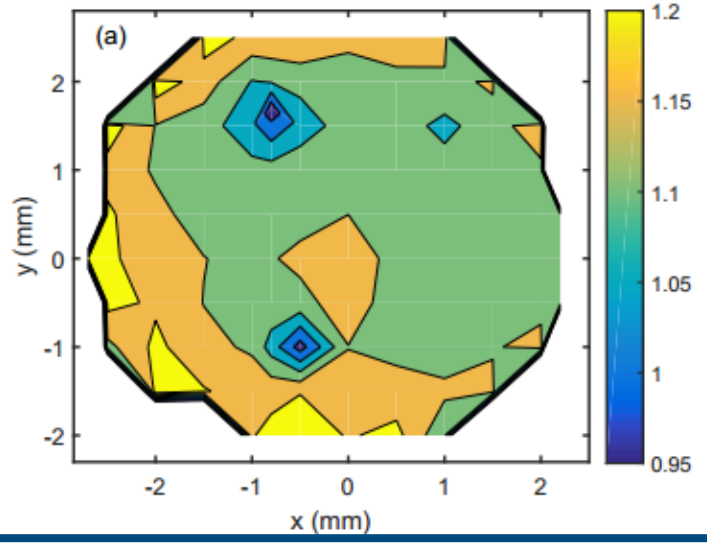




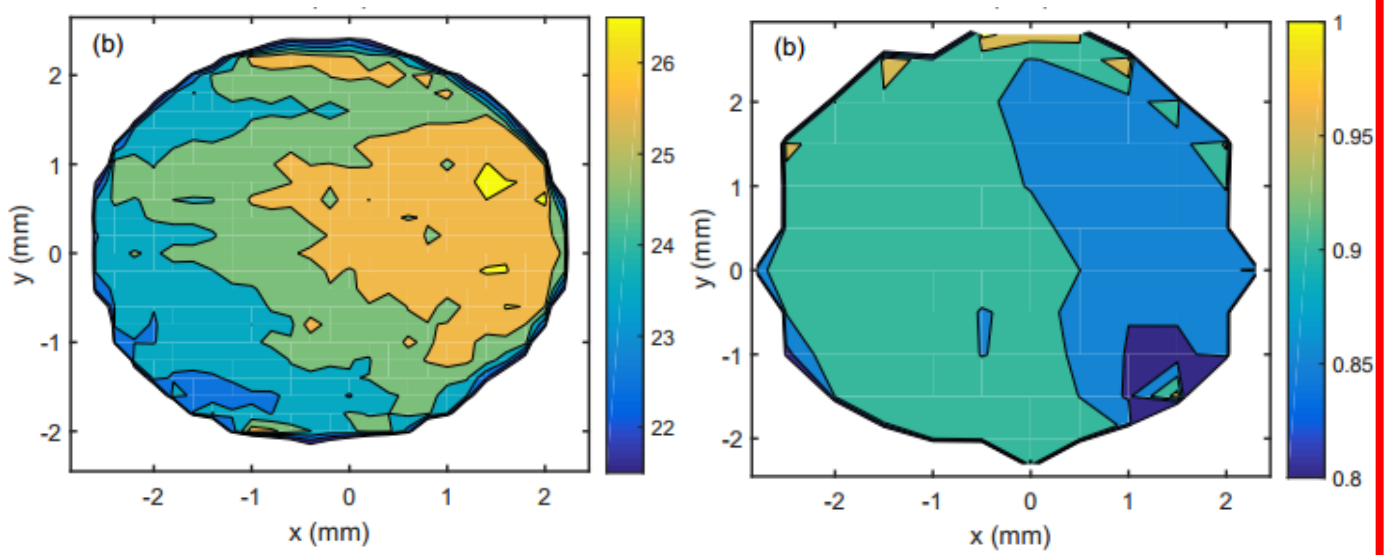
QE & Thermal emittance map

5 nm

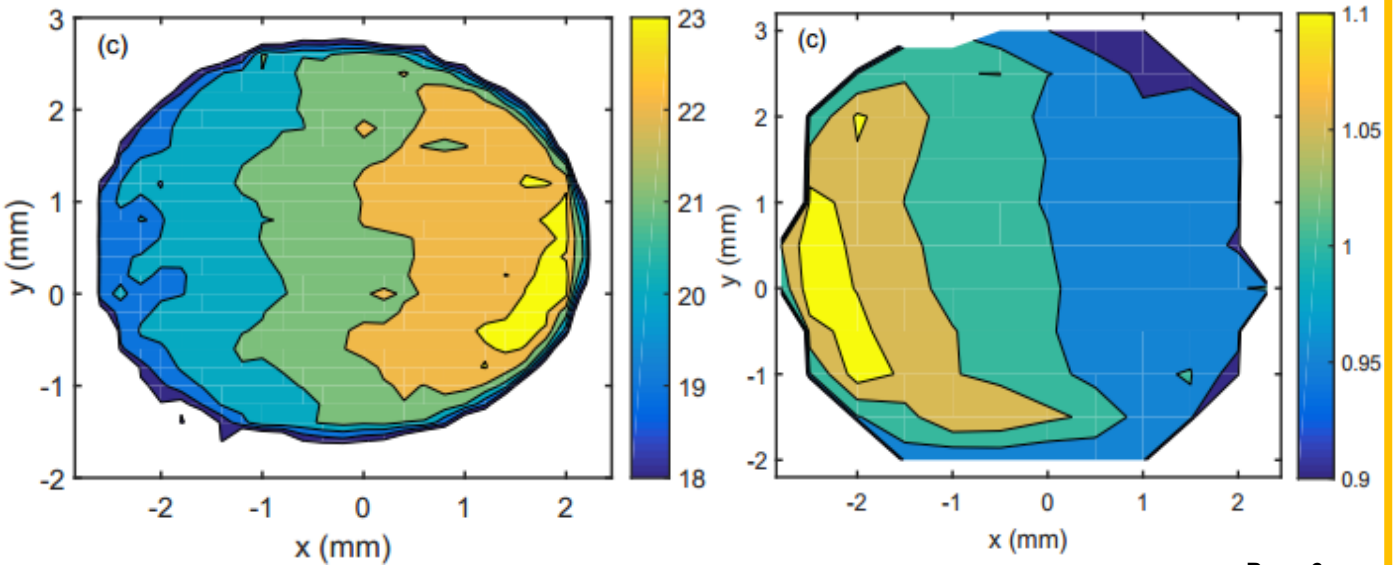




10 nm

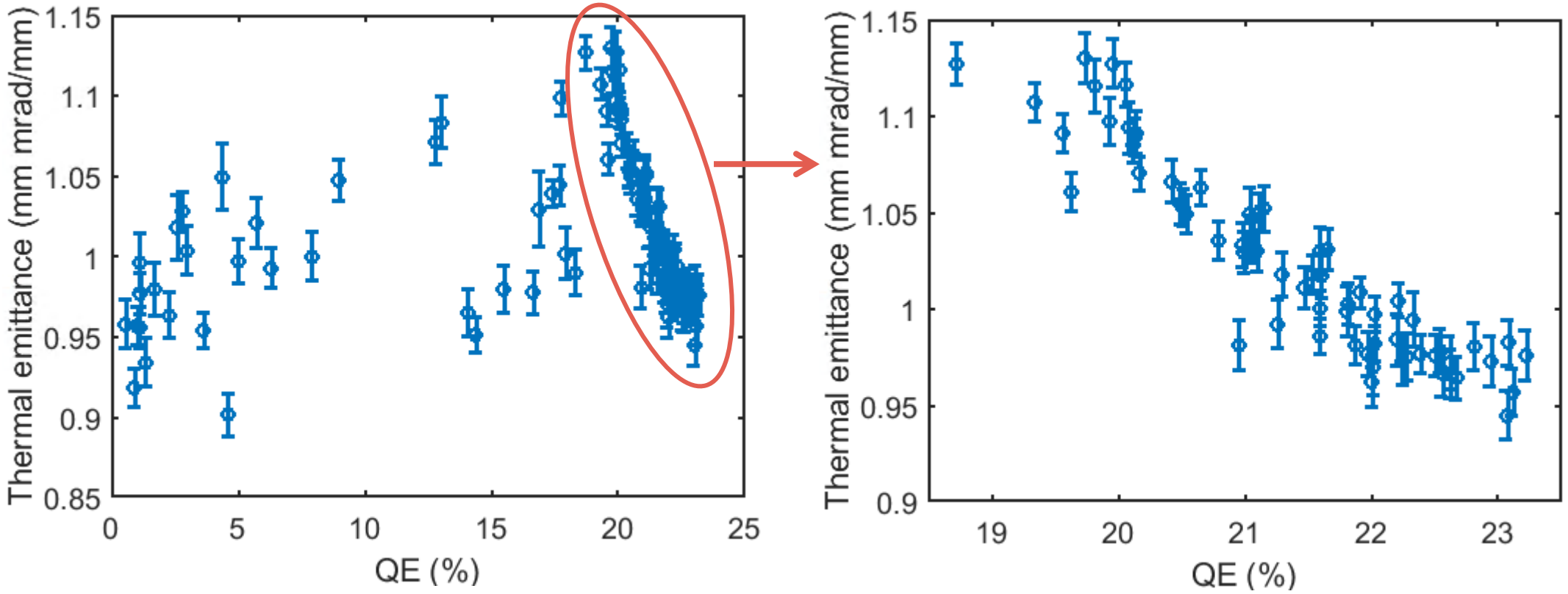


15 nm



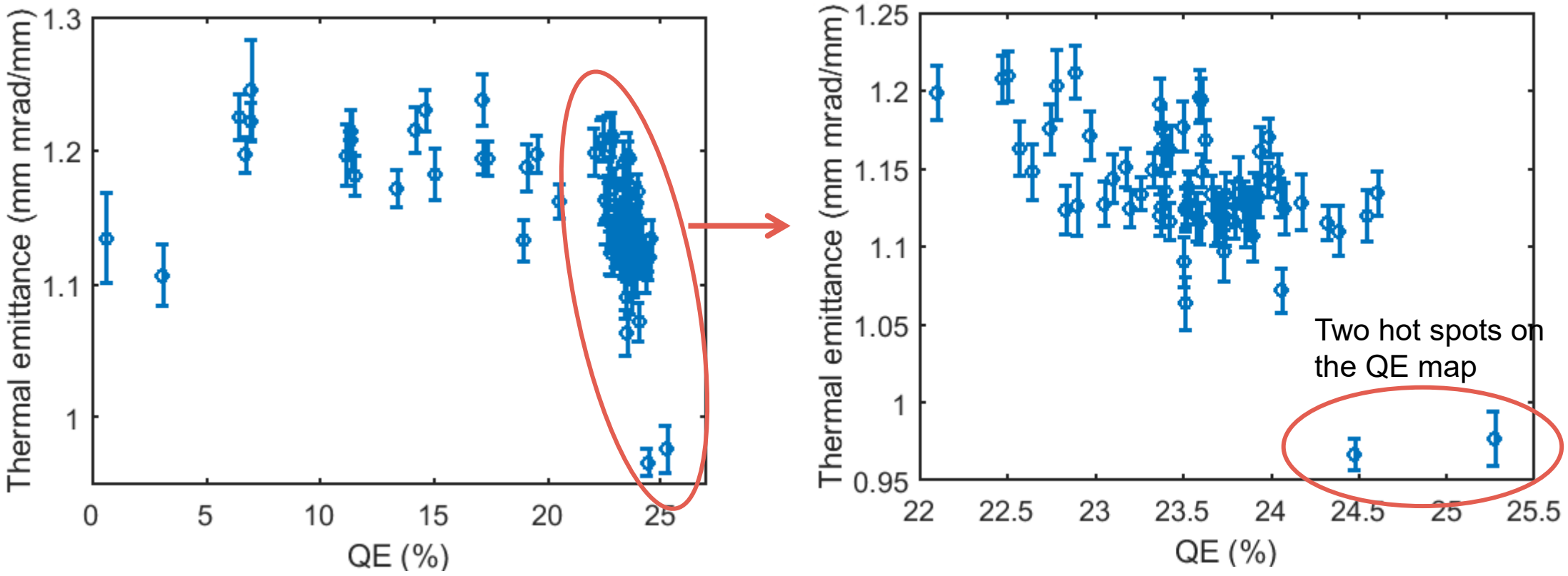
QE vs Thermal emittance – the 15 nm Te cathode

There is a good correlation between thermal emittance and QE at the high QE region.



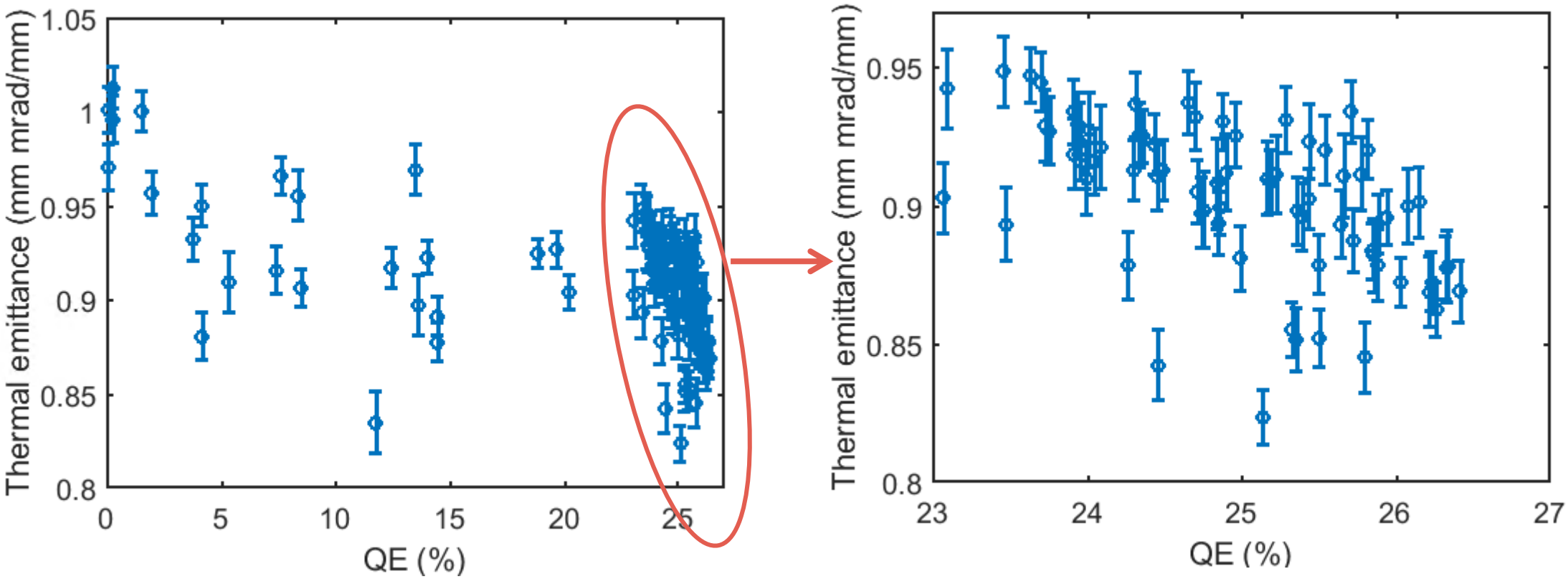
QE vs Thermal emittance – the 5 nm Te cathode

The correlation between thermal emittance and QE at the high QE region can still be seen.



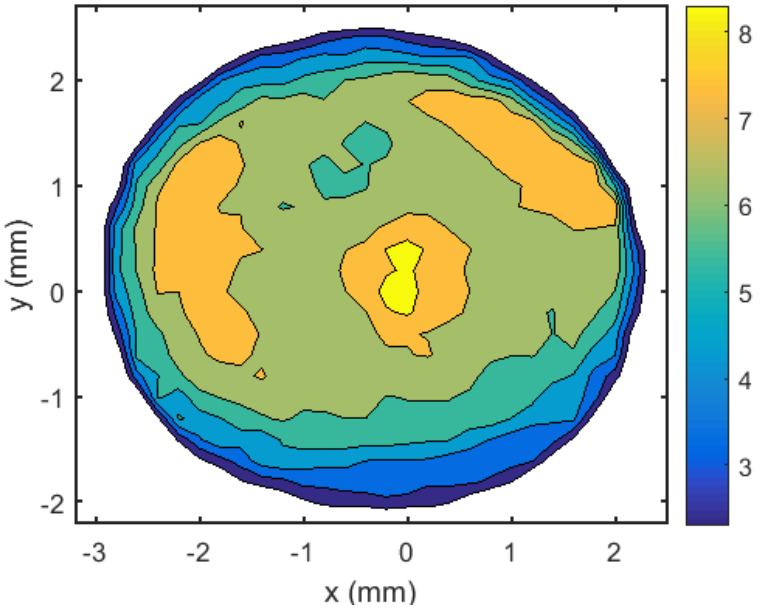
QE vs Thermal emittance – the 10 nm Te cathode

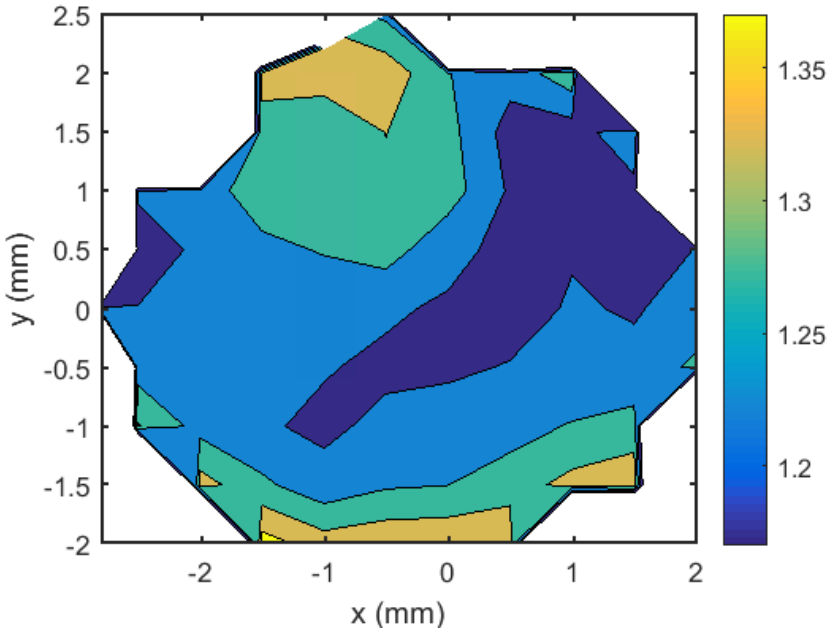
The correlation between thermal emittance and QE at the high QE region can still be seen.

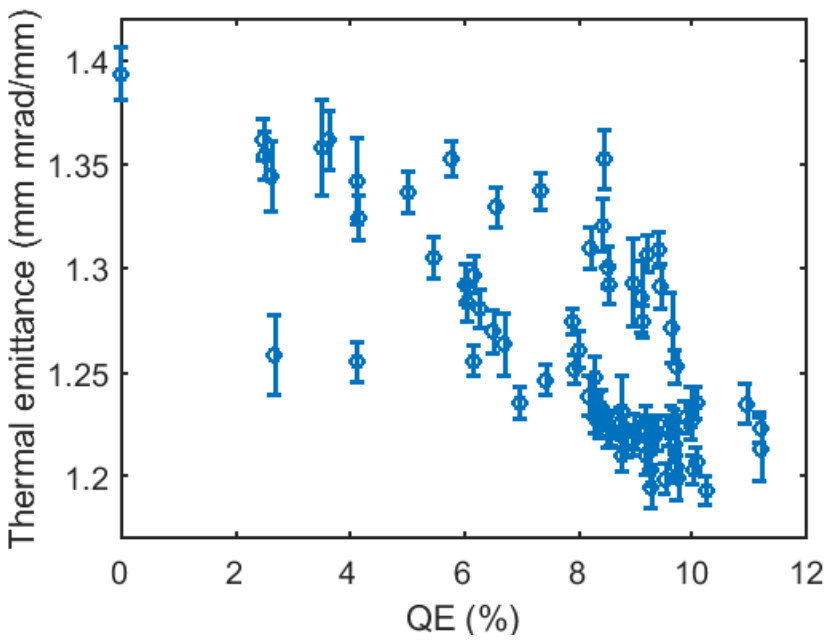


QE vs Thermal emittance – the old cathode

- The correlation between thermal emittance and QE at the high QE region can still be seen.

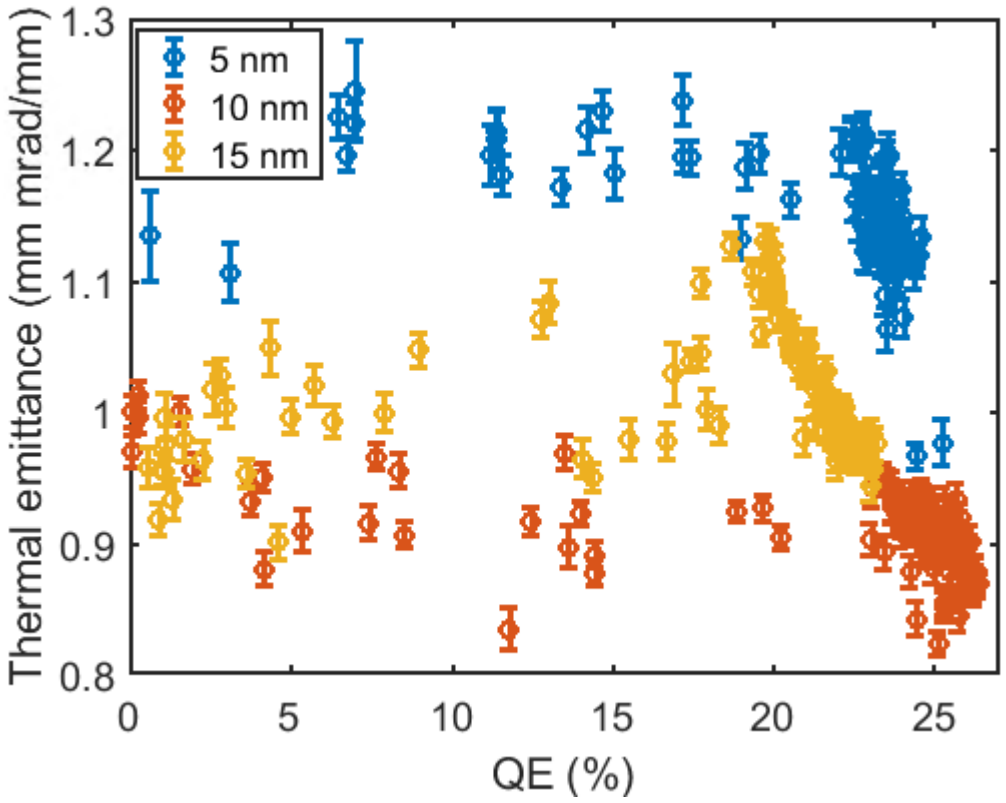


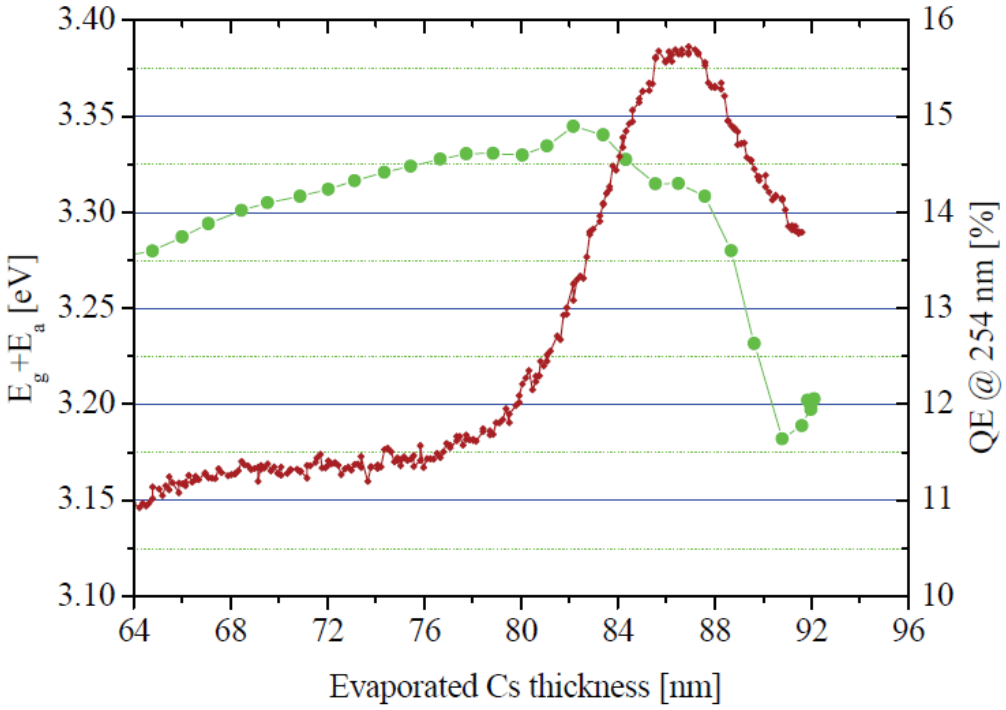




Summary of QE vs Thermal emittance

The results of the 10 nm Te cathode and the 15 nm Te cathode at the high QE region are consistent. Since they also have similar momentum profile, it is reasonable to assume they have more similar properties while the 5 nm cathode is slightly different.





L. Monaco et al, IPAC 10, TUPEC006

Performance at XFEL working point

XFEL working condition	
Charge	250 pC
Laser diameter	1 mm
Peak field	58 MV/m
Gun phase	MMMG
Emission field	40 MV/m
Gun exit momentum	6.3 MeV/c
Booster exit momentum	19.3 MeV/c

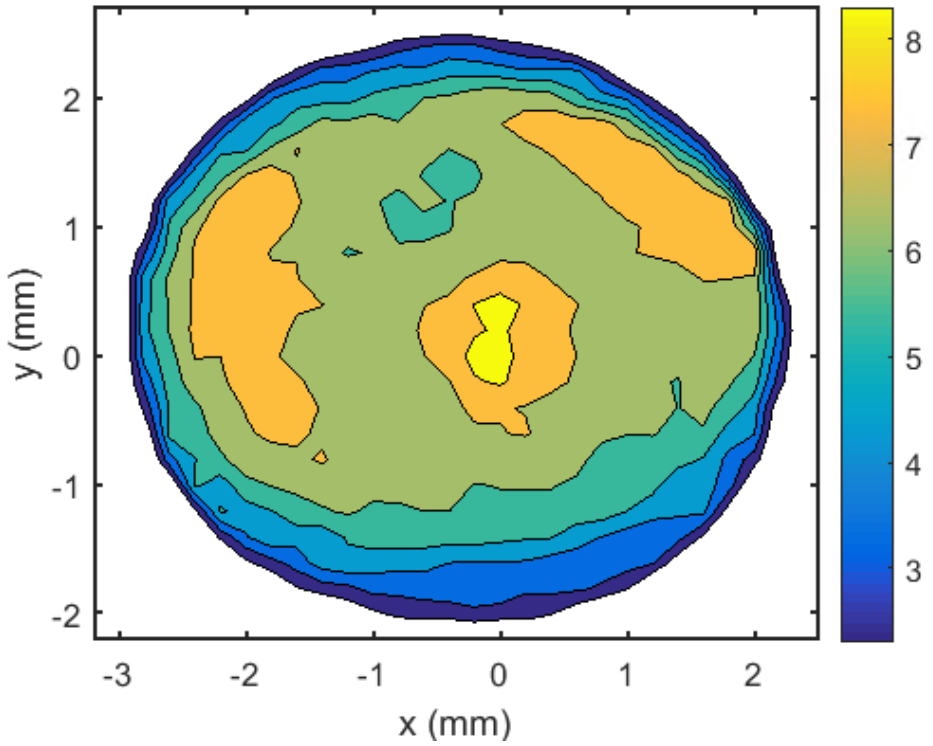
Cathodes (thickness of Te)	QE (%)	Thermal emittance (mm mrad/mm)	250 pC beam emittance (mm mrad)
5 nm	22.49	1.125±0.01	0.534±0.005
10 nm	23.37	0.969±0.008	0.468±0.013
15 nm	20.6	1.005±0.008	0.494±0.006
10 nm(old)	8.03	1.345±0.008	0.493±0.004

For these three new cathodes, the 10 nm Te cathode has the highest QE, smallest thermal emittance and 250 pC beam emittance at XFEL working point.

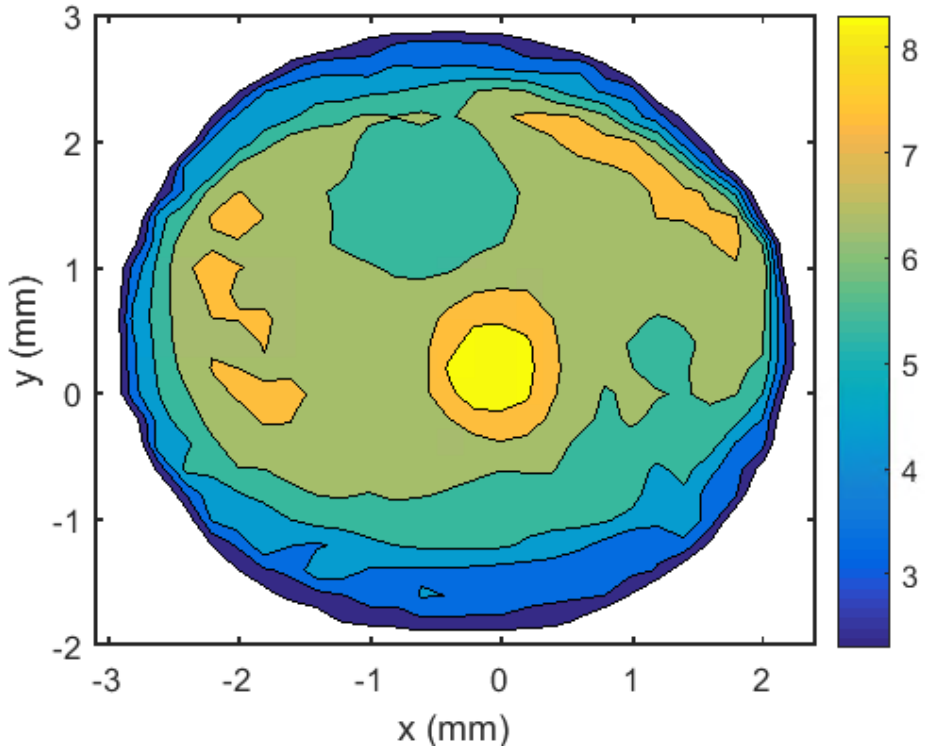
QE map evolution of the old cathode

- The hot spot in the center still exists. The QE of surrounding area has slightly decayed.
- The consistency of these two QE maps gives us more confidence on the repeatability and reliability of the QE map measurement.

2019.06.20



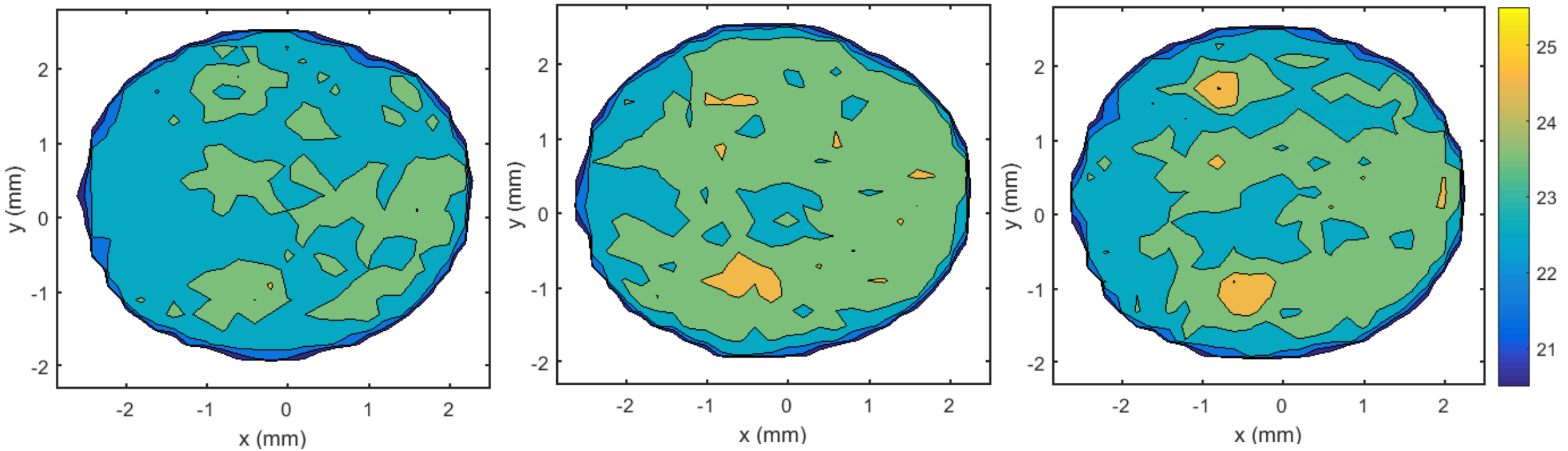
2019.07.10



QE map evolution of the 5 nm Te cathode

Three days continuous operation. Two hot spots were generated. A QE sink can be observed at the center.

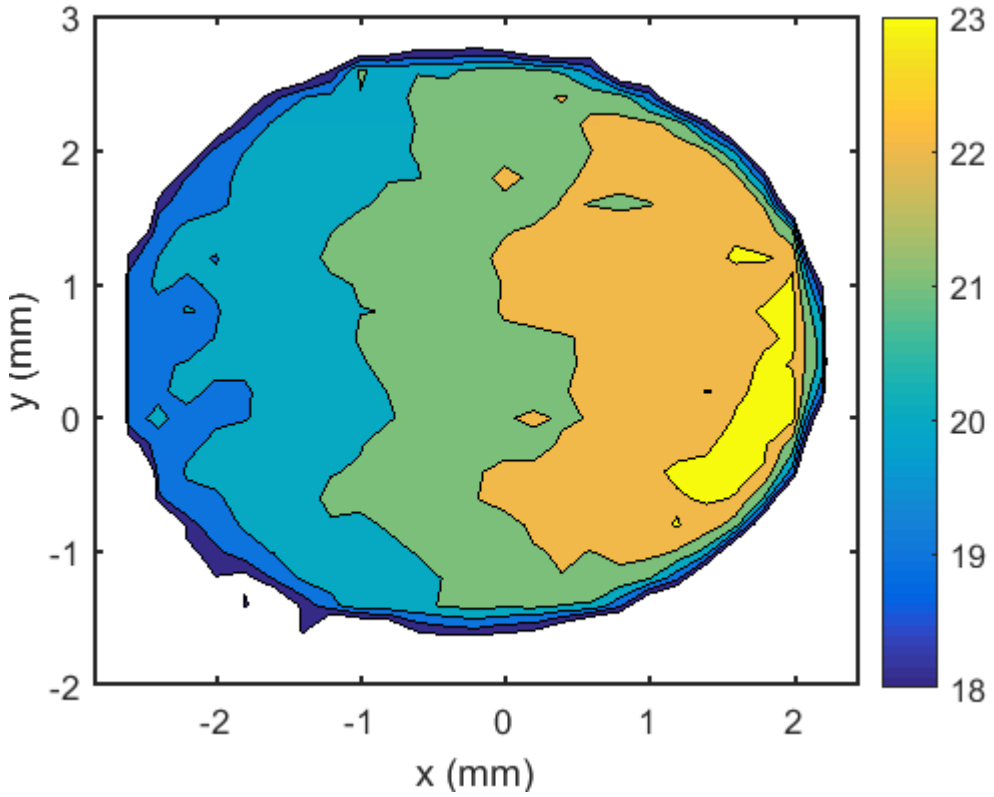
2019.07.01 **2019.07.02** **2019.07.03**



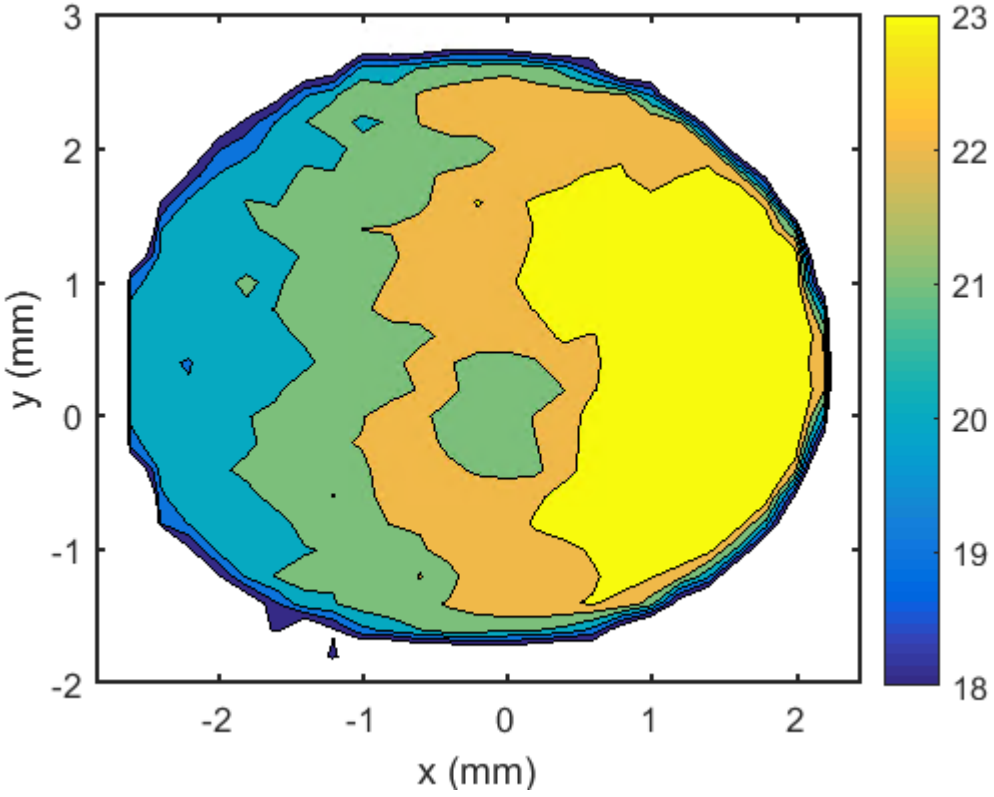
QE map evolution of the 15 nm Te cathode

- One day operation + two days shut down + one day operation.
- The QE has generally increased after 3 days. **Desorption of the gas molecules?**
- The gradient of QE from right to left still persists.
- A QE sink can be observed at the center.

2019.07.05



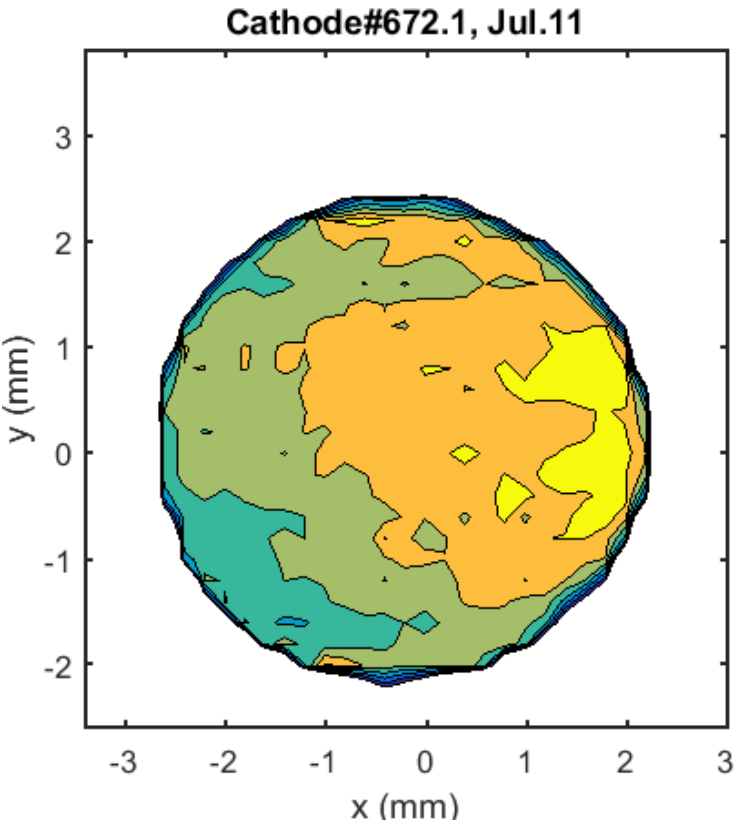
2019.07.08

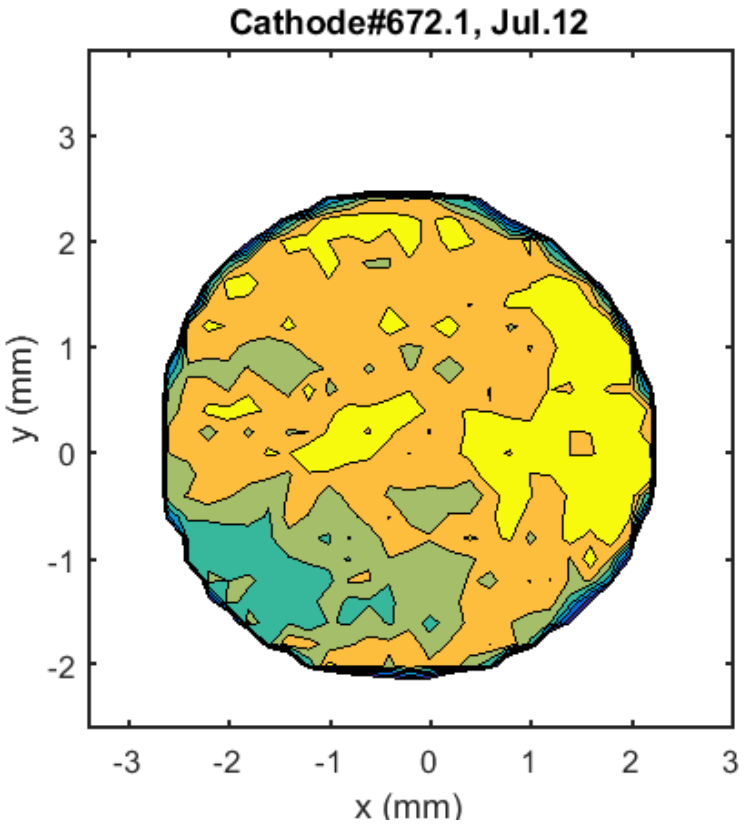


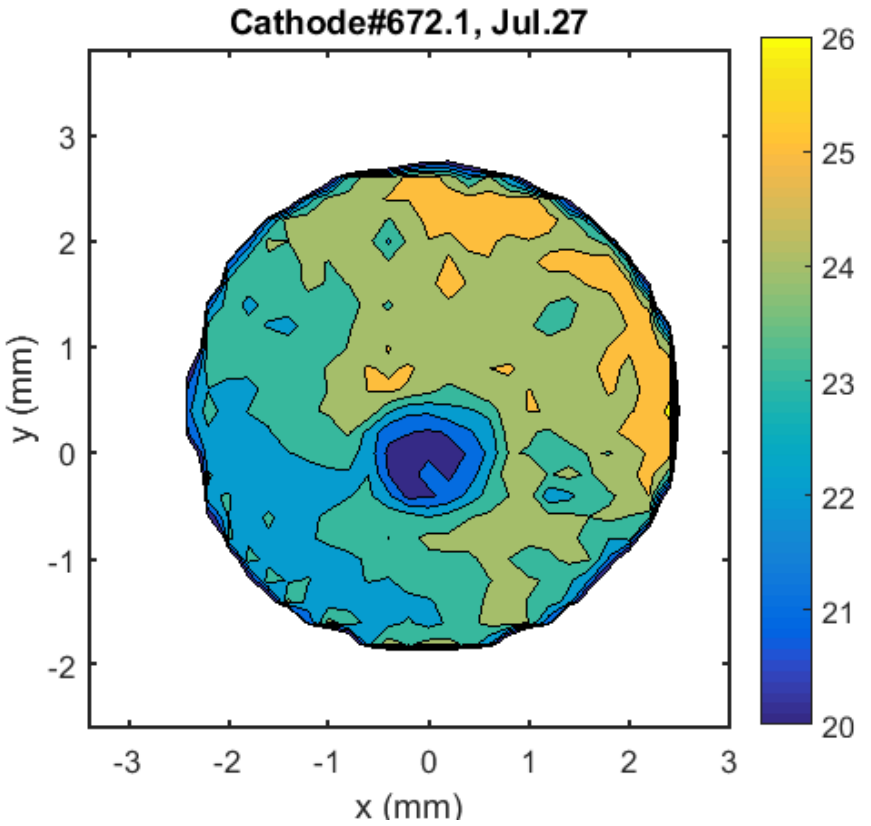
QE map evolution of the 10 nm Te cathode

07.11 ~ 07.12: operation
07.13 ~ 07.21: shut down
07.22 ~ 07.26: operation

At the beginning, the conditioning of the cathode increase the QE. But after weeks of shut down and operation, the QE of the whole cathode has decayed, especially at the center, from 25.63 % to 20.88 %. The size of QE sink in the center is similar to the laser diameter. **Laser effect? Dark current?**







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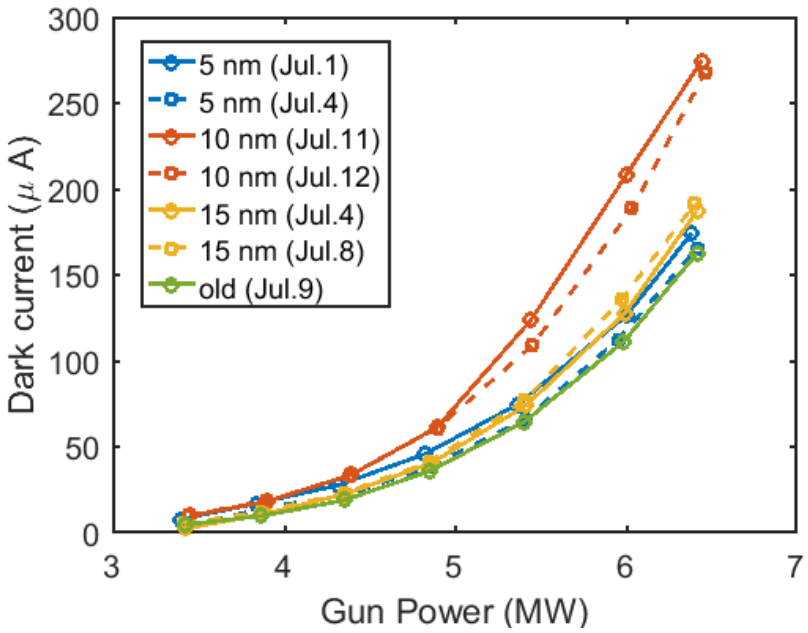
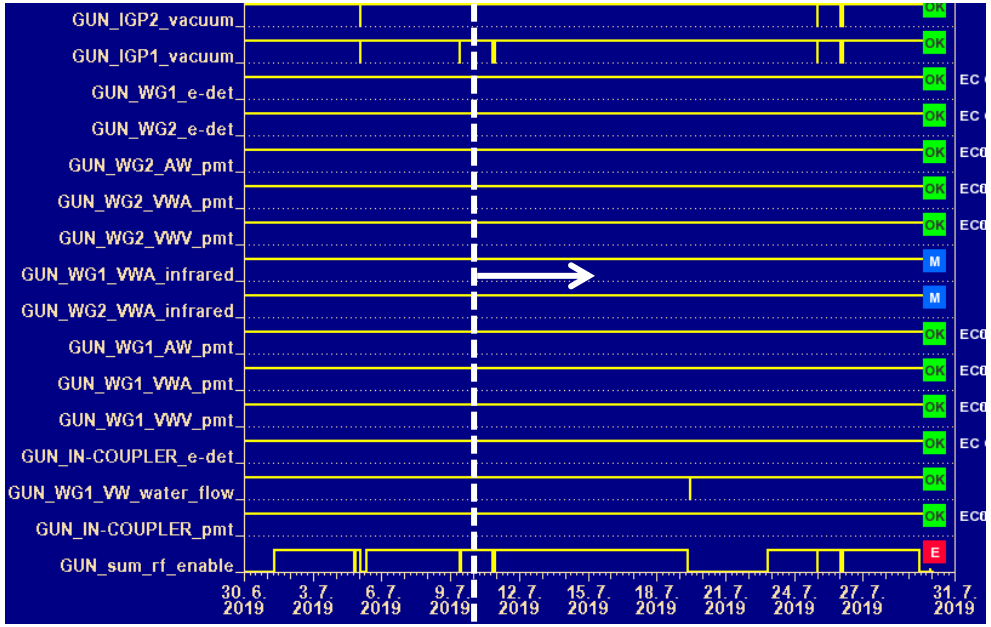
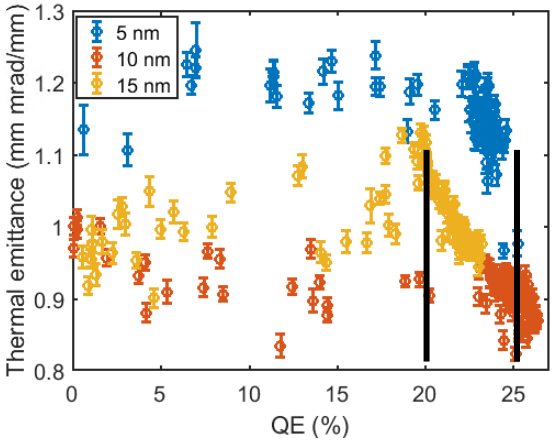


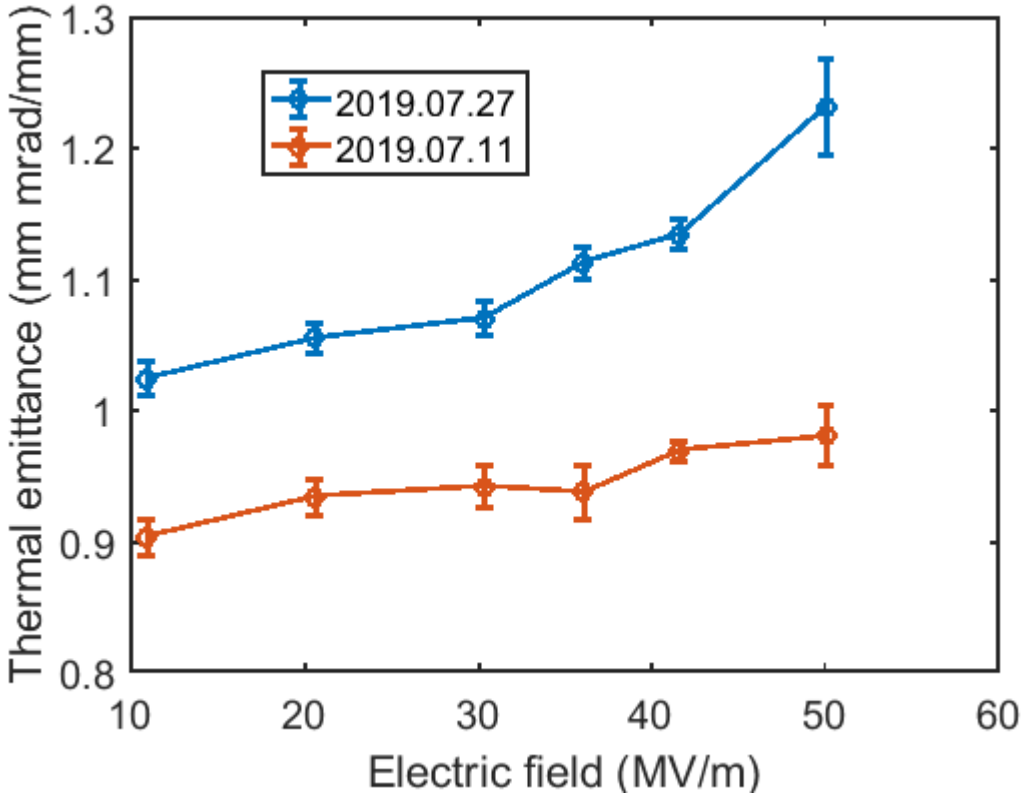


- The dark current of this cathode is high.
- Several vacuum trip events happened during the operation.

Thermal emittance evolution of the 10 nm Te cathode

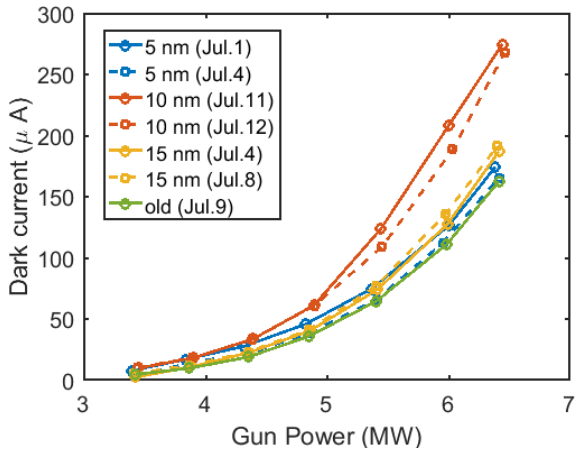
- The thermal emittance has generally increased for all the gradient.
- The slope of thermal emittance against electric field is higher. Since the Schottky effect should be the same, the surface roughness might become larger.
- According to the results from the thermal emittance against QE, the change of thermal emittance seems reasonable since QE changes from 25.63 % to 20.88 %.



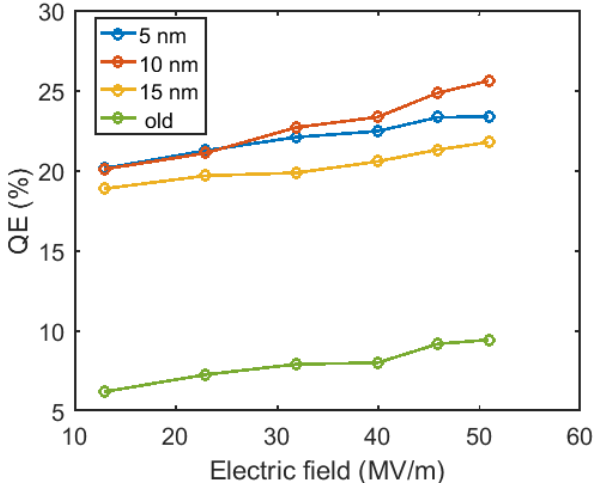


Summary

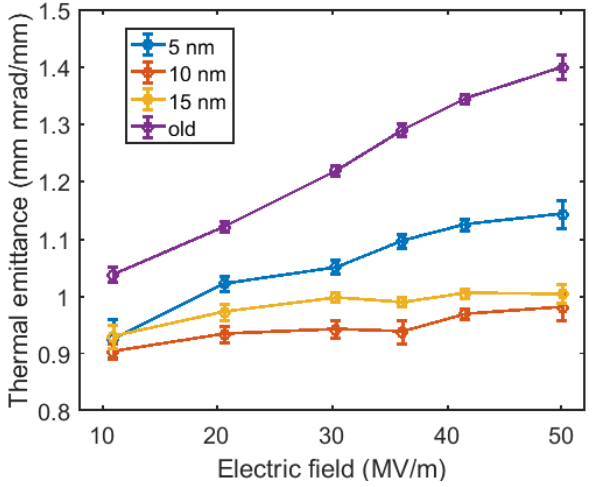
✓ Dark current



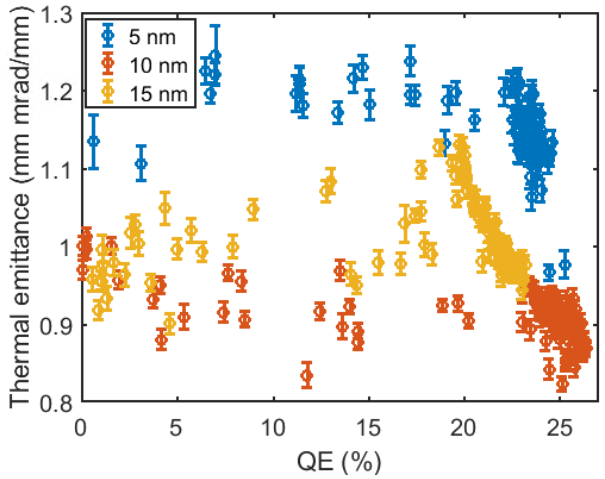
✓ QE



✓ Thermal emittance



✓ Correlation of QE and thermal emittance from map



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