Carbon nanotubes as cold electron field emitters for electron cooling in ELENA

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Electron Gun

It must produce a

- cold ($T_{\perp} < 0.1$eV, $T_{//} < 1$meV)
- intense electron beam ($n_e \approx 1.5\text{x}10^{12}$ cm^{-3})

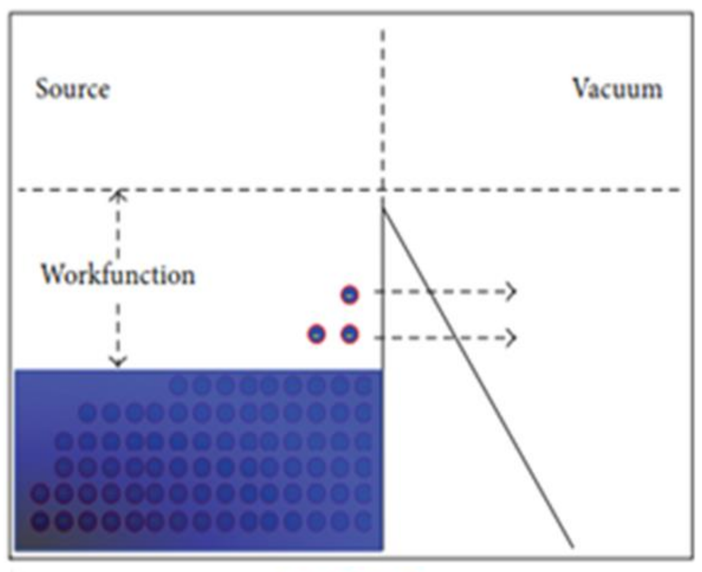
Thermionic cathodes limit the performance of electron cooling due to high $T_{\perp}$ of the emitted beam.

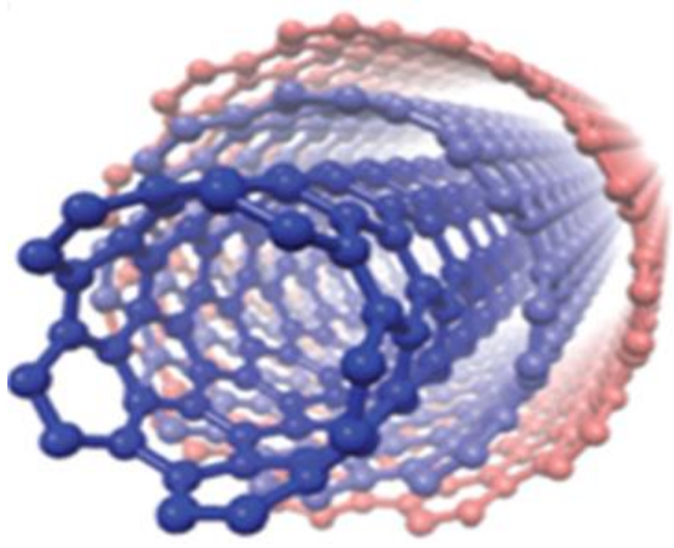
Alternative solution: **Field Emission** due to have a **Cold Cathode**.

Field Emission (FE) from CNTs

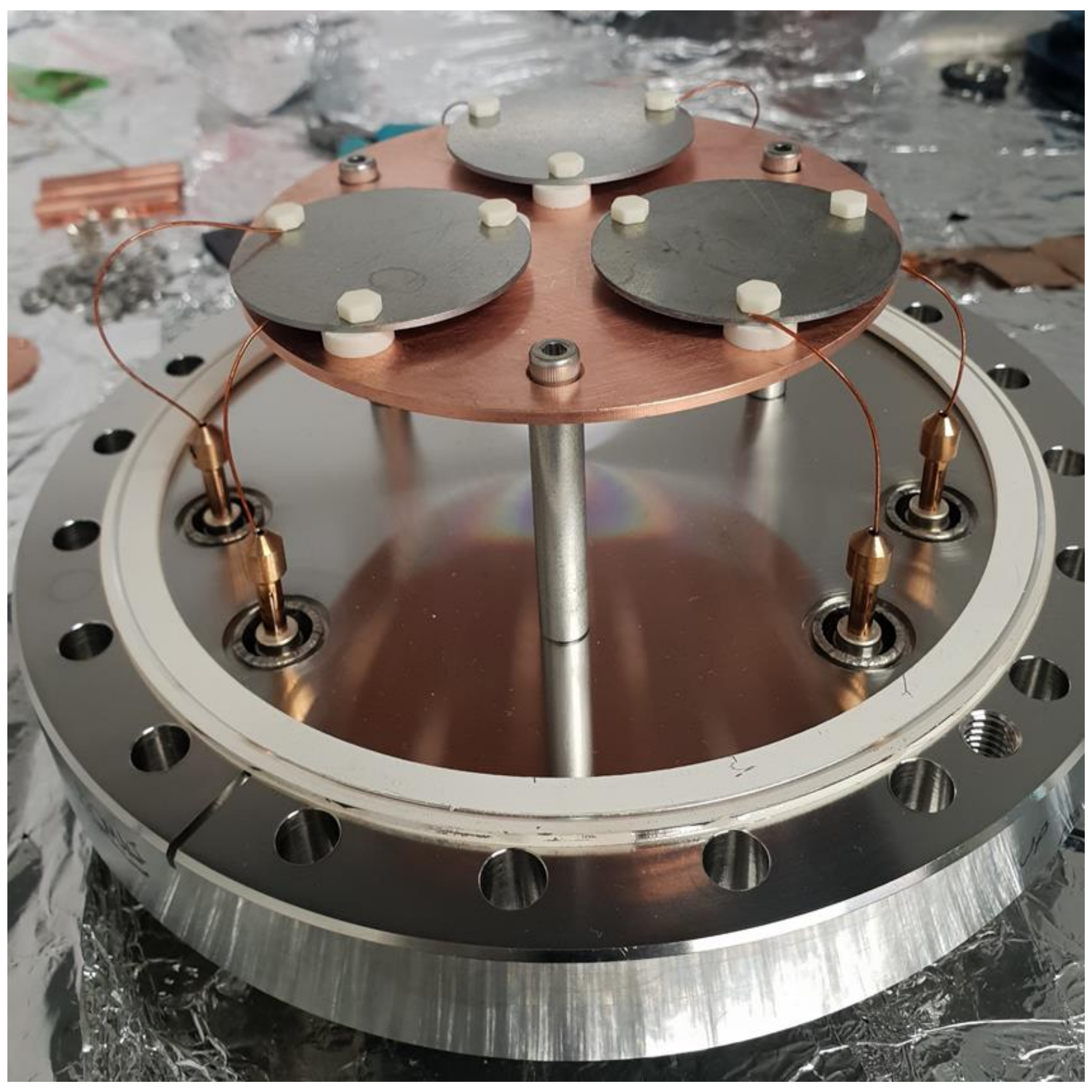
An electric current is generated from a metal or a semiconductor thanks to the application of a large electric field (~ *10^7 V/cm*). Electrons are emitted by tunnelling through the potential barrier between material surface and vacuum.

A carbon nanotube (CNT), with nanoscale diameter, can have a length that is millions of times larger than its diameter. Thanks to such a high-aspect-ratio structure, the local electric field is strongly enhanced near their tips and field emission can be achieved with an applied electric field on the order of some V/µm.



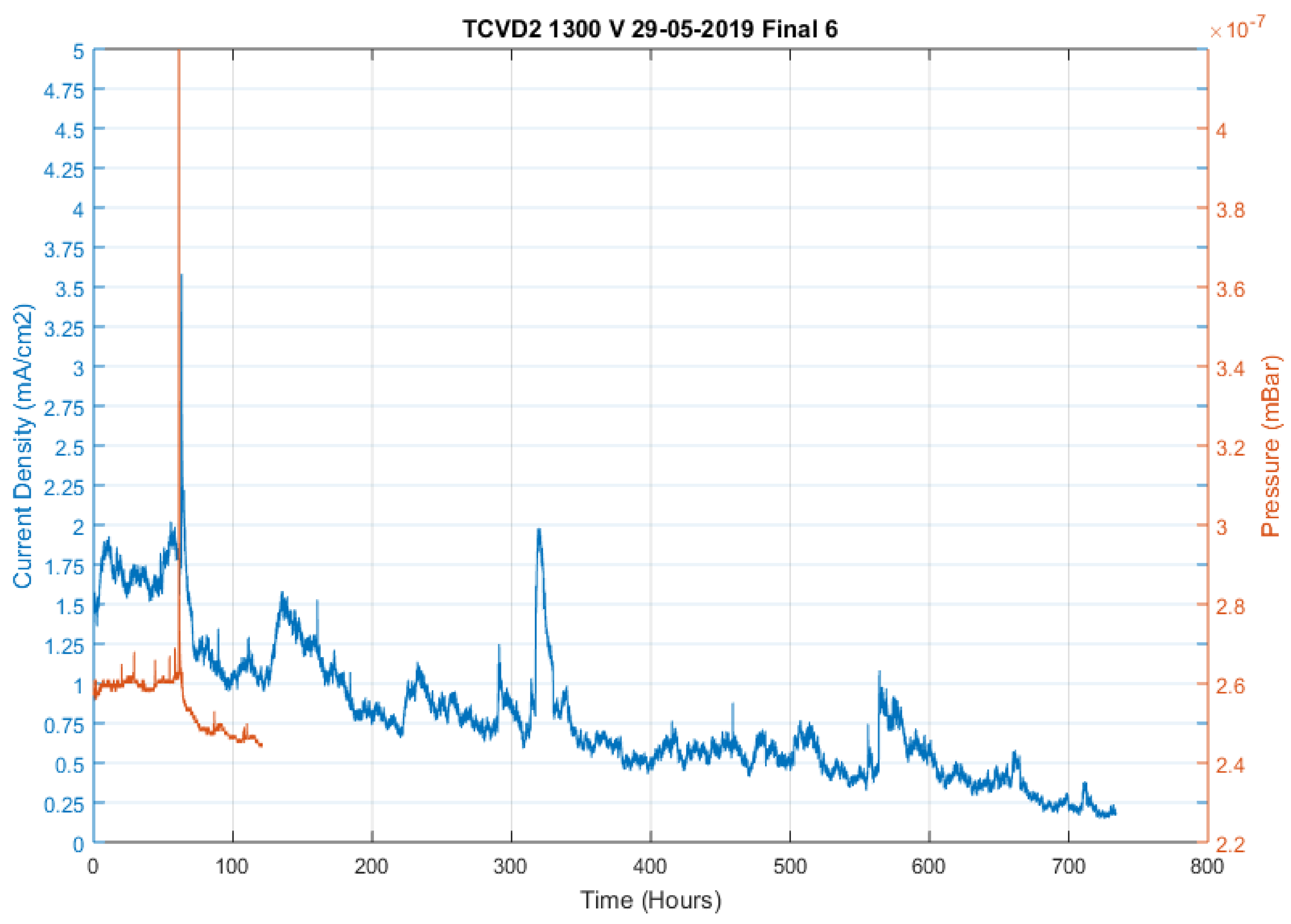


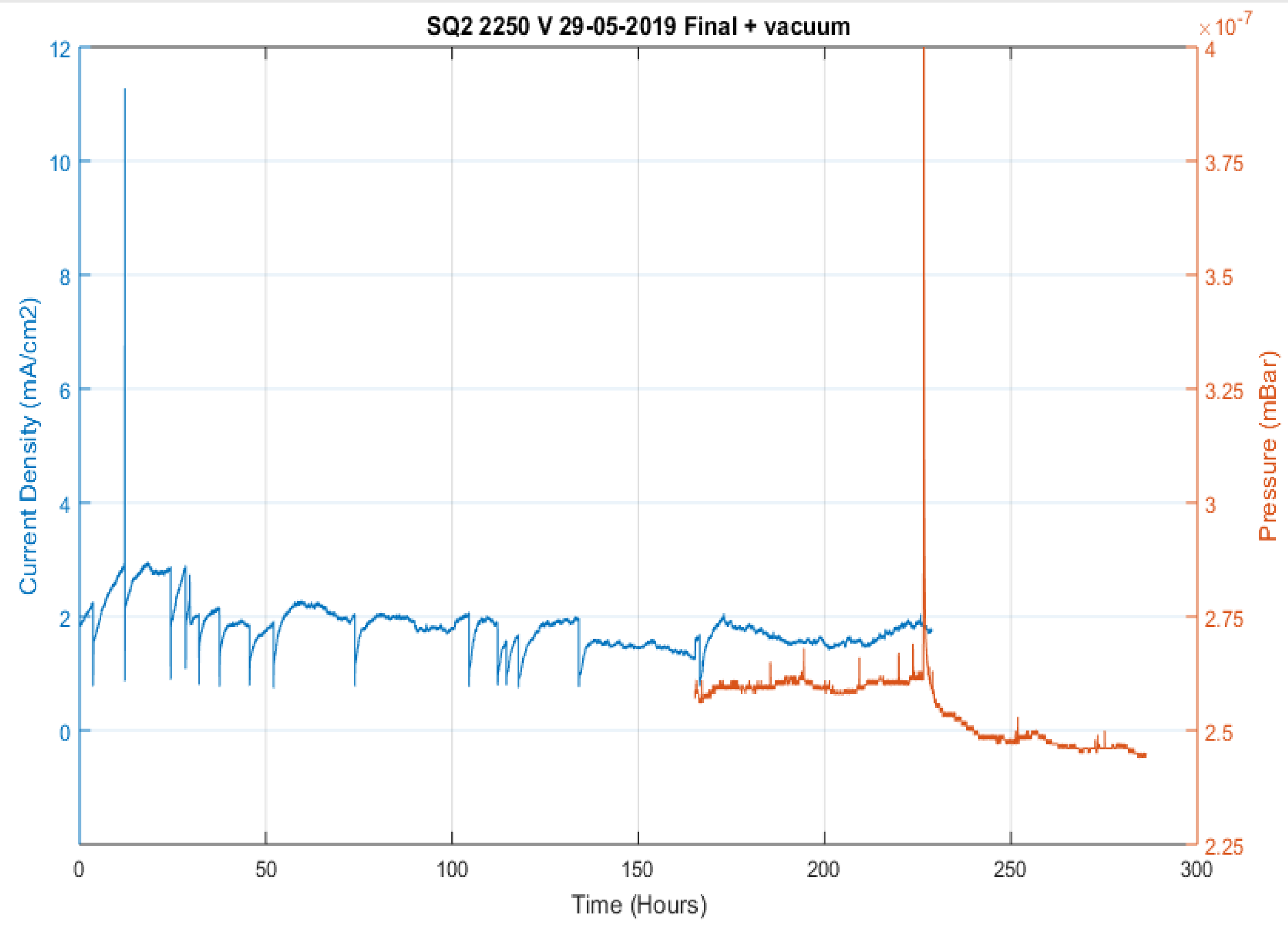
Experimental Setup



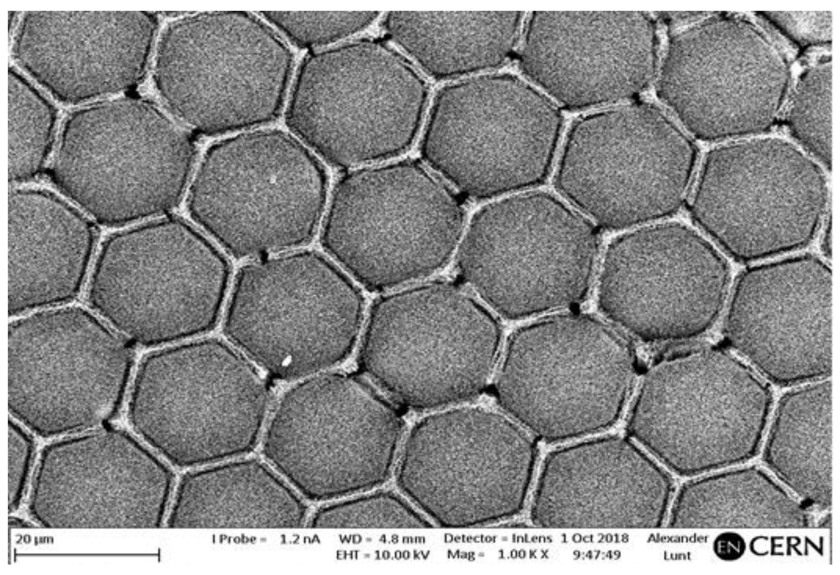
Lifetime Measurements 1

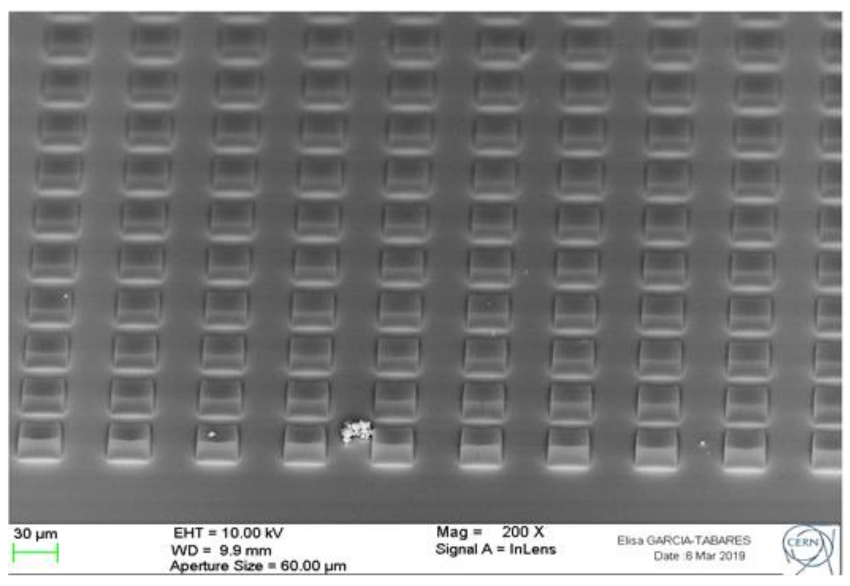
Vacuum: mid 10^{-7} mBar. CNT1: Total burn-out not reached after more than 1500 h of emission. E = 2.3 V/um. CNT2: Total burn-out after 500 h. E = 3.3 V/um. Decrease of current emission show to be strongly connected to vacuum level and environment. In the right figure the red peak at the end shows the moment of the burnout. In the left figure it is also possible to see the emission behavior after CNT2 burnout.





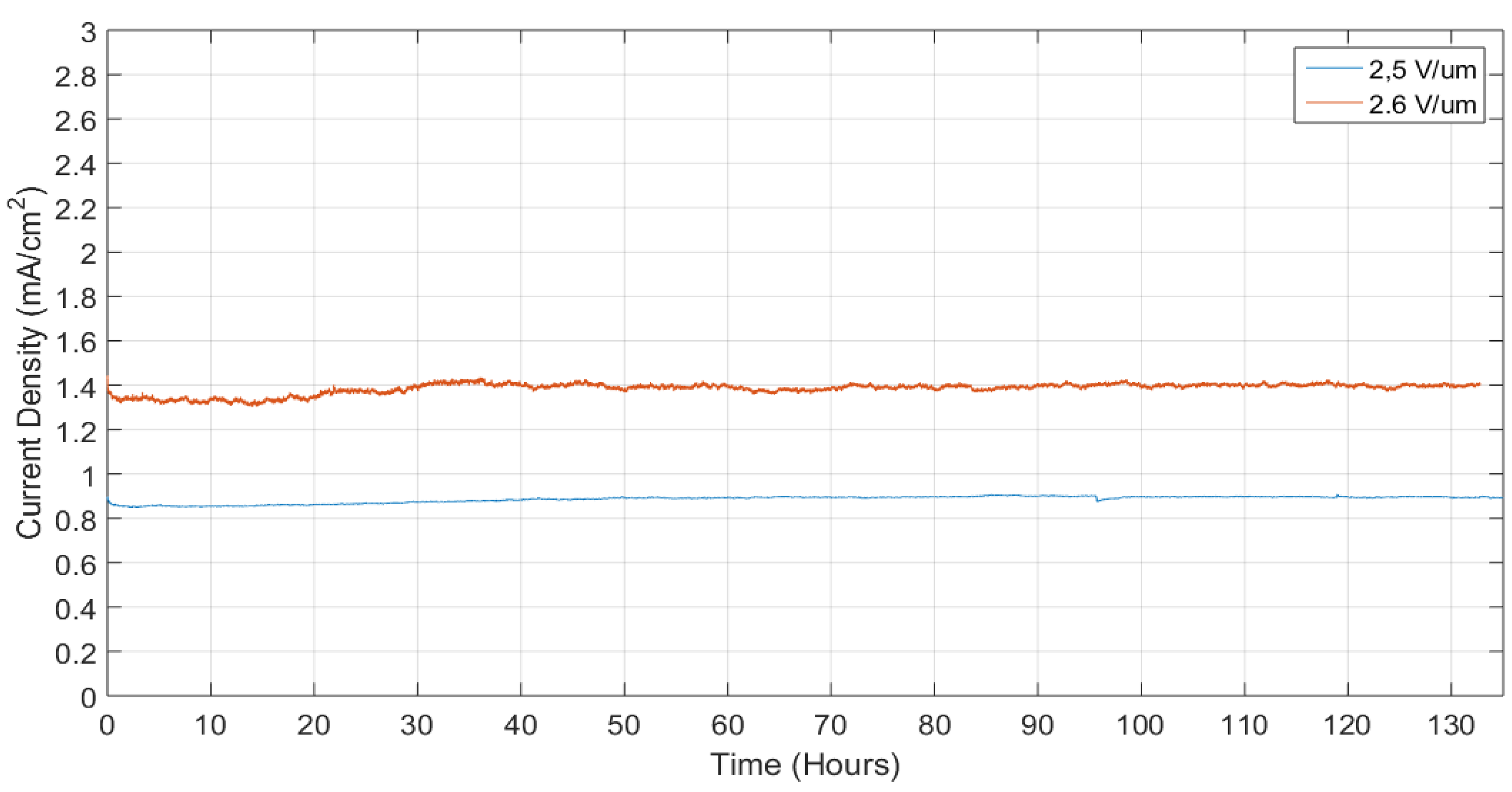
CNTs



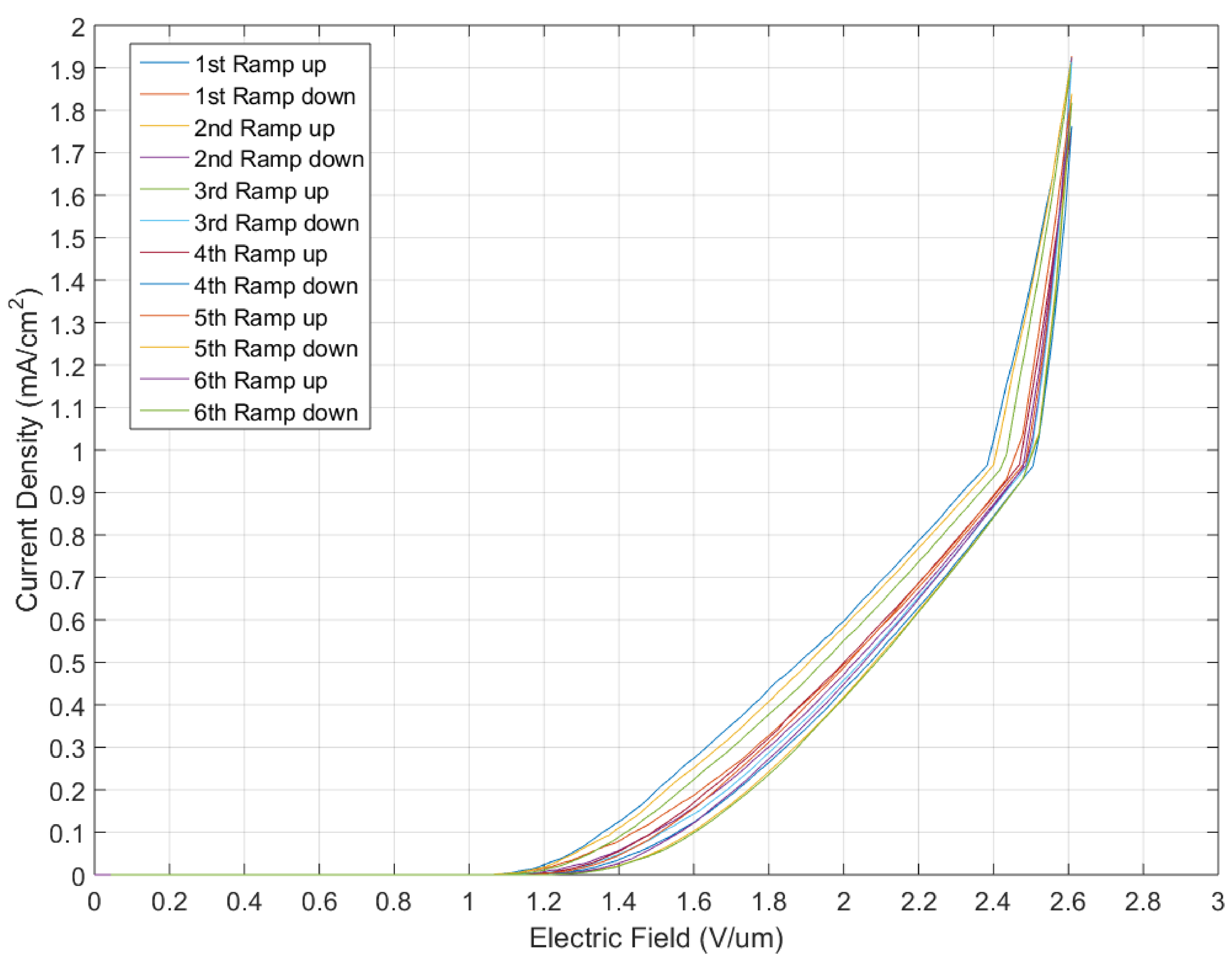


Lifetime Measurements 2

Vacuum: below 10^{-9} mBar. Same sample as CNT1.



FE Ramps on CNT1



Conclusions

CNTs, in particular CNT1 arrangement, show good stability and potentially quite long lifetime. Further studies are needed. But these results suggest that stability and lifetime may be suitable for operational use.

References

[1] - The ELENA electron cooler: Parameter choice and expected performance – G.Tranquille, A.Frassier, L.Joergensen

[2] – Carbon Nanotube Electron Source: from electron beams to energy conversion and optophotonics – A. Nojeh

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