



# DC Field Emission Scanning Measurements on Electropolished Niobium

A. Dangwal<sup>1,2</sup>, D. Reschke<sup>2</sup>, G. Müller<sup>1</sup>  
 1.FB C Physics, University of Wuppertal; 2. DESY, Hamburg



## Motivation

Enhanced field emission (EFE) from surface irregularities and particulates is one major obstacle for high gradient operations of SC Nb cavities.

$$E_{\text{peak}} \approx E_{p(\text{iris})} = 2 \cdot E_{\text{acc}}$$

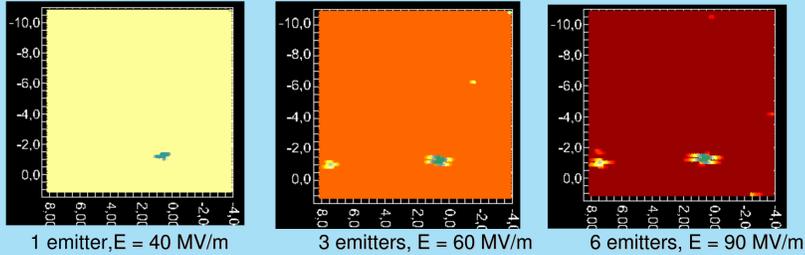
Strategy for improvement:

- Avoid field emission by improved surface cleaning e.g. Electropolishing (EP), High pressure rinsing (HPR), Dry ice cleaning (DIC)
  - FE measurements on Nb samples cleaned inside Nb cavities
- Automation of FESM with LabVIEW for faster scans, SEM images

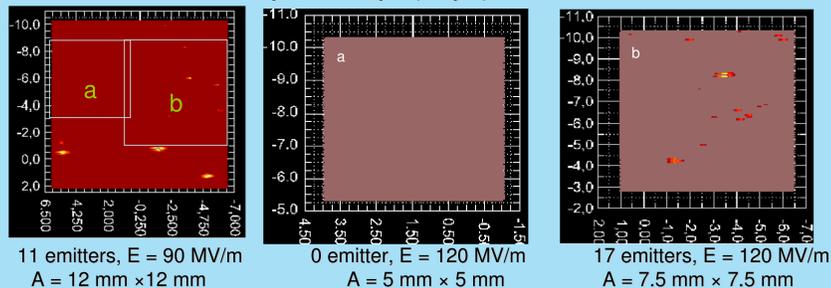
## Regulated V- scans

Nb sample EP at Saclay (Nb thickness removed 140  $\mu\text{m}$ )

- 1st series:  $\Phi_{\text{Anode}} = 300 \mu\text{m}$ ,  $\Delta z = 50 \mu\text{m}$  ( $\pm 5 \mu\text{m}$ ), scan area (A) = 12mm x 12mm

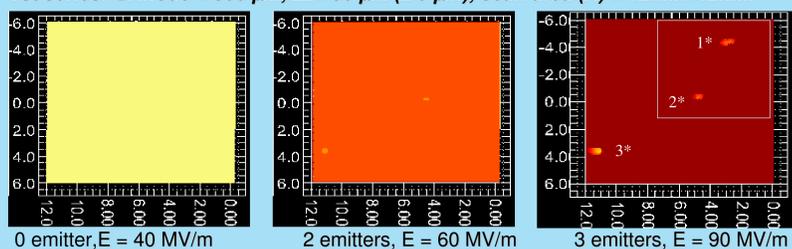


- 2nd series:  $\Phi_{\text{Anode}} = 100 \mu\text{m}$ ,  $\Delta z = 40 \mu\text{m}$  ( $\pm 5 \mu\text{m}$ )

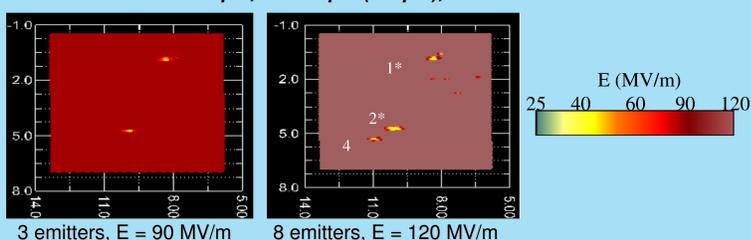


Same sample after HPR at DESY (cavity rotation speed 4-5 rpm; Pump pressure= 150 bar)

- 1st series:  $\Phi_{\text{Anode}} = 300 \mu\text{m}$ ,  $\Delta z = 50 \mu\text{m}$  ( $\pm 5 \mu\text{m}$ ), scan area (A) = 12mm x 12mm

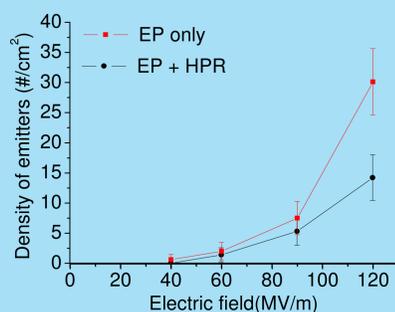


- 2nd series:  $\Phi_{\text{Anode}} = 100 \mu\text{m}$ ,  $\Delta z = 40 \mu\text{m}$  ( $\pm 5 \mu\text{m}$ ), A = 7.5 mm x 7.5 mm



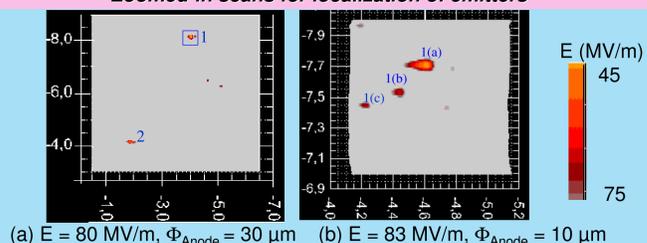
Comparison of emitters' distribution N(E) before and after HPR

E (electric field) MV/m	N (density of emitters) #/cm <sup>2</sup>	
	EP only	EP + HPR
40	0.7	0
60	2.1	1.4
90	4.2 - 7.6	2.1 - 5.3
120	30.2	14.2

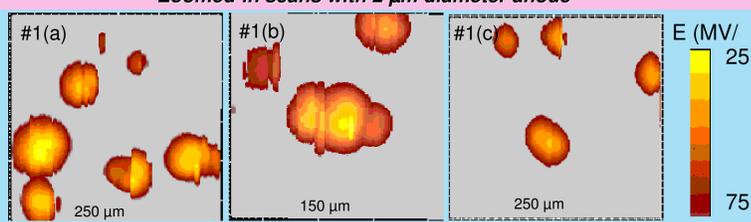


## Higher resolution V - scans

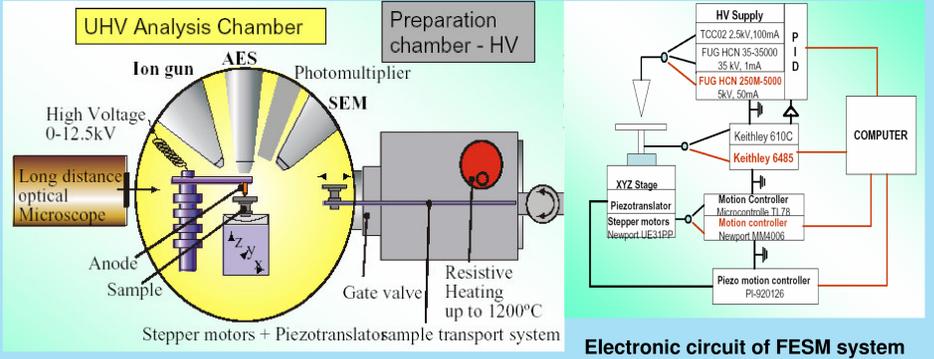
- Zoomed-in scans for localization of emitters



- Zoomed-in scans with 2  $\mu\text{m}$  diameter anode

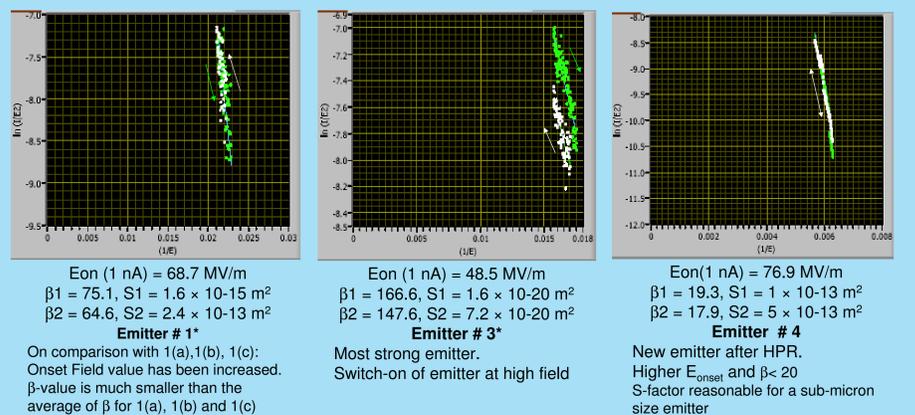
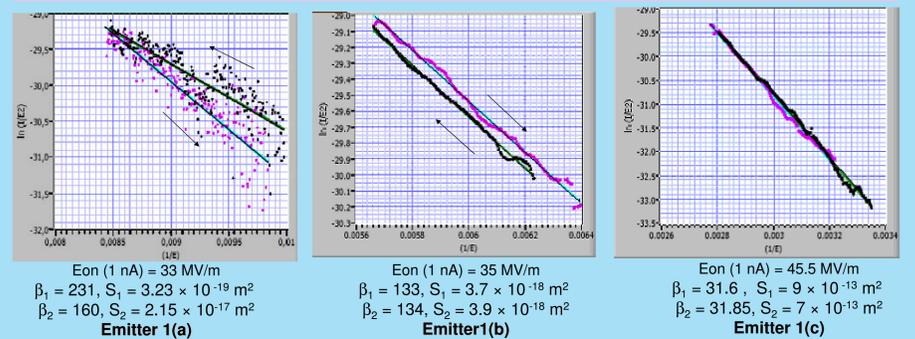


## DC Field Emission Scanning Microscope (FESM)

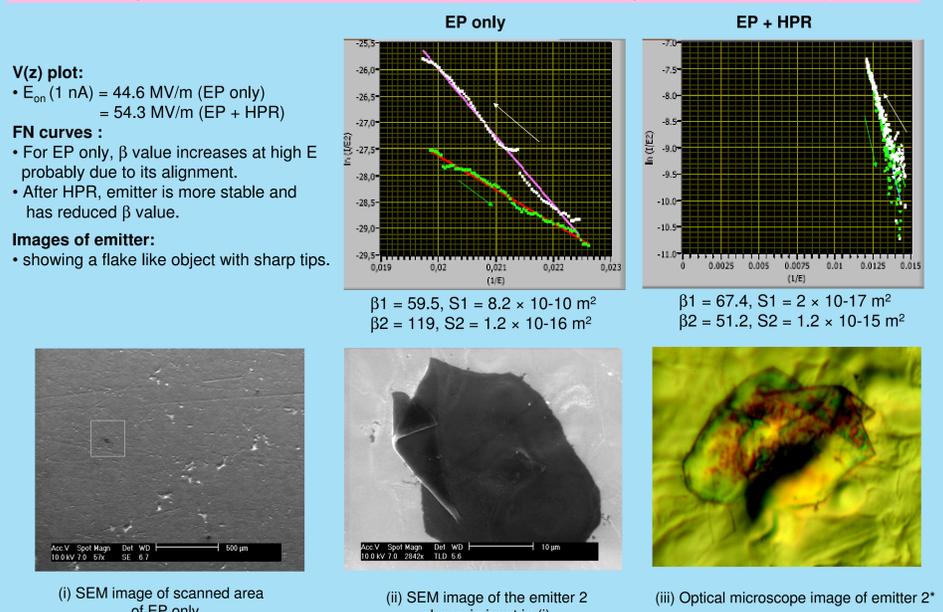


## Local measurements

FN curves for the strong emitters



Comparison of local measurements on emitter #2 (EP only) and #2\* (EP + HPR)



## Conclusions

Regulated V- scans on ~ cm<sup>2</sup> sample area

- EP only up to 30 emitters / cm<sup>2</sup> at 120 MV / m
- EP + HPR No FE at 40 MV / m ( $\approx E_{\text{acc}} \approx 20 \text{ MV / m}$ ) Reduced field emission up to 14 emitters / cm<sup>2</sup> at 120 MV / m ~3 emitters might be fixed due to FE current during scans before HPR.

High resolution scans and local measurements ( $\Phi_{\text{anode}} = 2 \mu\text{m}$ )

	(EP only)	(EP + HPR)
$E_{\text{on}}(1 \text{ nA})$	33 MV / m to 46 MV / m	48 MV / m to 77 MV / m
$\beta$ value	31 to 231	18 to 167
S-parameter	$10^{-13}$ to $10^{-19} \text{ m}^2$	$10^{-13}$ to $10^{-20} \text{ m}^2$

The SEM images show emitter as a flake like object or a particle.

Acknowledgement:

- Antoine Claire, Alain Aspart, Saclay
- Dr. Heiderhoff, FB E Electrical Engineering, University of Wuppertal