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AXIS
Towards an Advanced x-ray source based on field emitting Carbon Nanotubes cold cathode: LATEST UPDATES

M.Fratini[1], S. Iacobucci[1], A. Rizzo[2], M. Ilie[1], F. Scarinci[1],

S. Lagomarsino[1], G. Stefani[2] , Y. Zhang[3], M. Mann [3], W. I. Milne [3]

[1] CNR -IFN (Institute for Photonics and Nanotechnologies)
[2]Università degli Studi Roma Tre
[3]Engineering Dept., University of Cambridge, UK

OUTLINE

- Concept and project objectives
- State of the art
- Main results
- Conclusions

AXIS

Advanced x-ray source based on field emitting Carbon Nanotubes cold cathode

http://www.axisproject.eu/

Research for SME's 2008 –2010

Partners:

5 RTDs:

IFN CNR – Univ. Cambridge – Univ. Rome3 – Techn. Univ. Prague – D'appolonia

4 SME's

York Probe Source (UK) - Delong Intruments (Czech rep)
Xenocs (France) Scanco (Switzerland)

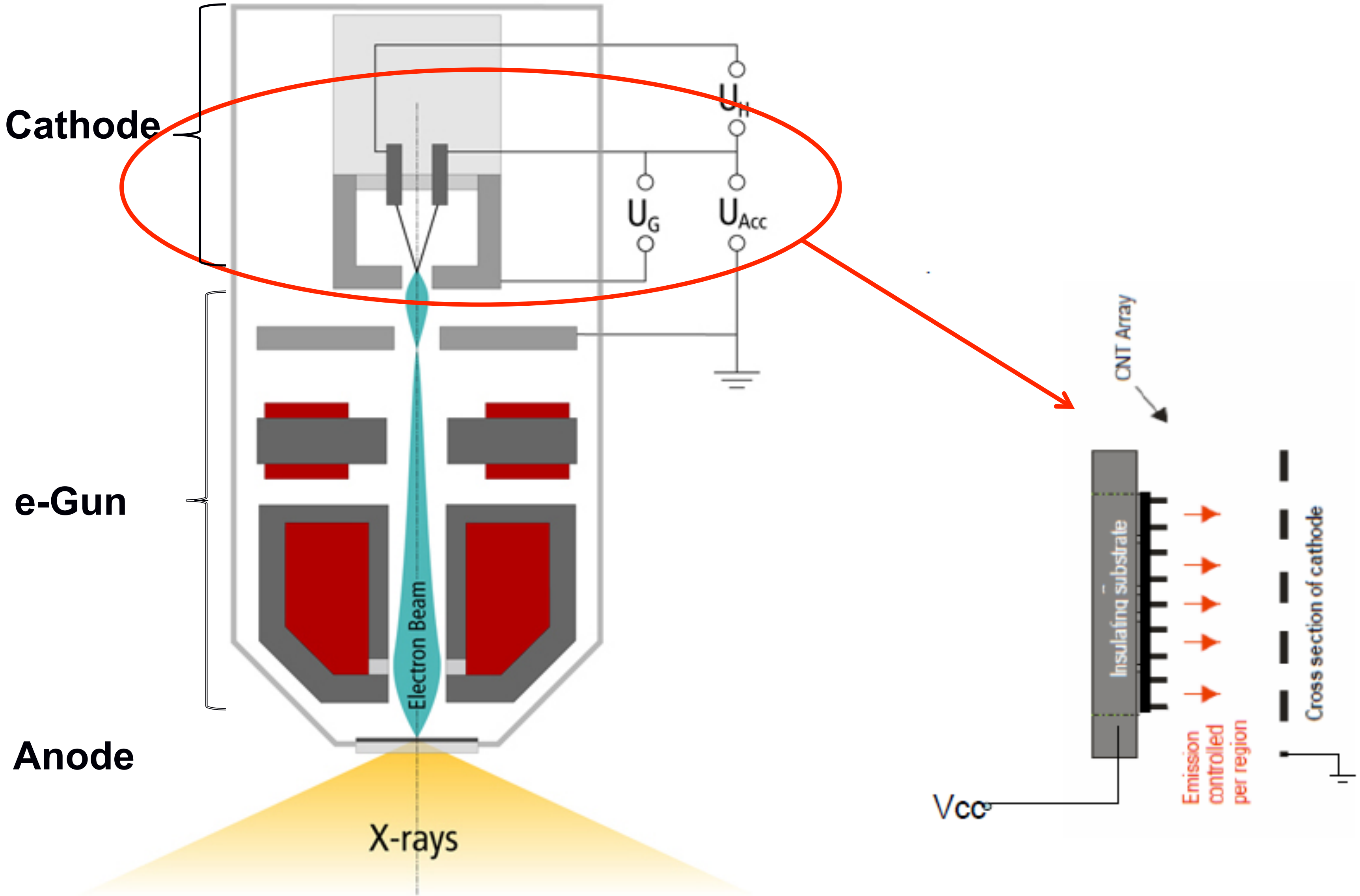
SPECIFICS OF AXIS SOURCE

a) Microspot
b) High power density

} **High Brilliance**

↓

High brilliance of electron beam



Cathode
e-Gun
Anode
U_H
U_G
U_{Acc}
Electron Beam
X-rays
CNT Array
Insulating substrate
Emission controlled per region
Cross section of cathode
Vcc

GOAL:

develop an innovative x-ray source based on field emitting

CNT cold cathode

WHY USING CNTs as an electron SOURCE?

Property	Thermionic (tungsten/ LaB_6)	Schottky (tungsten +ZrO)	Metalcold FE (tungsten)	Carbon nanotube FE
Virtual source size (nm)	10,000	<20	<10	<10
Energy spread (eV)	1	0.7	0.2 - 0.3	0.2 - 0.35
Brilliance (A/m^2srV)	10^6-10^7	10^8	10^8	10^9
Stability (%)	<1	<1	4-6	<0.5
Operating temp	1500 – 2100 C	1500 C	25 C	25 C – 400 C*
Lifetime	100 - 1000 hrs	>1 year	>1 year	>1 year

CHARACTERISTICS OF CNTs AS FIELD EMITTERS:

1) **Best shape for Field Emission** → Large field enhancement factors and low threshold fields for emission

D_{Tip} = 10 nm

2) **High electrical conductivity at room temperature** →
   - Metal or semiconductor conductor
   - Varying with doping
   - Change with the geometry of CNT

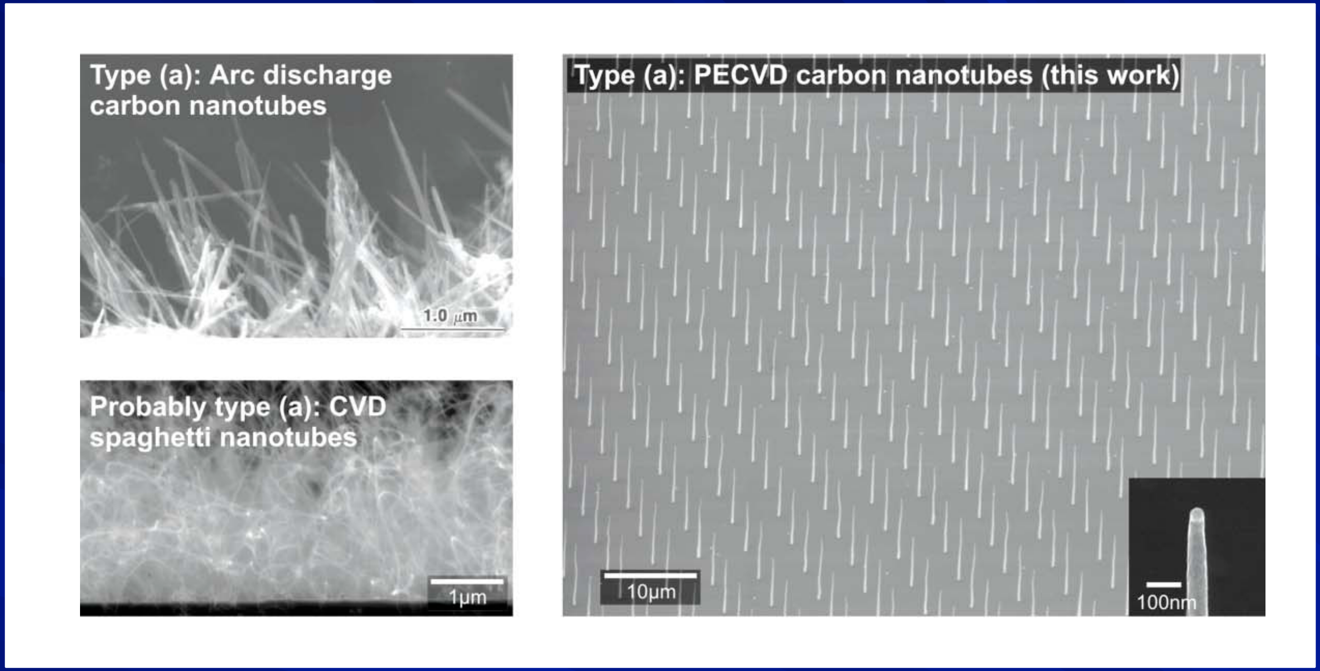
3) **Resistance decreases with T**

4) **Good temperature stability**

5) **Robust materials in term of their mechanical, thermal and chemical properties**

6) **For best efficiency CNTs should have uniform orientation and spatial distribution**

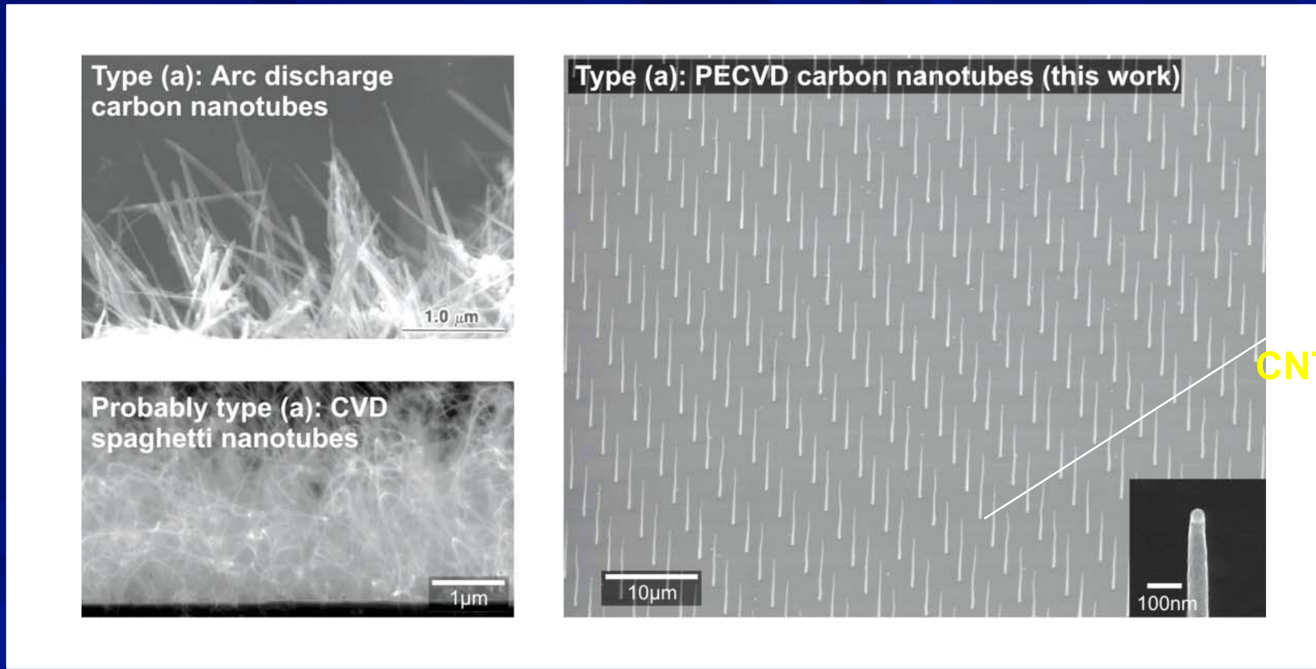
MACROSCOPIC CNT STRUCTURES:



In order to design and fabricate cathodes with optimized performance, it must be taken into account that when several emitters are assembled to form an array, an electrostatic screening effect appears between the emitters.

THE LARGEST CURRENT DENSITY WILL OFTEN NOT CORRESPOND TO THE SITUATION WITH THE HIGHEST DENSITY OF NANOTUBES.
A COMPROMISE MUST BE FOUND BETWEEN THE CNT-CNT DISTANCE, THE CNT DENSITY AND THE HOMOGENEITY OF THE STRUCTURE OF THE CNTs CAP.

N. De Jorge et al Phil Trans. R. Soc. London A (2004) .



H=5 um
d=50nm
Dcnt-cnt= 2.5 um
CNTs arrays= 250x250um2

It is necessary to have individual vertically aligned tubes spaced by controlling the height/distance ratio of adjacent tips to minimize field shielding effects and to optimise emitted current density

Best enhancement factor

X-ray source based on regular arrays of CNTs, with precise control of their emitting properties

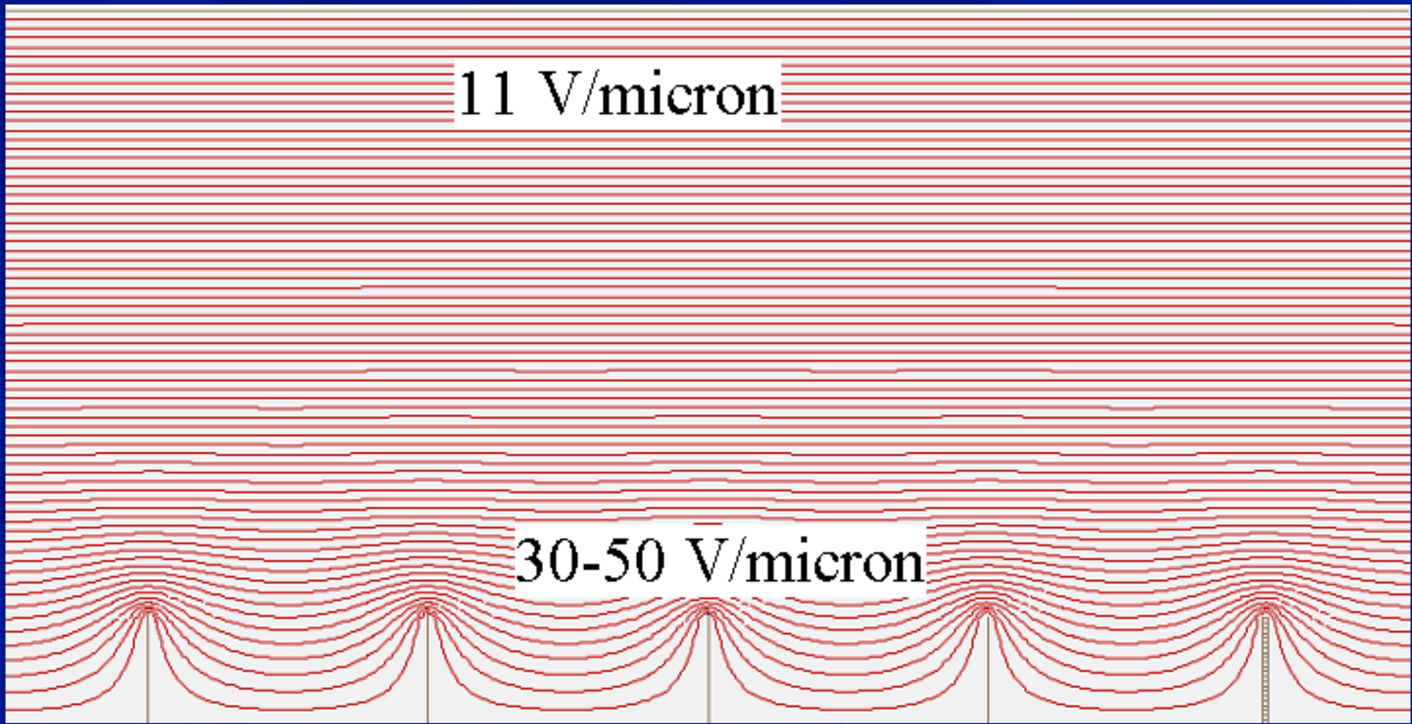
EXTRACTION FIELD:CNT's array

Simulation code: Simion 3D V.7.0- Idaho National and Environmental Laboratory - 95/0403 7.1 using Runge-Kutta method for computing electron trajectories in three-dimensions.

CNT Simulated cathode area :

•The extracting gate is simulated as a continuous flat electrode, fully trasparent to electrons at 200 um from the cathode and parallel to its plane.

•By applying a suitable potential V_G =2.2kV to the gate a macroscopic uniform extracting field is generated.



CRITICAL ISSUE

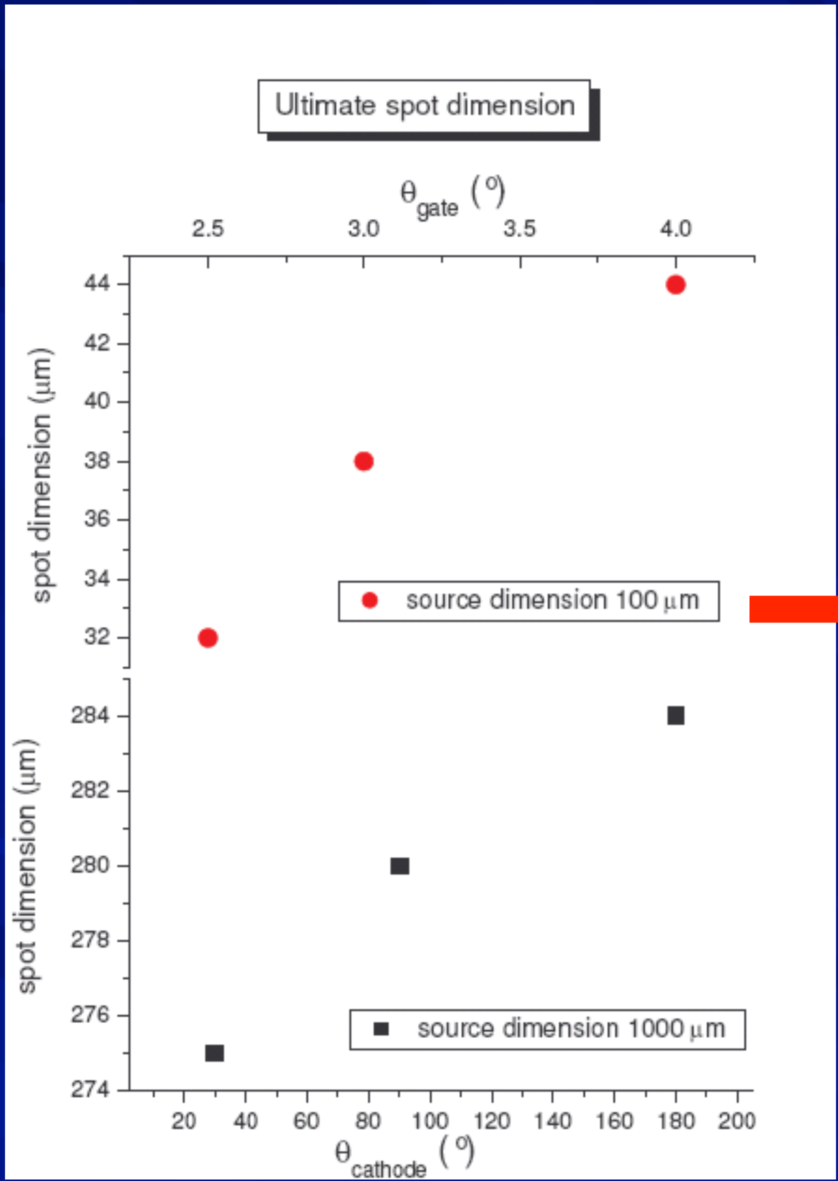
The ultimate focalizing performances of any electron optics
are limited by angle aberrations
hence it is crucial to have a control of the emission angle of electrons

CNT's emission angle

Extraction gate fabrication and assembly:

a) Grid contributes to steer the e-beam
b) Grid must dissipate a significant thermal load (high power spec)

THE SPOT SIZE AT THE ANODE AS A FUNCTION Θ_G AND Θ_{CNT} OF THE EMITTING TIPS

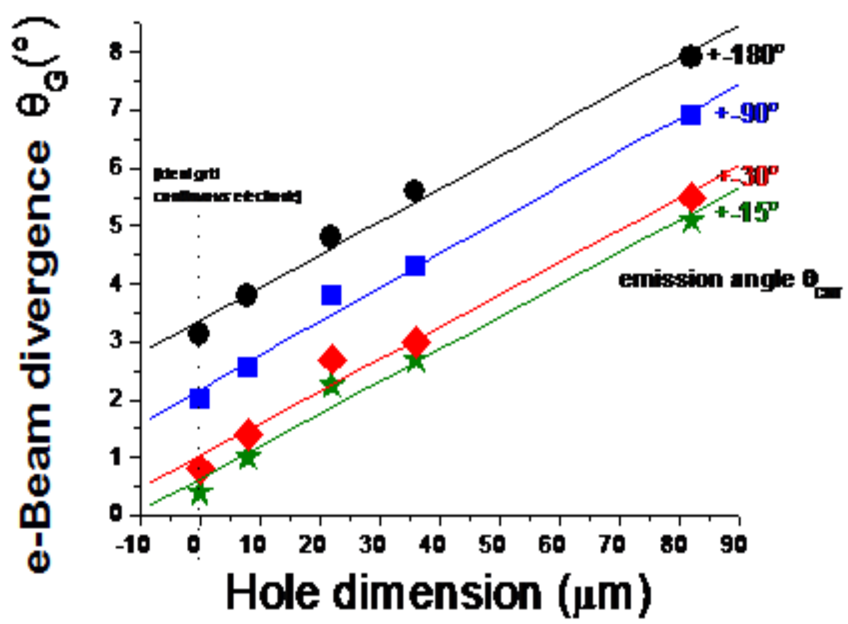


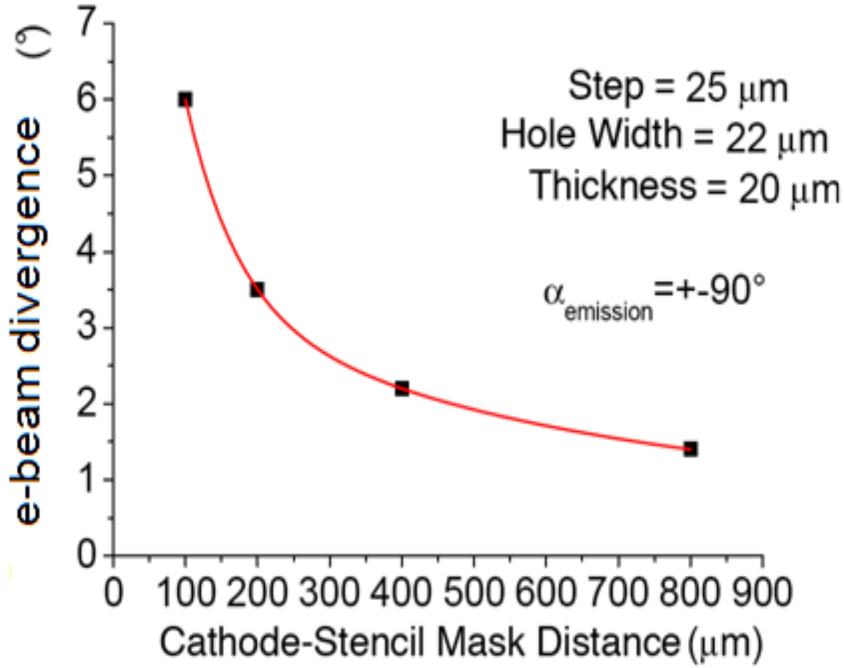
Increasing the θ_{CNT} and θ_G

increase the spot dimensions

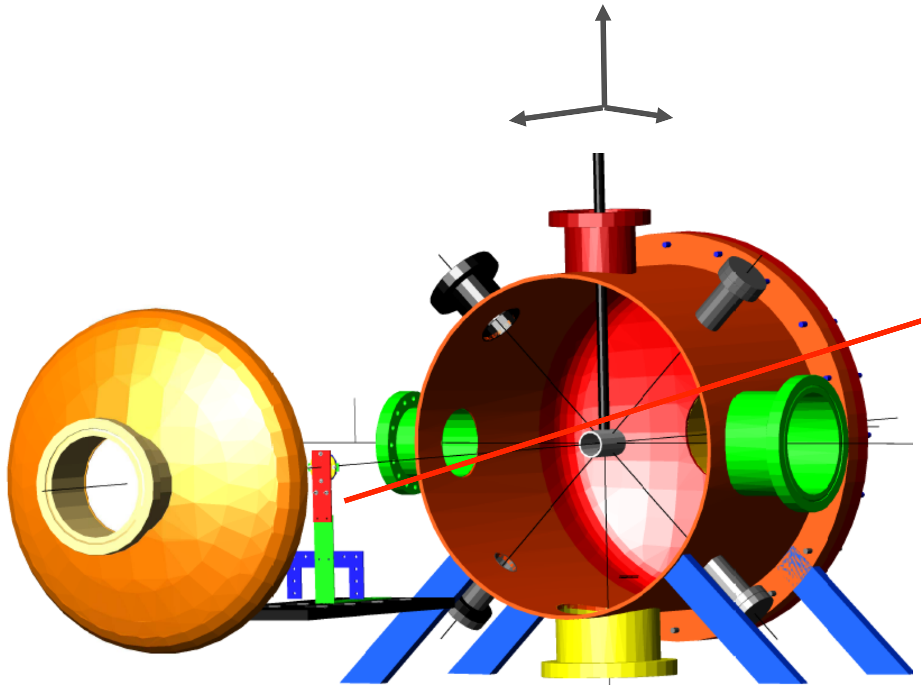
It appears that the angle of emission from
CNT is of paramount importance for obtaining a good re-focalization of the e-beam.

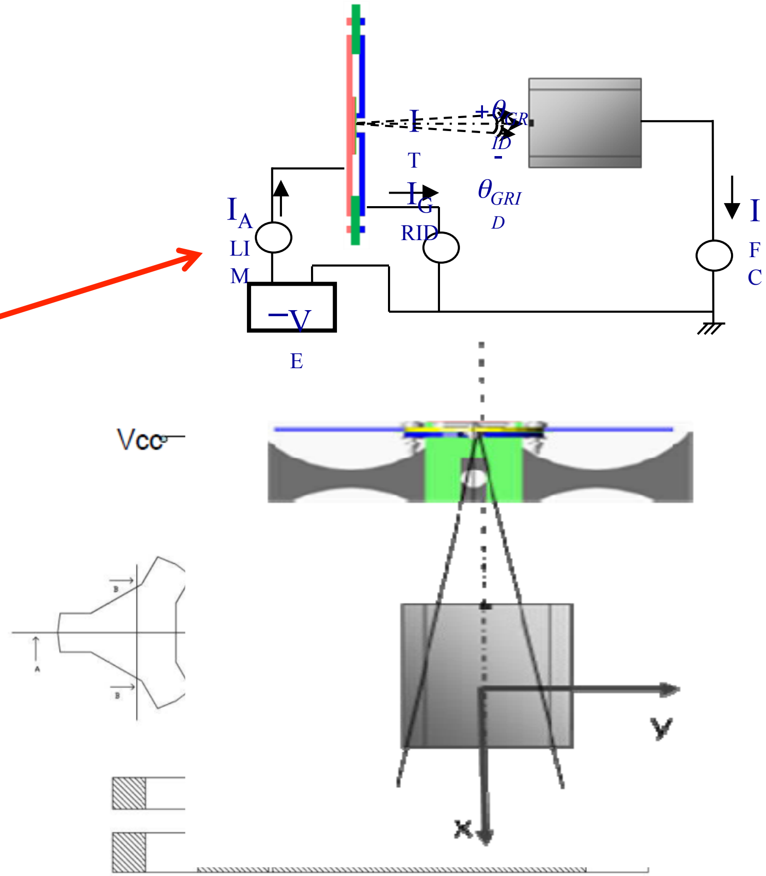
EXTRACTION GRID SIMULATION





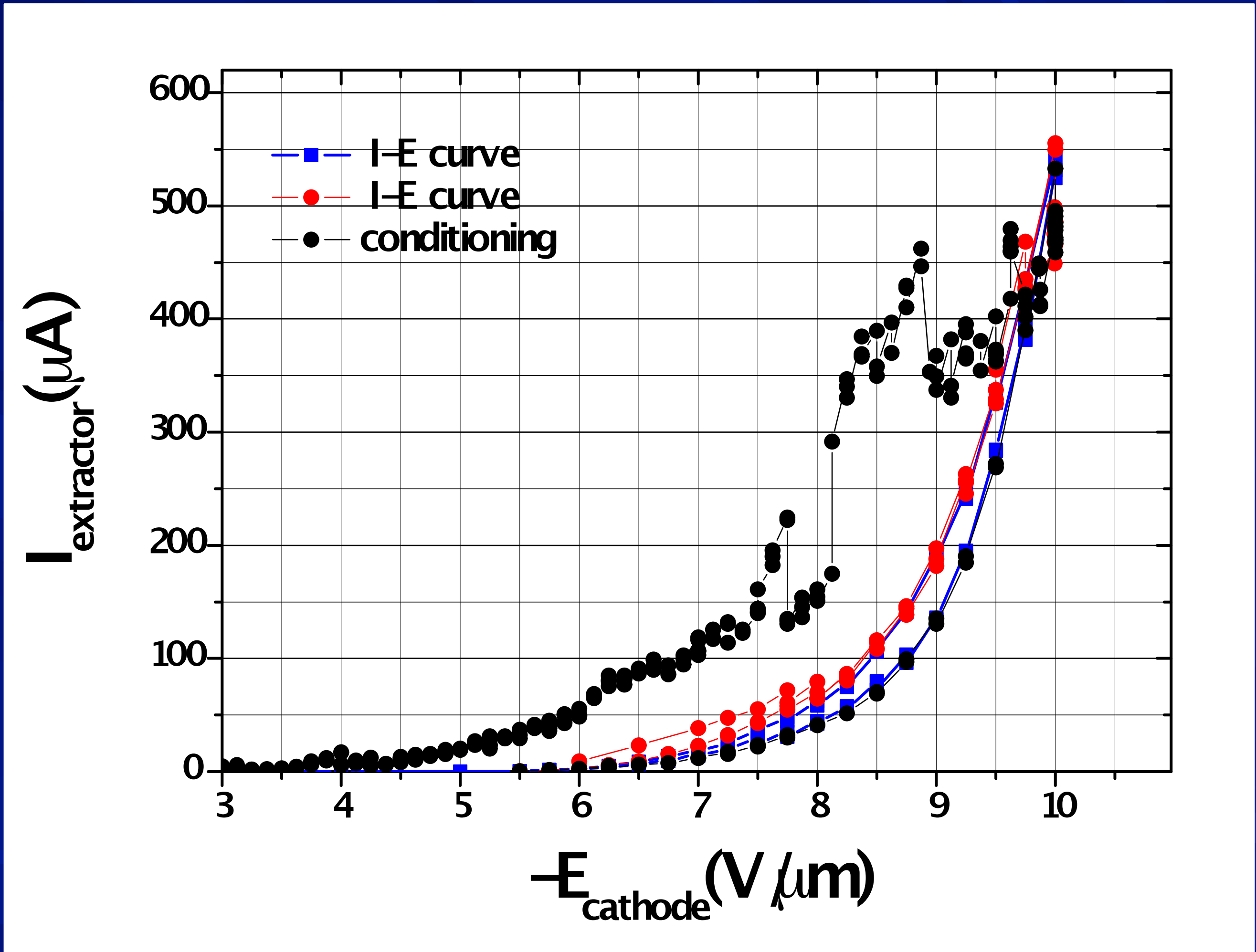
EXPERIMENTAL SET-UP FOR MEASURING :THE EXTRACTED CURRENT AND THE DIVERGENCE ANGLE





- Small aperture Faraday cup: movable geometry
- extractor device: grid assembly

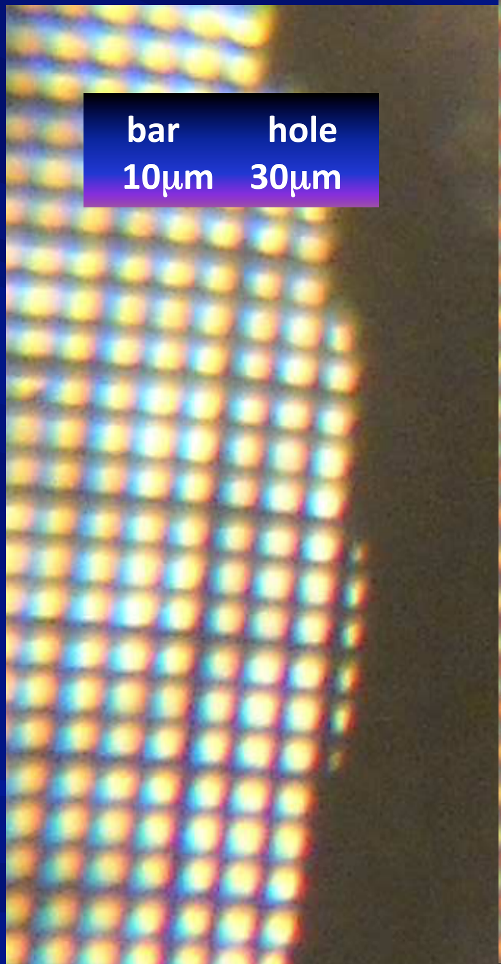
CHARACTERIZATION OF CNT CATHODE



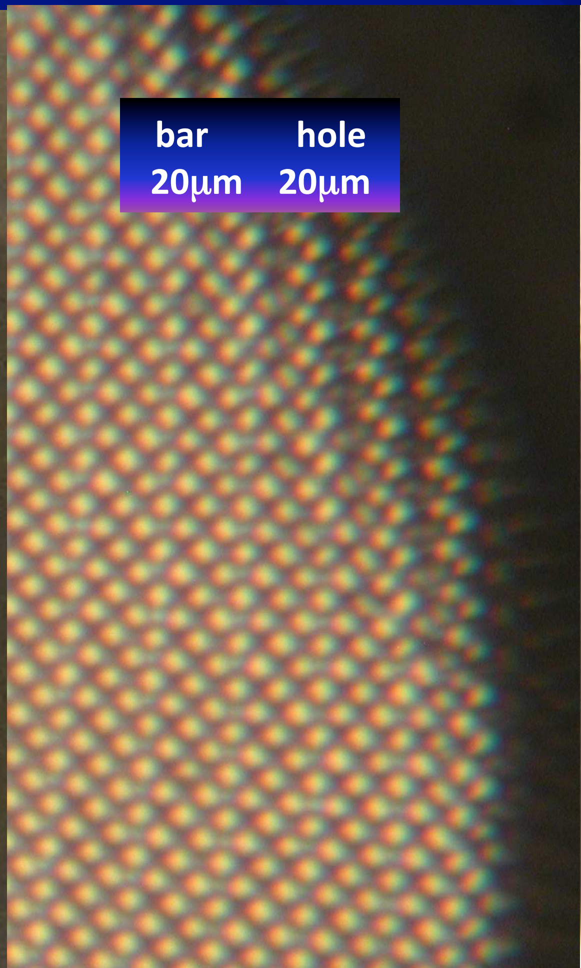
Maximum emission current : 550 μA @ 2000V (E=10 V/μm)
Gap=200 um

GRID SET TESTED

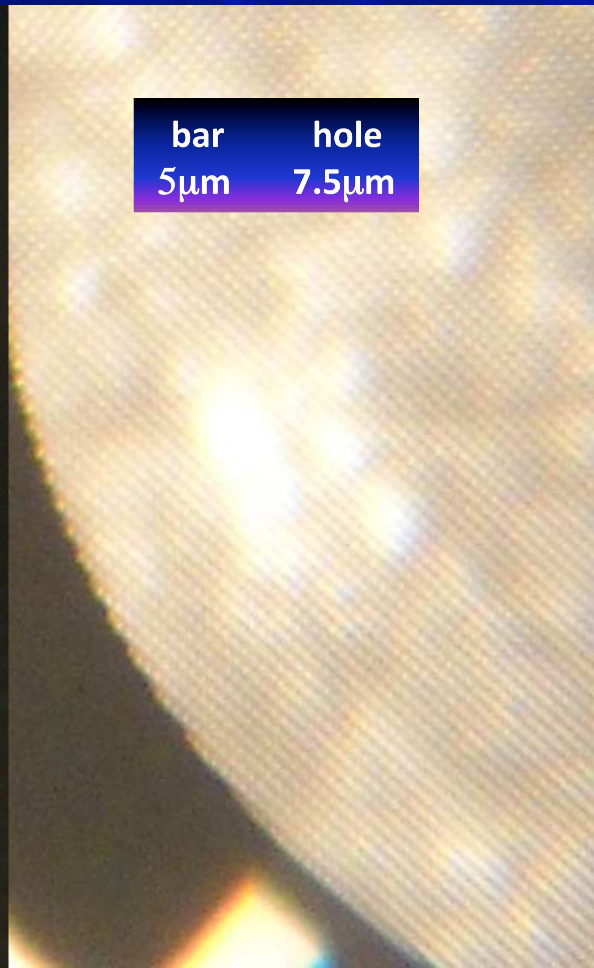
Commercial grid



Hand–shaped grid



Commercial grid



CONCLUSIONS

1. beam divergence measurements from aligned CNT cathode:

1.a) results indicate that a pencil angle of *few degrees* is achievable (in agreement with simulations upon the modeled CNTs emission angle)

2. Geometry used in the prototype suitable to achieve electron emission fitting the AXIS specs