Development of Cost-effective, Compact Electrical Ultrafine Particle (eUFP) Sizers and Wireless eUFP Sensor Network

PI: Da-Ren (or Daren) Chen[1] and Co-PI: Chenyang Lu[2]

[1]Floyd D. Gottwald, Sr. Chair and Professor
Department of Mechanical and Nuclear Engineering,
Virginia Commonwealth University
Richmond, VA 23284

[2] Professor
Department of Computer Science
Washington University in St. Louis
St. Louis, MO 63130

Air Sensors 2013 -- EPA Workshop and Kickoff Meeting

March 20, 2013

Future Need for Ultrafine Particle Sensing

- Portable ultrafine particle sizers, enabling the spatial and temporal monitoring of UFP size distribution in the ambient;
- Pocket sizers for measuring the UFP exposure at the personal level;
- A wireless sensor network, enabling to monitor the regional UFP distribution in real time

Measuring Particle Distributions in Ultrafine Size Range

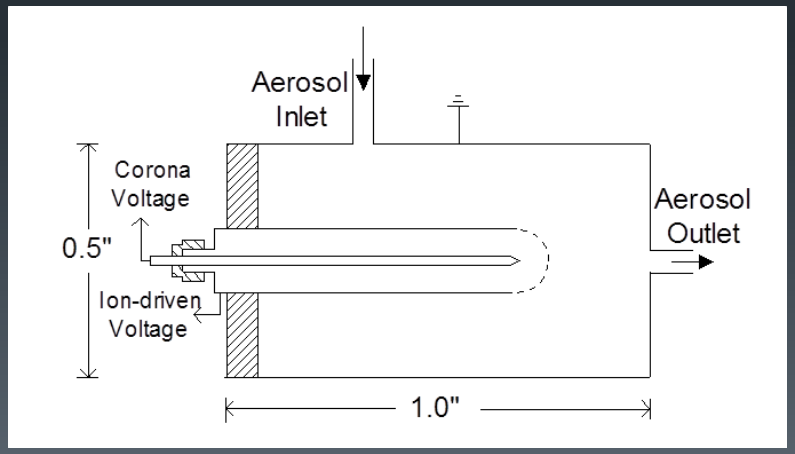
- The best practice is based on the electrical mobility of particles.
- Scanning mobility particle sizers (SMPSs):
  - particle charger for electrically charging particles
  - differential mobility particle classifier for size-classi
  - condensation particle counter (CPC) for counting t particles
  - voltage scanning operation

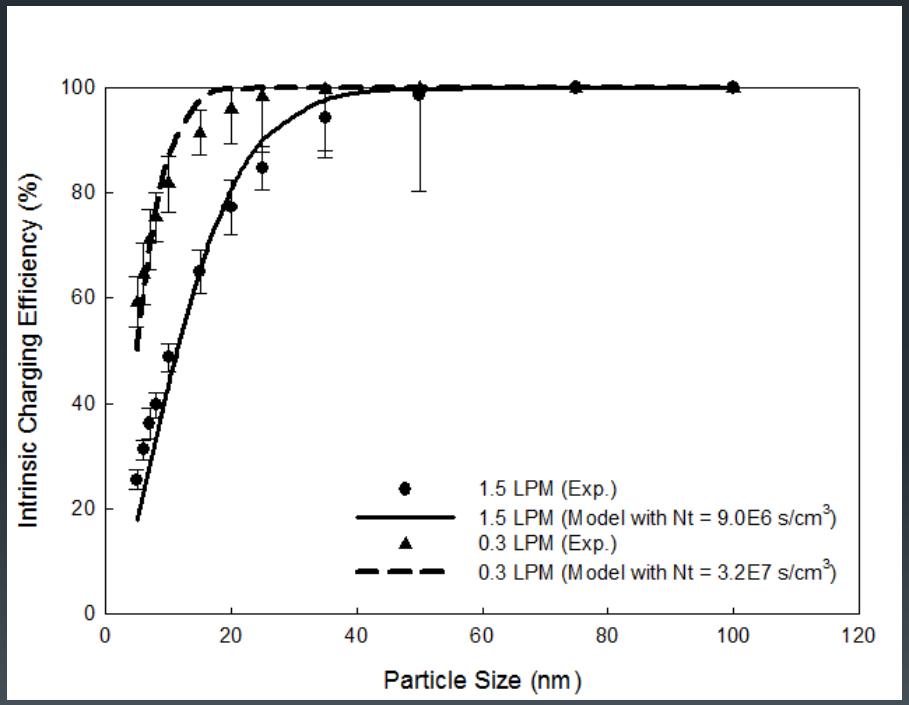
- Footprint and cost of SMPS are issues to carry out the spatial distribution measurement of ultrafine particles with SMPSs.

Our Previous Work on the Miniaturization of Particle Sizers

Performance of mini- unipolar particle charger

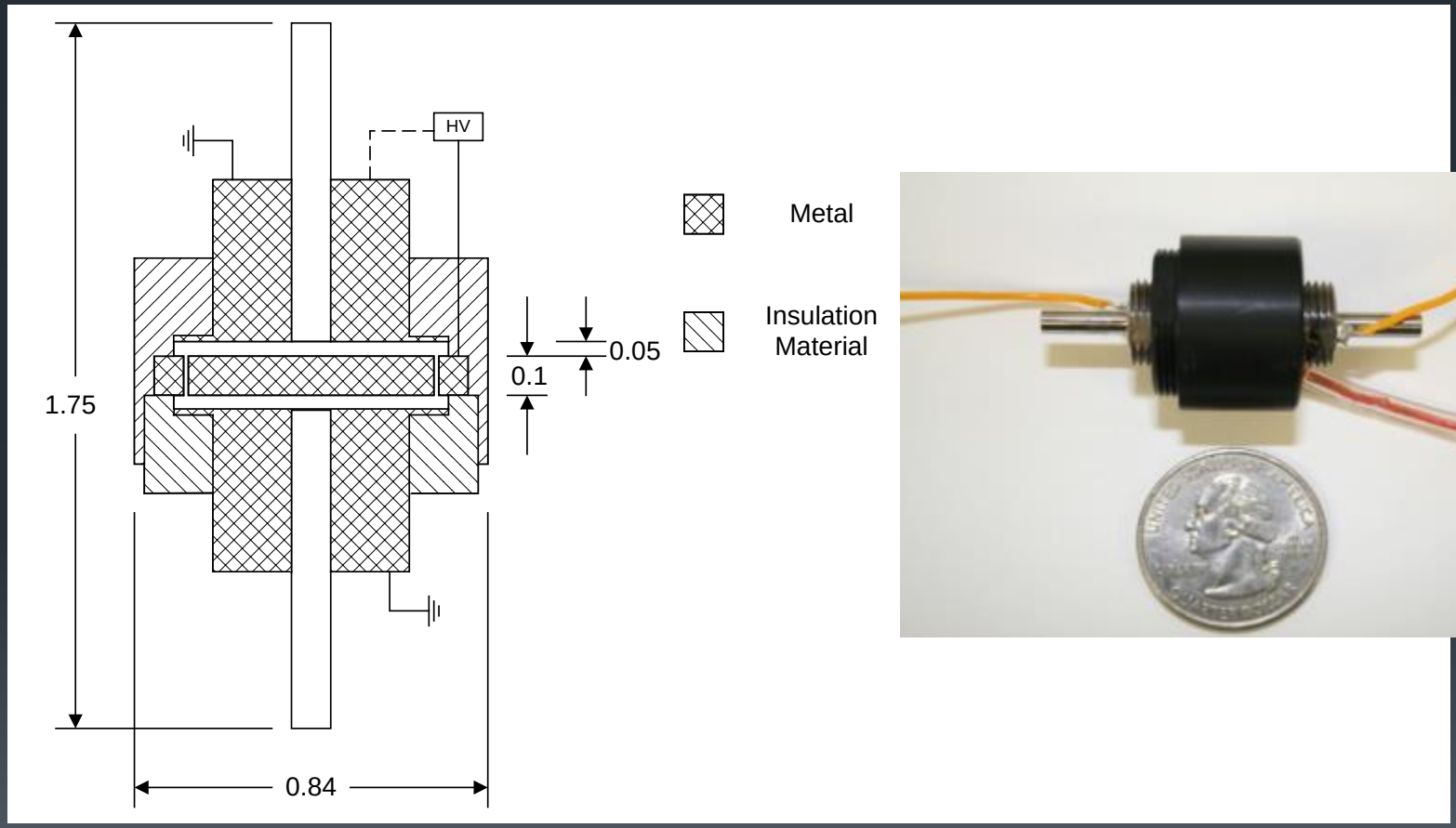
Unipolar min-charger

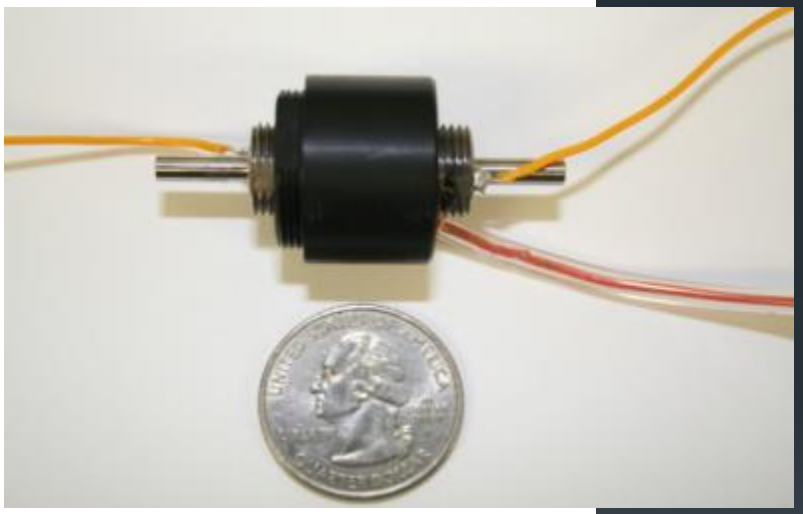




Qi et al, 2008a

Mini-disk precipitator and its performance

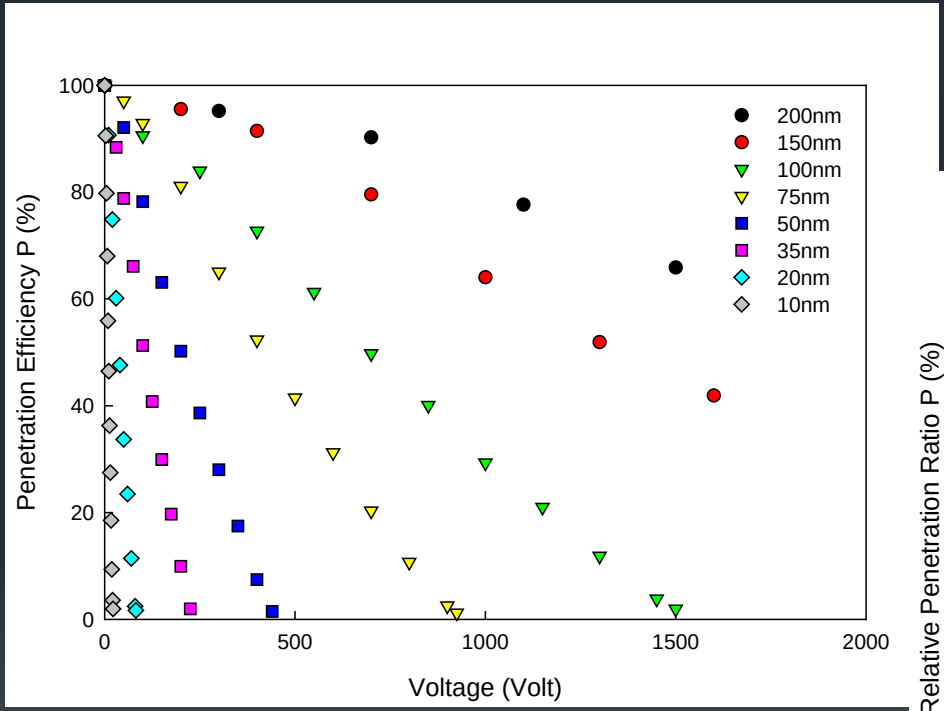




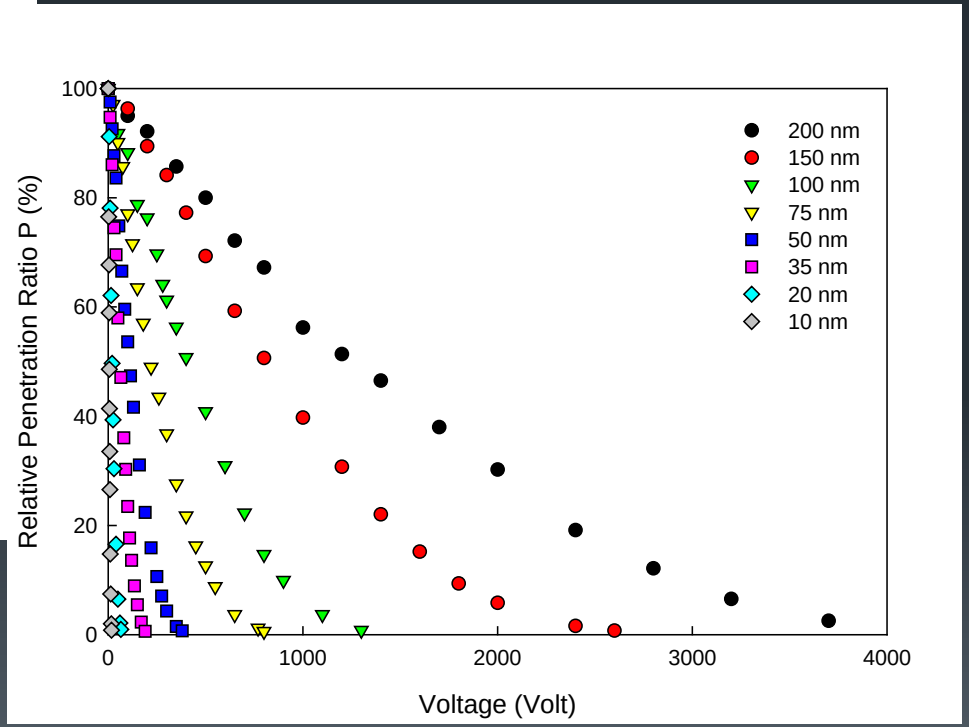
Qi et al, 2008b

Performance of mini-disk Precipitator

One-side Chamber

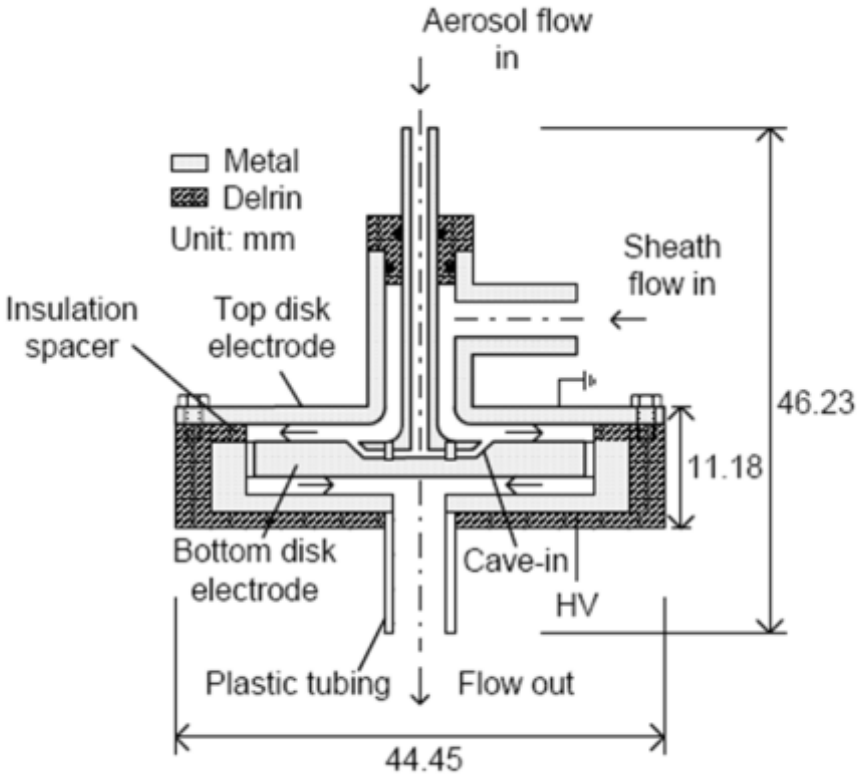


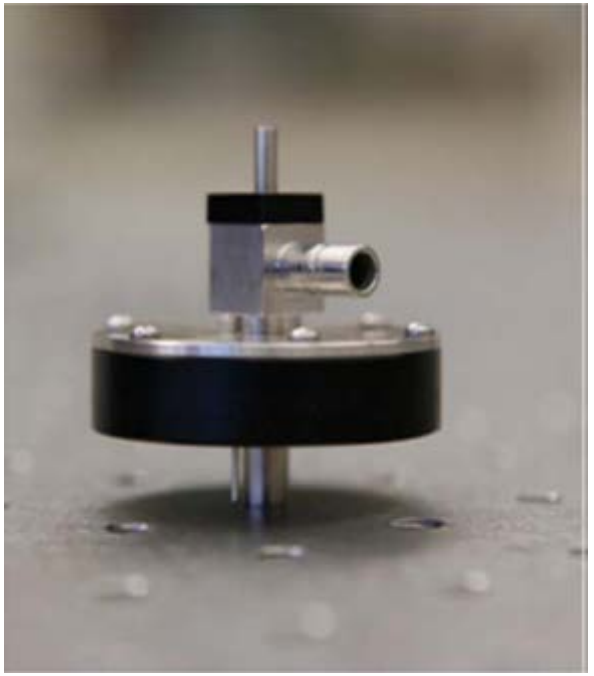
Dual Chamber



Qi et al, 2008b

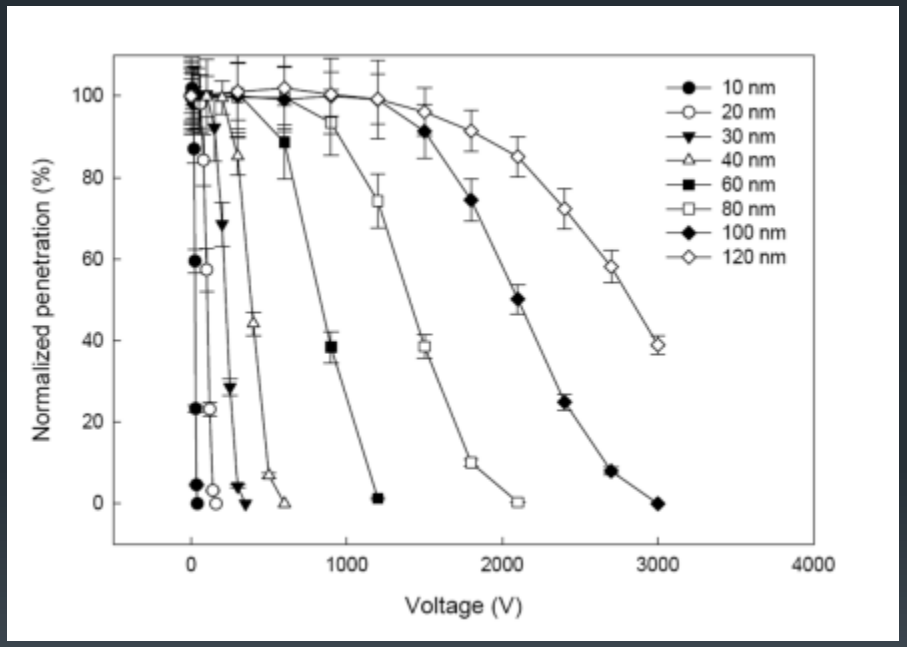
Development of mini- disk EAA (mini- disk Electrical Aerosol Analyzer)

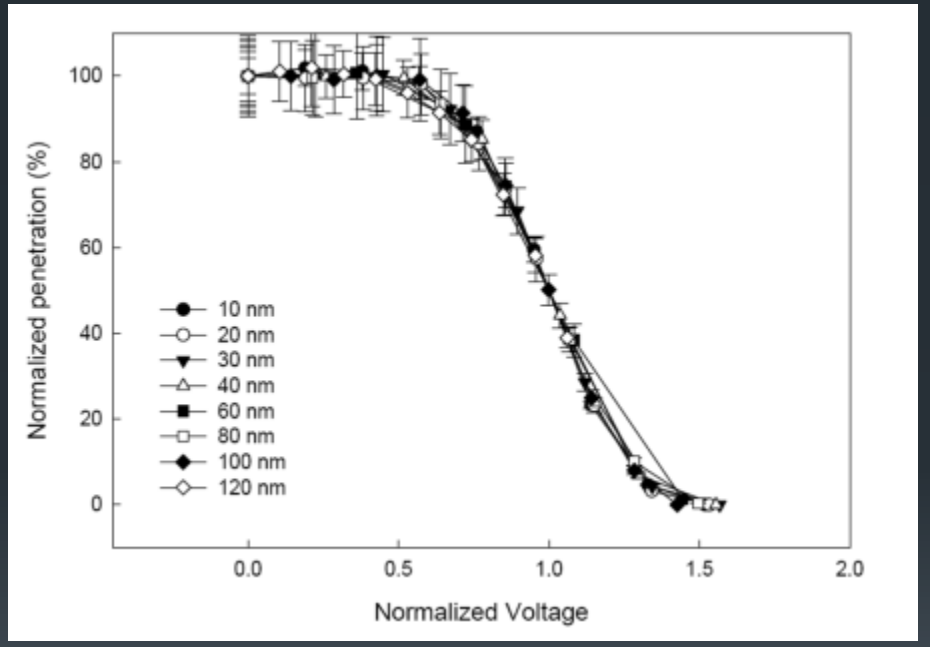




Li et al, 2009

Performance of mini- disk EAC

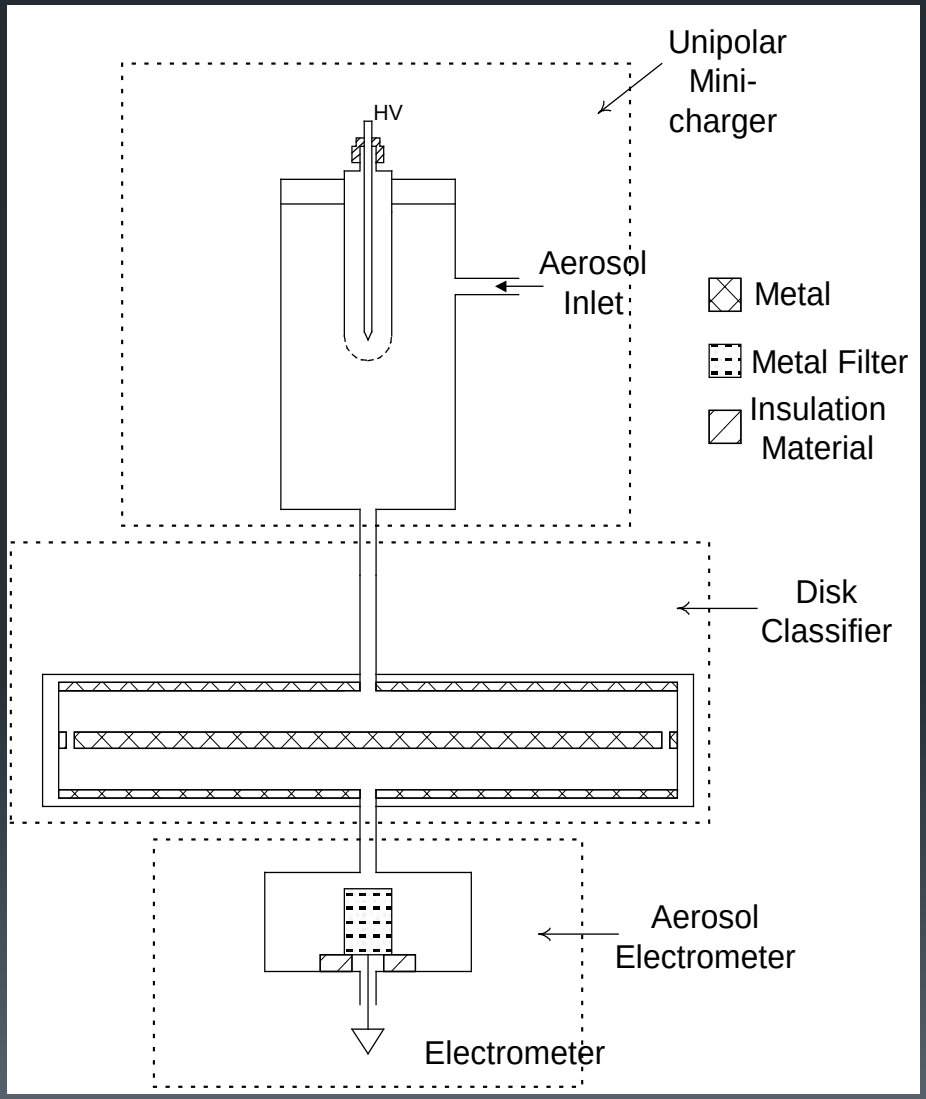




0.5 lpm aerosol and 1.5 lpm sheath flowrates

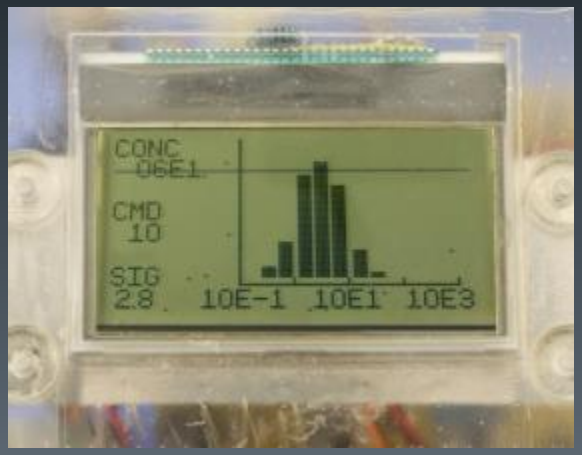
Li et al, 2008b

Schematic diagram of mini- ultrafine particle sizer



Prototype mini- ultrafine particle sizer

2009 R&D 100 Award (R&D magazine)



Aerosol flowrate: 0.7 lpm

Objectives of this EPA project

- to develop a cost-effective, portable electrical ultrafine particle (eUFP) sizer, enabling the spatial and temporal monitoring of UFP size distribution in the ambient;

- to develop a cost-effective, pocket eUFP sizer for measuring the UFP exposure at the personal level;

- to develop a wireless mesh network using proposed portable sizers as the nodes, enabling to monitor the working status of deployed sizers and to acquire data being collected via internet

Study Plan for this EPA Project

- Phase I: development of miniature components for eUFP sizers
- Phase IIa: Integration and assembly of both portable and personal eUFP sizers
- Phase IIb: development of the (small-scale) wireless mesh network via eUFP sizers (Dr. Lu)
- Phase III: field testing of eUFP sizers and their wireless network.

eUFP Sizers

- eUFP sizers:
  - Size-selective inlet
  - Corona-based particle charger
  - Miniature EAC/DMA
  - Miniature Faraday cage with sensitive pre-amp
- Two versions of eUFP sizers:
  - portable (can also be installed at light posts)
  - pocket
- Features to be included in eUFP Sizers
  - On-board data reduction
  - Self-diagnosis
  - Data log and download
  - Time and position stamp of logged data set
  - Wireless network and data hopping

Wireless Mesh Network (Dr. Lu)

- Portable sensors and base station will form a wireless mesh network for the collection of data from the proposed sizers to the base station.
- In the wireless mesh network, sensors relay data to each other through the peer-to-peer multi-hop routing
  - proposed network does not incur service charges like cellular networks
  - proposed network does not like traditional WiFi networks relying on Access Points that need to be connected through a wired network, which can be costly and difficult to deploy outdoors in a city or in the ambient
- Protocols:
  - OLSR-NG (http://www.olsr.org/) mesh routing protocol for each portable eUFP sizers and the base station to support multi-hop communication over the mesh network.
  - Dynamic Relay Associate Protocol (DRAP) (Chipara et al, 2010) to support data collection from pocket eUFP sizers.

Conclusion: current status

- Phase I: development of the major components for eUFP sizers (50% complete)
  - Design of miniature components (completed)
    - Miniature unipolar UFP charger with improved charging efficiency
    - Miniature eUFP classifier (EAC/DMA)
    - Size-selective inlet
  - Mechanical drawings submitted to the machine shop (completed)
  - ……
  - Performance evaluation of above-listed components (to be completed)

Thanks!