A MINIATURE DEVICE FOR SUB-PPB OXYGEN AND MOISTURE DETECTION

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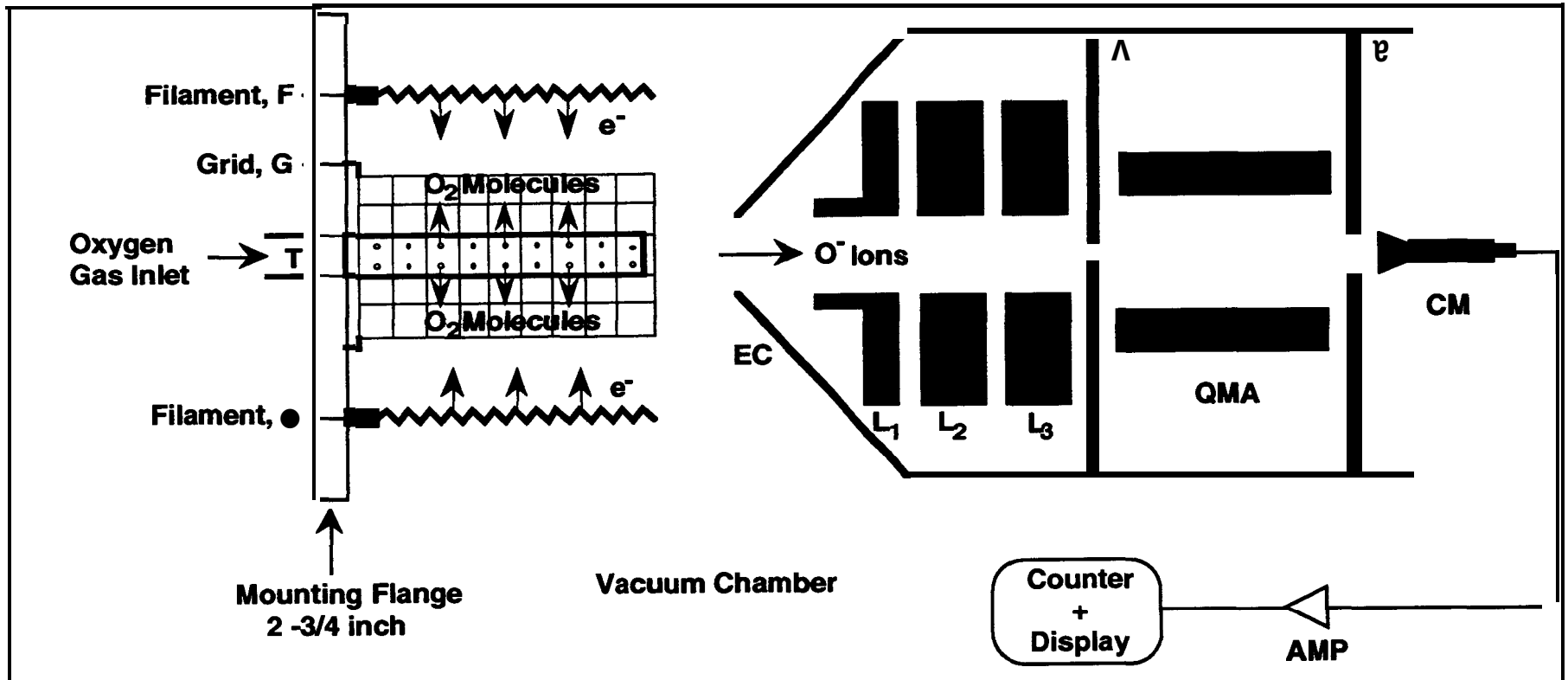
APPLICATIONS

- **Semiconductor Processing**
  - O_2 and H_2O form oxide layer, cause localized defect, affect material properties and product yield.
- **Containerless Materials Processing**
  - O_2 and H_2O form oxide layer or become unwanted nucleation sites in undercooling, nucleation, solidification and thermophysical measurement experiments.
- **High-Purity Gas Production**
  - O_2 and H_2O are impurities in ultra-high purity gases.
- **Planetary Atmospheres and Surfaces**
- **Planetary Satellite Atmospheres and Surfaces**
- **Cometary Atmospheres and Surfaces**

DEVICE SCHEMATIC



Pulsed Mode, Repetition Rate 9 KHz, 50 % Duty Cycle

'Electron ON'	G = +12 V	EC = L_1 = 0 V
'Electrons OFF and Ions ON'	G = -0.005 V	EC = L_1 = +50 V, L_2 = +170 V, L_3 = +40 V

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PRINCIPLE OF OPERATION

Modes of electron attachment:

$$e^- + AB \Rightarrow AB^- \qquad \text{(nondissociative)}$$

and

$$e^- + AB \Rightarrow (AB^-) \Rightarrow A + B^- \qquad \text{(dissociative)}$$

Resonant electron attachment of molecular oxygen:

$$e^- (E_R = 6.8\text{eV}) + O_2 \Rightarrow (O_2^-) \Rightarrow O + O^-$$

Resonant electron attachment of water vapor:

$$e^- (E_R = 10.5\text{eV}) + H_2O \Rightarrow (H_2O^-) \Rightarrow H_2 + O^-$$

* Detect O^- as signature for O_2 and H_2O contaminants.

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DETECTION LIMITS

O^- signal count rate:

$$S(Hz) = \kappa \cdot n_T \cdot V \cdot n_e \cdot v_e \cdot \sigma(E_R)$$

- E_R = electron energy at resonance.
- v_e = e^- velocity at the resonance energy.
- $\sigma(E_R)$ = cross section for O^- production at resonance energy.
- V = size of collision region, a spherical volume , ~ 2×10^{-2} cm^3.
- n_e = electron density, ~ 2.6×10^8 cm^{-3} for a 50 mA beam.
- κ = transmission coeff. corresponding to the QMA efficiency and the loss of ions during extraction, ~0.005 (includes 50% duty cycle).

$\Rightarrow$ n_T = target density at room temperature, a quantity to be determined.

	O_2	H_2O
Resonance energy, E_R	6.8 eV	10.5 eV
Electron Velocity, v_e at E_R	1.54×10^8 $cm \cdot s^{-1}$	1.92×10^8 $cm \cdot s^{-1}$
Cross section, $\sigma(E_R)$	1.34×10^{-18} cm^2	1.48×10^{-18} cm^2
Target gas density, n_T	1.73×10^7 cm^{-3}	1.21×10^7 cm^{-3}
Fractional concentration in air, C	0.67×10^{-12} (sub-ppt)	0.45×10^{-12} (sub-ppt)

* Assume minimum signal count rate of 100 Hz.

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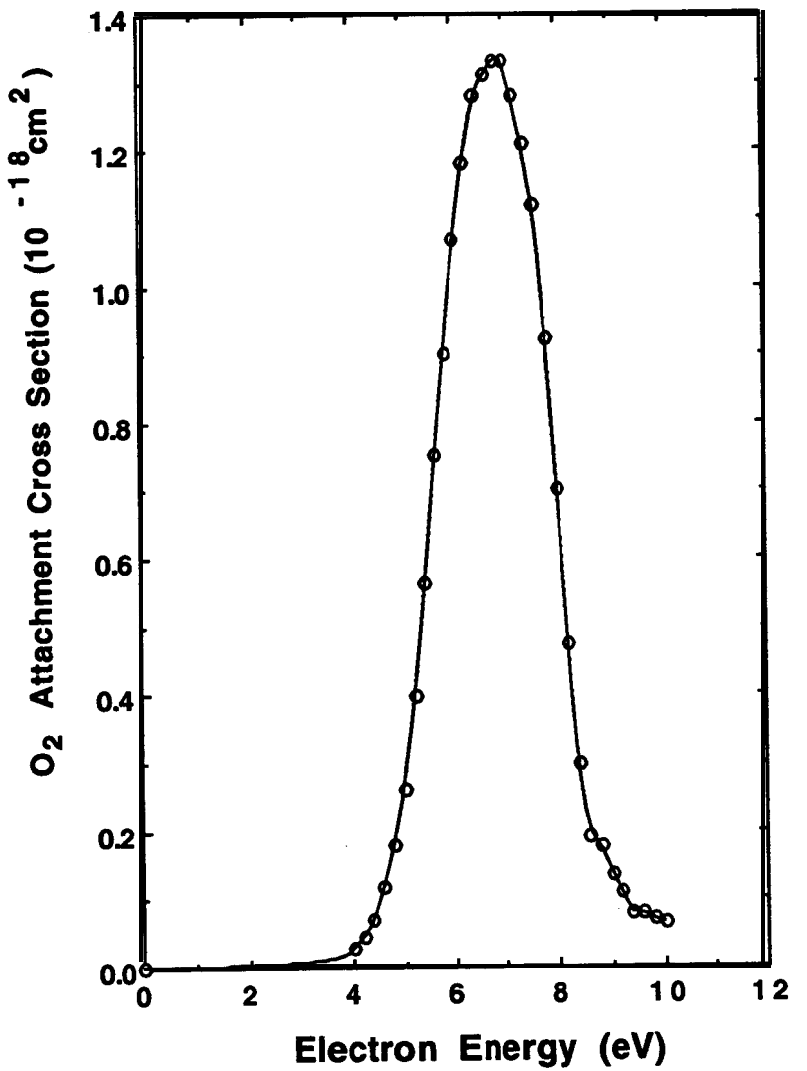
DISSOCIATIVE ELECTRON ATTACHMENT CROSS SECTION OF O_2



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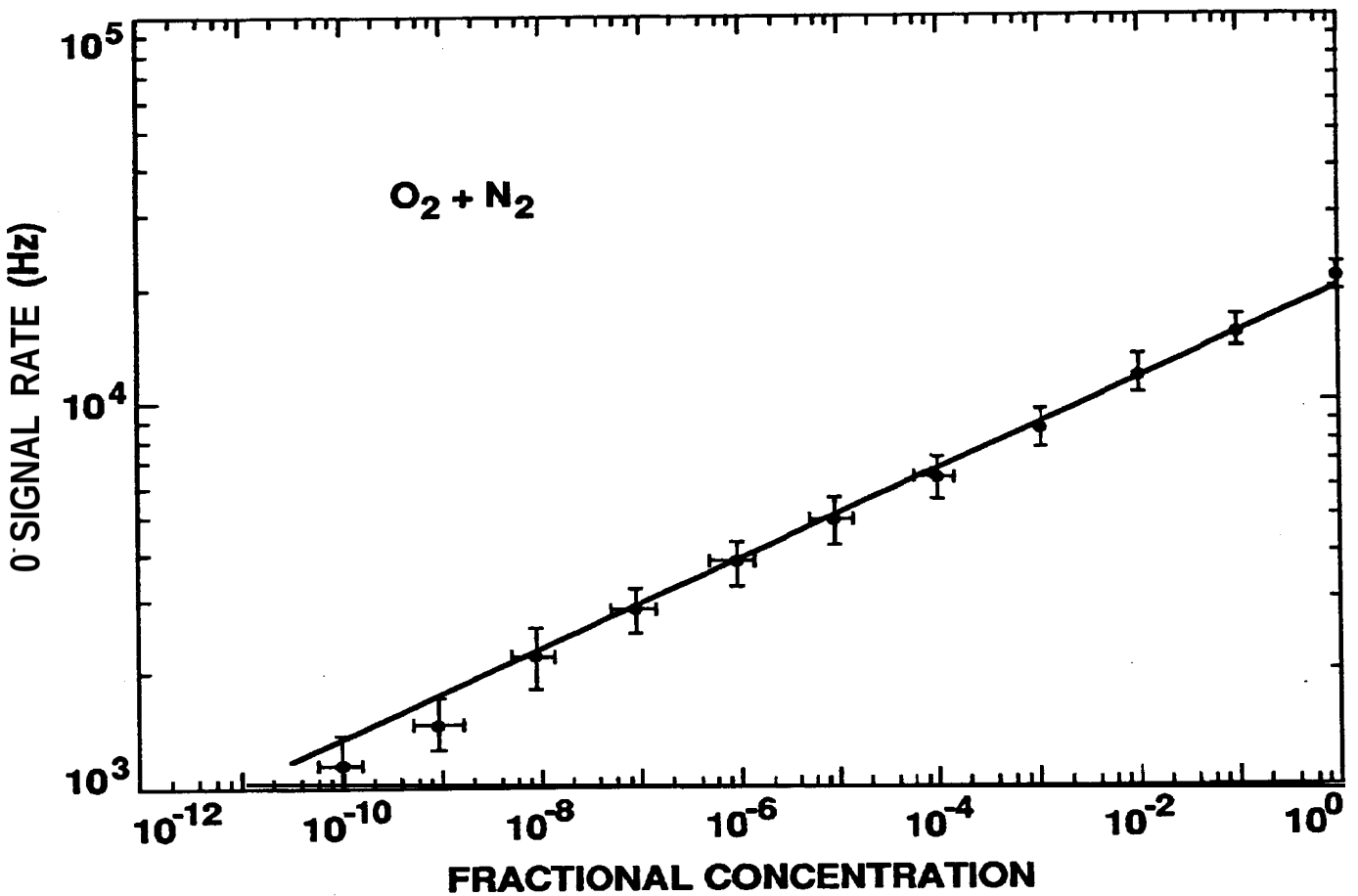
SENSITIVITY MEASUREMENTS FOR O_2



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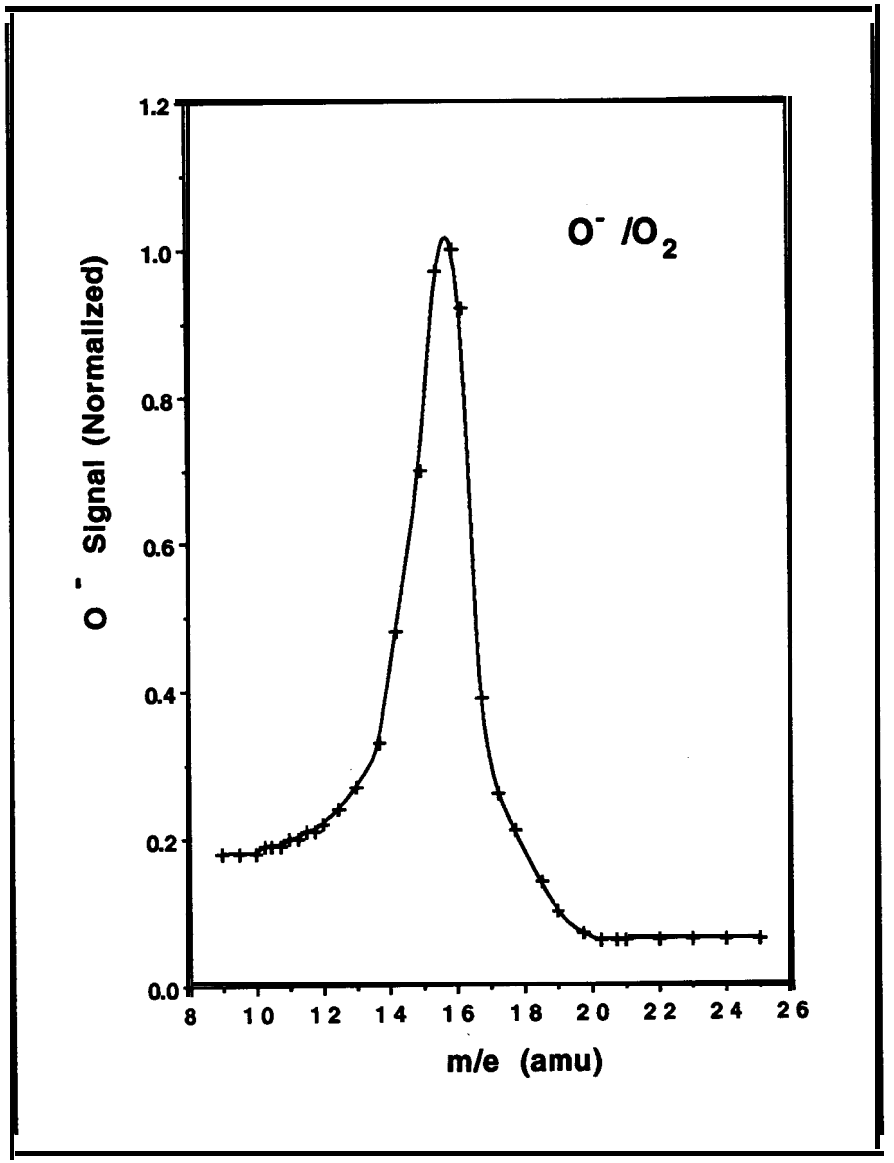
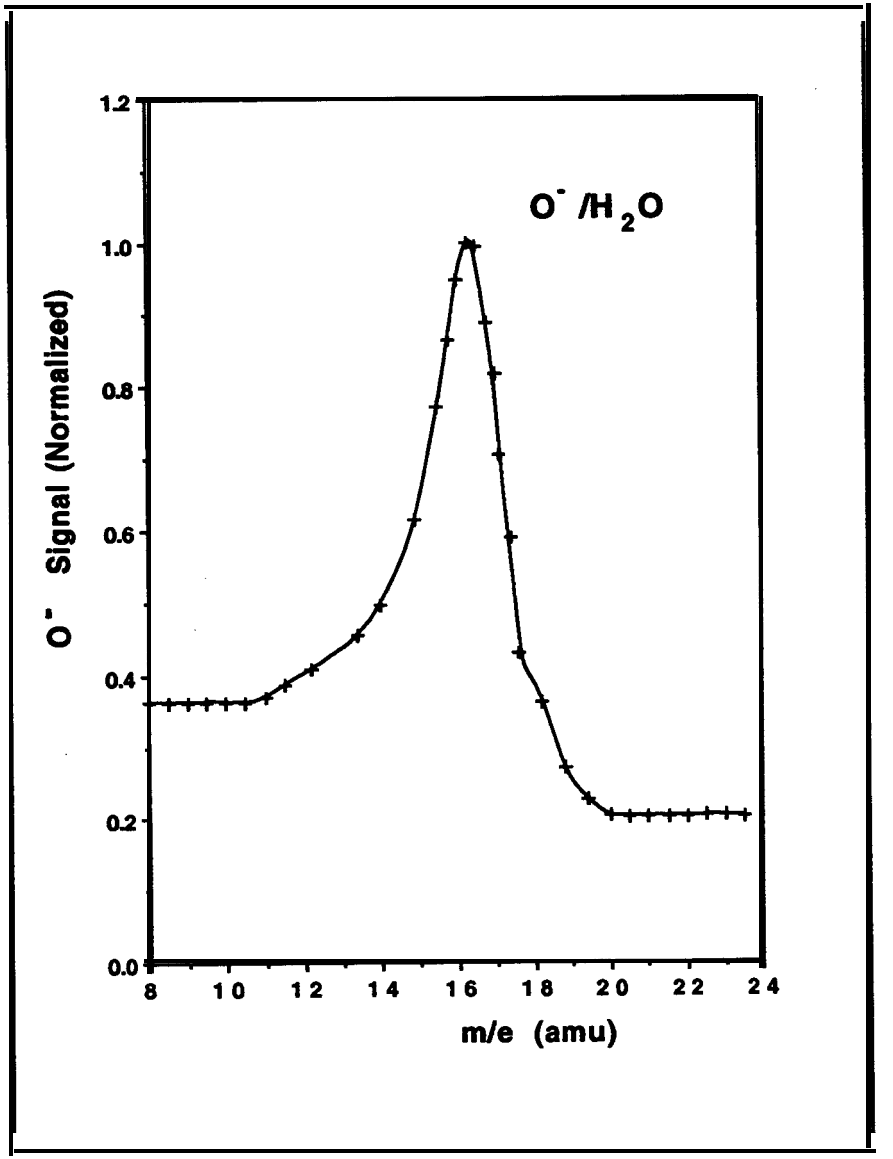
MASS SPECTRA OF O_2 AND H_2O





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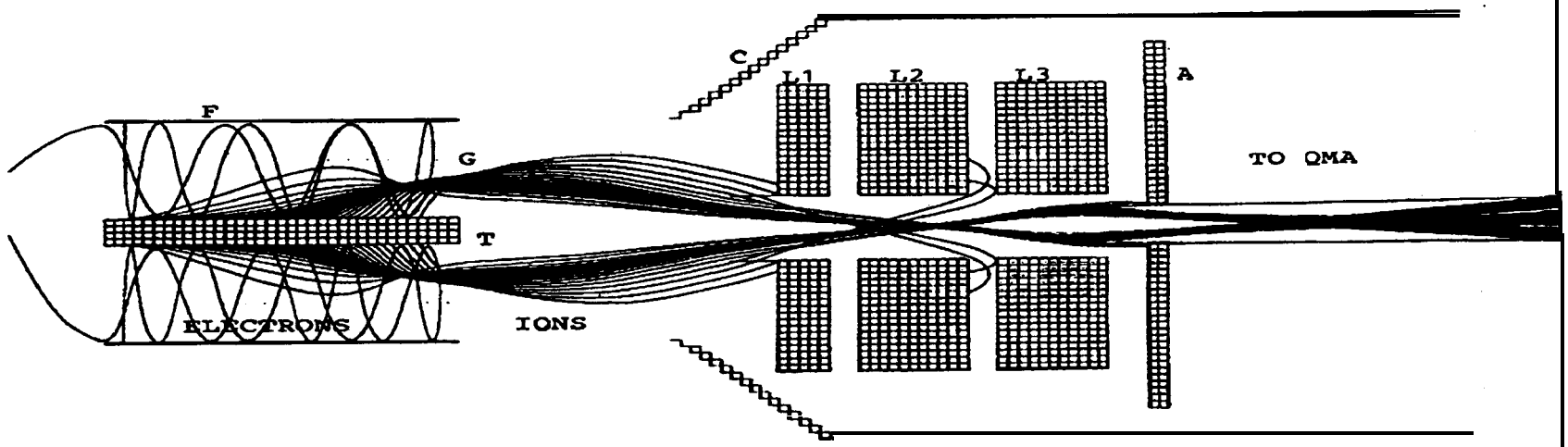
RAY TRACING SIMULATION FOR WATER VAPOR

Modeling with SIMION Program at E_R = 10.5 eV, EC=100V, L's=100, 400, 60V.



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FURTHER DEVELOPMENT

- Extend operational pressure to milli-torr.
- Use quadrupole array as interface to ionizer.
- Scale down dimension of ionizer to reduce path length.