Troubles with Electrostatics: How we lie to our students

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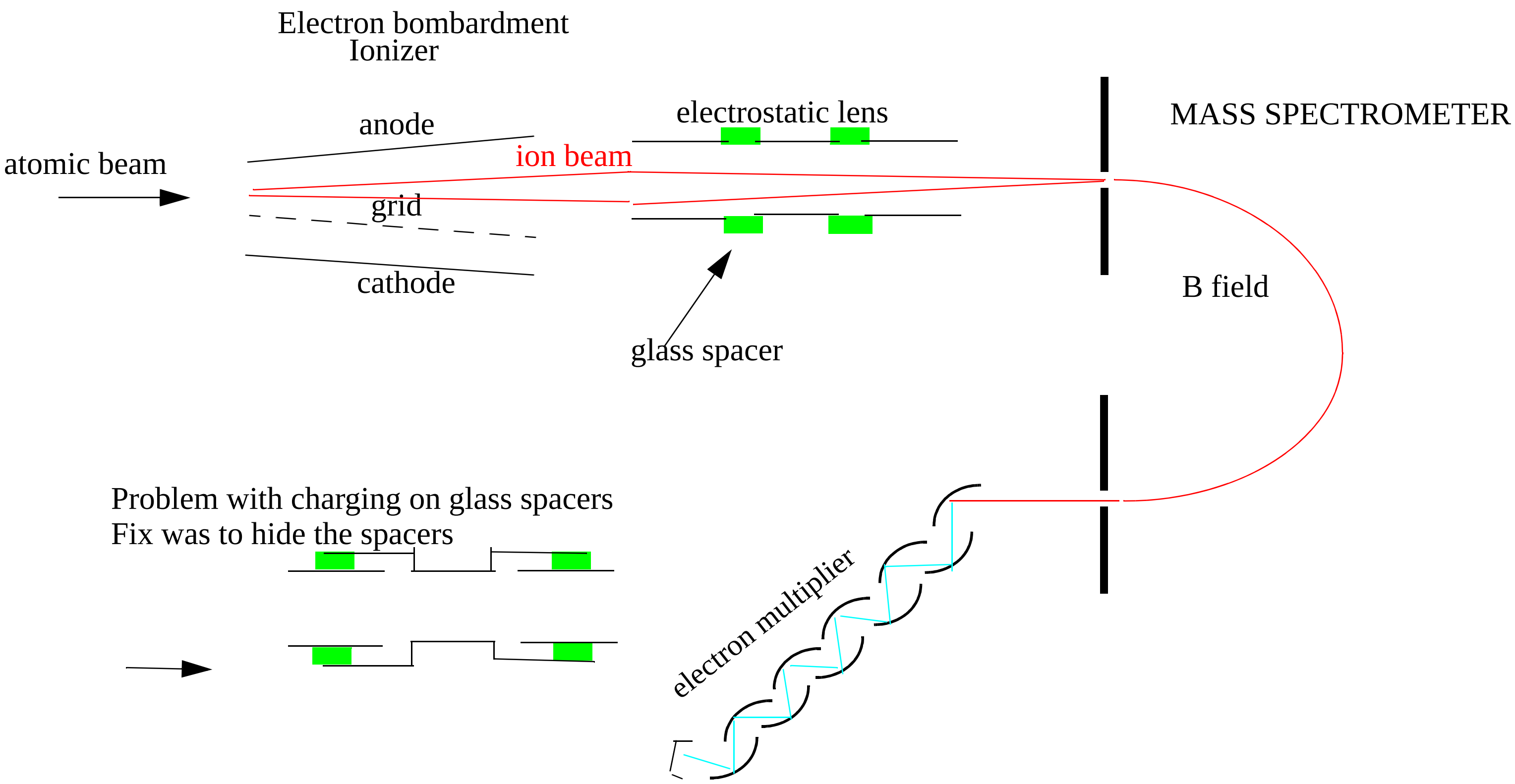
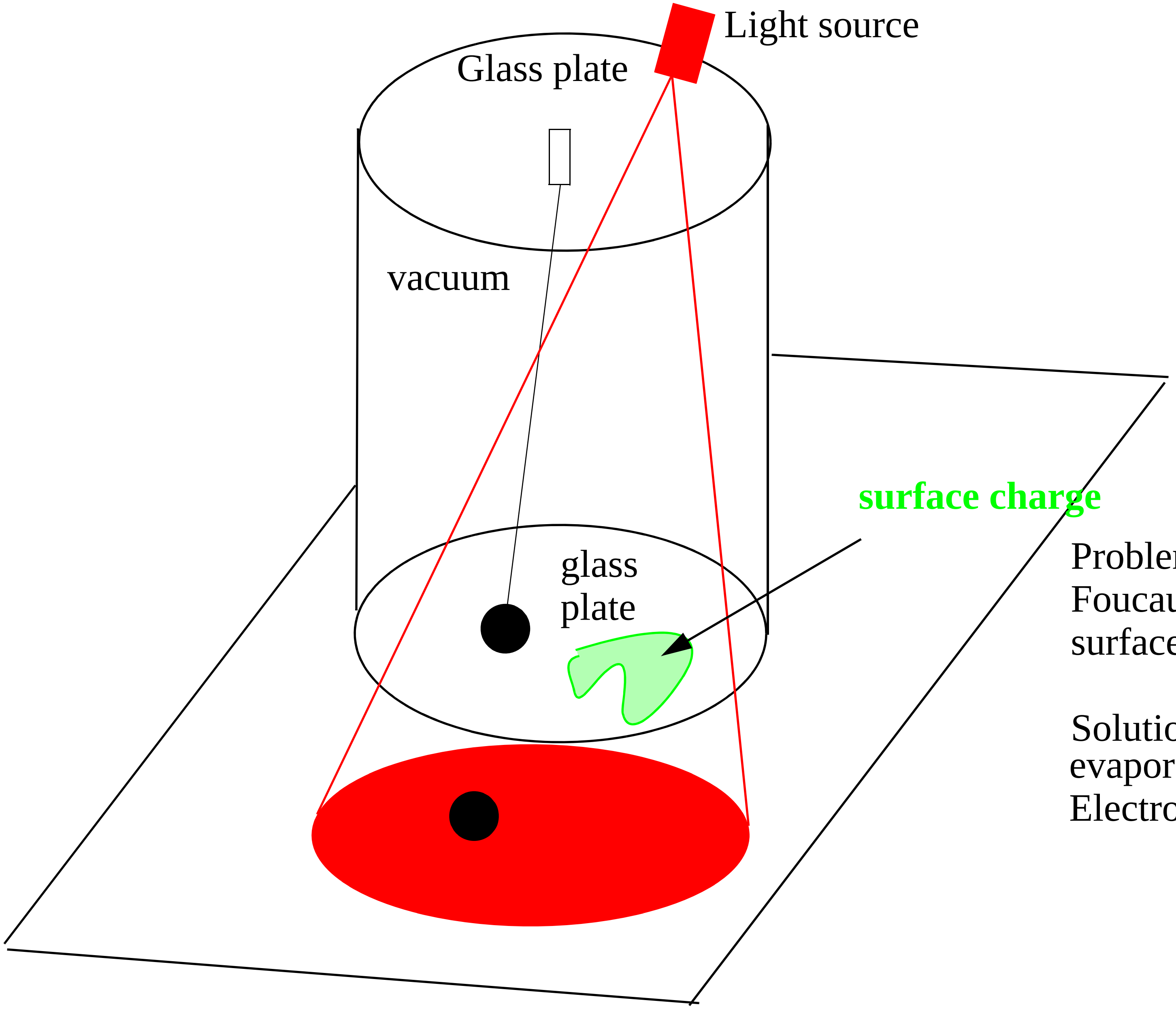
Outline

- The misinformation
  - Faraday cages are field free regions
  - Metallic surfaces are equipotentials
  - Insulators are not ambiguous
- Some examples in my experience
- Primitive model of electrostatic noise
- Some ambitions

Universal Ionizer for atomic beams and mass spectrometer



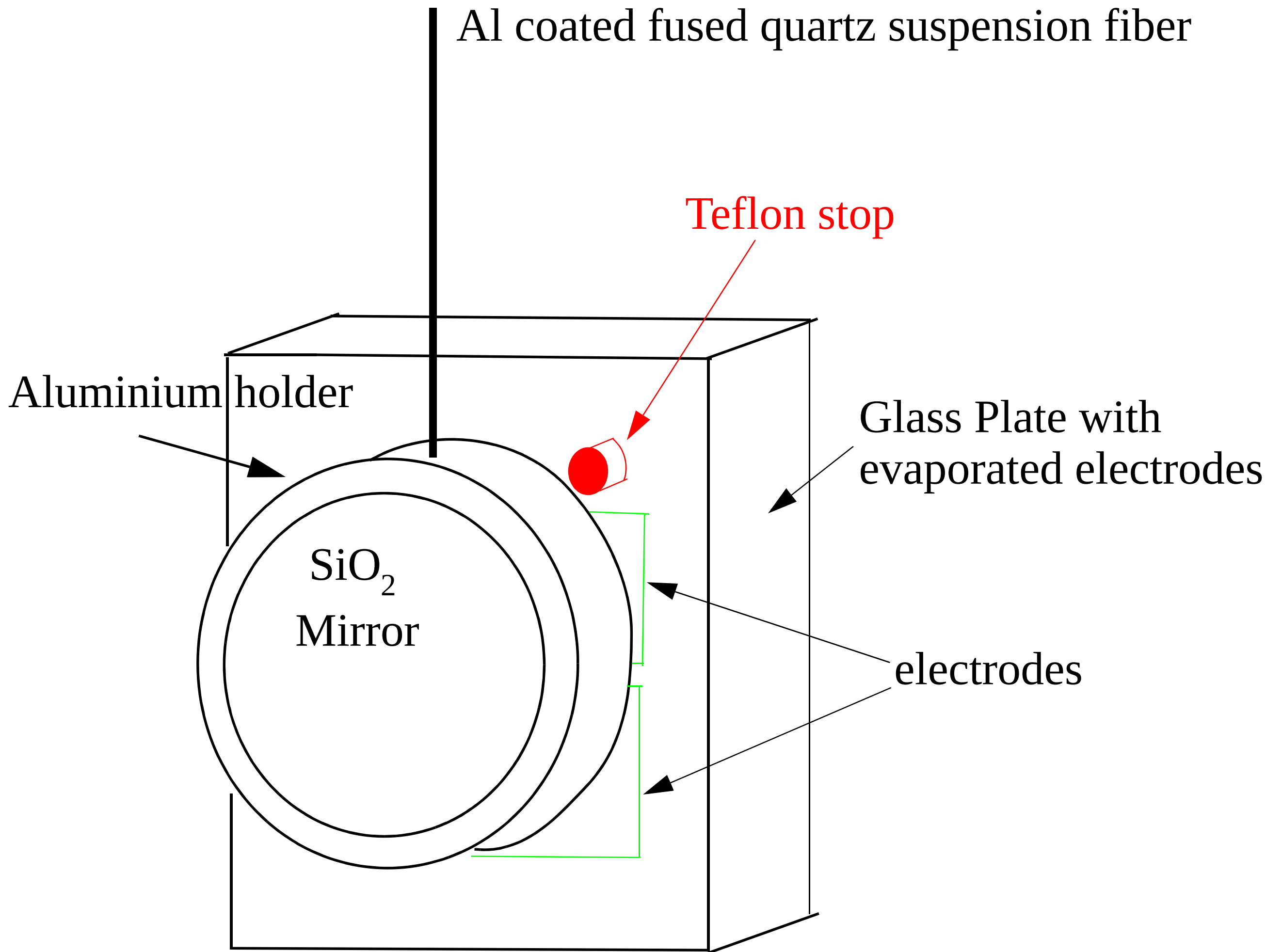
Evacuated Foucault Pendulum



Problem: Pendulum kept poor Foucault time because of surface charge layer on glass.

Solution: $SnCl_2$ film evaporated onto surface. Electrolytic conduction

1.5 meter prototype interferometric gravitational wave detector



Problem: Triboelectric charging on Teflon producing torque on suspension.
Fix: Replace with BUNA conducting rubber .

Primitive model of electrostatic fluctuating forces on insulators

Markov Process: Charge hopping on surface driven by surface charge electric fields.

Step time or relaxation time: $\tau_0 = \frac{\varepsilon}{\sigma} = \varepsilon_0 \kappa \rho$

on clean SiO_2 : weeks to years in vacuum

Average Force:

$$\langle F \rangle = \frac{E^2_{surface} A}{16\pi^2}$$

Fluctuating Force from charge hopping

$$F^2(f) = \frac{2\langle F^2 \rangle}{\pi\tau_0\left(\left(\frac{1}{\tau_0}\right)^2 + (2\pi f)^2\right)}$$

Leads to

$$x(f) \propto \frac{1}{f^3}$$

when f >> 1/τ_0 (Rupal Amin talk)

Typical surface charge densities in good vacuum

$10^{-14} < \sigma_{surface} < 10^{-10}$ Coulombs/cm^2 $\quad 10^5 < e_{surface} < 10^9$ electrons/cm^2

Conclusions and recommendations

- Avoid exposed or unguarded dielectrics in a precision experiment !
- If no other way, try to equalize the Fermi energy of touching surfaces (reduce triboelectricity).
- Best solution: find a slightly conducting (Gohms/square) film to cover the optics, fibers and dielectric clamps with little compromise to absorption and thermal noise, most likely electrolytic films.
- Use AC polarizing and control voltages in electrostatic controllers .
- If no way out, contemplate field terminating surfaces that have common motion – a tube in front of mirror

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4. *The Generation and Dissipation of Static Charge on Dielectrics in a Vacuum* D. K. Davies, in *Static Electrification Conference Proceedings* London, May 1967, Institute of Physics and Physical Society Conference Series # 4

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