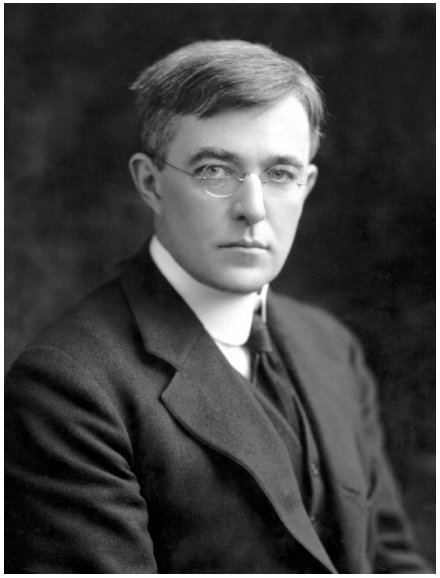
Gas Discharge Lamps – A Requiem

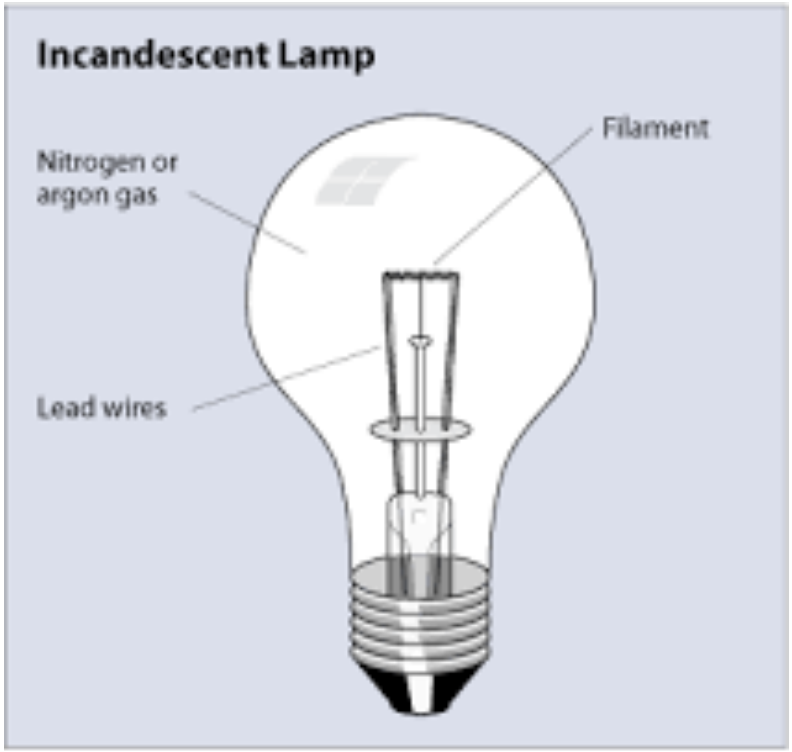
Graeme Lister – Lighting Consultant

The Physics of Discharge Lamps
G G Lister, J E Lawler, W.P. Lapatovich, V Godyak
2004, RMP **76**, 541

The Incandescent Lamp

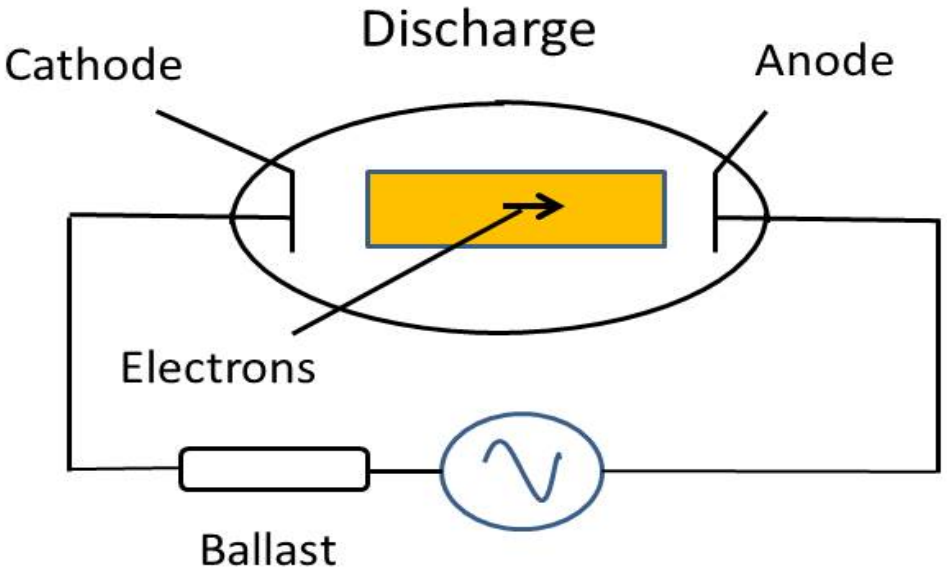


Irving Langmuir,
Perfected the
incandescent lamp, 1923



The incandescent lamp is the oldest and most common type of lamp. Light is emitted when electricity flows through—and heats—a tungsten filament.

Gas Discharge Lamps



Low Pressure Discharge Lamps

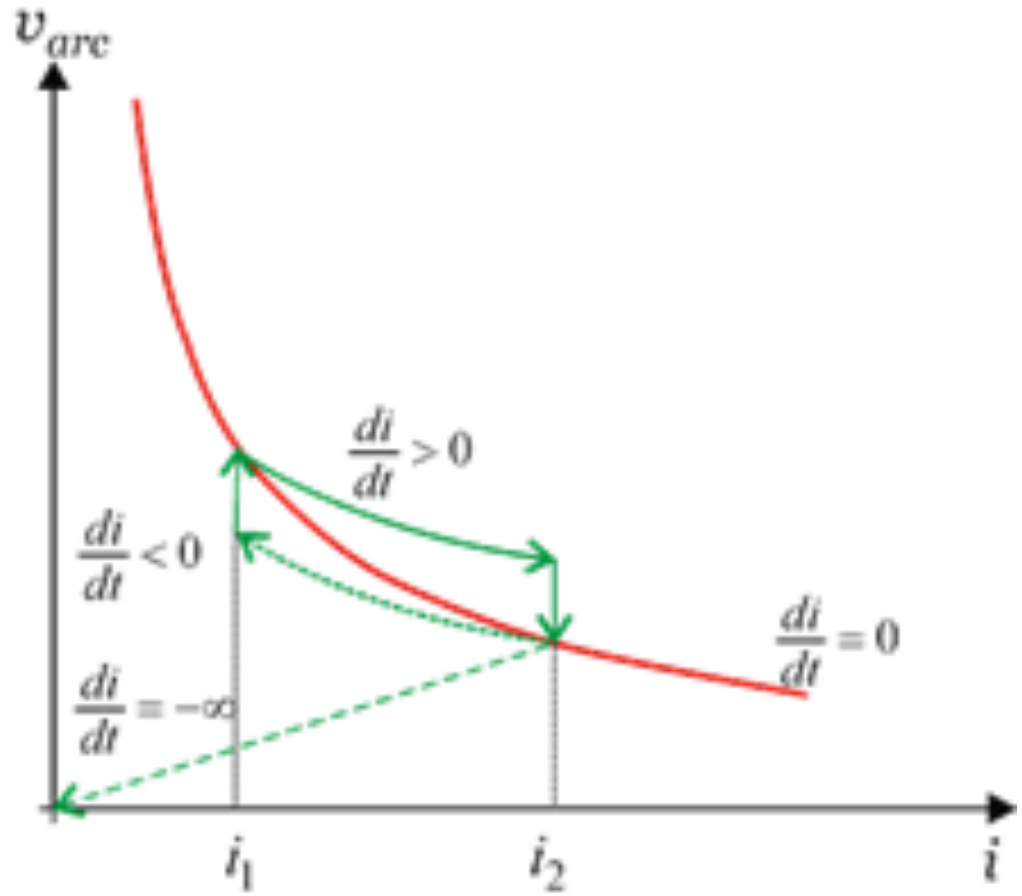
Fluorescent Lamp
Low power density, long

High Intensity Discharge (HID) Lamps

Metal Halide Lamps
High power density, short

Life of all gas discharge lamps limited by the electrodes

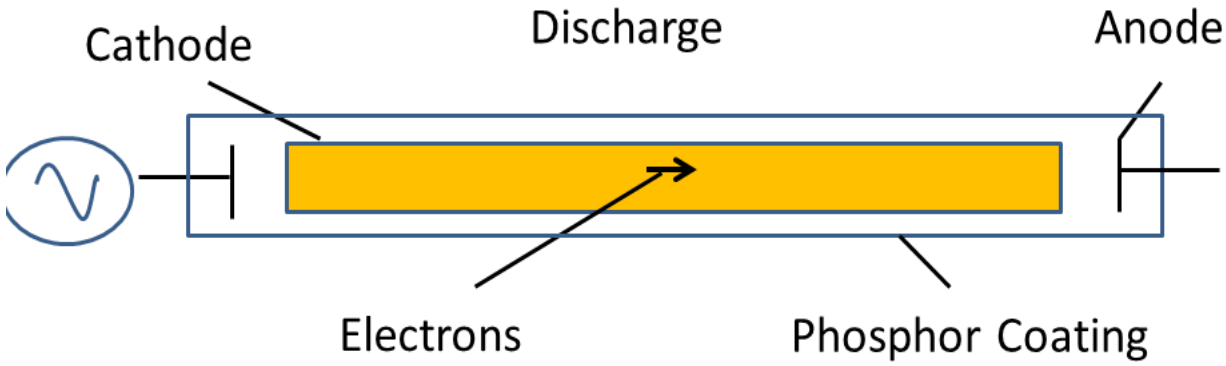
V-I Characteristic in the Positive Column



Negative Glow

- Cayless, Lister and Coe – “beam” model
- Ingold – Diffusion model
- Wamsley – Experimental measurements

Fluorescent Lamps



70 % electrical energy → UV (Hg atoms)

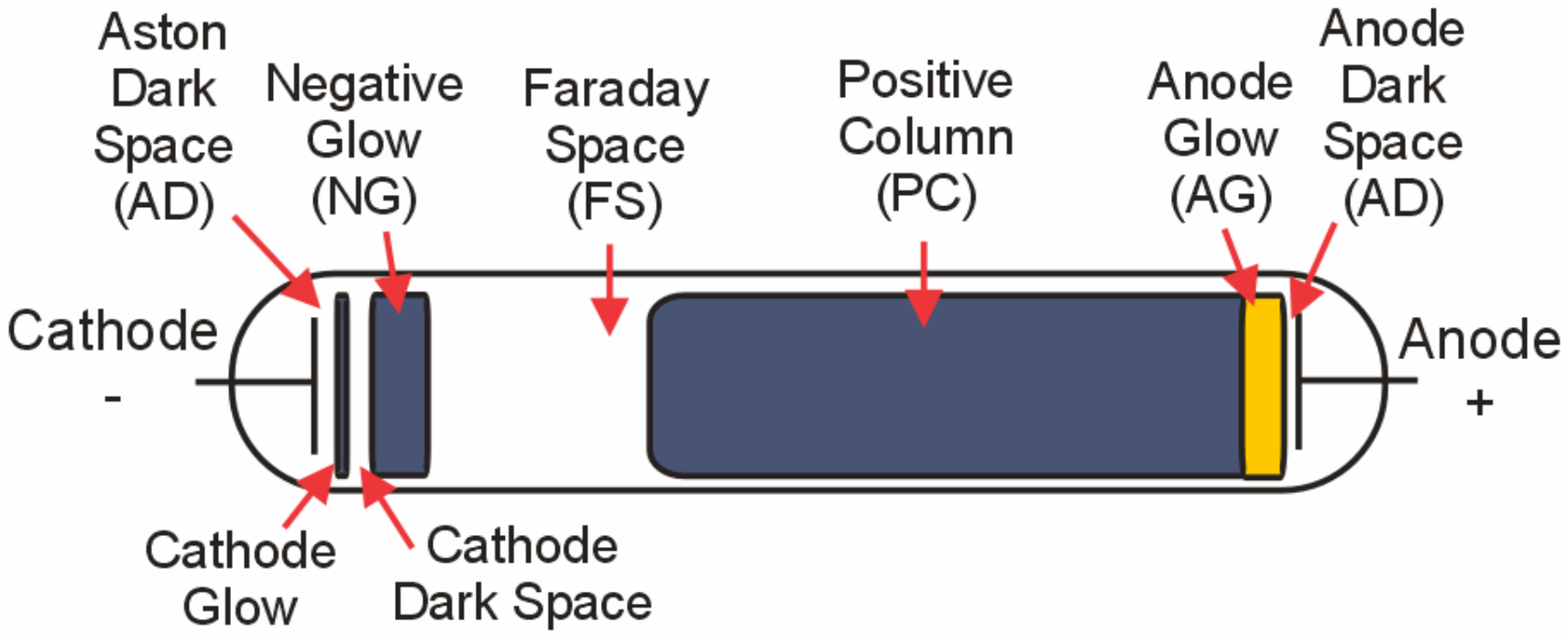
UV → Phosphor, 25 % visible light

7 % Heat loss to electrodes

Electrical power 35 W/m
i.e. 35 W lamp is 1 m long

Buffer gas (Ar) 3 torr Hg 7 micron

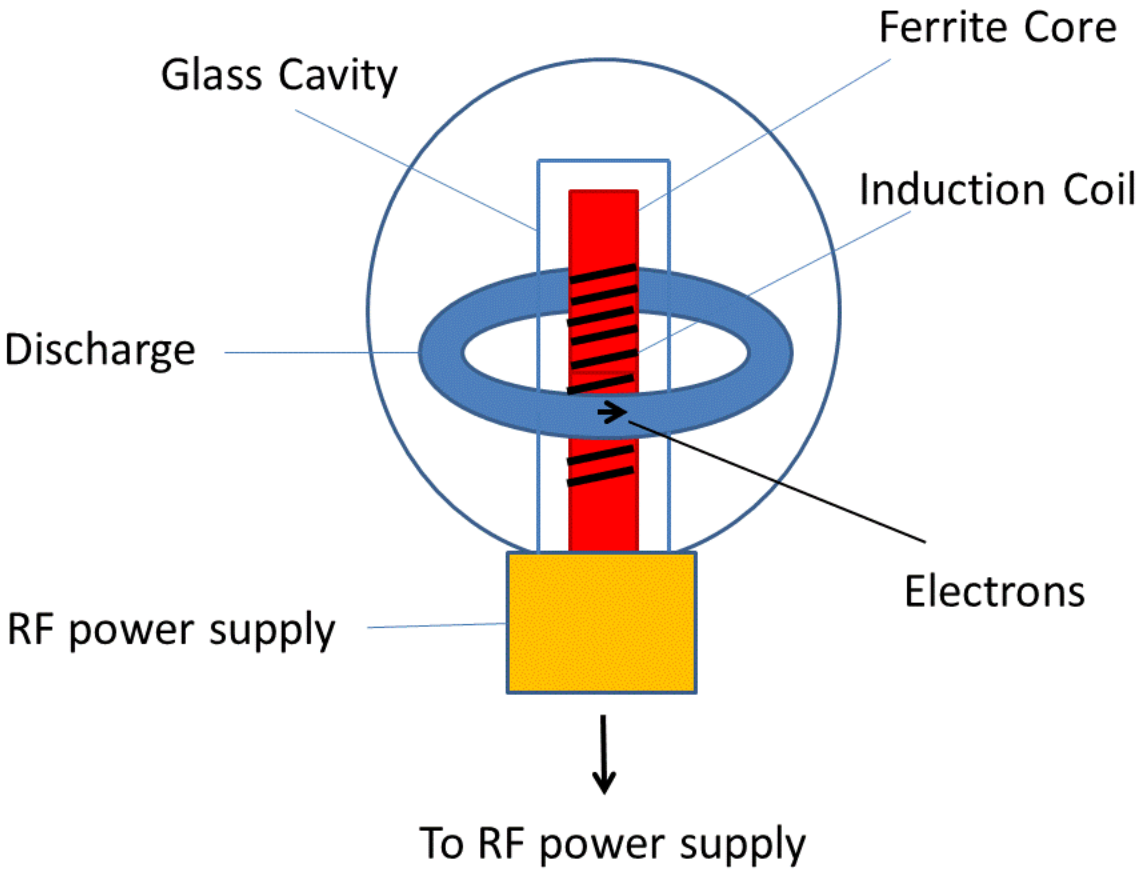
Gas Discharge



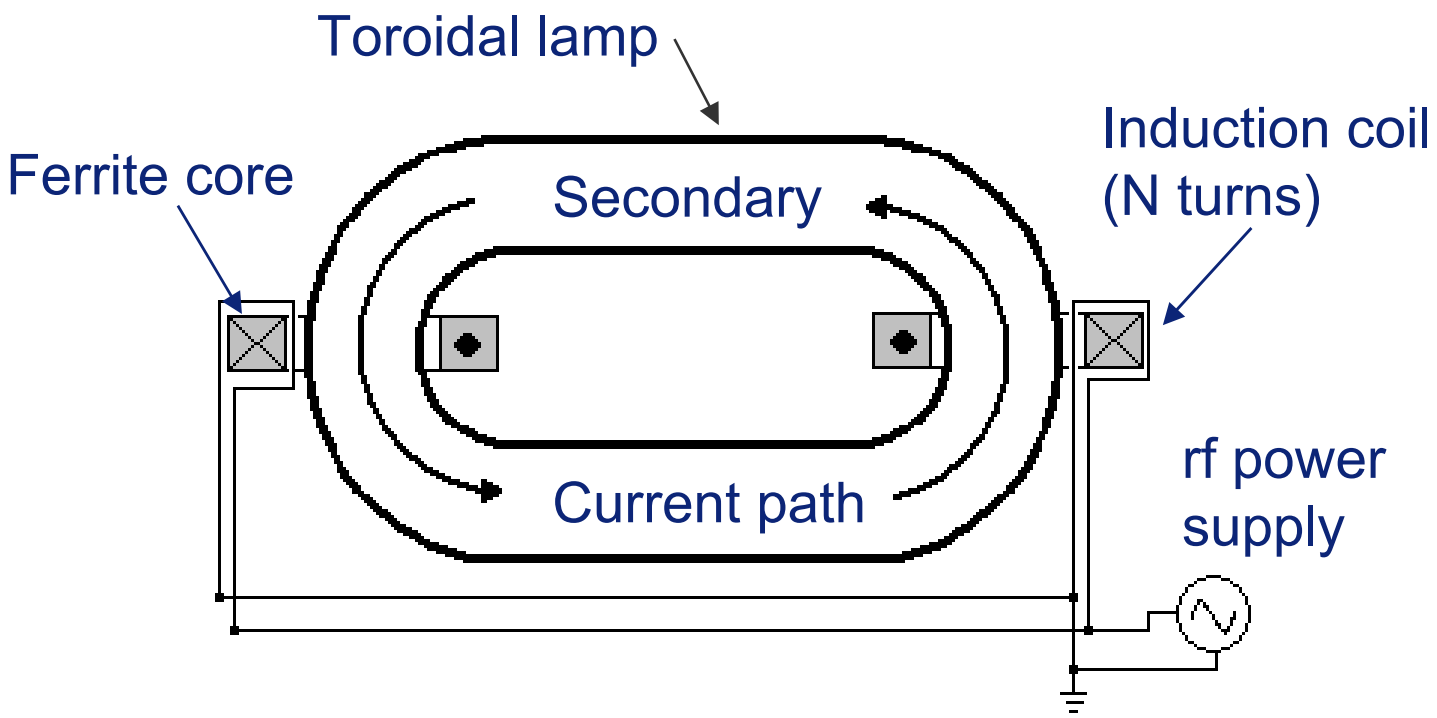
Fluorescent Lamp Electodes

- Conventional FL - lifetime 20,000-40,000 hours
- Two solutions
  - Remove electrodes
  - Improve electrode performance
- Current FL have up to 100,000 hours life

Re-entrant Cavity FL



“Racetrack” EFL



“Highly Loaded” I = 7 A (cf 500 mA)

EPRI/ALITE Lighting Consortium

Research in the Basic Science of Commercial Light Sources to Achieve Major Breakthroughs in Performance and Efficiency

Duration:
- October 1997 through September 2000

Topics:
- Radiation Trapping and Fundamental Atomic Processes in Low Pressure Discharge Lamps
- Atomic Data for Rare Earth Elements

Participants

- Electric Power Research Institute (EPRI)
- OSRAM SYLVANIA INC. (OSI)
- University of Wisconsin, Madison (UW)
- Polytechnic University of New York (PU)
- National Institute of Standards and Technology (NIST)
- Los Alamos National Laboratory (LANL)

Projects

UW	• Resonance radiation trapping (Hg, Ba) - modeling and experiment
	• Spectroscopy of highly loaded fluorescent lamps
PU	• Chemi-ionization experiments (Ne, Hg)
LANL	• Atomic physics computations (Ne, Hg, Ba)
NIST	• Absolute spectroscopic measurements (Hg)
OSI	• Lamp discharge modeling

Radiation Trapping

- Generalised resonance radiation trapping formula
    - Foreign gas broadening
    - Partial frequency redistribution
    - Cataphoresis
- 185 nm radiation – special treatment

Simple formulae for application in numerical models

Important Cross Sections

Electron Impact

$e + Hg \rightarrow e + Hg^*$ (Rockwood)

$e + Hg^* \rightarrow e + Hg^{**}$ (Kenty)

Quantum (CCC) Calculations (Flinders U)

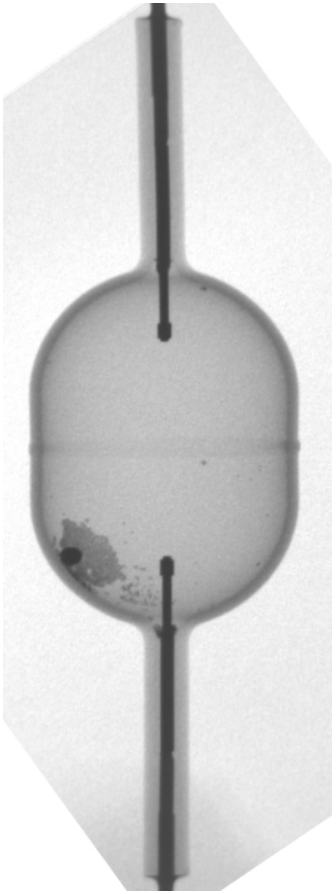
Chemi-Ionization

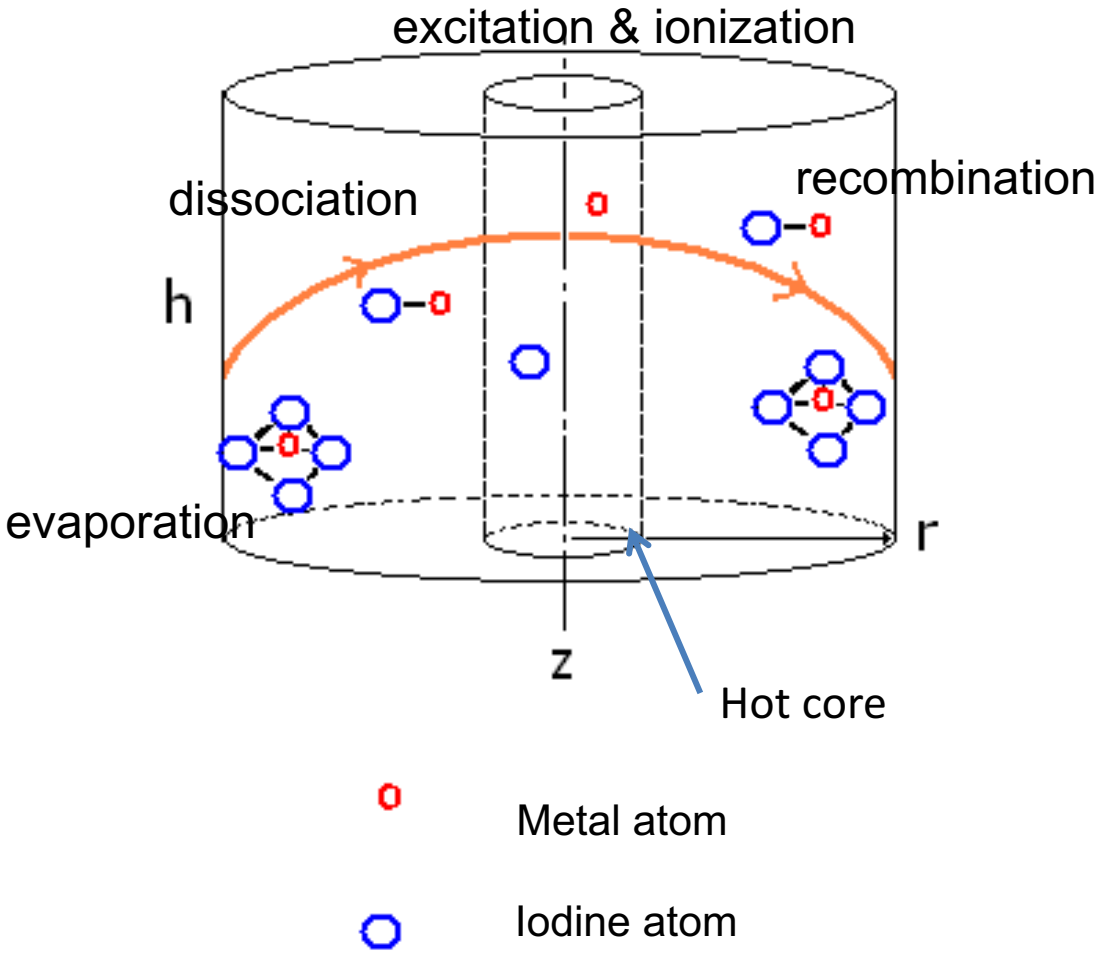
$Hg(3P_x) + Hg(3P_x) \rightarrow Hg+ + Hg(3S_0)$

$Hg_2+ + e$

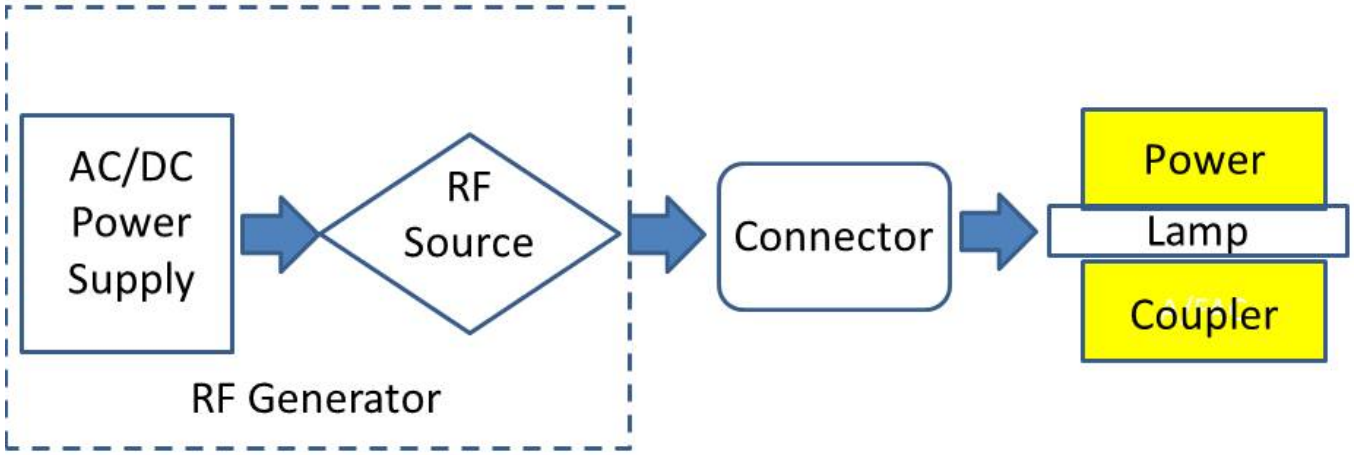
Calculations (LANL)
and measurements (Polytechnic U)

MH Lamp Operation



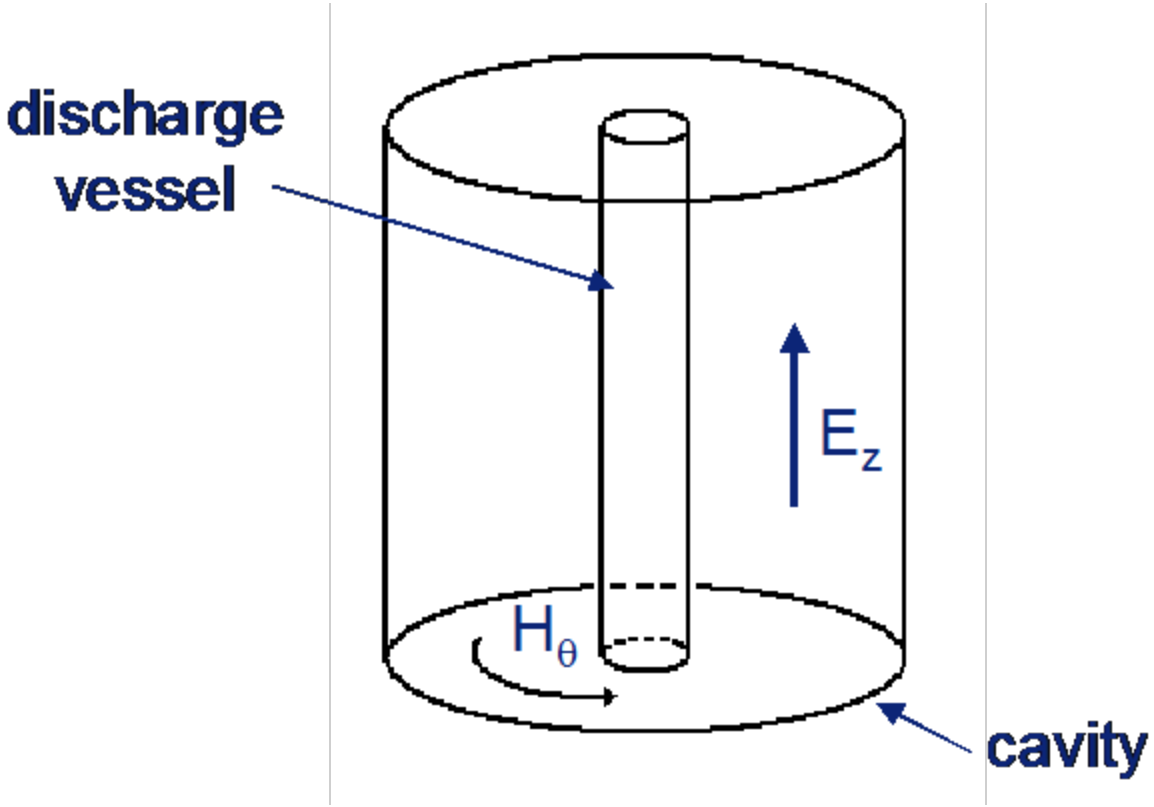


Plasma Lighting

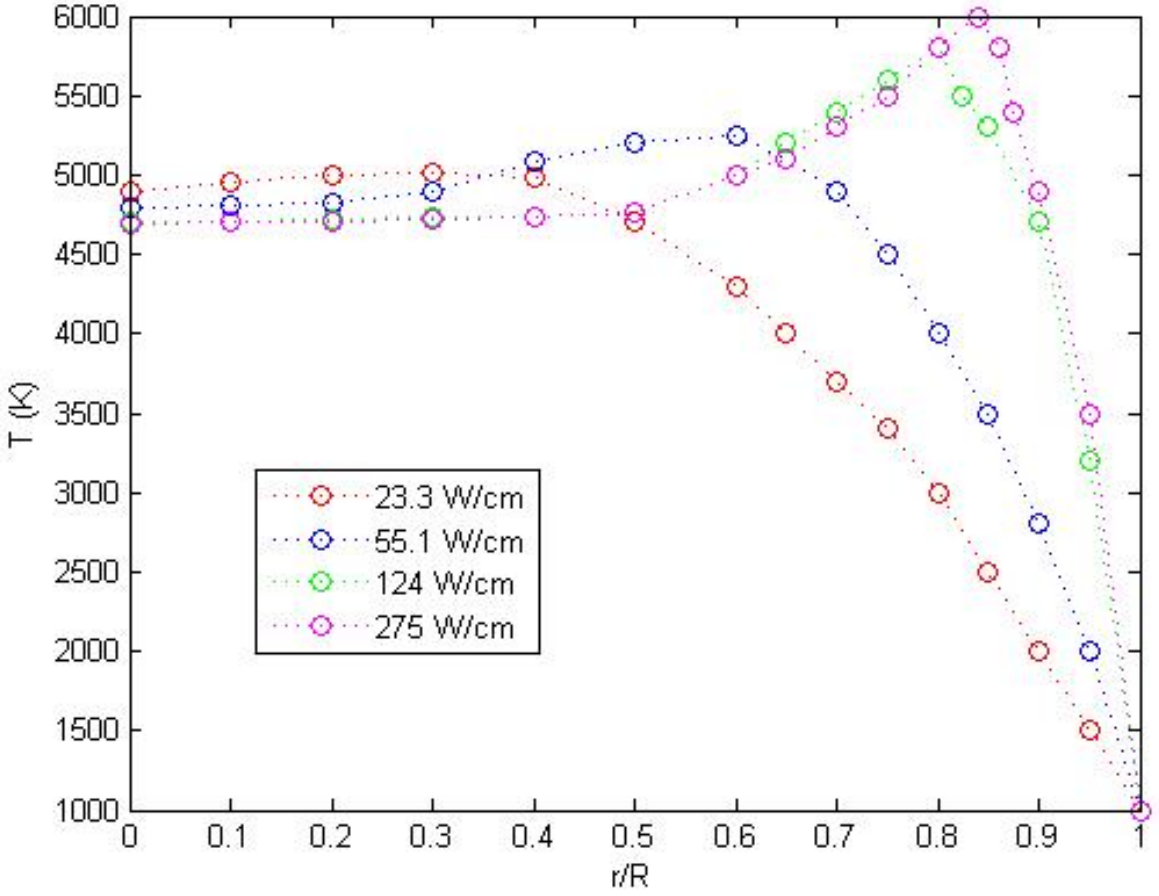


Magnetron	2.45 GHz
SS Electronics	433 MHz

Resonant Cavity TM_{010} Mode



Temperature Profiles



Waymouth, JF (1993) *Microwave discharges, fundamentals and applications*, edited by C.M. Ferreira and M. Moisan, NATO ASI

The Future of Gas Discharge Lighting?

Horticultural Lighting

- Vegetables and fruit can be produced in urban areas
- Most economically viable are plants with high water content – tomatoes and lettuce
- Legalization of cannabis in many states
- Plant growth sensitive to spectrum
- “Taste” influenced by UV A and UV B
- MH Lamps can provide “ideal” spectrum
- Much research still needed

Conclusions 2015

- Gas discharge lighting is alive and well
- Innovative solutions can provide new proiducts
- Gas discharges can challenge LEDs at higher electrical power
- Bright future for gas discharges as UV sources

Conclusions 2018

- LEDs now 200 lpw and cheap
- Gas discharge lighting cannot compete for general lighting
- Replacement of “legacy lighting” will be slow
- Gas discharge lighting can still address “niche” markets
- No new investment in gas discharge lamp research for general lighting
- “Window of opportunity” for horticultural lighting