[NWP.019]

Radial Cataphoresis in Hg-Ar Fluorescent Lamp Discharges at High Power Density

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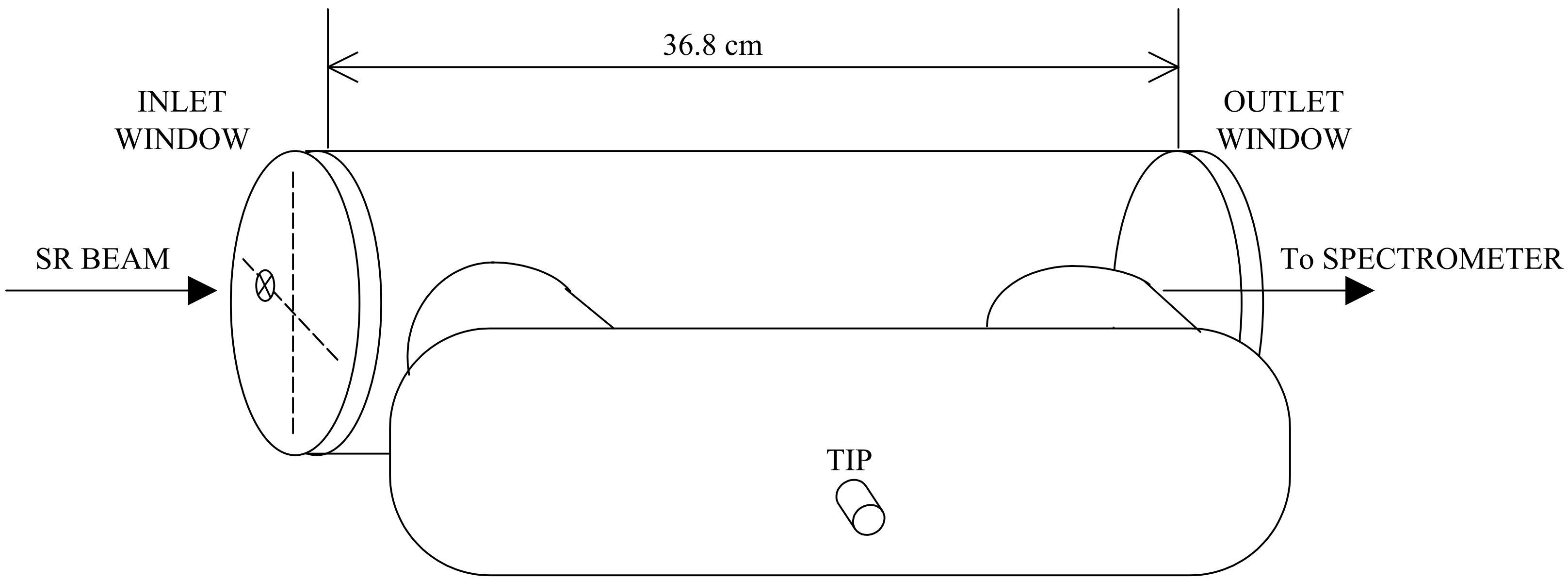
ABSTRACT

Radial cataphoresis is a process in which the lower ionization potential atoms (Hg) are preferentially ionized and expelled from a multi-component (Hg-Ar) discharge. This process is important at high power densities which occur in some types of fluorescent lamps (e.g. the electrodeless Endura/Icetron lamp developed at Osram Sylvanic Inc.). Recent attempts to reconcile extensive absolute measurements on Icetron lamp discharges with self-consistent numerical models were only partially successful [2]. Radial catphoresis as well as some other high power density phenomena need to be re-examined. We have set up an axial absorption experiment at 185 nm on the ground level Hg atoms in an operating Icetron lamp. The High Sensitivity Absorption Spectroscopy (HSAS) facility at the Synchrotron Radiation Center in Stoughton WI is used in this study. The HSAS facility provides an intense synchrotron radiation continuum, very high spectral resolving powers from a 3 m focal length vacuum echelle spectrometer, and superb S/N ratios from a CCD detector array. Preliminary results will bepresented and discussed.

[1] Supported by the NSF amp; USHIO Inc. Experimental lamp provided by OSRAM-SYLVANIA Inc. [2] J. J. Curry, G. G. Lister, J. E. Lawler, J. Phys. D: Appl. Phys. 35, 2945 (2002)

Experimental Lamp

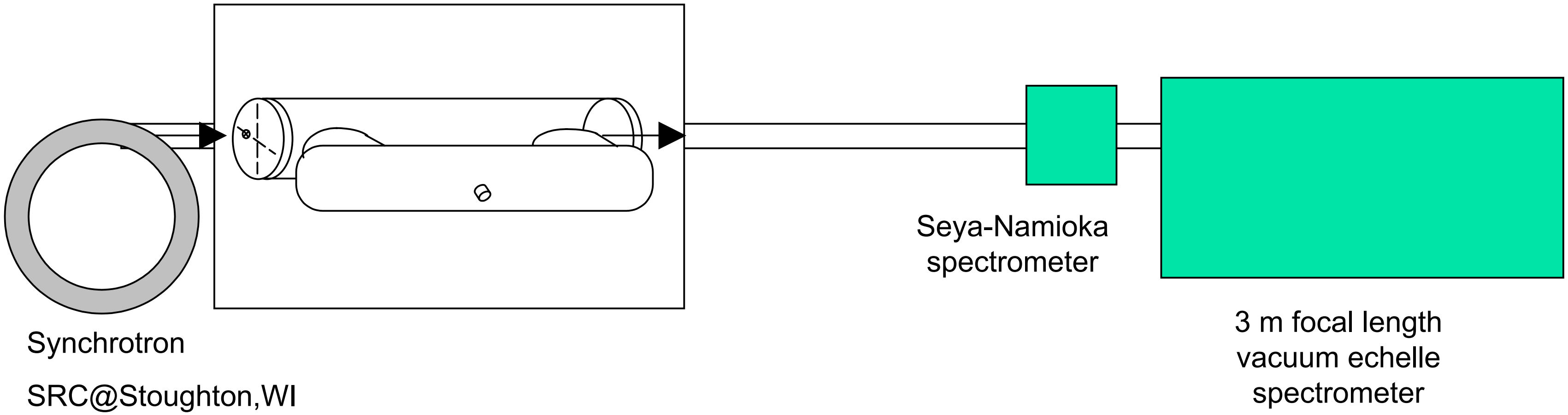
- Experimental lamp has two flat HIGH QUALITY Suprasil windows at the end of one arm.
- No phosphor
- Ar 40Pa(300mTorr) + Liquid Hg
- Hg pressure is controlled by tip temperature.



The High Sensitivity Absorption Spectroscopy (HSAS) facility

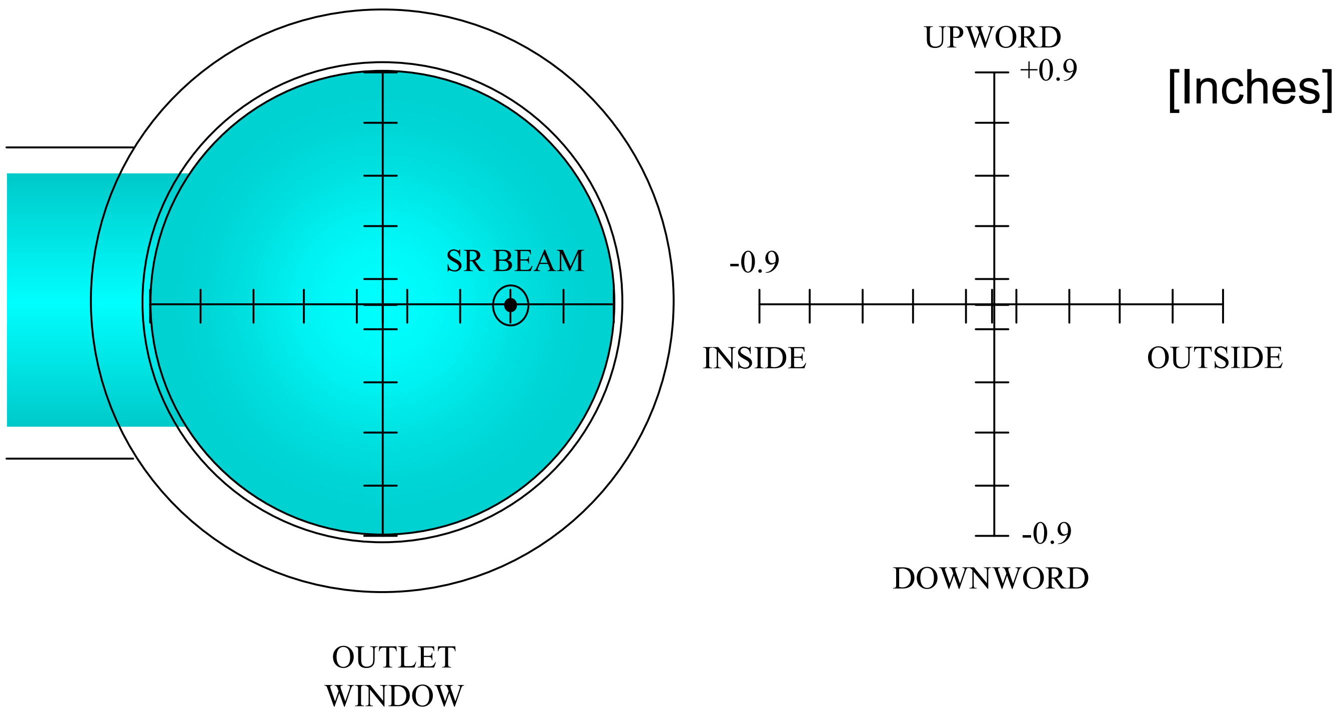
The High Sensitivity Absorption Spectroscopy (HSAS) facility at the Synchrotron Radiation Center in Stoughton WI

- Light Source : Synchrotron radiation (SRC)
- Spectrometer: Seya-Namioka + very high spectral resolving powers from a 3 m focal length vacuum echelle spectrometer
- Detector : superb S/N ratios from a CCD detector array.
- Light path : Vacuum or N2 flushed (Lamp Box)



Position of measurements

- **Lamp is on mechanical translation stage**
- **Measure in two dim., vertical and horizontal.**
- **Synchrotron Radiation (SR) gives beam divergence and cross section (beam ~Φ1mm)**



Spectrum Analysis (1)

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Problem : Establishing a reliable zero absorption background

- When the lamp is off, there is still Hg vapor which absorbs the SR beam.
- If the lamp is removed from the optical path, the alignment is changed and O2 absorption becomes a problem.

Solution

- Assume intensity of the SR is the same at nearly wavelengths.
- Background spectrum can be measured without turning off the lamp.

$$Absorption \quad Spectrum$$

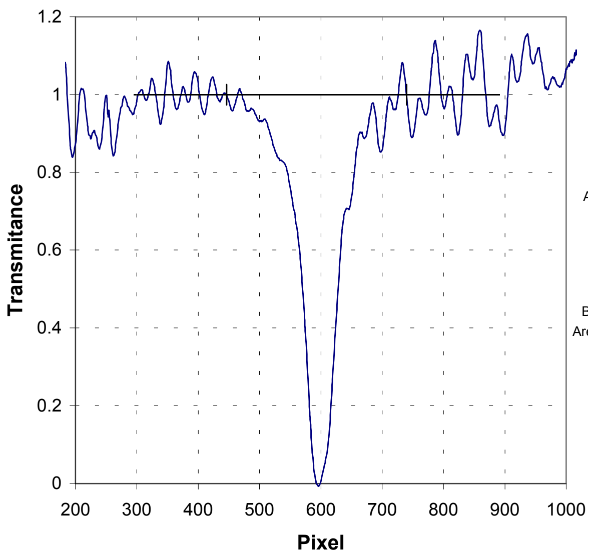
$$I = \frac{[SR + Lamp]_{\lambda_{sp}} - [Lamp]_{\lambda_{sp}}}{[SR + Lamp]_{\lambda_{bg}} - [Lamp]_{\lambda_{bg}}}$$

$$Hg \qquad 6^1S_0 \Rightarrow 6^1P_1 \qquad 185nm$$

$$Hg^+ \qquad 6^2S_{1/2} \Rightarrow 6^2P_{1/2} \qquad 194.2nm$$

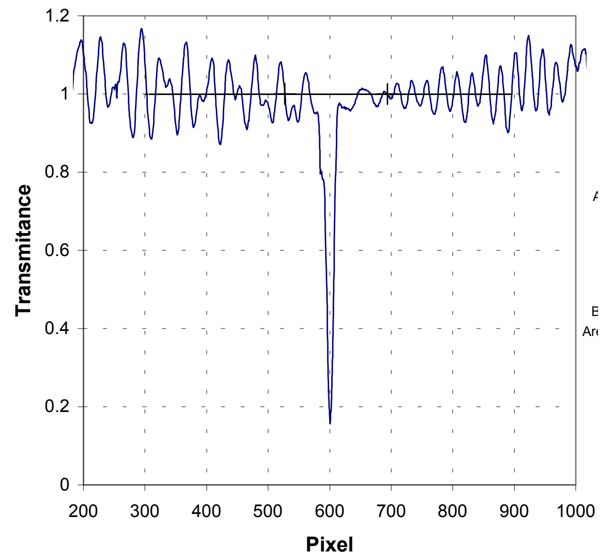
	Absorption spectrum	Background spectrum
Hg	185nm	186nm
Hg^+ ion	194.2nm	193nm

Spectrum Analysis (2)



Hg Absorption spectrum

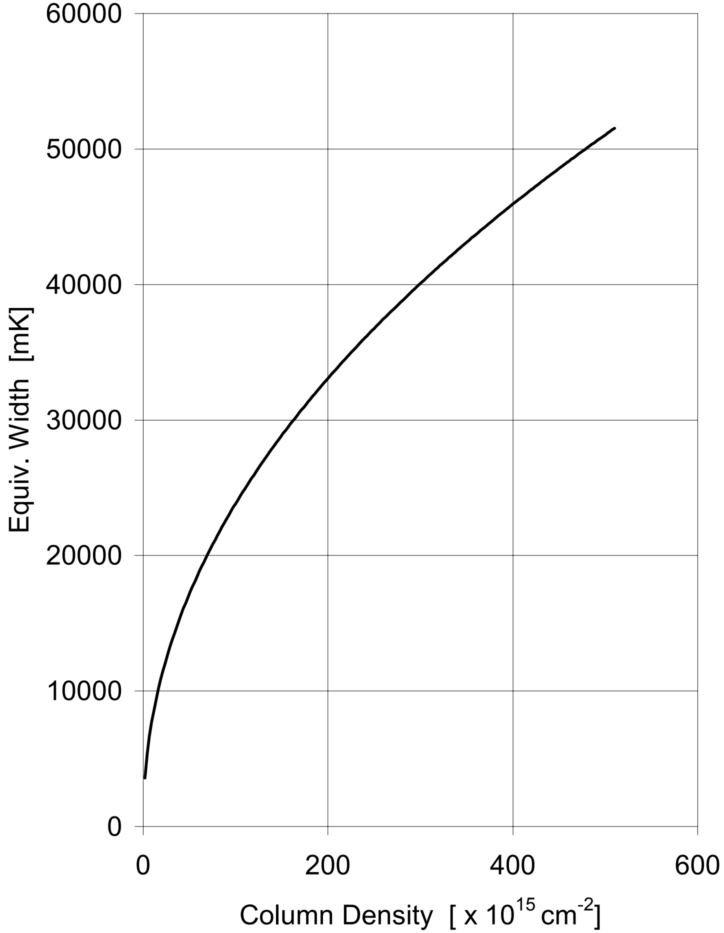
185nm



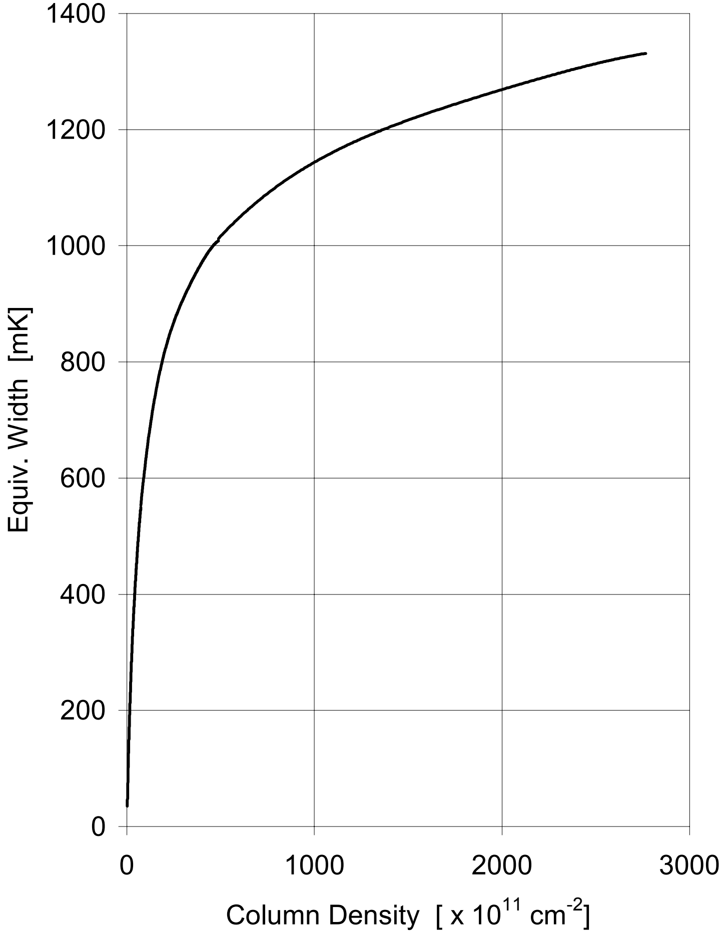
Hg^+ Absorption spectrum

194.2nm

Curve of growth



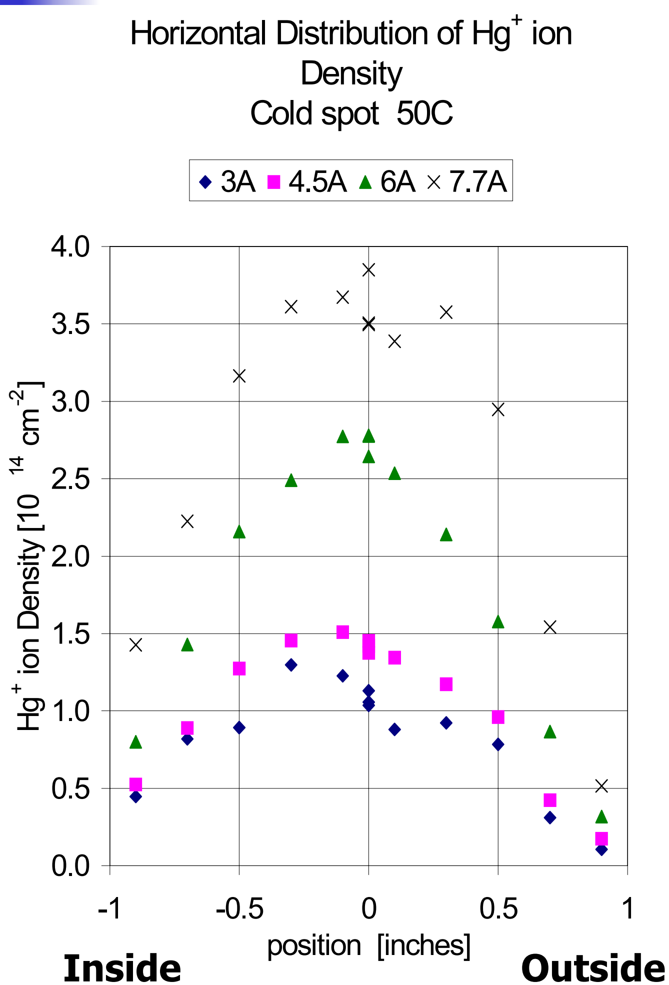
Curve of growth @ 185nm

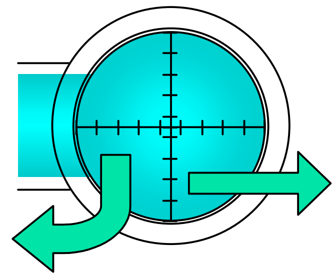


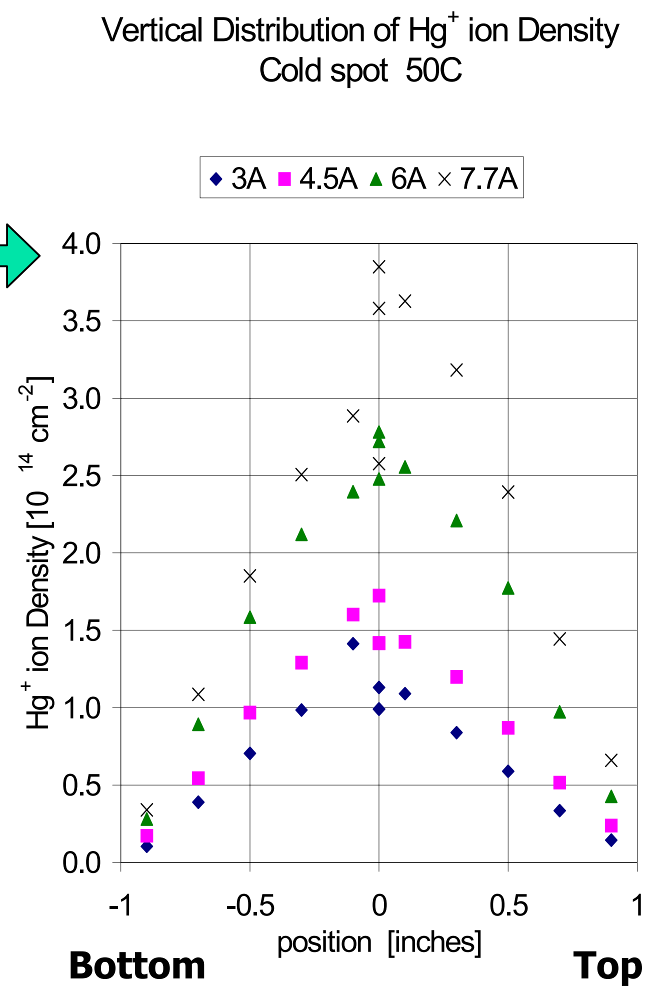
Curve of growth @ 194.2nm

Hg^+ Ion density vs. position

cold spot temperature = 50C° with various current





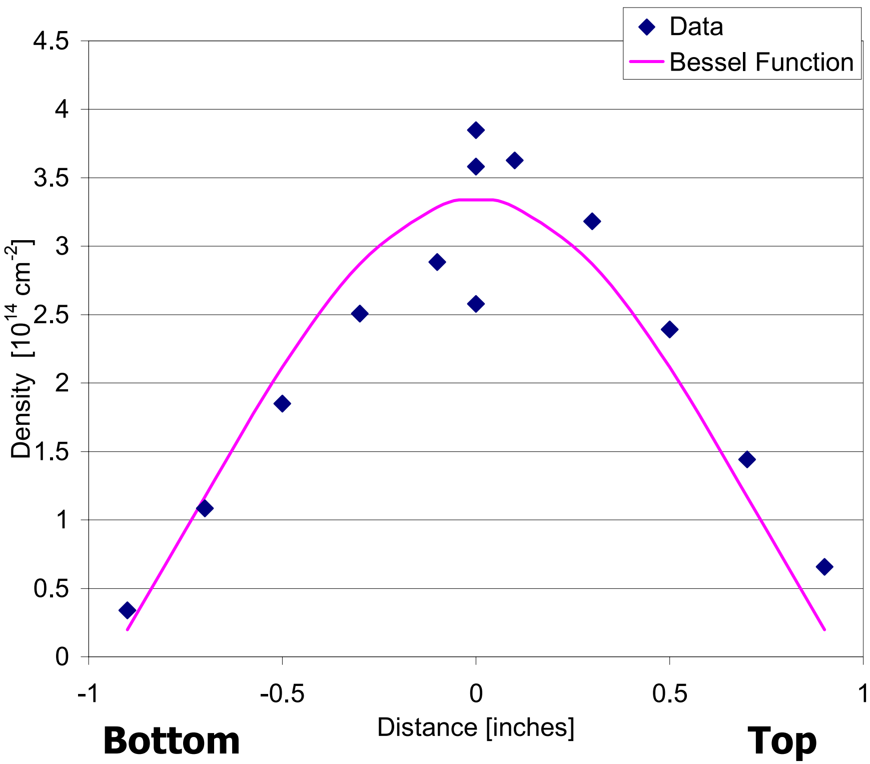


Fitting with Bessel function

- Assume cylindrical symmetry and lowest order ambipoler diffusion mode
- Hg^+ ion density distribution can be written as a Bessel function

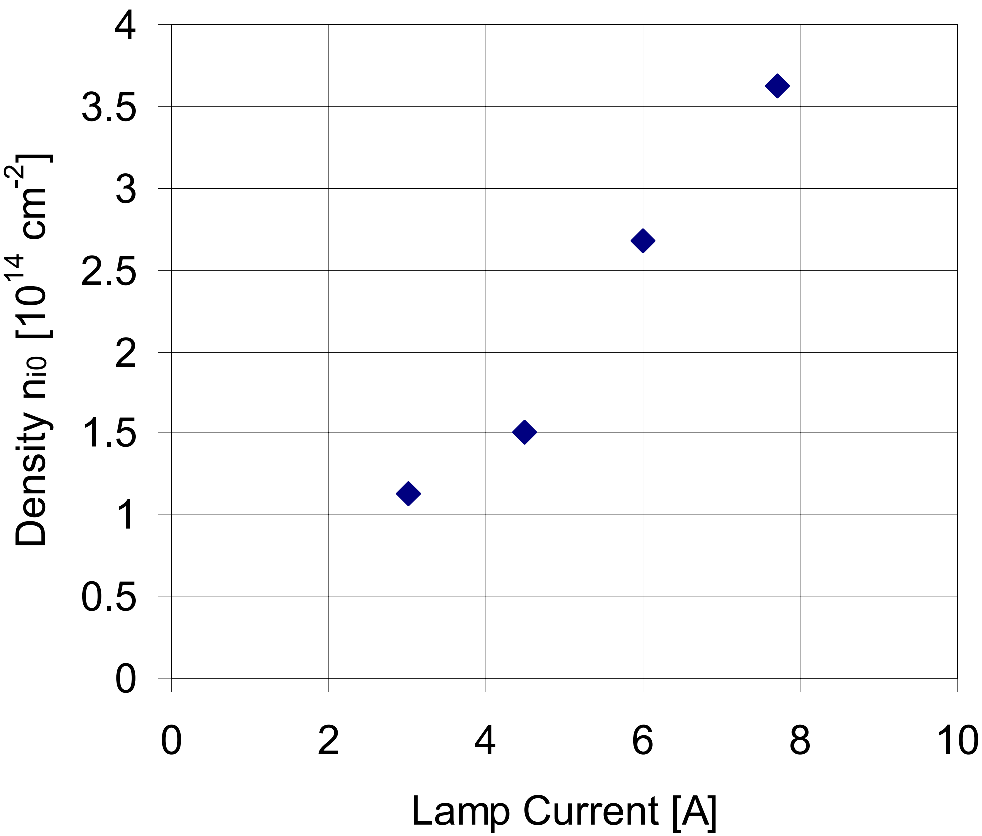
$$Density = n_{i0} J_0(x)$$

$$J_0(x) = \sum_{k=0}^{\infty} \frac{(-1)^k}{k!\Gamma(k+1)} \left(\frac{x}{2}\right)^{2k}$$



Hg^+ Ion density n_{i0} vs. Lamp Current

cold spot temperature = 50C° with various current



- Hg^+ ion density is almost linear to the lamp current

Data for Diffusion Equations

$$D_{Hg} N \frac{d}{dr}\left(\frac{n_{Hg}}{N}\right) = -D_a \frac{dn_e}{dr}$$

$$N_{Hg}(T,r) = N_{Hg0}(T) - \frac{D_a}{D_{Hg}} n_{e0} J_0\left(\frac{2.42r}{R}\right)$$

T	**cold spot temperature [K]**
R	**Radius = 0.9 [inches]**
r	**Position of radius [inches]**
N_{Hgo}	**# in vapor pressure**

Neutral Hg diffusion coefficient

$$D_{px} = 0.02956 \frac{D^0_{\rho k} T^{3/2}}{P_k} = 2.141\times 10^{21} \frac{D^0_{\rho k} T^{1/2}}{n_k}$$

Hg^+ ION diffusion coefficient

$$\mu_{ik} = 8.069 \frac{\mu^0_{ik} T^{1/2}}{P_k}$$

Assumption

- **Te=1eV=11600K**
- **$n_{i0}=n_{e0}$**

Ambipoler Hg diffusion coefficient

$$D_a = \frac{\mu_e D_i + \mu_i D_e}{\mu_e + \mu_i}$$

$$\mu_e >> \mu_i$$

$$T_e >> T_i$$

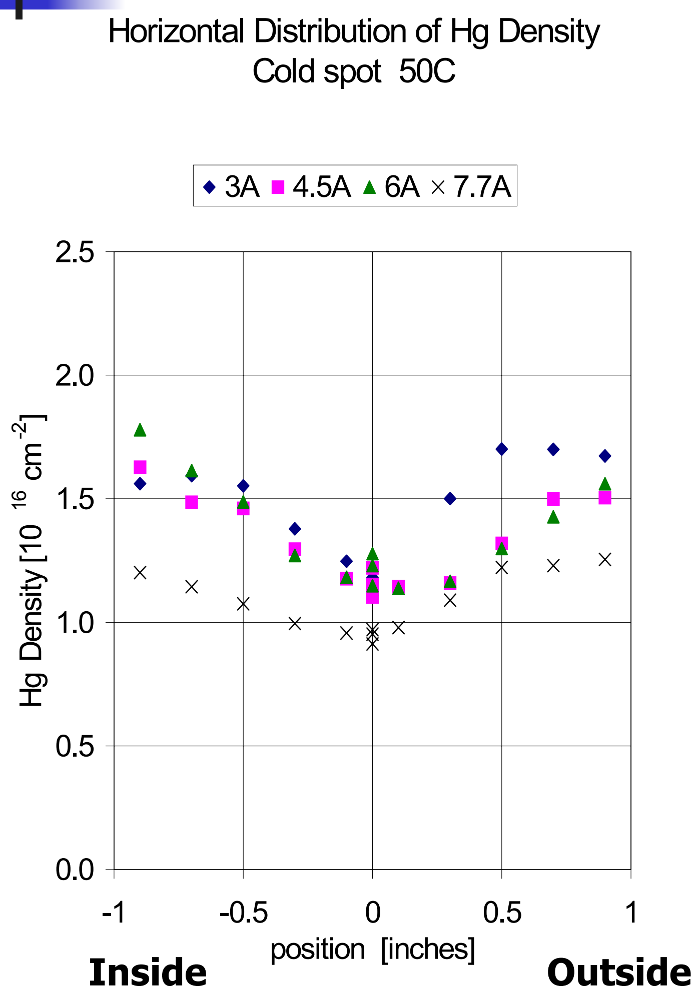
$$D_a \cong D_i + \frac{\mu_i D_e}{\mu_e}$$

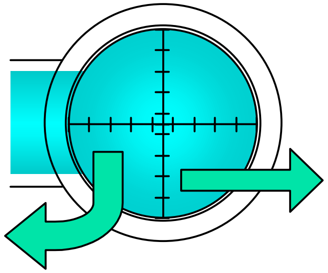
$$\approx D_i + \frac{T_e}{T_i} D_i$$

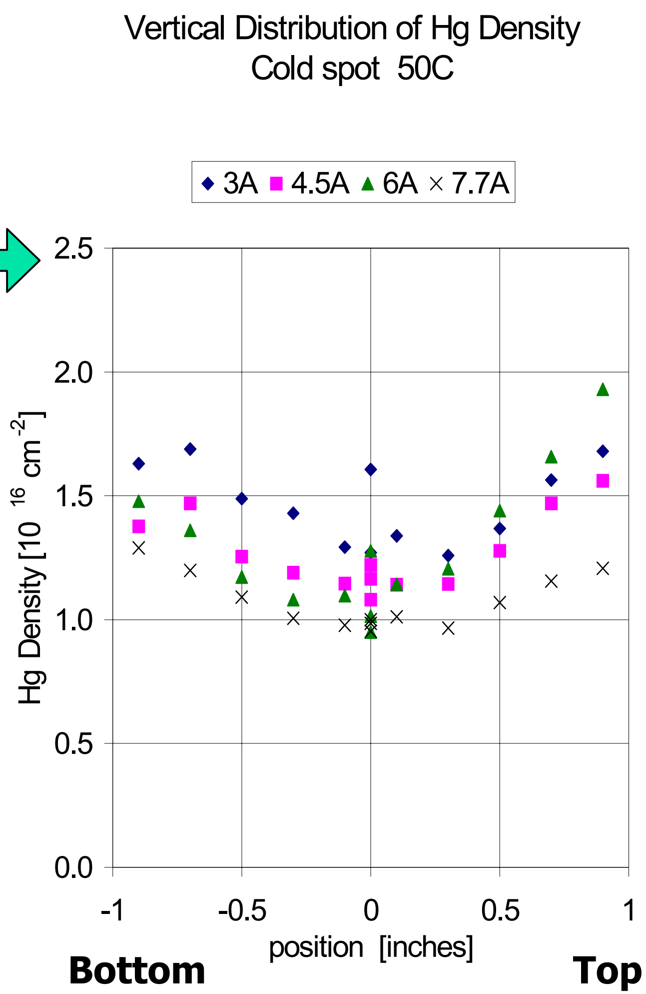
$$\approx \mu_i \frac{kT_e}{e}$$

Neutral Hg density vs. position

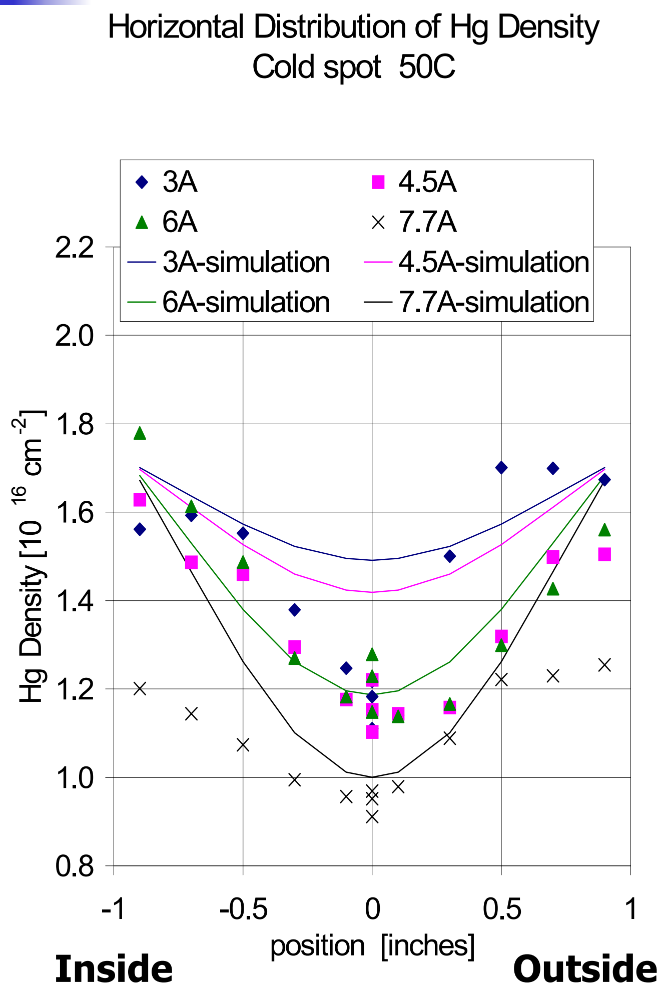
cold spot temperature = 50C° with various current

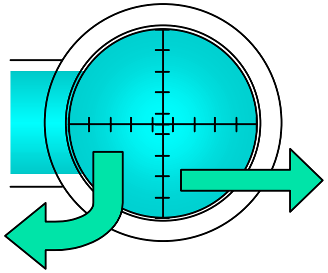


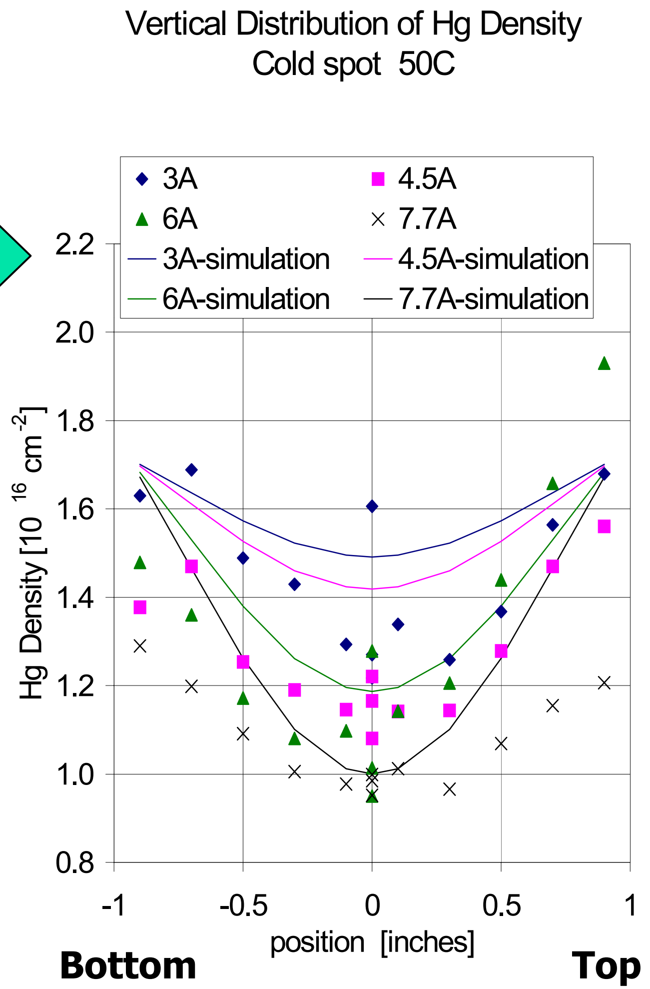




Comparison with Calculation using diffusion equations







Conclusion

- **Density distribution can be measured by using the High Sensitivity Absorption Spectroscopy (HSAS) facility**
- **Hg and Hg^+ ion density distribution shows there is radial cataphoresis in ICETRON lamps.**
- **Hg density distribution is consisted with Hg+ ion distribution and diffusion equations.**

Future work

- Different cold spot temperature analysis
- Correction of model for lamp shape
- Inclusion of effects from gas heating

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