BNL-104721-2014-TECH

AGS/AD/Tech Note No. 305;BNL-104721-2014-IR

Transmission of Hø through a Ring Magnetron Ionizer

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August 1988

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USDOE Office of Science (SC)

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Technical Note

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Introduction

The conversion efficiency of a ring magnetron ionizer was studied in a previous Technical Note. {1} The conclusion of that Technical Note was that the deuterium pressure in the ionization volume plays an important role in determining the overall conversion efficiency of the ionizer in the PONI-2 polarized ion source. The presence of large quantities of gas could have two effects: first, if the atomic beam sees a region of high pressure prior to entering the ionization volume a significant number of polarized atoms are lost prior to ionization, and second, since H^- is formed over an extended path length, a large part of the ionized beam will undergo scattering in the background gas.

This paper is organized in two major sections. First, a set of measurements was made to examine the atomic beam transmission through an ionizer equipped with the slotted anode used in the initial tests. Second, a description of a computer model of the ionizer developed to study the behavior of the ionization volume pressure during the time immediately after the deuterium gas valve pulse.

Transmission Measurements

The transmission was measured for both anode geometries by studying the H° pulse observed with a residual gas analyzer (RGA) placed 1.3 meters downstream from the ionizer. THe RGA mass selector was tuned to mass 1 for these measurements. The signal output of the RGA electronics was sent to a signal averager. Initially, a background measurement was made with the D_2 gas off. After the background was measured, the deuterium gas for the ionizer was pulsed as if the ionizer were operating. For these measurements, the ionizer discharge was not used. The width of the gas valve pulse was set to 0.6 ms and the inlet pressure varied. A limited number of data points were obtained by varying both the pressure and the length of the valve pulse.

The RGA output signal for a typical H° pulse is shown in Figure 1. The transmitted flux was determined 8 ms after the beginning of the RGA pulse. The results of the transmission measurements for the slotted anode are shown in Figure 2. The measurements are normalized to the transmission through the ionizer when the deuterium is not pulsed. The quantity shown as "gas flow" is the product of the length of the gas valve pulse and the inlet pressure. This quantity is useful for operation but does not lend itself readily to conversion to a magnetron pressure since the conductance of the gas valve is unknown at this time. The crosshatched region indicates the typical gas flow range when the ionizer is used to produce a negative beam.

It is possible to estimate the average molecular density of deuterium in the ionization volume of the magnetron. The transmission through a thick gas target is

$$T = e^{\sigma \bar{n} l}$$

Where σ is the scattering cross section, $\bar{n}$ is the density and l is the length of the gas target. The scattering cross section used in this Technical Note is $\sigma = 5.8 \times 10^{-15}$ cm^2. {2} The length of the ionization volume is l = 3 cm.

The average D_2 density in the slotted anode at its standard operating condition was 1.8×10^{14} cm^{-3}, corresponding to a mean free path length of 0.96 cm for H° in deuterium.

Pressure Calculations

A model of the gas flow in the magnetron and ionization volume has been developed. The aim of this model is to obtain an axial pressure distribution as a function of time and estimate the atomic beam attenuation along the axis.

A schematic representation of the calculation is shown in Figure 3. In this model, the deuterium gas enters a transfer manifold between the gas valve and the magnetron volume. The deuterium flowing into the magnetron enters uniformly through a set of holes. Gas leaving the magnetron flows into the center of the ionization volume. The deuterium flowing into the magnetron enters uniformly through a set of holes. Gas leaving the magnetron flows into the center of the ionization volume. The conductance from the magnetron into the ionization volume is considered to be viscous. The ionization volume is defined by the upstream and downstream grids. Flow through the grids and a short tube into the ionizer vacuum chamber is described by molecular flow. The ionizer vacuum chamber is pumped by a Sargent-Welsh turbomolecular pump at the end of a high conductance line. Table 1 gives the conductances and volumes for each section of the ionizer. The main body of the calculation is contained in a loop allowing the user to follow the ionizer through any number of pulses. The calculated pressures usually stabilized after 5 - 10 pulses.

Figure 4 shows the pressure in each section as a function of time after five gas pulses with a 1.0 ms valve pulse with 1.92×10^{20} molecules/sec flowing into the transfer manifold and a repetition rate of 1 Hz. The gas flow was adjusted to obtain a density of 1.8×10^{14} cm^{-3} in the ionization volume 3.2 ms after the beginning of the gas pulse. (This time corresponds to the shortest magnetron discharge delay used to obtain an ion beam.) The pressure in the magnetron and the pressure in the ionization volume both show a long exponential decay due to the low deuterium conductance between the transfer manifold and the magnetron volume, while the chamber pressure shows a slow rise in pressure over the observable time span. In order to ignite the magnetron, the pressure in the magnetron volume should be approximately 0.1 Torr. The magnetron volume pressure in the model remains above 0.1 Torr until 4 ms after the beginning of the gas valve pulse. Finally, both the magnetron and ionization volume pressures have relatively short rise times, and are seen track to each other, precluding the possibility of using the leading edge of the magnetron pressure pulse for normal operation.

Summary

The estimated average operating density in the ionization volume is 1.8×10^{14} cm^{-3} for the slotted anode. The mean free path length for scattering at this density is 0.96 cm resulting in 95 percent of the atomic beam undergoing to least one scattering during its transit of the ionization volume. The effect of high background gas densities on an ultra-cold atomic beam will be much more pronounced than in the current case due to the larger effective scattering cross section at lower atomic beam velocities.

In order to further increase the output with the current high temperature atomic beam and improve the compatibility with cold atomic beams it is necessary to redesign the ring magnetron ionizer to have lower deuterium pressure in the ionization volume during the ionization pulse. To achieve this condition, one must optimize the ratio of the magnetron and ionization volume pressures for good H° transmission while ensuring a high enough pressure in the magnetron volume for a stable discharge.

References

{1} C.R. Meitzler, AGS/ADD Technical Note No. 303, July 25, 1988

{2} H. Harrison, J. Chem. Phys. 37 (1962) 1164.

Table 1.

Element	Volume [cm^3]	Conductance [l/s]
Transfer Manifold	1.78	
Magnetron	1.99	2.36
Ionization Volume	8.08	62.30
Ionizer Chamber	11400	380

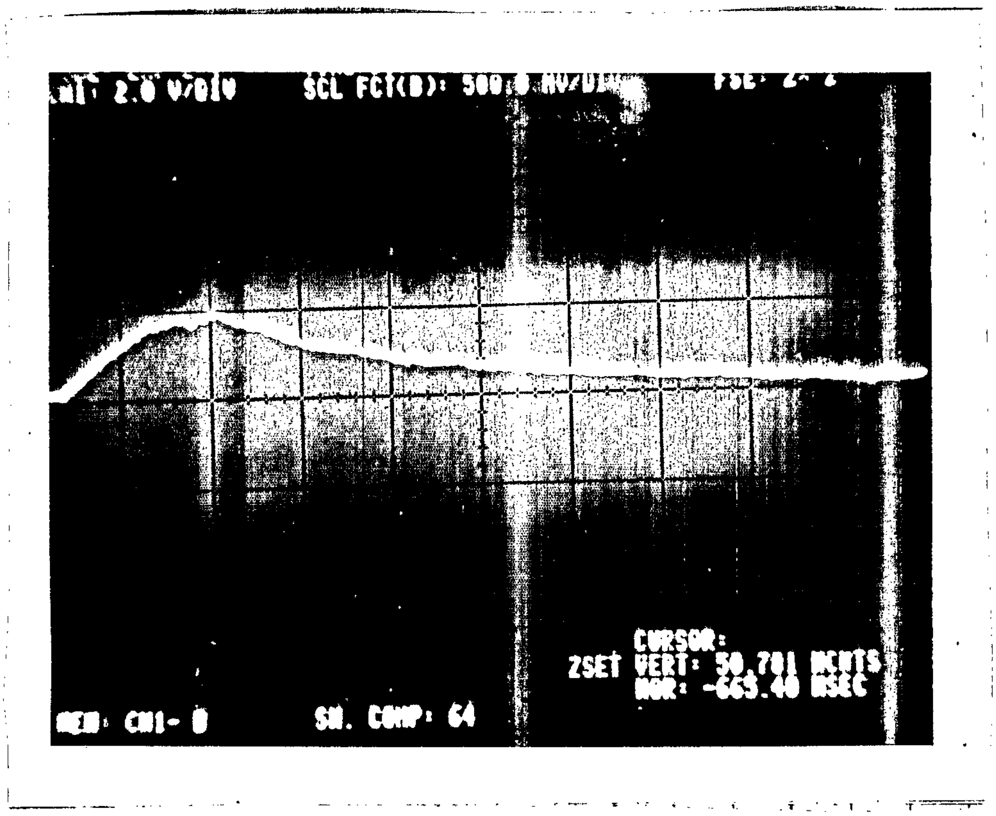


Figure 1

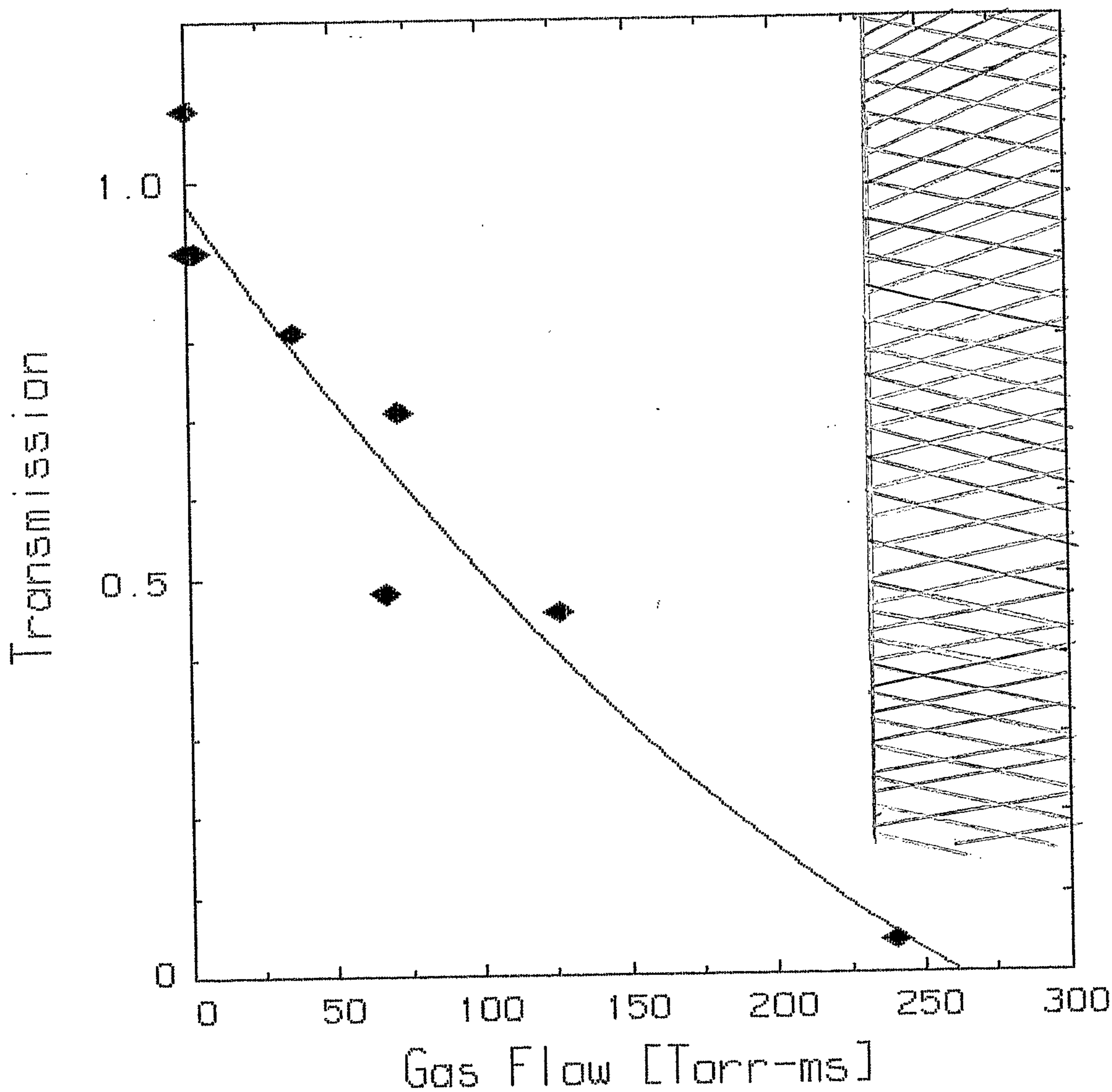
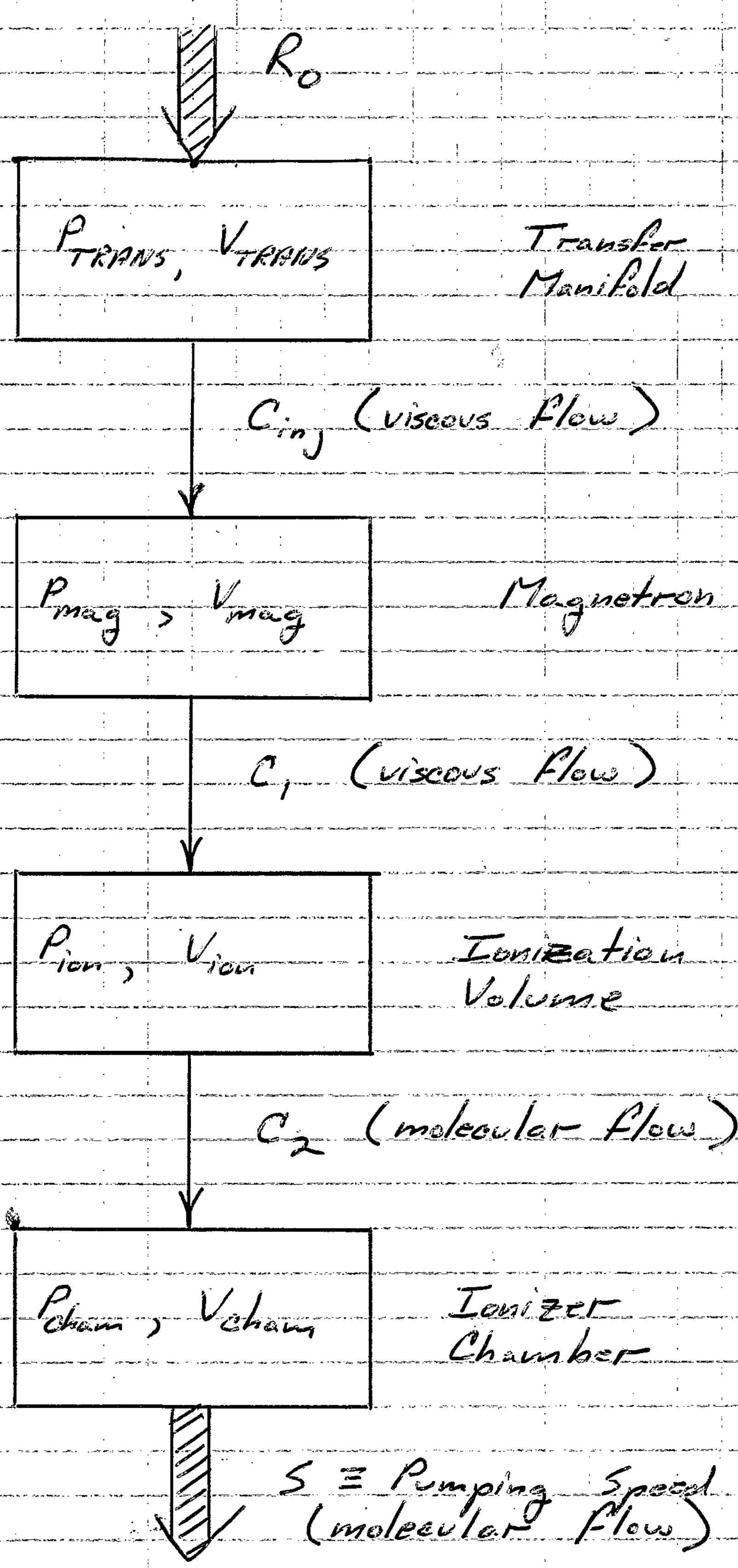


Figure 2



R0
P TRANS , V TRANS
Transfer Manifold
C inj (viscous flow)
P mag , V mag
Magnetron
C1 (viscous flow)
P ion , V ion
Ionization Volume
C2 (molecular flow)
P cham , V cham
Ionizer Chamber
S ≡ Pumping Speed (molecular flow)

Figure 3

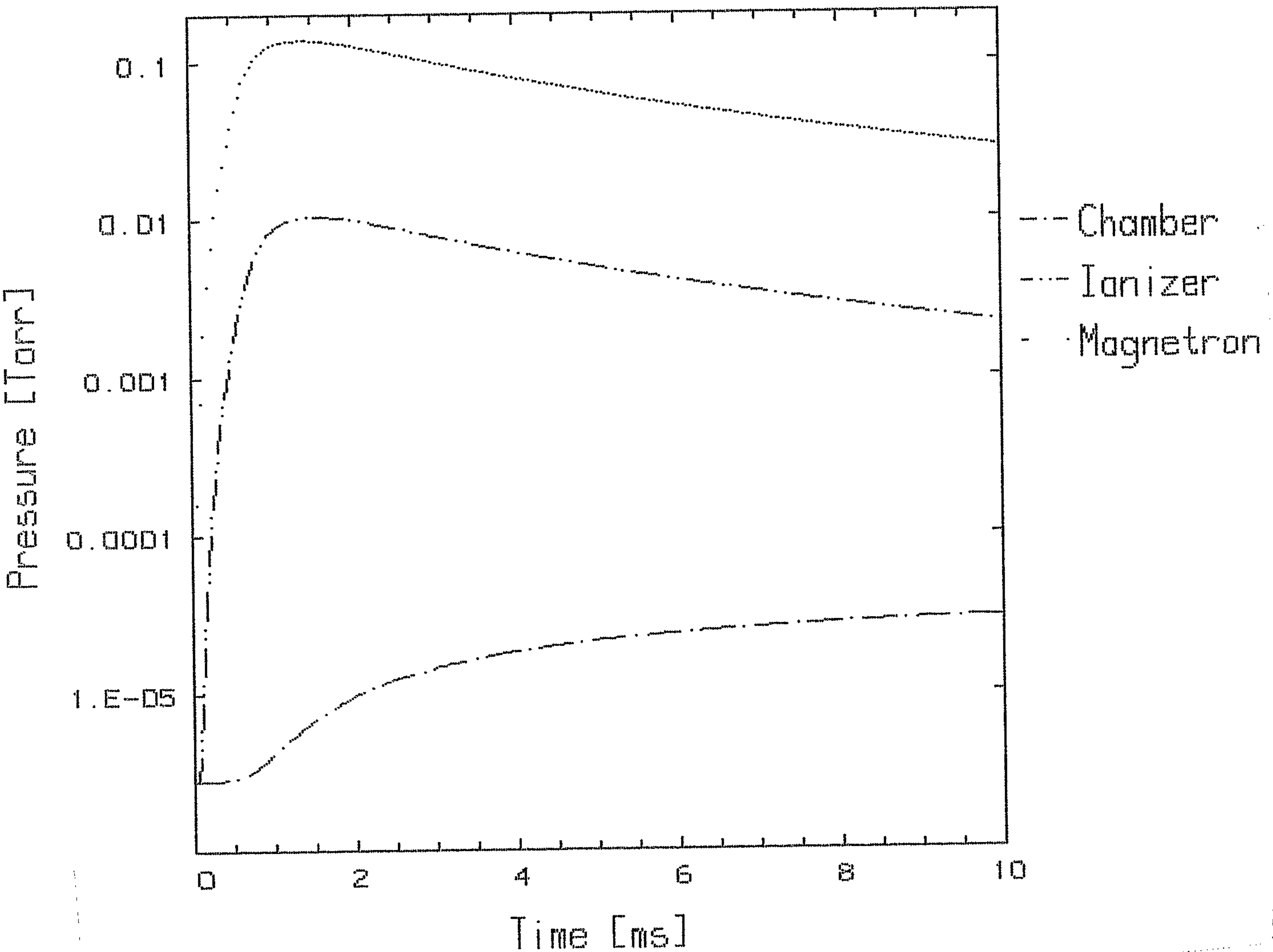

0.1
0.01
0.001
0.0001
1.E-05
Pressure [Torr]
0
2
4
6
8
10
Time [ms]
Chamber
Ionizer
Magnetron

Figure 4