with $x = z - u_s t$ and that the ionization rate is

$$dn/dt = \alpha N = \alpha N_0 \exp[-\alpha(z - u_s t)]$$

Integration of these two equations gives

$$n = (N_0/u_s)[\exp(-\alpha x) - \exp(-\alpha z)]$$

The plasma density at the distance x ahead of the shock front has reached a stationary state when the last term in the brackets can be neglected, compared with the first one. For the experimental conditions of Ref. 2 ($1/\alpha \approx 20$ cm) the plasma density has reached 90% of its final value when

$$z_c - x > 2.3/\alpha \approx 46 \text{ cm}$$

This means that the two probes will measure a stationary state at $x = 50$ cm ahead of the shock front if the distance of the first probe from the diaphragm station is larger than $z_c = 96$ cm.

In reality, z_c will be even larger because the shock itself must move a certain distance before it is fully developed, and before the region behind it starts to emit ionizing radiation. More complicated ionization mechanisms than the one assumed here should also increase z_c.

In Ref. 2 the diaphragm-probe distance is not given. However, the over-all length of the driven section is only 180 cm and one may estimate from the description of the shock tube that the first microwave cavity is not much more than 100 cm from the beginning of the driven section. It is, therefore, quite curious that Lederman and Wilson find stationary profiles in their shock tube.

References

[1] Zinman, W. G., "Comment on experimental precursor studies," AIAA J. **4**, 2073–2075 (1966).

[2] Lederman, S. and Wilson, D., "Microwave resonance cavity measurement of shock produced electron precursors," AIAA Paper 66-175 (March 1966); also AIAA J. **5**, 70–77 (1967).

[3] Holmes, L. B., "Plasma density ahead of pressure driven shock waves," Ph.D. thesis, Univ. of Rochester, 1965; also, Department of Mechanical and Aerospace Sciences, Univ. of Rochester, TN 1 (May 1965).

[4] Wetzel, L., "Far-flow approximations for precursor ionization profiles," AIAA J. **2**, 1208–1213 (1964).

Reply by Author to H. D. Weymann

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I WOULD like to thank Professor Weymann for his comments. I agree that the derivation of the second integral from the first integral should have been indicated in my comment[1]:

$$q(k_\nu) = q(\nu) = 1$$

and
$$N(k\nu) = \int_0^{V_{\text{ionization}}} N(\nu)\delta[k_\nu(\nu)]d\nu$$

where δ is the Dirac delta function. Every resonance line for which $k_\nu^0 > k_\nu$ makes a contribution to the foregoing Stieltjes integral for $N(k\nu)$. Figures 17 and 20 of Lederman and Wilson's work[2] show that the l folding length is independent of pressure, a result not in accordance with Wetzel's model.[3] The assumption of steady state is reasonable since the diaphragm to probe distance is about 2 m[4] whereas the apparent photon near free path is about 20 cm.

I hope that Dr. Holmes will publish his results[5] and discuss the discrepancies between his results and those of Lederman and Wilson in more detail. There could be at least two significant factors. First, Lederman and Wilson conducted their work in a stainless-steel tube while that of Holmes was performed in a glass tube; second, there might be a difference in the impurity content of the argon used in the two investigations.

References

[1] Zinman, W. G., "Comment on experimental precursor studies," AIAA J. **4**, 2073–2075 (1966).

[2] Lederman, S. and Wilson, D., "Microwave resonance cavity measurement of shock produced electron precursors," AIAA Paper 66–175 (1966); also AIAA J. **5**, 70–77 (1967).

[3] Wetzel, L., "Far-flow approximations for precursor ionization profiles," AIAA J. **2**, 1208–1213 (1964).

[4] Wilson, D., unpublished communication (1966).

[5] Holmes, L. B., "Plasma density ahead of pressure driven shock waves," Ph.D. thesis, Univ. of Rochester (1965); also Department of Mechanical and Aerospace Sciences, Univ. of Rochester, TN1 (May 1965).

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