MICROWAVE DISCHARGE IN A SUPersonic FLOW

P. Hoffmann, H. Hügel, W. Shall, W. Schock

To cite this version:

P. Hoffmann, H. Hügel, W. Shall, W. Schock. MICROWAVE DISCHARGE IN A SUPersonic FLOW. Journal de Physique Colloques, 1979, 40 (C7), pp.C7-489-C7-490. <10.1051/jphyscol:19797237>. <jpa-00219220>

HAL Id: jpa-00219220
https://hal.archives-ouvertes.fr/jpa-00219220
Submitted on 1 Jan 1979

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
MICROWAVE DISCHARGE IN A SUPersonic FLOW

P. Hoffmann, H. Hülge, W. Schall and W. Schock.

DFVLR-Institut für Technische Physik, Stuttgart, Germany.

ABSTRACT

The possibility of effectively ionizing a supersonic flow by a strong microwave field within a waveguide has been demonstrated. Electron densities beyond the cut-off have been achieved at gas temperatures far below room temperature. Hence this method promises to be a good candidate to preionize and stabilize supersonic, non-selfsustained laser discharges.

INTRODUCTION

Laser discharges in supersonic flows have to satisfy several conditions: the value of the reduced field strength \( (E/N) \) should be appropriate for optimum vibrational excitation while the electron density must be sufficiently high to allow effective energy deposition into the gas. Under these conditions one must avoid having the discharge in the boundary layer and/or having it blown downstream by the supersonic flow. In addition the discharge has to be stable and spatially uniform across the channel. This can be accomplished by preionizing the flow with an e-beam, or by applying a pulsar-sustainer discharge. However, with both concepts, technological problems arise, when one attempts to obtain true cw high power laser action. Utilizing a high frequency discharge as a preionization source or as a self-sustained main discharge, cw operation has been demonstrated. In addition to the advantages of the rf discharge, the use of microwaves allows one to establish a desired field distribution within the channel. This contribution describes an experiment, where the dimensions of the laser channel are comparable to the wavelength with metallic walls forming a waveguide.

EXPERIMENT

The experimental setup is shown in the figure. Amplitude stabilized cw microwave radiation at 2.45 GHz, with power up to 5 kW, is propagated through a pressure window along a rectangular waveguide which forms both the plenum chamber and the convergent-divergent nozzle. The latter has an area ratio of 10. It merges into a flow channel made of dielectric material with flush mounted electrodes for the main discharge. An optical cavity perpendicular to the flow direction is positioned downstream of the electrode. The dimensions of the waveguide permit the exclusive propagation of the basic \( TE_{01} \) mode. This mode's maximum electric field strength lies along the centerline of the channel with no electric fields in the vicinity of the narrow walls of the waveguide. Hence there is no ionization in the boundary layer. As the pressure rapidly decreases along the divergent part of the nozzle, conditions for breakdown are reached and a plasma with electron densities above cut-off is formed. Interferometric measurements show a decrease in electron density from \( 10^{11} \) cm\(^{-3} \) at a position 10 cm downstream of the nozzle throat to some \( 10^{10} \) cm\(^{-3} \) at 20 cm downstream of the throat. There the value of electron density is a function of the totally absorbed microwave power. Typical experimental conditions are: mass flow \( \dot{m}_{\text{He}} = 5 \) g/s, \( \dot{m}_{\text{CO}} = 5 \) g/s; plenum pressure \( P_0 = 1 \) bar; pressure in the channel, \( P_c \), depending on power input, from 8 to 14 mbar; gas temperature, \( T_c \), from 60 to 120 K; i.e. only about 20 % of the input power heats the gas, with most of the energy appearing in the form of ionization, electronic and vi-
brational excitation. The theoretical microwave penetration depth into the plasma of several millimeters in flow direction was found to agree with E-field measurements. Hence the microwave field strength at the position of the main discharge, located several centimeters downstream of the throat, is negligibly small while the electron density still remains above $10^{10}$ cm$^{-3}$. Superimposing the main discharge, the E/N values vary between $1.75 \times 10^{-16}$ and $3 \times 10^{-16}$ V cm$^{-2}$, only depending upon the absorbed microwave power. The power levels one can put into the main discharge without arcing are smaller than the corresponding microwave power. On the other hand a stable main discharge cannot be obtained without preionization. No laser action could be observed so far. Yet, one should take into consideration that both the expected gain would be low (some 0.1/m) and the optical path length very short, i.e. in the order of only 7 cm. Hence, one can easily be just below laser threshold.

CONCLUSIONS

It has been shown that a plasma can be effectively produced in a supersonic flow by means of microwaves. If the microwaves are used for preionization, their stabilizing effect on a superimposed main discharge is limited. On the other hand, the available energy loading of up to 0.3 eV/CO molecule, together with the molecular transit time of 100 μs through the discharge should, in principle, permit laser action.

REFERENCES

