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MEASUREMENT OF THE ELECTRON ENERGY DISTRIBUTION IN A CO₂ LASER PLASMA

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Introduction
Much theoretical work has been carried out on CO₂ laser plasmas in order to understand the excitation mechanisms and to optimize the laser efficiency. The electron energy distribution (EED) is obtained by numerical solution of the Boltzmann equation. The different excitation rates are then obtained by a convolution of the calculated EED and the excitation cross sections. /1,2/. Direct measurement of the EED would be difficult in high pressure, high current laser discharges. However we can obtain valuable information if we perform the measurement in a D.C. glow discharge at low pressure. It turns out that the essential parameters, the reduced field E/N, the reduced current density j/N, the ratio of the electronic density to the neutral density are the same as in high pressure discharges.

Experiment
All measurements were conducted in a 2/1/1 He-N₂-CO₂ mix at 0.35 Torr, in a 80 cm long, 65 mm int. diam. Pyrex tube. The axial electric field was measured between two probes 15 cm apart. The plane Langmuir probe is situated between the two probes and is perpendicular to the axis. A thermocouple gives the temperature of the neutral gas. All probes are located 10 mm off the center of the tube. The discharge was stable for currents ranging from 80 to 500 mA. We have noticed six striations between the anode and the cathode. The last striation next to the cathode was clearer indicating decomposition of CO₂ into CO. The electronic density could be obtained from the Langmuir probe saturation current, the values agreed within 30% with the integral of the distribution function. This one was determined from the second derivative of the probe current, obtained with the second harmonic. The modulation frequency was 450 Hz.

Results
Two series of experiments were done, one at constant flow, the other one at constant current. The essential data and measurements of the temperature, electronic density and reduced field are reported in Table 1. The EED for each series are depicted in Fig. 1 and 2. We see that varying the current has a relative little effect on the field. On the other hand, the EED is considerably modified. This effect was also observed by Polak et al. /3/ in pure CO₂ at 2 Torr, however the low-energy part of the EED decreased with increasing current while in our case the reverse is observed. We suggest the following hypothesis: at higher current more molecules are decomposed and the resulting products then slow down the electrons. This hypothesis is confirmed when we investigate the effect of the flow for a given current. The concentration of slow electrons increases when the flow is reduced or stopped, whereas the EED becomes wider with an important flow. In the fast flow regime, the effect can still be reinforced by decreasing the current as depicted in Fig. 3.
For these conditions the electronic density is reduced by a factor of 2 and the discharge tends to vanish.

**TABLE I.**

<table>
<thead>
<tr>
<th>Experiment No</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>flow rate (cc/min STP)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>current, mA</td>
<td>100</td>
<td>150</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>temperature</td>
<td>42</td>
<td>50</td>
<td>60</td>
<td>62</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>( n/V \times 10^{-16} \text{cm}^{-2} )</td>
<td>2.0</td>
<td>2.3</td>
<td>2.5</td>
<td>2.4</td>
<td>2.5</td>
<td>2.6</td>
</tr>
<tr>
<td>electronic density</td>
<td>2.8</td>
<td>5.0</td>
<td>5.4</td>
<td>4.8</td>
<td>3.1</td>
<td>2.6</td>
</tr>
</tbody>
</table>

**Conclusion**

Our measurements have shown the non-maxwellian characteristic of the EED with an important concentration of low energy electrons, as predicted by the computations. The current and the flow rate do have an important effect on the measured distributions.

References


/3/ L.S. Polak, Y.A. Ivanov, D.I. Slovetskii Khimiya Vysokikh Energii 2, 1971, 382