<table>
<thead>
<tr>
<th><strong>Author</strong></th>
<th>Muhammad Shahid Rafique</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title</strong></td>
<td>Compression dynamics and radiation emission from a deuterium plasma focus</td>
</tr>
<tr>
<td><strong>Institute</strong></td>
<td>Thesis (Ph.D.) National Institute of Education, Nanyang Technological University</td>
</tr>
<tr>
<td><strong>Year</strong></td>
<td>2000</td>
</tr>
<tr>
<td><strong>Supervisor</strong></td>
<td>Serban, Adrian</td>
</tr>
</tbody>
</table>
SUMMARY

This thesis reports the results of the investigations of the radiation (i.e. neutrons, deuterons, soft X-rays and hard X-rays) emitted from a 3 kJ Mather-type plasma focus device, National Institute of Education School of Science Plasma Focus Facility (NIE-SSC-PFF).

In order to study the correlation between the total neutron yield and the time-integrated energy spectra of the axially emitted deuteron beam, on a shot-to-shot basis, a magnetic spectrometer was successfully designed, constructed and implemented.

More importantly, an automated scanning and measurement system was also successfully developed and employed to overcome the traditional time-consuming and laborious counting and measurement of ion tracks.

Our analysis shows a clear correlation between the intensity of the axially emitted deuteron beam and the corresponding total neutron yield. The deuteron energy spectra range from 80 keV to 250 keV, with 100 keV < E_d < 140 keV as the most frequent energy range for each operating pressure. The experimental ion energy distribution is relatively well fitted by an exponential function of the form \( \exp(-E_d/B) \). It is also noted that the spectra at higher energies are in good agreement with the empirical relation \( dN/dE \propto E^{-\gamma} \).

The time-resolved soft X-ray measurements employed two filtered PIN diodes. For some discharges, the electron temperature of the pinch was determined by employing the filter ratio method. The time-resolved hard X-ray and neutron
measurements were performed using three scintillator-photomultiplier systems in a
time-of-flight arrangement.

An average neutron energy of 2.48 (± 0.04) MeV and 3.00 (± 0.09) MeV were
determined in the radial and the axial directions, respectively. Deuterons of energy
100 keV were found to be responsible for the production of 3.00 MeV neutrons in the
forward direction.

An average value of 1.48 for the neutron anisotropy was determined. The
correlation of the neutron anisotropy with the total neutron yield revealed that,
regardless of the operating pressure, the anisotropy is greater for discharges with
higher neutron yield. The correlation between the anisotropy and the soft X-ray
production shows that the anisotropy is lower for discharges with high soft X-ray
production (regardless of the operating pressure).

The soft X-ray and the total neutron yield were also correlated. The discharges
with high neutron yield exhibit low soft X-ray production. The higher operating
pressures favour the soft X-ray production.

Two regimes of the plasma focus were identified namely: the
single-compression regime and the multiple-compression. The neutron yield is greater
in discharges exhibiting the single-compression regime.

A three-frame computer-controlled laser shadowgraphic system was designed,
developed and implemented successfully.

The growth rate of the instabilities was correlated with the radiation output:
higher growth rates favour neutron emission. A correlation of the instability growth
rate with the pinch lifetime shows that the pinch lifetime is shorter for the discharges
with higher growth rates. The radiation output is higher for the discharges with shorter
pinch lifetime. The pinch dimensions (column radius, column length and aspect ratio) are also correlated with the radiation output. The correlation shows that the neutron yield is higher for smaller radius, and the soft X-ray production is lower. The neutron yield is lower for the discharges with the longer pinch length, which appears to be more favorable for the soft X-ray production. The radiation output (both the neutron yield and the soft X-ray) appears higher for the discharges with larger aspect ratio.

The trajectories of the inward radial shock front and its axial elongation were determined from the shadowgraphic images. Radial and axial elongation velocities were also calculated. The discharges with higher radial implosion speeds exhibit higher radiation output.

A computational modeling of the plasma focus was also performed. The experimentally measured radial and axial elongation trajectories, along with the radial implosion speed were compared with the simulated results. The simulated results are in fairly good agreement with the experimental data.