DEVELOPMENT OF A 600 JOULES SMALL PLASMA FOCUS AS PULSED RADIATION SOURCE

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Abstract

The work starts at developing a 600 joules small plasma focus based on previous experience and works on the 3 kJ plasma focus system [Lee et al. (1988), Favre et al. (1992), Moo et al. (1995), Yap et. al. (2005)]. The objectives of this project are two folds, first, to scale down the energy of the plasma focus device from kJ to few hundred joules; and second to develop the new system as a pulsed radiation source.

The development and construction of the small Mather type plasma focus system employed a novel design with electrodes of 60 mm in length and without an insulator as the conventional plasma focus. The investigation of the discharges is focused on getting an optimum operating condition for plasma focus with reproducible radiation emission. Argon gas is used, while the operating pressures are varied to study the dynamics of the plasma focus as well as the radiation output.

The plasma focus discharges have been investigated by using a Rogowski coil, resistive voltage divider, X-ray Detector (XRD), EUV detector and biased ion collectors, for the discharge current, discharge voltage, X-ray radiation output, EUV radiation output and ion beam output. Suitable condition has been identified at a low pressure regime of 9.0×10^{-3} mbar to 2.2×10^{-2} mbar of argon. Reproducible results with good plasma focus and radiation output are obtained. The plasma focus is observed consistently; with good reproducibility of above 80 % in this pressure range. Radiation emissions are mainly in the ultra soft X-ray to EUV region. A total EUV energy vary from 7.8 mJ to 275 mJ is obtained, which corresponds to a conversion efficiency of 0.0013 % to 0.046 %. The ultra-soft radiation and EUV are emitted during the plasma focus time, where the signals are coincide with the voltage spike. The best condition of

focusing discharge is identified to be in a very narrow range of argon pressures of $1.0 - 1.8 \times 10^{-2}$ mbar. The highest EUV energy output of 275 mJ is also obtained at about 1.6×10^{-2} mbar. In these pressures, the ion beams observed are relatively low in intensity. Conversely, the ion beam is found to increase at lower pressures. Energies of the ion beams measured are calculated based on the time of flight method. Argon ion beam with energy of 38 keV to 560 keV are obtained. It is also found that 9.0×10^{-3} mbar is the optimum argon pressure for high energetic ion beam production.

Abstrak

Penyelidikan ini bermula dengan merekabentuk sebuah 600 joules plasma fokus kecil berdasarkan kepada pengalaman dahulu dan kerja yang dilakukan di atas sistem plasma fokus 3 kJ [Lee et al. (1988), Favre et al. (1992), Moo et al. (1995), Yap et al. (2005)]. Objektif projek ini terdapat dua bahagian. Yang pertama adalah mengurangkan tenaga peranti plasma fokus dari kJ ke beberapa ratus joules; Yang kedua adalah memajukan sistem plasma fokus ini sebagai suatu sumber pemancaran sinaran denyutan.

Penghasilan dan pembinaan sistem plasma fokus kecil ini yang berjenis Mather telah menggunakan reka bentuk yang baru dengan elektrod berpanjang 60 mm dan tanpa kehadiran suatu penebat seperti pada plasma fokus konvensional. Penyiasatan nyahcas ini telah memberi tumpuan kepada keadaan operasi yang optimum supaya plasma fokus dengan pancaran sinaran dapat dihasilkan semula. Gas argon digunakan sementara tekanan operasi diubahkan untuk mengkaji dinamik plasma fokus serta penghasilan sinaran.

Nyahcas plasma focus telah disiasat dengan menggunakan gegelung Rogowski, pembahagi voltan berintangan, pengesan sinar-X (XRD), pengesan ultra ungu lampau dan pemungut-pemungut ion yang dipesong untuk menyiasat arus nyahcas, voltan nyahcas, pemancaran sinar-X, sinar ultra ungu lampau dan alur ion. Keadaan yang sesuai telah dikenalpasti pada rejim tekanan argon yang rendah iaitu dari 9.0×10^{-3} mbar ke 2.2×10^{-2} mbar. Keputusan yang boleh dihasilkan semula dimana plasma fokus dan sinaran yang baik dihasilkan telah diperolehi. Plasma fokus yang diperhatikan adalah konsisten dengan kebolehan penghasilan semula mencapai 80 %

keatas pada julat tekanan ini. Kebanyakan pancaran sinaran adalah dalam rantau sinar-X ultra lembut hingga ke ultra ungu lampau. Jumlah tenaga ultra ungu lampau dari 7.8 mJ hingga 275 mJ telah diperolehi dan ia adalah berpadanan dengan kecekapan penukaran dari 0.0013 % hingga 0.046 %. Sinar ultra lembut dan ultra ungu lampau yang dipancarkan pada masa plasma fokus, di mana isyaratnya serentak dengan pepaku voltan. Keadaan yang terbaik untuk nyahcas berfokus telah dikenalpastikan pada julat tekanan argon yang sempit iaitu 1.0 - 1.8 $\times 10^{-2}$ mbar. Penghasilan tenaga sinar ultra ungu lampau tertinggi iaitu 275 mJ telah diperolehi pada hampir 1.6 $\times 10^{-2}$ mbar. Pada tekanan ini, keamatan alur ion yang diperolehi agak rendah dari segi perbandingan. Sebaliknya, alur ion didapati meningkat pada tekanan yang lebih rendah. Tenaga alur ion telah dikira berdasarkan kepada kaedah masa penerbangan. Alur ion argon dengan tenaga dari 38 keV ke 560 keV telah diperolehi. Didapati tekanan argon pada 9.0 $\times 10^{-3}$ mbar adalah tekanan argon yang optimum untuk penghasilan alur ion bertenaga tinggi.

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Glory to The Lord.

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