

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

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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  $9.0 \times 10^{-3}$  mbar to  $2.2 \times 10^{-2}$  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  $1.6 \times 10^{-2}$  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  $9.0 \times 10^{-3}$  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  $9.0 \times 10^{-3}$  mbar ke  $2.2 \times 10^{-2}$  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.

Seng Huat

# Contents

	<b>PAGE</b>
<b>Title</b>	i
<b>Declaration</b>	ii
<b>Abstract</b>	iii
<b>Abstrak</b>	v
<b>Acknowledgements</b>	vii
<b>Contents</b>	viii
<b>List of Figures</b>	x
<b>List of Tables</b>	xiii
<b>Chapter 1      Introduction</b>	
1.1    Introduction and Motivation	1
1.2    Literature Review of the Plasma Focus	5
1.3    Plasma Focus Radiation Sources	13
1.3.1    X-ray Source	13
1.3.2    Ion Beam Source	19
1.3.3    EUV Source	22
1.4    Layout of this Dissertation	26
<b>Chapter 2      The Plasma Focus</b>	
2.1    Introduction	27
2.2    Plasma Focus Tube Design	28
2.3    Dynamics of the Plasma Focus Discharge	29
2.3.1    The Breakdown Phase	30
2.3.2    The Axial Acceleration Phase (The Axial Rundown Phase)	31



2.3.3	The Radial Compression Phase (The Radial Collapse Phase)	32
2.3.4	The Disruption Phase	34
<b>Chapter 3</b>	<b>Experimental Setup</b>	
3.1	Introduction	35
3.2	Plasma Focus System Design	35
3.3	Diagnostics Techniques	40
3.3.1	Discharge Current Measurement	40
3.3.1.1	Calibration of the Rogowski Coil	43
3.3.2	Discharge Voltage Measurement	46
3.3.3	Ultra-Soft (UV-EUV) Radiation Measurement	47
3.3.4	EUV Measurement	48
3.3.5	Ion Beam Measurement	52
<b>Chapter 4</b>	<b>Results and Discussions</b>	
4.1	Introduction	54
4.2	Plasma Focus Discharge at Low Operating Pressure	54
4.3	Emission Characteristics of the Plasma Focus Discharge	65
4.3.1	EUV Energy	73
4.3.2	Ion Beam Energy	77
<b>Chapter 5</b>	<b>Conclusion and Recommendation</b>	
5.1	Conclusion	84
5.2	Suggestions for Future Work	86
	<b>REFERENCE</b>	88

## List of Figures

<b>Figure 1.1</b>	Schematic drawings of Mather and Filippov type dense plasma focus devices (DPF) [Fillippov et al. (1962), Mather (1964)].	6
<b>Figure 2.1</b>	The cross section of a plasma focus electrodes set.	28
<b>Figure 2.2</b>	The plasma focus tube. Current sheath in the breakdown phase, axial acceleration phase and radial compression phase is indicated at the respective position. Emission from the plasma pinch is also schematically indicated.	29
<b>Figure 3.1</b>	Block diagram of the entire plasma focus experimental setup.	36
<b>Figure 3.2</b>	The 3D drawing of the small plasma focus system complete with the three diagnostic ports.	38
<b>Figure 3.3</b>	Schematic diagram of the Rogowski coil.	40
<b>Figure 3.4</b>	Rogowski coil operated in the current transformer mode.	41
<b>Figure 3.5</b>	Lightly damped sinusoidal waveform for calibration factor of a Rogowski coil.	45
<b>Figure 3.6</b>	Schematic diagram of the resistive voltage divider.	46
<b>Figure 3.7</b>	The operation and the schematic diagram of the XRD.	47
<b>Figure 3.8</b>	The schematic diagram of the EUV detector.	48
<b>Figure 3.9</b>	Responsivity for EUV detector, SXUV5A.	50
<b>Figure 3.10</b>	Filtered quantum efficiency for EUV detector, SXUV5A.	50
<b>Figure 3.11</b>	The schematic diagram of a biased ion collector.	52
<b>Figure 3.12</b>	The arrangement of the two biased ion collectors.	53
<b>Figure 4.1</b>	Electrical, XRD and EUV signals obtained for non-focusing argon discharge at $3.0 \times 10^{-2}$ mbar, 18 kV.	56

<b>Figure 4.2</b>	Electrical, XRD and EUV signals obtained for argon discharge at $1.8 \times 10^{-2}$ mbar, 18 kV.	58
<b>Figure 4.3</b>	Electrical, XRD and EUV signals obtained for argon discharge at $1.5 \times 10^{-2}$ mbar, 18 kV.	60
<b>Figure 4.4</b>	Percentage of the discharges producing plasma pinch from the 600 joules small plasma focus device.	61
<b>Figure 4.5</b>	Breakdown time at different argon pressures. $T_b = 14785P^2 - 612.66P + 7.19$ represents the relation between the breakdown time $T_b$ ( $\mu s$ ) and the operating pressure $P$ (mbar).	62
<b>Figure 4.6</b>	The average velocity of the current sheath at different argon pressure.	63
<b>Figure 4.7</b>	Electrical, XRD and EUV signals obtained for argon discharge at $2.0 \times 10^{-2}$ mbar, 18 kV.	66
<b>Figure 4.8</b>	Electrical, XRD and EUV signals obtained for argon discharge at $1.6 \times 10^{-2}$ mbar, 18 kV.	67
<b>Figure 4.9</b>	Electrical, XRD and EUV signals obtained for argon discharge at $1.4 \times 10^{-2}$ mbar, 18 kV.	68
<b>Figure 4.10</b>	Population density ratios of argon ionic species as a function of electron temperature based on the Coronal Equilibrium Model (CE Model).	71
<b>Figure 4.11</b>	Variation of the average total EUV energy at argon pressure of $1.4 \times 10^{-2}$ mbar to $2.2 \times 10^{-2}$ mbar. The optimum pressure that emitted highest EUV radiation occurred at about $1.6 \times 10^{-2}$ mbar.	75
<b>Figure 4.12</b>	Variation of the average total EUV energy and the corresponding of current sheath average velocity at argon pressure of $1.4 \times 10^{-2}$ mbar to $2.2 \times 10^{-2}$ mbar.	76
<b>Figure 4.13</b>	Typical electrical and biased ion collector signals obtained for the argon discharge at $9.0 \times 10^{-3}$ mbar, 18 kV.	78
<b>Figure 4.14</b>	Variation of average ion beam intensity of the first peak ion beam pulse in the first biased ion collector at various operating pressures.	79

- Figure 4.15** The voltage spike and time resolved signals of the ion beam obtained for discharge at  $9.0 \times 10^{-3}$  mbar, 18 kV. 81
- Figure 4.16** Argon beam energy obtained at operating pressures of  $8.0 \times 10^{-3}$  mbar to  $2.2 \times 10^{-2}$  mbar. 82

## List of Tables

<b>Table 1.1</b>	Mather-type plasma focus devices with different input energy.	3
<b>Table 3.1</b>	System parameters of the 600 joules small plasma focus.	39
<b>Table 3.2</b>	Specification data of the EUV detector, IRD-SXUV5A with integrated thin film filters of 100 nm Si/ 200 nm Zr.	49
<b>Table 4.1</b>	Argon ions species with the corresponding characteristics line radiation. [Source: <a href="http://spectr-w3.snz.ru/">http://spectr-w3.snz.ru/</a> ]	72