UNIVERSITI PUTRA MALAYSIA

TIME-RESOLVED CHARACTERISTICS OF SOFT X-RAYAND HARD XRAY EMITTED FROM NITROGEN AND NEON GAS MIXTURES IN 4 kJ PLASMA FOCUS DEVICE

AFSHIN ROOMI

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By

AFSHIN ROOMI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,

in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

September 2011

This Thesis Is Dedicated To

Professor Reza Amrollahi

Who Has Had a Unique Contribution to the Development of Nuclear Science and Technology in Iran.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia, in fulfillment of the Requirement for the degree of Doctor of Philosophy

TIME-RESOLVED CHARACTERISTICS OF SOFT X-RAY AND HARD X-RAY EMITTED FROM NITROGEN AND NEON GAS MIXTURES IN 4-kJ PLASMA FOCUS DEVICE

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Chairman : Professor Elias Saion, PhD

Faculty : Science

Plasma focus (PF) is a pulsed plasma producing device which consists of two coaxial electrodes separated by an insulator sleeve, a vacuum chamber filled with working gas at low pressure, and an electrical circuitry. Upon discharging a capacitor bank, a plasma column is created in nanosecond rise time. The Lorentz force accelerates the plasma sheath along the anode towards the anode tip and compressed magnetically to form a dense plasma column. As a result of electrons interaction with atoms of the anode and working gas, Soft X-rays (SXR) and hard X-rays (HXR) are produced. The effects of applied voltage, operating pressure and working gas composition on SXR and HXR emitted from a 4 kJ plasma focus device which is called 'APF' have been investigated. Nitrogen (N_2) and Nitrogen: Neon (N_2: Ne) admixture with three volumetric ratios of (90: 10), (75: 25), and (50: 50) were used as the working gas in order to study the effect of gas composition on X-ray emission from the device. To investigate the effect of

applied voltage and operating pressure on the behavior of SXR and HXR emissions, four voltages of 10, 11, 12, and 13 kV with a range of pressures of 1.5, 2, 2.5, 3, 3.5, 4, 4.5, and 5 torr were applied. The diagnostic devices employed during the experiments were a scintillation detector for HXR detection, an array of five filtered PIN-diodes for SXR detection with different energies, a Pin-hole camera with two different filtered apertures for analyzing the dense plasma column, a Rogowski coil for measuring the discharge current, a voltage probe to measure the tube voltage and four oscilloscopes for getting the signals obtained by the different detectors. The results of HXR signals obtained by the scintillation detector showed that the intensity of HXR decreases with an increase of neon gas in the working gas admixture. On the other hand the signals obtained by three PIN-diodes filtered by Al + Mylar (12μm), Al + Mylar (24 μm), and Be (230 μm) which were for SXR, illustrated that the intensity of SXR increases with an increase of neon percentage in the admixture. Also the signals detected by two PIN-diodes covered by Al + Mylar (150 μm), and Cu (10 μm) which are for HXR, were in agreement with the results of the scintillation detector. For all compositions of the working gases, it was observed that the intensity of both SXR and HXR increased with increase of the applied voltage. For applied voltages used on every working gas, the optimum pressures for maximum intensity of SXR and HXR emitted were obtained. The results showed that the optimum conditions for maximum emissions of SXR and HXR using nitrogen (N_2) and neon (Ne) mixture are different. Therefore, it was found that the APF is in the optimum condition either for SXR or HXR emission. Our results concluded that the mixing neon (Ne) and nitrogen (N_2) as the working gas in the APF is a power source of SXR emission.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENCIRIAN PELERAIAN MASA SINAR-X LEMBUT DAN SINAR-X KERAS DIPANCARKAN DARIPADA CAMPURAN GAS NITROGEN DAN NEON DALAMPERANTI PLASMA FOKUS 4-KJ

Oleh

AFSHIN ROOMI

September 2011

Pengerusi : Profesor Elias Saion

Fakulti : Sains

Plasma fokus (PF) adalah peranti pengeluar plasma yang terdiri daripada dua elektrod sepaksi yang dipisahkan oleh lapisan penebat, satu ruang vakum diisikan dengan gas tindak balas pada tekanan rendah, dan satu litar elektrik. Selepas kapasitor discas, plasma dihasilkan dalam tempoh beberapa nano saat peningkatan masa. Daya Lorentz memecutkan plasma sepanjang anod ke hujung anod dan plasma dimampatkan secara magnet kepada lanjur plasma mampat. Hasil daripada tindakbalas electron dengan atom anod dan gas maka terhasillah sinar-X lembut (SXR) dan sinar-X keras (HXR). Kesan daripada voltan digunakan, tekanan operasi, dankomposisi gas tindakbalas terhadap pengeluaran SXR dan HXR dipancarkan daripada peranti plasma focus APF 4-kJ telah dikaji. Nitrogen (N_2) dan campuran Nitrogen: Neon (N_2:Ne) dengan nisbah (90: 10), (75: 25), and (50: 50) telah digunakan sebagai gas tindakbalas untuk mengetahui kesan komposisi gas terhadap sinar-X yang dihasilkan oleh peranti ini. Untuk mengkaji kesan

voltan digunakan dan tekanan operasi terhadap perlakuan SXR dan HXR, empat voltan digunakan iaitu10, 11, 12, and 13 kV dengan tekanan operasinya 1.5, 2, 2.5, 3, 3.5, 4, 4.5, and 5 torr telah dikaji. Peranti diagnostik yang digunakan semasa eksperimen terdiri daripada pengsan sentilator untuk mengesan HXR, susunan lima PIN-diod berturas untuk mengesan SXR pada tenaga berbeza, satu kamera Pin-aperture celah dua berturas untuk menganalisis lanjur plasma tumpat, satu gelong Rogowski untuk mengukur arus discas, sebuah meter voltan untuk mengukur voltan, dan empat osiloskop untuk mendapatkan isyarat daripada pengesan yang berbeza. Keputusan isyarat HXR yang diukur dengan pengesan sentilator menunjukkan bahawa keamatan HXR berkurangan dengan pertambahan gas neon dalam campuran gas tindakbalas. Pada masa yang sama isyarat SXR yang diukur dengan tiga PIN-diod dituraskan oleh Al + Mylar (12µm), Al + Mylar (24 µm), dan Be (230 µm), menunjukkan keamatan SXR bertambah dengan pertambahan neon dalam campuran gas. Juga isyarat yang dikesan oleh dua PIN-diod disaluti dengan Al + Mylar (150 µm), and Cu (10 µm) untuk isyarat HXR adalah setuju dengan keputusan daripada pengesan sentilator. Untuk semua komposisi gas tindakbalas didapati bahawa keamatan kedua SXR dan HXR bertambah dengan pertambahan voltan. Untuk voltan digunakan terhadap setiap gas tindakbalas, tekanan optimum untuk keamatan maksimum dipancarkan oleh SXR dan HXR telah diperolehi. Keputusan kajian menunjukkan bahawa keadaan optimum pancaran SXR dan HXR maksimum dengan menggunakan nitrogen (N_2) dan neon (Ne) adalah berbeza. Oleh itu didapati bahawa operasi APF berada dalam keadaan optimum untuk kedua SXR dan HXR. Kita boleh membuat keputusan disini bahawa campuran nitrogen (N_2) dan neon (Ne) sebagai gas tindakbalas dalam APF adalah sumber kuasa pemancaran SXR.

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Afshin Roomi
October 2011

Appendix D1
Approval Sheet 1

I certify that an Examination Committee has met on **29/09/2011** to conduct the final examination of Afshin Roomi on his thesis entitled **"Time-Resolved Characteristics of Soft X-Ray and Hard X-Ray Emitted from Nitrogen and Neon Gas Mixtures in A 4-kJ Plasma Focus Device"** in accordance with the Universities and University Colleges Act 1971 and the constitution of the Universiti Putra Malaysia [P.U.(A)] 15 March 1998. The Committee recommends that the student be awarded the PhD.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

AFSHIN ROOMI

Date: 29 September 2011

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