NUKLEONIKA 2002;47(3):123–125

TECHNICAL NOTE

Experimental study of X-ray emission yield in a Filippov-type Plasma Focus operating in neon and neon-krypton mixture

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Abstract Since the installation of PF-DENA at AEOI about one year ago, we performed quantitative studies of variation of X-ray radiations from a new Filippov-type plasma focus device: Dena (90 kJ, 25 kV, 288 μF). The operating gas was neon at a constant low pressure of 1 torr and different pressures of krypton admixture (up to 0.3 torr), with the discharge voltage up to 18 kV. For a charging voltage of 17 kV with 41 kJ stored energy and spark gap pressure of 1.2×10^{-2} torr, the maximum soft and little hard X-ray (SXR-HXR) emission is found for the neon, resulting in a total SXR yield of 2 V/shot measured by silicon semiconductor diode detectors. Concerning the effect of krypton admixture, a maximum intensity of SXR radiation has been observed at low krypton pressure that is about 1 V/shot. At higher pressure, the quantity of the SXR emission decreases down to zero. However, the maximum intensity of the HXR radiation yield in the same pressure range was found to be 2.5 V/shot. By increasing the pressure of krypton up to 0.3 torr, the results show that the krypton admixture gas generally causes, a decrease of the SXR radiation yield down to zero, whereas, the HXR emission yield carries a maximum value at the optimum pressure of krypton that is about 0.1 torr. Nevertheless, the pressure increments of krypton admixture lead to decreasing in the discharge voltage for the maximum X-ray production.

Key words Filippov-type plasma focus • gas admixture • X-ray

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Received: 1 October 2001, Accepted: 20 May 2002

Introduction

Properties of the variety of plasma focus devices [2], have been widely studied as an intense source of X-ray emissions, fast neutrons production and an efficient producer and accelerator of energetic charged particles with several MeV. The mechanism of plasma focus dynamics is the subject of several independent researchers especially attracted by the important development of hot spots. The characteristics of the diagnostic methods of measuring these radiations is also an important matter and there are some published results, for example, the X-ray diagnostic methods [3–5].

The subject of the present study is devoted to a general survey of characteristic X-ray emissions from a new Filippov-type plasma focus “Dena” (90 kJ, 25 kV, 288 μF), device operating in a neon and neon-krypton mixture.

Experimental set-up

The new Filippov-type plasma focus “Dena” [1], provides the so-called flat geometry of electrodes that gives an opportunity to vary the operating discharge conditions on a large scale. The energy source is a 288 μF capacitor bank which has a source inductance of 2 nH and operates at a maximum voltage of 25 kV (90 kJ), delivers a peak discharge current of about 2.8 MA into a short circuit with a rise time of 2.8 μs. Rogowski’s coils were used to measure

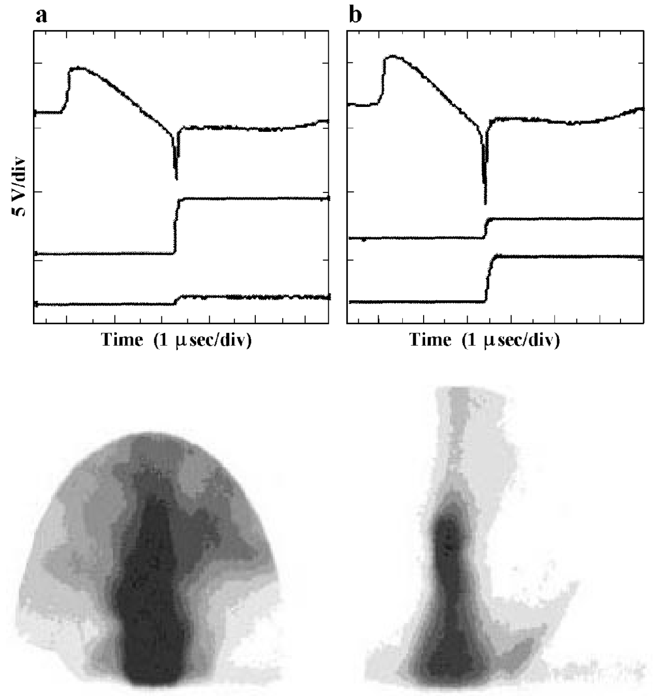

Fig. 1. Characteristic signals for neon filling gas. From top to bottom, (a) and (b) signals correspond to current derivatives, time-integrated soft and hard X-rays and the pinhole photographs in soft X-radiations.

the discharge current and its derivative. The soft X-ray intensity was detected with a PIN diode (SPPD type), filtered with a 10 μm thick beryllium, and the soft X-ray photograph was taken with a pinhole (10–100 μm aperture) camera on the opposite side of the PIN diode. The hard X-ray intensity was detected with a NaI-scintillator coupled to a photo element coaxial (PhEC) detector placed on the top of the device, and a photo multiplier (PM-53) coupled to an NE-102 plastic scintillator, with a 5 ns resolution.

Results and discussion

In Fig. 1 we show an amplified photograph of two pinches soft X-ray images, together with the discharge currents, current derivatives, *dI*/*dt*, the soft and hard X-ray intensities of the Dena discharge working with neon gas only. A darker image can be clearly observed in Fig. 1a, which corresponds to the intense soft X-ray and is duplicated in the same Figure by the time-integrated measurements. The hard X-ray signal in Fig. 1b has a higher value with a dipper negative spike on the current derivative. The negative spike on *dI*/*dt* signal in Fig. 1, corresponds to the characteristics of the high density and temperature plasma formation, and its dip is perfectly correlated to the intensity of X-ray emissions. The width of spike varies from shot-to-shot (in our measurement, on the average of around ten shots), and a value of 100 ns with the variation of about 13% was found.

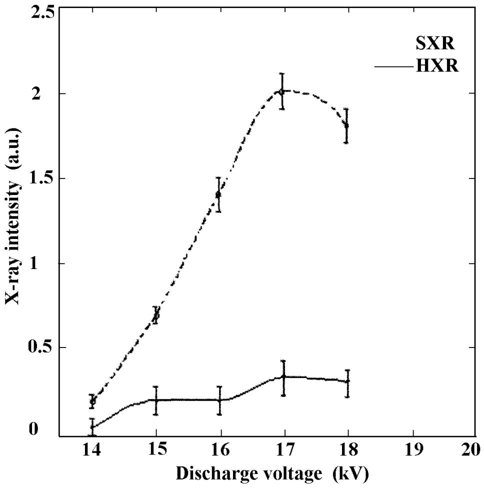

Fig. 2. Variation of soft and hard X-ray intensities *vs.* the discharge voltages (P_{neon}=1 torr).

The characteristic behavior of the focus device has been examined in an experiment with the neon filling gas at a constant pressure of 1 torr, and a range of discharge voltages of 14–18 kV. We have displayed our results in Fig. 2. The maximum soft and hard X-ray intensities were found to be 2 and 0.3 V/shot at the voltage of 17 kV. As shown in the Figure, the intensity of soft X-ray increases sharply as the discharge voltage increases, whereas, the hard X-ray intensity variation is rather slow in the same configuration.

The investigation of X-ray enhancement is followed by adding krypton admixture to the neon working gas. The maximum pressure of krypton was 0.3 torr, and we have

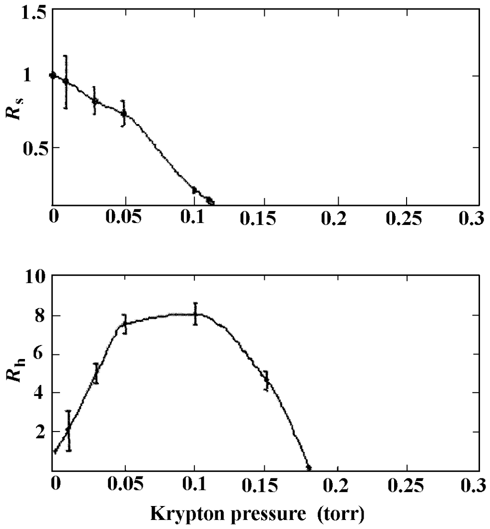

Fig. 3. Variation of R_s and R_h as a function of krypton admixture gas.

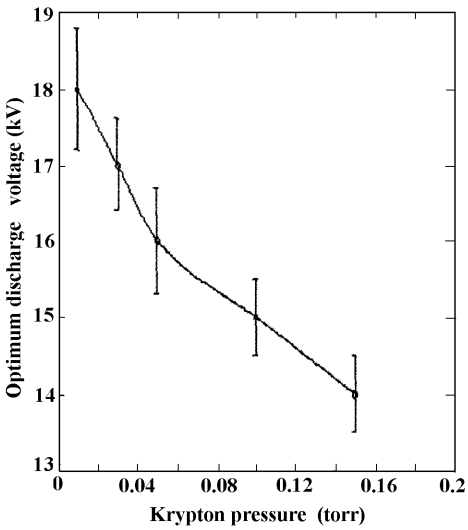

Fig. 4. Optimum voltage correspond to maximum X-ray yield, as a function of krypton admixture pressure.

kept the same discharge voltage range. Although, the pressure of krypton was up to 0.3 torr, nevertheless, we were not able to see any pinches after 0.2 torr. In Fig. 3 we presented the results of these measurements in terms of the ratio of X-ray intensity produced by the neon-krypton mixture, to the one obtained with the neon gas only. Each point in the Figure 3 corresponds to the optimum discharge voltage that produce the maximum X-ray intensity. We indicate these ratios R_s and R_h for the soft and hard X-ray emissions, respectively. The effect of the krypton admixture on the intensity of the soft X-ray was a decreasing manner; the maximum soft X-ray intensity obtained was about 1 V/shot, at a krypton pressure of 0.01 torr. The situation is different for the hard X-ray intensity; the intensity increases and reaches its maximum of about 2.5 V/shot, at the optimum pressure of krypton admixture of about 0.1 torr. We have displayed in Fig. 4 the result of the measurement concerning the relationship between the maximum X-ray yield and the pressure of krypton admixture. We have found that the optimum discharge voltage that produce maximum X-ray intensity decreases when the krypton pressure is increased. At higher discharge voltages, however, the chance of obtaining a good pinch was very little.

Conclusion

The results of the investigations presented here, the soft and hard X-ray, indicate that when the focus operates at a constant neon pressure of 1 torr, there exists an optimum discharge voltage for which the soft X-ray emission has a maximum value. In this case, it seems that by increasing the discharge voltage, the thermal processes in the focused plasma column (which lead to the soft X-ray emission) is considerably increased. The effect of different pressure of the krypton admixture on the intensity of X-ray shows that, as the admixture pressure raises, the discharge voltage for the maximum X-ray emission decreases. At the krypton pressure of 0.1 torr, the hard X-ray enhancement was up to about eight times of the initial value (only neon gas), whereas, for the soft X-ray this was always a decreasing manner. Meanwhile, as the non-thermal processes are generally responsible for the hard X-ray emissions, it can be concluded that the krypton admixture would appreciably enhance the non-thermal processes.

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