Optimizing UNU/ICTP PFF Plasma Focus for Neon Soft X-ray Operation

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***Abstract*—The United Nations University/International Centre for Theoretical Physics Plasma Focus Facility (UNU/ICTP PFF), a 3.3-kJ plasma focus, was designed for operation in deuterium with a speed factor S such that the axial run-down time matches the current rise time at an end axial speed of nearly 10 cm/μs. For operation in neon, we first consider that a focus pinch temperature between 200 and 500 eV may be suitable for a good yield of neon soft X-rays, which corresponds to an end axial speed of 6–7 cm/μs. On this basis, for operation in neon, the standard UNU/ICTP PFF needs to have its anode length z_0 reduced by some 30%–40% to maintain the time matching. Numerical experiments using the Lee model code are carried out to determine the optimum configuration of the electrodes for the UNU/ICTP PFF capacitor system. The results show that an even more drastic shortening of anode length z_0 is required, from the original 16 to 7 cm, at the same time, increasing the anode radius "a" from 0.95 to 1.2 cm, to obtain an optimum yield of $Y_{\rm sxr} = 9.5$ J. This represents a two- to threefold increase in the $Y_{\rm sxr}$ from that computed for the standard UNU/ICTP PFF.**

***Index Terms*—Dense plasma focus, neon plasma, numerical experiments, soft X-ray (SXR) source.**

I. Introduction

THE UNITED Nations University/International Centre for Theoretical Physics Plasma Focus Facility (UNU/ICTP PFF) has a unique standing in the study of plasma focus. This plasma focus system was developed under the funding and support of UNU, ICTP, and the Asian African Association for Plasma Training to initiate and promote practical knowledge and skills in plasma physics, including fusion, in developing countries [1]. It is the only plasma focus machine operating in nine research laboratories in seven countries. Research studies carried out using the UNU/ICTP PFFs have led, at last count, 11 years ago [2], to the publication of more than 200 research papers, 20 Ph.D. degrees, and 40 master's degrees. It has been successful in achieving its objectives and remains one of the most cost-effective and reliable plasma focus machines for the studies of dense multiradiation plasma sources.

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The UNU/ICTP PFF is a 3.3-kJ Mather-type plasma focus system powered by a single 15-kV 30-μF Maxwell capacitor switched on by a simple parallel-plate swinging cascade air gap [3]. The system produces remarkably consistent focusing actions and neutron yields of $0.5-1.0 \times 10^8$ neutrons per discharge at 3.0 torr of deuterium operating at 15 kV and 180 kA [3], [4]. This was not unexpected as the UNU/ICTP PFF was designed for optimum neutron yield in deuterium. It has a speed factor $S = (I/a)/P_0^{0.5}$ of 97 kA/cm per $[\text{torr of deuterium}]^{1/2}$ that is consistent with the range of other neutron-optimized plasma focus devices operating in deuterium [5]. The speed factor determines the speed in both the axial and radial phases. For operation in deuterium, this corresponds to just under 10 cm/μs for the end axial phase (just before the start of the radial phase) and a radial speed of 25 cm/μs when the imploding shock nears the axis. The ratio of average to end axial speed for a typical focus device is around 0.6. Thus, the UNU/ICTP PFF is designed for an average axial speed of 6 cm/μs running over an anode length of 16 cm. This ensures that the axial run-down time matches the effective current rise time of 2.6 μs at an end axial speed of nearly 10 cm/μs [3].

However, for operation in neon, Liu [6] and Bing [7] have shown that a focus pinch compression temperature of 200–500 eV is suitable for a good yield of neon soft X-rays (SXRs). For the UNU/ICTP PFF, Liu has shown that the required end axial speed is around 6–7 cm/μs, giving an average axial speed of around 4 cm/μs. In terms of time matching, this means that, for operation in neon, the standard UNU/ICTP PFF has too long an anode and that this anode has to be reduced by some 30%–40% to maintain the time matching. These factors in design consideration are basic and have been discussed in more detail in an introductory document (paragraph titled "Designing a new plasma focus") of the Lee model code [8]. We use these considerations as a starting point in our optimization of the UNU/ICTP PFF for neon operation. The numerical experiments, as will be seen, then go on to show that the required reduction on anode length z_0 is more drastic than expected.

II. Lee Model Code Incorporating Line Radiation

The Lee model code couples the electrical circuit with plasma focus dynamics, thermodynamics, and radiation, enabling a realistic simulation of all gross focus properties. The basic model, described in 1984 [9], was successfully used to assist several projects [3], [10], [11]. Radiation-coupled dynamics was included in the five-phase code, leading to numerical experiments on radiation cooling [12]. The vital role of a finite small disturbance speed discussed by Potter in a Z-pinch situation

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