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ORIGINAL PAPER

Numerical Experiments on Soft X-ray Emission Optimization of Nitrogen Plasma in 3 kJ Plasma Focus SY-1 Using Modified Lee Model

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Abstract The X-ray emission properties of nitrogen plasmas are numerically investigated using corona plasma equilibrium model. The X-ray emission intensities of nitrogen Ly_α, Ly_β and He_α, He_β lines are calculated. The optimum plasma temperature for nitrogen X-ray output is concluded to be around 160 eV. The Lee model is modified to include nitrogen in addition to other gasses (H_2, D_2, He, Ne, Ar, Xe). It is then applied to characterize the 2.8 kJ plasma focus PF-SY1, finding a nitrogen soft X-ray yield (Ysxr) of 8.7 mJ in its typical operation. Keeping the bank parameters and operational voltage unchanged but systematically changing other parameters, numerical experiments were performed finding the optimum combination of pressure = 0.09 Torr, anode length = 7.2 cm and anode radius = 2.58 cm. The optimum Ysxr was 64 mJ. Thus we expect to increase the nitrogen Ysxr of PF-SY1 sevenfold from its present typical operation; without changing the capacitor bank, merely by changing the electrode configuration and operating pressure.

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Introduction

The dynamics of plasma focus discharges is complicated; for this purpose, to investigate the plasma focus phenomena, the Lee model couples the electrical circuit with plasma focus dynamics, thermodynamics and radiation, enabling realistic simulation of all gross focus properties. The model provides a useful tool to conduct scoping studies, as it is not purely a theoretical code, but offers means to conduct phenomenological scaling studies for any plasma focus device from low energy to high energy levels.

The model in its two-phase form was described in 1984 [1]. It was successfully used to assist in the design and interpretation of several experiments [2–6]. Radiation-coupled dynamics was included in the five-phase code leading to numerical experiments on radiation cooling [7]. The vital role of a finite small disturbance speed discussed by Potter in a Z-pinch situation [8] was incorporated together with real gas thermodynamics and radiation-yield terms. Before this 'communication delay effect' was incorporated, the model consistently over-estimated the radial speeds by a factor of ~2 and shock temperatures by a factor ~4. This version using the 'signal-delay slug' assisted other research projects [9–11] and was web-published in 2000 [12] and 2005 [13]. All subsequent versions of the Lee model code incorporate the 'signal-delay slug' as a must-have feature. Plasma self-absorption was included in 2007 [12] improving soft X-ray yield simulation in neon, argon and xenon among other gasses. The model has been used extensively as a complementary facility in several machines, for example, UNU/ICTP PFF [2, 5, 9, 10,

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