Energy transfer efficiency measurements in a Theta-Pinch

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Abstract

We have obtained an increase in energy transfer efficiency of the capacitor bank to the plasma, when the electrical system of a theta-pinch was changed so that the ratio of total inductance to coil inductance was switched of 1/6 to 1/2. A further increase about 20% was obtained for 16/1 ratio. The measurements were made through the current discharge decay, and the spectral analisys of the emitted light from theta-pinch shows a correspondent efficiency increase.

1 Introduction

A Theta-Pinch is a device for producing a high temperature and high β plasma (β is defined as the ratio of plasma kinetic pressure to external magnetic pressure). It consists basically of a capacitor bank and a glass wich is surrounded by a discharge coil. The capacitor is discharged through the coil producing a magnetic field, wich is excluded from the plasma due to the plasma conductivity. Thus a "magnetic piston" is formed wich drives the plasma toward the axis of the coil, the plasma being heated and compressed in the process.

The magnetic field increasing rate ($\dot{B}$) must be chosen large enough to cause the electron multiplication in the gas, wich is the most important factor to obtain an apropriated conductivity and to produce a plasma of a high temperature by driving the strong shock waves. We have changed the electrical system of Theta-Pinch, and increase the rate of the magnetic field, through the decrease of the inductance of the transmission line and with a new magnetic coil with four turns. The energy transfer efficiency measurements reveal an increase about four times.

2 Breakdown Condition and Eficiency Transfer-Energy

Sato [1] has calculated the marginal $\dot{B}$ for electron multiplication at the radius r is given by

$$\dot{B} = 2 \times 10^8 bp/(r \log(apr)) \tag{1}$$

where $\dot{B}$ is in G/s, p in mmHg, r in (cm) a=12 and b=342 for argon [2]. And in his analisys of energy gain in the non-adiabatic regimes reveals that de energy gain is proportional to the product $\dot{B}a_0^2$, where a_0 is the tube radius. Since the adiabatic condition in expressed as $\dot{\omega}/\omega^2 \ll 1$, where $\omega = eB/mc$ is the cyclotron frequency and most magnetic compression experiments a $\dot{B}$ about 10^{10} to 10^{12} G/s are used, the efective acceleration from the induced electric field take places only in a short time interval at beginning of discharge.

Using a single-turn circuit to describe the discharge circuit which the plasma is represented as a linear resistance reflected from gaseous secondary [3], the governing equation of the discharge is

$$(L_0 + L_p)\frac{di}{dt} + (R_0 + R_p)i + 1/C\int idt = 0\,. \tag{2}$$

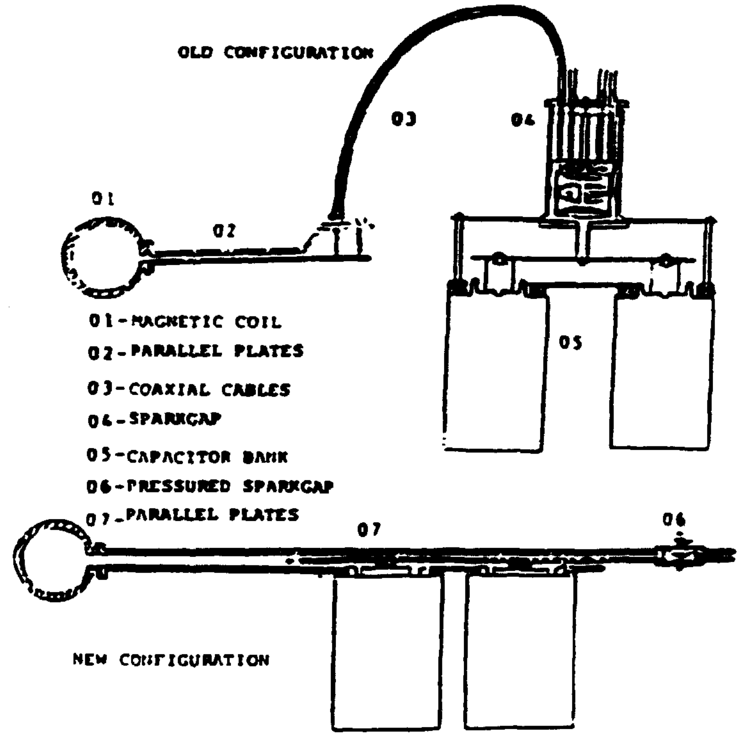

Figure 1: Old and new configuration of TPIII-Unicamp.

where the subscripts 0 are related to the circuit parameters in a plasma absence. L and C represent the inductance and capacitance respectively. This well-known equation has the solution

$$i = i_0 \exp[-\beta\ t/2]\ sen(\Omega t)\,. \tag{3}$$

here $\Omega^2 = \frac{1}{C(L_0+L_p)}$; $i_0 = \frac{V}{(L_0+L_p)\Omega}$; $\beta = \frac{R_0+R_p}{L_0+L_p}$ and V, the capacitor bank voltage.
The efficency (η) of energy transfer from capacitor to the resistance R_p defined by the ratio the energy stored in the capacitor bank to the energy $R_p \int i^2 dt$ may be written as

$$\eta = \frac{R_p}{R_0 + R_p} = 1 - \frac{T_p^3 \times ln((I_1/I_2)_0)}{T_0^3 \times ln((I_1/I_2)_p)}. \tag{4}$$

where I_1 , I_2 are two successive extreme values of the current discharge and T is the associated time interval.

3 Modifications in Electrical System and Results

The theta-pinch TPIII-Unicamp consists basically of a capacitor bank (7.89μF X 60kV), a high voltage switch and transmission line to drive the energy to the magnetic coil.
The following modifications were made : replacement of a high voltage three electrodes sparkgap switch, built at Los Alamos Scientific Lab., by a pressured sparkgap ; b) exchange of coaxial transmission line by a parallel plate transmission line and ; c)replacement of the single turn coil by a four turn coil. Figure(1) shows schematically the theta-pinch after (lower) and before (upper) modifications. The efficiency measurements were made through the measured current discharge decay and employing the equation(4). Figure(2) shows typical

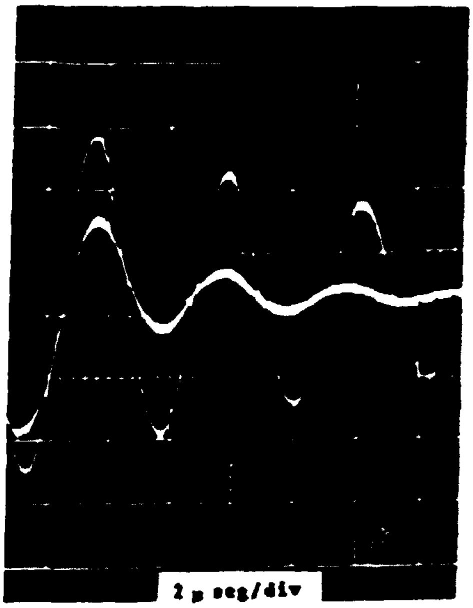

Figure 2: typical currrent decay in TPIII-Unicamp

parameters	before	after	after 4-turns
Inductance L_0	176 nH	31,2 nH	31.2 nH
coil inductance	32.2 nH	32.2 nH	532 nH
efficiency(η)	5%	22%	28%
tube radius	100 mm	100 mm	100 mm
$\dot{B}$	$1,4 \times 10^9$ G/s	6.9×10^9 G/s	1.2×10^{10} G/s

Table 1: Some TPIII-Unicamp parameters

signal developed by the current discharge, where the biggest signal was obtained in the plasma absence. Table(1) shows some parameters of the theta-pinch system after and before the modifications. To record the spectra, a 2-m normal incidence VUV spectrograph was aligned to view the plasma axially. The spectrograph is equipped with a 1180 grooves/mm grating, with an inverse dispersion of 4.62 Å /mm blazed at 1100Å in a 300-2000Å range. The spectrograms were recorded in SWR-KODAK emulsion plate. The obtained spectra for argon, using 24kV in capacitor bank, are reproduced in a new electrical configuration using only 10kV in capacitor bank.The similar results were obtained in the Xenon spectra

4 Conclusions

The energy transfer efficiency was increased for a lower inductance transmission line compared with coil inductance. When we made the replacement of single-turn coil to a multiple-turns coil, there was an additional efficiency increase. However by this way, the increase in the circuit resitance must be taken account wich may to cause an efficiency degradation. In any case it is found that a multiple-turn coil showed a higher transfer efficiency that a single -turn coil.

Acknowledgements

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