Magnetic pulse compression in the prepulse circuit for a 1 kW, 1 kHz XeCl-excimer laser

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ABSTRACT

Using high quality low loss ferrite, a single stage magnetic pulse compression network has been demonstrated working at 1 kHz PRF. A pulse compression factor of 4 has been achieved, delivering a 50 ns pulse as prepulse in the excitation circuit for a high power XeCl-excimer laser.

1. INTRODUCTION

In the Eureka-project running at the University of Twente for the development of a 1 kWatt, 1 kHz XeCl-excimer laser a prepulse-main pulse excitation circuit[1)] will be used for high efficiency operation. A ferrite race-track configuration forms the magnetic switch[2,3,4)]. A fast prepulse minimizes the amount of ferrite in the switch and therefore allows a fast risetime of the discharge current. Another important item is long life operation at high repetition rates of the thyratron in the prepulse circuit. For these reasons magnetic pulse compression is used in the prepulse circuit.

2. EXPERIMENTAL SETUP

Figure 1 shows the electrical scheme of the magnetic pulse compression circuit. The primary capacitor C_0 = 5.4 nF is charged to 20-50 kV. An EEV-CX1725 thyratron forms the switch for the primary circuit. When the switch has been closed, the energy of C_0 is transferred through L_1 = 4 μH to C_1 = 5.4 nF. The values of C_0, L_1 and C_1 give a pulse of FWHM ≈ 200 ns and peak current of maximum 1.2 kA. This allows the thyratron to operate far below its maximum ratings, and a long life time of the tube is expected.

In the secondary circuit the magnetic switch L_2 has been designed in such a way that the ferrite saturates at the moment when C_1 is fully charged. The ferrite, in the form of toroids to minimize rest-inductance has been pre-magnetized to take advantage of the complete achievable ΔB (maximum voltage hold-off). When L_2 satureates C_2 = 5.1 nF is rapidly charged from C_1. The pulse charging C_2 will be the prepulse when the MPC-system has been coupled to the laser electrodes. For that reason a capacitor has been chosen as a load to simulate the peaking capacitor at the laserhead.

A cross sectional view of the heart of the pulse compressor is shown in figure 2, showing C_1, the ferrite ring cores and the cables to the load. The ring cores have dimensions of 8.0 cm OD, 4.4 cm ID ad 2.0 cm thickness. We have used two types of ferrite. The first one (I) is K4-ferrite from SEI-company (UK), the second one (II) CMD5005-ferrite from Ceramic Magnetics (USA). These ferrites have been tested for their capabilities of voltage isolation, degree of compression and losses. The tests described below concern single shot experiments. After that high repetition rate operation of the second ferrite has been achieved.

3. RESULTS

3.1 Single shot operation

Typical wave forms of current and voltage are given in figures 3 and 4, for ferrite I and II respectively. In this case V_0 = 30 kV. The area is the same for both ferrites. Due to the different width of the hysteresis loop ferrite I is biased with 100 A and ferrite II with 5 A. U_1 denotes voltage across C_1, U_2 voltage across C_2.

Clearly demonstrated is the better performance for our application of ferrite II over ferrite I. Better isolation, a higher pulse compression factor, γ, and lower loss. The most significant results are given in table I. The pulse compressor generates a pulse with 50 ns rise time. The peak current in the thyratron has been reduced by a factor of 3 and the dI/dt by a factor of 15.

Table 1 Measured material specification of two types of ferrite based on V_0 = 30 kV.

	I	II
ΔB (T)	0.4	0.4
μ_r^{sat}	10	5
loss	8%	4%
γ	3	4

3.2 High repetition rate operation

Because of the lower loss and better pulse compression the CMP5005-ferrite has been chosen for high repetition rate operation. Capacitor C_2 has been removed and replaced by an almost matched resistive load, R = 8Ω, V_0 = 30 kV, so that at 1 kHz prf. the pulser operates at 2.4 kW power level.

Up to now 1 kHz operation has been demonstrated for maximum 1 minute, with typical wave forms as shown in figure 5. No changes in the wave forms did occur during the burst.

4. CONCLUSIONS

A suitable type of ferrite has been found with good pulse compression properties. High repetition rate at 1 kH has been demonstrated with low losses.

5. REFERENCES

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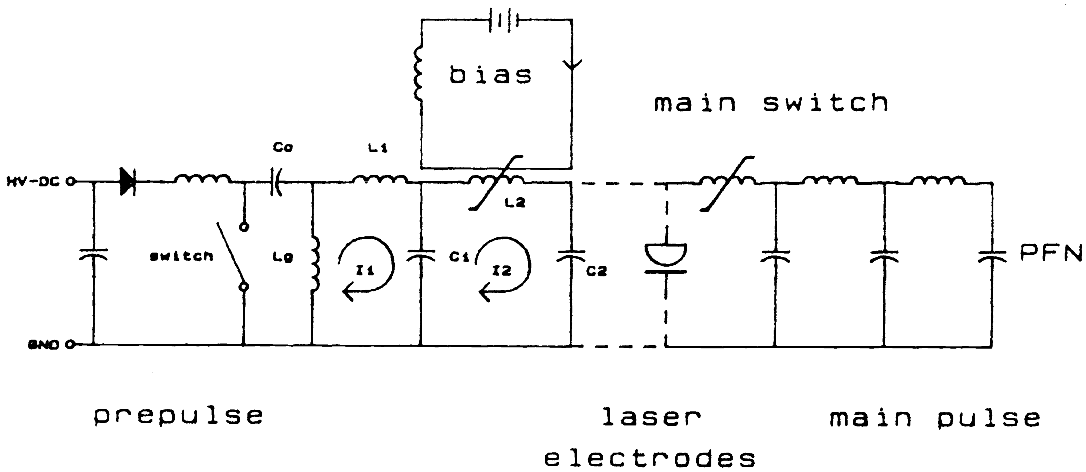

Fig. 1 Electrical scheme of the magnetic pulse compression circuit.

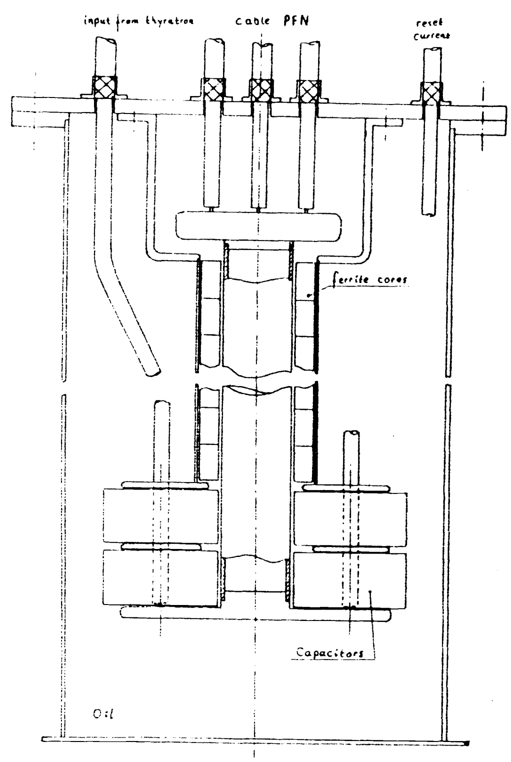

Fig. 2 Cross-section of the pulse compressor showing C_1, the ferrite ring cores and the cables to the load.

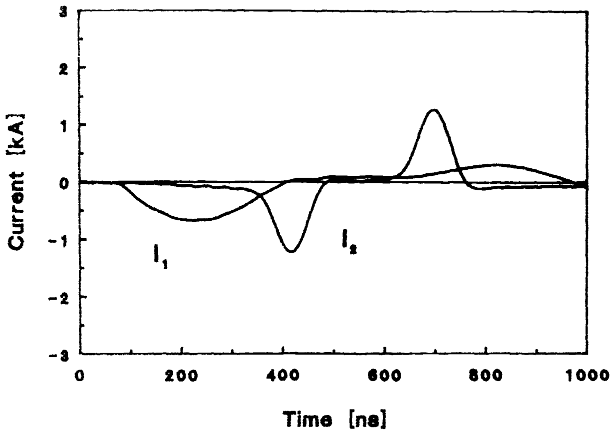

Fig. 3a Current waveforms of ferrite I, V_0 = 30 kV.

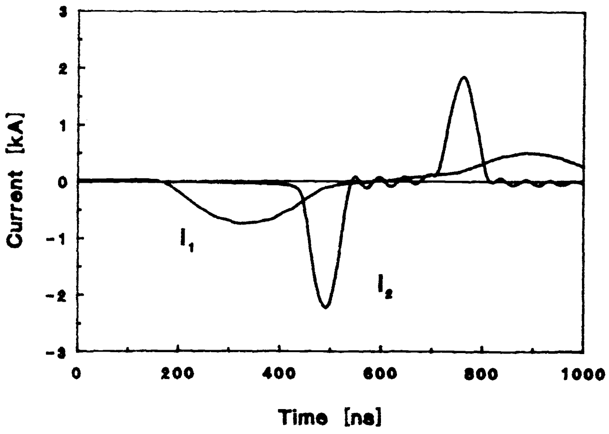

Fig. 4a Current waveforms of ferrite II, V_0 = 30 kV.

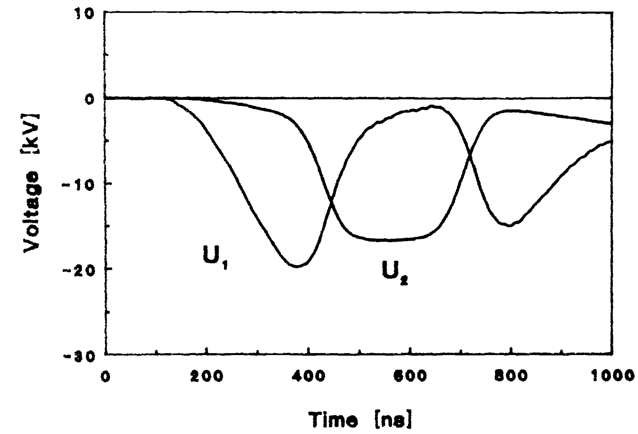

Fig. 3b Voltage waveforms of ferrite I, V_0 = 30 kV.

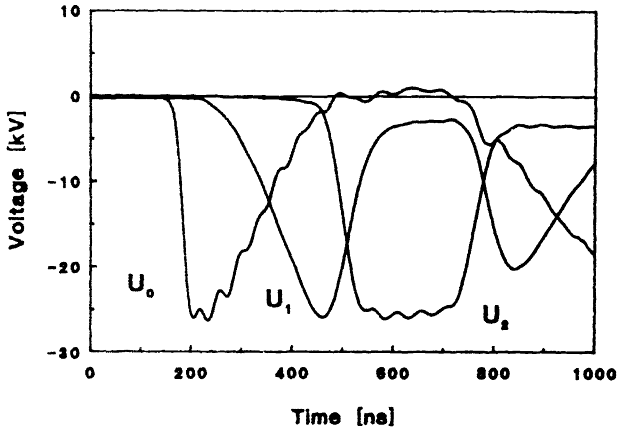

Fig. 4b Voltage waveforms of ferrite II, V_0 = 30 kV.

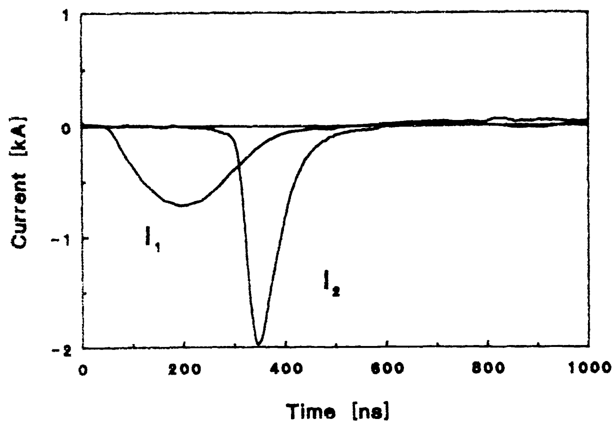

Fig. 5 Current waveforms of ferrite II at 1 kHz PRF.