CHAPTER 2

THE TRANSIENT HOLLOW CATHODE DISCHARGE (THCD) SYSTEM

The THCD system used in this project comprises of two main parts : i) the electrodes and the vacuum chamber, and ii) the electrical energy supply system that includes the triggering system and the Marx bank.

2.1 The Electrodes and The Chamber

The hollow cathode is made from a small copper rod with length of 30 mm and diameter of 10 mm. A hole which is 5 mm deep and 1.5 mm in diameter is drilled at the center of the copper rod to act as the hollow cathode region. The diameter of the hollow cathode will be widened to 5 mm in another series of experiments. The cathode is connected to the Marx generator via a cable and is inserted inside a perspex holder as shown in Figure 2.1.

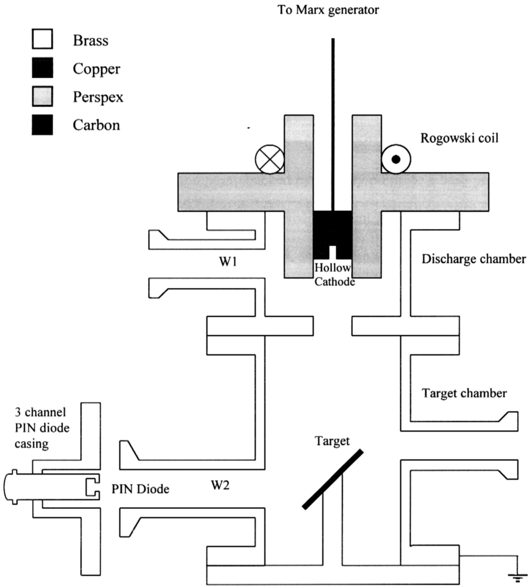

Figure 2.1 The schematic setup of the THCD chamber.

The chamber of the system is divided into two sections, an upper chamber which is the discharge chamber and a lower chamber which is the target chamber. Both of the chambers have inner diameter of 51 mm and outer diameter is 54 mm. The length of the discharge chamber is 49 mm and that of the target chamber is 98 mm. The chambers are separated by a brass plate with a 10 mm diameter hole along the axis. This brass plate acts as the anode of the discharge. The chambers are pumped together with a diffusion pump backed by a rotary pump to a base pressure of less than 2×10^{-3} mbar. The window W2 is used to mount a three channel Diode X-ray Spectrometer (DXS) system (see chapter 3, section 3.6). A target is placed at an inclination of 45° towards the electron beam and W2. A Rogowski coil is placed on the hollow cathode holder to pick up the rate of change of the discharge current, as illustrated in Figure 2.1.

2.2 The Electrical System

2.2.1 The Marx Circuit

The Marx circuit *[S. Lee, 1985]* uses the technique of charging several capacitors in parallel and then 'erecting' them into a series circuit by means of switches. The erection process occurs extremely rapid and the output voltage will be increased by double, triple or more, depending on how many stages of Marx circuit is built.

In this project, two 40 kV, 0.22 μF Maxwell capacitors are connected in series to give a total capacitance of 0.11 μF. The schematic circuit diagram of the Marx bank of this project is shown in Figure 2.2.

In order to obtain a voltage of –60 kV, the spark gap SG1 is set to breakdown at a voltage of 60 kV, while SG2 is a triggered spark gap. When the capacitors are charged up in parallel to 30 kV, the potentials at B and D (see Figure 2.2.) are 30 kV. A, C and E remain at earth potential. A pulse is sent to the triggering electrode of SG2 to initiate a spark across the gap, upon which the potential at C will drop from 0 V to -30 kV. This will cause the potential across SG1 to become 60 kV. Subsequently the gap will breakdown and the potential at A decreases from earth to -60 kV. The function of the 40 MΩ resistors, R1 and R2 is to limit the current flow so as to hold the voltage at A for sufficiently long time to facilitate the ion format of the electron beam from the transient hollow cathode.

The hollow cathode is connected to point A through a cable. This will result in a high inductance discharge. However, this will not affect the formation of the pre-breakdown electron beam.

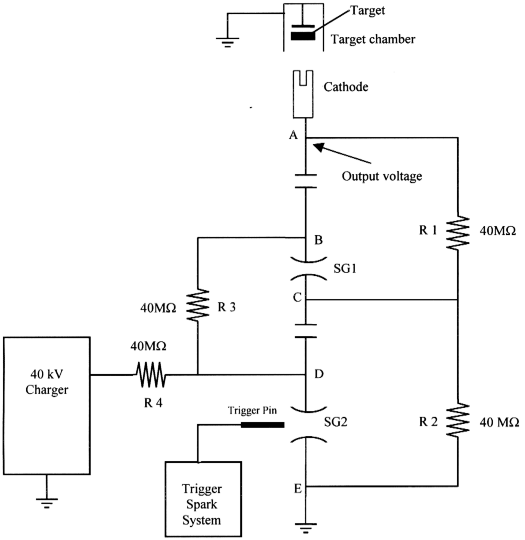

Figure 2.2 Schematic circuit diagram of the Marx circuit.

2.2.2 The Triggering Circuit

The triggering of the Marx bank is provided by a parallel-plate spark gap arranged with swinging cascade configuration, as shown in Figure 2.3 *[A. J. Smith et. al., 1986]*. The swinging cascade spark gap is essentially a three electrode device forming two gaps in series. The common (or trigger) electrode is positioned between the main electrodes. Gap ratio of 3 : 2, with the gap toward the high voltage main electrode being large, is used. The common electrode is held at a proportion of the gap voltage corresponding to the physical spacing. The total gap length is such that before triggering the gaps are holding the operating voltage. A rounded 1-m long UR67 coaxial cable functioning as an isolating capacitor triggers the spark gap upon an earlier triggering from a 750 V SCR unit via a step-up TV transformer (step-up ratio 17 : 1, rise time 1 μs).

Fast operation is achieved by applying a large negative voltage pulse with a fast rise time to the trigger electrode and thus swinging its potential negative until the high voltage (large) gap breakdown. This connects the high voltage to the trigger electrode whose potential swings positive past its initial value thus applying a high voltage across the second (smaller) gap which in most cases breakdown because of a very large overvoltage. Figure 2.4 shows the variations in gap voltages during operation.

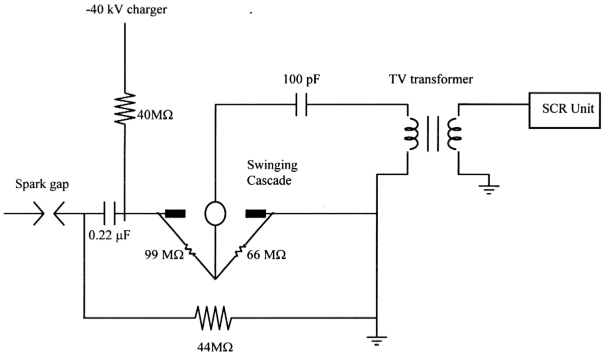

Figure 2.3 The triggering system.

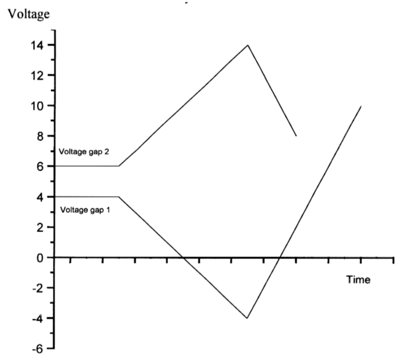

Figure 2.4 Voltage waveform for a swinging cascade spark gap.

2.3 Operational Procedures of The THCD

To operate the THCD system, the capacitors are first charged up to the required voltage. The voltage will be held by both spark gaps. The spark gaps are adjusted at a distance to hold some of the charging voltage so that when the trigger spark is applied via an isolating capacitor (~ 100 pF) from a 750 V SCR pulse stepped up 17 times by a TV transformer, breakdown will occur at both spark gaps. The full voltage is then transferred from the capacitor to the electrodes. Subsequently, a strong electric field is built up between the hollow cathode and the anode. A burst of electrons will be collimated by the electric field into a beam from the hollow cathode region and accelerated along the cylindrical axis of the chamber. The electron beam bombards at the target, which is slanting at 45° to the incident electron beam. Intense X-rays, which are detected by the PIN diode, will be produced from the target. The electron beam will stop when the main breakdown occurs. The transient hollow cathode device is shown in Figure 2.5.

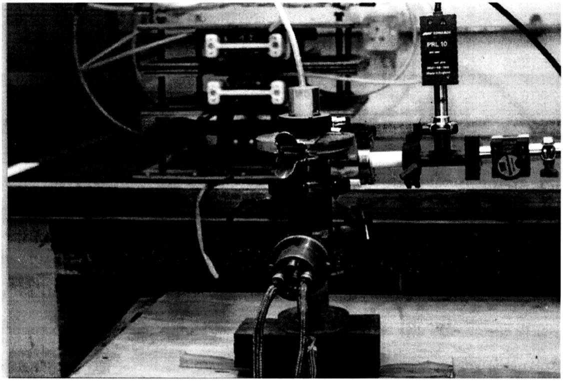

Figure 2.5 The THCD system.