CHAPTER 2

THE VACUUM SPARK SYSTEM (UMVS)

The vacuum spark apparatus employed in this work is similar to the one constructed by Ong [1992]. In the present setup, both the cathode and the anode can be replaced with different materials having various geometrical features. This is made possible through threaded design for attaching the electrodes.

In this work, intensive studies are carried out with various cathode aperture diameter and interelectrode spacing to find out the best electrode configuration that would produce plasma x-ray emission consistently. Using this setup, the plasma x-ray emission is studied. The type of trigger system used, is described in section 2.1 and in section 2.2 a brief description of the system is given.

2.1: Trigger system

A trigger system is used to initiate the main discharge of the vacuum spark. There are various designs of triggering system used for vacuum spark research. However, they can be grouped into two types. One is the electrical trigger system where an auxiliary sliding spark at the cathode surface is used [Lee & Conrads, 1976]. The other is the laser triggering system where a powerful pulsed laser beam is focussed onto the anode tip [Wong & Lee, 1984] [Koloshnikov et. al., 1985].

For the auxiliary sliding spark, the spark acts as a source of electrons which are attracted towards the anode by the electric field in the interelectrode
space. The bombardment of the anode by these electrons produces a weakly ionized plasma of the anode material. For the laser triggering, the interaction between the focused laser beam and the anode produces the weakly ionized plasma. Both types of triggering lead to the formation of identical plasmas after the breakdown of the main discharge.

The reproducibility of dense plasma spots from a vacuum spark operated with a sliding spark is very erratic. This method is only effective if the sliding spark is powered by a high energy capacitor discharge. On the other hand, the use of a high power laser system is not economical nor practical. Therefore, a different form of triggering system is used for the UMVS. By using the electron beam produced from a transient hollow cathode discharge (THCD) effect [Christiansen et al., 1979] to trigger the UMVS, the operation of the vacuum spark discharge has been simplified.

Basically, a THCD is a low pressure high voltage discharge initiated across an anode and a hollow cathode. The cathode has a constricted opening at the axis and a large cavity behind it called the hollow cathode region (HCR). The electrodes are arranged axisymmetrically as shown in Figure 2.1. Since the discharge is operated with its value of $pd$ at the left-hand branch of the Paschen curve, the primary electron collision rate is insufficient to generate the breakdown avalanche. Therefore, a trigger spark is used to initiate the THCD effect to produce an electron beam and it has been reported that the THCD effect enhances the x-ray emission from low energy x-ray sources [Skowronek et al., 1989] [Wong et al., 1992].
Fig. 2.1: The axisymmetrical arrangement of the hollow cathode device.
Fig. 2.2: The schematic diagram of the triggering system.
The schematic diagram of the triggering system is illustrated in Figure 2.2. The input of the pulsed high voltage transformer is supplied with a positive 750 V sharp voltage pulse from a SCR (TYN 1012) module. A single core wire with high voltage insulation is connected to the output of the pulsed transformer. The other end of the single core wire is mounted at the rim of the cathode hole, close to the cathode surface. This wire acts as the trigger pin.

The triggering of the SCR would create a spark between the tip of the trigger pin and the cathode. This spark would release electrons into the HCR. The electrons will be collimated into a beam and accelerated along the cylindrical axis of the chamber. This effect is due to the electric field distribution of the hollow cathode configuration [Ong, 1992]. The bombardment of the electron beam on the tip of the anode vaporizes some anode material into the inter-electrode space, causing breakdown to occur.

2.2: The experimental setup

The vacuum spark system shown schematically in Figure 2.3 consists essentially of an energy storage capacitor on which the vacuum spark chamber is mounted. The energy storage capacitor used in this work has a capacitance of 1.85 μF, an internal inductance of 15 nH and can be charged-up to a maximum of 60 kV. For the work reported here, the charging voltage is 20 kV which gives an electrical input energy of 370 J.

A threaded brass bolt enclosed in a PVC cylinder block and connected to the capacitor serves as (i) an electrical connection between the anode and the
Fig 2.3: The schematic diagram of the vacuum spark system.
capacitor, and (ii) as the anode holder. A brass cylinder that houses the cathode is attached to the earth return plate. This cylinder has four diagnostic ports through which an x-ray pinhole camera, time-resolved x-ray detectors and a portable spectrometer or slit-wire camera are mounted.

Both the anode and the cathode can be easily removed. Various metals can be used as the anode to study a particular metal plasma. The interelectrode spacing can be varied from 0 to 10 mm and cathodes with various designs and apertures can be used. In the present work, the anode is made from copper and has a rounded tip. The diameter of the anode is 5 mm. As for the cathode, a stainless steel cylinder is machined into a threaded disk ($\phi = 40$ mm, $t = 5$ mm). A tapered hole is made in the centre of the cathode disk. The narrower end of the hole has diameter ranging from 2 mm to 10 mm. The cathode disk is attached to the cathode cylinder with the narrower end of the aperture near to the anode.

A copper extension tube which is attached to the cathode cylinder serves as an end-on diagnostic port. Three filtered PIN diodes are mounted on top of this tube to monitor the temporal development of the hard x-ray component of the discharge.

To measure the rate of change of discharge current, $dl/dt$, a magnetic pickup coil is radially placed near the central conductor below the earth return plate. The induced voltage signal which is proportional to the time derivative of the current is fed to an oscilloscope. The current derivative is preferred because the current dip associated with the hot spot formation can be observed more clearly in current derivative signal than in the current signal.

The whole apparatus is continuously evacuated with an oil diffusion pump
backed by a rotary pump. The chamber pressure is measured as accurately as possible by connecting a Penning ionization gauge at the pumping port using a T joint. For all the discharges carried out in this work, the pressure is maintained at about $1 \times 10^{-4}$ mbar.