## Product Brief 2021

# Triggered Switching Spark Gaps

The triggered switching spark gaps (TSG's) by TDK are a family of versatile high voltage switches, hermetically sealed in a ceramic/metal envelope. Spark gap tubes with a DC hold-over voltage in the range 17 to 32 kV are available. TDK offers various types of spark gaps for this purpose with different self-breakdown voltages and trigger designs. A triggered switching spark gap enables the discharge of a capacitance to be controlled for voltages below the hold-over- or self-breakdown-voltage. Typically, the operating voltage range is between about 40% and 80% of the self-breakdown voltage. The advantage of triggered operation is that the discharge voltage of the capacitor becomes variable.

### Features

- Long life time
- Stable performance over life
- High voltage and high current switching
- Very short breakdown time
- High reliability by robust design
- RoHS-compatible

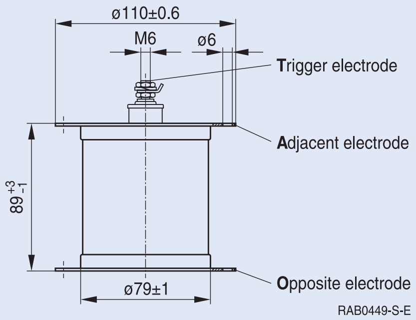
### Application

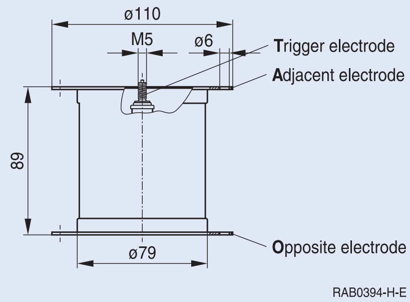
- High power impulse switching for medical applications, ESWT and ESWL
- High voltage pulse generator for pasteurization by pulse electric field
- High voltage pulse generator for semiconductor components cleaning equipment

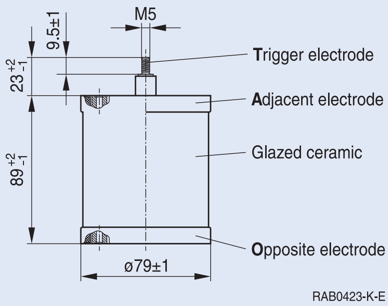

# Triggered Switching Spark Gaps

## Specifications TF series

| TF25E/ TF32E | TF26/ TF28 | TF17R/ TF28R |
|---|---|---|
|  |  |  |




| Type | TF17R | TF25E | TF26 | TF28 | TF28R | TF32E | Unit |
|---|---|---|---|---|---|---|---|
| Ordering code | B88069X6803B011 | B88069X1093B011 | B88069X9601B011 | B88069X9091B011 | B88069X3523B011 | B88069X1443B011 | |
| Self-breakdown voltage | 17 | 25 | 26 | 28 | 28 | 32 | kV |
| Tolerance of SBV | ±10 | ±10 | ±10 | ±10 | ±10 | ±10 | % |
| Triggered breakdown voltage, initial | 6 … 12 | 8 … 19 | 8.5 … 21 | 8.5 … 22 | 8.5 … 22 | 10 … 22 | kV |
| Triggered breakdown voltage, during lifetime | 7 … 10 | 8 … 16 | 9.5 … 19.5 | 10 … 20 | 10 … 20 | 10 … 20 | kV |
| Switching operations @ 2 Hz | 1400000 | 4000000 | 2000000 | 2000000 | 4000000 | 4000000 | |
| Discharge capacitance | 0.5 | 1.2 | 1.2 | 1.2 | 0.1 | 1.2 | µF |
| Max. impulse currents | 3 | 7 | 8 | 8 | 5 | 8 | kA |
| Open-circuit trigger peak amplitude | > 25 | > 15 | > 35 | > 35 | > 35 | > 15 | kV |
| Trigger peak current | ~ 10 | ~ 10 | ~ 10 | ~ 10 | ~ 10 | ~ 10 | A |
| Breakdown | < 50 | < 50 | < 50 | < 50 | < 50 | < 50 | ns |
| Insulation resistance | > 100 | > 100 | > 100 | > 100 | > 100 | > 100 | MΩ |

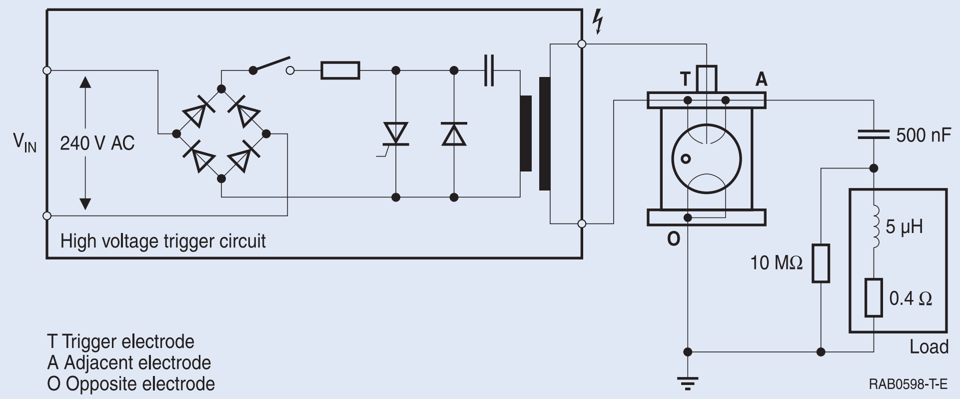
# Triggered Switching Spark Gaps

## Mode of operation

Triggered spark gaps consist of three electrodes including the trigger electrode and two main gap electrodes. The trigger electrode is disconnected to the adjacent main electrode (anode) by a trigger ceramic. The opposite main electrode (cathode) lays opposite to the adjacent and the trigger electrode. Both adjacent main electrode and trigger electrode are disconnected to the opposite side by an outer ceramics envelope and by the center main gap with a gas filling of noble gas at fixed pressure. For switching the breakdown voltage of the main gap must be reached and the perfect gaseous insulator will become a good conductor within a time typical t < 50 ns with a current increase dI/dt > $10^9$ A/sec.

For application the triggered spark gap discharges the capacitor energy through the pair of main electrodes, when a voltage impulse is applied to the trigger electrode relative to the adjacent electrode. In first approximation the sum of actual capacitor voltage plus peak value of trigger voltage should be larger than the hold-over or self-breakdown voltage of spark gap.

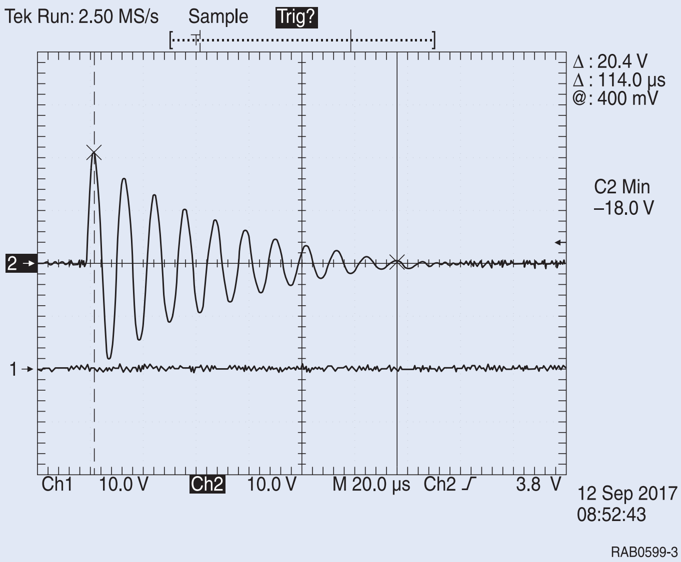
## Figure 1: Discharge circuit with trigger source in (T-A)




As described in figure 1 the main capacitor will be charged by a DC generator to high positive voltage. The trigger voltage too is on high positive voltage, when closing the thyristor switch on primary trigger side. Within short time delay the main capacitor will be discharged and in the discharge circuit a damped oscillation acts with in this case a typical frequency in the 90 kHz range. Figure 2 shows the current oscillation for one pulse with 2 kA max. value.

# Triggered Switching Spark Gaps

**Figure 2: Poor damped oscillation with 10 ups and downs for the current through the TSG according to circuit in figure 1.**

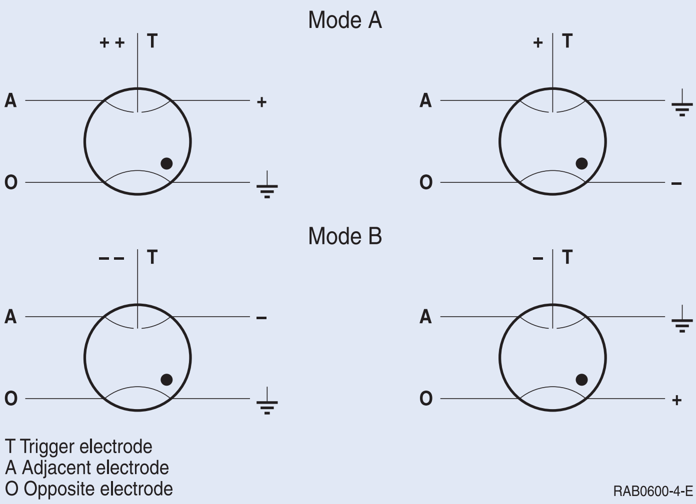



Besides the here explained case A of positive trigger voltage and positive adjacent voltage (anode) against the counter negative opposite voltage (cathode) also the other polarity for case B should be possible in practice. However, this must be checked then in every case regarding the chosen spark gap and chosen charge- and discharge parameters. For case A and B it is possible to connect the adjacent or the opposite electrode to the mains potential. This is important for the application, since no human must get contact to high voltage!

The two cases are described in the table.

| Mode | Polarity of trigger pulse trigger to adjacent | Polarity of main discharge opposite to adjacent | Characteristics |
|---|---|---|---|
| A | + | - | Suitable for wide range of working voltage, recommended mode. |
| B | - | + | In general can be also possible |

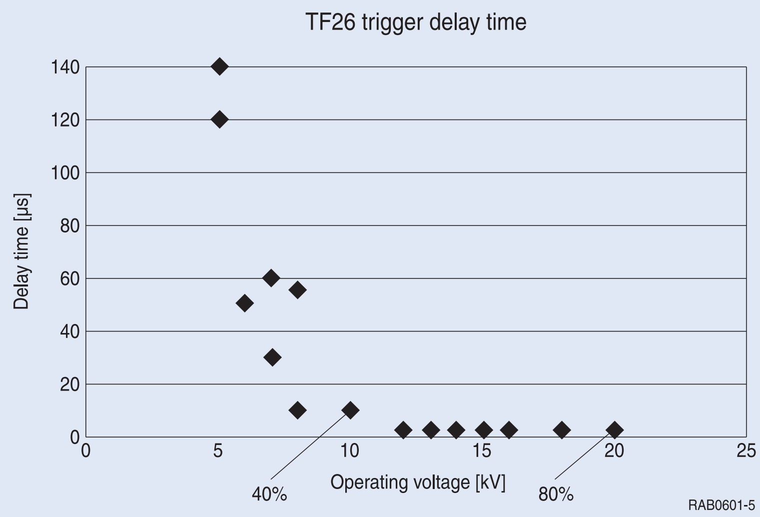
**Figure 3: Usually used modes A and B for operating the TSG**



# Triggered Switching Spark Gaps

The range of operation for TSG's can be described by the response of breakdown following the trigger impulse. Fast breakdown with low trigger delay time means a correct function of spark gap.

**Figure 4: Mode A and Mode B: Operating voltage range curve for a 26 kV TSG**




For operating voltage 40 to 80% stable delay time and reliable triggering. For < 40% strong increase of delay time and uncertain function. For > 80% spontaneous discharge of TSG.

## Principle of design

The trigger spark gap switch is a small, sturdy and fast switching element, especially suitable for normally open application and which can switch large currents. The triggered spark gap consists of a pair of electrodes and a gaseous dielectric in the main gap. In the open state, it is insulated. The dielectric prevents the current from flowing between the electrodes. In the conducting state, the electric breakdown will establish a conductive path between the electrodes, and the two electrodes are connected by a high-conductivity arc bridge.

The DC high voltage generator contents in principal a rectifier for AC voltage and a network of voltage doubling to reach the very high charging voltage of up to 32 kV to charge the HV capacitor.

The charging of capacitor must be controlled by an End of Charge EoC signal. With enabling this signal the spark gap can be triggered by a thyristor switch in the trigger circuit.

An impulse high voltage generator to develop the trigger pulse of approximate 15 kV with a slope of approximate 15 kV/µs and a peak current of maximal 10 A is necessary to provide a reliable trigger impulse.

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## Applications function block

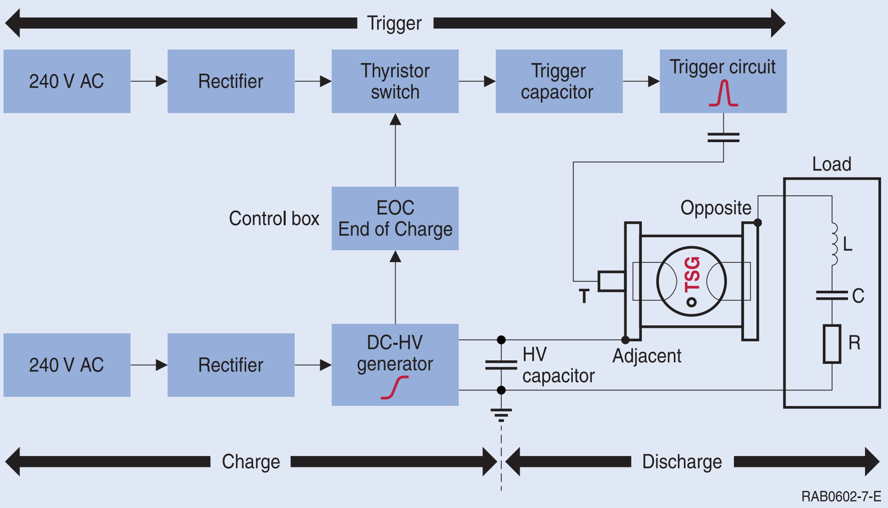
In general, there are 3 circuits to obey:
**Charging circuit**, to which belongs the DC charger and the high voltage capacitor.

**Trigger circuit**: A high voltage trigger pulse will be provided with approx. 15 kV/µs and 15 kV peak value. The trigger will be started by a thyristor on the primary side of trigger transformer.

**The load or discharge circuit**: It consists of the special application, enclosing a capacitor and also an inductivity and an ohmic damping resistor. Depending on the application, the L and R can be larger in the 1 µH and 1 Ω range, here normally there will be a stronger damped oscillation with 4 to 5 half waves only. Or there are small values for R in the < 1 Ω-range, then there will be a poor damped oscillation, as described in figure 2 with more half waves of current. For small damping, the energy from capacitor discharge often will flow hence and force through the spark gap, what will reduce the life time of spark gap.

The principal arrangement of complete circuit is described in next figure:

## Figure 5: Outline of a complete application circuit with TSG



# Triggered Switching Spark Gaps

## Application examples

**Application 1:**

**Extracorporeal shock wave lithotripsy ESWL and extracorporeal shock wave therapy ESWT**

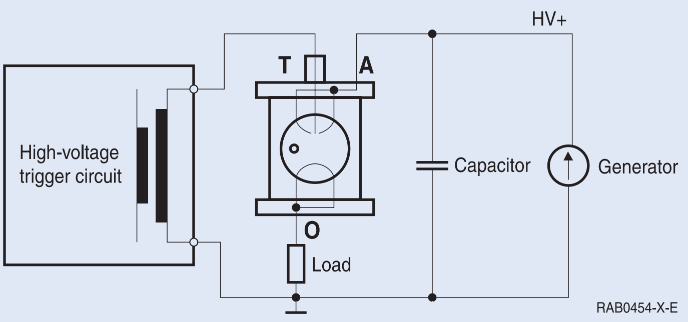
A typical application is the method of Extracorporeal Shock Wave Therapy (ESWT) or Extracorporeal Shock Wave Lithotripsy (ESWL) for medical treatments. For this application the capacitance, with typical values of between 100 nF and 1.2 µF, is discharged across an inductance of a coil with a membrane (electro-dynamic principle), or across a spark gap immersed in an electrolyte fluid (spark plug principle). The mechanical impulse wave is focused onto the specified object (e.g. a kidney stone) in order to disintegrate it. TDK electronics offers various TSG types for this purpose with different self-breakdown voltages and trigger designs. A triggered switching spark gap enables the main discharge of the capacitance to be controlled for voltages below the self- breakdown voltage. Typically, the triggered voltage is between about 40% and 80% of the self-breakdown voltage. The advantage of triggered operation is that it controls the discharge voltage of the capacitor and, in the case of ESWL and ESWT, it enables the medical treatment to start with low current impulses which can subsequently be increased.

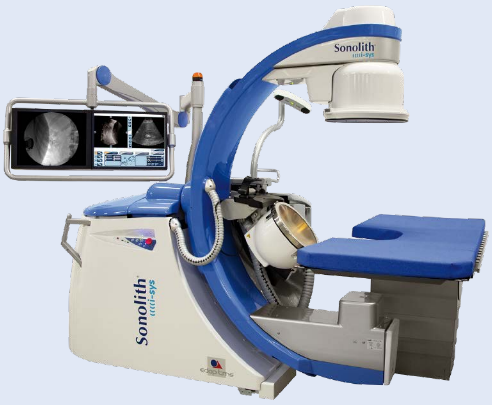
For this application TDK electronics offers the triggered spark gaps of the TF series with maximum operating voltages of approximately 22 kV and currents up to 10 kA.

General technical information

A typical circuit for creating a high energy surge impulse is shown in figure 6. The capacitance C is charged by means of a generator and then at the required frequency the discharge to the switching spark gap is triggered by the trigger circuit. For high capacitances the switching spark gaps are triggered at a rate of 2 Hz. Under the conditions defined in the data sheet, a service life of between two and four million operations can be achieved.

**Figure 6: Typical circuit and example for ESWL equipment**

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# Triggered Switching Spark Gaps

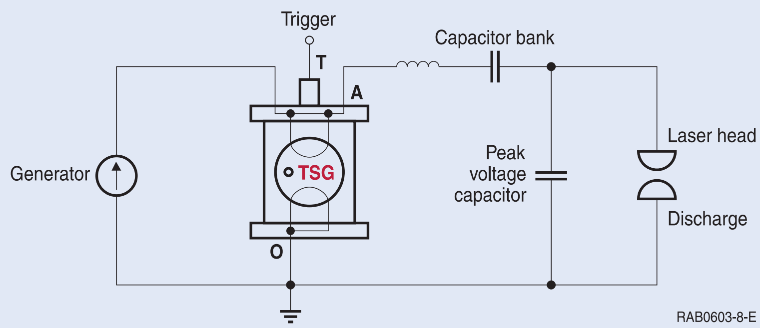
## Application examples

**Application 2:**

**High voltage provision for high power pulsed excimer lasers**

Excimer gas lasers will be ignited with high voltage in the 20 kV range. 2 solutions to create the high voltage are usual: Besides the semiconductor IGBT's for lower powers the triggered thyratron gas switches will be used for high powers. The thyratron cathode must be heated and for operation the thyratron has only reduced ability to switch negative currents. These oscillating currents are no problem by operating with triggered spark gaps, replacing the thyratrons. A principal circuit is shown in figure 7.

**Figure 7: Application of TSG for pulsing a high voltage excimer laser tube**



## Application examples

**Application 3:**

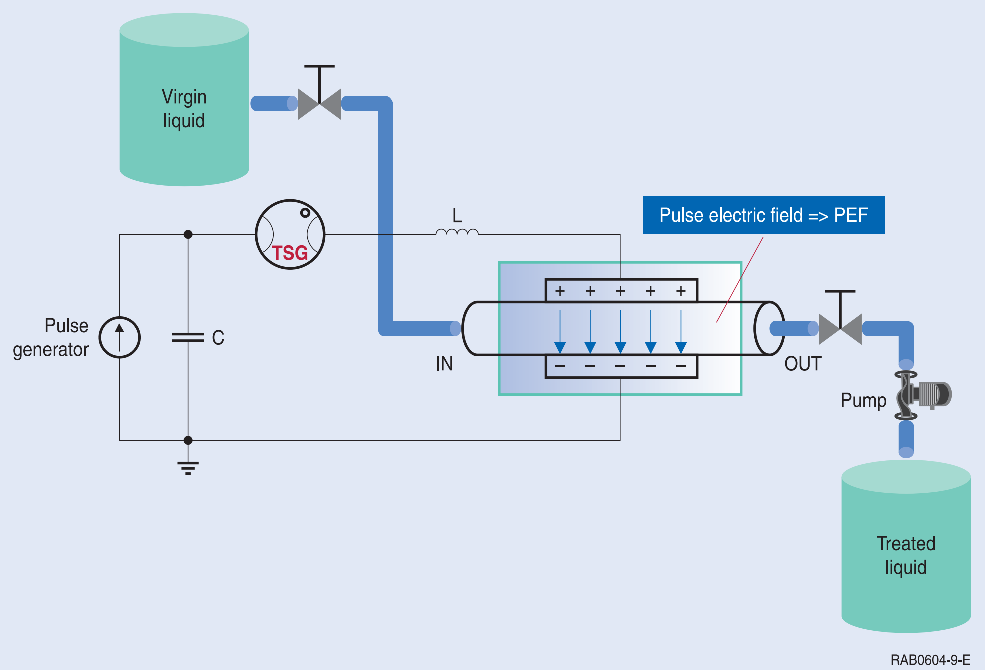
**High voltage pulse generator for pasteurization by Pulse Electric Field (PEF)**

Pulsed Electric Field (PEF) is a new non thermal technology, which is suitable for non-thermal food processing. The high voltage pulse is applied to the food through an electrode system inside a chamber at room temperature for a few seconds. The advantages of this method is the passivation of microorganisms and enzymes at room temperature, keeping the quality, safety and freshness of high value nutrition products. The processing time is relatively short.

The traditional scheme will produce energy loss in the heating process. For example, the preservation of apple juice generally adopts the thermal pasteurization method, and the apple juice is heated to 76 °C to 87.7 °C. Thermal sterilization will damage the microbiological cells and cell membranes in the juice, thus affecting the quality of products.

For the application of PEF, it is necessary to adjust the level of high voltage pulse and to control the processing time in order to obtain the electric field intensity matching with the start-up of microorganism. The number of pulses multiplied by the pulse width, defines the treatment time. The intensity of the electric field depends on the shape of the PEF cavity. Typical electric field strength for PEF process vary between 1 kV/cm to 15 kV/cm, this means high voltage capacitors and switches have to be used.

**Figure 8: Principal arrangement of a PEF system for preservation of a liquid solution like juice**



# Triggered Switching Spark Gaps

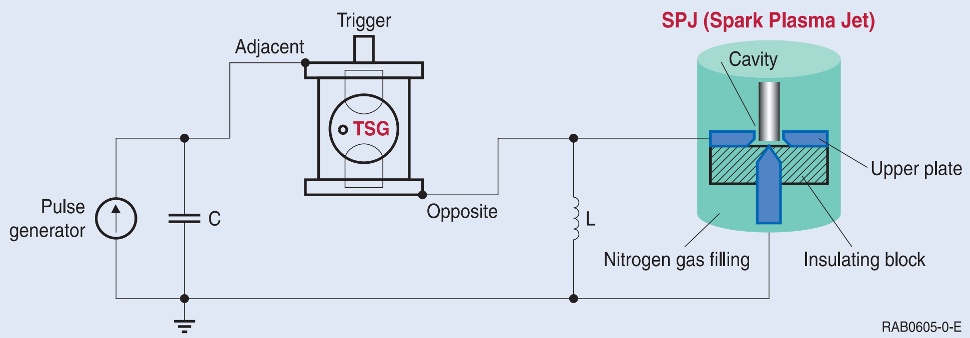
## Application examples

**Application 4:**

**Cleaning, etching and activation of electronic components surfaces as preparation step for assembly and soldering electronic components by a spark plasma jet SPJ.**

The development of a spark plasma jet stream is a method to clean and activate by example wire connections for a 100% reliable wettability for solder material. By using our TSG a circuit with high impulse current and very high dI/dt > $10^9$ A/s can be accomplished. Inside a cavity then by a high electric field the plasma jet is created. The new technique of spark plasma jet SPJ in normal atmospheric conditions at 0.1 MPa Nitrogen pressure shall be used for this method. (Source W. Tie, Y. Zhang, C. Meng, Q. Zhang, Z. Yan, P. He, Plasma Sources Science and Technology, 27,1,015005, 2018).

**Figure 9: Generation of SPJ spark plasma jet**





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