DESIGN AND CONSTRUCTION OF LASER'S SPARK GAP

Dr. Basem Alaibei Shwya
Mustansiriyah University

ABSTRACT:-

The spark gap is simply a high voltage , high speed switch for firing the laser,there are a number of applications in both civilian and military markets where **CO_2** lasers can be used to advantage over other coherent light source .In all of the following applications the laser is used in a pulsed mode and the influence of triggered spark gap has been found to be a most useful device for achieving this operation .

The two - electrode spark gap is designed to drive pulse laser and transmission mode systems by means of switching high voltage up to 30 κV at a repetition rate as high as 100 Hz . The device has been operated for several months , firing in a variety of applications without any electrode failure .

INTRODUCTION:-

Triggered spark gaps are very popular as fast high current switches. With proper design , a triggered spark gap can switch megawatts of power in a few microseconds with jitters of less than a nanosecond . These devices make use of the very low impedance of an arc once the arc is established [1] .Two electrodes are separated by sufficient distance that the gap dosen't spontaneously breakdown . The breakdown is initiated by a variety of means : UV irradiation from another spark or a lasser an over voltage pulse , or reducing the gas pressure in the gap .

Conceptually , a spark gap is a single device consisting of two conductors and an over stressed dielectric . The dielectric can be any insulator , gas , solid , liquid , or vacuum . A spark gap is typically used as a high – voltage closing switch with the requirement that the applied voltage must be removed for recovery to the open state [2].

There are many application used a spark gap as a high voltage switch such as gas laser system , flash lamp , pulsers and plasma research . The study of gaseous conduction and its connection with spark gap switch behavior has received a lot of attention from scientists and engineers who work in the area of pulsed power technology [3,4] .

There is a lot of similarity to a xenon flash tube here . In a triggered spark gap , the idea is to switch a lot of current at high voltage so the arc characteristics are optimized for that in a flash tube, the idea is to generate light , so the design is optimized for that (i.e use xenon (high lummens / watt) , long path (limit watts \ volume) , etc) .

Triggered spark gaps are the best means of switching high levels of stored energy with low loss and low inductance .Spark gaps have been employed in laser to give long , trouble – free performance , faster energy transfer rates , and tower jitter.

Unlike thyratrons , the voltage polarity is reversible ; unlike sealed gaps , pressurized operation allows a wide operating range for each design to be pressurized with nitrogen gas (oil – free or zero grade) from 0 – 40 p sig [3].

There are two types of spark gaps which are commonly used in high –voltage switching applications . These are the three – electrode spark gap and the linear rail spark gap . The three – electrode is a single channel closure device with nanosecond jitter characteristics , provided the trigger pulse rate of rise exceeds nominally 2κV/ns . On the other hand , the rail gap , a multichannel closure device , has low inductance but relatively high jitter [5] .

An additional benefit associated with the multichannel closure device is reduced electrode erosion due to decreased current density and shot – to – shot random distribution . This not only increases spark gap lifetime but could make electrode contouring a more useful design parameter .

APPLICATIONS:

When considering the choice of spark gap the following factors should be taken into accounts [6] :

. peak current and waveform .

. Coulombs per shot .

. Repetition switch rate .

. Main gap voltage .

. Environmental conditions .

. Medical lithotripsy .
. High voltage switches for laser firing .
. Crowbar circuits .
. Flash lamp pulses .
. Plasma & Fusion research .

Theory of Operation :

A simple two – electrode spark gap is shown in fig (1) . At low voltage the is an insulator . As the voltage increases , the few free electrons (present in the gap as a result of cosmic radiation and other ionizing effects) are accelerated to higher velocities , until they are able to ionize atoms of the gas filling builds up .

This leads to an avalanche effect ; as the additional electrons produce further ionization and as the current builds up there is a range of current over which emission from the cathode takes the form of a glow discharge and the voltage almost constant .A further increase in current produces cathode heating by ion bombardment , leading to the formation of emission sites and another voltage drop across the gap[6].

The are discharge formed in this stage is able to carry very high currents at a few tens of volt across the gap and the peak current value is determined by the external circuit . The arc persists until the current falls to a value insufficient to maintain arc conditions ; this current is lower than that required to establish the arc initially.current flow then ceases and the ionization of the gas decays until the gap has returned to its original state .

SPARK GAP :-

Pascheu's law states that the length of spark gap is inverse Proportional to the pressure .For a fixed length to diameter ratio of the spark , the inductance is proportional to the length [7] . Compare with dipole antenna is electrodes of the spark gap are glued or welded on a dielectric spacer – ring . Toreduce the danger due to the pressure , the volume is minimized to prevent sparks outside space ring in the low pressure, the spacer usually gets thicker outwards in an S- shaped manner .

A great deal of work is documented that relates breakdown voltage to gap geometry and such related parameters as gas dielectric and pressure [8] . The most commonly considered geometries are :

spherical point – to – plane and uniform field . The limitation are obvious with respect to an engineering instrument . Probably the greatest limitation is the one – point nature of the indication . Neglecting use as a protective device , spark gap measurements seem most appropriate for a laboratory environment .

There are some advantages , one is that the use of large spheres to avoid corona will permit measurements to very high voltages . Also , neither electrode must be at ground potential so that voltages of large differential can be addressed . If one electrode is at ground potential , it becomes possible to vary the gap until breakdown occurs without under complexity .

One side point is that literature below is based on arc breakdown The gap current might be limited by an external ballast , but there are several regimes of breakdown . To ensure accuracy , enough current must be permitted to flow for an arc to occur [9].

EXPERIMENTAL WORK:-

There is an extensive literature concerning low inductance spark gaps for many applications , laser technology among them [3] .

Pressurized switches have previously been used to drive nitrogen lasers at repetition rates exceeding 1.5 κHz. Nevertheless , we consider it of interest to report on the main measured electric parameters of a simple self – triggered nitrogen spark gap operating at a high repetition rate . The switch was designed to drive the Blumlein circuits of a small nitrogen lasers at high repetition rate ((capacitance`s and voltages were of the order of 1 nf and 10 κV)) [10,11] .

Certain problems are often encountered with spark gaps , these are :- 1 . The trigger electrodes tend to deteriorate very rapidly because of high current peaks ; 2 . The insulation of the trigger electrode is easily burned ; 3 . It is difficult to avoid frequency instabilities when operating at high repetition rates (about 50 Hz) , because of arc persistency [12].

Fig (1) , shows a cross section of the annular rail gap design for a simple and inexpensive spark gap which provides a solution to these problems . The body is made of nylon and has two Teflon sheets at the ends . The large bodies of dielectric that surround the electrodes were designed to prevent arcing along the exterior of the gap .

The electrode connected to the storage capacitor consists of the Steel ball (12.5 mm in diameter) of a ball – bearing , which is pressed against the Brass part by a threaded Teflon cap conducted by the spark gap . The other electrodes connected to the nitrogen laser , consists of the terminal external part of a cold spark plug of a motor car .

The internal electrode of this, is our trigger electrode. The Trigger pulse was applied through a pulse transformer and a small capacitor (500 PF) between the internal electrode and the body of the spark plug . The last threads of the spark plug were removed with a lathe to avoid spurious sparks . With a fixed distance between the electrodes of 15 mm , voltages from 12 to 30 KV have been switched at repetition rates varying from 1 to 100 pulses sec^{-1}.

The life of a spark gap increases with decreasing repetition rate burst or higher repietion rates may be acceptable but may shorten life . The DC breakdown voltage of the spark gap reduces slowly with operational life as shown in fig (3).

The spark gap operation is dependent on the relationship of gas type , pressure , applied voltage , load characteristic , gas spacing and the spatial parameters of the triggering laser beam .

When considering the choice of spark gap , the above factors should be taken into account .

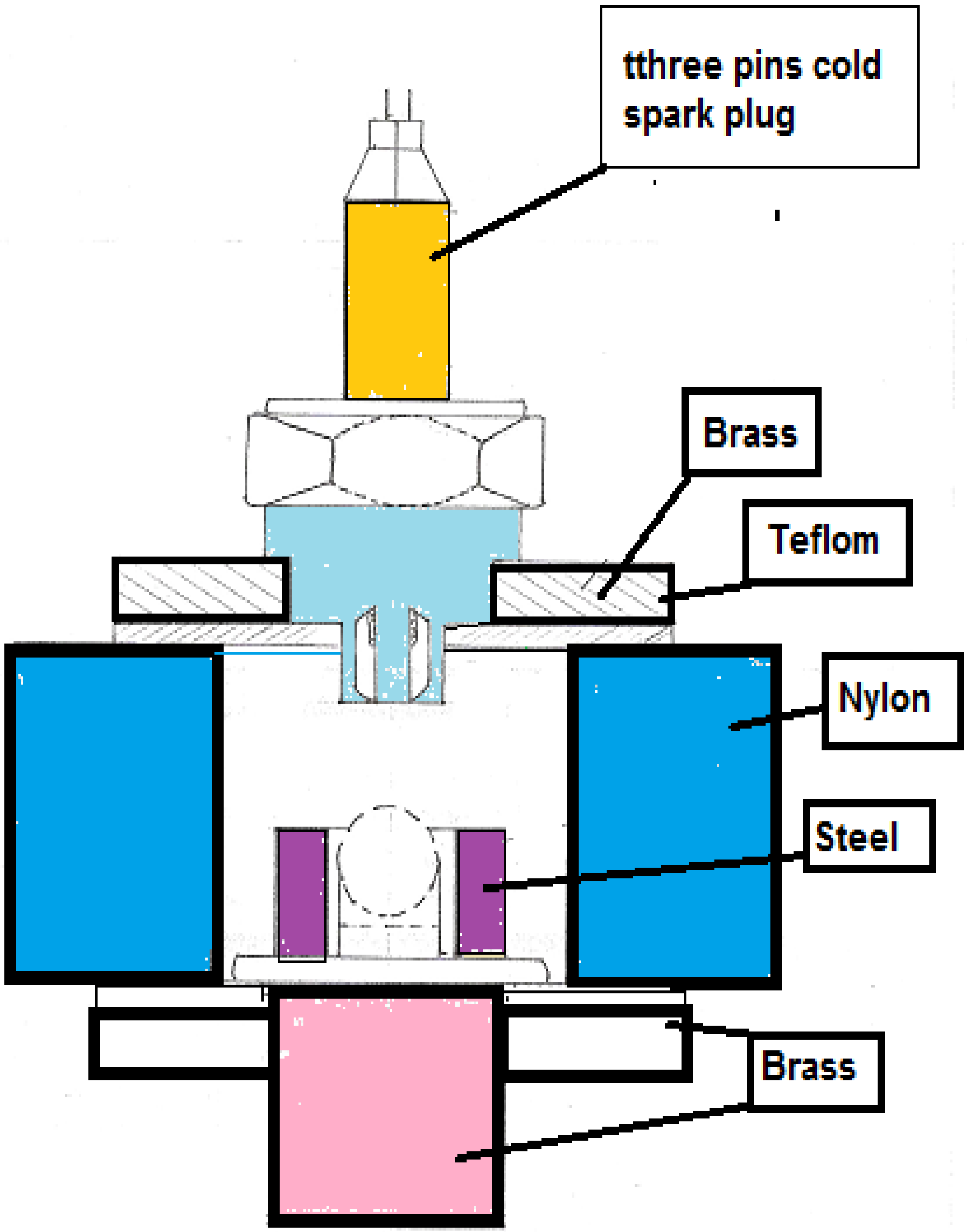
CONCLUSION:

This work deals with design and construction of the fast switching spark gap to determine some physical processes associated with the operation of this device .The switch was designed to drive Blumlien circuits of a small nitrogen laser at high repetition rate about 50 Hz.

The rail gap design provides a solution to the problems encountered with spark gaps.It was found that the life of a spark gap increases with decreasing repetition rate and the DC breakdown voltage reduces slowly with operational life. Also the operation of the spark gap is dependent on gas type , pressure , applied voltage and the type of applications.

REFERENCES : -

1 . T.R. Burkes et al, IEEE, vol.26 (10), pp.1401-1411,oct,1979.
2 . M.A.Gurderson, IEEE, vol.19,pp.1123-1131,1991.
3 . J.W.Keto et al,Rev.Sci.Instrum,51,1980.
4. L.Small et al, Rev.Sci.Instrum , 55 (7), July 1984.
5 . E.H.Gaxiolo and J.M. Wetzer,11th , International Symposium On High Voltage Engineering, pp.11-14,vol.3,August,1999
6 . AIA – Two Electrode Spark Gap, ezv technologies, Essex – UK, 4-May-2003
7 . R.J. Denhurst et al , J.Phys-D-Applied Physics, vol.5,No.1,1972
8 . Symposium On Plasma Physics and Technology,Prague, Czech Republic , P,35,(14-17) June,2004.
9 . T.W. Hussey et al , 12th IEEE International Pulsed Power Conference,Technical Papers,vol.2,pp.1171-1174,June,1999.
10 . R.Gratton et al,J,Phys,E,Sci-Instrum,21,1988.
11 . H.Li et al , IEEE Trans, Plasma Sci,35,1787,2007.
12 . Nitroge Laser-Wikipedia , the free encyclopedia . rnht,2011.



Fig(1)Schematic diagram showing the structure of the spark gap

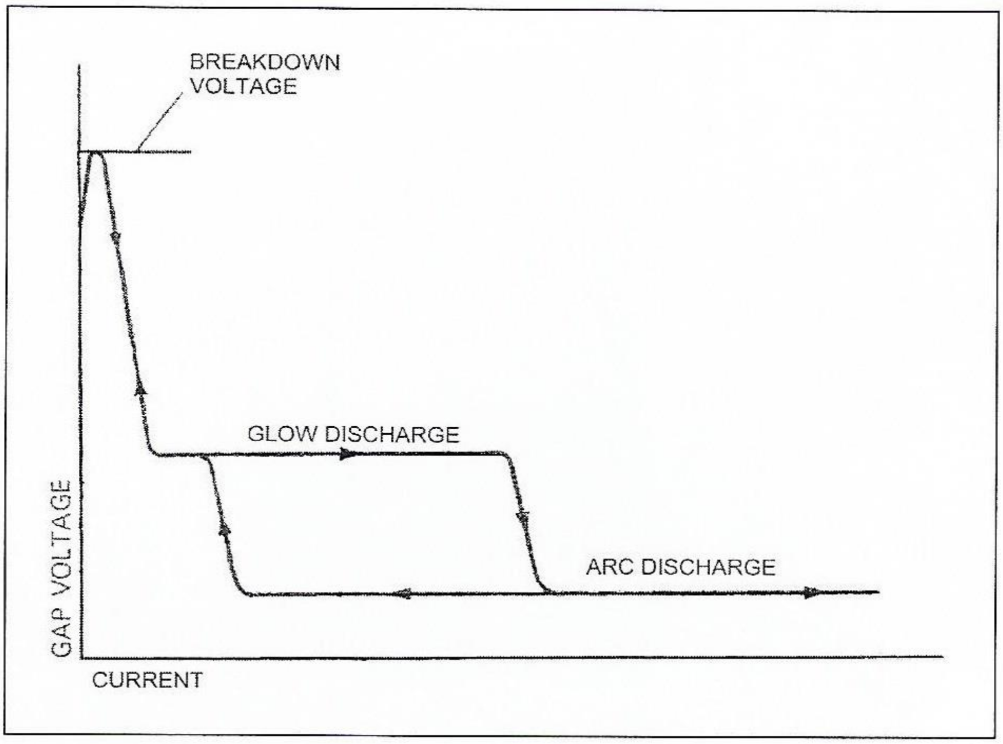


Fig (2): Voltage – current characterestics of a two – electrode spark gap.

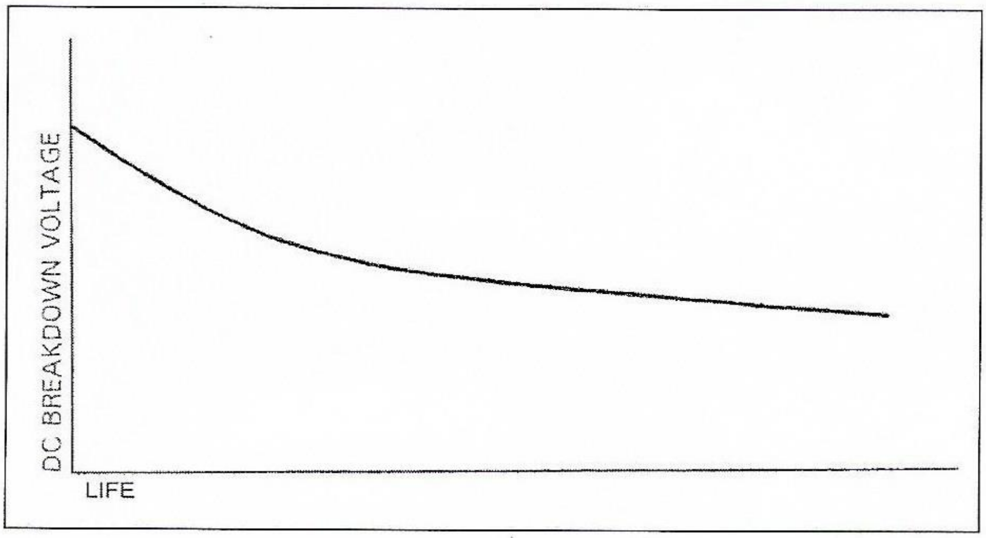


Fig (3): Typical plot of spark gap breakdown voltage over operational life.