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DIAGNOSTIC OF PRELIMINARY BREAKDOWN IN AN ARTIFICIAL THUNDERCLOUDS

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Abstract. Lightning is a destructive phenomenon. It can cause fire, damage and electrocute human being and animal. Therefore, we need to have some kinds of protective devices to trigger lightning before it could strike naturally. One way of doing it is by using laser. In this study unfocused UV laser was used to actively discharge the electrodes. Electrodes are used to represent thunderclouds. The separation distance between the electrodes was adjusted to determine the condition for preliminary breakdown. The result showed that, preliminary breakdown occurred at a short ranges separation distance of electrodes, hence very high electric field is required. The breakdown is found stimulated by interfering a UV laser in the thunderclouds. In this respect, the separation distance for breakdown is tri ple that of without laser. Hence minimum electric field can be achieved for such occurrence of preliminary breakdown.

Key words: Breakdown, lightning, electric field, electrical spark, high voltage, laser

Abstrak. Kilat ialah satu fenomena kemusnahan. Kilat boleh menyebabkan kebakaran, kerosakan dan membunuh manusia dan haiwan. Oleh itu, kita perlu mempunyai sejenis alat pencegahan untuk memicu kilat sebelum ia boleh menyambar secara semula jadi. Salah satu kaedah yang boleh digunakan ialah dengan menggunakan laser. Dalam kajian ini satu laser UV digunakan untuk mengaktifkan penyahcasan cas elektrik. Elektrod dianggap sebagai awan petir. Jarak pisah antara elektrod dilaraskan untuk menentukan kewujudan permulaan runtuhan. Keputusan menunjukkan, permulaan runtuhan berlaku pada jarak yang pendek. Ini bermakna medan elektrik yang tinggi diperlukan. Runtuhan terangsang apabila diganggu oleh laser UV dalam awan petir. Dalam situasi ini, jarak pisah didapati mencapai tiga kali ganda berbanding jarak tanpa laser. Oleh itu medan elektrik yang minimum diperlukan untuk kejadian permulaan runtuhan seperti itu.

Kata kunci: Runtuhan, kilat, medan elektrik, percikan api elektrik, voltan tinggi, laser

1.0 INTRODUCTION

Lightning is a giant electrical spark in the sky, usually occurring in the earth's atmosphere during storms. It often strikes tall buildings, above, and may do little damage. But lightning can kill people, destroy property, or cause fire. Therefore, it is important for us to study the nature of lightning. Scientific study of lightning was done by Benjamin Franklin in the 1750's [1].

There are always many thunderstorms occurring all around the world, and it is estimated that during any given second lightning strikes the earth a hundred times [1].

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In Malaysia the average number of days per year in which there is a thunderstorm ranges from less than 10 to 300 days [2].

Lightning burns and electrocutes human being and animal. Football and golf are among the deadliest sport, due to lightning strikes [3-4]. Lightning causes a great amount of property damage every year. The heat produced by lightning when it passes through a material with high electrical resistance, such as wood or brick, produces fires and explosions. The explosions result from the sudden expansion of air and moisture in the materials when they are heated by the current.

Since the effects of lightning are destructive, therefore researchers would like to devise a method to trigger lightning and guide the discharge to harmless spots. Ball, [5] was the first to propose using laser to actively discharge electrical charges in thunderclouds to a safe place. This is taking advantage of laser response time which is normally within microsecond compared to the whole process of a typical lightning discharge which normally lasts a few millisecond [6]. However due to the small laser and the high altitude of thunderclouds and hence the weak electric field, their project turned to be unsuccessful.

Various other groups are also involved in the same projects but they are using different laser wavelengths and powers. Most of the work is still laboratory based, except one group in Japan who has initiated the lightning strikes during field experiments on the shore of the sea of Japan [7-9]. An experimental site was chosen on the seacoast of Japan since that area is expected to have high possibility of being attacked by winter thunderstorm [10]. They have diagnosed the thunderstorm by using several sophisticated equipments including, electrical field meter (FM), corona current probes (CP), meteorology radar systems, broadband capacitive antennas (slow Antenna, SA) [11], and ultra high frequency (UHF) interferometer [12].

In this present paper, we tried to initiate the same study of lightning by using laser according to the environment in Malaysia. In this investigation we tried to diagnose the condition of preliminary breakdown by using a low power nitrogen laser in artificial thunderclouds.

2.0 EXPERIMENTAL SET-UP

We started the project by repairing an existing high voltage power supply. The voltage can be varied in the range of 1 kV up to 15 kV. This voltage is applied across an electrodes, which acted as artificial thunderclouds. A copper metal was shaped to form nozzle electrodes. Such shape was chosen since it can easily produce uniform and concentrate breakdown. The nozzle electrodes were mounted on a scanner using an insulated material likes Perspex. The negative electrode was adjusted by using a remote control in regards to protect the hazards of electrical shock. In this case, a computer program was developed to command the electrode to move at a desirable place. A personnel computer was conducted to govern the motion of the electrode.

Initially the electrode was placed at a short distance of separation. The current of the voltage supply was increased until the occurrence of breakdown in between the electrodes was observed. The experiment was repeated five times and an average reading of the current for that particular separation distance was taken. The distance then was increased with an increment of 1 mm for a system without laser and 2 mm for a system with laser. The voltage for an average current was then determined by using an available calibration curve. All the collected data for this experiment are listed in Table 1.

Table 1 Data without laser

Displacement (mm)	**Current (I ± 1) μA**					**Average current (μA)**	**Voltage (kV)**
	i	**ii**	**iii**	**iv**	**v**		
3	8	9	10	9	11	9.4	3.5
4	20	22	22	21	20	21.0	6.7
5	30	31	29	30	29	29.8	9.1
6	40	39	38	39	38	38.8	11.6
7	41	42	42	40	41	41.2	12.2
8	50	49	51	50	50	50.0	14.7

A repetitive nitrogen laser (Photonic LN 120C) is used as a pumping source. The wavelength of the laser is 337 nm, with pulse width of 300 picosecond. The energy of the laser output is 75 mJ. The laser was operated at two rates that are at low frequency (almost 1 Hz) and at high frequency (20 Hz). Since a nozzle electrode type was employed, the ultraviolet (UV) laser was delivered transversely to the electric field. Began with low frequency laser, the unfocused beam was directly send within the electrodes which initially set at a shortest separation distance and the current of the voltage was increased until the breakdown appeared. Various separation distances were examined without changing the position of nitrogen laser beam. The same procedure of experiments was repeated but by using a high frequency laser. All the collected data from the two types of laser operation are listed in Table 2 and Table 3 respectively.

The schematic diagram of the whole experimental set up is shown in Figure 1. The photograph of experimental set up developed in this project is shown in Figure 2. An example of static electrical spark (air breakdown) in between the nozzle electrodes obtained in this experiment is enlarged, and it is shown in Figure 2c. The figure shows a streak breakdown whose ionized channel is clearly visible as a single line.

Table 2 Data for low frequency laser

Displacement (mm)	Current (I ± 1) μA					Average current (μA)	Voltage (kV)
	i	ii	iii	iv	v		
4	15	16	14	13	14	14.4	4.8
6	19	20	18	19	18	18.8	6.1
8	24	23	25	24	25	24.2	7.5
10	29	28	30	31	29	29.4	9.0
12	34	35	34	35	34	34.4	10.4
14	38	40	39	42	40	39.8	11.9
16	44	45	45	43	44	44.2	13.1
18	48	47	47	46	50	47.6	14.0

Table 3 Data for high frequency laser

Displacement (mm)	Current (I ± 1) μA					Average current (μA)	Voltage (kV)
	i	ii	iii	iv	v		
10	21	22	20	19	21	20.6	6.6
12	24	25	23	24	23	23.8	7.4
14	26	27	28	27	26	26.8	8.3
16	30	31	29	29	28	29.4	9.0
18	32	31	31	32	32	31.6	9.6
20	34	33	33	32	35	33.4	10.1
22	36	35	34	35	36	35.2	10.6
24	38	37	39	37	38	37.8	11.3
26	42	40	40	41	39	40.4	12.0
28	44	43	43	44	42	43.2	12.8
29	48	46	46	45	46	46.2	13.6

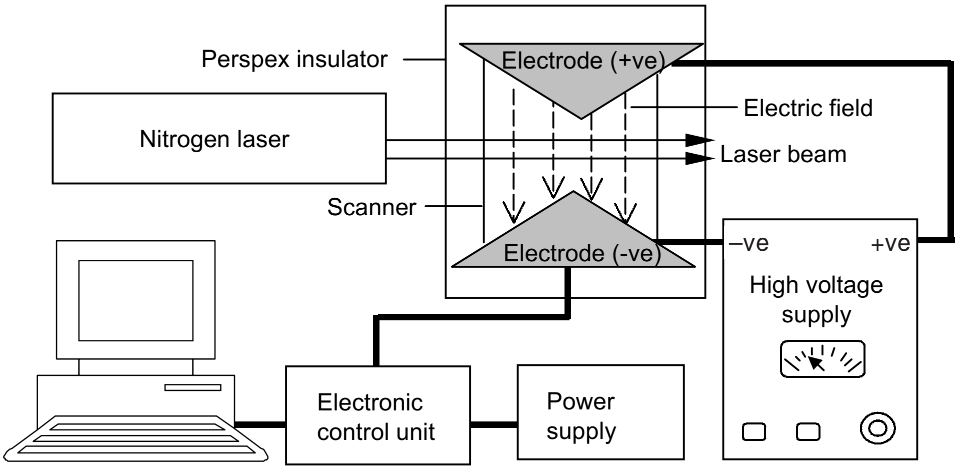
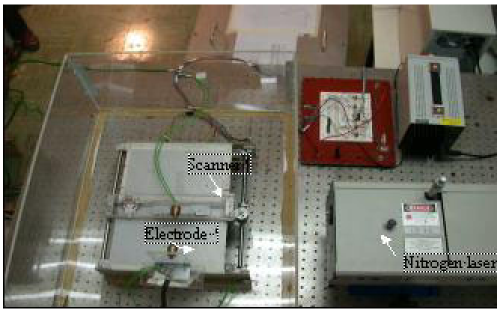
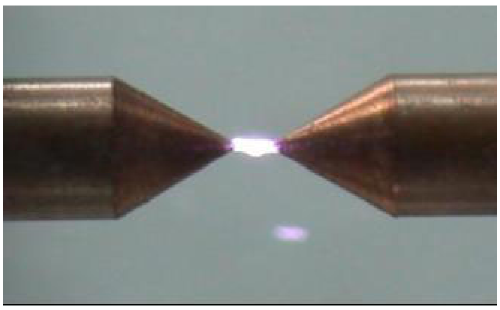


Figure 1 Schematic diagram of the whole experimental set-up

a. Side view of the experimental set-up



b. Top view of the experimental set-up



c. Enlarged view of the electrical spark

Figure 2 Photograph of the whole experiment for diagnostic of preliminary breakdown in between nozzle electrodes

3.0 RESULTS AND DISCUSSION

The collected data in Table 1, shows that a preliminary breakdown (PB) appeared when the electrode separation distance is in the range of 3 mm up to 8 mm. Beyond that range no breakdown could be seen. This means that the electrical charges can only be discharged if the electric field is strong enough. The discharge is generated due to the ionization atoms of air in that region. The air supposed to act as an insulator to the electrodes.

The present of laser beam, in between the electrodes, made the range of separation distances became obviously larger in obtaining the PB. During the application of low frequency laser, the maximum distance obtained under the test electrodes in attempt to gain the PB could reached up to 18 mm (Table 2). It is almost double from the previous distance obtained in the system without laser. In this case, the electric field for the occurrence of PB became weaker by less than half of the value obtained with the absence of laser. When the laser was operated at high frequency the separation distance for PB became much longer. The maximum distance achieved for PB in the region in this last experiment is 29 mm, which is almost triple (Table 3) the distance obtained for the system of without laser. Of course, the corresponding electric field within the electrodes which is responsible to attain PB also became much lower.

The lightning data collected from various experiments are plotted together in one graph as shown in Figure 3. Three straight lines are produced which indicated the

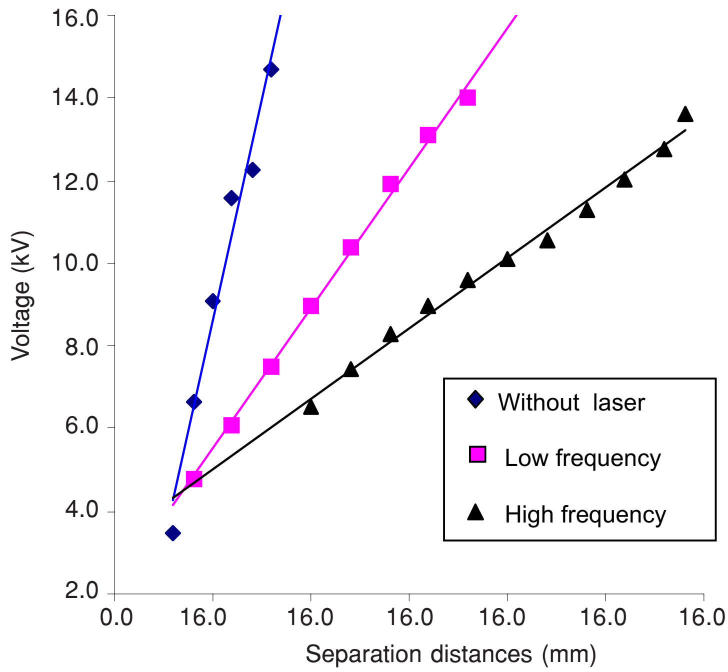


Figure 3 Graph of voltage against separation distance of electrodes

linear relationshi p between the potential differences and the separation distances of the electrodes necessary to obtain the PB. The gradient of the curve represents the average strength of corresponding electric field for PB occurrence in between the electrodes. The maximum electric field was obtained when the electrode system operated without the present of laser beam. Clearly, the minimum electric field for PB was obtained when the electrodes were interposed with high frequency laser. A moderate electric field for PB was obtained when the laser was operated at a low frequency. These graphs indicated that, the occurrence of preliminary breakdown (PB) required very strong electric field, that is 2.15×10^6 V/m, when the electrodes were operated without the aid of laser beam. Compared to the experimental results obtained with the present of UV laser in the field, the magnitude of electric field dropped to 0.7×10^6 V/m, which is almost 30 % of the value required for PB in the non-laser system. The electric field dropping even much lower for the occurrence of PB that is 0.34×10^6 V/m, which is almost 16% of the value in non-laser system, when a high frequency laser interposed within the electrodes. Summary of the parameters required for PB appearance within the electrodes are listed in Table 4.

Table 4 The parameters required for the occurrence of Preliminary Breakdown (PB)

Repetitive rate	**Maximum Distances (d ± 0.5)mm**	**Maximum Voltage V ± 0.01(kV)**	**Average Electric field, $E \times 10^6$ (V/m)**
No laser	8.0	14.70	2.15
Low	18.0	14.00	0.68
High	29.0	13.60	0.34

Lets us now look at the physical explanation behind these results. From Figure 2c we observes a single bright line connecting the two electrodes. Such a line is referred as a breakdown or electric spark. The breakdown consists of a narrow stream of charged particles that ionizes the atoms of air. The ionized atoms form a channel that readily conducts electricity. The strong electric field that existed across the high voltage is intense enough to ionize the atoms in the air. Positive and negative charges are generated as a result of ionization. The different charged particles are attracted to one another, thereby forming a spark.

Without laser interruption, the ionization atoms of air is totally due to the intensity of electrical field created between the electrodes. The strength of the electric field depends on separation distance and the voltage supplied to the electrodes. If the electric field is high enough, flow of current between electrodes occur. The lightning discharge involves the flow of charges across the potential difference.

Why does the breakdown or the electrical sparks become greater or faster when the laser beam is sent within the electrodes? The present of UV light within the electrodes result in the enhancement of the ionization process eventough the electric field is much weaker due to the large value of separation distance. Consequently, static electric spark was appeared, although the separation distance is triple times without the presence of laser in the electrodes. The application of high frequency laser beam within the electrodes cause an increase in the number of charge particles. These charge particles are produced from the excitation due to the interaction of photon energy given by the UV light. Due to large accumulation of charges, the insulating effect of the air is overcome and lightning is produced. In other words, nitrogen laser pumps energy to the air molecules within the electrode. The faster the rates of pumping the more number of atoms become excited or ionized. The excited atoms or charged particles either became positive or negative depending on whether they lose or gain electrons during interaction. When they move through air toward one another, they form an electric current that causes a spark. Lightning is the spark that results from the rapid movement of electrically charge particles within a thundercloud. Therefore introducing charge particles within thunderclouds may possibly be a catalyst in the generation of spark.

Clearly, UV light from nitrogen laser can provide external energy within the electrodes. This is why the electrode that has a weak electric field may also generate spark. As a result we can say that UV Laser can trigger PB in the electrodes. Thereby, low power laser can still play an important role in triggering lightning under the tested potential difference. We do believe that by taking into account the wavelengths and the output power, laser has a potential to be a protective device in the real field.

4.0 CONCLUSION

In this study unfocused UV laser was used to actively discharge the electrical charge in the electrode medium. In this case the electrodes themselves were assumed to act as thunderclouds. Although a low power laser was applied, the laser has enough energy to trigger preliminary breakdown or electrical spark in the thunderclouds.

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