International Journal of Information Technology and Business Management
29th Jan 2014. Vol.21 No.1

ISSN 2304-0777 www.jitbm.com

"CLOUD FORMATION & ATMOSPHERIC RAINMAKING BY ENDOTHERMIC REACTION DUE TO PLASMA LASER & UV RADIATION IN THE ATMOSPHERE"

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Abstract

It is well known that, after lightning precipitation is formed and heavy rain follows due to dissociation, ionization, and natural seeding process in the atmosphere. It is shown in this paper that, these natural phenomena can be used for artificial rain making by plasma laser pulse in the atmosphere which is also confirmed in the laboratory experiment. As per our calculations 2.2 x 10^{19} gm of water drops are formed in the atmosphere by laser pulse of energy 500 mJ . In this system, plasma laser pulse creates high temp up to 3000°C. At these temp bonds of major species of N_2 and O_2 break up into excited N^* and excited O^*. These excited atoms are very unstable and immediately react to form NO and O_3. These reactions are endothermic and absorb a large amount of heat from the surrounding atmospheric clouds, where condensation takes place (condensation is the basic need for formation of water drops). Simultaneously N_2 and O_2 will be ionized to form N_2^+, O_2^+ and O_2^- . These precursor ions will undergo several reactions and will become big clustered ions. These big ions will act as seed which will lead to precipitation and rain. Low temperature created by dissociation will further help to grow bigger ions fast to produce CCN (cloud condensation nuclei) water drops and rainfall. These rain drops will act as natural seeding process and due to the flow of air in the upper atmosphere another set of rain drops will be formed, resulting in more rainfall. Model system for artificial rainmaking is also proposed in the paper.

Keyword: Laser, Endothermic reactions, Cloud Condensation Nuclei, Artificial Rain

Introduction :-

Rain plays an important role in world economy by influencing the agriculture yield. But rain is a natural phenomenon, and it does not fall as and when man needs it. Researchers are trying to create artificial rain for the past many years. At present, the seeding process is used of artificial rain fall. The chemicals such as silver iodide, calcium chloride or sodium chloride are used as seed. Chemicals are spread from the aircraft in the cloud region. Nucleation starts on these chemicals, which lead to the precipitation and then rain. This process has been tried in South Africa, Thailand, Japan, Mexico, Brazil and some parts of India. This process is not reliable and fails many times. Besides, it is harmful to mankind because, sprayed chemicals come to the earth along with the rain. It is, also, quite expensive. In this paper, a non polluting, economical and more reliable method is proposed. The plasma laser pulse is used to trigger the rainfall and this can be applied to warm white clouds also.

Laser has not, so far, been applied to create artificial rain. Only recently, Rohwetter et al. (2010) have shown that, self-guided ionized filaments generated by ultra-short laser pulses are able to induce water-cloud condensation in the free, sub-saturated atmosphere in the altitude region between 45 and 75 m. In this method, a high power pulse laser creates a bunch of filaments (low resistance path) between lightning cloud and the earth.

Theory :-

Nitrogen (N_2, 78%) and oxygen (O_2, 21%) are the two major gases in the atmosphere. When a laser pulse is shot in atmosphere, depending on the energy of the pulse, it may dissociate N_2 and O_2 as follows:

$$N \equiv N \rightarrow N_2 + hV \rightarrow N^* + N \quad \ldots\ldots\ldots\ldots\ldots (1)$$

$$O = O \rightarrow O_2 + hV \rightarrow O^* + O \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Bond energy of N_2 = 226 kcal/mole (A. Kerr 1999-2000). Therefore energy required to break 1 molecule of $N_2 = 226x10^3x4.184/(6x10^{23}) = 1.58x10^{-18}$ Joule. Bond energy of O_2 = 96 kcal/mole (A. Kerr1999-2000). Therefore energy required to break 1 molecule of $O_2 = 96x10^3x4.184/ (6x10^{23}) = 0.67x10^{-18}$ Joule. So the total energy required for breaking 1 molecule of N_2 and 1 molecule of O_2 will be $2.25x10^{-18}$ Joule. The laser pulse with energy 500 mJ is capable of dissociating a column of N_2 and O_2 containing about $(0.5/2.25x10^{-18}) = 2.2x10^{17}$ molecules (Chopkar & Chakrabarty 2010).

In reactions 1 and 2, two excited atoms, N* and O* are formed. So total numbers of excited N* and

International Journal of Information Technology and Business Management
29th Jan 2014. Vol.21 No.1

ISSN 2304-0777 www.jitbm.com

excited O* atoms formed by laser pulse of 500mJ in a column of N_2 and O_2 is 2.22×10^{17} . They are very unstable and react immediately to form NO and O_3 as follows:

a) $N^* + O_2 \rightarrow NO + O$
□H = 43,200 cal/mol.)

b) $O^* + O_2 + M +$ □H $O_3 + M$ .... (4)
□H = 67,600 cal/mol.)

Reactions (3) and (4) occur simultaneously in the atmosphere. These endothermic reactions absorb heat energy nearly equal to 1.22×10^{19} k cal from surrounding atmospheric clouds (Chopkar S K et al,2010). Both the reactions occur in the atmosphere and have been measured in the laboratory (Sander et al 2003). Reaction (3) is important for the formation of NO in the thermosphere and reaction (4) is one of the main source of formation of O_3 in the stratosphere. Both the reactions are endothermic and absorb large amount of heat energy (43,200 cal/mol for reaction 3 and 67,600 cal/mol for reaction 4) from the surrounding atmosphere. The reaction 4 also occurs by photochemical reaction due to ultraviolet rays. The energy from uv rays is absorbed by the oxygen molecule and leads to reaction 4. As a result, the atmosphere is cooled below the condensation temperature of water vapor. The water vapors particles come close enough, due to condensation, and natural seeding takes place. Means, this cooling will create CCN (clouds condensation nuclei) in cloud parcel and produce tiny water droplets in the atmosphere. These tiny water droplets then act as natural seed for the formation of rain drops in the atmosphere (Drake 2006). These water droplets may also shift to other places due to flow of air motions and form another set of rain drops there.

Result & Discussion :-

On several occasions it has been found that precipitation follows after lightning. Golde (1977) from a number of radar observations has reported that intense precipitation is not even present in the clouds before the first discharge but it develops abruptly in the same region after discharge from which the lightning flashes originate. Battan (1981) has observed very rapid growth of precipitation particles/ice crystals caused by electrical forces following a lightning discharge. In many cases the on-set of strong electrification follows the appearance of heavy precipitation within the cloud in the form of hail stones (Wallance and Hobbs, 1977). The correlation between lightning and precipitation is as follows: heavy gushes of rain or hail often reach the ground in 2-3 min. after the lightning flash and it is evidenced that lightning is the cause rather than the result of the rapid intensification of the precipitation (Mason, 1975). It is further speculated that the rapid intensification of the precipitation from about 1mm/h to 50mm/h in this 2-3 min period is brought about by a greatly accelerated rate of coalescence of water drops under the influence of electrical forces by a mechanism that is obscure and has no convincing experimental or theoretical base (Mason, 1971). From the above work it is clear that precipitation is formed after lightning. In an earlier theoretical study, it has been shown that the bonds of N_2 and O_2 break at temperature above 3000 K (Chopkar 1993). An experiment was done in the laboratory in which electrical spark was produced in a glass chamber to act as artificial lightning. Formation of water droplets was seen on the walls of the glass chamber (Chopkar and Chakrabarty, 2008). This experiment shows that water droplets are formed by condensation, which is due to endothermic reactions associated with artificial lightning created in the glass chamber by electrical spark. Carls and Brock (1987) did an experiment in which atmosphere was heated by a laser pulse up to 1600 to 2400 K. They observed water droplet formation in the atmosphere. Braun et al. (1995). Kasparian et al., 2003, Mejean et al., 2006, They did the experiment in a fog chamber. They observed water droplet formation inside the chamber after every laser shot. They postulated that water droplets were formed by ionization process. N_2 and O_2 would be ionized (Rohwetter et al., 2010) as follows:

$N_2 + h\nu \rightarrow N_2^+ + e^-$ ....(5)

$O_2 + h\nu \rightarrow O_2^+ + e^-$ .... (6)

Ionizing potential of N_2 = 15.58 ev = 2.49×10^{-18} Joule and ionizing potential of O_2 = 12.2 ev = 1.95×10^{-18} Joule. Hence the total energy required for ionizing 1 molecule of N_2 and 1 molecule of O_2 is (2.49×10^{-18} + 1.95×10^{-18})= 4.44×10^{-18} Joule. If the energy of the laser pulse is 500 mJ, then thismuch energy is capable of ionizing a column of N_2 and O_2 containing about($0.5/4.44\times10^{-18}$)= 10^{17} molecules or ~ 10^{17} ions and electrons. Electrons will react with O_2 to form negative ion O_2^- ,which after a series of reactions will form heavy negative cluster ions. N_2^+ and O_2^+ will also undergo a series of reactions to form heavy positive cluster ions. According to Rohwetter et al. (2010), these ions act as seed to create artificial rain in the atmosphere. But, it is well understood that, energy (2.25×10^{-18}Joule) required for disassociation is less than the energy (4.44×10^{-18}Joule) required for ionization (**Frost D C & McDowell CA,1956),(Lide, David R., ed, 1997-1998).** Yoshihara et al. (2007) have shown that the pulsed UV-laser irradiation of ambient air induces the formation of water droplets or small ice particles in the laboratory. They also observed that the atomic oxygen which is formed in this process quickly reacts with oxygen molecules to form ozone. In their experiment ozone is formed due to endothermic process by which condensation takes place and CN (condensation nuclei) is formed which produces water droplets or ice crystals. Chopkar (1993) also

International Journal of Information Technology and Business Management
29th Jan 2014. Vol.21 No.1

ISSN 2304-0777 www.jitbm.com

concluded the same. The rate of precipitation is enhanced by the uv radiation because it also adds to the ozone formation.

Thus, in endothermic reaction given by equation 1 to 4, the heat from the atmosphere is absorbed. In white warm clouds also the seeding can take place due to the endothermic reaction triggered by plasma laser pulse. The ionization, proposed by Rohwetter et al. (2010), is also accompanied with the disassociation and endothermic reaction proposed by Chopkar(1993). This dissociation and the occurrence of endothermic reactions are responsible for cooling and capable of CCN formation.

MODEL SYSTEM TO TRIGGER ARTIFICIAL RAINFALL :-

To trigger actual artificial rainfall, we propose a model as shown in Figure 1. This Model system consists of three main parts : 1. Receiver Unit 2. Processor Unit and Transmission Unit. The communication between these units will be through satellite.

The receiver unit will receive the data about the clouds like cloud temperature, humidity, height from earth surface, pressure etc. It will also receive the information about the necessity of rain in the region. The data is transferred to processor unit, where the data is processed and the technical details about the intensity, pulse duration etc. of plasma laser pulse will be calculated.

The processor unit will also decide which transmission unit to be used to trigger the artificial rainfall by applying laser pulse. One can have number of transmission units in the region as per necessity. The main function of the transmission unit is to send a laser pulse in the given direction of the intensity calculated by the processor. This unit is connected to processor unit by using satellite, so more than one transmission units can be connected to one centrally located receiver and processor unit. This will cut cost of the system and will cover larger region.

The transmission unit can be designed as given in figure 2.

The transmitter could be a terawatt femtosecond Ti: sapphire pulse laser. Its fundamental wavelength could be ~800nm. The pulse will have energy ~400mJ, duration 100fs and repetition frequency of 10-100Hz. The laser pulse has to propagate with almost high peak intensity over a distance of ~500m. This transmitter unit can be mounted on a moving platform, so it can be used in larger area as per requirement. This nonlinear phenomenon is caused by the subtle interplay between self-focusing induced by optical Kerr effect and the defocusing by the self-generated plasma. Further experimental work is necessary to determine accurately what should be the power and wavelength of the laser so that the bond breaking and ionization could take place at the cloud height of ~500m. A block diagram of the system to be used is shown in Fig. 1. The system is controlled by Micro Controller (remote unit), which consists of data acquisition and processing system. The peripherals of the system include fast transient digitizer, computer controlled stepper motors (SM-1 and SM-2). The laser beam energy will be adjusted by SM-2. The system will be operated by a MV power supply. Initially the beam will be of 15cm arc and then the beam expander will vary the width of the beam to get significant amount of rain. A movable mirror will direct the beam in the larger area of the atmosphere. Further experimental work is necessary to determine what should be the cross-section of the beam for rainfall to cover a reasonably wider area.

Artificial rain making at any place as per human need for green revolution in the whole world can be achieved by this model system.

CONCLUSIONS :

By dissociation reaction, artificial rain making can be done at laser energy by using plasma laser pulse.

1. Ionization at high temperature also supports the artificial rainfall due to the proposed dissociation theory.
2. The proposed model is non-polluting economical, more reliable and can be used effectively on larger area.

Acknowledgement

We express our sincere thanks to several scientists of Physical Research Laboratory, Ahmedabad We also thank Prof. B. Padmanabha Murthy and Dr. Anwar Hussain of J. N. University, New Delhi; Mr. Thakur Prasad of Regional Meteorology Centre, Coloba, Mumbai; Prof. A. D. Tillu and Prof. B. Korgaokar of University of Pune, Pune; Dr. G. S. Katlyar of Bombay University, Mumbai; Dr. G. L. Agrawal of National Environmental Engineering Research Institute, Nagpur; Dr. A. K. Kamra of IITM, Pune; Prof. Bijesh Kumar and Prof. Pratima Sen of Ahilya Devi Holkar Visha Vidyalaya, Indore and Dr. A. K. Nath of IIT, Kharagpur for help at different stages of this work.

SCHEMATIC FLOW CHART SHOWING METHODOLOGY TO CREATE ARTIFICIAL RAIN IN THE ATMOSPHERE

High-energy plasma laser pulse creates high temperature in a fraction of a second

ISSN 2304-0777 www.jitbm.com

↓

At this high temperature bonds of N_2 and O_2 break (dissociate) to form at least one excited N^* and one excited O^*

↓

$N \equiv N \rightarrow N^* + N$

$= O \rightarrow O^* + O$

↓

Excited N^* and O^* are very unstable and immediately react to form NO and O_3

↓

$N^* + O_2 \rightarrow NO + O$

$O^* + O_2 + M \rightarrow O_3 + M$

↓

These two reactions are endothermic and absorb a large amount of heat from the surrounding atmosphere

↓

This lowers the temperature of the surrounding atmosphere and condensation nuclei (CCN) is formed in the cloud

↓

These condensation nuclei act as seed and start rain

↓

Simultaneously with the breaking of their bonds, N_2 and O_2 will also be ionized

↓

a. $N_2 + hV \rightarrow N_2^+ + e$

b. $O_2 + hV \rightarrow O_2^+ + e$

Free electrons 'e' thus produced will get attached to O_2 and form negative ion O_2^-

↓

N_2^+, O_2^+ and O_2^- ions are quickly transformed into heavy clustered ions

↓

These heavy ions in cooled atmosphere act as CCN for formation of rain droplets.

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ISSN 2304-0777 www.jitbm.com

Figure captions:

Figure1. Block diagram of the laser system to create artificial rain.

Figure 2 Proposed Model of transmitter for emission of plasma laser pulse.

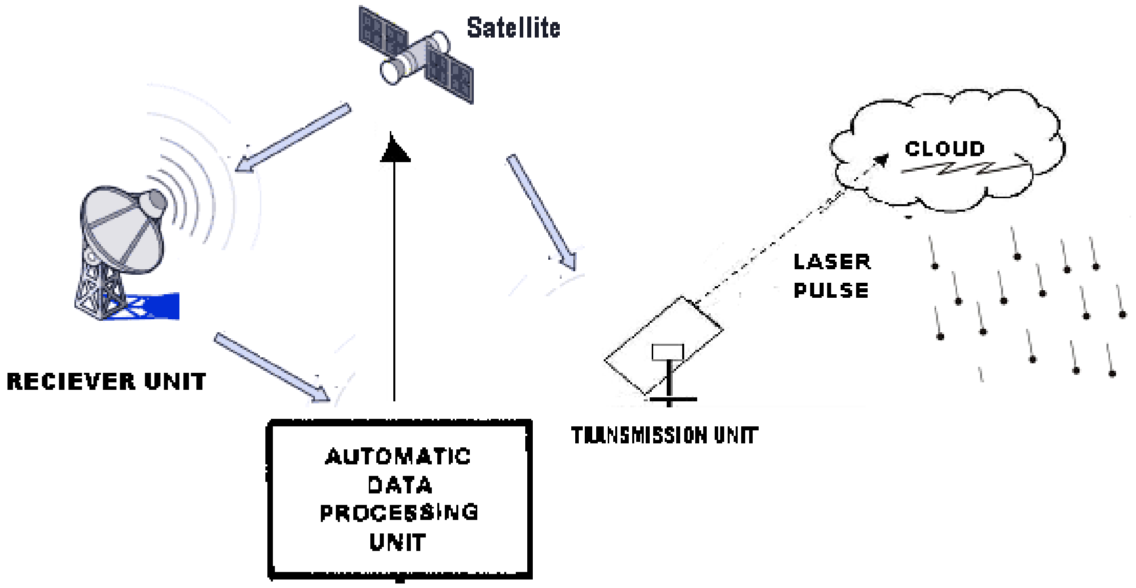

Fig 1 MODEL FOR ARTIFICIAL RAINFALL USING PLASMA LASER PULSE

ISSN 2304-0777 www.jitbm.com

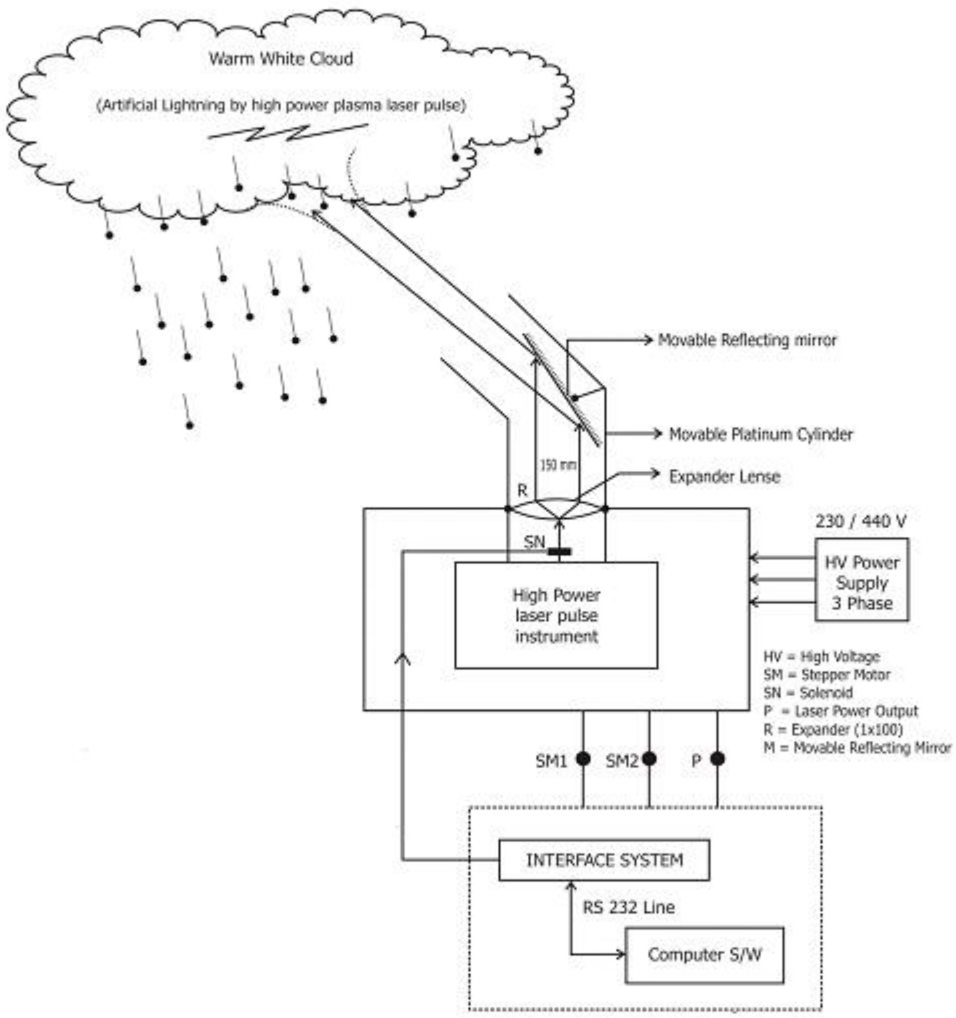

Fig 2

Proposed Model of transmitter for emission of plasma laser pulse.