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Economical and non-pollute system for artificial rainmaking by laser pulse in a way of natural phenomena

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Abstract

It is well known that after lightning; the precipitation formed and heavy rain occurs due to dissociation, ionization and natural seeding process by lightning phenomena in the atmosphere. It is shown in this paper; these natural phenomena will be used for artificial rain making by laser pulse in the atmosphere. As per our calculations, 2.2 x 10^{19}gm of water drops are formed in the atmosphere by laser pulse energy 500 mJ; it is very cheap. These systems are economical, non-polluted and trigger only natural process for artificial rainmaking, which will be also used as extra fertilizer for crops. No doubt, it is most useful for human being. In our system, laser pulse creates high temperature up to 3000^{o}C at high temperature, and bonds of major species of N_2 and O_2 break out into excite [N] and excite [O]. These excited atoms are very unstable and immediately react to form NO and O_3. These reaction are endothermic and absorbs a large amount of heat from surrounding atmospheric clouds where the condensation take place (condensation is the basic needs 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 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 grow bigger ions fast as produce CCN (cloud condensation nuclei) to form water drops occur rainfall. These rain drops act as natural seeding process due to flow of air in the upper atmosphere to formed another sets of raindrops, result into more rainfall. These natural phenomena proved by theoretically and practically in laboratory scale. Now experimental work is necessary to determine the characteristics of laser system and atmospheric parameters to be use for actual artificial rainmaking in the atmosphere.

Key words: Rain; Laser; Endothermic reactions; Cloud Condensation Nuclei; Artificial Rain.

Introduction

Rain plays a great role in national economy by influencing the agriculture yield. Nevertheless, rain is a natural phenomenon and it does not fall as and when man needs it and hence, man has been trying to create artificial rain for the past many years. At present, the process, which is used for creating artificial rain, is seeding. In this process, chemicals such as silver iodide, calcium chloride or sodium chloride are used as seeds. They 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. However, this process, on most of the occasion fails. Besides, it is harmful to humankind because it brings harmful chemicals on earth along with the rain. It is, also, expensive. In this paper, we propose a laser system to produce artificial rain. Our system has advantages over the seeding process that it does not pollute the environment; it is a onetime investment and is less expensive. In addition, it can be targeted to even warm white clouds, which are not rainy (in seeding process only black rainy clouds are targeted).

So far, Laser has not 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. These authors were able create precipitation in the atmosphere in the altitude region between 45 and 75 m. This group has been doing research for the past several years to trigger lightning and guide the discharge to a

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harmless spot. In their method, a high power pulse laser creates a bunch of filaments (low resistance path) between lightning cloud and earth. Since the whole path between cloud and the earth is ionized, their pulse energy is attenuated as it travels in the atmosphere and hence, not able to create precipitation at higher altitude (rain bearing clouds are not located in the 45-75m altitude region). In our technique, the pulse does not ionize the whole path from the earth to cloud. Hence, it can travel to a higher altitude (~500m) up to the cloud region.

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

$$N \equiv N \rightarrow N_2 + h\nu \rightarrow N^* + N \quad (1)$$

$$O = O \rightarrow O_2 + h\nu \rightarrow O^* + O \quad (2)$$

N_2 has triple bond [N≡N] and O_2 has double bond [O=O]. Bond energy of N_2=226 kcal/mole [1cal=4.184 Joule, Avogadro number=$6x10^{23}$]. 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. 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 is $(1.58x10^{-18} + 0.67x10^{-18})$=$2.25x10^{-18}$ Joule. If the energy of the laser pulse is 500 mJ, then this much energy 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 excite N* and excite O* molecules by dissociating a column of N_2 and O_2 containing about = 2.22 x 10^{17} molecules. They are very unstable and react immediately to form NO and O_3 as follows:

$$N^* + O_2 + \Delta H \longrightarrow NO + O \quad (3)$$

ΔH = 43,200 cal/mol.)

$$O^* + O_2 + M + \Delta H \longrightarrow O_3 + M \quad (4)$$

ΔH = 67,600 cal/mol.)

$2.22x10^{17}$ molecules of excite N* and excite O* are formed in the atmosphere by laser pulse energy 500 mJ. So total 2.22 x 10^{17} Nos. of both the reactions (3) and (4) occur simultaneously in the atmosphere. This endothermic reactions heat energy absorbs from surrounding atmospheric clouds is ~ (43.2 +67.6)/2 x 2.22 x 10^{17} K cal. = ~ 1.22 x 10^{19} k cal. As a result, the atmosphere is cooled below the condensation temperature of water vapor. This cooling will create CCN (clouds condensation nuclei) in cloud parcel and produce tiny water droplets in the atmosphere.

This ~$1.22x10^{19}$ kcal heat energy absorbs and condensed surrounding atmospheric clouds and formed water drops in the upper atmosphere, (1.22 x 10^{19})/0.540 = ~2,2x 10^{19} gm. In this way, $2.2x10^{19}$gm of water drops are formed in the atmosphere by laser pulse energy 500mJ and it is very cheap. 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 the main source of formation of O_3 in the stratosphere. Both the reactions are endothermic and abstract a large amount of heat energy (43,200 cal/mol for reaction 3 & 67,600 cal/mol for reaction 4) from the surrounding atmosphere. As a result, the atmosphere is cooled below the condensation temperature of water vapor. 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 raindrops 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 raindrops there.

The above-mentioned theory can also be looked in another way. Bonds of N_2 and O_2 break if the temperature of the region becomes higher than 3000K. A natural phenomenon in which such thing is happening is lightning. In lightning a temperature as high as 3,000K reaches in a fraction of a second. An important point on which so far no satisfactory understanding has reached is as follows: in lightning, a temperature as high as approximately 3,000K is produced (Newcott, 1993). However, for the formation of precipitation a temperature as low as approximately (-10K) is needed. How a region, which is at a temperature of approximately 3,000K, attains a temperature of approximately -10K so fast? Who removes the heat produced in the lightning? On that matter, three theories exist. They are i) Reynolds's effect ii) Ion capture theory and iii) Breaking drop theory. However, these theories are not tenable because they are applicable before lightning. Lightning creates a large amount of

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heat. This heat energy will evaporate the precipitation, which is formed before lightning. Then according to these theories, we cannot observe any precipitation after lightning. Nevertheless, we observe precipitation after lightning. That means after lightning, some process occurs which creates precipitation. Our explanation is that endothermic reactions (3) and (4) remove the heat and produce the cooling. Higher the temperature, more number of N* and O* will be formed and more cooling and rain will be produced. If temperature is not very high, less number of N* and O* will be formed and that may not lead to reasonable precipitation. That is why, after lightning, sometimes precipitation is not observed. Therefore, if the laser pulse could produce this much temperature, then also raindrop formation is possible.

When a laser pulse is shot in the atmosphere, depending on the energy of the pulse, N_2 and O_2 would be ionized (Rohwetter *et al*., 2010) as follows:

$$N_2^- + hu \rightarrow N_2^+ + e \qquad (5)$$

$$O_2 + hu \rightarrow O_2^+ + e \qquad (6)$$

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 this much 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^- that after a series of reactions will form heavy negative cluster ions. N_2^+, O_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. However, Rohwetter *et al*. (2010) did not consider that these molecules could also have been dissociated because the dissociation energy is about half of that of the ionization energy.

Therefore, it should be clear that when a laser pulse is shot in the atmosphere, first bonds of N_2 and O_2 would break by dissociation or high temperature. Then excited N* and O* will be formed, endothermic reactions will take place, surrounding will be cooled, tiny water particles will be formed which will result in rain. In addition, N_2^+, O_2^+ and O_2^- ions will be formed which will quickly be converted to clustered ions. These clustered ions will act as seed to produce artificial rain.

Literature Survey

Our theory is analogous to what happens after lightning. On several occasions, it has been found that precipitation follows lightning. After precipitation there may be or may not be heavy rains. In addition, it is not necessary that always lightning will precede rain, as during monsoon period when rain falls as shower. This is due to the supper saturation process. However, it has been observed that if it rains after lightning, it is a heavy rain.

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 hailstones (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 works, it is clear that precipitation is formed after lightning. In an earlier theoretical study (Chopkar, 1993), it has been shown that the bonds of N_2 and O_2 break at temperature above 3000 K. In this work, it has been shown that the heat energy produced in a thunderstorm is more than 4.2×10^3 kcal and the total energy needed to break the bonds of N_2 and O_2 is 4.16×10^3 kcal. Hence, lightning is capable of breaking the bonds of N_2 and O_2 to produces N^* and O^*. These active species are unstable and further react to form stable molecules NO and O_3. These reactions are endothermic they absorb 8.37×10^3 kcal of heat from the surrounding atmosphere. We have also shown that to

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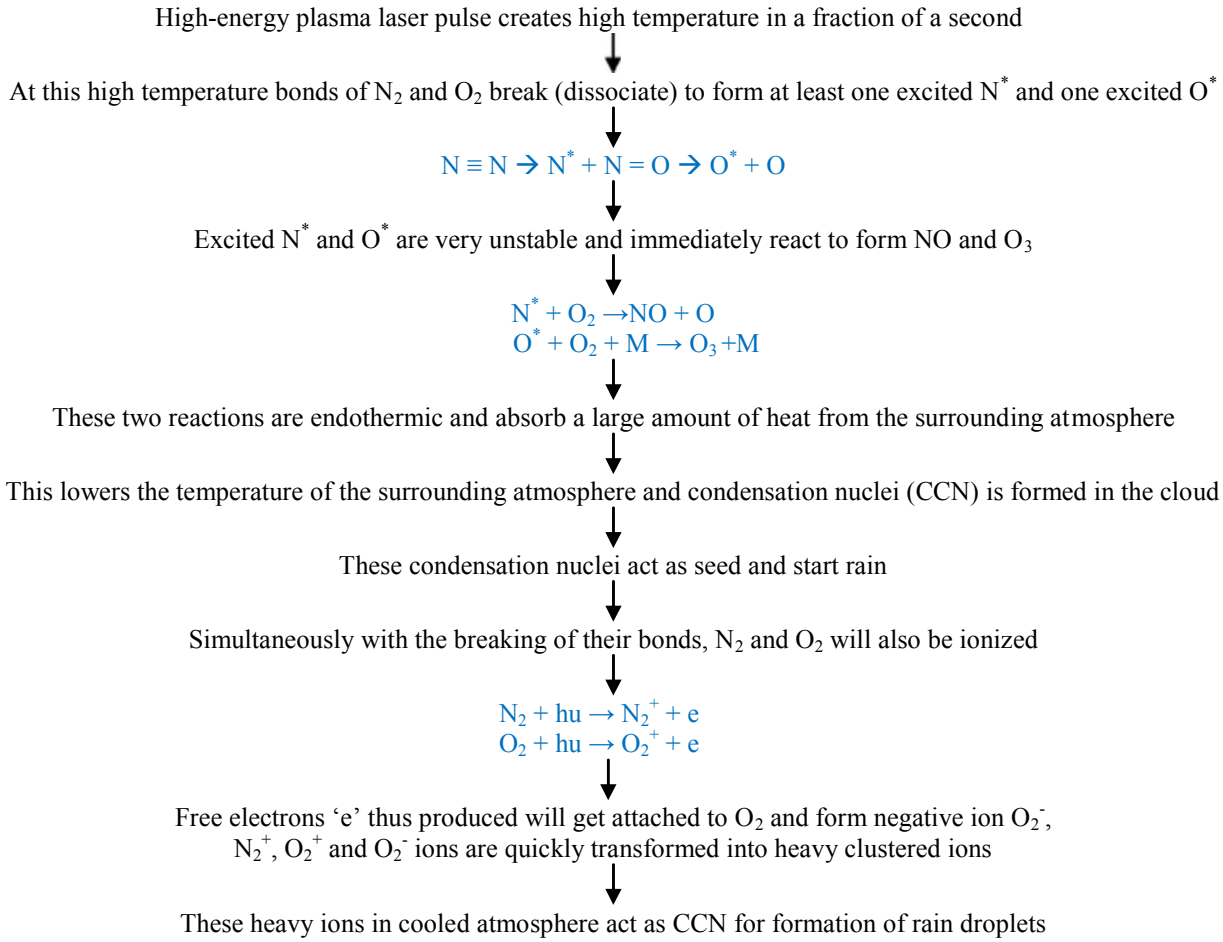

Flow chart 1. Schematic flow chart showing methodology to create artificial rain in the atmosphere

reach the dew point, 1.58×10^3 kcal energy is to be abstracted from the atmosphere. This value (1.58×10^3 kcal) is much less, than 8.37×10^3 kcal and hence super cooling will be produced by endothermic reactions to form water droplets in the atmosphere. These water droplets will act as natural seed for formation of raindrops resulting in rainfall. These steps are shown in Schematic Flowchart.

Results and Discussion

Rainmaking Phenomena

An experiment was done in the laboratory in which electrical spark was produced in a glass chamber to act as artificial lightning (Flow chart.1). Formation of water droplets was seen on the walls of the glass chamber. The details of this experiment and results have been described in 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. They postulated that water droplets were formed by ionization process. This is partly true because they did not consider dissociation and the occurrence of endothermic reactions, which are responsible for cooling and capable of CCN formation. Braun *et al*. (1995) have shown that high-power laser pulses, which produce self-guided ionization filaments (a low resistance conducting path) in air, also produces water droplets as a side effect. A group consisting of French and German scientists has been doing research with laser to alleviate damage caused by lightning to persons and property for a long

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period of time (Kasparian *et al*., 2003; Mejean *et al*., 2006). Their laser produces a bundle of ionization filaments which triggers and guides high voltage lightning to discharge to a desired spot. They did the experiment in a fog chamber. They observed water droplet formation inside the chamber after every laser shot. They postulated that these droplets were formed due to the ionization process; the charged species N_2^+, O_2^+ and O_2^- act as nuclei (Kasparian *et al*., 2000). However, as it has been shown earlier that water droplets could have been formed not only due to

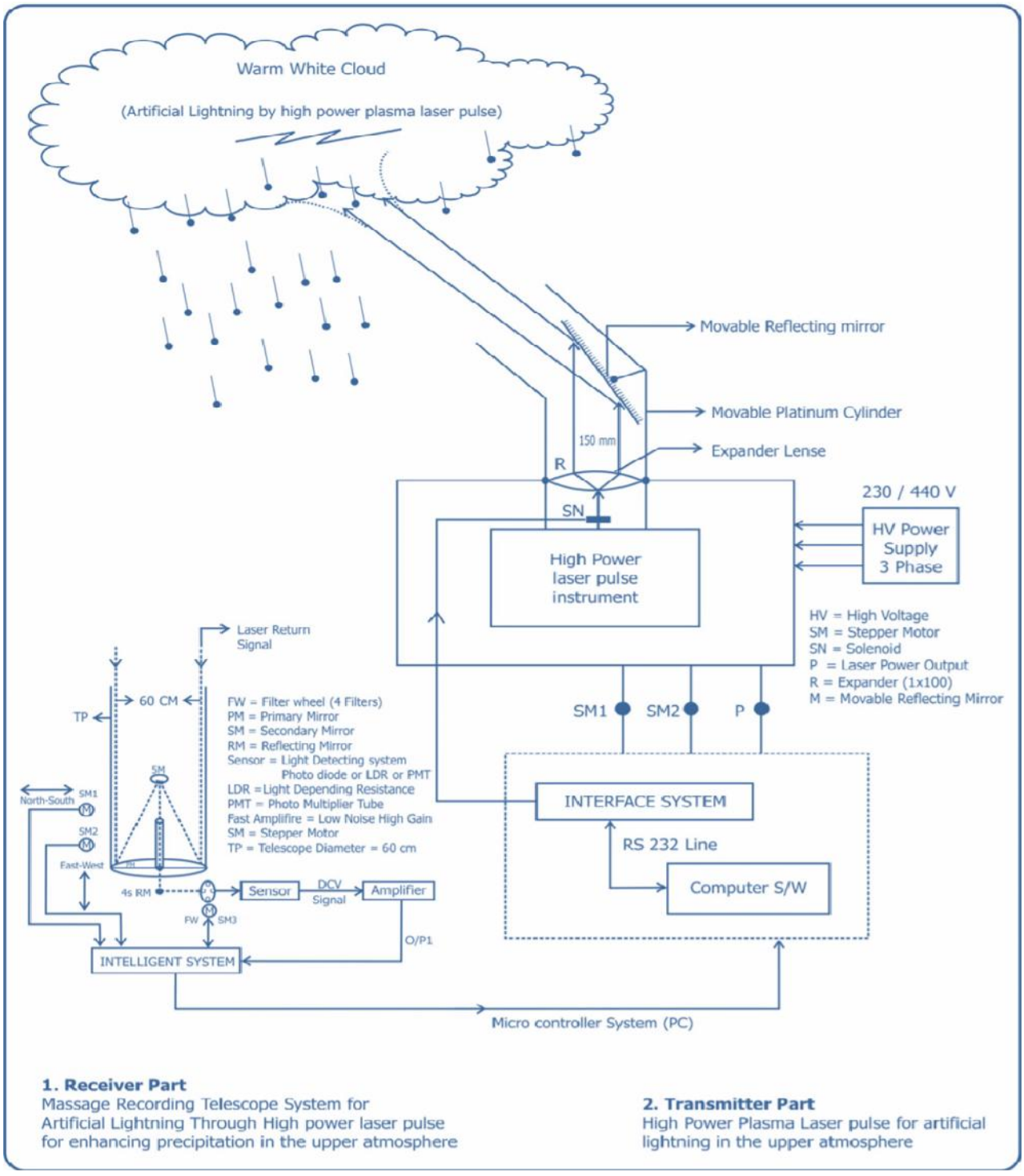

Fig.1. Block diagram of the laser system to create artificial

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ionization but also due to dissociation followed by endothermic reactions because, dissociation takes less energy compared to ionization, and hence dissociation will precede ionization. When laser pulse shot in the atmosphere, first breaking bond of N_2 and O_2 take place then ionizing of N_2 and O_2 because 2.25×10^{-18} Joule, the potential energy of breaking bonds of N_2 and O_2 is less than the potential energy of ionizing of N_2 and O_2, 4.44×10^{-18} Joule.

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. It may be mentioned here that a group at Indian Institute of Tropical Meteorology, Pune who is experimenting with lidar, has also observed that a few drops of water fall after the laser beam is shot in the atmosphere.

System for artificial rain

The system to be used for creating artificial rain by laser system consists of a transmitter and a receiver. The transmitter could be a terawatt femto-second *Ti:sapphire* pulse laser. Its fundamental wavelength could be ~800nm. The pulse will have energy ~500mJ, 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 non-linear 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

Fig.2(a). Demonstration of the laser system creating artificial rain from ground

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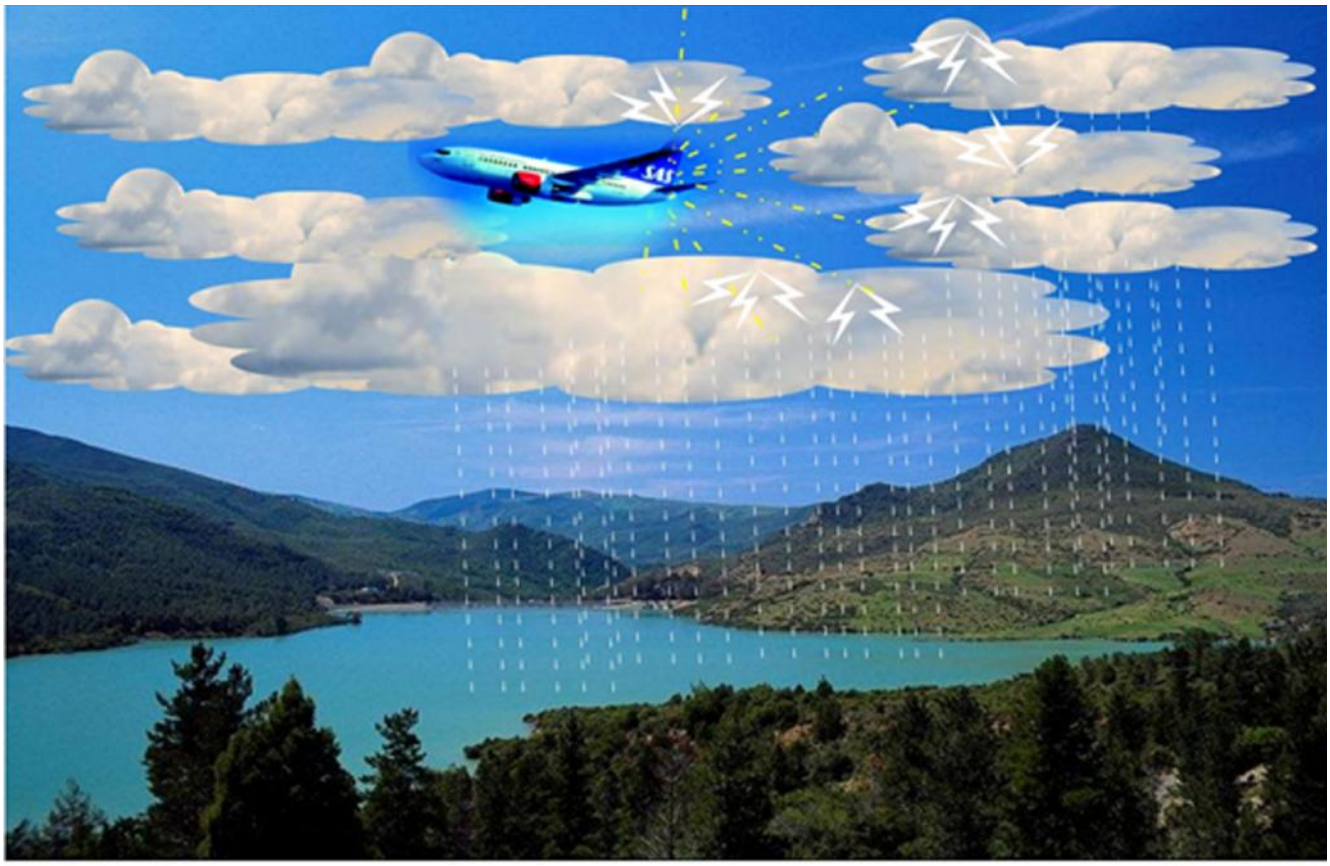

Fig.2(b). Demonstration of the laser system creating artificial rain from aircraft

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.

Receiver will be used for measuring the water vapor content or liquid water vapor content before sending the pulse in the atmosphere. It operates in another wavelength sensitive to water vapor. It may also be used to measure the water vapor content after the propagation of the pulse. A Caesarian telescope of 60cm diameter will be used which will be controlled by an intelligent system of Micro Controller (local unit). The telescope can be adjusted in North-South and East-West direction by a SM-1 and SM-2 respectively. In the acquired mode of the laser system, the back scattered laser light signal will pass through a selected wavelength filter through filter wheel (FW) and fall on the sensor (photodiode or IrDA or PMT) of high gain low noise, which convert the light in to electrical signal (which is directly proportional to the concentration of water vapor). This signal will be again amplified with the help of high gain low noise fast amplifier. The output signal will be communicated to micro controller of the system to PC and the acquired data will be stored in required format in the system memory for later processing. Further experimental work is necessary to determine how much moisture should be present in the atmosphere for precipitation to occur before sending the pulse.

Economical and non-pollute system

Economical

Artificial rainmaking by laser pulse system is very cheap and economical because it is a onetime investment and is less expensive. The whole system can be mounted on a mobile van so that experiment can be done at any place one like. The system can also be mounted on aircraft. Demonstration of the laser system creating artificial rain from ground as well as from aircraft is given in Fig.2. Experiment from ground at one place can over a land area up to a radius of 80 to 100 km, but the experiment from aircraft and that land cover more than 100 km. Such type of artificial rainfall; it is most useful for crops as fertilizer. No doubt, it is most useful for human being.

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Non-Pollute

The whole system depends upon natural process. In this process, only natural process is triggering for artificial rainmaking by laser pulse in the upper atmosphere. In addition, it can be targeted to ever-warm white clouds, which are not rainy in seeding process, only black rainy clouds are targeted. In seeding process, there are chemicals used as silver iodide, calcium chloride or sodium chloride. Besides, it is harmful to mankind because it brings harmful chemicals on Earth along with the rain. In our system, no any chemicals added into atmospheric clouds. Only we will trigger natural process in the atmosphere. That is why; our artificial rainmaking procedure is non-polluted.

All Scientist agree with our phenomena "Artificial rainmaking by laser pulse" in national conference at Triputi (ARRWPCC-2011). But, one scientist said that I had send laser beam in the atmosphere; but no rainfall occurs why? We said him, it is a good question, such type of laser pulse was not capable to break the bonds of N_2 and O_2, or ionized N2 and O_2. Means there is no endothermic reaction, no CCN (Cloud condensation nuclei) formed in the atmosphere that is why no rainfall occurs. Personally we were visiting to his laser lab in Shri S.V University, Triputi (A.P.) and discussing about this matter, our opinions is in right way, there are only one Laser beam which is not capable to break the bonds of atmospheric N_2 and O_2, or ionized N_2 and O_2.

When laser pulse is shot in the atmosphere depending on the energy of the pulse, which is cloud and create high temperature. Such type of laser pulse design which laser pulse has explode at top of upper atmosphere in the parcel cloud, but no any effect at the middle portion of the atmosphere. Neither be destroyed nor be dissipated heat energy from the laser pulse, in a way of ground to atmosphere (transmitting way) such type of laser pulse effect only at top of upper atmosphere in partial cloud. Therefore, laser pulse must be capable to break the bond of N_2 and O_2 and ionized in the atmosphere then rain occurs. Unless and until rain cannot occur, our laser pulse faction of design is given in our practical system as above, which is capable to break the bonds of N_2 and O_2. It is necessary to explode laser pulse in parcel.

Conclusion

A high power pulse laser system is capable of creating precipitation in the atmosphere. It is being believed that these water droplets are formed due to the ionization of N_2 and O_2. Ions N_2^+, O_2^+ and O_2^- (electrons will get attached to O_2) thus formed act as seed for condensation. However, it has been shown in this paper that dissociation (bond breaking) precedes ionization because dissociation energy is much smaller than that of ionization. Hence bonds of N_2 and O_2 will break before they are ionized and excited N^* and O^* will be formed. These excited ions are very unstable and immediately undergo endothermic reactions to form NO and O_3. These endothermic reactions absorb heat from surrounding atmosphere, as a result, condensation takes place and tiny droplets of water are formed which result in rain. Simultaneously ionization processes will take place and N_2^+, O_2^+ and O_2^- ions will be formed. These ions will immediately be converted into bigger cluster ions and will act as seed for rain.

The cost of the whole experiment is ~$1million. We do not have this much fund to conduct the experiment. However, we hope that some organization would do this experiment and demonstrate its great benefit to mankind. The technique has been patented both nationally and internationally.

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