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P5_1 Light-ning rod

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Abstract

The following paper aims to introduce the reader to the potential application of lasers as generators of ionised gas paths which will act as lightning conductors in the event of a storm. Using a simple model of laser operation, values for energy, pulse duration and ultimately, power required have been calculated. While yielding no revolutionary data in the field of weather manipulation, the subject of this paper remains a valid source of research.

Introduction

Lightning conductors operate by guiding the lightning to the ground through a path of minimal resistance [1]. This technique, carried to its theoretical limit, would be most effective if the path began in the storm clouds where the lightning causing static build up occurs. This paper investigates the use of a laser to generate a temporary path of ionised air between the clouds and the ground to trigger and control lightning strikes.

Theory

In order to generate a path of ionised gas through the atmosphere, the air within that path could be energised to a point that ionization occurs. Since air consists of 78.1% molecular nitrogen[2] it has been assumed that the first ionization energy of the air through which the lightning must pass is equal to that of molecular nitrogen; 1502 $KJmol^{-1}$, 2.49×10^{-18}J per atom or 15.5eV per atom[3]. From this, the frequency of the laser required is calculated to be 3.76×10^{15}Hz.

We take the average length of a lightning bolt to be 5km [4] and thus require the ionisation path to be of this length. The radius of cross-section for the laser was chosen to be 1mm. This provided a volume for the column of air to be ionised of $0.015m^3$. The number density of air is assumed to be constant across the laser's path, with a value of $2.49\times10^{25}m^{-3}$[5]. Using the equation

$$E_T = n\pi r^2 h E_i \tag{1}$$

Where *n* represents the number density, *r* represents the radius of the laser, *h* represents the lightning bolt length, E_i represents the ionisation energy and E_T represents total energy required to ionize the air up to 5km. Using the values above, Eq. (1) gives the energy to be 0.931MJ.

$$v_{rms} = \sqrt{\frac{3R}{M_m}\left(T + \frac{E_T}{C_V}\right)} \tag{2}$$

The sudden deposition of energy within such an enclosed volume will cause a significant change in temperature; as such the particles will become highly energised. On a macroscopic scale this will result in a dispersal of particles from the path of the laser. On a microscopic scale, the increase in temperature will result in an increase in speed for the individual particles. Eq. (2), models the ionized gas within the beam as an ideal gas in order to offer some estimate of the particle speeds. V_{rms} represents the root mean squared velocity of the individual particles, *R* is $8.31Jmol^{-1}K^{-1}$, the molar gas constant, E_T is the change in energy given by Eq. (1), M_m is 28, the molar mass of the gas, *T* is the initial temperature of the gas, taken to be 283K, C_V is $0.718Jkg^{-1}K^{-1}$[6], the specific heat capacity of air, ρ is 1.247kgm^{-1}[7], the density of the Earth's atmosphere and V is 0.015m^{3}, the volume of the beam; these last two quantities, when multiplied together, give the mass of the air in the laser beam. The mean speed value provided by Eq. (2), is 33981ms^{-1}. At this speed it would take a particle 29.4ns to move across the diameter of the laser beam. While this value is, at best, an estimate of the order of magnitude of what a true result may resemble, it provides an idea for the lifetime of the conducting path.

Discussion

With values for both lifetime and required energy to form a path of least resistance through the application of a ground based laser, an estimate of the power requirements can be made. Using a 50ns pulse and applying a total of 0.931MJ of energy, the power requirements of the laser would reach 18.62TW. Lasers operating at the terawatt power level do exist [8], however these are highly specialised scientific instruments and not suitable for the role suggested by this paper.

Conclusion

The projected power requirements of this scheme lend more to the construction of permanent facilities than mobile units. Specialised modern lasers achieve terawatt power levels for durations of femtoseconds, and this only occurs under heavily controlled conditions. The energy projected by such machines is insufficient to ionize a path for lightning to discharge.

References

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