Dark Energy and Extreme CPA Laser Pulses for Non-thermal Igniting Laser Boron Fusion

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Abstract: The difficulty with pressures at equilibrium temperatures in the range of dozens of hundred millions of °C for igniting nuclear fusion, can be overcome by the non-thermal pressures from interacting electric and magnetic laser fields with varying optical constants at laser interaction shown by nonlinear forces. Their domination at the just reached picosecond CPA (chirped pulse acceleration) laser pulses at ultra-extreme powers led to measurements of laser fusion of hydrogen with boron-11 with orders of magnitudes higher energy gains than the earlier known classical low gains. These types of field densities without optical line radiation may be considered as an interstellar plasma state within galaxies representing the dark matter and dark energy.

Key words: Electromagnetic energy density, CPA laser pulses, laser boron fusion, interstellar magnetic dark energy.

1. Introduction

The existence of dark energy and dark matter in the universe was concluded in the beginning [1] by Lord Kelvin, Henri Poincare and followed up from astrophysical observations by Zwicky [2] as a fundamental property as discussed e.g. in relation to the axion-photon interaction [3]. This question is related to the energy density of CPA laser pulses of sub-picosecond ps duration and ultra-extreme power above Petawatts PW [4]. This is based on the measured highest reaction gains of the nuclear fusion of hydrogen H with the boron isotope 11 (HB11 fusion) [5, 6] on which the design of a fusion reactor [7] was based for electric power generation without any environmental problem with radioactive radiation, as safe, low-cost and abundant solution [8, 9].

2. Non-thermal Ignition of Fusion

The high energy density in laser pulses was demonstrated by the experiment of Steinke et al. [10, 11]. The ignition of fusion reactions is usually based on thermal pressures at very high temperatures due to the fact that the nuclear energy per reaction is about ten million times higher than the chemical reaction energy. Burning of carbon can be ignited at few hundred °C temperatures while nuclear reactions need some hundred million degrees temperature [9, 10]. Reacting hydrogen H in the sun to helium happens at temperatures of about 15 million degrees when burning heavy hydrogen D (deuterium) into He. Measured from the emitted neutrons in a plasma confined by a torus magnetic field stellarator-Wendelstein in 1980 [8], a temperature of ten million degrees was measured as theoretically expected. The fusion of D with super-heavy hydrogen T (tritium), DT fusion, is producing some more energy and succeeded at temperatures above of 50 million degrees within magnetic fields or in small laser driven micro-explosions ignited by lasers, however during such short times that an energy gain for an electric power station will be reached not before several years.

When the laser was discovered, there was the hope, that the pressures for the necessary forces should be produced in a non-thermal way [12] by the electric and the magnetic fields of the laser beams. Even in the sixtieth [13], it was photographed how next to the
thermally driven plasma, very fast plasma particles were driven by the laser fields, however on a scale below the level for a fusion energy generator. After elaborating the necessary theory, computations showed under what conditions of laser beams, sufficient fusion can be ignited [12]. The laser pulses had to be very short, less than about a picosecond, one millionth of a millionth of a second. The diagrams of 1978 (Figs. 4.14 and 4.15 or drawn together in Fig. 8.4 of Ref. [4]) showed a plasma acceleration of $10^{20}$ cm/s$^2$. The measurement of these ultrahigh accelerations [14] was possible not before 1996 only with CPA (chirped pulse acceleration) laser pulses, discovered in 1985 [15]. The measured accelerations were about hundred thousand times higher than those measured with the largest laser on earth National Ignition Facility (NIF) at Livermore/California under thermal conditions.

The DT fusion reaction is the easiest from all and therefore mostly aimed, though it is not radioactive clean due to the generation of large amounts of neutrons during the reaction and also when storing the tritium fuel before use by emitting of neutrons. An alternative fusion fuel without any primary generation of radioactivity is the reaction of hydrogen H with the abundant isotope 11 of boron B(11) (HB11 fusion). The classical inertial fusion reaction by spherical compression produces about hundred thousand times less efficient energy than DT as extensively studied (see Chapter 9.6 of Ref. [4]). However, when using plane geometry with plasma block ignition, the five orders of magnitudes are bridged [16] and four orders more due to the avalanche processes from generating three helium (alpha) particles at each reaction. After measuring the first one thousand reactions per CPA-laser pulse [17] more than one million [18] and more than one billion [5] were measured as reproduced by computations [19]. It was essential that the reaction does not thermally need the many hundred million degrees temperature, but non-thermally [9] as the most important point of progress. The main result is seen (Fig. 5 of Refs. [7, 8]) about an extreme energy density of more than $6 \times 10^{12}$ J/cm$^3$ [9] in an 18 nm (2 vacuum laser wavelength thin) diamond foil as target.

The question is what property this measured extremely high energy density of the electromagnetic field has compared with that of the dark energy at extremely low density in the interstellar space within our Milky Way. This is the point of the following consideration. The property of the exotic energy conversion of the energy density of the electric and magnetic laser fields including dielectric properties is the heuristic step to consider the property of dark matter and dark energy. The laser field energy density of the laser field cannot be detected as optically by absorbing or emitting spectral line radiation.

3. Electromagnetic Energy in Maxwell’s Stress Tensor and Dark Energy

In comparison of the energy in the CPA pulses we are evaluating the dark energy in the universe and evaluate what electromagnetic energy from the energy components of the Maxwell’s stress tensor

$$E^* = \frac{(E^2 + H^2)}{4\pi}$$

(1)

can be derived based on the following from the equation of motion in the interstellar plasma of our galaxy. This is based on the equation of motion [9] that is

$$f = -\nabla p + f_{NL}$$

(2)

At fusion, both at magnetic confinement and inertial confinement, the first term is assumed to be dominating with the gas dynamic pressure $p$ given at equilibrium temperature in the before-mentioned hundred million °C. The second term is the non-thermal nonlinear force $f_{NL}$ given in Maxwell’s stress tensor by the electric and magnetic fields $E$ and $H$ of the CPA laser pulse driving the fusion ignition including that the dynamically varying dielectric response by the refractive index is dominating. To overcome the problem with the high temperatures [9], this non-thermal term was directly seen from photographs (Fig. 1 of Ref. [9]).
Taking into account that the numbers about our Milky Way are given within a range of uncertainty any evaluation is to be taken with caution. The following is based on a diameter of hundred thousand light years with the mass of the stars by $5.8 \times 10^{11}$ solar masses and assuming that the dark matter is 90% of the total gravitation mass of the Milky Way, converting the dark mass into dark energy by Einstein’s multiplication by the square of speed $c$ of light, the result of the magnetic field $H$ in average is resulting in a few Gauss, very close to the magnetic field on the earth. The dark mass is then given by the magnetic plasma property in the interstellar space within the Milky Way and may be similar within the whole universe.

The fields of the plasmas should then be detected by low level bremsstrahlung, because this is then a component to explore the property of the Milky Way different to the line radiation emission and absorption. The result is that the high energy density at the CPA pulse is present in the interaction volume but one cannot see it optically in a similar way as it seems to be with the magnetic field in space.

4. Conclusions

Though the problems of dark energy and dark matter in the Universe is involved with a number of unsolved problems [20], the results of high energy densities in a particle-free focus of an extreme CPA laser pulse may be a further hypothetical kind of consideration.

References

[1] Wikipedia. “Milky Way.” https://en.wikipedia.org/wiki/Milky_Way.
[2] Zwicky, F. 1933. “Die Rotverschiebung von extragalaktischen Nebeln.” Helvetica Physica Acta 6: 110-27.
[3] Hoffmann, D. H. H., et al. 2017. “New CAST Limit on the Axion-Photon Interaction.” Nature Physics 13: 584-90.
[4] Hora, H. 2016. Laser Plasma Physics. Forces and the Nonlinearity Principle. 2nd Ed. Bellingham WA: SPIE Book.
[5] Picciotto, A., Margarone, D., Velyhan, A., Bellini, P., Krasa, J., Szydlowski, A., et al. 2014. “Boron-Proton Nuclear-Fusion Enhancement Induced in Boron-Doped Silicon Targets by Low-Contrast Pulsed Laser.” Phys. Rev. 4 (3).
[6] Giuffrida, L., Margarone, D., et al. “Brilliant and Energetic Alpha Particle Source Based on Proton Boron Nuclear Fusion.” Presented at 3rd ICEL Conference, Prague.
[7] Hora, H., Korn, G., Giuffrida, L., Margarone, D., Picciotto, A., Krasa, J., et al. 2015. “Fusion Energy Using Avalanche Increased Boron Reactions for Block Ignition by Ultrahigh Power Picosecond Laser Pulses.” Laser and Particle Beams 33: 607-19.
[8] Miley, G. H., and Hora, H. 2019. “Extreme CPA-Laser Pulses for Environmentally Clean Laser Boron Fusion.” Journal of Fusion Science and Technology 75: 575-80.
[9] Hora, H., Miley, G. H., Eliezer, S., and Nissim, N. 2020. “Pressure of Picosecond CPA Laser Pulses Substitute Ultrahigh Thermal Pressures to Ignite Fusion.” High Energy Density Physics 35: 100739-42.
[10] Hora, H., Götz, J., Kirchhoff, McKenzie, W. R., and Kirchhoff, J. 2019. “First Option for Fusion with CPA Laser Pulses Instead of Thermal Pressures with Dozens of Million Degrees Temperatures for Laser-Boron-Fusion.” Journal of Energy and Power Engineering 13: 116-23.
[11] Steinke, S., Henig, A., et al. 2010. “Efficient Ion Acceleration by Collective Laser Driven Electron Dynamics with Ultrathin Films.” Laser and Particle Beams 28: 215.
[12] Hora, H., and Miley, G. H. 2011. “Possibility for Gaining Nuclear Energy without Radioactivity from Solid Density Hydrogen Boron Using Laser with Nonlinear Force Driven Plasma Blocks.” Journal of Energy and Power Engineering 5: 728.
[13] Hora, H. 1971. Laser Interaction and Related Plasma Phenomena, New York: Plenum Press, 273.
[14] Sauerbrey, R. 1996. “Acceleration in Femtosecond Laser-Produced Plasmas.” Physics of Plasmas 3: 4712.
[15] Strickland, D., and Mourou, G. 1985. “Compression of Amplified Chirped Optical Pulses.” Optics Communications 56: 219-21.
[16] Hora, H., Miley, G. H., Ghorannviss, M., Malekynia, H., Azizi, N., and He, X. T. 2010. “Fusion Energy without Radioactivity: Laser Ignition of Solid Hydrogen-Boron (11) Fuel.” Energy and Environment Science 3: 479-86.
[17] Belyaev, V. S., Krainov, V. P., Matafonov, A. P., Zagreev, B. V. 2005. “Observation of Neutronless Fusion Reactions in Picosecond Laser Plasmas.” Phys. Rev. E 72: 026406.
[18] Labaune, C., Deprierraux, S., Goyon, S., Loisel, C., Yahia, G., and Rafelski. J. 2013. “Fusion Reactions Initiated by
Laser-Accelerated Particle Beams in a Laser-Produced Plasma.” *Nature Communications* 4: 2506.

[19] Eliezer, S., Hora, H., Korn, G., Nissim, N., and Martinez-Val. J.-M. 2016. “Avalanche Proton-Boron Fusion Based on Elastic Nuclear Collisions.” *Physics of Plasmas* 23: 050704.

[20] Pitchwein, E., and Voglesberger, M. 2019. “Search of Traces in Space.” *Physik Journal* 18 (11): 17.