CPA-Laser Pulses for Non-Thermal Initiation of Laser-Boron-Fusion

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The key problem for controlled generation of nuclear fusion energy in a reactor for generating electricity is the needed temperature of hundreds of million degrees Kelvin for thermal pressures. The sixty-five years of research has well achieved these temperatures under conditions in laboratories, both for ITER-like magnetic confinement as well as for NIF-like ICF when using nanosecond laser pulses. The temperatures were produced, but for too short times such that a breakthrough for a reactor has not yet been reached.

The need for million degrees temperatures is no surprise. The temperature for chemical reactions - as the burning of carbon - is in the range of eV needing ignition temperatures of few hundred of degrees Kelvin. Nuclear reactions are at ten million times higher energies. Nuclear burning needs then dozens of million degrees under thermal pressures. The sun burns hydrogen to helium at 15 Million degrees and the first deuterium fusion reactions at thermal equilibrium in a stellarator were measured in 1980 at 10 Million degrees.
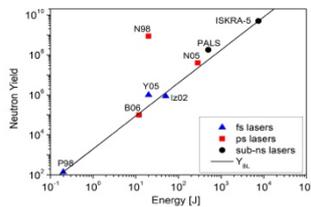

Fig.1.Neutrons from irradiation of laser pulses of fs to 100ps on the irradiated energy from targets with deuterium as fusion fuel [7] showing about 10,000 thousand higher yield with ps-CPA pulses (N98: P.Norreys et al 1998) than from thermal plasmas.

The laser initiated that ultra-extreme energy densities in pulses of picosecond ps duration will solve the nuclear fusion. Referring to the hydrodynamic equation of motion for the force density

$$\mathbf{f} = -\nabla p + \mathbf{f}_{NL}$$

contains the gasdynamic pressure p with the product of density and temperature T and the nonlinear force $\mathbf{f}_{NL}= \nabla \bullet \mathbf{M}$ with Maxwell's stress tensor $\mathbf{M}$ containing the electric and magnetic fields $\mathbf{E}$ and $\mathbf{H}$ of the laser, the laser frequency ω and the optical refractive index n of the plasma. To understand early measured nonlinear interaction, most general hydrodynamics resulted at interaction of 10^{18}W/cm^2 laser pulses, that within 1.5ps plasma blocks reached velocities of about 10^{10}cm/s without much heating, see Fig. 8.4 [1], confirming the dominance of the nonlinear force driven plasma block acceleration by ps against thermal pressures. The

ultrahigh acceleration was 100,000 times higher than from best laser heating. Thanks to the Chirped Pulse Amplification CPA [2] the accelerations were measured at the predicted values [3].

Including the triple-alpha avalanche reaction of HB11 resulted in an increase by further four magnitudes [5] explaining the measurements, leading to the design of a fusion reactor see Fig. 16 of [6] – avoiding the hundred million degrees Kelvin of thermal pressures. For an environmentally clean, absolute safe, low-cost and unexhaustive electricity supply.

The nonlinear effect (see R. Feynman in Chapter 6.3 of [1]) of the plasma-block acceleration with the extreme ultrahigh ps CPA laser pulses can be seen in the diagram of Fig. 1 in the re-evaluation [7] of earlier DD-fusion measurements under the aspects of the recent results [6].

The non-thermal properties of the ultrahigh picosecond acceleration of plasma blocks by nonlinear-force acceleration resulted in ten-thousand times higher fusion neutron generation [3] than by thermal interaction, confirmed by much lower temperatures measured, clarified by comparison in the diagram, Fig. 1 [4]. Computations on non-thermal plasma-block ignition arrived at the surprising result that the well known extremely low classical thermal energy gain from fusion of hydrogen H with the boron isotope 11 with producing three alpha particles (HB11 fusion) arrived at about five orders of magnitudes higher gains than classical up to the level of deuterium-tritium fusion. Including the three alpha avalanche increased the gain by further 4 magnitudes. This explains the measured billion times increased fusion yields of HB11 [5] than classically.

The fact that the measured bremsstrahlung was significantly lower than at thermal conditions (Fig. 1) and also at [6], indicated the extreme non-equilibrium properties of plasmas for the generators during times of less than several 100ps, as discussed as conclusion [8] of the presentation at the Symposium Hirschegg 2019

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