Progress in Nuclear Energy 78 (2015) 349–354

Contents lists available at ScienceDirect

Progress in Nuclear Energy

journal homepage: www.elsevier.com/locate/pnucene

The pioneers' legacy of inertial confinement nuclear fusion

Natividad Carpintero-Santamaría*, Guillermo Velarde

Institute of Nuclear Fusion, José Gutiérrez Abascal n° 2, Madrid 28006, Spain

ARTICLE INFO

Article history:
Received 16 October 2013
Accepted 23 October 2013
Available online 4 December 2013

Keywords:
Ulam-Teller Method
Palomares nuclear accident
Nuclear fusion
Nuclear fusion pioneers
Nuclear confinement fusión in Spain
Madrid Manifesto

ABSTRACT

Some years ago Professor Guillermo Velarde visited his good friend Academician Nicolai G. Basov, Nobel Prize in Physics and Director of the Lebedev Institute, and discussed the possibility of publishing a book on the History of the Inertial Confinement Nuclear fusion to be written by its Pioneers. They thought that only the own Pioneers could focus the book on a realistic and truthful manner.

The years passed and unfortunately on July 1, 2001, Nicolai G. Basov passed away. In June 2002 Professor Velarde was invited to Moscow to give a Memorial lecture on Academician Basov in the Academy of Sciences. There in Moscow, Professors Vladislav Rozanov, Sergey Guskov, Natividad Carpintero-Santamaría and Guillermo Velarde decided to carry on with the project.

Unfortunately, it was time to close the deadlines and the chapter of Academician Robert Dautray, former Haut-Commissaire of the CEA was not received. We regretted very much that the contribution of this very relevant Pioneer to the ICF is not included in the book. We did not receive also any material from Professor Edouard Fabre from the Ecole Polytechnique.

The absence of the contributions of Nicolai G. Basov and Edward Teller was very significant. All of us would like that this ICENES 2013, hosted by the Institute of Nuclear Fusion, could be a posthumous tribute to these two outstanding Pioneers as well as a tribute to all of them.

1. Introduction

The making of this book (Fig. 1) was a challenging work. It allowed us to deepen nuclear science development in an exciting historical framework. (Velarde and Carpintero-Santamaria, 2007).

The first step in the book process was to send letters to the Pioneers from different countries: United States, Japan, Russian Federation, Europe, Israel and Australia. Their response was positive and we started a task that sometimes proved to be hard and discouraging, but always worth.

To establish a temporal historical basis the only condition to contribute to this book was that every Pioneer should present a photocopy of the first page of his first paper on Inertial Confinement Nuclear Fusion (ICF). We decided to leave the chapters in the form that they were sent by the Pioneers. This freedom allowed the authors to focus on their own history according to their personalities. The result is an independent and valuable personal account.

Unfortunately, it was time to close the deadlines and the chapter of Academician Robert Dautray, former Haut-Commissaire of the CEA and close friend of Prof. Velarde during 40 years was not received. Robert Dautray is an eminent scientist and French pioneer in inertial confinement nuclear fusion.

According to the requirements of the book, the first papers on ICF published by the Pioneers were the following:

John Nuckolls. Lawrence Livermore National Laboratory (USA): *Laser Compression of Matter to Super-High Densities*: *Thermonuclear (CTR) Applications* (1972).

Ray Kidder. Lawrence Livermore National Laboratory (USA): *A 1964 Computer Run On Laser-Imploded Capsule* (1973).

John Holzrichter. Lawrence Livermore National Laboratory and F.J. Hertz Foundation (USA): *Implosion Experiments with an Asymmetrically Irradiated Laser Fusion Target* (1976).

Keith A. Brueckner. KMS Fusion, Ann Arbor, Michigan, and University of California at San Diego (USA): *Laser-Driven Fusion* (1974).

Gerold Yonas. Sandia National Laboratory (USA): *Electron Beam Focusing using Correct-Carrying Plasmas in High-ν/γ Diodes* (1973).

Keith Boyer. Los Alamos National Laboratory (USA*): Power from Laser-Initiated Nuclear Fusion* (1964).

Robert McCrory. Laboratory for Laser Energetics, University of Rochester (USA): *Laser-driven Implosion of Thermonuclear Fuel to 20 to 40 g cm*$^{-3}$ (1988).

Stephen Bodner. Naval Research Laboratory, (USA): *Rayleigh-Taylor Instability and Laser-Pellet Fusion* (1974).

* Corresponding author.
E-mail addresses: natividad.csantamaria@upm.es (N. Carpintero-Santamaría), guillermo.velarde@upm.es (G. Velarde).

0149-1970/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.pnucene.2013.10.019

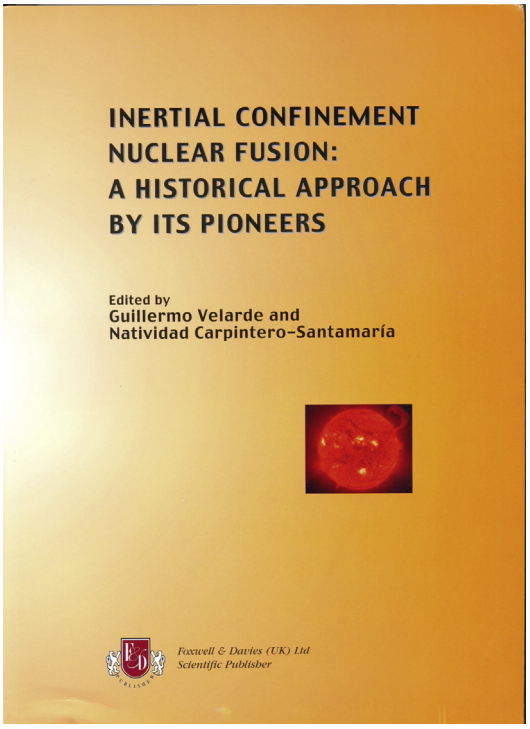

Fig. 1. Book on inertial confinement nuclear fusion: a historical approach by its Pioneers.

Guillermo Velarde. Spanish Atomic Energy Commission, JEN, and Institute of Nuclear Fusion, DENIM (Spain): *Analysis of Laser-Fission-Fusion Systems: Time-dependent Coupled Nuclear Thermo-hydrodynamic Analysis and Applications* (1978).

Michael Key. Rutherford Appleton Laboratory, Central Laser Facility (UK), and Lawrence Livermore National Laboratory (USA): *Experimental and Theoretical Studies of the Time and Space Development of Plasma Parameters in a Laser Induced Spark and Helium* (1969).

Rudolf Bock. Gesellschaft für Schwerionenforschung (Germany): *Die Schwerionen-Gezündete Thermonukleare Fusion* (1978).

Klaus Witte and Richard Sigel. Max-Planck-Institut für Quantenoptik (Germany): *Laser Produced Plasma from Solid Hydrogen Foils* (1968).

Angelo Caruso. Laboratorio Gas Ionizzati, LGI-CNEN, ENEA Frascati (Italy): *Ionization and Heating of Solid Material by Means of a Laser Pulse* (1966).

Shalom Eliezer. Soreq Nuclear Research Center, Yavne (Israel): *Reflection and Transmission of Light through Transparent Materials at High Power Densities* (1978).

Nikolay Kolvalskiy and M. J. Pergament. Kurchatov and Troitsk Institutes (Russian Federation): *High Power Output Stages of a Nd: Glass Laser System for Fusion Applications* (1976).

Igor Krasyuk and A. M. Prokhorov. General Physics Institute (Russian Federation): *Generation of Thermonuclear neutrons by Laser Action on a Conical Target* (1977).

Vladislav Rozanov and Sergei Gus'kov. P.N. Lebedev Physical Institute (Russian Federation): *Similarity Solution of Thermonuclear Burn Wave with Electron and* α^- *Conductivities* (1976).

Gennadii Kirillov. All Russian Scientific Research Institute of Experimental Physics (former Arzamas-16) VNIIEF (Russian Federation): *Irradiation of Microspheres with the 2 Tw Iodine Laser.*

R.I. Il'kaev and Vladislav N. Mokhov. All Russian Scientific Research Institute of Experimental Physics (former Arzamas-16), VNIIEF, (Russian Federation): (1977).

Evgeny N. Avrorin. All Russian Scientific Research Institute of Technical Physics (former Chelyabinsk), VNIITF, (Russian Federation).

Chiyoé Yamanaka. Institute of Laser Engineering, Osaka University and Institute for Laser Technology (Japan): *Experiments on Collisionless Shock Waves in Plasmas* (1969).

Sadao Nakai. Institute of Laser Engineering, Osaka University and G.S. for the Creation of New Photonics Industries, (Japan): *Nonlinear Interaction Processes between a* CO_2 *Laser and a Plasma* (1978).

Heinrich Hora. University of South Wales, (Australia): *Estimation of Heating of a Plasma by Lasers* (1965)

2. Ulam-Teller method

First works on ICF were based on the Ulam-Teller (U-T) Method on X-ray implosion developed by Stanislaw Ulam and Edward Teller in 1951 for thermonuclear bombs. When the United States used the U-T Method in the thermonuclear bomb tests, they got their first success with Mike Test in October 1952. Mike Test reached a yield of 10.4 MT. Andrei Sakharov in the Soviet Union and Robert Dautray in France rediscovered the U-T Method. This allowed these countries to reach yields of MT in both the Soviet and French tests in 1955 and 1968, respectively.

As a consequence of the Palomares nuclear accident in 1966, Guillermo Velarde rediscovered the U-T Method. In the early 70s, Chiyoé Yamanaka developed the Cannon Ball system.

3. Beginnings of inertial confinement fusion

In 1960 first real experiments with ruby laser were obtained. From 1961 and during the decade of the 60s, Teller, Nuckolls, Kidder

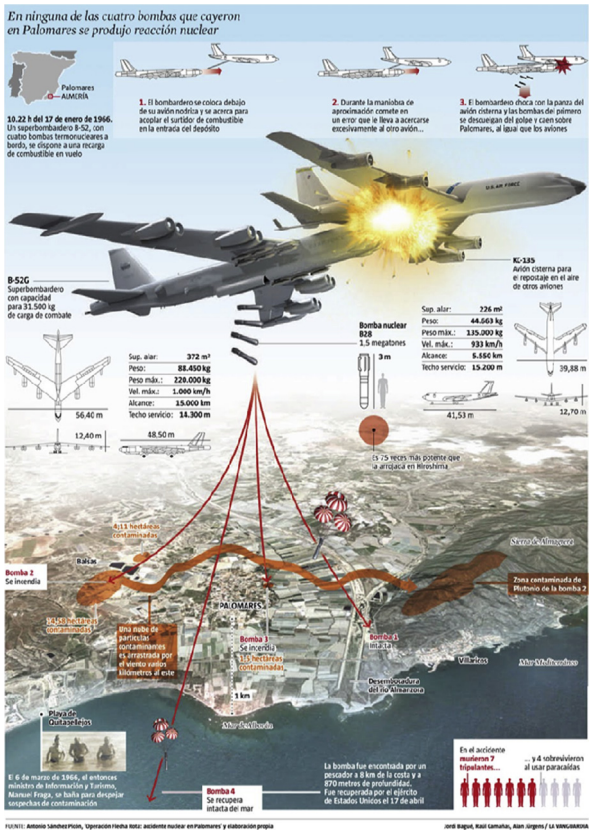

Fig. 2. Source: Raúl Camañas, Alan Jürgens and Jordi Baqué. La Vanguardia.