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BOOK REVIEW

Controlled Thermonuclear Fusion

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Controlled Thermonuclear Fusion by Jean Louis Bobin, World Scientific, Singapore, 2014, pp. xvi + 194. Scope: monograph, £56, ISBN 978-981-4590-68-6 (Hardcover). Level: general physicists, undergraduates, postgraduates.

Thermonuclear fusion offers the possibility of virtually-unlimited, low-carbon, electrical power generation without leaving an extensive legacy of radioactive waste. For almost as long as I can remember, its practical application has been predicted to be about thirty or forty years in the future, so why does it never seem to come closer to reality?

Jean Louis Bobin seeks to answer the question by providing a concise description of the present status of the enterprise, written at a level accessible to any physicist, including undergraduates. Thermonuclear fusion occurs when a plasma of appropriate nuclei (e.g. mixed deuterium and tritium), at sufficient density, is raised to a temperature of about 10^8 K. The thermal energies of nuclei in the high-velocity tail of the distribution then bring them close enough together for fusion to occur via quantum tunnelling, a reaction that is enormously exothermic. Although these conditions are simply stated, it has proved hard to realise them in practice, and enormously much more difficult than was originally expected when work started in the middle of the last century.

The main problem, of course, is that of containment. On account of its enormous temperature, the plasma is at a high pressure and tending to expand. Yet it must not come into contact with any solid wall or surface, but must be bounded by vacuum. Stars solve the containment problem gravitationally, but that is not possible on Earth. The main containment options currently being developed are either magnetic e.g. electrical heating of plasma within a tokamak, or inertial where an initially cold pellet is laser-heated so fast that the resultant plasma undergoes thermonuclear reactions before it has time to blow apart. Bobin describes and discusses both approaches in considerable detail.

Addressing his general audience of physicists, he starts from the basics with a chapter reviewing atoms, nuclei, and nuclear reactions. Chapters on thermonuclear reactions and plasmas then complete most of the physics background needed for what follows. Three chapters on magnetic confinement cover the physical principles, instabilities, tokamaks and, in particular, focus on the International Thermonuclear Experimental Reactor (ITER). The ITER project was originally launched in 1986 following a Gorbachev-Reagan summit. The resultant tokamak being built in Cadarache, France is still a long way off completion. Bobin then turns to inertial confinement, the interaction of laser beams with solid targets, the design of deuterium-tritium pellets, and the giant lasers developed to drive inertial fusion. He describes the National Ignition Facility (NIF) at the Lawrence-Livermore National Laboratory, USA, which failed to achieve ignition as hoped in 2012.

As well as covering ITER and NIF, the two highest-profile projects, Bobin's discussions also range much more widely, including fissile blankets, hybrid fusion/fission devices, muon-catalysed

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cold fusion, alternatives to deuterium-tritium as a thermonuclear fuel, tritium breeding, and fusion reactors more generally. Although he mostly sticks rigorously to science, his personal views show through from time to time, and are illuminating and helpful in understanding how we have got to where we are. On ITER, for example, he points out that the 1998 design was intended to achieve ignition, but was scaled back in 2003 for cost-saving reasons – aiming for a 1.3 times smaller machine at half-price, not necessarily reaching ignition. He comments on the timidity of this decision, made prior to the development of widespread concern about climate change and global warming, and speculates that if the decision were being made again in the present context the result might very well be different.

The book is nicely printed with clear typography and well-rendered equations, illuminated by numerous illustrations, graphs and tables. The usual convention of italicising variables is not followed, which occasionally makes for ambiguities when variables appear in the text. The translation from the original French has not been made by a native English-speaker, and this has led to some infelicities that make the text less smooth to read. There is a commendable level of care and attention to detail, e.g. a foreword note about units, numerous explanatory boxes scattered throughout the text, a thoughtful Epilogue, a Glossary, a list of Acronyms, and a Selected Bibliography in addition to the References at the ends of chapters.

Bobin has packed an immense amount of information into this relatively short book which, as an accessible answer to the initial question, and as an assessment of the current state of the thermonuclear power enterprise and where it is going, it seems to me could hardly be bettered.

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