Control of Distributed Parameter Systems in Magnetic Fusion

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Abstract:
As fossil fuel depletes and the environmental impact of their use starts to be felt, fusion arises as an economically affordable, environmentally sustainable, and politically acceptable source of energy. Although controlled fusion is a very challenging technology, a fusion power reactor would offer significant advantages over existing energy sources, including no air pollution or greenhouse gases, no risk of nuclear accident with impact on the public, no generation of material for nuclear weapons, low-level and short-lived radioactive waste, and a worldwide available, nearly infinite supply of fuel, which would thus eliminate international tensions caused by imbalance in fuel supply. The immediate next step in the international fusion roadmap is the construction and operation of the ITER tokamak, a multibillion-dollar device whose construction has recently started as the result of an unprecedented cooperative effort by governments around the world. The ITER tokamak, which will be the first tokamak to produce more energy than it consumes, will demonstrate the physics understanding and several key technologies necessary to maintain burning plasmas (i.e., plasmas having sustained high levels of fusion reactions). The planned ITER device will be capable of exploring advanced tokamak (AT) modes of operation, characterized by high plasma pressure, long confinement times, and low level of inductively driven plasma current, which allows steady-state operation. These advanced modes rely heavily on active control to develop and maintain high performance plasmas with sufficient density, temperature, and confinement to produce a self-sustaining fusion reaction for long durations. Tokamaks are high order, distributed parameter, nonlinear systems with a large number of instabilities, so there are many extremely challenging mathematical modeling and control problems, which must be solved before a fusion power system becomes a viable entity. This seminar will provide an overview of fusion science and tokamak operation, and will describe several of the challenging control problems remaining to be solved including magnetic control of the magnetohydrodynamic equilibrium, kinetic control of the plasma burning condition, control of magnetohydrodynamic instabilities and distributed-parameter control of the plasma spatial profiles. Emphasis will be made on the latter control problem since the regulation of plasma spatial profiles of quantities such as toroidal current density, pressure and temperature may be the enabler of a steady-state, instability-free, high-confinement tokamak fusion reactor.

Bios:

Dr. Eugenio Schuster (schuster@lehigh.edu) is Assistant Professor in the Department of Mechanical Engineering and Mechanics at Lehigh University in Pennsylvania, where he leads the Laboratory for Control of Complex Physical Systems. Dr. Schuster holds undergraduate degrees in Electrical Engineering (University of Buenos Aires, Argentina, 1993) and Nuclear Engineering (Balseiro Institute, Argentina, 1998), as well as M.Sc. (2000) and Ph.D. (2004) degrees in Mechanical & Aerospace Engineering from University of California San Diego. He is particularly interested in the application of nonlinear and distributed-parameter control techniques to complex physical systems such as fusion reactors, plasmas, and magnetohydrodynamic flows. Dr. Schuster is the recipient of the NSF CAREER Award for his work on Nonlinear Control of Plasmas in Nuclear Fusion. Mr. Chao Xu and Mr. Yongsheng Ou are Ph.D. candidates in the Laboratory for Control of Complex Physical Systems at Lehigh University.