

With the recent results in hand, the company is now building a larger apparatus for a three- to four-year experimental program. The new facility will include more beams of around 15 keV to supply the fast particle fuel and energy, says Binderbauer. Tri Alpha's goal is to fuse protons and boron-11, a reaction that, unlike the conventional deuterium-tritium (D-T) combination, will yield few or no neutrons.

The $p\text{-}^{11}\text{B}$ reaction produces three alpha particles, hence the company's name. But the combination will require temperatures around 3 billion kelvin, far higher than the 100 million to 300 million kelvin needed for D-T. To burn $p\text{-}^{11}\text{B}$, Tri Alpha will have to attain a temperature 300 times as hot as the plasma it worked with in the C2U, Binderbauer says. The company's plan to reach such an extreme temperature is aided by the fact that confinement in a beam-driven FRC improves with temperature, the opposite of what occurs in a tokamak, he says.

According to Ronald Davidson, former director of Princeton Plasma Physics Laboratory and a scientific adviser to Tri Alpha, "It was not very long ago that when the FRC configuration was pursued in lab experiments, they were lasting fractions of a millisecond and were highly unstable, certainly not [this] quiescent," he says. Based on what Tri Alpha has done, "one should certainly declare that the approach they

are using has been very successful, and the next step is likely to be successful as well."

Tri Alpha's concept requires continuous energy input, unlike the goal of a self-sustaining plasma for a tokamak-based fusion power plant. One question, notes Stephen Dean, president of the industry trade group Fusion Power Associates, is whether the output from a $p\text{-}^{11}\text{B}$ reaction would exceed the input power by enough to make a power plant economically attractive. Working further against the input-output equation is the fact that $p\text{-}^{11}\text{B}$ produces about half the energy per reaction as D-T.

Still, Binderbauer is "very confident" that sufficient net power can be achieved to make the fuel cycle attractive for baseload electricity generation. "What remains is to make sure that this is not some super-strange coincidental artifact at the particular design and energetics of the C2U," he cautions, but he says he doesn't believe that is the case. He declines to say whether additional experimental devices will be needed before a commercial plant is constructed.

Tri Alpha does not have a website. The company won't name its investors, but published reports have identified Microsoft cofounder Paul Allen as one. It also won't reveal the full composition of its scientific advisory board, which includes former SLAC director Burton

Richter, nor identify all the members of its board of directors, which is chaired by former hedge fund manager and early-stage technology "angel" investor Arthur Samberg. A partial list includes some well-known venture capitalists; former Nuclear Regulatory Commission chair Richard Meserve; and Steven Specker, former chief executive officer of the Electric Power Research Institute.

David Kramer

NSF engineering research centers take on heat and water

New methods for increasing the power density of electric systems used in transportation and more efficient and improved water treatment technologies are the focus of two new engineering research centers announced by NSF in August.

Led by the University of Illinois at Urbana-Champaign, the Center for Power Optimization of Electro-Thermal Systems (POETS) will aim to increase the power density of electrified systems by 10 to 100 times. That increase should lead to lighter, more compact, and more efficient power electronics for cars, airplanes, construction equipment, tools, and other mobile applications. Center researchers will integrate three-dimensional cooling circuitry, power converters, and algorithms to improve power management. Success could lead to a doubling of the range of electric vehicles, according to center officials. The NSF award is valued at \$18.5 million over five years.

Andrew Alleyne, POETS's principal investigator, says that while heat dissipation limits power density, thermal considerations are often viewed as a problem to be solved only after the power electronics have been designed. "We take a multidisciplinary approach," he says. "We have electrical engineers, mechanical engineers, materials scientists, and physicists." The objective is to codesign electronics from the beginning to take account of thermal and electric limits.

"It took people who knew computational algorithms and numerical methods, and people who knew semiconductors and chip design, to come up with ways bit by bit to keep climbing up the Moore's law path," he says. "Similarly, we are going to need to have folks

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who know the mechanical, materials, and thermal side and people who know the electrical power electronics side. Together we will keep climbing up the ladder of increased power density."

The early stages of the research program will involve a considerable amount of physics, says Alleyne. "We're going to be building up a thermal equivalent of electrical circuits. That is, we'll be building a thermal diode or gate, the thermal equivalent of a capacitor, and the equivalent of a thermal potentiometer. If we can build these components, we can route thermal power throughout a volume, in a fashion similar to routing electrical power—clearly not as fast, but as easily."

Stanford University, Howard University, and the University of Arkansas are partners in the center, which will engage up to 25 faculty and 50 students, Alleyne says.

Rice University is the recipient of a five-year NSF award, also valued at \$18.5 million, for the Nanosystems Engineering Research Center for Nanotechnology-Enabled Water Treatment Systems. Principle investigator Pedro Alvarez says the goal is to develop modular, portable, and more efficient catalytic and physical water-treatment processes.

As one example, Rice scientists found that when electrons in some nanoparticles are excited by sunlight, they produce water vapor. "If you put these particles on the surface of a hydrophobic

membrane, water vapor can get on the other side, leaving behind salt and other pollutants and microbes," he explains.

The center will also look at enhancing reverse-osmosis membranes (see the Quick Study by Greg Thiel, *PHYSICS TODAY*, June 2015, page 66) that won't get clogged or biofouled. Possible improvements include coatings and antimicrobial particles.

"We are still using Victorian-era technologies like sand filters" for water treatment, Alvarez notes. "They work very well to remove suspended solids and bacteria. But what about endocrine disruptors, or pharmaceuticals, or trace-level carcinogens? Current systems aren't doing a very good job" of eliminating them, he says.

Other technology options for improving treatment include sorbents and catalysts. Self-assembling nanoparticle surfaces might be used to reduce biofouling and corrosion in water distribution systems.

Partnering with Rice are Arizona State University, the University of Texas at El Paso, and Yale University. Alvarez expects about 20–30 faculty members and 200 students to participate in center research.

Including the new pair, NSF supports 20 engineering research centers in the areas of advanced manufacturing; biotechnology and health care; energy, sustainability, and infrastructure; and microelectronics, sensing, and information technology.

David Kramer

news notes

ESO and ESA team up. On 20 August, Europe's premier organizations for ground-based and space-based astronomy signed an agreement to formalize and increase their cooperation. The European Southern Observatory and the European Space Agency will work together mainly in the areas of scientific research, technology, and public outreach.

Cooperation between ESO and the science division of ESA goes back to the 1980s with the establishment of a European coordination facility for the *Hubble Space Telescope*. The overlap between space-based and ground-based astronomy is increasing, says Fabio Favata, who heads ESA's science planning and community coordination office. "People are growing out of the distinction and using whatever they need to address the science goals." Dark energy and exoplanets are examples where close cooperation makes sense, he says.

The purpose of the new agreement is



Directors general Johann-Dietrich Wörner (ESA; left) and Tim de Zeeuw (ESO) shake hands on their agencies' new cooperation agreement.

to set a general framework for cooperation and exchange of information. Implementation is being discussed, and could include such activities as joint data analysis, conferences, and exchange of personnel, says ESO director general Tim de Zeeuw.

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