Tuesday Afternoon, November 14, 2006

Industrial Physics Forum
Room 2020 - Session IPF-TuA

Frontiers in Physics

Moderator: M.T. Bernius, The Dow Chemical Company

2:00pm **IPF-TuA1 Future Nanosystems: Towards Systems Biology of the Individual Cell*, M. Roukes,*** California Institute of Technology **INVITED**

Nanoscience now enables creation of ultrasmall electronic devices that offer unprecedented opportunities for sensing. Transitioning these devices from the realm of one-of-a-kind “feats” into robust, reproducible nanosystems useful for medical and biological research is a monumental challenge. Only the very first steps have been taken towards this end, even though such efforts are absolutely crucial for realizing the promise of "active" nanotechnology. At least two essential elements must be in place to realize the vast applications potential that awaits. First, an unfamiliar fusion of technologies is required, one that melds techniques from surface biochemistry and microfluidics with sensor technologies from nanoelectronics, nanomechanics, and nanophotonics. Second, robust methods for large-scale nanobiotechnological integration are required, and these must engender identifiable routes to production en masse. This disciplined assemblage of disparate technologies is crucial, whether for fundmental discovery work in medicine and the life sciences, or for the development of future clinical products. The requisite methodology is probably more familiar to the commercial sector than to academia. Despite impressive recent achievements in what I term "unit" nanoscience (which focuses upon individual phenomena and novel structures), nature's systems-nanotechnology still far outstrips what is engineerable today. For example, the mammalian acquired immune response represents a profoundly adaptive system that provides essentially single-molecule sensitivity to pathogens. In this light, harnessing cellular systems within hybrid devices appears to have immense potential for early disease detection, drug discovery, and fundamental medical and biological research. Today’s micro- and nanoscale technologies can provide the requisite tools for such applications. We are managing some awkward first steps toward these ends, embedding nanoscale biosensor arrays into microfluidic systems to form chip-based electronic "laboratories" for cell biology. When fully realized, this approach will permit simultaneous observation and control of multiple intra- and inter-cellular interactions. This, in turn, will reverse-engineering of biochemical networks through the techniques of systems biology, but at the level of the individual cell. There is an inevitability about such pursuits; they are increasingly being carried out by laboratories worldwide. Ultimately, active nanobiotechnology will enable a detailed real-time window into the complexity of cellular processes.

2:40pm **IPF-TuA3 Accelerating in the Future with Laser-Plasma Accelerators*, W. Leemans,*** Lawrence Berkeley National Laboratory **INVITED**

More than twenty five years ago, a new method was proposed for the acceleration of electrons to high energies using lasers. The simplest implementation of a so-called laser wakefield accelerator involves sending an intense laser pulse through a gas to ionize it and form a plasma of dissociated electrons and ions. The radiation pressure of the laser pushes the plasma electrons aside, creating a density modulation, or 'wake.' This changing electron density can result in fields that accelerate particles thousands of times more strongly than in conventional machines, accelerating electrons to high energies in short distances. The compactness of these accelerators would allow higher energies for the frontiers of fundamental physics and make clinical and laboratory applications of accelerators practical. In work that brings the promise of laser-driven particle accelerators dramatically closer to reality, we have produced high-quality GeV electron beams in a plasma channel based accelerating structure akin to an optical fiber of only a few centimeters long. Recent progress will be presented, including the generation of intense THz and x-ray radiation. Applications for such accelerators as drivers for future light sources and high energy physics particle colliders will be described, including a discussion on the challenges in laser technology to drive these accelerators.

3:20pm **IPF-TuA5 Wireless "Non-Radiative" Energy Transfer*, M. Soljačić,*** Massachusetts Institute of Technology **INVITED**

The emerging vast acceptance of autonomous electronic devices (e.g. radios, cell-phones, laptops, robots), which are currently being powered by on-site conversion of chemical energy, justifies revisiting the old dream of the pioneers of electrical applications (e.g. Tesla, Edison): transporting electrical energy wirelessly; where for optimal practicality, the energy transfer should be independent of the details of the geometry of the space in which the scheme is being used (e.g. of the exact position of the device with respect to the source, and whether there exists a direct line-of-sight between the device and the source.) Of course it is well known that freely-radiative modes satisfy this requirement (making them very suitable for information transfer), but they are not suitable for powering remote devices, since most of the power ends up being wasted into empty space. In our work, we investigate whether, and to what extent, the unique physical phenomenon of long lifetime resonant electro-magnetic states can, with long-tailed (non-radiative) modes, be used for efficient energy transfer. Intuitively, if both the device and the source are resonant states of the same frequency with long lifetimes, they should be able to exchange energy very efficiently, while interaction with other environmental off-resonant objects could be negligible. Of course, intricacies of the real world make this simple picture significantly more complex. Nevertheless, via detailed theoretical, and numerical analyses of typical real-world model-situations and realistic material parameters, we establish that such a non-radiative scheme could indeed be practical for middle-range wireless energy transfer (i.e. within a room, or a factory pavilion). Important novel applications are thus enabled.

4:00pm **IPF-TuA7 Neutron Stars and Black Holes*, R. Blandford,*** Stanford University **INVITED**

No longer a creation of the theoretical physicists' imagination, neutron stars and black holes have been found in abundance in the observed universe and have allowed astrophysicists to push our exploration of basic physics into extreme environments unattainable in the laboratory. Neutron stars exist as radio pulsars that are splendid clocks for testing general relativity and high energy astrophysics. They can spin with almost kHz frequencies and support 100GT magnetic fields. They can be gravitational machines for transforming the rest mass energy of accreting gas into X-rays and can explode to create gamma ray outbursts with millisecond timescales. Black Holes are gravitational collapsed objects that possess event horizons that outgoing matter and radiation cannot cross. They come in two sizes. Star-sized holes are observed when they have binary companions that evolve to supply them with gaseous fuel which can spiral inward towards the event horizon through an "accretion disk". Stellar holes may be formed during special supernova explosions accompanied by gamma ray bursts. Holes as massive as millions to billions of suns reside in the nuclei of most normal galaxies, including our own. When they are supplied with gas they can easily outshine their host galaxies and are then called quasars. When black holes merge, they can create burst of gravitational radiation which may be detectable.

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