Vincent Meyer Colloquium

Professor Eli Yablonovitch

"Searching for the Milli-Volt Switch"
Wednesday, March 28, 2012, at 12:30 , Meyer Bldg, Room 1003

Professor Yablonovitch will also deliver two additional lectures:

"The Two Conflicting Narratives of Metal-Optics"
Monday March 26, 14:30

"The Opto-Electronic Physics Which Just Broke the Efficiency Record in Solar Cells"
Thursday 29 March, 14:30

Please register online!

Prof. Eli Yablonovitch

Research Areas

Physical Electronics (PHY)

Optoelectronics, high speed optical communications, photonic crystals at optical and microwave frequencies, the milli-Volt switch, optical antennas and solar cells

Research Centers

Center for Energy Efficient Electronics Science (E3S)

Teaching Schedule (Spring 2012)

EE 117. Electromagnetic Fields and Waves, MWF 10-11A, 237 Cory

Biography

Eli Yablonovitch is the Director of the NSF Center for Energy Efficient Electronics Science (E^3S), a multi-University Center based at Berkeley. He received his Ph.d. degree in Applied Physics from Harvard University in 1972. He worked for two years at Bell Telephone Laboratories, and then became a professor of Applied Physics at Harvard. In 1979 he joined Exxon to do research on photovoltaic solar energy. Then in 1984, he joined Bell Communications Research, where he was a Distinguished Member of Staff, and also Director of Solid-State Physics Research. In 1992 he joined the University of California, Los Angeles, where he was the Northrop-Grumman Chair Professor of Electrical Engineering. Then in 2007 he became Professor of Electrical Engineering and Computer Sciences at UC Berkeley, where he holds the James & Katherine Lau Chair in Engineering.

Prof. Yablonovitch is a Fellow of the IEEE, the Optical Society of America and the American Physical Society. He is a Life Member of Eta Kappa Nu, and a Member of the National Academy of Engineering and the National Academy of Sciences. He has been awarded the Adolf Lomb Medal, the W. Streifer Scientific Achievement Award, the R.W. Wood Prize, the Julius Springer Prize, and the Mountbatten Medal. He also has an honorary Ph.d. from the Royal Institute of Technology, Stockholm Sweden.

In his photovoltaic research, Yablonovitch introduced the $4n^2$ light-trapping factor that is used commercially in almost all high performance solar cells.

Yablonovitch introduced the idea that strained semiconductor lasers could have superior performance due to reduced valence band (hole) effective mass. Today, almost all semiconductor lasers use this concept, including telecommunications lasers, DVD players, and red laser pointers.

Yablonovitch is regarded as one of the Fathers of the Photonic BandGap concept, and coined the term "Photonic Crystal".

Selected Publications

M. Xiao, I. Martin, E. Yablonovitch, and H. W. Jiang, "Electrical detection of the spin resonance of a single electron in a silicon field-effect transistor," *Nature*, vol. 430, no. 6998, pp. 435-439, July 2004.

E. Yablonovitch, H. W. Jiang, H. Kosaka, H. D. Robinson, D. S. Rao, and T. Szkopek, "Optoelectronic quantum telecommunications based on spins in semiconductors (Invited Paper)," *Proc. IEEE*, vol. 91, no. 5, pp. 761-780, May 2003.

H. Kosaka, D. S. Rao, H. D. Robinson, P. Bandaru, K. Makita, and E. Yablonovitch, "Single photoelectron trapping, storage, and detection in a field effect transistor," *Physical Review B: Condensed Matter and Materials in Physics*, vol. 67, no. 4, pp. 045104/1-5, Jan. 2003.

E. Yablonovitch, "Photonic crystals: Semiconductors of light," *Scientific American*, vol. 285, no. 6, pp. 47-55, Dec. 2001.

I. Gontijo, M. Boroditsky, E. Yablonovitch, S. Keller, U. K. Mishra, and S. P. DenBaars, "Coupling of InGaN quantum-well photoluminescence to silver surface plasmons," *Physical Review B: Condensed Matter and Materials in Physics*, vol. 60, no. 16, pp. 11564-1156, Oct. 1999.

Lecture 1 Summary

Title:
"The Two Conflicting Narratives of Metal-Optics"

Abstract:

There are two conflicting narratives of Electromagnetics in metals:

1. The *microwave circuit narrative* in which metals, distributed capacitors, and distributed inductors function together in a high frequency circuit, albeit as distributed components. Here there is a rich tradition of various electromagnetic functions, including the antenna function.

2. This is countered by *the optical-plasmonic narrative*, in which metallic electromagnetics is thought to be dominated by plasmons, electromagnetic normal modes in which the inertia of the electrons plays a major role.

Given that Electromagnetics is generally invariant with frequency, it is not clear why there need to be two separate narratives. Is metal-optics simply the high frequency version of microwave electromagnetics? There is great benefit in unifying our understanding of the two regimes of metallic electromagnetics, and to distinguish the occasional role of electron inertia.

We find that some of the most important metal-optics functions are best understood as extensions of microwave electromagnetics: Antennas, for example, have been thoroughly under-estimated, and are well-poised to change the rules of optical physics.

Lecture 2 Summary

Title:

Center for Energy Efficient Electronics Science;
Searching for the Milli-Volt Switch

Abstract:

In contemplating the headlong rush toward miniaturization represented by Moore's Law, it is tempting to think only of the progression toward molecular sized components. There is a second aspect of Moore's Law that is sometimes overlooked. Because of miniaturization, the energy efficiency of information processing steadily improves. We anticipate that the energy required to process a single bit of information will eventually become as tiny as 1 electron volt per function, truly indeed a molecular sized energy. Inevitably, most logic functions including storage, readout, and other logical manipulations, will eventually be that efficient.

However there is one information-processing-function that bucks this trend. That is communication, especially over short distances. Our best projections, of improvements in the short distance communication function, show that it will still require hundreds of thousands of electron volts just to move one bit of information the tiny distance of only 10 micrometers. Why this energy per bit discrepancy for communications? It is caused by the difference in voltage scale between the wires and the transistor switches. Transistors are thermally activated, leading to a required voltage >>kT/q. Wires are long, and they have a low impedance, allowing them to operate efficiently even at ~1 millivolt.

The challenge then is to replace transistors with a new low-voltage switch that is better matched to the wires. I will present some of the technical options for such a new switch, which are being explored by the new NSF Science & Technology Center for Energy Efficient Electronics Science.

http://www.e3s-center.org/

Lecture 3 Summary

Title:

The Opto-Electronic Physics Which Just Broke the Efficiency Record in Solar Cells

Abstract:

The solar cell field is changing. We are finally approaching the Shockley-Queisser (SQ) limit for single junction solar cell ~33.5% efficiency under the standard solar spectrum. Previously, the record had been stuck at 25.1%, during 1990-2007. Why then the 8% discrepancy between the theoretical limit 33.5% versus the previously achieved efficiency?

It is usual to blame material quality. But in the case of GaAs double heterostructures, the material is almost ideal with an internal fluorescence yield of >99%. This deepens the puzzle as to why the full theoretical SQ efficiency was not achieved?

Counter-intuitively, efficient external fluorescence is a necessity for approaching the ultimate limits. Now new efficiency records are being broken. Alta Devices has reached 28.3%. A great Solar Cell also needs to be a great Light Emitting Diode.

The single-crystal thin film technology that achieved these high efficiencies, is created by epitaxial liftoff, and can be produced at cost well below the other less efficient thin film solar technologies. The path is now open to a 30% efficient photovoltaic technology, that can be produced at low cost.

Suggested Reading: "Intense Internal and External Fluorescence as Solar Cells Approach the Shockley-Queisser Efficiency Limit", http://arxiv.org/abs/1106.1603, and other references contained therein.