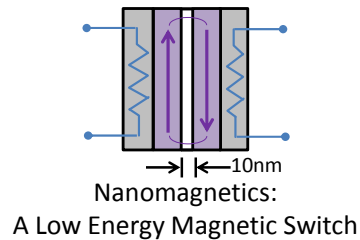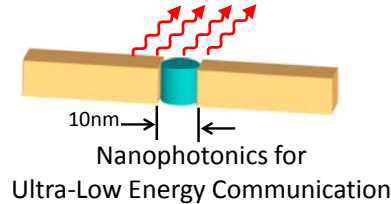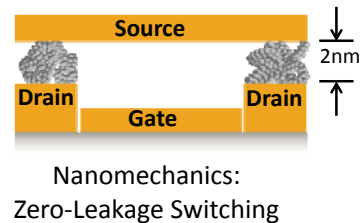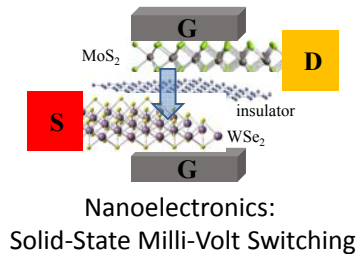# EE290B ADVANCED TOPICS IN SOLID STATE DEVICES

Autumn 2016 Semester, 299 Cory Hall, Tuesday-Thursday, 11:00AM-12:30PM
The first day of class will be Tuesday Aug. 30, 2016, not the prior Thursday.
The National Science Foundation Center for Energy Efficient Electronics Science, (E^{3}S).
This class is available for off-campus audit by asynchronous video. Register for video by email:
INSTRUCTOR: Professor Eli Yablonovitch, eliy@eecs.berkeley.edu

Nanoelectronics:
Solid-State Milli-Volt Switching

Nanomechanics:
Zero-Leakage Switching

Nanophotonics for
Ultra-Low Energy Communication

Nanomagnetics:
A Low Energy Magnetic Switch

COURSE DESCRIPTION:

In this course we will analyze the opportunity to make major reductions in the power consumption of electronic devices.

Some limits on energy efficiency for logic operations, memory operations, and communications, will be derived. The apparent major obstacle appears to be the excess signal-to-noise ratio that is designed into conventional digital electronics. This is dictated by the fact that the universal switch, the transistor, is thermally activated, and requires a high voltage $\gg kT/q \sim 1$Volt to achieve a good On/Off ratio. On the other hand the wires in a circuit would have tolerable signal-to-noise ratio operating even at 10 mVolt. This manifests itself as a factor $\sim 10^4$ inefficiency in current digital electronics.

We will project some anticipated technical options that could eventually eliminate this huge numerical penalty:
   i.   solid-state switching devices, that operate in the milli-Volt regime.
  ii.   nano-transistor options with steeper sub-threshold slope.
 iii.   nano-optical links.
  iv.   novel nano-scale impedance matching transformers, including plasmonics.
   v.   new forms of amplification using giant magneto-resistance, and other spintronic effects.
  vi.   nano-mechanical switching elements that are capable of very low voltage operation.
 vii.   low-temperature electronics.
viii.   electro-chemical switching elements.

The goal of the course is to anticipate which device option would most likely represent the future of digital electronics.

Credit: 3 units.   Credit Requirements: Mid-term exam, and a final term paper.
Prerequisite: A course in Solid-State physics or devices.

LIST OF LECTURES:

1. Introduction

2. mVolt Candidates

3. Conductance Quantum

4. Noise

5. Communications Cost

6. Charge Sensing

7. General Charge Sensors

8. Static versus Dynamic Power

9. The Backward Diode

10. Well-to-Well Tunneling1. Asymmetric Tunneling

12. pn-Junction Dimensionality

13. BiLayer and 0d-0d Switch

14. Rent's Rule, part 1

15. Rent's Rule, part 2

16. A Nano Mechanical Switch

17. Pull-In Voltage

18. Magneto-Resistive Switch

19. Spin-Orbit Torque

20. NanoPhotonics

21. Conductance Requirement

22. Clock Speed Limit

23. Cryo, Opto, Electrochemical Switching