Welcome and Review of Agenda

Eli Yablonovitch

Director

Center for Energy Efficient Electronics Science

This is a Private Meeting.

This is not a public disclosure of information.

For our corporate partners, please share the information from this meeting with your Company to help build bridges between your Company and the Center.

Welcome to the 2017 E^{3}S Annual Retreat

- E^{3}S Faculty, Students, Postdocs and Staff
  - Berkeley
  - MIT
  - Stanford
  - UTEP
  - FIU
- Industry Partners
  - IBM: Paul Solomon

Retreat Agenda: Day 1, Thursday, September 7

Time	Activity / Topic	Speakers
7:30 AM	*Breakfast & Check-In*	
8:00 AM	**Welcome & Introduction**	
	Review of Agenda Goals for the Retreat Center Overview	**Eli Yablonovitch**
8:30 AM	**Theme I: Nanoelectronics**	
	Theme I Overview	**Eli Yablonovitch**
	Progress on III-V Nanowire Transistor Project	**Jesús del Alamo**
	Progress on 2D Chalcogenide Transistor Project	**Ali Javey**
	Progress on Graphene Nanoribbon Project	**Eli Yablonovitch**
	Open Discussion	
9:45 AM	*Break*	

Retreat Agenda: Day 1 *continued*

10:00 AM	**Theme II: Nanomechanics**	
	Theme II Overview	**Tsu-Jae King Liu**
	Progress on NEM Relay Project	**Bivas Saha**
	Progress on Squitch Project	**Farnaz Niroui**
	Progress on Stritch Project	**David Zubia**
	Open Discussion	
11:15 AM	**Keynote Presentation**	
	Large-Scale Photonic Integrated Circuits for Quantum Information Science and Machine Learning	**Dirk Englund**
12:00 PM	***Lunch***	
1:00 PM	**Theme III: Nanophotonics**	
	Theme III Overview	**Ming Wu**
	Progress on III-V Epitaxial Growth	**Eugene Fitzgerald**
	Progress on Antenna-Enhanced LEDs	**Seth Fortuna**
	Open Discussion	

Retreat Agenda: Day 1 *continued*

2:25 PM	**Theme IV: Nanomagnetics**	
	Theme IV Overview and Ultrafast Magnetic Switching	**Jeffrey Bokor**
	Spin-Orbit Torque Switching Project	**Charles-Henri Lambert**
	CMOS Integration Project	**Jean-Anne Incorvia**
	Open Discussion	
3:40 PM	**Knowledge Transfer**	**Michael Bartl**
3:50 PM	***Break***	
4:00 PM	**Meeting with Industry Partners**	
4:45 PM	***Walk to Poster Session & Dinner***	
5:15 PM	**Reception and Poster Session**	
	Café ArtScience, 650 East Kendall St., Cambridge (www.cafeartscience.com)	
6:30 PM	**Dinner and Recognitions**	
	Café ArtScience, 650 East Kendall St., Cambridge	

Retreat Agenda: Day 2, Friday, September 8

Time	Activity / Topic	Speaker / Facilitator
7:30 AM	*Breakfast*	
8:00 AM	**System Integration**	
	System Integration Overview	**Vladimir Stojanović**
	Open Discussion	
8:30 AM	**Elevator Pitches**	
	90-Seconds Research Presentations	**E^{3}S Students & Postdocs**
	Feedback & Discussion	Moderators: **Lea Marlor, Kedrick Perry**
10:00 AM	*Break*	

Retreat Agenda: Day 2, *continued*

10:15 AM	**Education and Diversity**	
	Inclusion and Diversity Overview	**Kedrick Perry**
	Education Overview	**Lea Marlor**
	Open Discussion	
11:15 AM	**Center Management**	**Michael Bartl**
11:30 AM	**A Look Beyond 2020: Center Legacy**	
	Open Discussion	Moderator: **Vladimir Bulović**
11:55 AM	**Closing Remarks**	**Eli Yablonovitch**
12:00 PM	***Lunch (boxed)***	

Vision for 2025: Swarms of Electronics

Infrastructural core

promotes More of Moore's Law

Self-driving vehicles

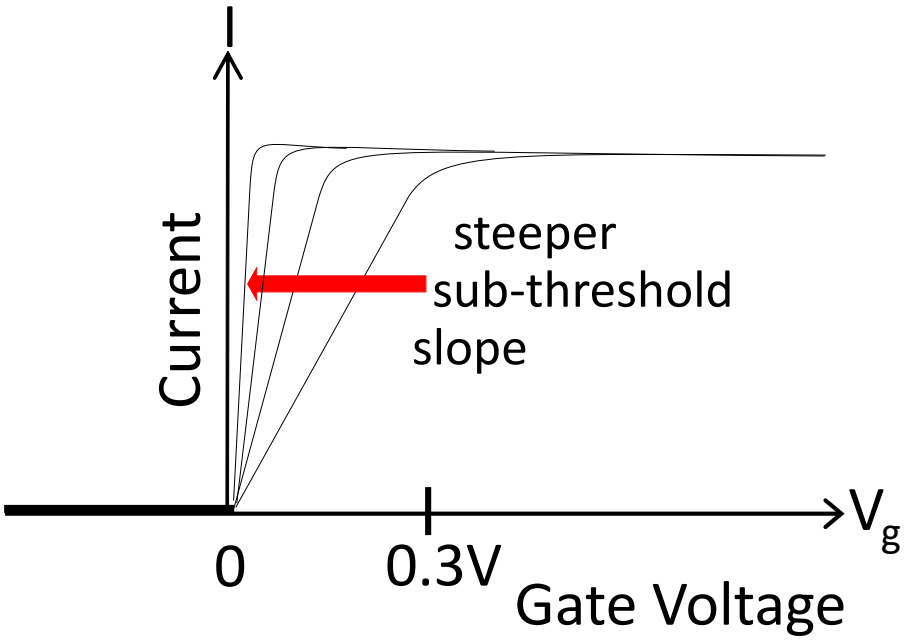
Mobile access

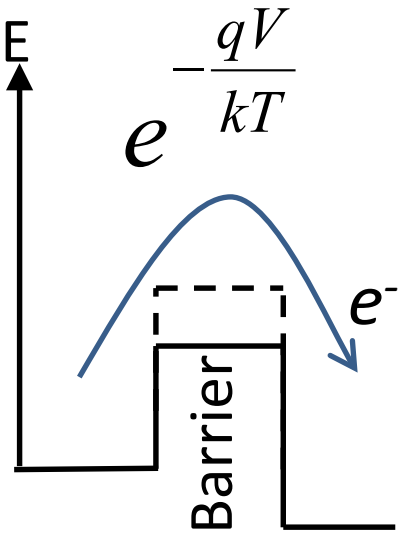
promotes More Than Moore's Law

Sensory swarm (trillions of devices)

Body Centered Networks (Medicine)

The Next Transistor:
A New More Sensitive Electronic Switch





ordinary
transistor

Take the powering voltage from ~1Volt down to milli-Volts
(noise is in μVolts)

The New Switch has to Satisfy Three Specifications

1. Steepness (or sensitivity)

   switches with only a few milli-volts

   60mV/decade $\Rightarrow$ **1mV/decade**

2. On/Off ratio. **10^6 : 1**

3. Current Density or Conductance Density

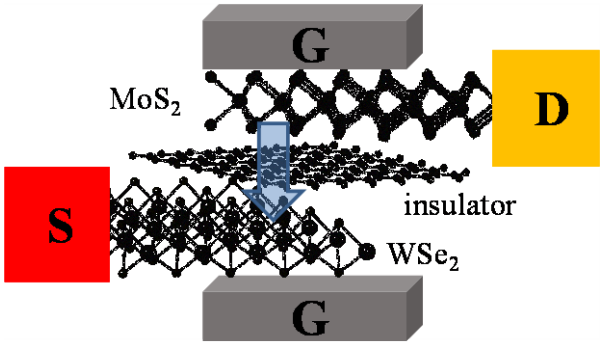
   (for miniaturization)

   old spec at 1Volt: 1 mAmp/micron

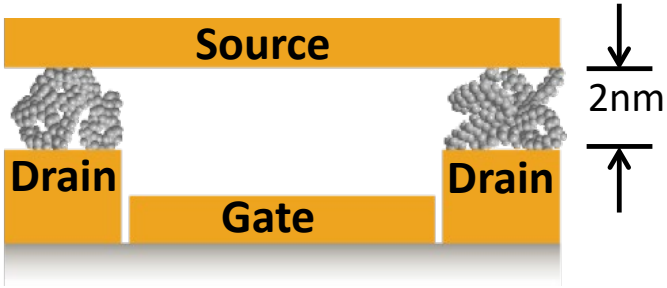
   our spec: **1 milli-Siemen/micron**

A One micron device should conduct at 1kΩ in the on-state.

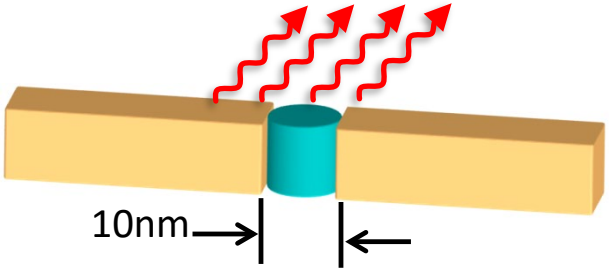
Four Interconnected Approaches



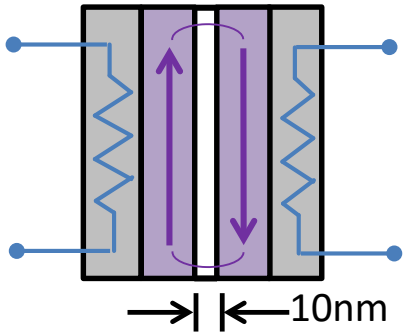
Nanoelectronics:
Solid-State Milli-Volt Switching



Nanomechanics:
Zero-Leakage Switching

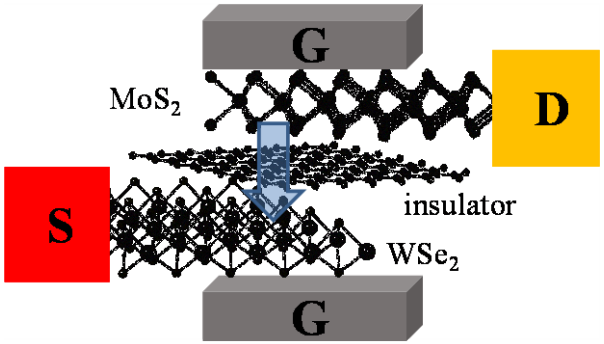


Nanophotonics:
Ultra-Low Energy Communication



Nanomagnetics:
A Low Energy Magnetic Switch

Each Theme has an Issue--maybe embarrassing—
That we can discuss freely at this Retreat.



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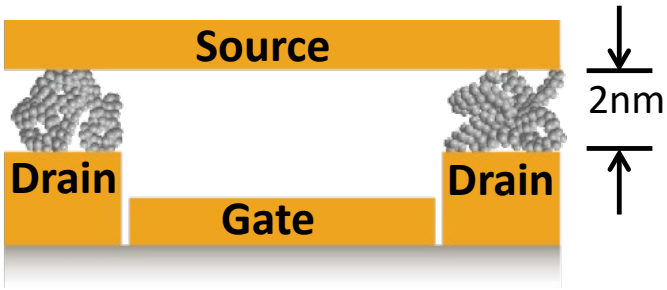

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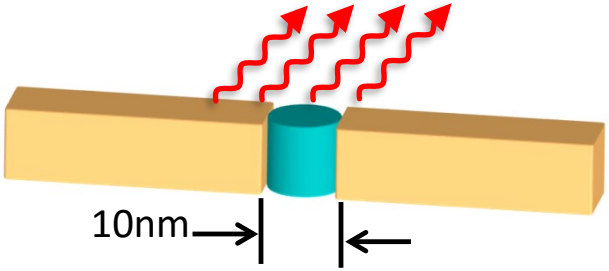

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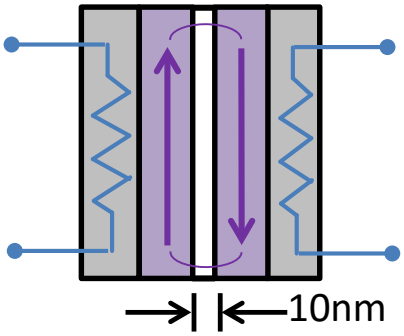

Nanomagnetics:
A Low Energy Magnetic Switch

E2 SWITCH
Energy Efficient Tunnel FET Switches and Circuits

LEAST
LOW ENERGY SYSTEMS TECHNOLOGY

E3S
Center for Energy Efficient Electronics Science

STEEP TRANSISTORS WORKSHOP 2016

ESSDERC/EPFL, Lausanne, Switzerland
September 11 - 12, 2016

Following the first successful workshop at University of Notre Dame, USA, a second workshop related to Steep Slope Transistors will be arranged in combination with the ESSDERC conference at EPFL, Lausanne, Switzerland. Steep transistors with subthreshold swings less than 60 mV/decade are attracting attention worldwide due to their promise to enable electronic systems operating at 300 mV and below. Interband tunneling or internal gain mechanisms in the gate enable the

Organizing committee:

Lars-Erik Wernersson	Lund University, Sweden (Chair)
Alan Seabaugh	University of Notre Dame, USA
Kirsten Moselund	IBM Zuerich, Switzerland
Aaron Thean	IMEC, Belgium
Eli Yablonovitch	University of California Berkeley, USA Adrian
Adrian Ionescu	EPFL, Switzerland

Center for Energy Efficient Electronics Science

The 2017 Symposium & Workshop will be held at Berkeley;
Oct. 19-20, 2017

Berkeley Symposium on Energy Efficient Electronics

Fifth Berkeley Symposium on Energy Efficient Electronic Systems and Steep Transistors Workshop

October 19-20, 2017
Sutardja Dai Hall, University of California, Berkeley, California, USA

Keynote Speaker:
Amir Khosrowshani, Intel Corporation, USA
Topic: Analog and digital accelerators for deep learning

Invited Speakers:
Jeffrey Bokor, University of California, Berkeley, USA
Topic: Ultra-high-speed magnetic switching

Gert Cauwenberghs, University of California, San Diego, USA
Topic: Energy efficiency of adaptive neural circuits

Jesus del Alamo, Massachusetts Institute of Technology, USA
Topic: I-V spectroscopy of the electronic energy levels in nanopillars

Paolo Gargini, ITRS, USA
Topic: Roadmap evolution: from NTRS to ITRS, from ITRS 2.0 to IRDS

Takahiro Hanyu, Tohoku University, Japan
Topic: Potential energy savings through the integration of logic and memory

Ru Huang, Peking University, China
Topic: Tunneling switches: characteristics and improving performance

Adrian Ionescu, Ecole Polytechnique Fédérale Lausanne, Switzerland
Topic: Sub-unity body factor: the next CMOS and beyond CMOS technology booster

Engin Ipek, University of Rochester, USA
Topic: Analog accelerators, as part of a digital systems

Masaharu Kobayashi, University of Tokyo, Japan
Topic: Negative Capacitance as a pathway toward lower voltage transistors

Zoran Krivokapic, GlobalFoundries, USA
Topic: Negative Capacitance Transistors

Subhasish Mitra, Stanford University, USA
Topic: Systems benefits and the technology of 3D integration

Oleg Mukhanov, Hypres, USA
Topic: Rapid single flux quantum technology

Hideo Ohno, Tohoku University, Japan
Topic: Use of magnetism in performing neuro-morphic computing functions

Lucian Prejbeanu, SPINTEC, CEA Grenoble, France
Topic: High-speed magnetic switching

Sayeef Salahuddin, University of California, Berkeley, USA
Topic: Metastable ferro-electric gate insulators for reducing the operating voltage of transistors

Alan Seabaugh, University of Notre Dame, USA
Topic: Optimizing TFET switching characteristics

Marin Soljacic, Massachusetts Institute of Technology, USA
Topic: Analog optical processing to assist deep learning

Shinichi Takagi, University of Tokyo, Japan
Topic: Improving the characteristics of tunnel switches

Anne Verhulst, IMEC, Leuven, Belgium
Topic: Conduction and valence band wavefunction mismatch in limiting tunneling currents

Lars-Erik Wernersson, Lund University, Sweden
Topic: Nanowire I-V spectroscopy to measure steepness of semiconductor bandedges

Masanao Yamaoka, Hitachi, Japan
Topic: Suitability of spin-Ising chips to solve combinatorial optimization problems

Education & Diversity Goals

- Professional Development
  (including Leadership Certificate for graduate students and postdocs)

- Community Colleges
  (Transfer to Excellence Program and Research Experience for Teachers)

- Broadening Participation
  (REU, HBCU-REU, workshops, outreach to schools and communities)

Transfer-to-Excellence Program

Created a National Model of Student Transfer Success

California transfer rate: 40%

Nationwide transfer rate: 67%

TTE transfer rate: 93% (64) of eligible students

- 88% (56) enrolled at a UC campus
  - 61% (39) enrolled at Berkeley
- 93% (78) from underrepresented groups

EEC 1157089
EEC 1461157

American Association of Community Colleges (AACC). (2012a, April)., Reclaiming the American Dream: A report from the 21st-Century Commission on the Future of Community Colleges., Washington, DC: Author. http://datamart.cccco.edu

We have educated students from 43 of the 114 California Community Colleges