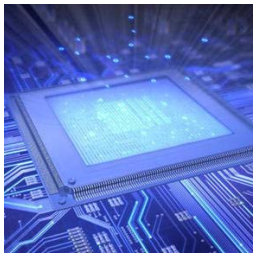
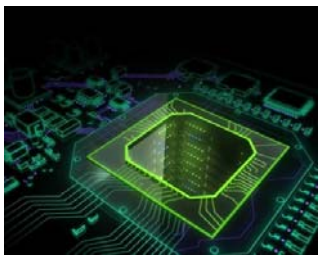
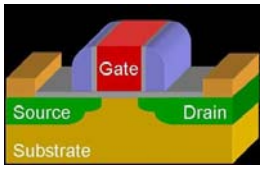
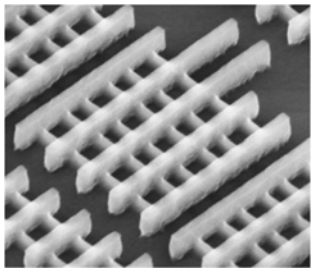
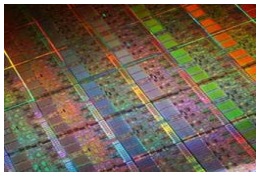
ECE 3150: Microelectronics

ECE 3150: Microelectronics

Instructor: Farhan Rana
Office: PH316
Email: fr37@cornell.edu

Syllabus:

This is a comprehensive undergraduate level course on microelectronics. Topics covered include

Basic semiconductor physics
Electrons and holes in semiconductors
Electrical transport in semiconductors
PN junctions and diodes
MOS capacitiors
MOS field effect transistors
Bipolar junction transistors
Large signal and small signal models of electronic devices
Single stage amplifiers, multistage amplifiers, differential amplifiers
Analog circuit analysis and design
High-frequency models of devices and high-frequency circuit analysis
Digital logic and MOS logic devices,
Complimentary MOS (or CMOS) logic gates
Fundamental trade-offs in high speed analog and digital circuit design

Course Website and Homeworks

• All course documents, including:

- Lecture notes
- Homeworks and solutions
- Exam solutions
- Extra course related material
- Labs

will appear on the course website:

https://courses.cit.cornell.edu/ece315/

Homeworks

• Homeworks will be due on Thursdays at 7:00 PM in course drop box in Phillips Hall

• New homeworks and old homework solutions will appear on the course website by Thursday night

• Homework 1 will be due next Thursday and will be available on the course website by tomorrow night

Course Grading and Textbooks

• Course grading will be done as follows:

- Homeworks and Labs (30%)
- Midterm (30%)
- Final Exam (35%)
- Instructor discretion (5%)

• No in-class quizzes, no pop-quizzes, no clickers,

• Midterm and the Final exam will both be comprehensive

Textbooks

• There are no required textbooks. Highly recommended textbooks are:

- Microelectronics: An Integrated Approach
  by Howe and Sodini (out of Print)
- Microelectronic Devices and Circuits
  by Clifton Fonstad (out of print)

Course Recitation Sections

There will be recitation sections on MW 7:30-9:00 PM in PH219 almost every week

Goals: Homeworks, discussion, problem solving, etc

Course Labs

There will be labs on MTWRF 2:30-4:30 PM in PH237

There will be 4-5 labs total in the semester

Make sure you are signed up for one lab slot

Lab reports/writeups will be due the week following the lab

Goals: Characterize devices, build and test circuits

Labs are mandatory!

Course Staff

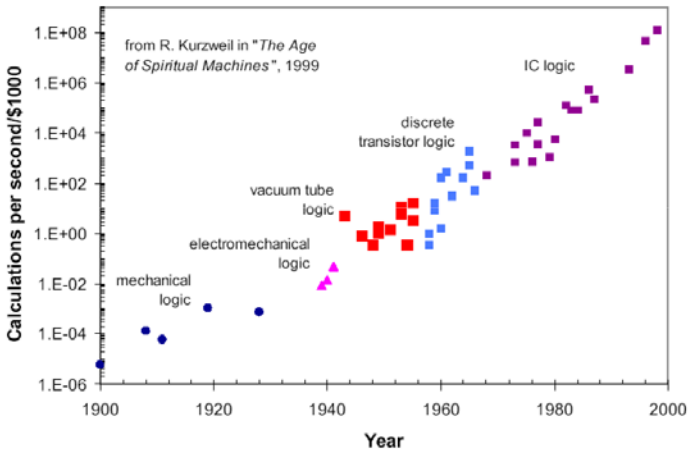
PhD TA: Okan Koksal
ok74@cornell.edu

PhD TA: Ali Mostajeran
am2457@cornell.edu

MEng TA: Nagaraj Gunipati Murali
ng435@cornell.edu

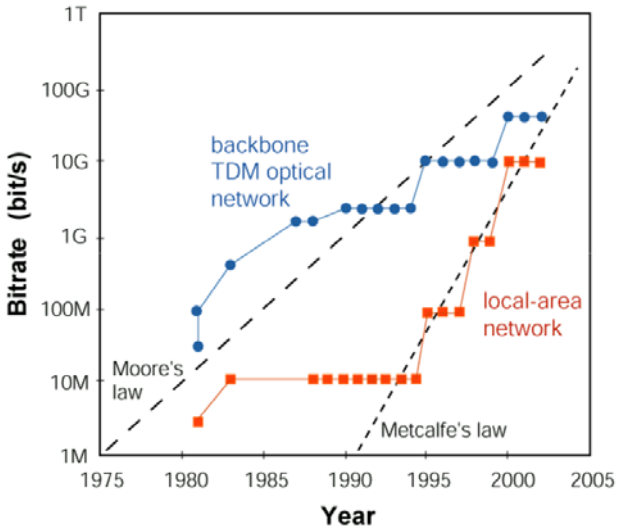
TA office hours and locations: PH 429
(Times/days: Tuesdays/Thursdays 4:30-6:00 PM)

The Computing Revolution



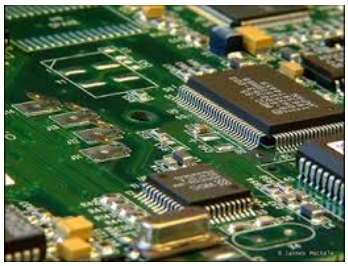
The computing ability per dollar has improved by ~5 orders of magnitude in the last 30 years

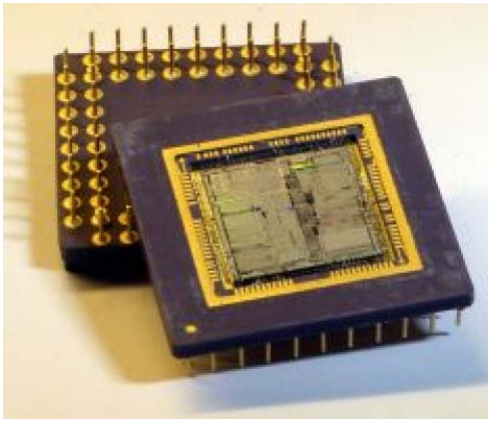
The Communication Revolution

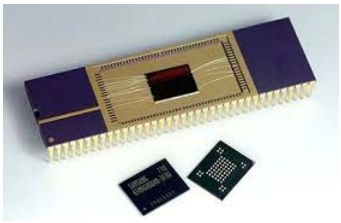


The communication rate has improved by ~4 orders of magnitude in the last 30 years

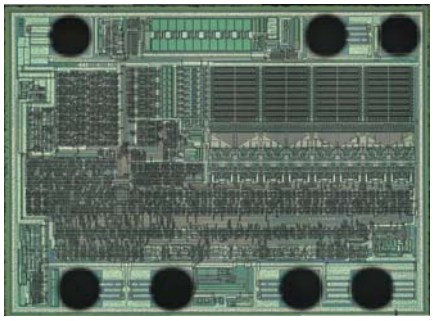
The Key Technology Driver: The Silicon Integrated Chip



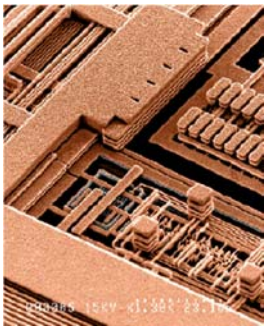




The Key Technology Driver: The Silicon Integrated Chip



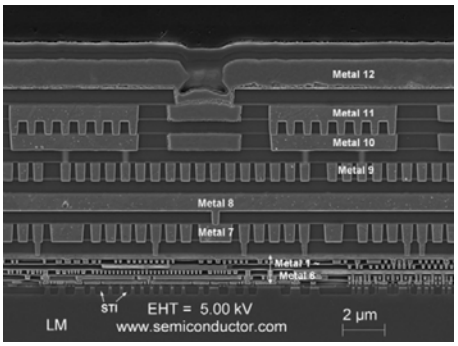
A Memory chip from Nintendo Wii



(SEM) Copper interconnects in an IBM chip

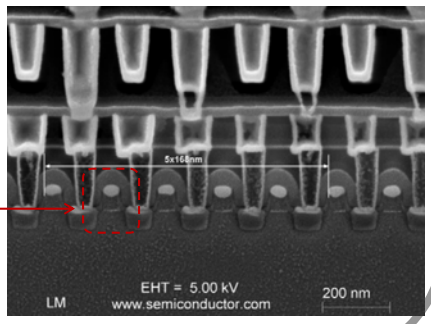
Metal interconnects

The Key Technology Driver: The Silicon Integrated Chip

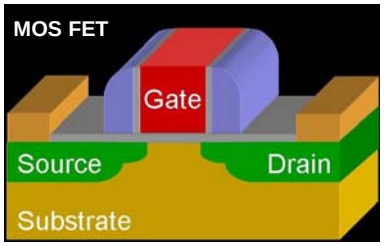


More than ~10 layers of metal interconnects in a 40 nm technology

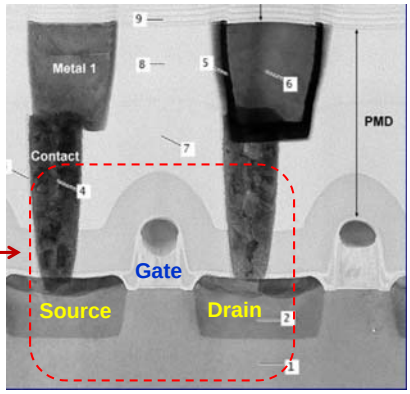
Silicon FET

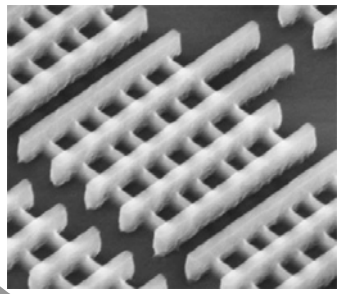


The Key Technology Driver: The Silicon Transistor



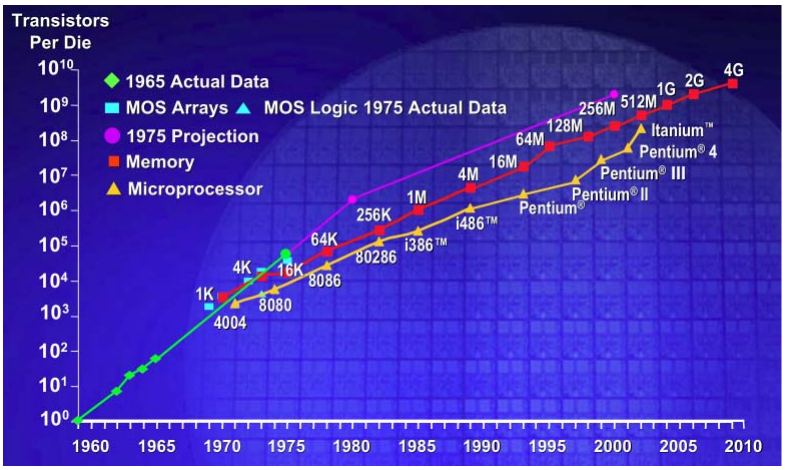
Silicon FET





22 nm gate Tri-gate Silicon transistors (INTEL)

Technology Scaling: Moore's Law



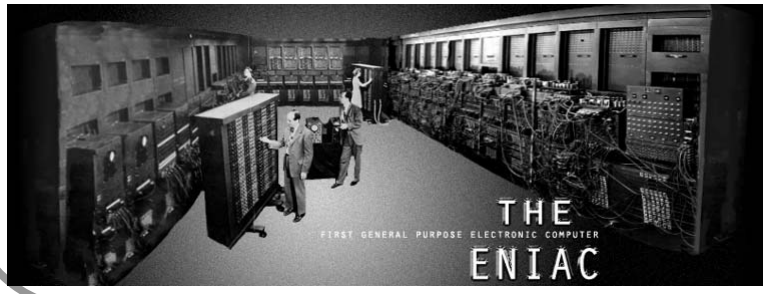
The number of transistors in a dense integrated circuit doubles approximately every two years (Gordon E. Moore – 1965)

Benefits of Integration

Exponential improvements in:

1) **System performance (speed)**
2) **Cost per function**
3) **Power per function**
4) **System reliability**

(2013)

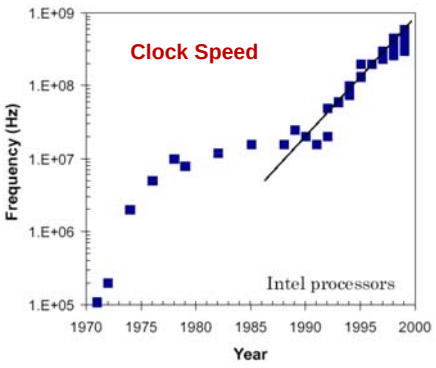


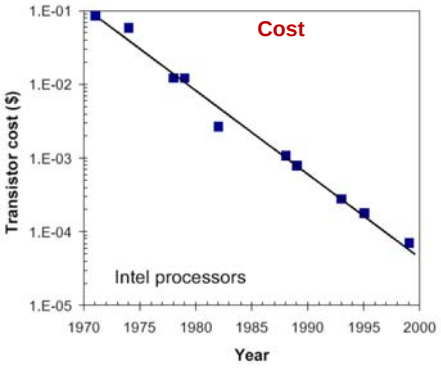
30 tons

150 kW of power

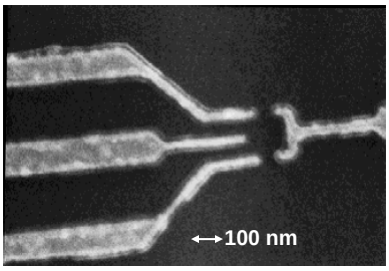
(1946)

Benefits of Integration

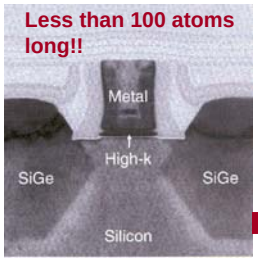




Nano-Electronics

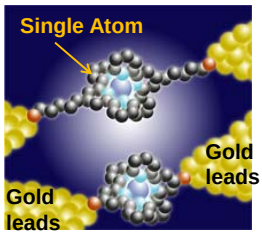


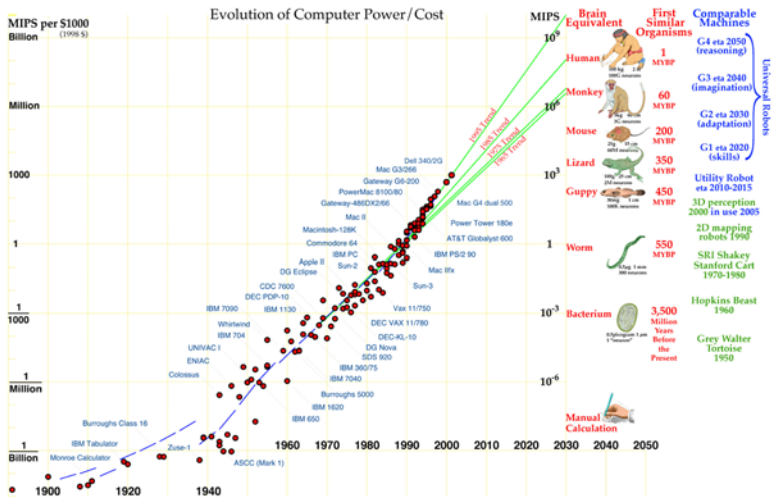
A single electron transistor (works on the principle of strong electrostatic repulsion between electrons in nanostructures)



A 45 nm gate MOS transistor (electrostatics become more important as device dimensions shrink)

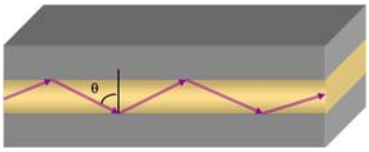
A single atom transistor (Cornell)

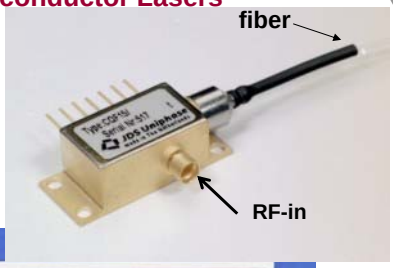


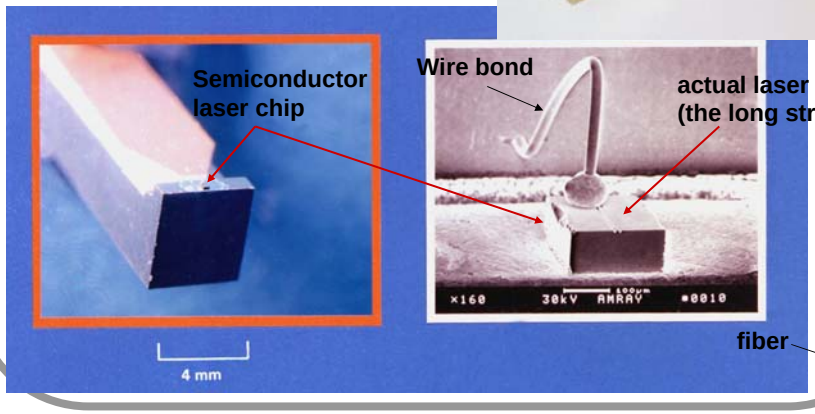


Nano-Photonics and Semiconductor Lasers

Light can be guided in integrated waveguides

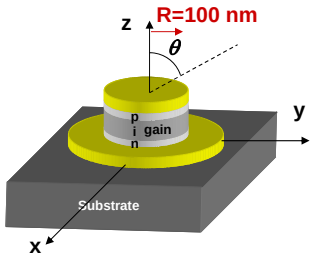




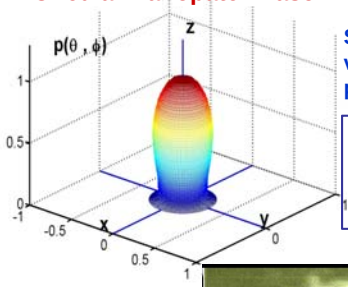


Nano-Photonics and Semiconductor Lasers

Nanopatch Plasmonic Lasers



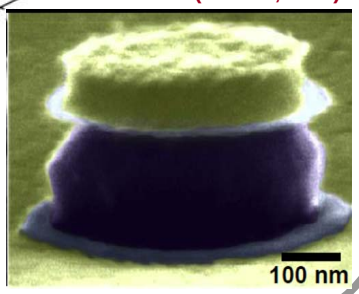
Circular Nanopatch Laser: Radiation Pattern



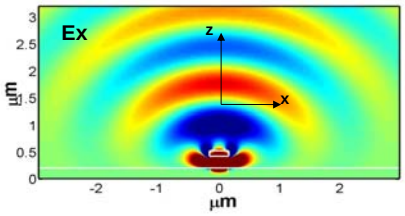
SNLs are optical versions of microwave patch antennas

Lasers on chip are becoming much smaller than the size of a photon!!

(Cornell, UCB)



Surface-normal emission



Future of Integration: Electronics, Photonics, MEMs, Biology

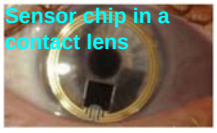
Portable health monitoring (Terahertz, mm-wave, optics, sonic)

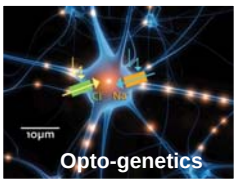
MEMs
Microsystems
Photonics
Electronics

Bio-Electrical
Bio-Photonics

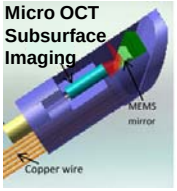
- Biomedical Instrumentation and interfacing
- Neural Interfacing
- Imaging, modeling

Sensor chip in a contact lens

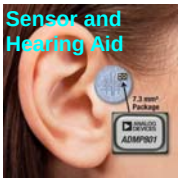




Micro OCT Subsurface Imaging

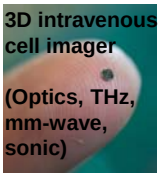


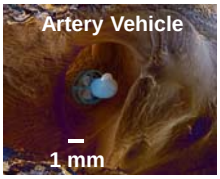
Sensor and Hearing Aid



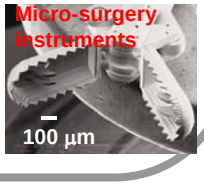
3D intravenous cell imager

(Optics, THz, mm-wave, sonic)

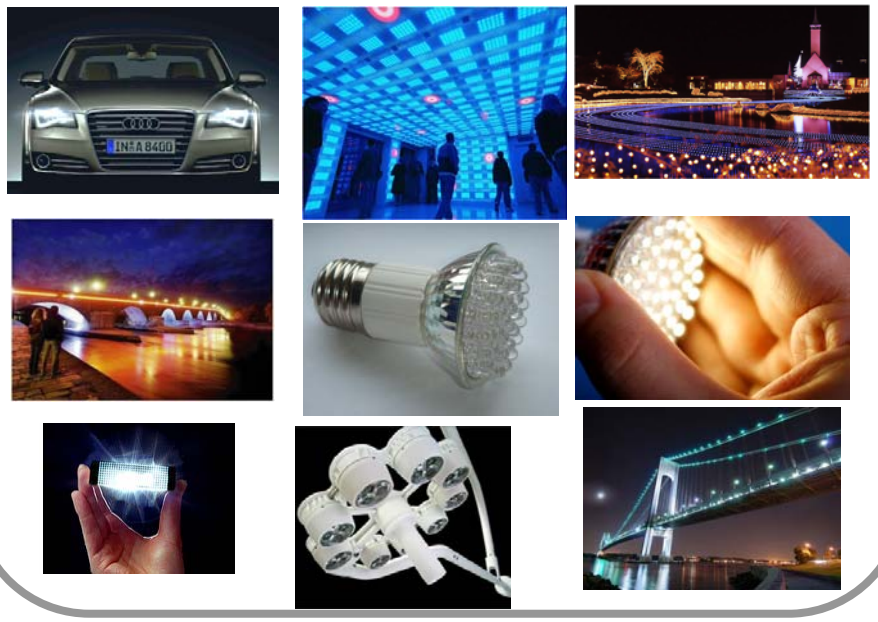




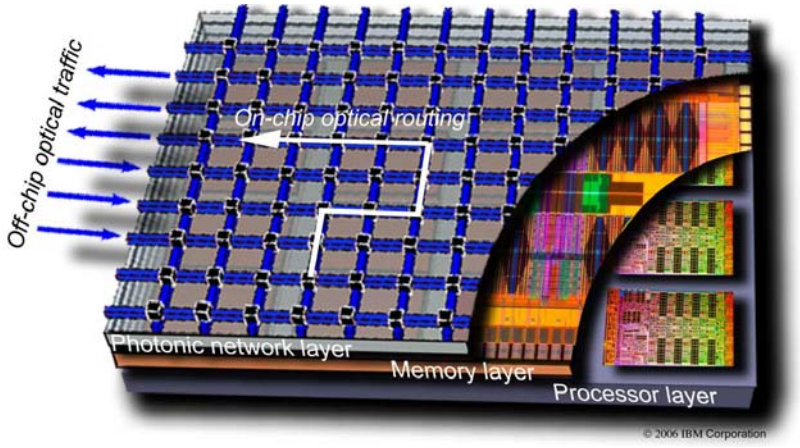
Micro-surgery instruments



Semiconductors Taking Over: Solid State Lighting



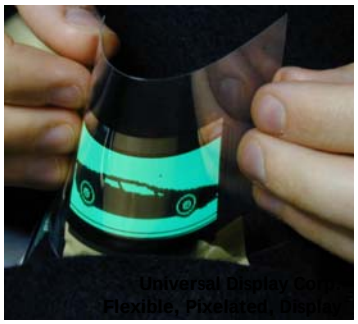
Future of Integration: Electronics, Photonics, MEMs, Biology



IBM (Electronic/Opto-electronic Processors)

Flexible Displays

Iphone (today)



Flexible Internet Display Screen

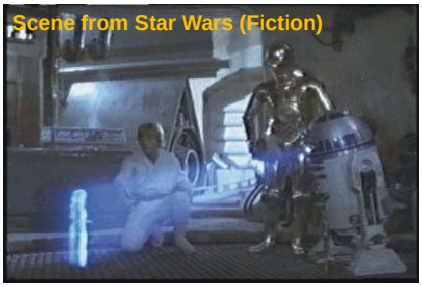
Wireless (Micro Antennae)

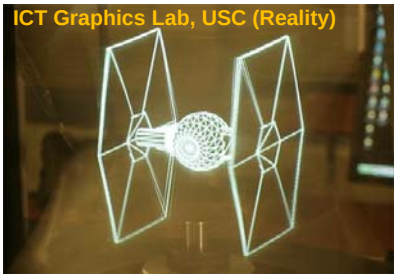
Display (LEDs, Optoelectronics)

Transparency and Flexibility

Electronics (Graphene)

Or No Displays!





Wireless (Antenna)

Display (LEDs, Optoelectronics)

Electronics

Lasers (Hologram)