EE 232 Lightwave Devices
Lecture 1: Overview and Introduction

Instructor: Ming C. Wu

University of California, Berkeley
Electrical Engineering and Computer Sciences Dept.

Course Information (1)

- **Website:** www-inst.eecs.berkeley.edu/~ee232/sp17/
  - All lecture notes, homeworks will be posted there
  - HW and exam scores will be posted in bCourses
  - Discussion in Piazza
- **Instructor:**
  - Prof. Ming Wu (511 SDH, wu@eecs)
  - GSI: Kevin Han (kyh@eecs)
- **Lectures:** TuTh 11:00A-12:29P | 293 Cory
- **Discussion:** Th 12:30P-1:29P | 293 Cory
- **OH: tbd**
- **Textbook (on reserve in Eng Lib)**
  - S.L. Chuang, *Physics of Photonic Devices*, 2nd Edition, John Wiley and Sons, 2009

Course Information (2)

- **Reference Books** (on reserve at Engineering Library)
  - Yariv & Yeh, *Photonics: Optical Electronics in Modern Communications*, Oxford University Press, 2006
  - L A Coldren; S W Corzine; Milan Mashanovitch, *Diode Lasers and Photonic Integrated Circuits*, John Wiley & Sons, 2012
  - Saleh & Teich, Fundamentals of Photonics, 2nd Ed. Wiley, 2007
  - [Reference for discussion session] Lukas Chrostowski and Michael Hochberg. *Silicon Photonics Design: From Devices to Systems*. Cambridge University Press, 2015.
- **PREREQUISSITES**
  - **EECS 130:** Simple p-n junction, semiconductor physics, concept of energy bands, Fermi levels.
  - **PHYS 137A:** recommended. Basic concept of quantum mechanics, perturbation theory
  - **EECS 117:** recommended. Concept of dielectric waveguide, electromagnetic waves.

Course Information (3)

- **EXAM & GRADES**

– **Homework**	**10%**
– **2 Midterms**	**20% + 20%**
– **Final Exam**	**30%**
– **Projects**	**20%**

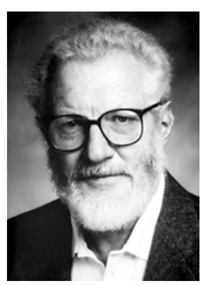
- **Final Exam**
  - **TBA (may move to the week before RRR, pending on everybody's availability)**
- **HW/Project policy**
  - **Discussion is permitted (and encouraged), but you must do your own HW, including literature search, derivation, or calculation.**
  - **The subject of your project should not be exactly the same as other students**

Course Information (4)

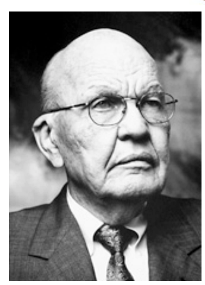
- **Discussion Session**
  - GSI, Kevin Han, will go over introduction to Lumerical simulation tool, and discuss various design examples
  - Attendance is mandatory since the materials do not overlap with lecture materials
  - **Bring your laptop** (Lumerical will be installed on your laptop)
- **Project**
  - Project will include design and simulation of new optoelectronic devices or circuits. The passive optical components need to be simulated using Lumerical.
  - Some examples will be given in discussion session.

The Nobel Prize in Physics 2000

Zhores I. Alferov,



Herbert Kroemer,



Jack S. Kilby

The Nobel Prize in Physics 2000 was awarded *"for basic work on information and communication technology"* with one half jointly to Zhores I. Alferov and Herbert Kroemer *"for developing semiconductor heterostructures used in high-speed- and opto-electronics"* and the other half to Jack S. Kilby *"for his part in the invention of the integrated circuit"*.

The Nobel Prize in Physics 2014


Isamu Akasaki


Hiroshi Amano


Shuji Nakamura

The Nobel Prize in Physics 2014 was awarded jointly to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura *"for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources"*.

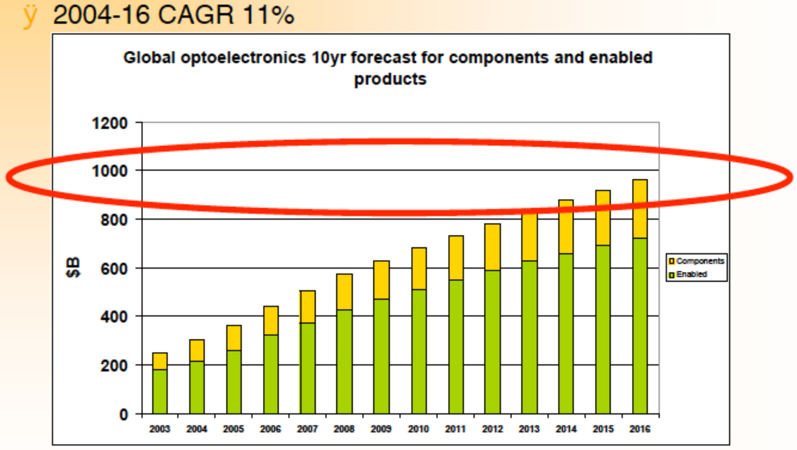
Common Optoelectronic Components

Optoelectronics Market Segment

- **Flat panel displays**
  - PC, Tablet, TV, mobile devices, head-mount displays
- **High brightness LEDs**
  - Solid state lighting, large display panels, automotive applications, LCD backlighting
- **Imaging array sensors**
  - Digital cameras
- **Diode lasers**
  - Data communications and telecommunications
  - Computer mice
  - High power laser pumping source
- **Renewable energy**
  - Solar cells

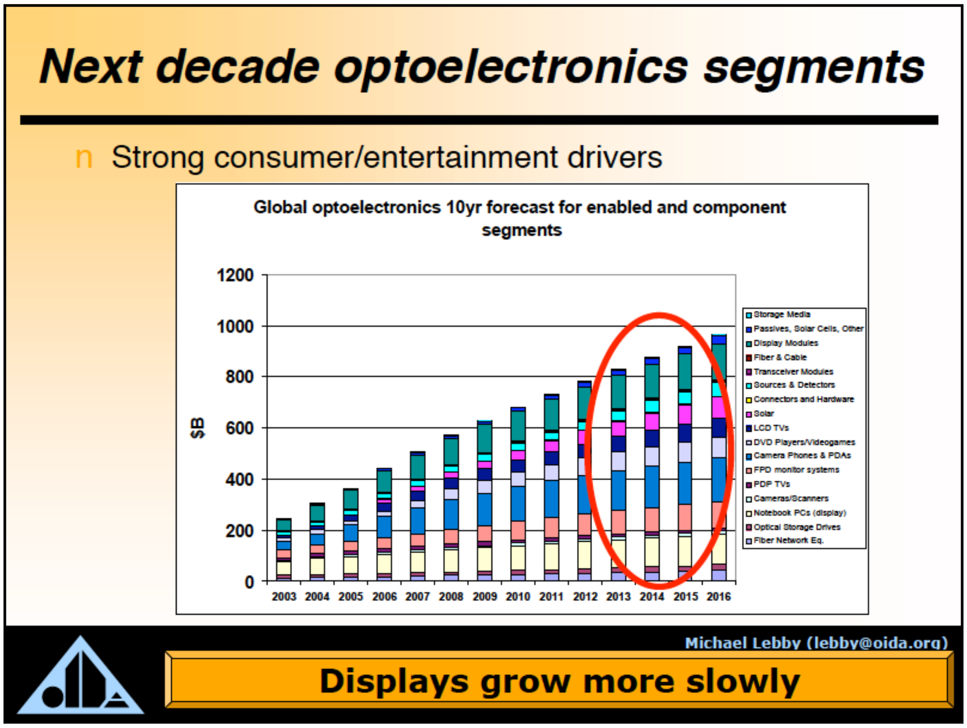
Next decade in optoelectronics

- Combined OE components and enabled products
  - 2004-16 CAGR 11%

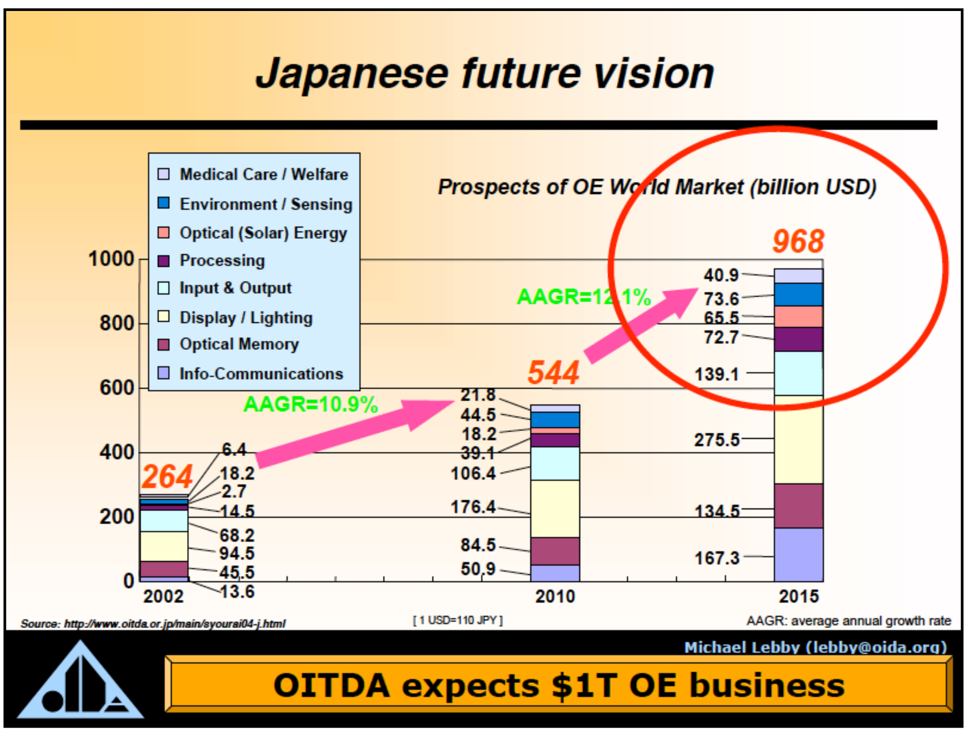


Michael Lebby (lebby@oida.org)

Is this a $T industry?

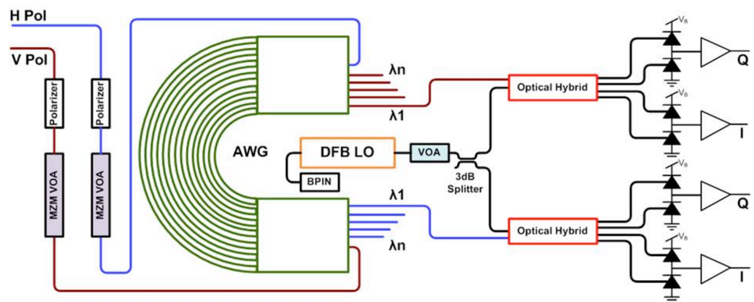


Next decade optoelectronics segments
Strong consumer/entertainment drivers
Global optoelectronics 10yr forecast for enabled and component segments
$B
1200
1000
800
600
400
200
0
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Storage Media
Passives, Solar Cells, Other
Display Modules
Fiber & Cable
Transceiver Modules
Sources & Detectors
Connectors and Hardware
Solar
LCD TVs
DVD Players/Videogames
Camera Phones & PDAs
FPD monitor systems
PDP TVs
Cameras/Scanners
Notebook PCs (display)
Optical Storage Drives
Fiber Network Eq.
Michael Lebby (lebby@oida.org)
Displays grow more slowly



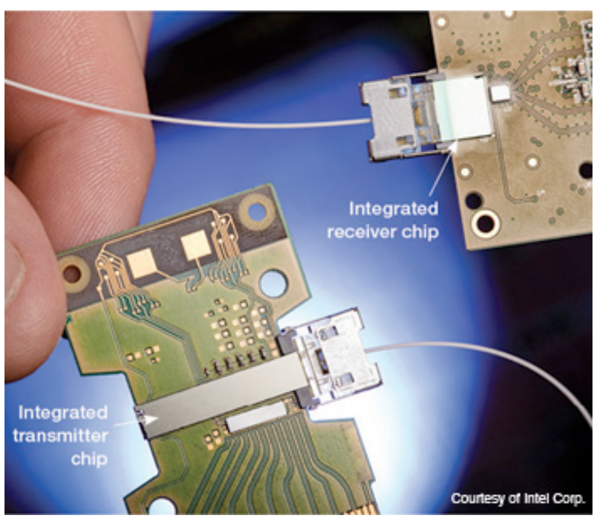
Japanese future vision
Medical Care / Welfare
Environment / Sensing
Optical (Solar) Energy
Processing
Input & Output
Display / Lighting
Optical Memory
Info-Communications
Prospects of OE World Market (billion USD)
1000
800
600
400
200
0
264
6.4
18.2
2.7
14.5
68.2
94.5
45.5
13.6
AAGR=10.9%
544
21.8
44.5
18.2
39.1
106.4
176.4
84.5
50,9
AAGR=12.1%
968
40.9
73.6
65.5
72.7
139.1
275.5
134.5
167.3
2002
2010
2015
Source: http://www.oitda.or.jp/main/syourai04-j.html
[1 USD=110 JPY]
AAGR: average annual growth rate
Michael Lebby (lebby@oida.org)
OITDA expects $1T OE business

Photonic Integrated Circuits (PIC) for Telecommunication Networks



Infinera

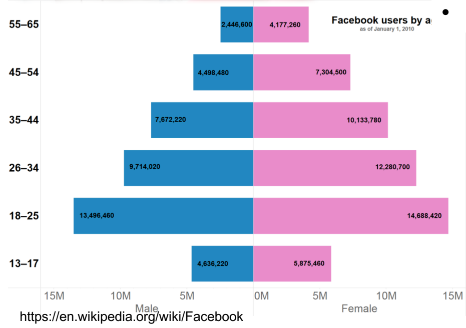
Silicon Photonic Links



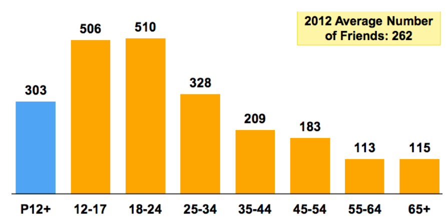
Who's Driving the Growth of Photonic Devices?

Facebook example

- 1.45 billion monthly users @ 12.8% Y/Y
- 1.25 b mobile users
- 10b photo uploaded every month
- 2b photos shared daily across Facebook instagram , whatsApp
- 3b video views daily on facebook



https://en.wikipedia.org/wiki/Facebook



http://heidicohen.com/2013-social-media-trends-and-your-business/

Young people are driving the growth of internet → datacenters → photonics

Internet and Data Centers

Every 60 Seconds

204 MILLION Emails

5 MILLION Google Searches

1.8 MILLION "Likes"

Global Data Center IP Traffic Growth

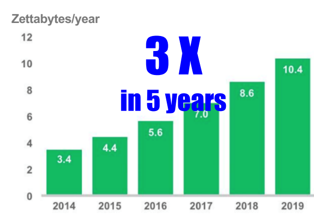
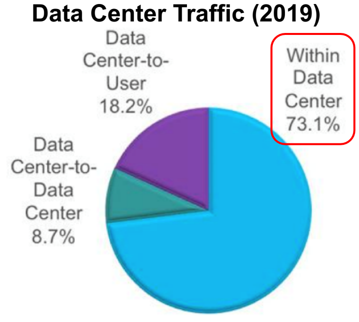


Image of Google Data Center

http://www.google.com/about/datacenters/gallery

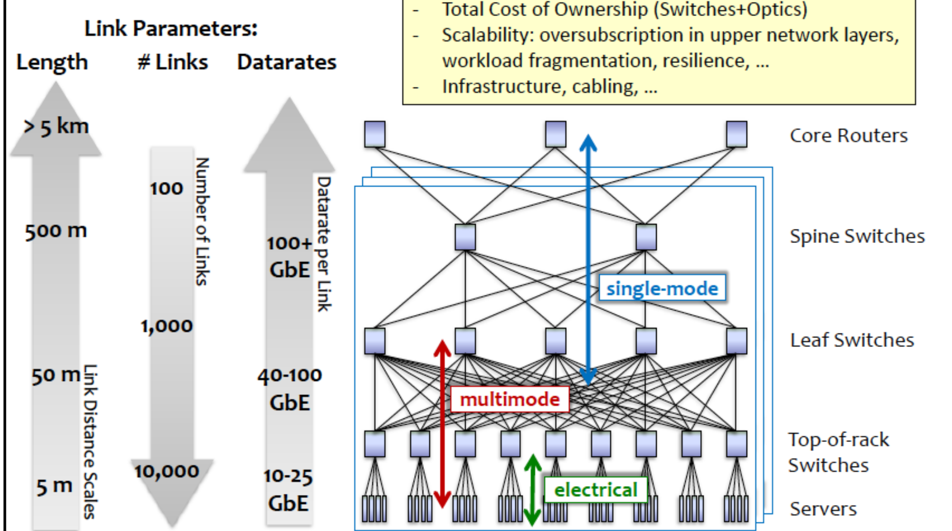
Data Center Traffic (2019)



Generic Intra-Datacenter Network Model

VG by Laurent Schares (IBM)

Intra-DC Network Pain Points (Physical Layer):
- Total Cost of Ownership (Switches+Optics)
- Scalability: oversubscription in upper network layers, workload fragmentation, resilience, ...
- Infrastructure, cabling, ...

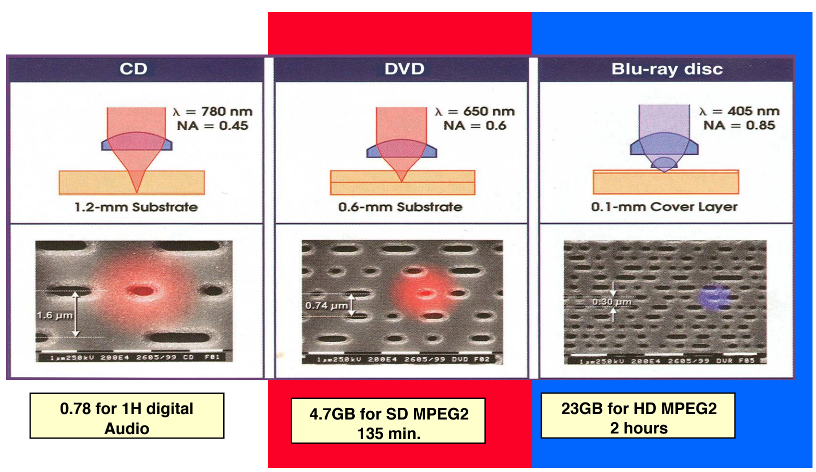


Generalized picture based on public information from a variety of datacenter operators

Data Centers come in all sizes. Just a few racks ... to largest ones in the world: ~ 1 million square feet, ~ 100,000 servers.

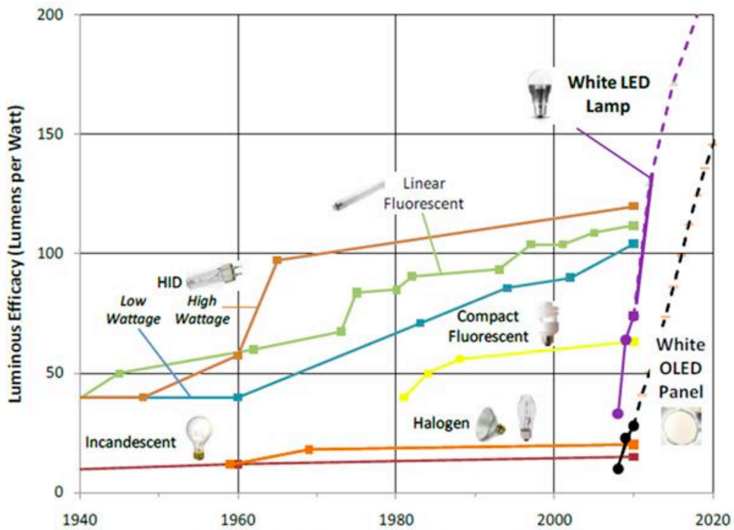
5

InGaN (405nm) for Optical Storage

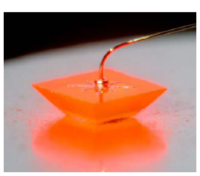


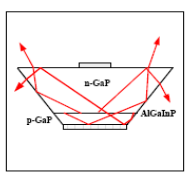
Source: Photonics Spectra, Jan. 2004. LaserFocusWorld Marketplace Seminar

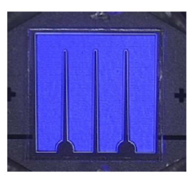
Evolution of LED Materials/Performances

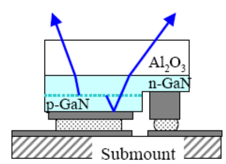


HB-LED Technology



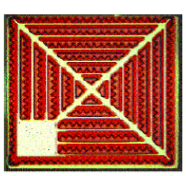


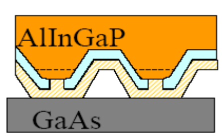


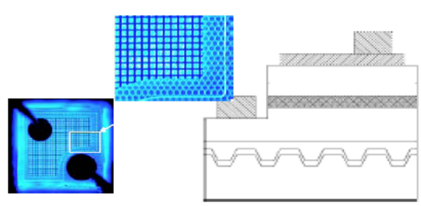


AlInGaN flip-chip (Lumiled)

AlGaInP/GaP truncated inverted pyramid (Lumiled)





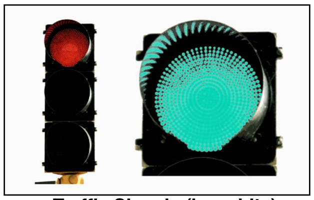


AlInGaP micro mirror (Osram),

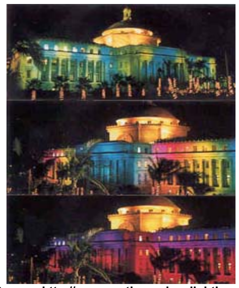
AlInGaN patterned substrate and mesh electrode (Nichia)

Source: LumiLeds

Applications of HBLEDs



Traffic Signals (inc white)



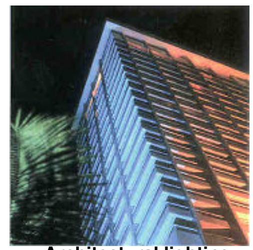
Source: http://www.northamericanlighting.com

Source: Toshiba (Technorainbow)

Outdoor lighting scenarios

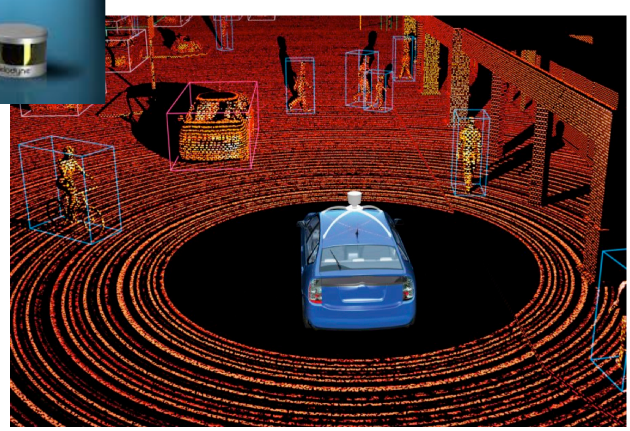
Source: Wustlich Design AG

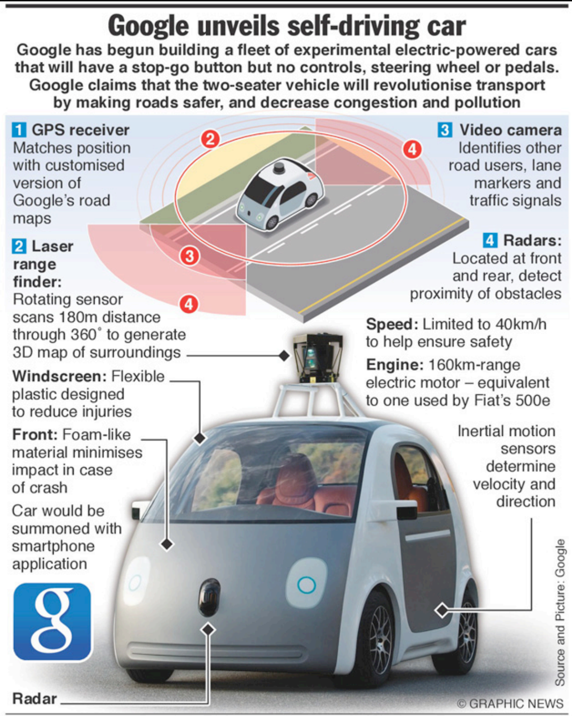
Furniture Lighting



Architectural lighting

3D Imaging: Velodyne LIDAR




Google unveils self-driving car
Google has begun building a fleet of experimental electric-powered cars that will have a stop-go button but no controls, steering wheel or pedals. Google claims that the two-seater vehicle will revolutionise transport by making roads safer, and decrease congestion and pollution
1 GPS receiver Matches position with customised version of Google's road maps
2 Laser range finder: Rotating sensor scans 180m distance through 360° to generate 3D map of surroundings
3 Video camera Identifies other road users, lane markers and traffic signals
4 Radars: Located at front and rear, detect proximity of obstacles
Speed: Limited to 40km/h to help ensure safety
Engine: 160km-range electric motor – equivalent to one used by Fiat's 500e
Windscreen: Flexible plastic designed to reduce injuries
Front: Foam-like material minimises impact in case of crash
Inertial motion sensors determine velocity and direction
Car would be summoned with smartphone application
Radar
Source and Picture: Google
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