Electromagnetics:

Introduction

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Course book: Field and Wave Electromagnetics

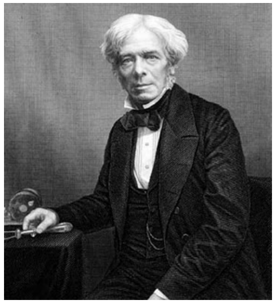
(D. K. Cheng, 2nd ed., Addison-Wesley, 1989)

- What you have learnt (I presume):
  - *Chap. 1. The Electromagnetic Model*
  - *Chap. 2. Vector Analysis*
  - *Chap. 3. Static Electric Fields*
  - *Chap. 4. Solution of Electrostatic Problems*
  - *Chap. 5. Steady Electric Currents*
  - *Chap. 6. Static Magnetic Fields*

This is all you need to learn!

- *What you will be learning:*
  - *Chap. 7. Time-Varying Fields and Maxwell's Equations*
  - *Chap. 8. Plane Electromagnetic Waves*
  - *Chap. 10. Waveguides and Cavity Resonators (incl. Optical Fibers)*
  - *Chap. 9. Theory and Applications of Transmission Lines*
  - *Chap. 11. Antennas and Radiating Systems*

Maxwell's Equations



Michael Faraday
(1791–1867)

Andre Marie Ampere
(1775 - 1835)

Carl Friedrich Gauss
(1777 - 1855)

$$\nabla\times\mathbf{E}+\frac{\partial\mathbf{B}}{\partial t}=0$$

Faraday's law

"Displacement current"

$$\nabla\times\mathbf{H}-\boxed{\frac{\partial\mathbf{D}}{\partial t}}=\mathbf{J}$$

Ampère's law

$$\nabla\cdot\mathbf{D}=\rho$$

Gauss's law

$$\nabla\cdot\mathbf{B}=0$$

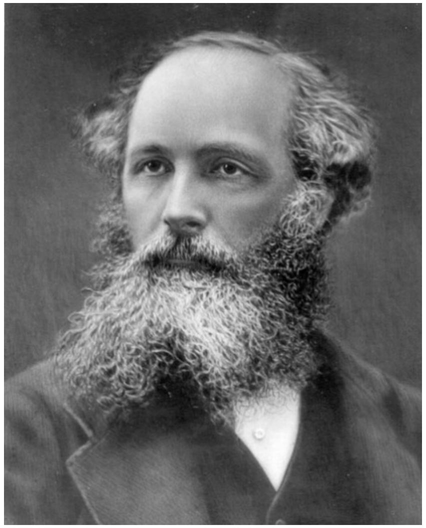
No free magnetic monopole (?)

$$\mathbf{D}=\varepsilon\mathbf{E}=\varepsilon_0\mathbf{E}+\mathbf{P}$$

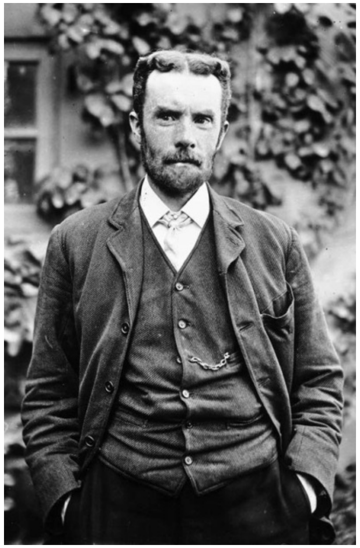
$$\mathbf{H}=\frac{1}{\mu}\mathbf{B}=\frac{1}{\mu_0}\mathbf{B}-\mathbf{M}$$

Constitutive relations

Findings of 19^{th} century!!



James Clerk Maxwell
(1831–1879)



Oliver Heaviside
(1850–1925)

Electromagnetic Waves

Wave equations:

$$\nabla^2 \mathbf{E} - \mu\varepsilon \frac{\partial^2 \mathbf{E}}{\partial t^2} = 0, \quad \nabla^2 \mathbf{H} - \mu\varepsilon \frac{\partial^2 \mathbf{H}}{\partial t^2} = 0$$ *(Homogeneous and no source)*

Plane wave:

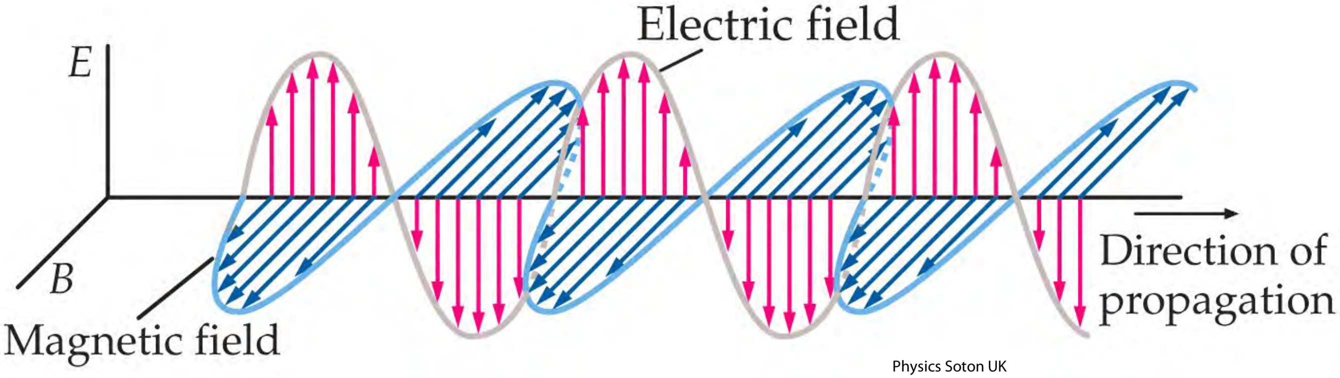
$$e.g. \ f(x,t) = f(x-\delta x, t-\delta t)$$

$$\psi = e^{i(\omega t - \mathbf{k}\cdot\mathbf{r})}, \quad |\mathbf{k}| = \omega\sqrt{\mu\varepsilon}$$

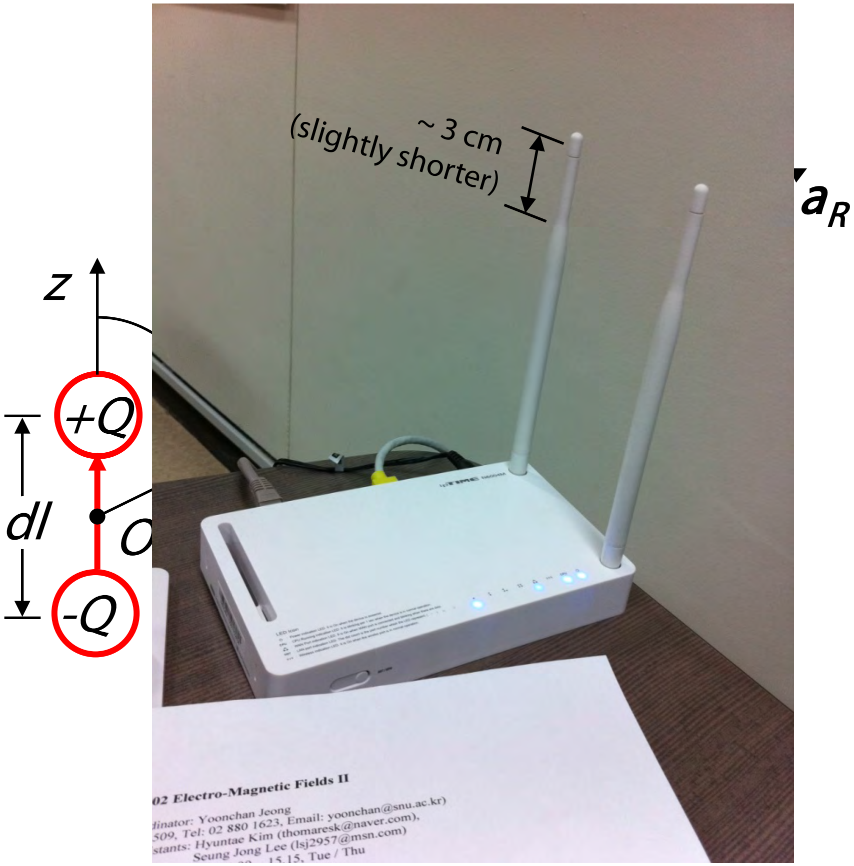
Phase velocity:

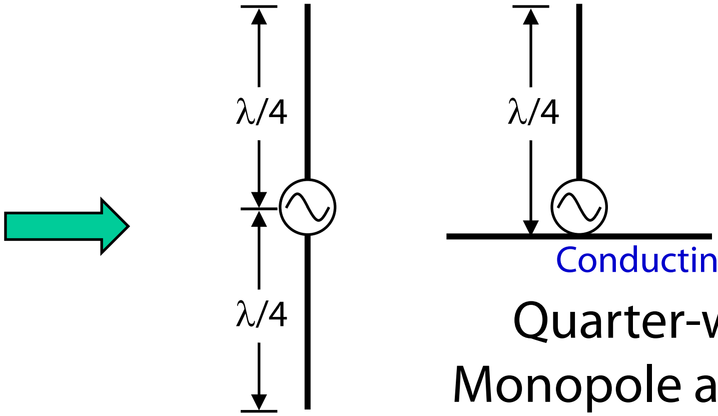
$$\omega t - \mathbf{k}\cdot\mathbf{r} = \text{constant}, \quad \mathrm{u_p} = \frac{\omega}{k} = \frac{1}{\sqrt{\mu\varepsilon}},$$

$$c = \frac{1}{\sqrt{\mu_o \varepsilon_o}} = 2.997930 \ \times 10^8 \, m/s$$



Time-Varying (Oscillating) Fields: Electromagnetic Waves (RF/MW)





Quarter-wave
Monopole antenna

Half-wave
dipole antenna

$$c = f\lambda$$

Speed of EM wave

Frequency

Wavelength

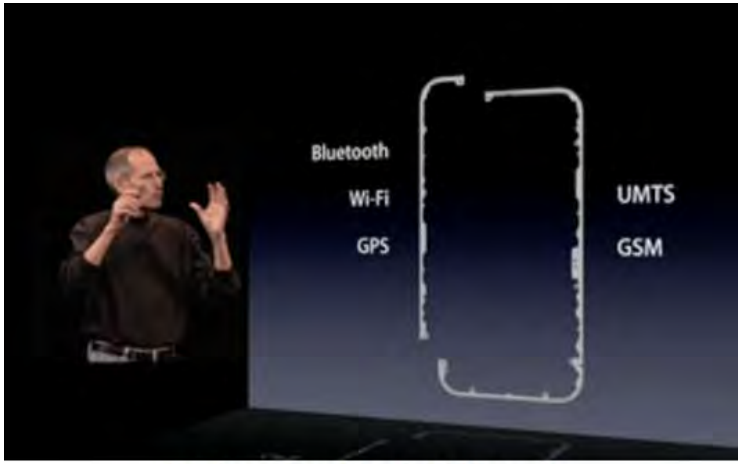
WiFi router (f = 2.4 GHz)

$$\boxed{\lambda/4 = 3\times10^8 / 2.4\times10^9 / 4 \approx 0.031 \text{ m}}$$

How about mobile-phones?

For example:

iPhone 4



The 2 antenna in the iPhone 4

Source: http://techpp.com/2010/07/19/all-about-the-iphone-4-and-antenna-engineering/

Stainless Steel Band

Created from our own alloy, then forged to be five times stronger than standard steel, the CNC-machined band is the mounting point for all the components of iPhone 4. The band provides impressive structural rigidity and allows for its incredibly thin, refined design. It also functions as both iPhone 4 antennas.

Source: www.apple.com

Death Grip & Antennagate?

Loss of signal if lower-left side is covered?

http://www.knowyourmobile.in/news/542339/apple_addresses_iphone_4_antenna_problems.html

Source: http://latimesblogs.latimes.com/technology/2010/08/apple-iphone-ipod-mark-papermaster.html

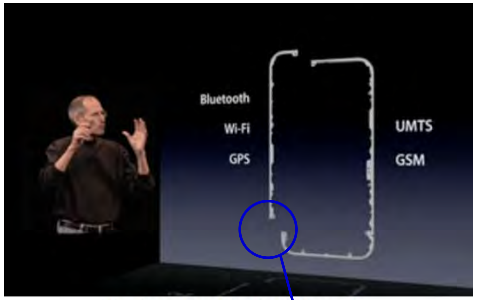
http://gizmodo.com/#!5770481/consumer-reports-confirms-verizon-iphone-4-death-grip-problems

Could we explain why this happens?

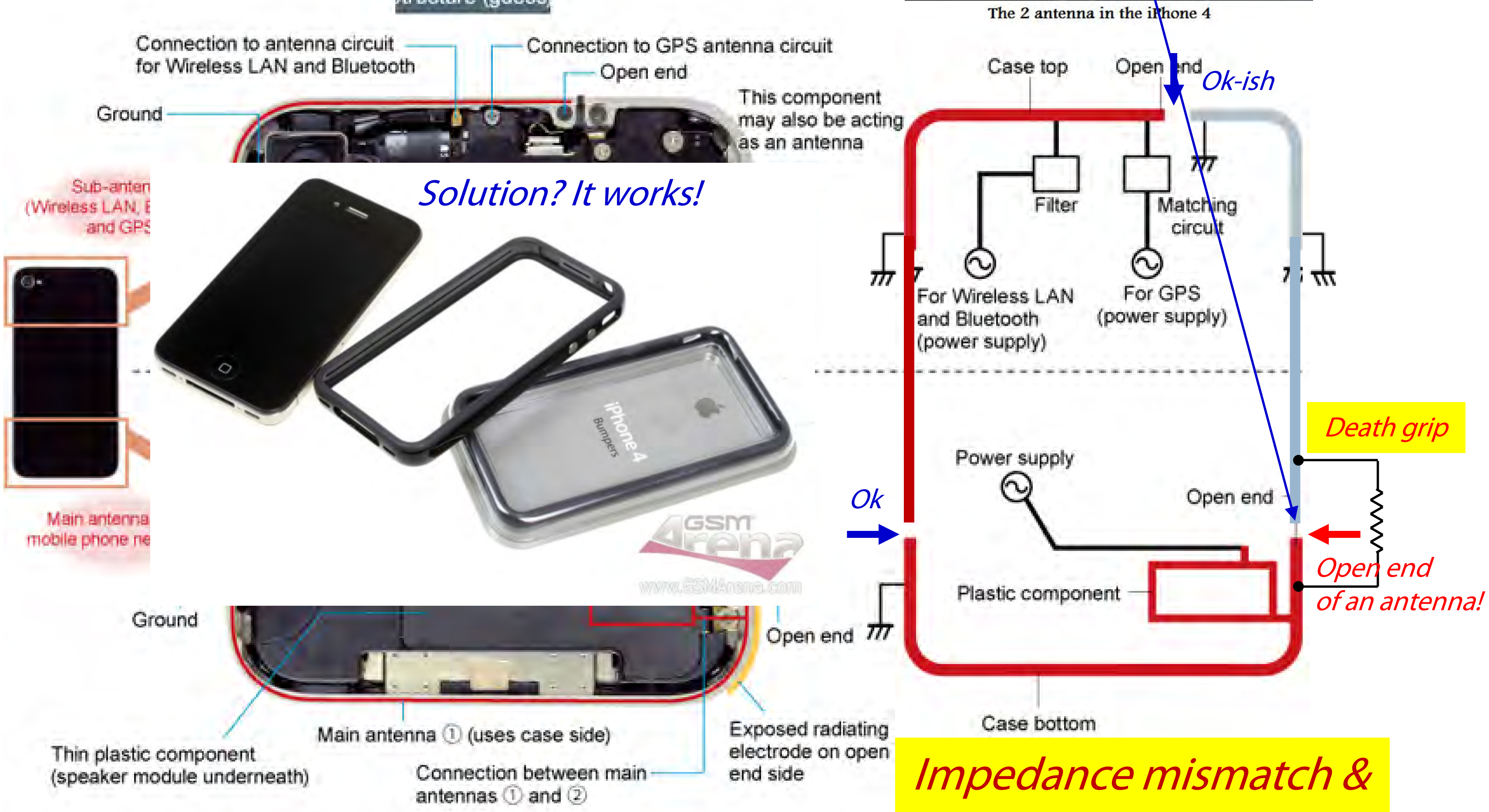
Source: http://techpp.com/2010/07/19/all-about-the-iphone-4-and-antenna-engineering/

Some Teardown Analysis

By Nikkei Electronics:



The 2 antenna in the iPhone 4



Solution? It works!

Ok-ish

Ok

Death grip

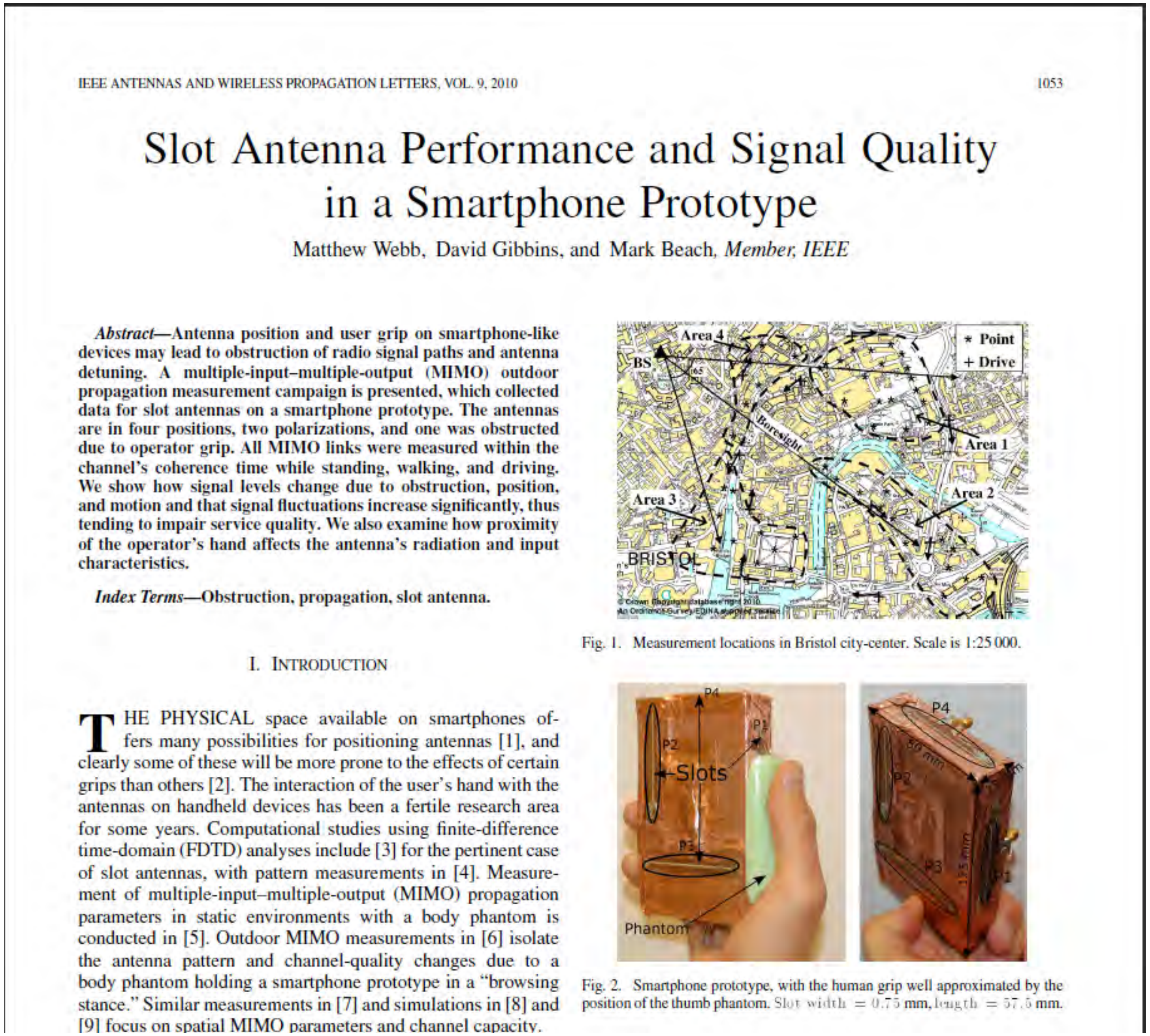
Open end of an antenna!

Impedance mismatch & Absorption!!

Source: http://techon.nikkeibp.co.jp/article/HONSHI/20100924/185836/?SS=imgview&FD=-751788434

Source: http://blog.gsmarena.com/apple-iphone-4-free-bumper-case-program-will-soon-end-but-you-can-still-get-a-free-bumper-after-that/

More Scientific/Engineering Approaches



Slot Antenna Performance and Signal Quality in a Smartphone Prototype

Matthew Webb, David Gibbins, and Mark Beach, *Member, IEEE*

***Abstract*—Antenna position and user grip on smartphone-like devices may lead to obstruction of radio signal paths and antenna detuning. A multiple-input–multiple-output (MIMO) outdoor propagation measurement campaign is presented, which collected data for slot antennas on a smartphone prototype. The antennas are in four positions, two polarizations, and one was obstructed due to operator grip. All MIMO links were measured within the channel's coherence time while standing, walking, and driving. We show how signal levels change due to obstruction, position, and motion and that signal fluctuations increase significantly, thus tending to impair service quality. We also examine how proximity of the operator's hand affects the antenna's radiation and input characteristics.**

***Index Terms*—Obstruction, propagation, slot antenna.**

I. INTRODUCTION

THE PHYSICAL space available on smartphones offers many possibilities for positioning antennas [1], and clearly some of these will be more prone to the effects of certain grips than others [2]. The interaction of the user's hand with the antennas on handheld devices has been a fertile research area for some years. Computational studies using finite-difference time-domain (FDTD) analyses include [3] for the pertinent case of slot antennas, with pattern measurements in [4]. Measurement of multiple-input–multiple-output (MIMO) propagation parameters in static environments with a body phantom is conducted in [5]. Outdoor MIMO measurements in [6] isolate the antenna pattern and channel-quality changes due to a body phantom holding a smartphone prototype in a "browsing stance." Similar measurements in [7] and simulations in [8] and [9] focus on spatial MIMO parameters and channel capacity.

Fig. 1. Measurement locations in Bristol city-center. Scale is 1:25 000.

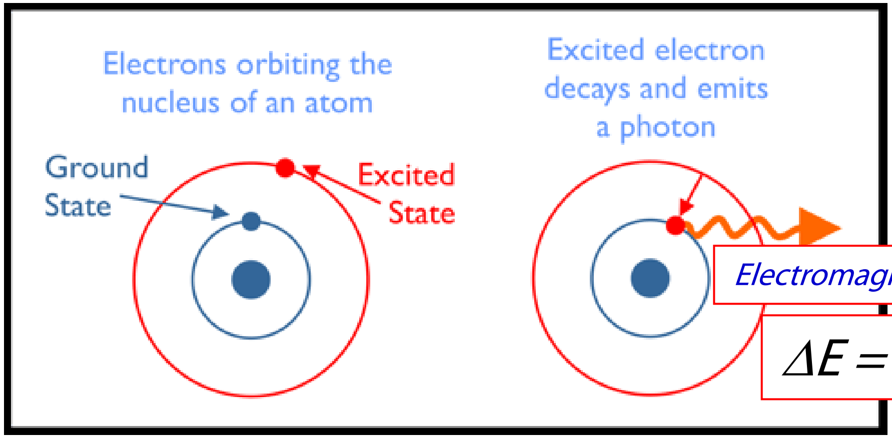
Fig. 2. Smartphone prototype, with the human grip well approximated by the position of the thumb phantom. Slot width = 0.75 mm, length = 57.5 mm.

Technology will improve with research efforts!

If the oscillation is even faster than electronics can handle?

Photonics! (IR/VIS/UV/…)

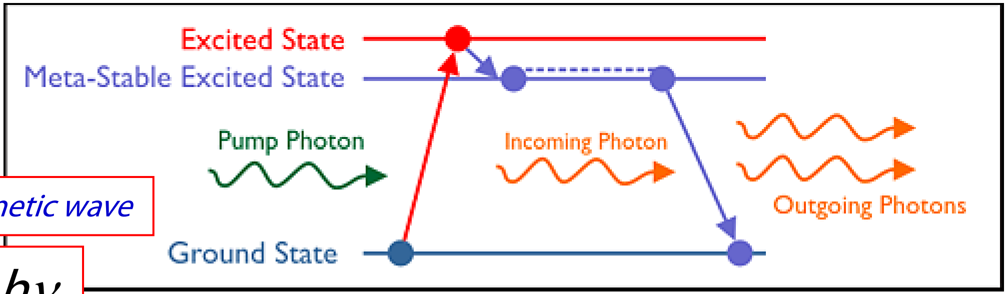
Spontaneous emission



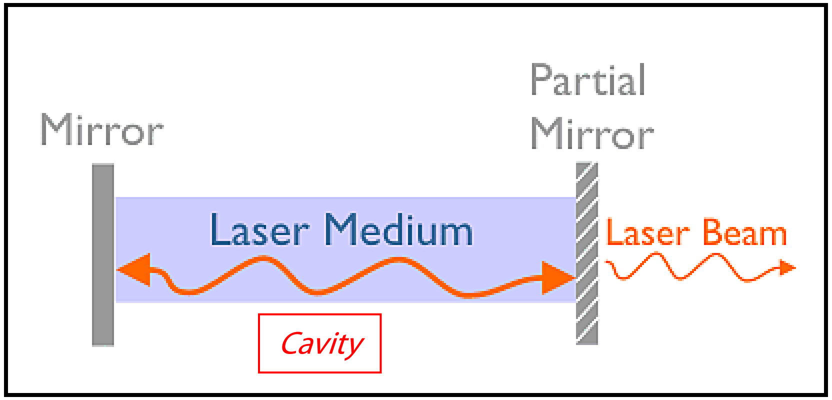
Electromagnetic wave

$$\Delta E = h\nu$$

Stimulated emission

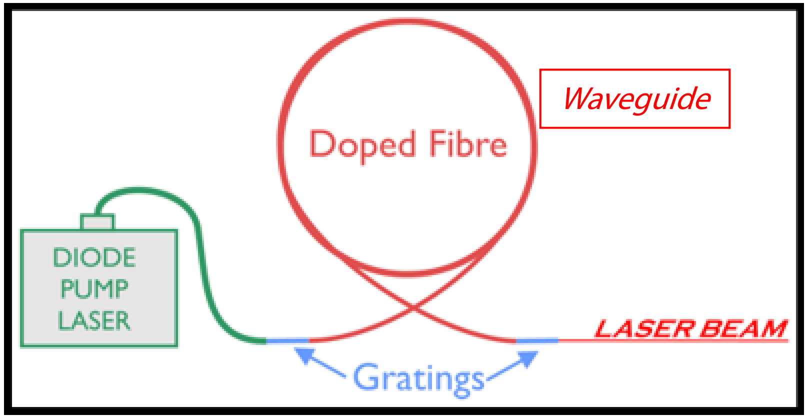


Laser oscillation



Cavity

Fibre technology



Waveguide

Source: www.orc.soton.ac.uk

Conclusions

- Electromagnetics, simple or complicated?
  - Only 4 independent equations!
  - *Maybe, even easier than "Introduction to electromagnetism with practice"!*
- A lot of exciting things to do if you've made it through!
  - Electronics (Wired/Wireless communications, high-speed circuits, etc.)
  - Photonics (Optical communications, lasers, sensors, displays, bio-medicine, energy, nano/meta materials, etc.)
  - Quantum Electrodynamics (Bose-Einstein condensation, superradiance, etc.)