EE2025

Why Study Electromagnetics?

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Electrical Engineering
IIT Madras, July-Nov 2024

How will we run this course?

- Lectures: Tue 11a, Wed 10a, Thu 8a, Fri 5p
  NO separate tutorials, problem solving folded into lectures
- Additional problems will be shared (e.g. Moodle)
- Evaluation pattern: Quiz 1 & 2 = 50%, End-sem = 50%
  closed notes but one sided A4 sheet allowed for formulae
- TAs (for Prof Uday): Anant Goyal, Karthik, Priyanka
- Attendance will be recorded but there is no W grade!

Something important, before we talk about EM

scientific reports

OPEN

The mere presence of a smartphone reduces basal attentional performance

Jeanette Skowronek✉, Andreas Seifert & Sven Lindberg

https://www.nature.com/articles/s41598-023-36256-4

scientific reports

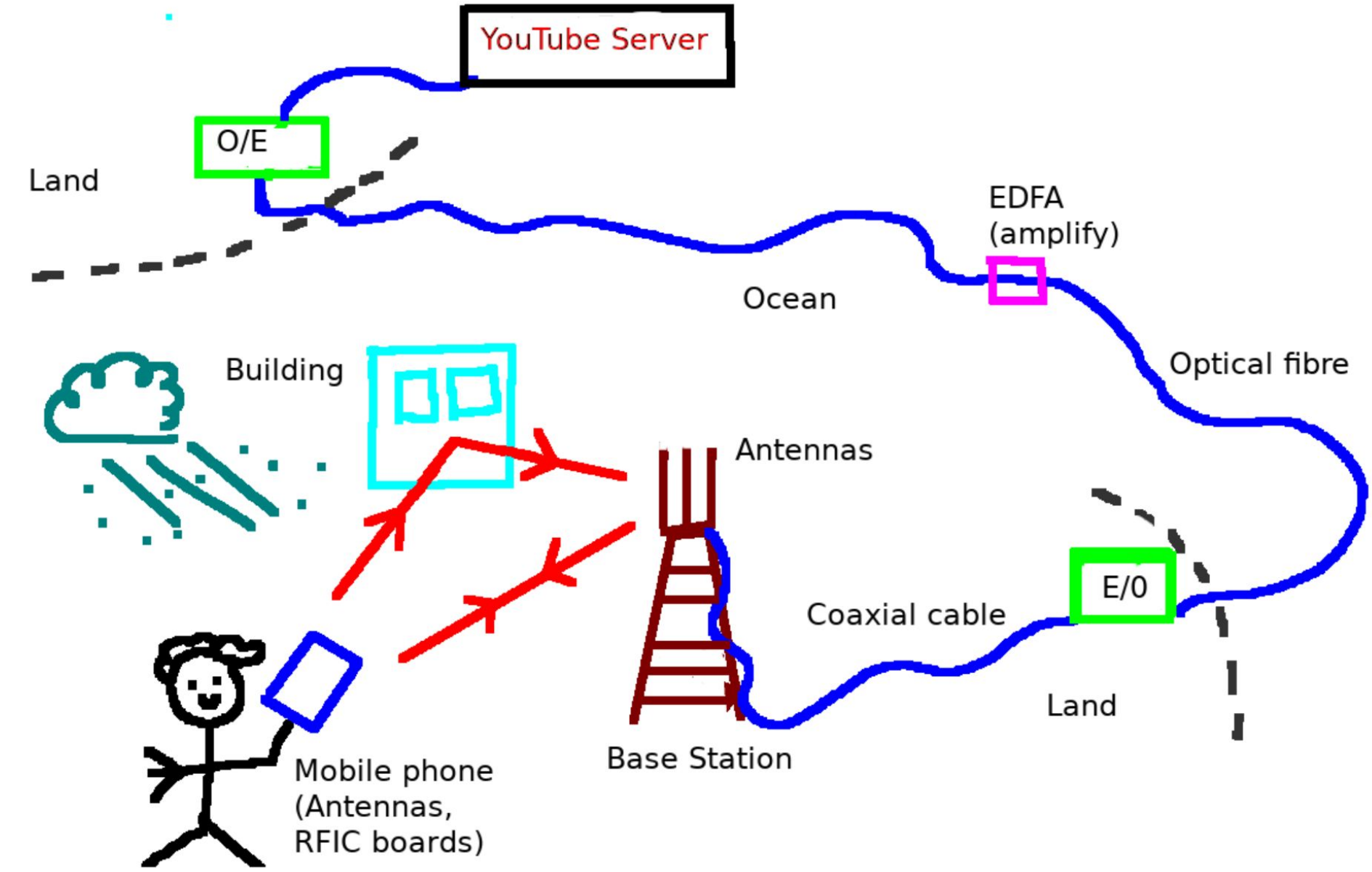
OPEN

The mere presence of a smartphone reduces basal attentional performance

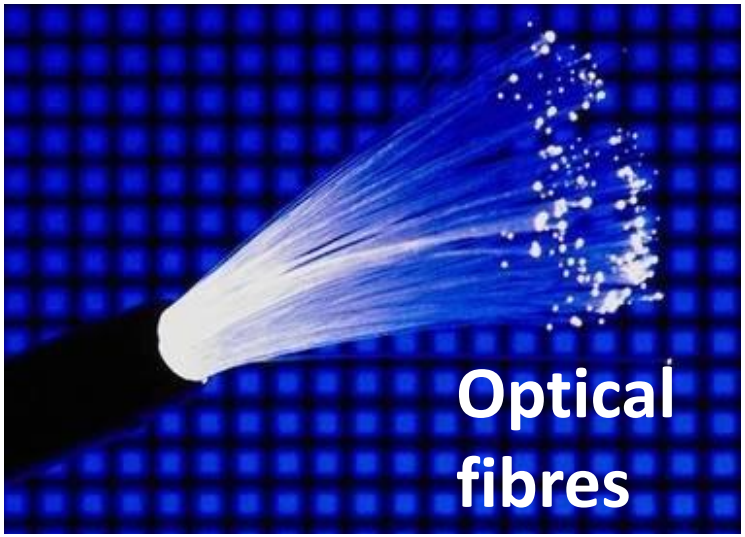
Jeanette Skowronek✉, Andreas Seifert & Sven Lindberg

	Attention	Speed
No phone	109	109
W/ phone	100	98

In this research, the hypothesis of the mere smartphone presence leading to cognitive costs and a lower attention is being tested. The smartphone may use limited cognitive resources and consequently lead to a lower cognitive performance. To investigate this hypothesis, participants aged 20–34 perform a concentration and attention test in the presence and absence of a smartphone. The results of the conducted experiment imply that the mere presence of a smartphone results in lower cognitive performance.


YouTube Server
O/E
Land
EDFA
(amplify)
Ocean
Optical fibre
Building
Antennas
E/0
Coaxial cable
Land
Base Station
Mobile phone
(Antennas,
RFIC boards)

Where else do we see EM?



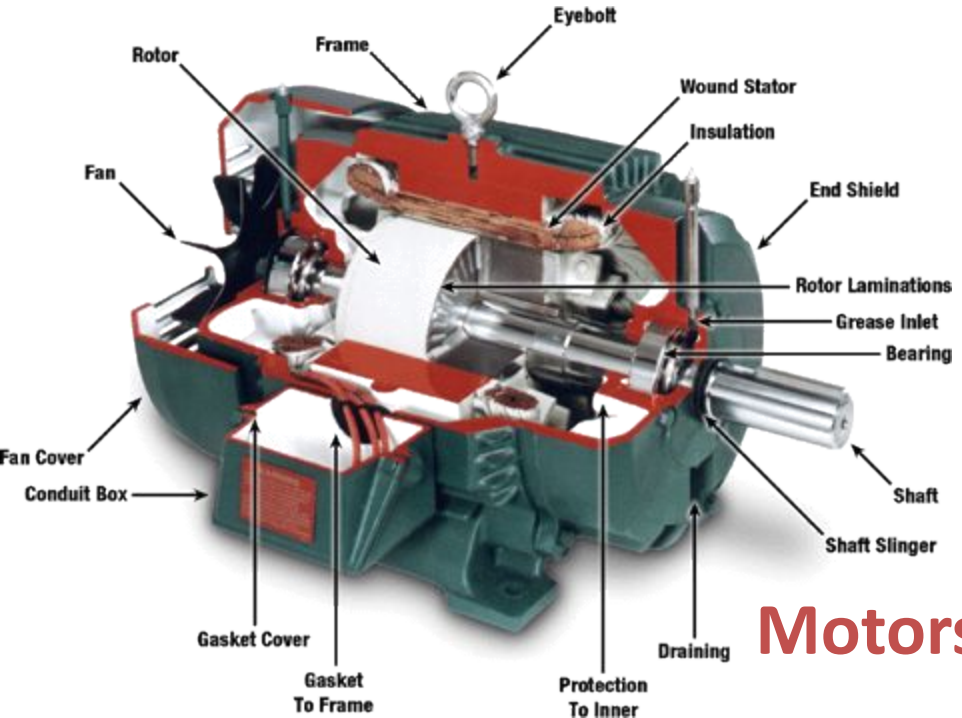
Cell towers

Where else do we see EM?

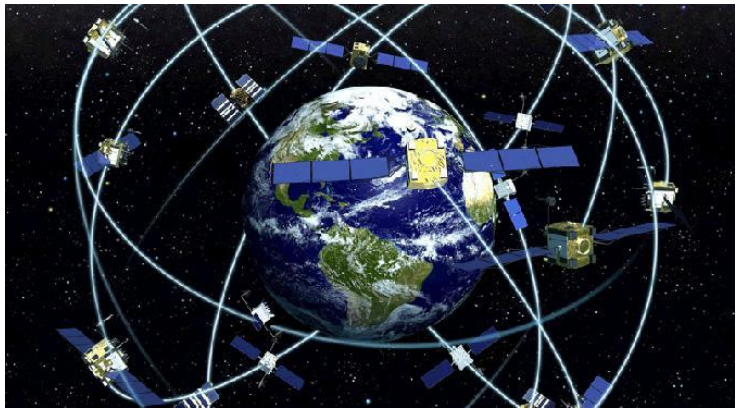
Radio astronomy

LCD screens

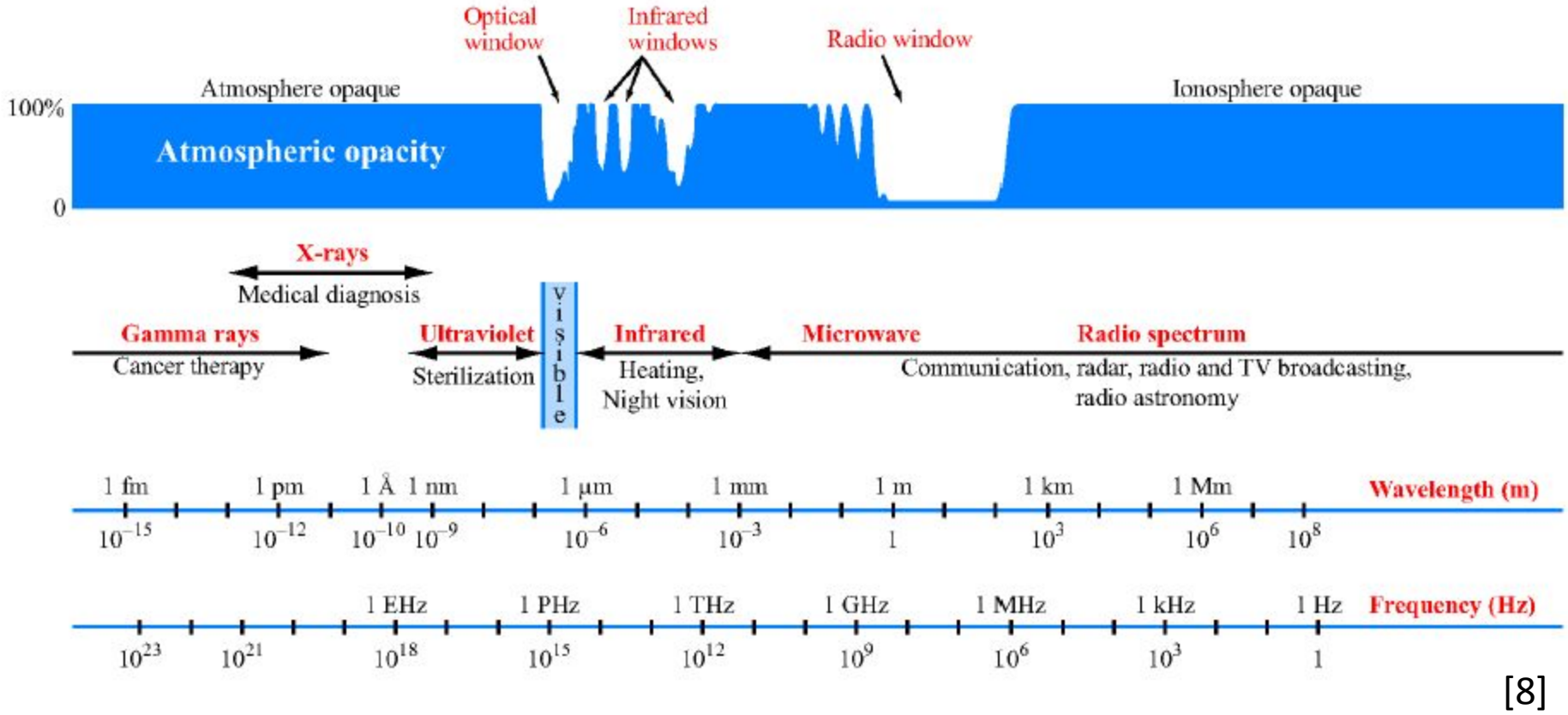
GPS



Motors



Electromagnetic Spectrum

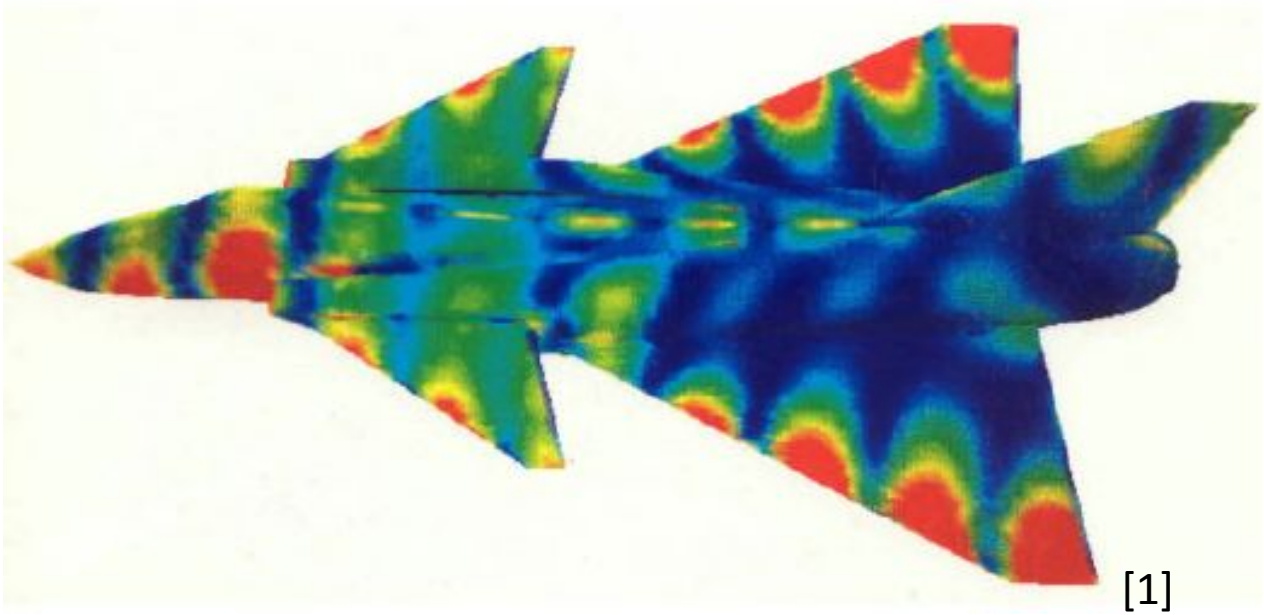


[8]

EM Applications over time

- 1900 – 1990s: Dominated by military applications – Radar, stealth technology, electromagnetic weapons, etc.
- 1990s – today:
  - Computing
  - Communication
  - Imaging (bio-medical, remote-sensing, ground-penetrating radar, oil well exploration, etc.)

Military applications



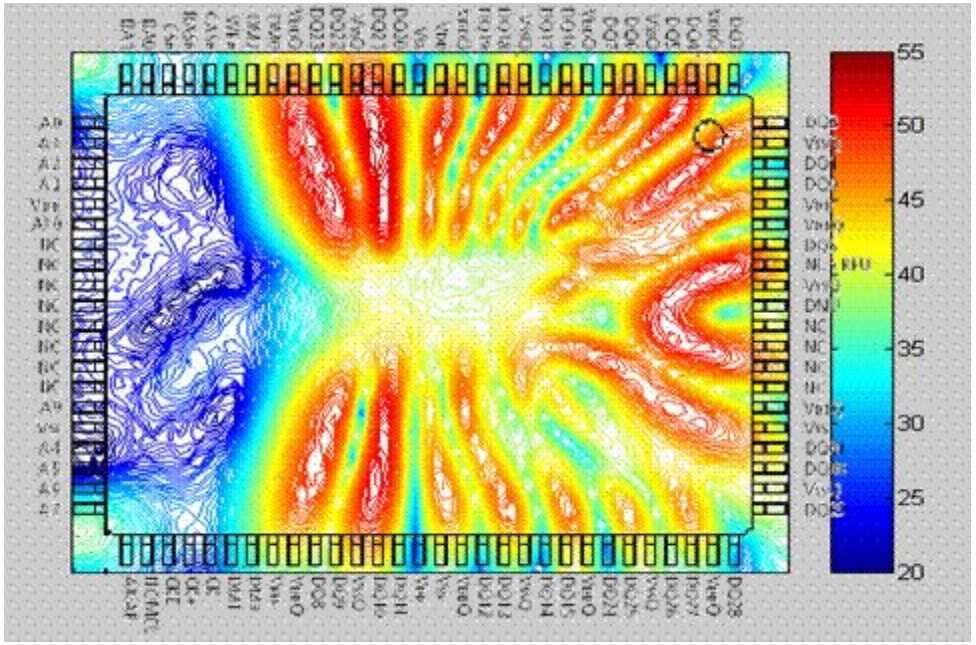
[1]

100 MHz radar wave interacts with a fighter jet. False colours correspond to induced surface currents which re-radiate EM energy

High-speed circuits

Circuit theory is actually a *subset* of electromagnetic field theory:

At high switching speeds, signals are ***not*** confined to circuit paths!

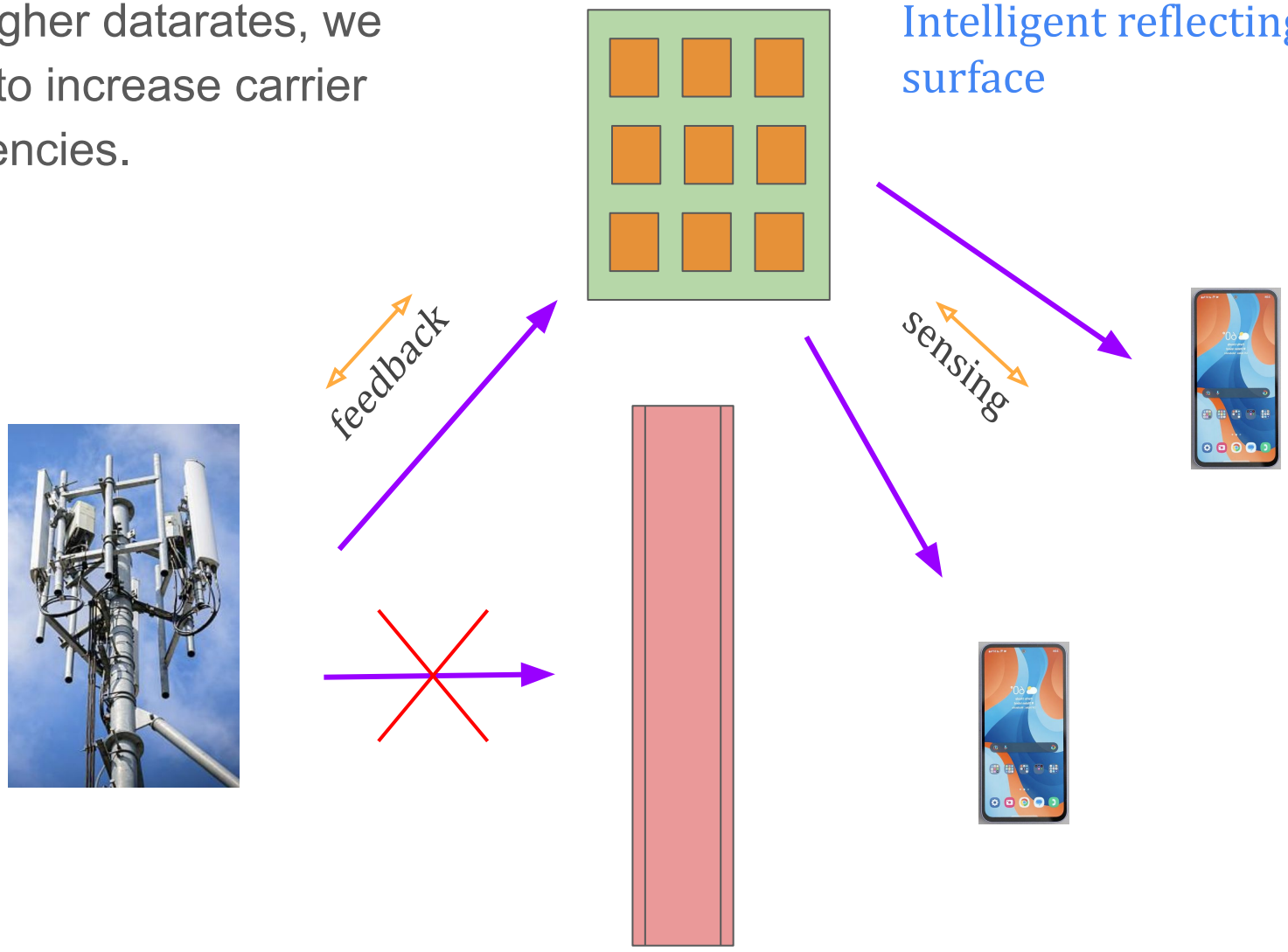


Shrinking circuit size **+** high speed operation **=>** Higher coupling between circuit elements via EM

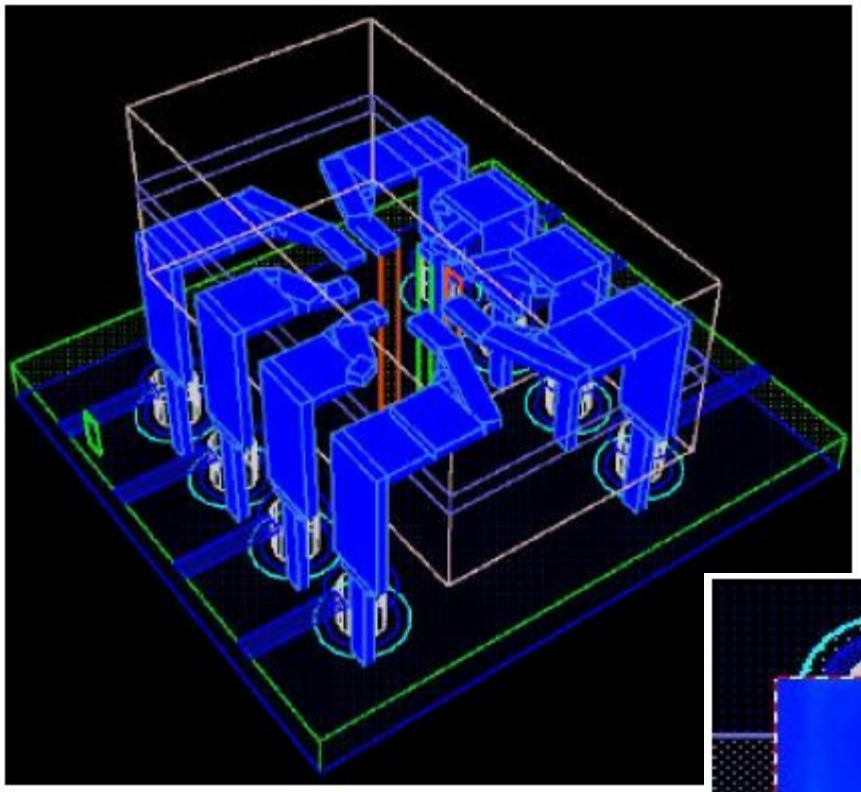
Near magnetic field above a packaged integrated circuit.[2]

Upcoming 6G technology

For higher datarates, we need to increase carrier frequencies.

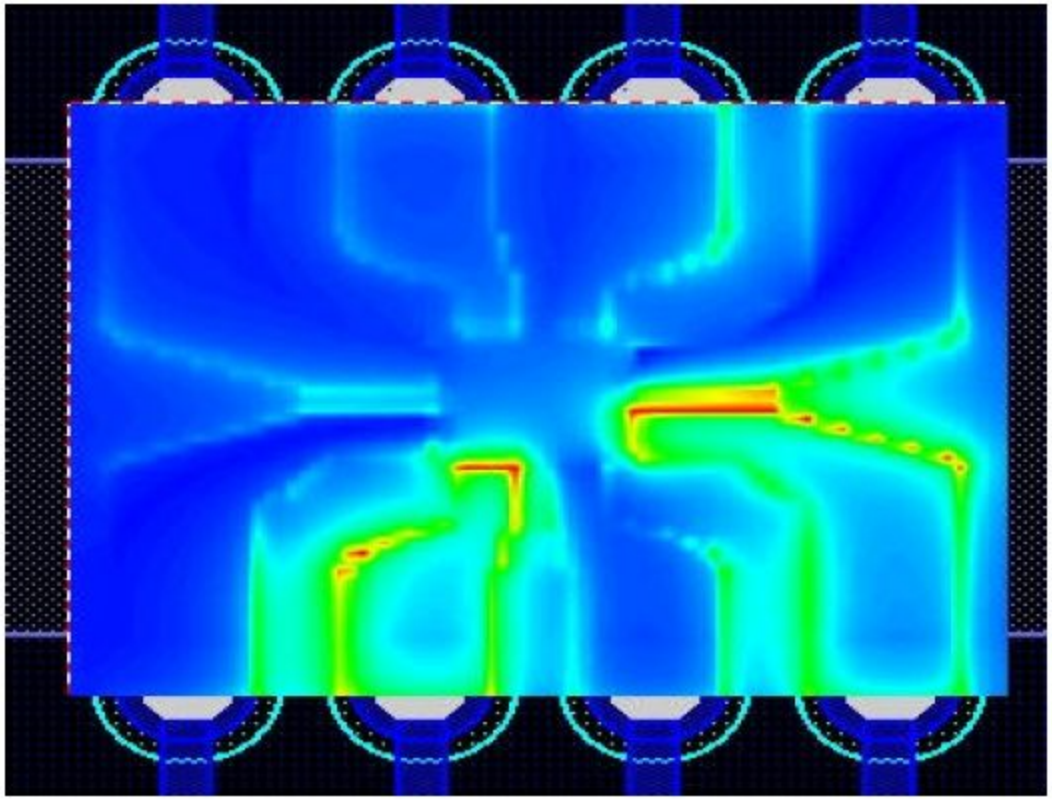


High-speed circuits



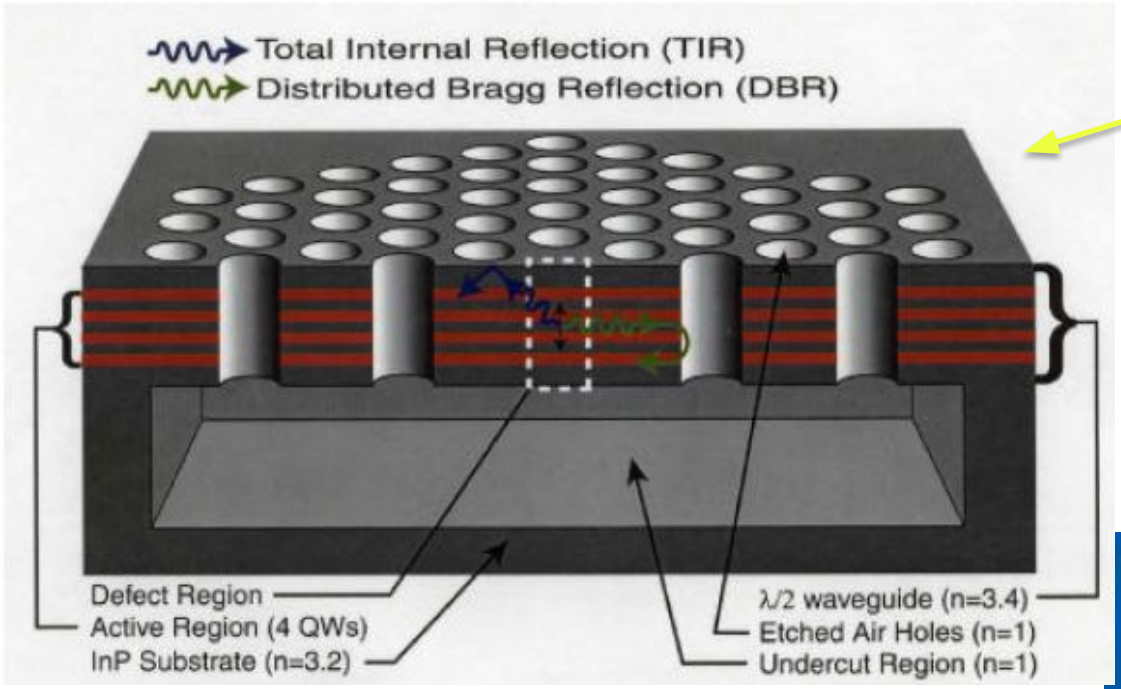
Microchip embedded within a dual inline IC

[1]



Fields associated with a logic pulse are not confined to metal paths

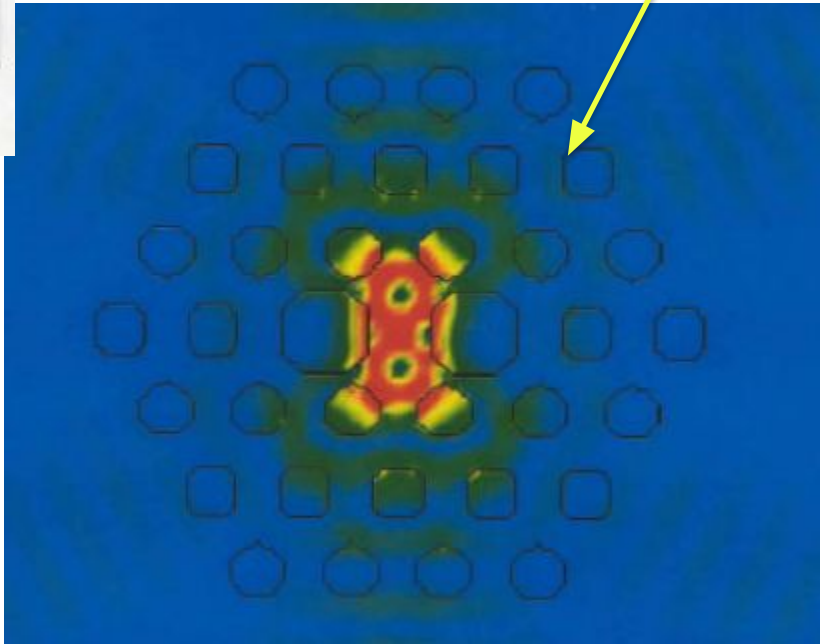
Micro-cavity Laser Design



Periodic air holes in a slab – *Photonic Crystal*

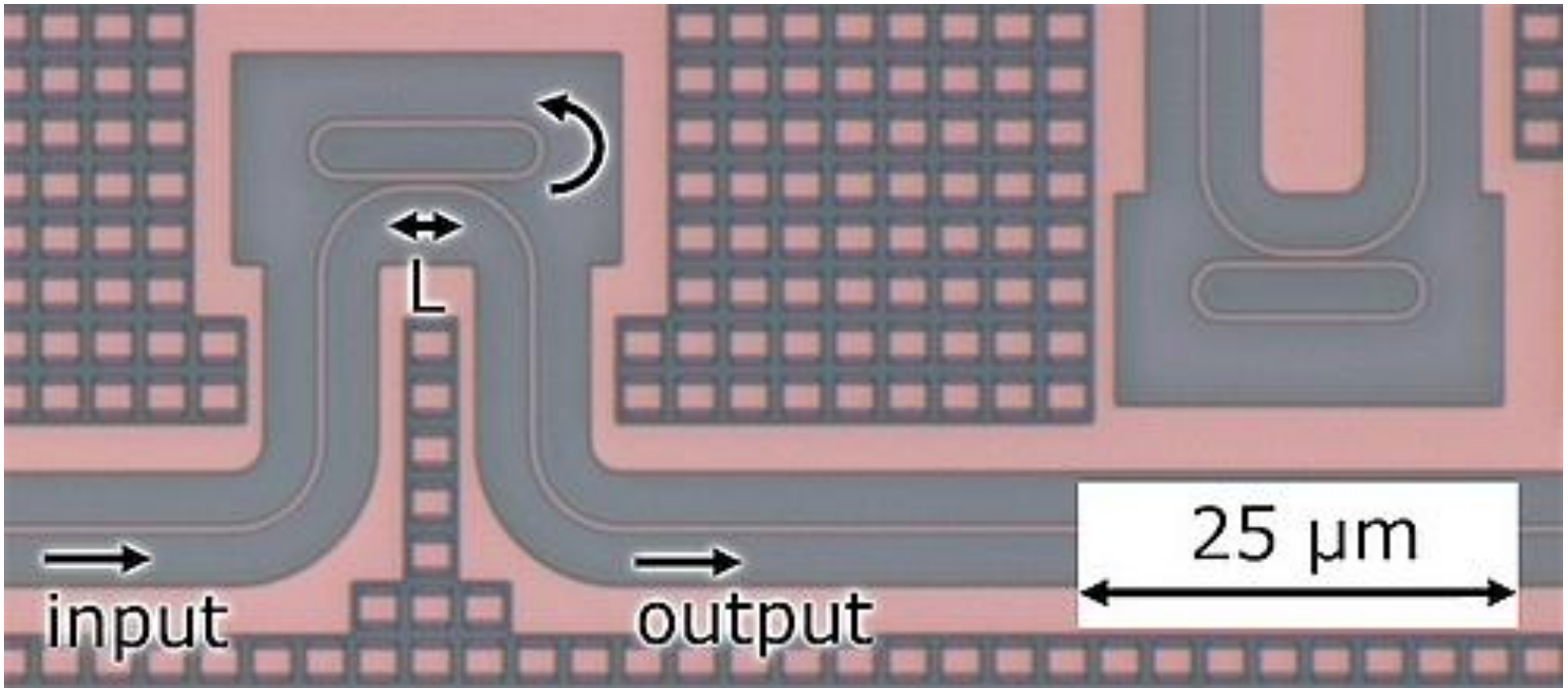
Simulation showing trapped electro-magnetic fields

[7]



Used for making ultra-compact lasers, quantum-entanglement devices, etc.

Photonic integrated circuits



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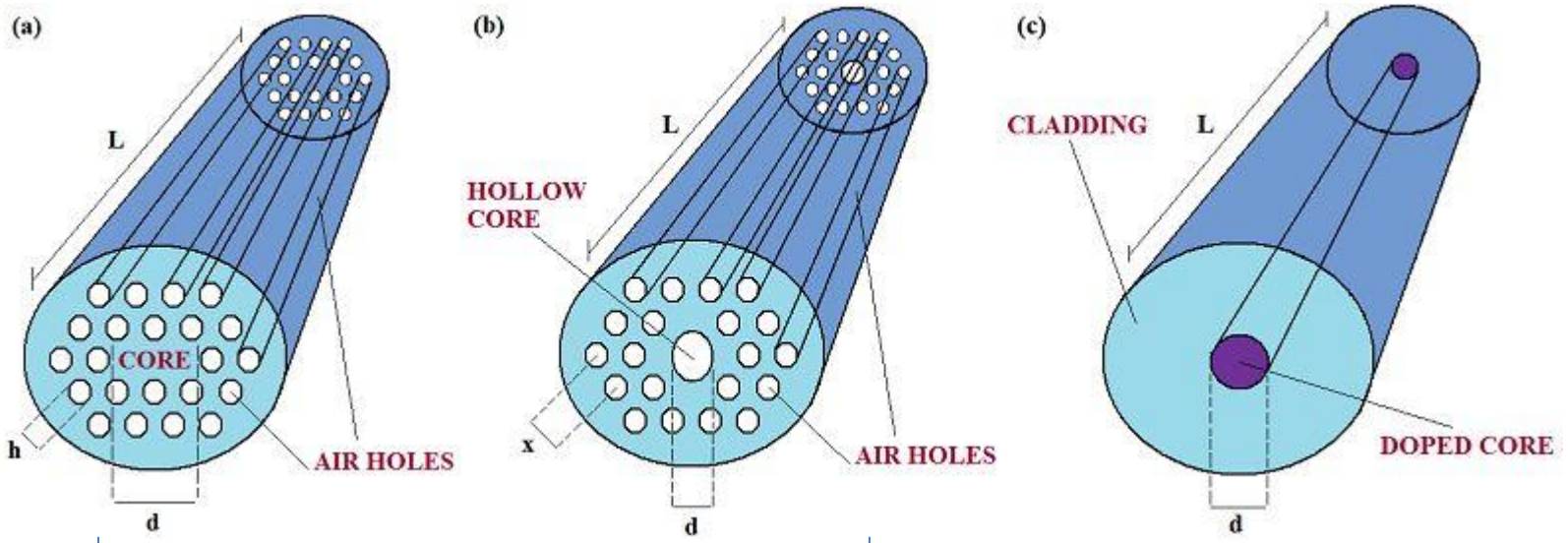
Circuits for light : simple example of a wavelength dependent filter. At the resonance frequency of the loop, output drops off.

Optical Fibres



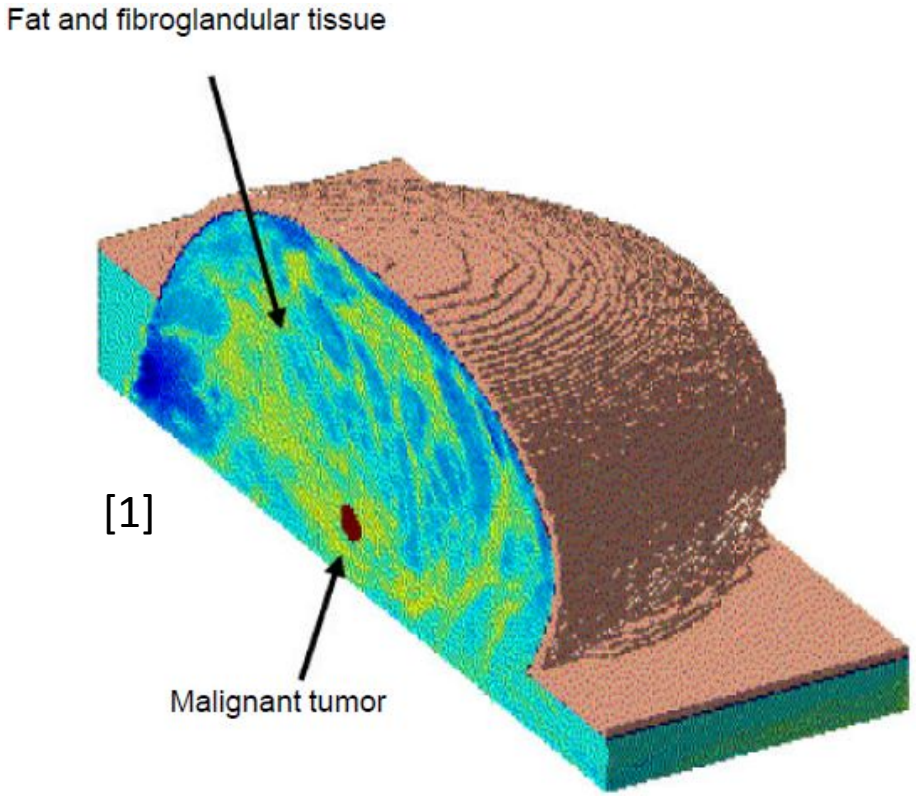
[4]

Photonic crystal fibres

Conventional fibres

In addition to simply guiding light, gives control over dispersion, polarization properties, non-linear effects, etc.

Human Body Imaging : medicine

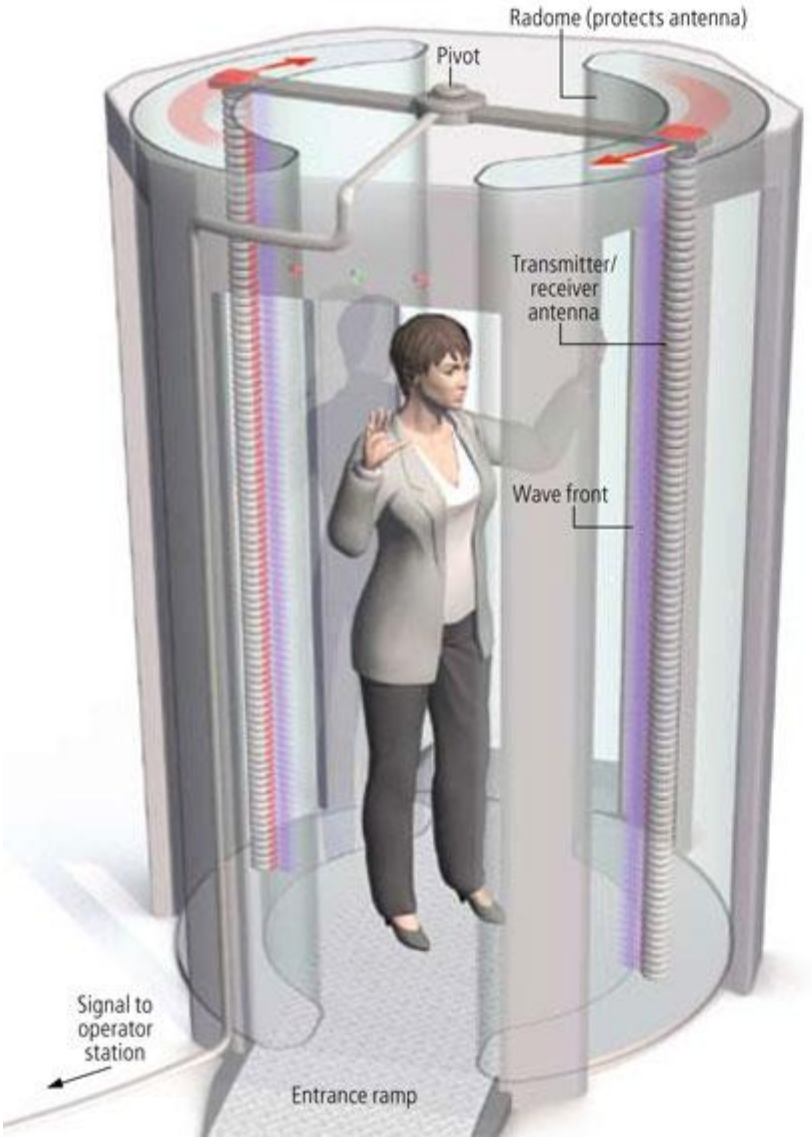


Tumour region has different refractive index as compared to surrounding fatty tissue

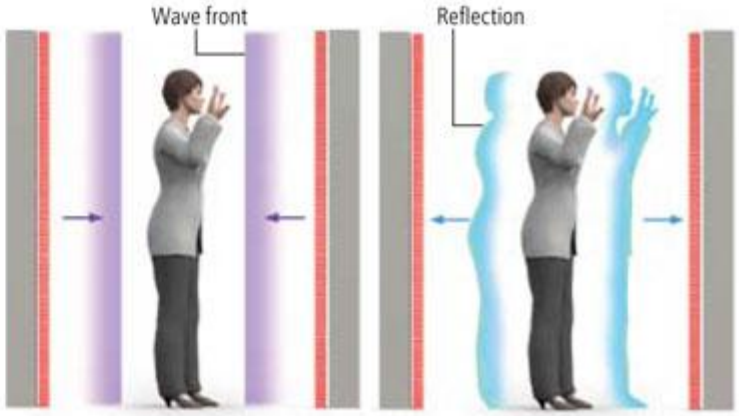
Surround the tissue by antennas: properties of the scattered electro-magnetic energy depends on refractive index distribution

Reconstruct refractive index profile based on scattered electro-magnetic fields

Human Body Imaging : security



Very active area of research : terahertz frequency (millimetre wavelength) sources and detectors.



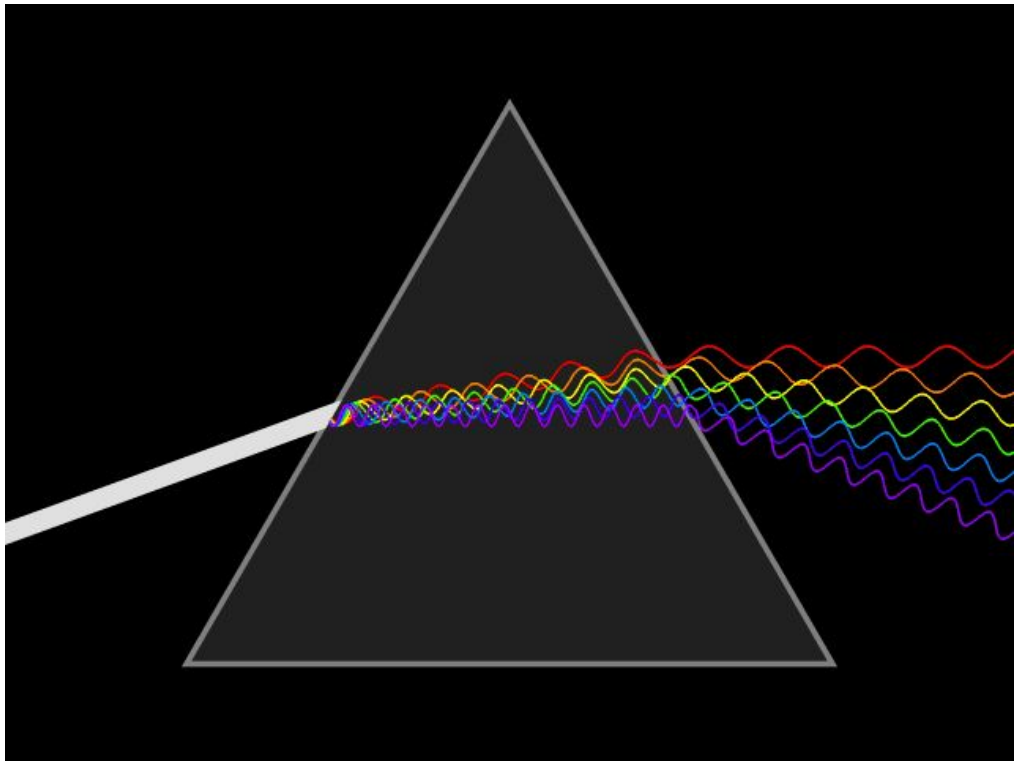
MILLIMETER-WAVE IMAGING

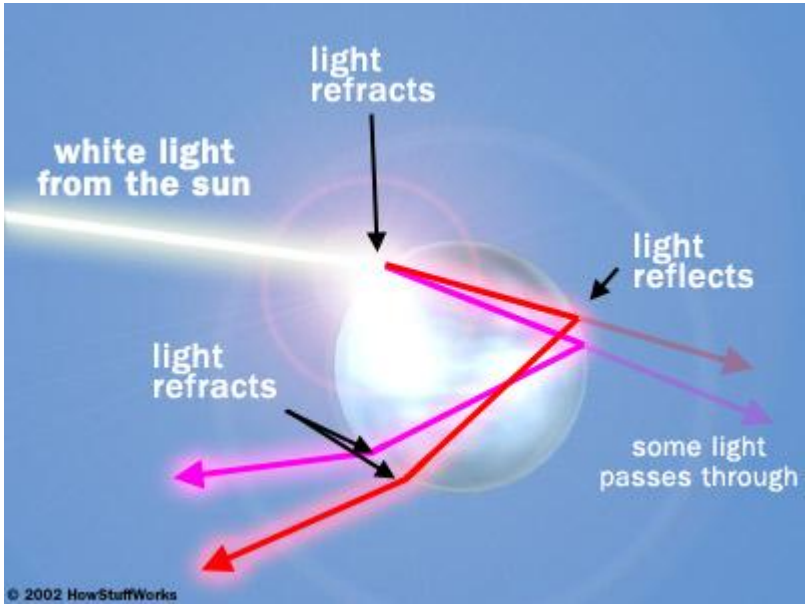
A passenger steps inside. Two vertical banks of transmitter/receivers pivot in tandem, each emitting a wave front that penetrates clothing and reflects off the person's body and any concealed objects. For privacy, the security operator viewing the resulting image sits at a remote location.

Scan time = 10 seconds
Beam frequency = 24–30 GHz
Beam power density = 6×10^{-6} mW/cm^2

[3]

Natural Phenomena: rainbow!





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http://www.naturphilosophie.co.uk/rainbows-rainbows-everywhere/
http://science.howstuffworks.com/nature/climate-weather/storms/rainbow2.htm

Course Topics

1. Transmission Lines – electricity travels like a wave
2. The simplest electromagnetic waves – plane waves
3. What happens when waves meet matter
4. Transmitting electromagnetic energy – antennas
5. How to confine and guide waves – waveguides

Looking ahead …

- Study of EM is fundamental to most applications of computing, circuit design, imaging, and communications

- Many prominent future technologies are highly dependent on a sound understanding of EM: quantum computing, high-speed optical interconnects, wireless power transfer

References

[1] Taflove, Allen. "Why study electromagnetics: the first unit in an undergraduate electromagnetics course." *Antennas and Propagation Magazine, IEEE* 44.2 (2002): 132-139.

[2] http://www.cvel.clemson.edu/emc/ic_emc/ic.html

[3] http://projektas-kalejimai.blogspot.in/2011_11_01_archive.html

[4]http://www.intechopen.com/books/advances-in-photonic-crystals/photonic-crystals-for-optical-sensing-a-review

[5]http://www.tnw.tudelft.nl/en/about-faculty/departments/imaging-physics/research/researchgroups/optics-research-group/research/integrated-photonics/

[6] Imanol Andonegui and Angel J. Garcia-Adeva. “Designing integrated circuitry in nanoscale photonic crystals” http://spie.org/x104683.xml

[7] O. Painter, R. K. Lee, A. Scherer, A. Yariv, J. D. O’Brien, P. D. Dapkus, and I. Kim, “Two-dimensional photonic band-gap defect mode laser,” Science, vol. 284, June 11, 1999, pp. 1819–1821.

[8] Ulaby, Michielssen, Ravaioli, “Fundamentals of Applied Electromagnetics”, Pearson 6th ed.