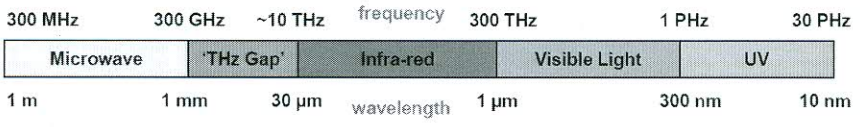
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TeraHz: from visible to invisible

- **TeraHz based systems**
- **Metamaterials**

The THz gap in the electromagnetic spectrum



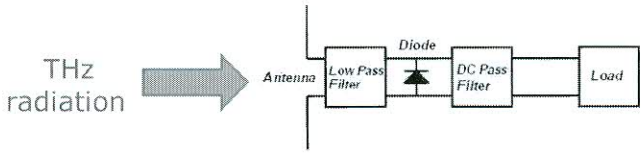
- THz radiation: between 300 GHz and 10 THz
- Has been difficult to access but offers enormous opportunities for imaging, metrology and testing
- Renewed interest due to recent work on meta-materials
- THz "gap" is shrinking
  - at the low f end: CMOS will cross the 0.5 THz barrier in a few years
  - at the high f end: new applications e.g. rectennas for energy harvesting

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Sub THz integrated circuits: new opportunities for CMOS

- Cut-off frequency of CMOS (the workhorse of the chip industry) will exceed 0.5 THz in the near future
- Integration of complex sub - THz products on a single chip will become possible at much lower cost and lower energy consumption
- Applications: biosensing, imaging, security, radar, ..., with virtually free bandwidth, allowing extremely high speed wireless communication

THz rectenna arrays for energy harvesting based on progress in nanotechnology



Major Challenges
- Bandwidth and cost of antenna: printable designs
- Efficient rectifying: MIM diodes, ballistic rectifiers

Competitor for thermoelectric elements ,based on Seebeck effect ? Will it also work at optical frequencies and compete with solar cells ?

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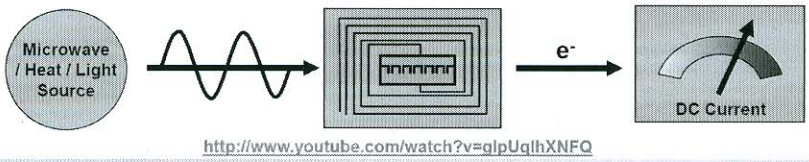
THz Rectennas for Energy Harvesting

Antenna + **Rectifier** ➡ **Rectenna**

- Collects radiation
  - Broad spectrum
  - Insensitive to angle
- Efficient
  - 90% demonstrated
- Printable
  - Low cost, roll-to-roll
  - Steven Novak et. al.

- Converts 'AC' radiation to DC
  - Usable, storable power
- Diodes with required characteristics
  - Zero-threshold
  - Non-exponential I-V
  - High speed

- Wireless Power Transmission
  - W. Brown 1960's
- Efficient
  - 80% demonstrated at GHz range
- Low Cost
  - Few, Printable components
- Energy Harvesting
  - GHz to THz



http://www.youtube.com/watch?v=glpUqlhXNFQ

THz rectennas could enable efficient, low cost energy harvesting

Program

16h30	Welcome coffee
17h00	**Opening remarks and introduction** Robert Mertens, Senior Vice President SLT, imec
17h15	**THz and metamaterials** Guy Vandenbosch, Prof. Department Electrical Engineering (ESAT-TELEMIC), K.U.Leuven
17h45	**Concept of THz technologies** Christian Jansen, Technical University of Braunschweig, Institute for High Frequency Techniques
18h15	Coffee Break
18h45	**Application of metamaterials** Johan Stiens, Prof. Department Electronics and Informatics (ETRO), V.U.B.
19h15	**Terahertz Reflectometry and Imaging** DD Arnone, Chief Executive Officer and Co-Founder, TeraView ,Cambridge
19h45	**Q & A**
20h00	**Closing remarks** Robert Mertens, Senior Vice President SLT, imec
20h10	**Drink and snacks**