Optically powered ‘smart dust’ motes

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Sensor networks

- Billions of devices (100s per person)
- Enabling
  - Internet of things
  - ‘Smarter planet’
- Challenges
  - Reducing energy consumption
  - Communications and power
- Trends in computing
  - Smaller ICs
    - Significant ‘intelligence per square micron’
    - I/O pins an increasing problem
  - Wireless communications?
  - Wireless power?

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Communications and power for sensors

	Optical	Radio
Path loss	Low	High
Path type	Line of sight required	Non line of sight /Line of sight
Link margin	Poor	Good
Architecture	Base station + nodes	Flat architecture
Node energy consumption	10s pJ/bit demonstrated	nJ/bit
Wireless power transmission	Simple- photodiode	Complex rectification

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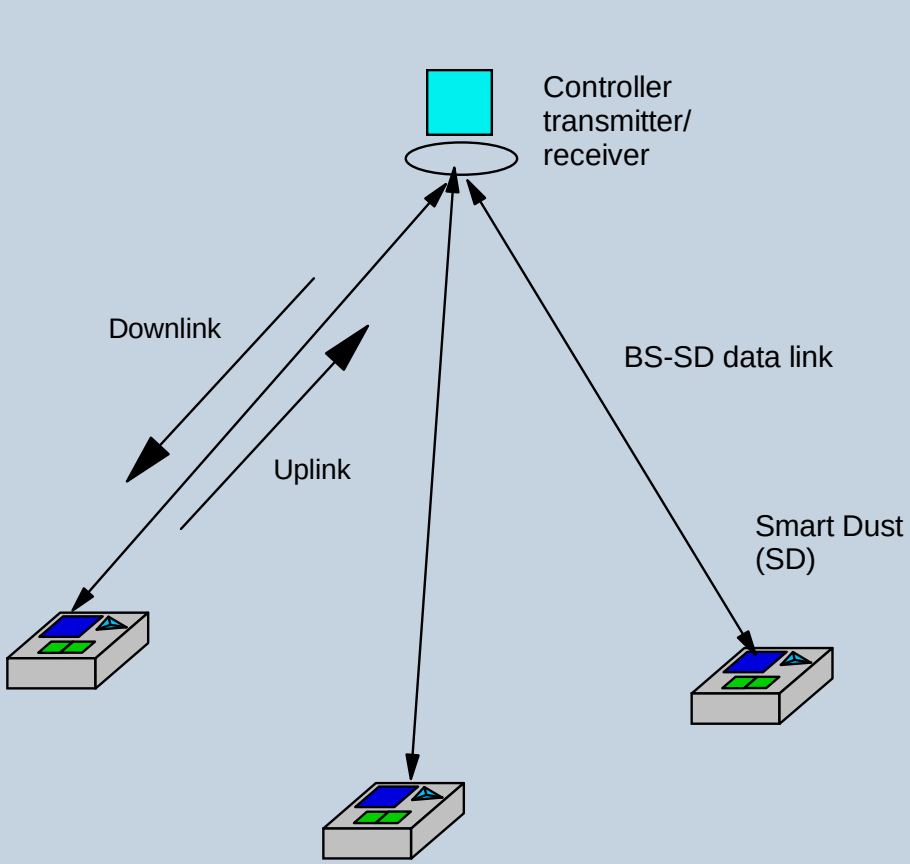
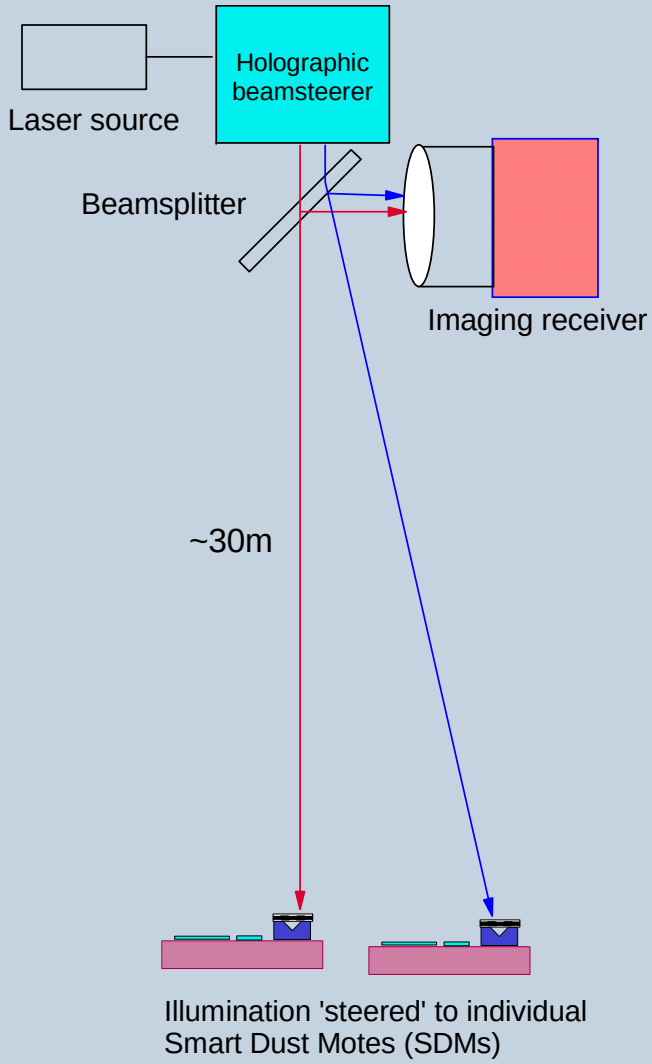
Sensor networks: smartdust architecture





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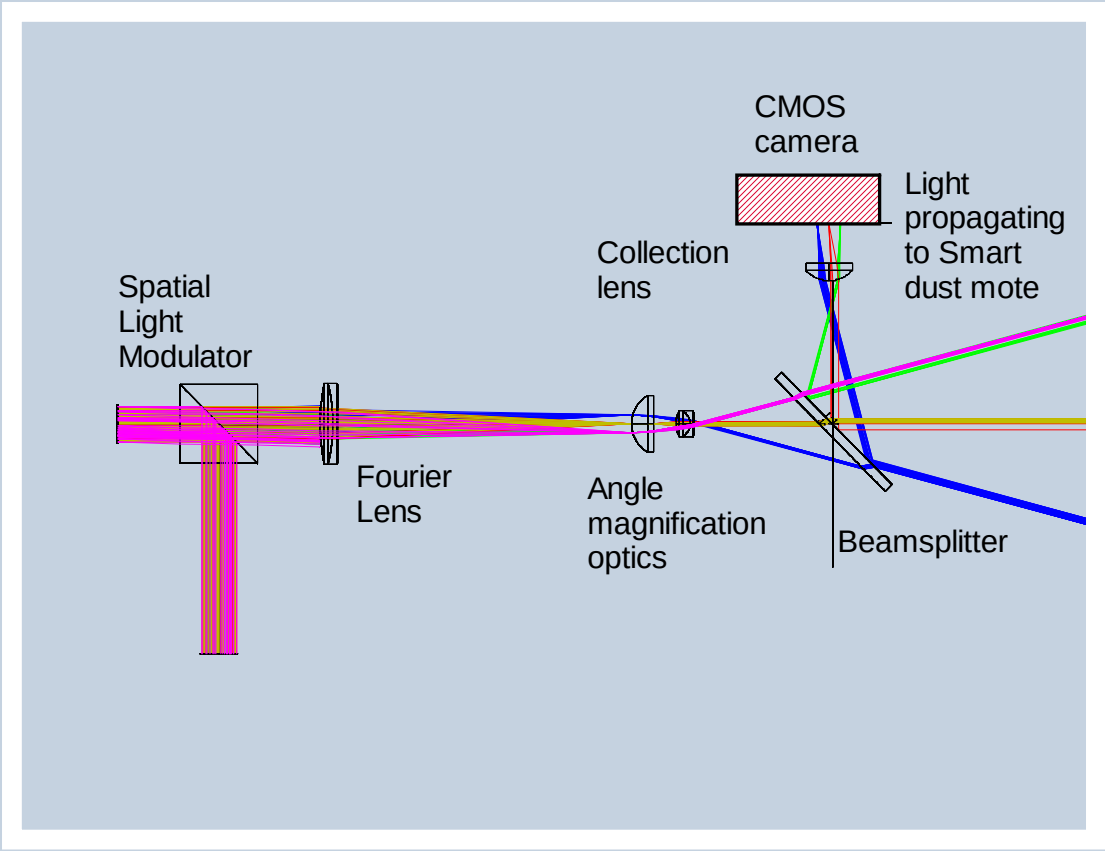
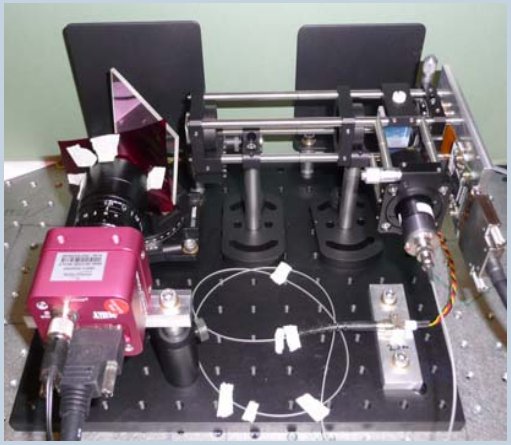
Sensor networks: BS implementation



Base Station optical design



Base Station
implementation

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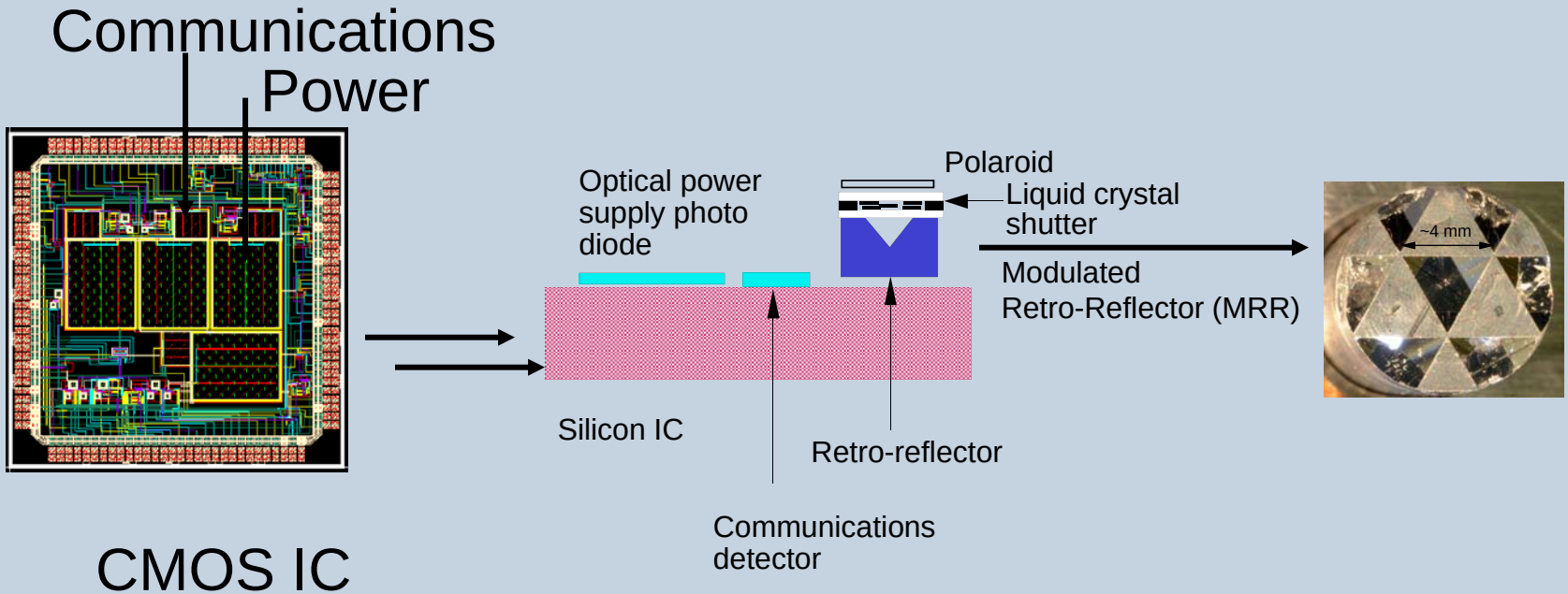
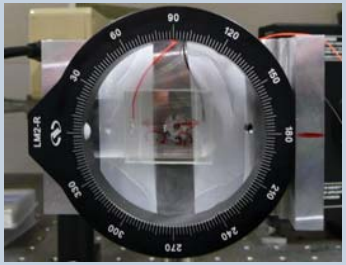
Sensor networks: SDM implementation





Prototype MRR

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Loopback demonstration(1)

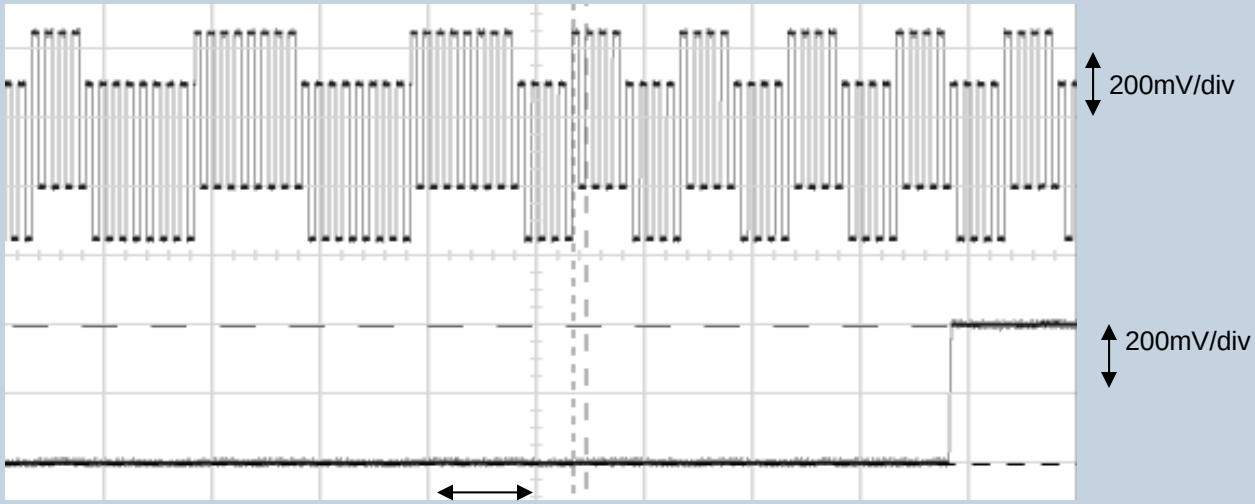
Base station

ASCII
'U' or
ASCII
'D'

Output
data

Downlink waveform
transmitting 'U' signal

'U' or 'D'
switches LC
shutter and
modulates
return beam



Smart dust mote

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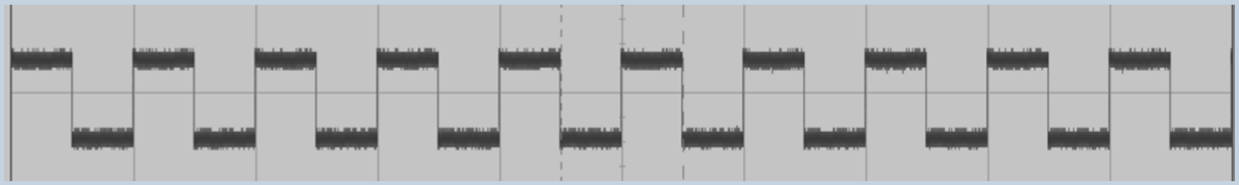
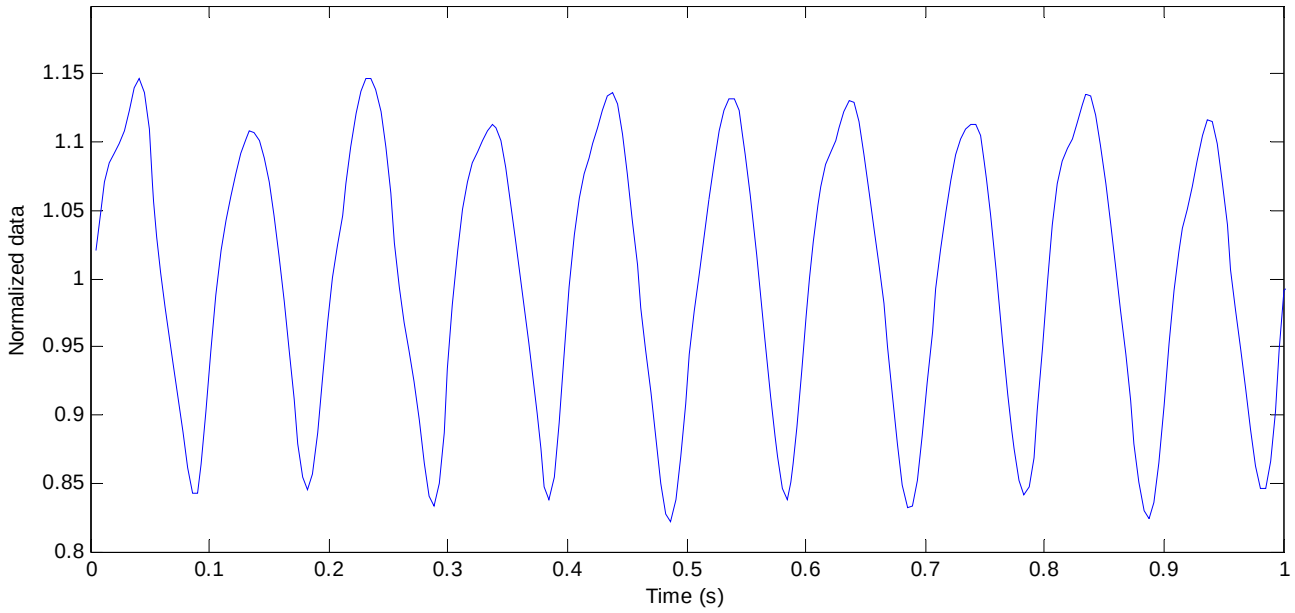
Loopback demonstration(2)

LC modulator circuit input





Received waveform at Base Station showing correct ‘loopback’ operation

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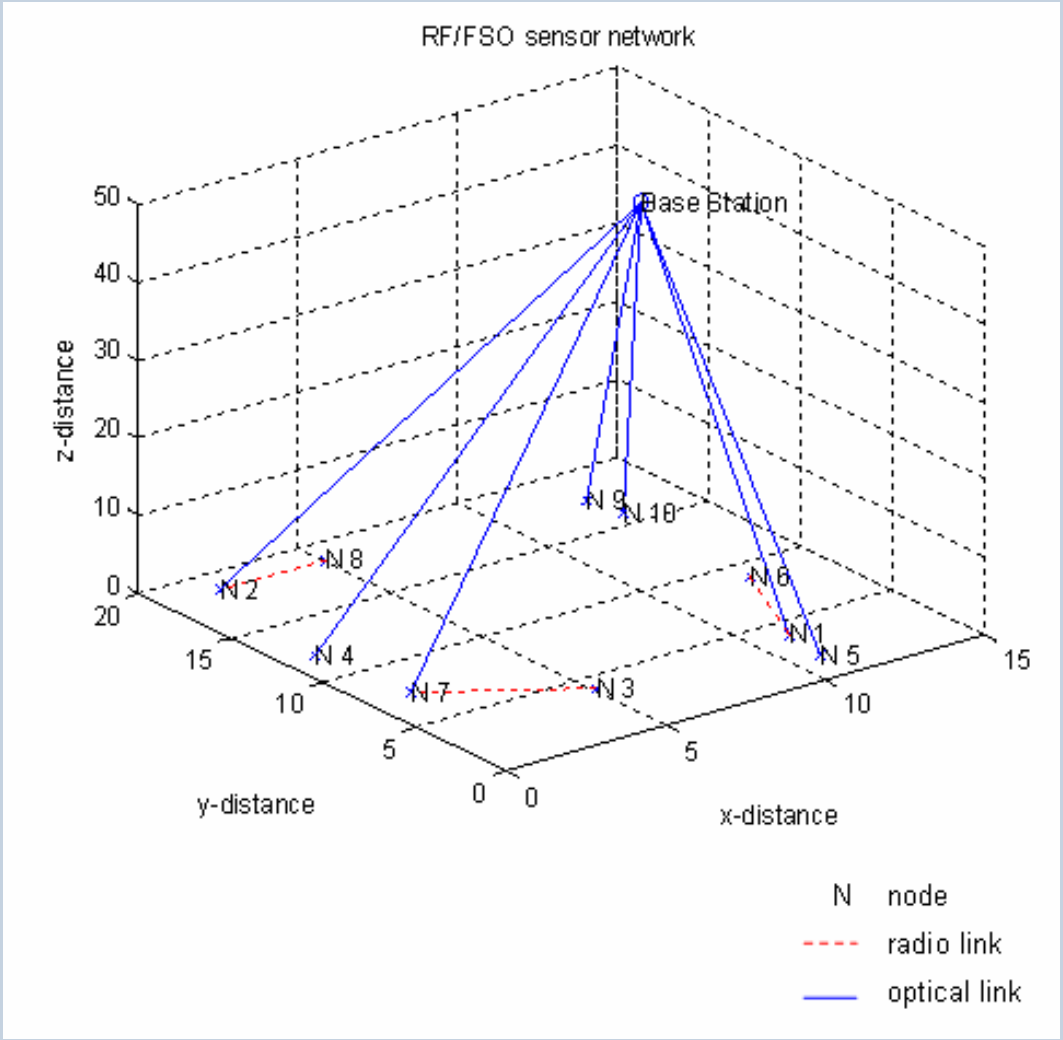
Hybrid sensor networks

- Optical links require LOS
- RF links used when LOS not available
- Network formed of
  - Cluster heads: optical link to BS
  - Nodes linked to cluster head using RF links
- Results
  - Hybrid has lower energy consumption even for a high proportion of nodes without LOS



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S. Sivathasan and D. C. O'Brien, "RF/FSO Wireless Sensor Networks: A Performance Study," in *Global Telecommunications Conference, 2008. IEEE GLOBECOM 2008. IEEE*, 2008, pp. 1-5.

Sensor networks: what next

- Future trends
  - Smaller nodes- down to 10 λ ‘straightforward’
- Nano-scale systems
  - Problems
    - Wiring
    - Power
  - Hierarchy of systems
    - Silicon microsystem
      - – Provides interface between external world and nano-scale
    - (Optical) wireless power/communications from micro-scale to ‘full’-scale

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Conclusions

- Optics offers highly directive communications
  - Simple architecture
  - Low power
    - ‘Complete’ smartdust consumes 100nA@0.6 V
    - Uplink- 7pJ/bit/mm^2@~30bits/s
- Hybrid RF/Optical architecture provides additional non-line-of sight communications
- Future trends
  - Optical wireless well suited to wiring and powering
    - Smaller sensor nodes
    - Very high density sensor networks
  - Potential to use as an interface to sub-micron scale systems

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