Smart Dust

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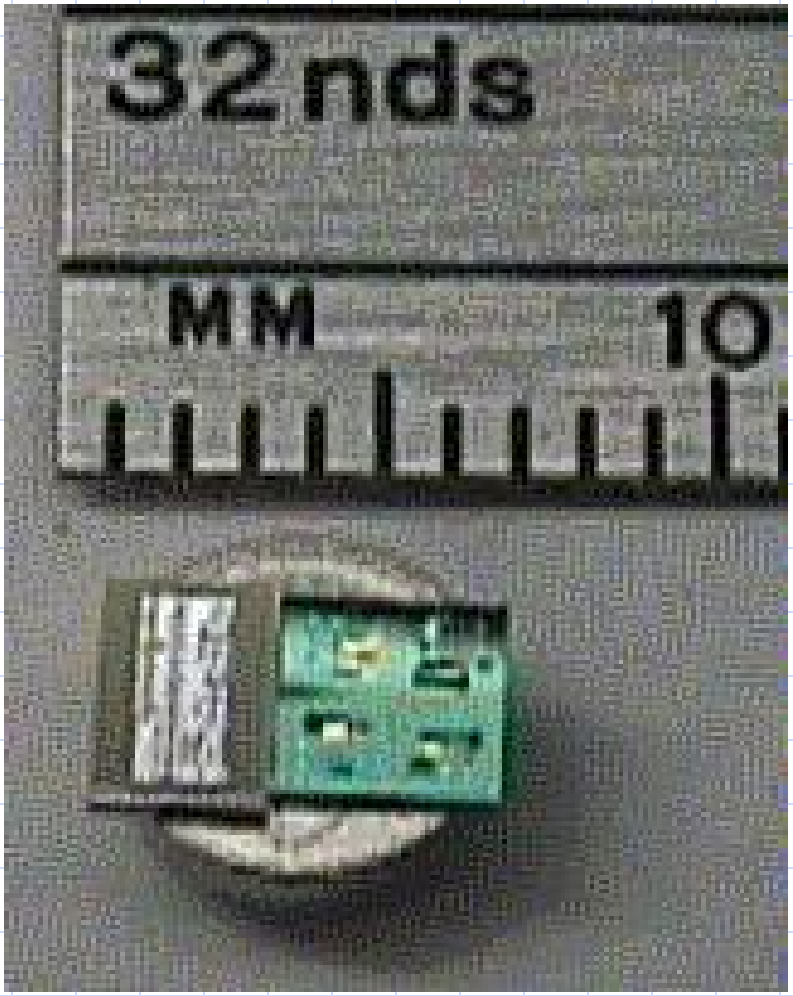
What is Smart Dust?

- A tiny dust size device with extra-ordinary capabilities.
- Often called *micro electro-mechanical sensors*
- Combines sensing, computing, wireless communication capabilities and autonomous power supply within volume of only few millimeters.
- Useful in monitoring real world phenomenon without disturbing the original process.

Cont…

- so small and light in weight that they can remain suspended in the environment like an ordinary dust particle.
- the air currents can also move them in the direction of flow.
- It is very hard to detect the presence of the Smart Dust and it is even harder to get rid of them once deployed.

Smart Dust Mote

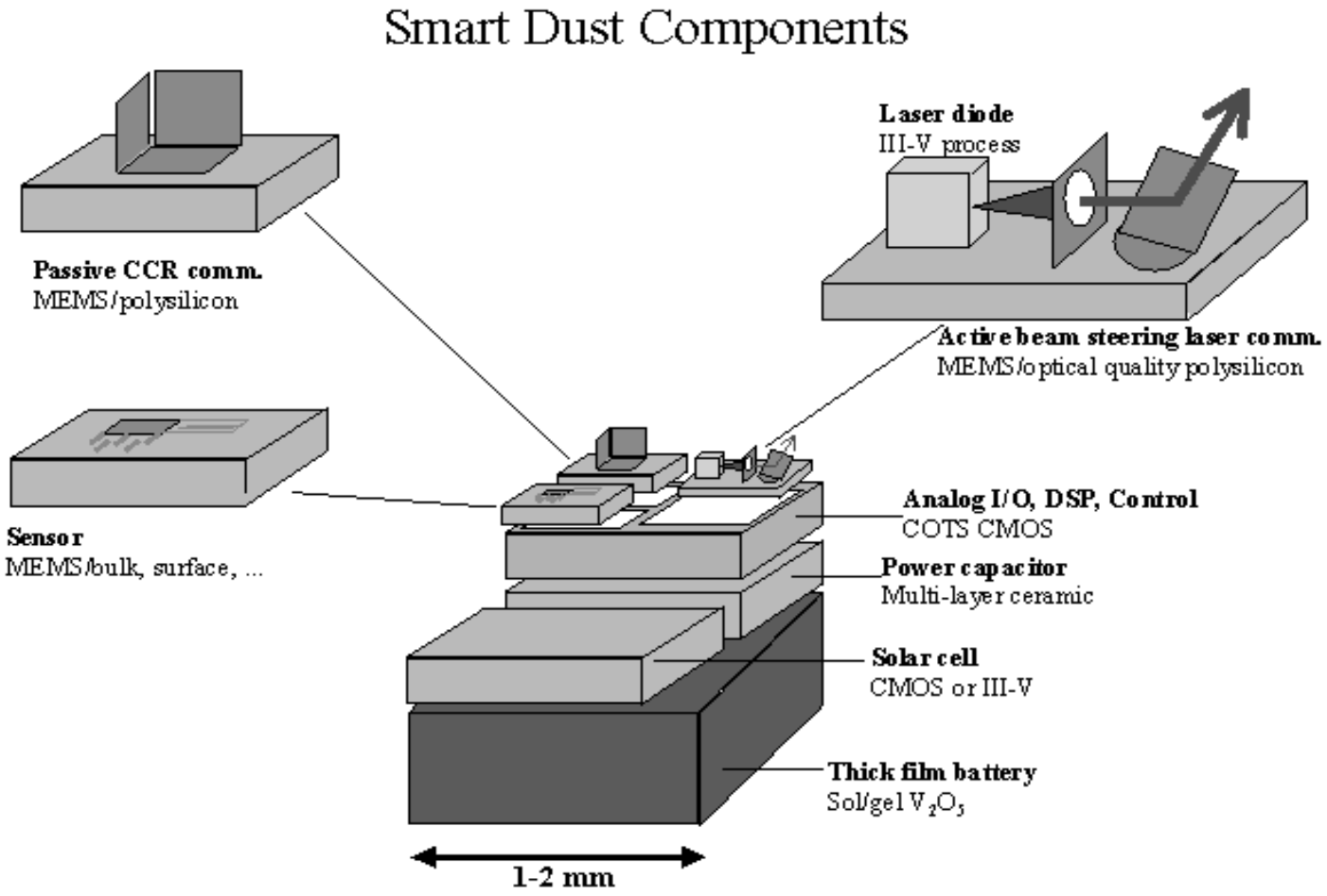


Architecture

A single Smart Dust mote has:

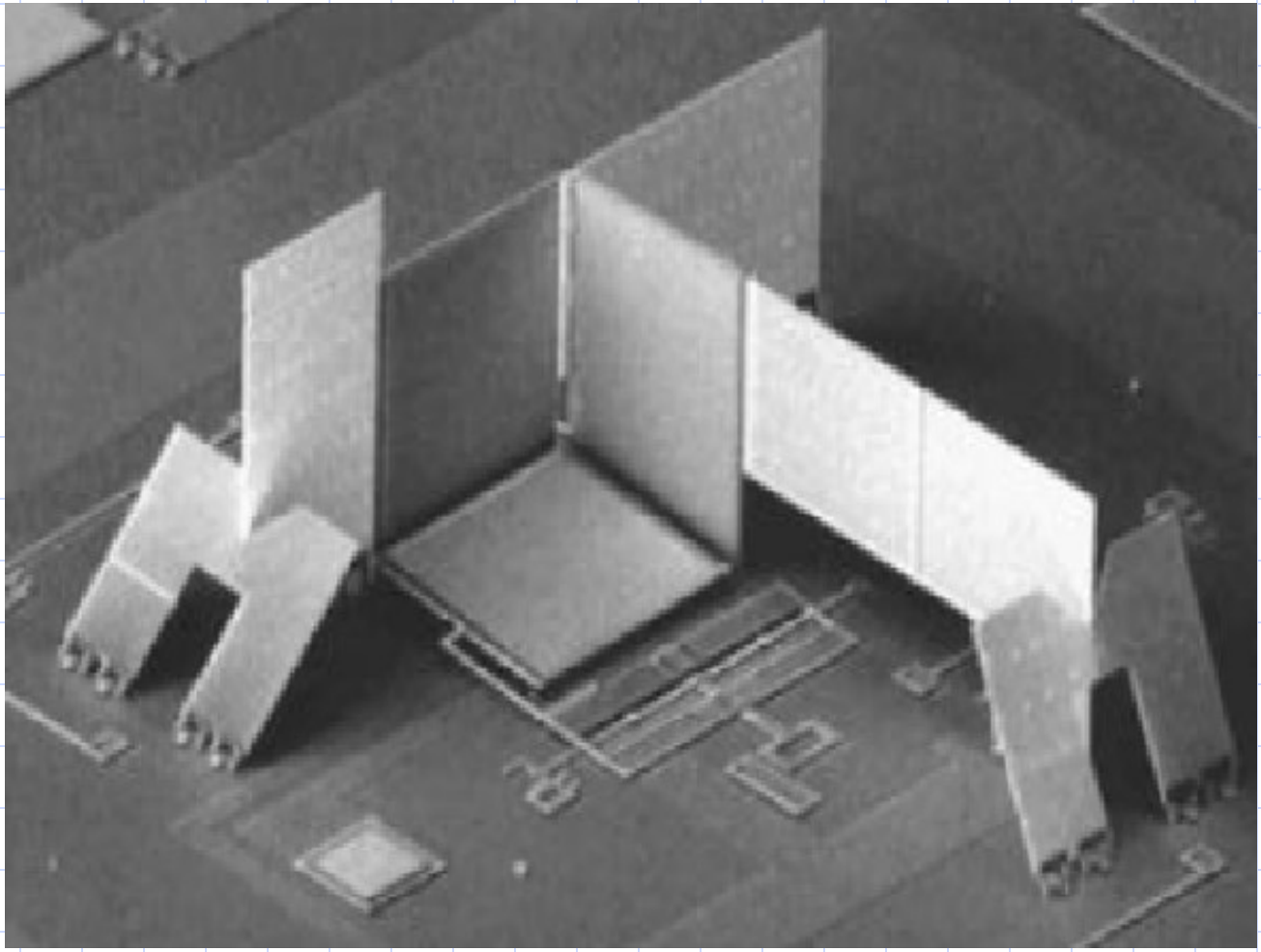
- a semiconductor laser diode and MEMS beam steering mirror for active optical transmission
- a MEMS corner cube retro-reflector for passive optical transmission
- an optical receiver
- a signal processing and control circuitry
- a power source based on thick-film batteries and solar cells.

Components of Smart Dust



Corner Cube Retro-reflector(CCR)

- Comprises of three mutually perpendicular mirrors of gold-coated poly-silicon.
- Has the property that any incident ray of light is reflected back to the source provided that it is incident within a certain range of angles centered about the cube's body diagonal.



CCR cont…

- The micro-fabricated CCR includes an electrostatic actuator that can deflect one of the mirrors at kilohertz rates.
- Thus the external light source can be transmitted back in the form of modulated signal at kilobits per second.

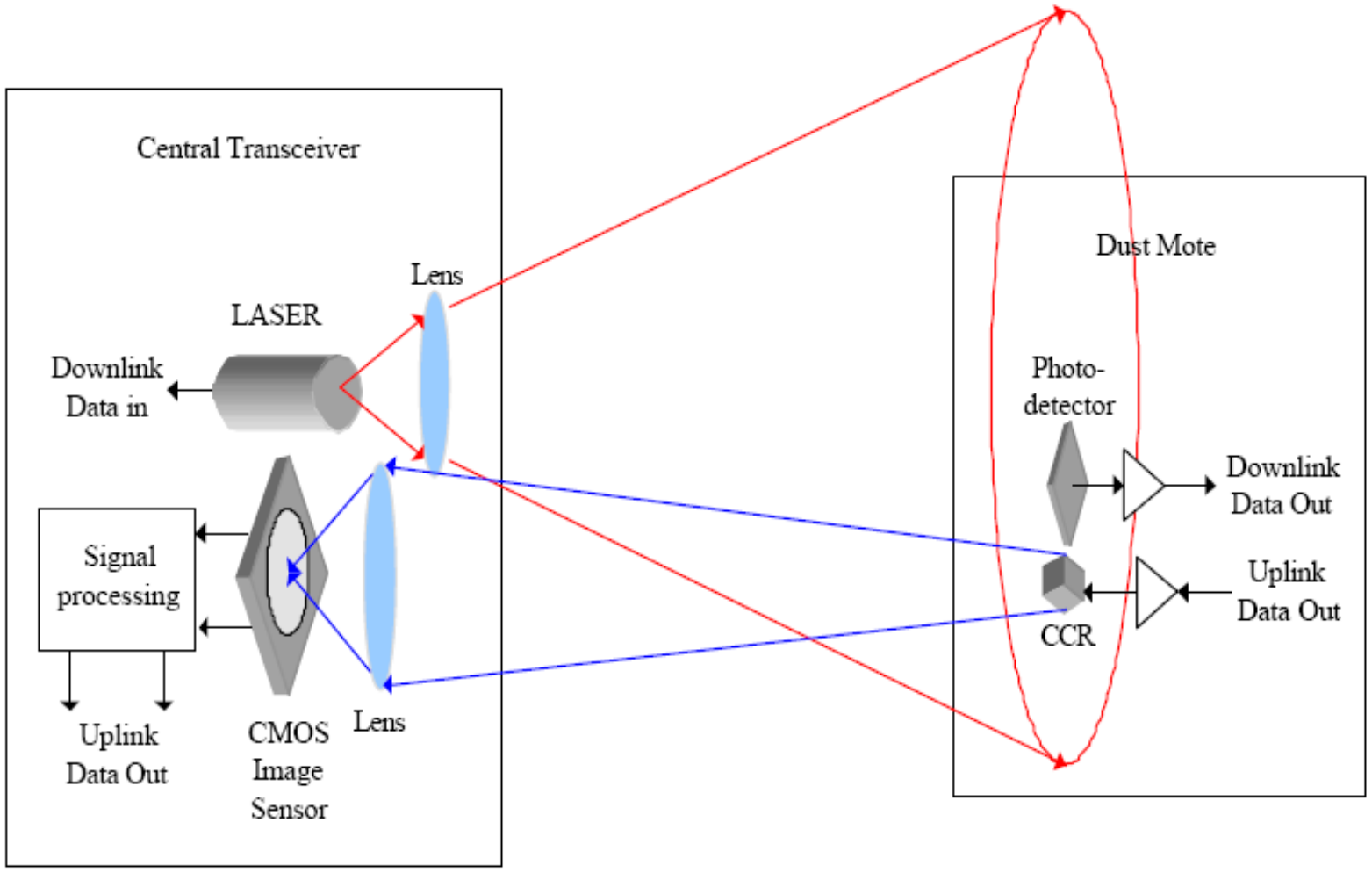
Note (CCR cont…)

- CCR-based passive optical links require an uninterrupted line-of-sight path.
- CCR can transmit to the BTS only when the CCR body diagonal happens to point directly toward the BTS, within a few tens of degrees.
- A passive transmitter can be made more omni-directional by employing several CCRs oriented in different directions, at the expense of increased dust mote size.

Challenges

- It is difficult to fit all these devices in a small Smart Dust both size wise and Energy wise.
- With devices so small, batteries present a massive addition of weight.

Free Space Optical Network



Communication Technologies

- Radio Frequency Transmission
- Optical transmission technique
  - a) Passive Laser based Communication
  - b) Active Laser based Communication
  - c) Fiber Optic Communication

Radio Frequency Transmission

- Based on the generation, propagation and detection of electromagnetic waves with a frequency range from tens of kHz to hundreds of GHz.
- Multiplexing techniques: time, frequency or code-division multiplexing.
- Their use leads to modulation, bandpass filtering, demodulation circuitry, and additional circuitry, all of which needs to be considered, based on power consumption.

Problems with RF comm..

- Large size of antenna.
- RF communication can only be achieved by using time, frequency or code division.
- TDMA, FDMA, and CDMA have their own complications.

Passive Laser based comm..

- Downlink communication (BST to dust)- the base station points a modulated laser beam at a node.Dust uses a simple optical receiver to decode the incoming message
- Uplink communication (dust to BST)- the base station points an un-modulated laser beam at a node, which in turn modulates and reflects back the beam to the BST

Advantages

- Optical transceivers require only simple baseband analog and digital circuitry; no modulators, active bandpass filters or demodulators are needed.
- The short wavelength of visible or near-infrared light (of the order of 1 micron) makes it possible for a millimeter-scale device to emit a narrow beam (i.e. high antenna gain can be achieved).

Advantages cont…

- A base-station transceiver (BTS) equipped with a compact imaging receiver can decode the simultaneous transmissions from a large number of dust motes at different locations within the receiver field of view, which is a form of space-division multiplexing.
- The CCR makes make it possible for dust motes to use passive optical transmission techniques, i.e., to transmit modulated optical signals without supplying any optical power.

Limitations

- Is a single-hop network topology, where dust nodes cannot directly communicate with each other, but only with a base station.
- Communication may suffer from variable delays if the laser beam is not already pointing at a node that is subject to communication with the BST.

Active Laser Based comm..

- Has a semiconductor laser, a collimating lens and a beam-steering micro-mirror.
- Uses an active-steered laser-diode based transmitter to send a collimated laser beam to a base station .
- Suitable for peer-to-peer comm.., provided there exist a line of sight path between the motes.

Advantages

- One can form multi-hop networks using active laser based comm..
- Burst-mode communication provides the most energy-efficient way to schedule the multi-hop network.
- The active laser-diode transmitter operates at up to several tens of megabits per second for a few milliseconds

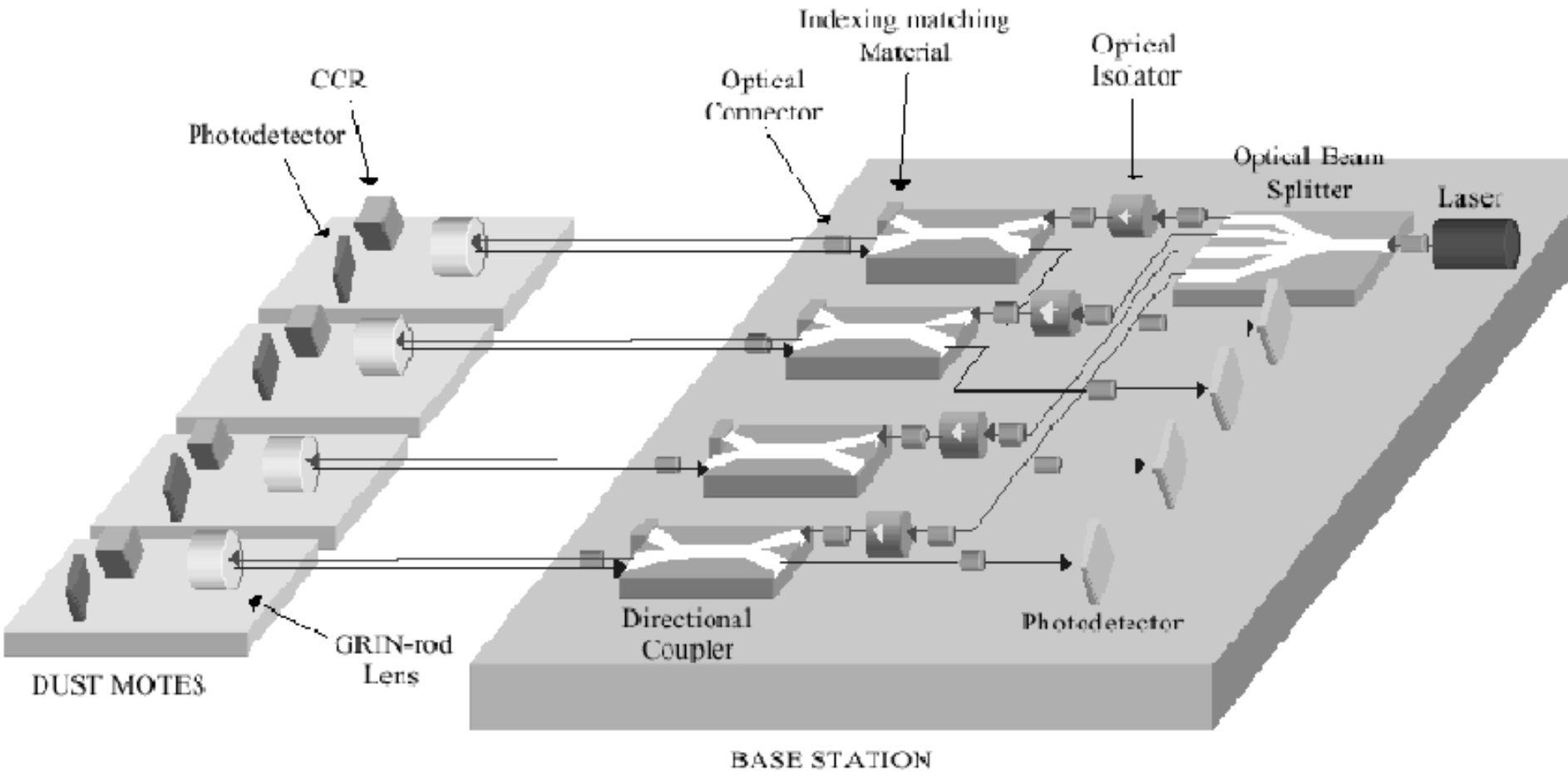
Disadvantages

- Relatively high power consumption .
- Thus can be used only for a short duration burst-mode communication.
- Components like active beam-steering mechanism makes the design of the dust mote more complicated.

Fiber Optic comm..

- Employs semiconductor laser, fiber cable and diode receiver to generate, transfer and detect the optical signal.
- Similar to passive optical comm..
- Relatively small size of the optical transceiver is employed with low-power operation.
- CCR employed on each Dust mote to modulate uplink data to base station.

Fiber Optic comm. setup



Advantages

- Does not require unbroken line-of-sight and the link directionality.
- Each dust mote does not need to employ more than one CCR.
- Comm.. between dust motes and a base station can be guaranteed.
- It has a longer range of communication link than that of a free space passive optical comm..

Limitations

- Optical fiber cables restrict the mobility of dust mote.
- Since a base station should employ several optical components for fiber connection to each dust mote, it may complicate base station design.

Applications

- Environmental protection (identification and monitoring of pollution).
- Habitat monitoring (observing the behavior of the animals in there natural habitat).
- Military application (monitoring activities in inaccessible areas, accompany soldiers and alert them to any poisons or dangerous biological substances in the air).
- Indoor/Outdoor Environmental Monitoring.

Applications cont...

- Security and Tracking
- Health and Wellness Monitoring (enter human bodies and check for physiological problems).
- Factory and Process Automation.
- Seismic and Structural Monitoring.
- Monitor traffic and redirecting it.

Conclusion

There are many ongoing researches on Smart Dust, the main purpose of these researches is to make Smart Dust mote as small as possible and to make it available at as low price as possible. Soon we will see Smart Dust being used in varied application from all spans of life.

References

1. Yunbin Song: ”Optical Communication Systems for Smart Dust”
2. J. M. Kahn, R. H. Katz, K. S. J. Pister: Next Century Challenges:

Mobile Networking for “Smart Dust”

3. An Introduction to Microelectromechancal System Engineering: Nadim Maluf, Kirt William
4. B.A. Warneke, M.D. Scott, B.S. Leibowitz: Distributed Wireless Sensor Network
5. http://www.coe.berkeley.edu/labnotes

Thank You!