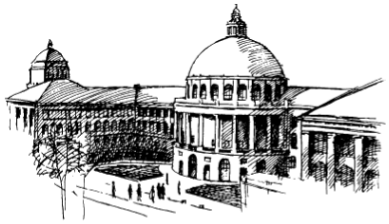
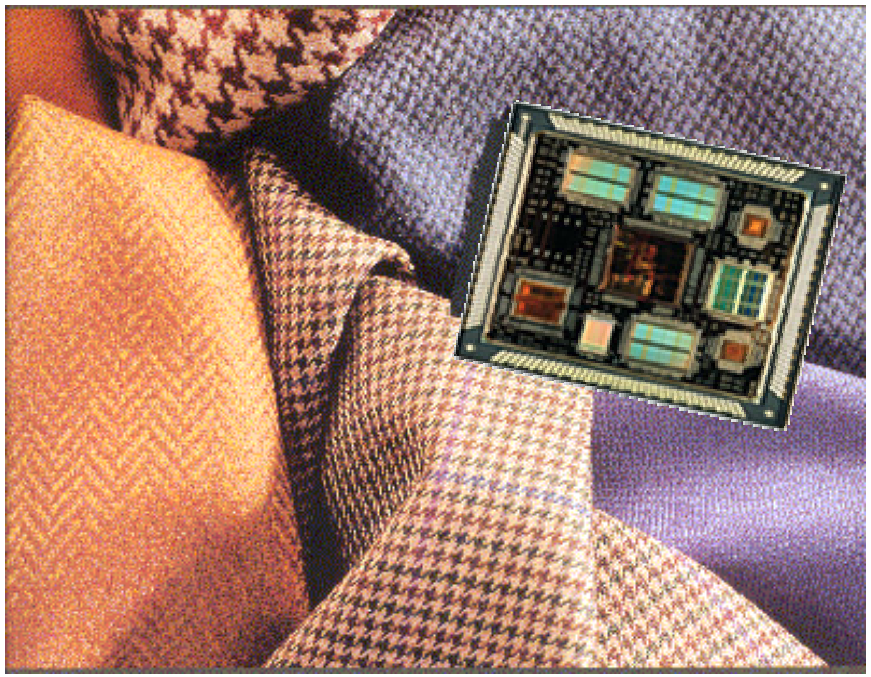


Electronic Textiles

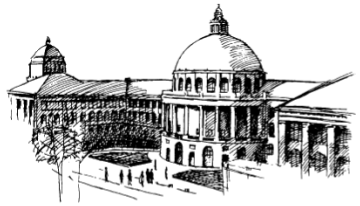


...opposites attract?

Ivo Locher
Dr. Tünde Kirstein

ICEWES'02

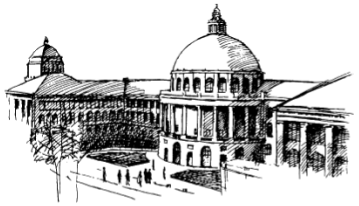
Suitability ?



- **We want to determine the suitability of textiles for signal transmission in Wearables**
  - Characterization of electrical properties of conductive textiles is necessary.
  - Utilization of electrical engineering measurement methods for characterization

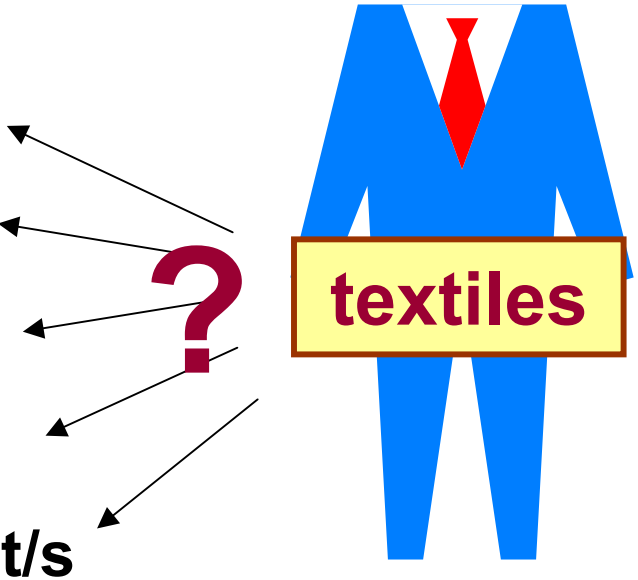
Can textile replace regular printed circuit boards?

Speed ?

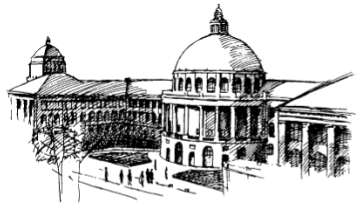


How many bits/sec can we transmit from tip to toe through textiles?

- **Analog Modem** **56 kbit/s**
- **Bluetooth** **1 Mbit/s**
- **WLAN (IEEE 802.11)** **11 Mbit/s**
- **LAN (Ethernet)** **100 Mbit/s**
- **PCI Bus** **> 700 Mbit/s**



Textiles under Test

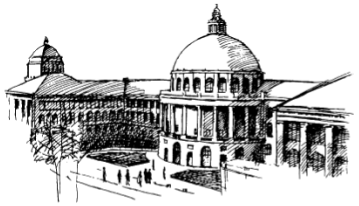


Textiles used in our experiments:

- Woven fabrics with insulated metal fibers
- Metal fibers are twisted with polyester yarns
- Different yarn fineness and direction of conductive fibers

Yarn Ø	Copper fiber Ø
228µm	40µm
334µm	40µm

Textile Geometry

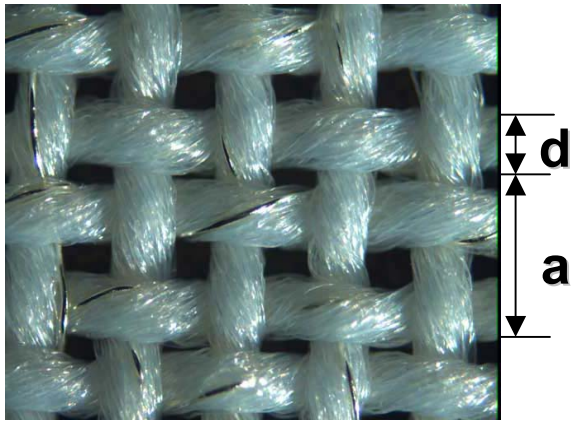


Irregularities in textile geometry

- Variations of yarn diameters (i)
- Variations of yarn distances (ii)
- Bending of yarn within plane (iii)

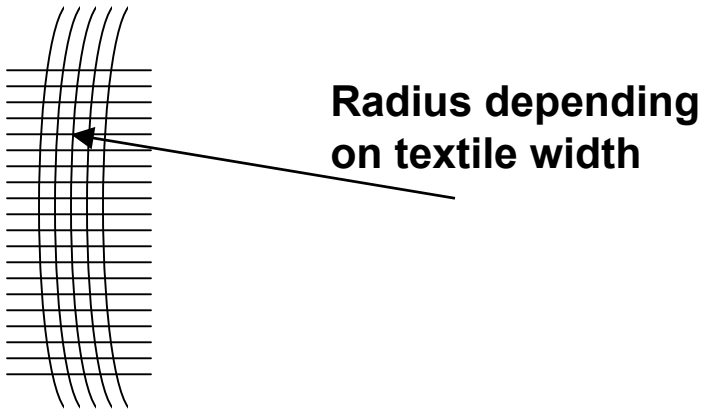
Example to (i) and (ii)

dimensions	variations
d=334µm	σ=28.0µm
a=876µm	σ=25.0µm

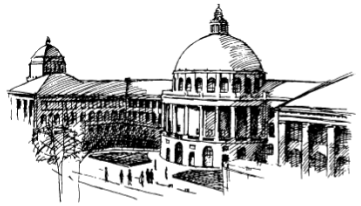


Distributor: Elektro-Feindraht AG

Example to (iii)

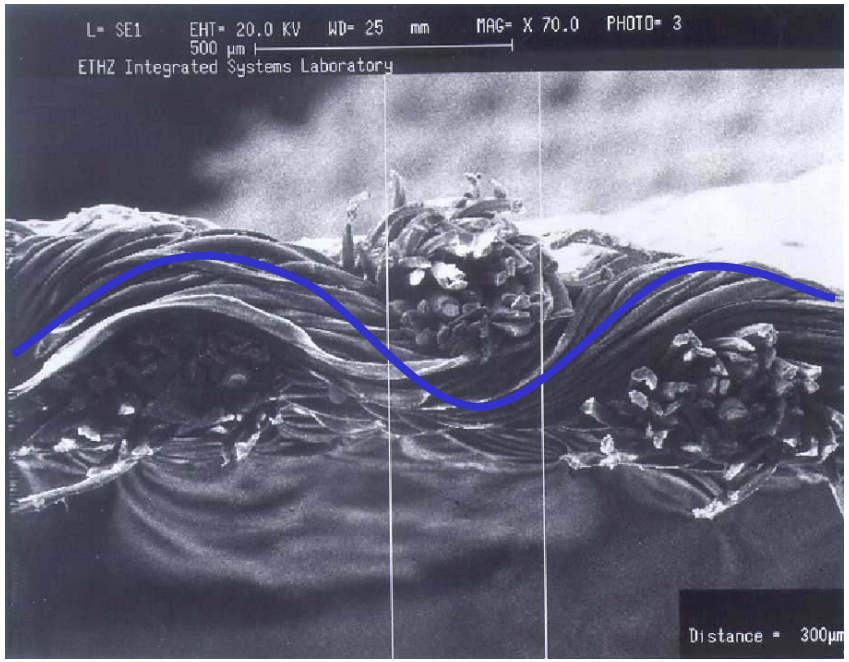


Conductor in Yarn



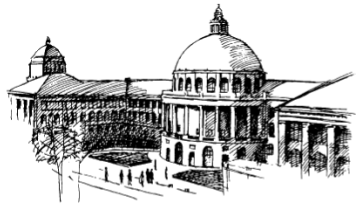
- Fibers follow a helical path within the yarn
- Yarns are periodically bent in woven structure

⇒ Result: electrical length of conductive fiber is greater than length of fabric



Yarn Ø	Length of conductive fiber compared to fabric
228µm	+7.5% (tolerance 0.5%)
334µm	+25.5% (tolerance 2.0%)

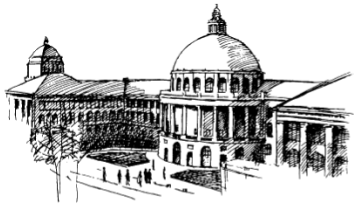
Characterization



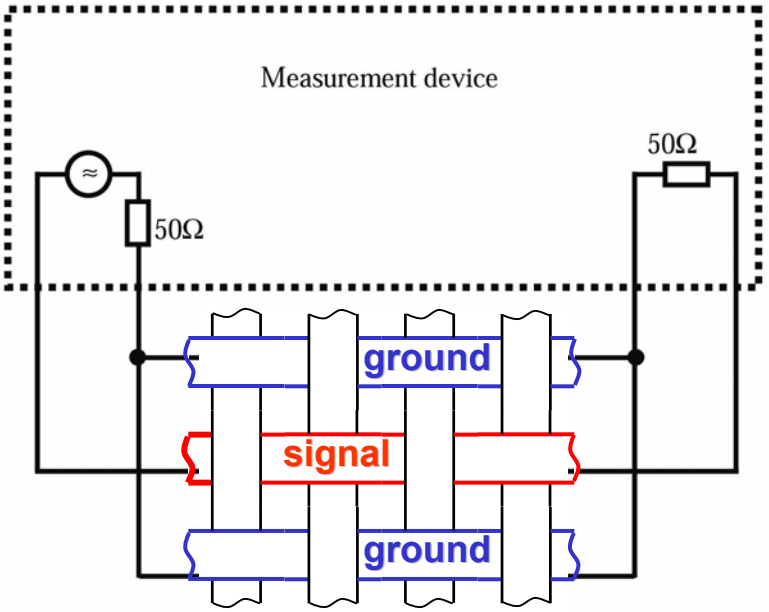
Measurements:

- **Electrical impedance**
- **Characteristic impedance Z_0**
- **Frequency Response (Bandwidth)**
- **Cross-Talk**
- **Digital Signal Transmission Analysis**

Measurement Setup

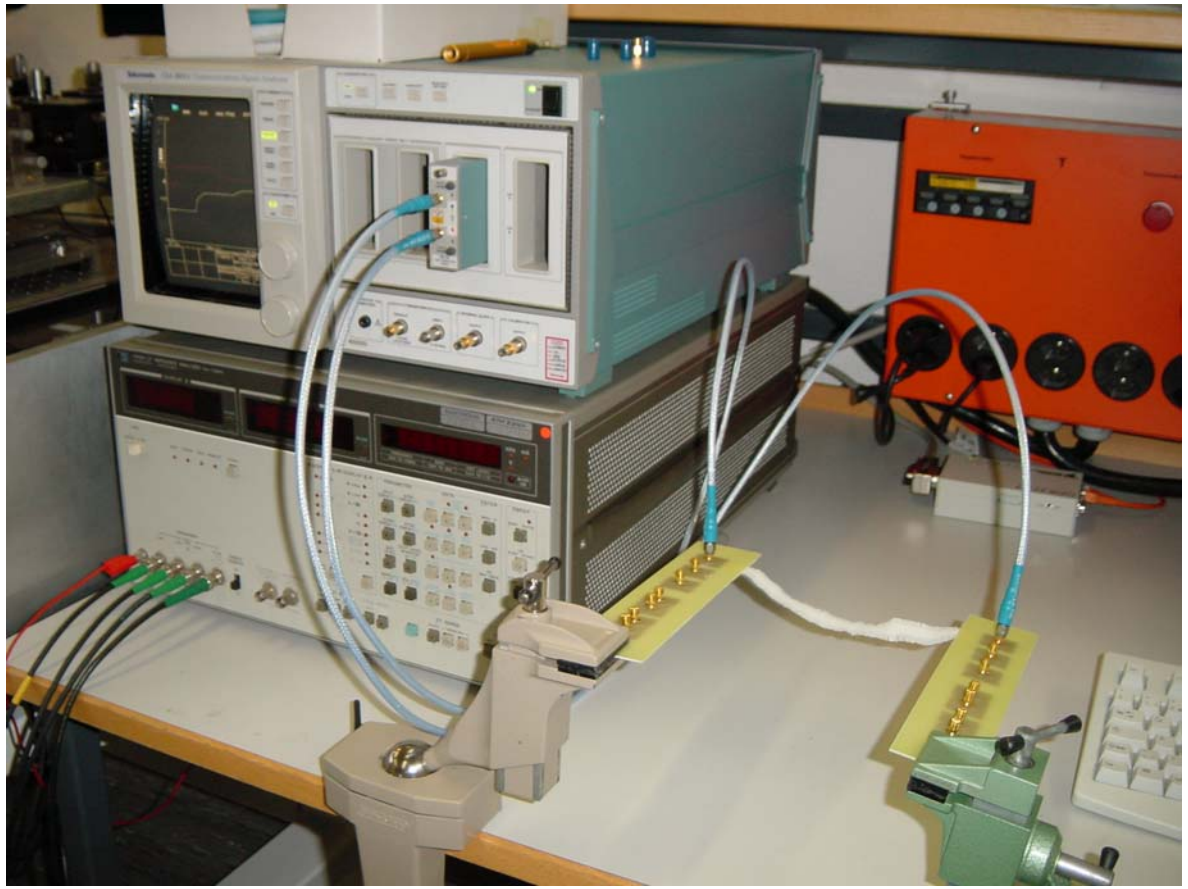


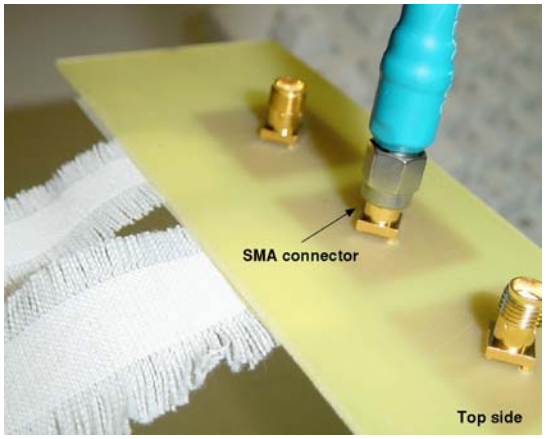
- For time and frequency domain analysis
- Utilization of different number of signal line configurations

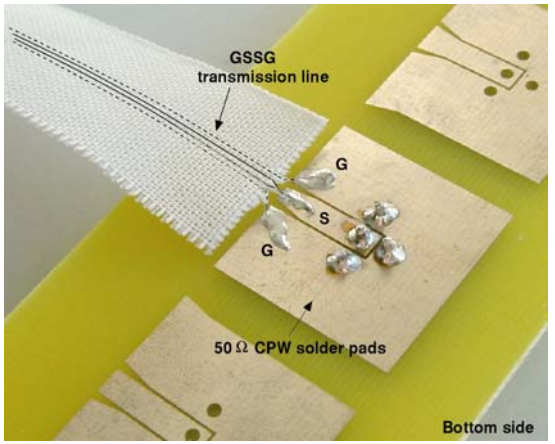


configurations:
- GS (1 signal line)
- GSG (1 signal line)
- GSSG (2 signal lines)
- GSSSG (3 signal lines)

Measurement Setup (cont'd)

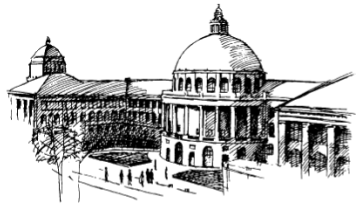




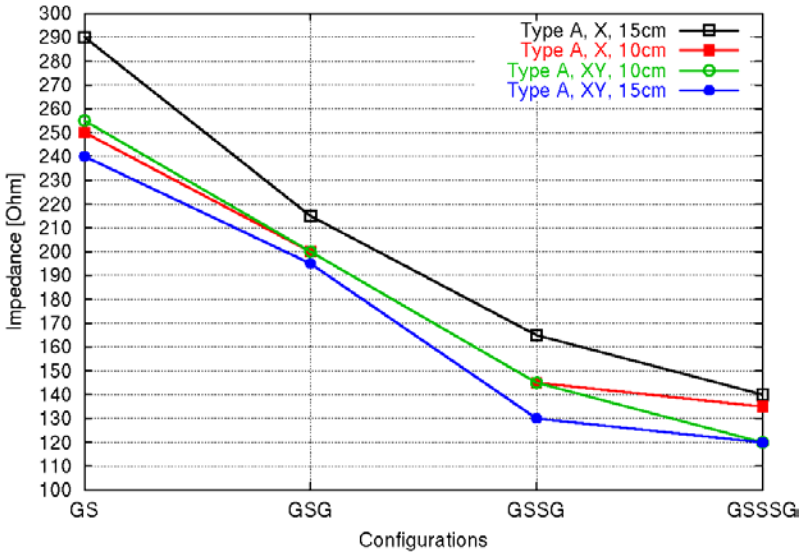


For time and frequency domain analysis

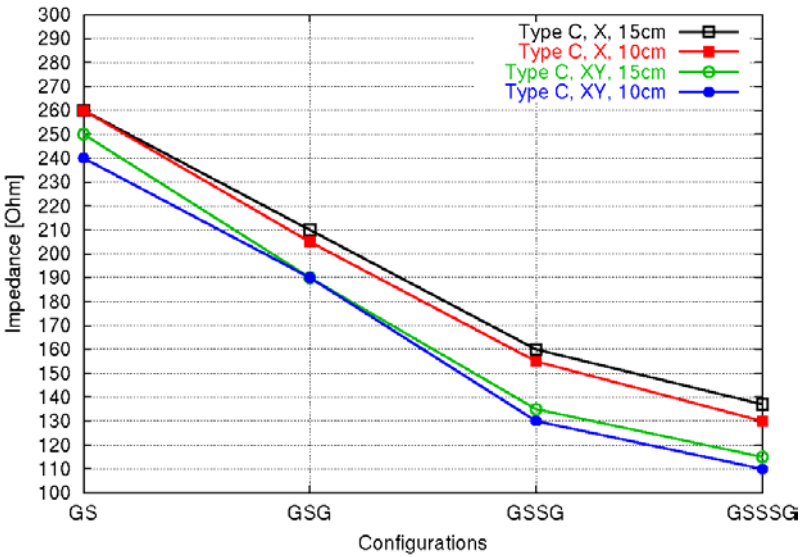
Characteristic Impedances Z_0



- As number of signal lines increases, the characteristic impedance decreases.
- Impedance variations (about 10%) along the signal line caused by geometric irregularities within textile

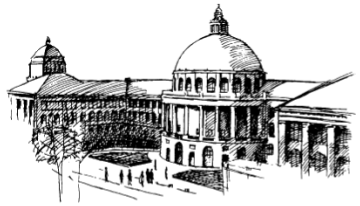


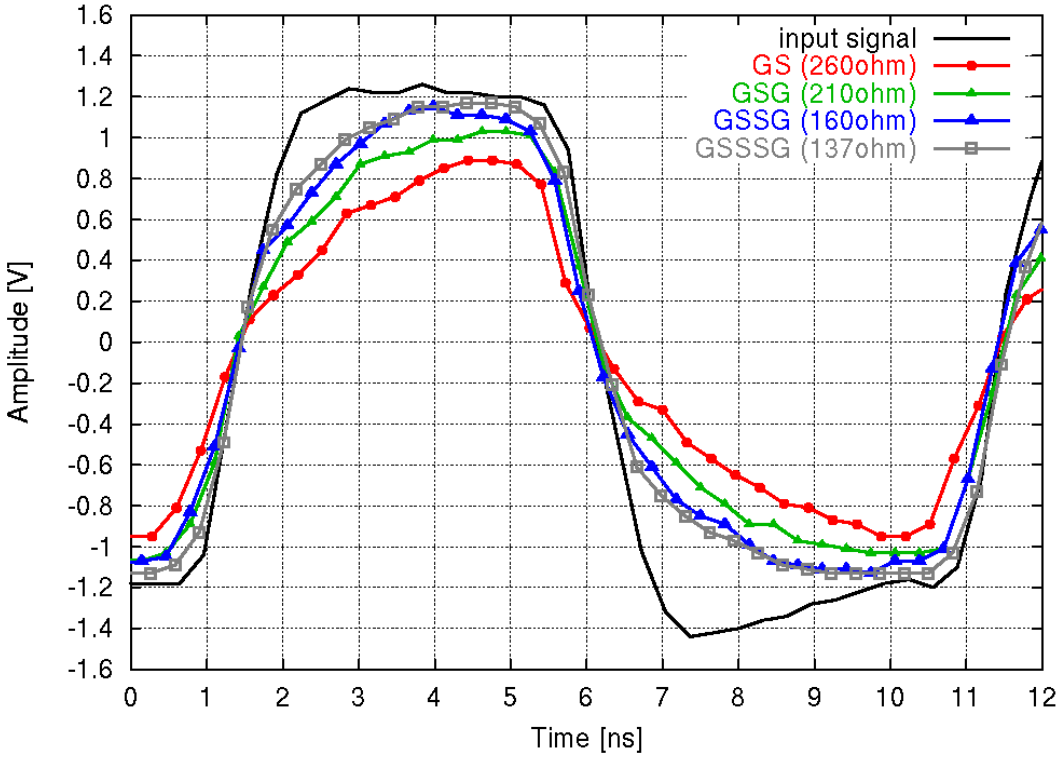
Ø 228µm



Ø 334µm

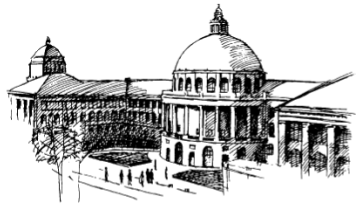
Digital Signal Transmission





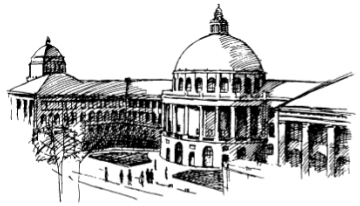
- **Good signal integrity at 100MHz and 20cm line length**
- **As fast as LAN (Ethernet)**

Conclusions



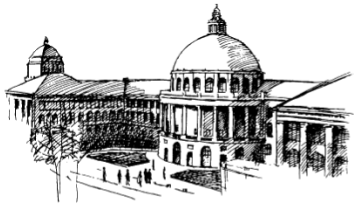
- **We have introduced electrical engineering methods for characterization of conductive textiles**
  - Electrical Impedance
  - Characteristic Impedance Z_0
  - Frequency Response
  - Cross-Talk
  - Digital Signal Transmission Analysis
- **High signal integrity up to several 100MHz.**
- **These results are fundamental for interconnections among truly wearable computers**

Current & Future Work



- **Investigation of wearing stresses**
- **Realization of electrical circuits and connectors in textiles**
- **First applications in:**
  - Medical prevention
  - Medical monitoring

The „Wearable Revolution“



- **Advances in:**
  - Textile technology
  - Material science
  - Computing
- **Interdisciplinary research necessary!**

Electronic  **Textiles**