Self-sufficient Sensors in Automation Technology – Requirements from the Application Side

Results from the "EnAS" funded research project

Self-powered sensor actuator systems
for wireless networked intelligent factory automation

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next generation media

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Structure

- Motivation
- Objective
- Previous results
  - Wireless communication
  - Power supply
  - Application examples
- Outlook

"Wireless" - just a major trend?

Tangible benefits in automation technology

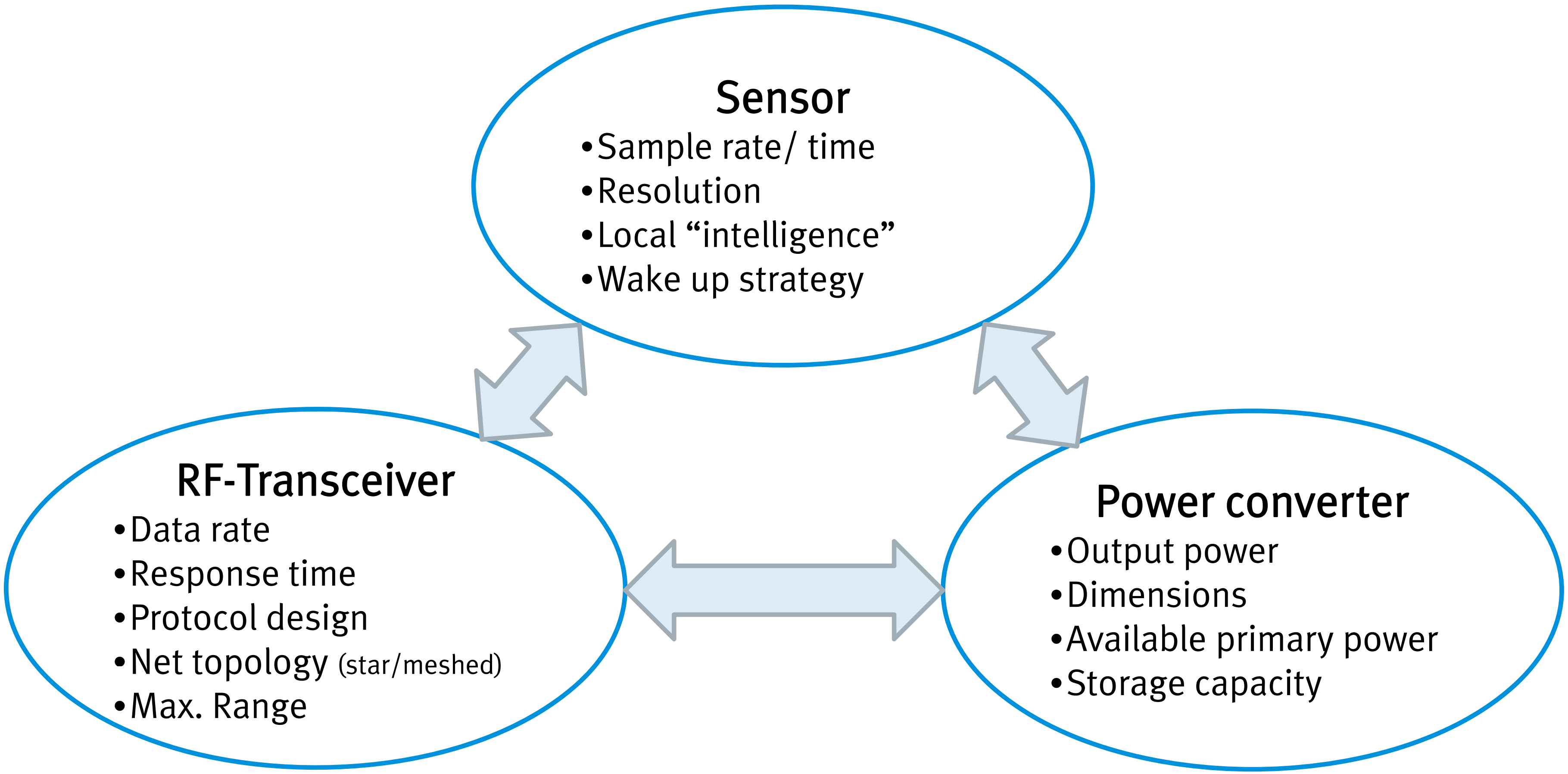
- High flexibility for system modifications
- Low system costs
- New fields of application
- High availability of information

Main shortcomings

Power supply for distributed sensors and actuators not satisfactorily resolved yet!

- Complex wiring leads to high costs and limited availability
- Suitable radio standard not yet established!
- Power consumption is too high and/ or power supply is not sufficient
- Primary batteries are often seen as problematic

The Power – Performance dilemma



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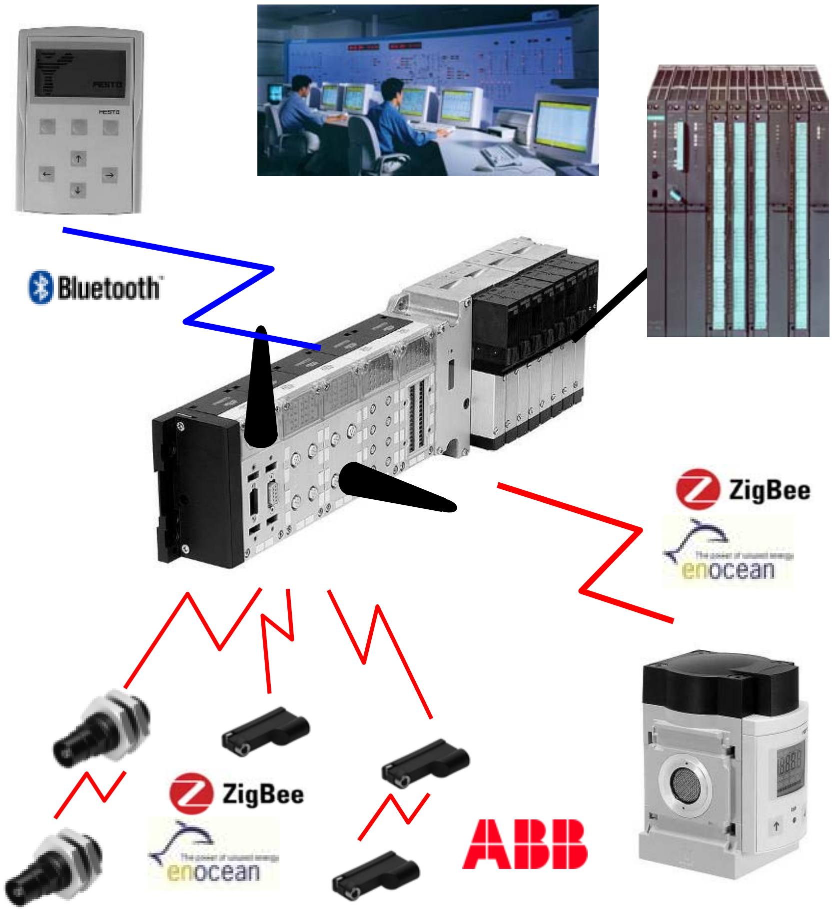
Objective

- Wireless sensor and actuator network for industrial automation technology

  - Self powered system

  - Reliable communication technology

  - Self-organising distributed control concept



Participating partners

- Festo AG & Co KG, Esslingen
- EnOcean GmbH, Oberhaching
- FhG Technologieentwicklungsgruppe, Stuttgart
- Technische Universität Ilmenau
- InTraCom, Stuttgart
- Helmut Schmidt University, Hamburg
- Martin Luther University, Halle

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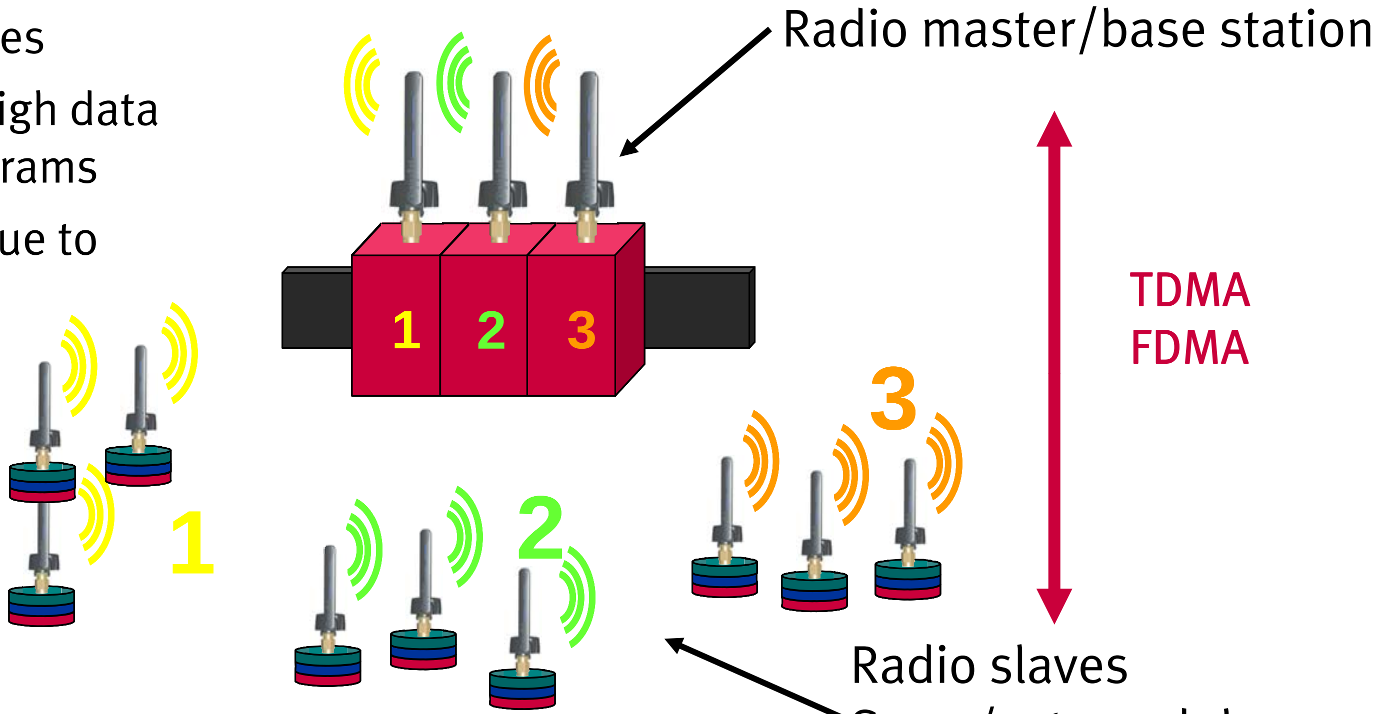
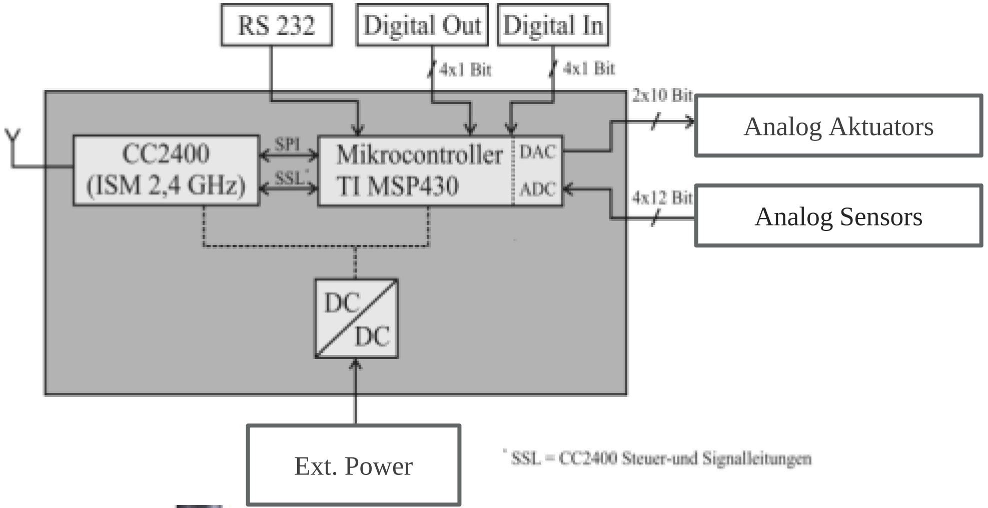
High speed radio concept: Cellular and modular system

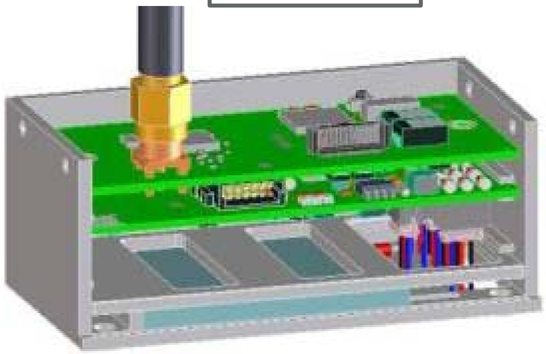
- Low latency through the use of several frequencies
- Low power due to high data rate and short telegrams
- Good coexistence due to frequency hopping
- Scalability



Implemented sensor/actuator module

- Low power µ controller
- Radio module for high data rates
- Sensor interface for
  - 4 x analogue in (12 bit)
  - 2 x analogue out (8 or 12 bit)
  - 4 x digital in
  - 4 x digital out





Power spectrum of the sensor/actuator module (SAM)

Measurement results:

Medium power consumption of 10.13 mW
in the following operating conditions:

- FDMA/TDMA with frequency hopping feature
- Super frame cycle of T_{SF} = 6 ms

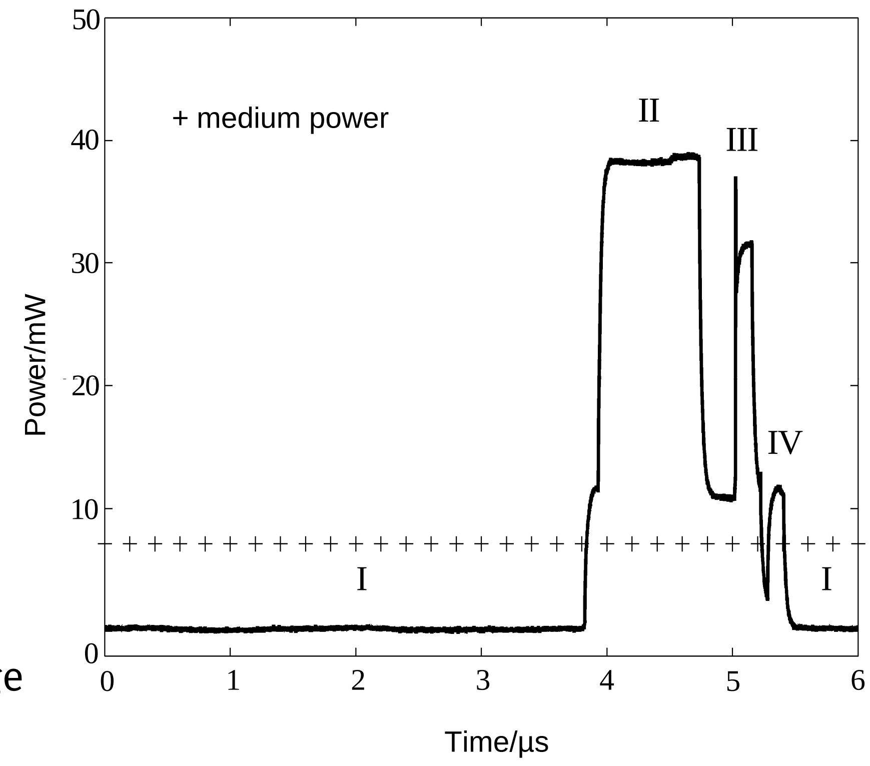
➔ Lower data rate?

Phase I : Standby status

Phase II : Receive mode

Phase III : Transmit mode

Phase IV : Frequency change



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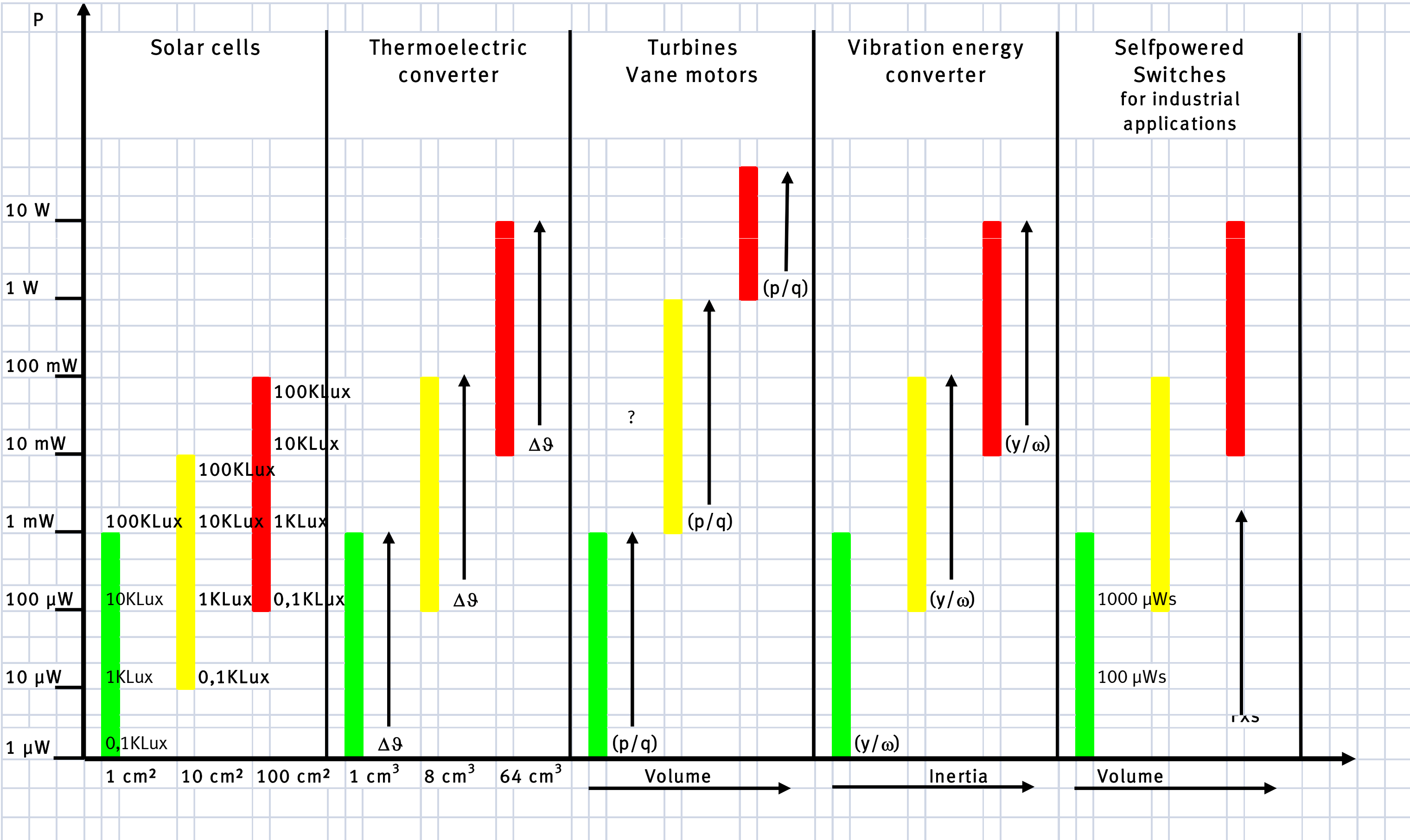
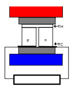
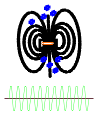
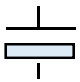
Possible energy transducers



A different view




Energy Source	**Power**	Unit	**Energy** (per life of) 5 years; Wh	**Av. Power** w/o service over life in mW	**Cost** (no service) w/o encaps. USD	**Fig. of merit** Wh/USD/risk	**Risks** w/o power 1=very low 4=very high
PV 1000 Lux a-Si	0,034	mW/cm²	9,0	0,21	0,3	15,0	2
PV 100 Lux a-Si*	0,0029	mW/cm²	0,8	0,02	0,3	1,3	2
PV 1000 Lux GaAs*	0,102	mW/cm²	26,9	0,62	3	3,0	3
Thermal (thin film) * dT=10K	0,0063	mW/cm²	1,0	0,02	1	0,3	3
HF 100 kHz (7A/m)	1	mW/cm³	105,7	2,41	1	52,8	2
HF 13 MHz	0,23	mW/cm³	24,3	0,55	1,5	8,1	2
HF 433 MHZ*	0,3	mW	13,1	0,30	2	3,3	2
Batterie LiSoCl2	1,1	Wh/cm³	2,7	0,06	2	1,3	1
Batterie AlMn	0,32	Wh/cm³	0,8	0,02	0,2	3,9	1
Fuel Cell, H2 20MPa	0,25	Wh/cm³	0,6	0,01	5	0,03	4
Fuel Cell, Hydrid H2	1	Wh/cm³	2,4	0,06	5	0,16	3
Fuel Cell, Methanol	2,2	Wh/cm³	5,3	0,12	2	0,66	4

(6 cm², 3 cm³ volume) Source: ABB

Highly efficient solar cells

- Fraunhofer ISE solar cells:
  various sizes, rectangular sizes,
  e.g. : 30 mm x 7 mm
- Modules arranged using shingle technique

  -> better use of space

  -> higher efficiency
- Serial production by RWE Space Solar Power GmbH in Heilbronn
- Large quantities (>5 Million wafers) per year no problem

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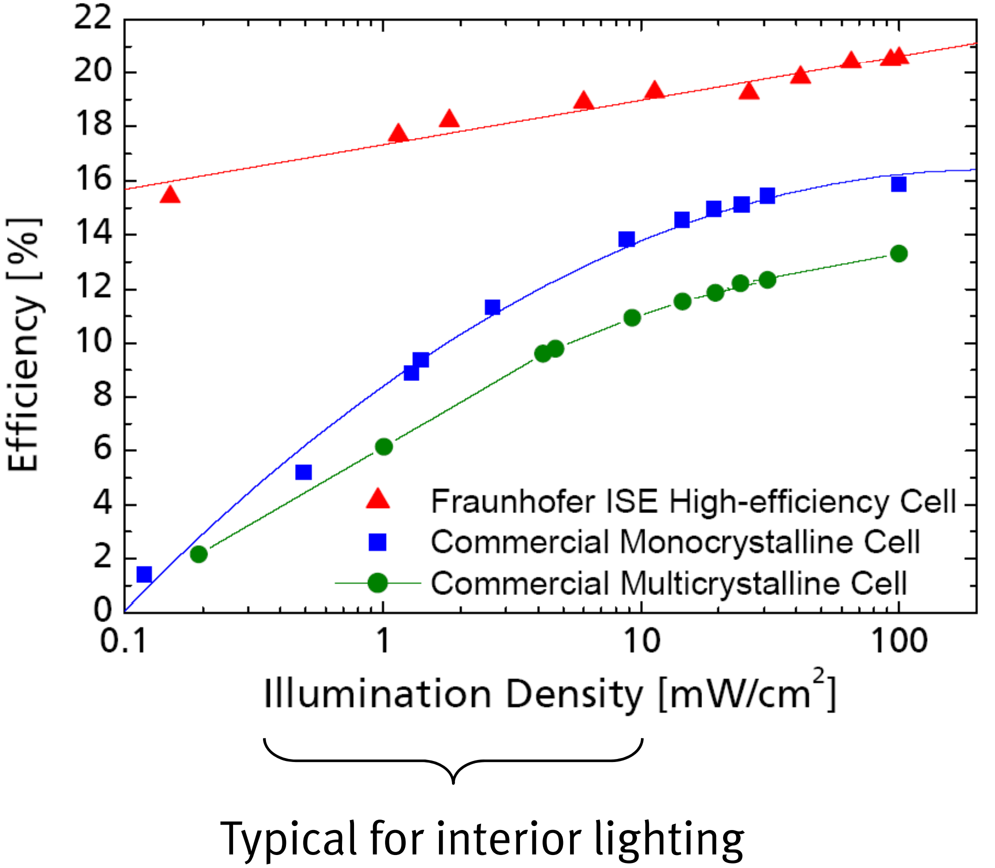
Fig.: FhG ISE cells and modules

Comparison of efficiency of different technologies



Source: Glunz et. al., Fraunhofer ISE

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Solar cell generator for indoors ‹ 200 lux

For the current consumer, including the STM100, differently sized solar supply areas for varying lighting conditions were made available and tested.

40 mm x 21 mm
STM100
sensor transmitter

648 mm^2
27.0 x 24.0
4.4 V x 6.0 µA

437 mm^2
48.5 mm x 9.0 mm
4.4V x 5.0 µA

853 mm^2
55.0 mm x 15.5 mm
3.6 V x 12.5 µA

2726 mm^2
56.1 mm x 48.6 mm
4.4 V x 36.0 µA

1857 mm^2
66.8 mm x 27.8 mm
4.4 V x 25.0 µA

363 mm^2
24.7 x 14.7
4.2 V x 5.0 µA

5518 mm^2
96.8 mm x 57.0 mm
5.8 V x 52.5 µA

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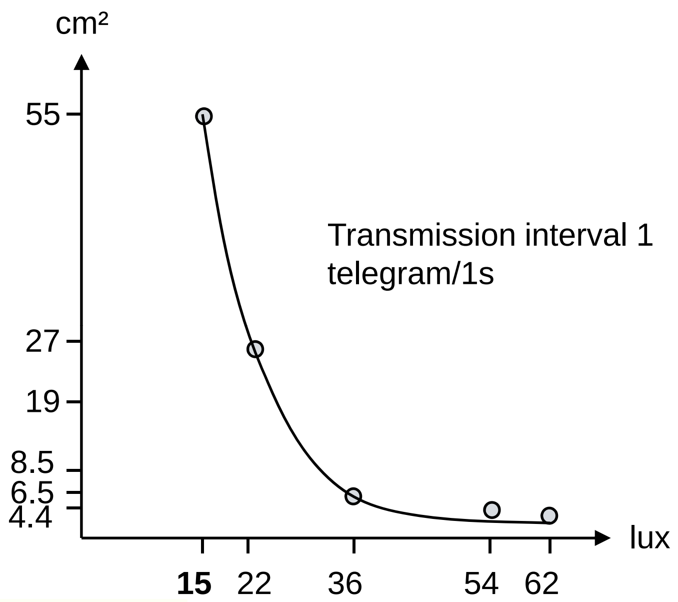
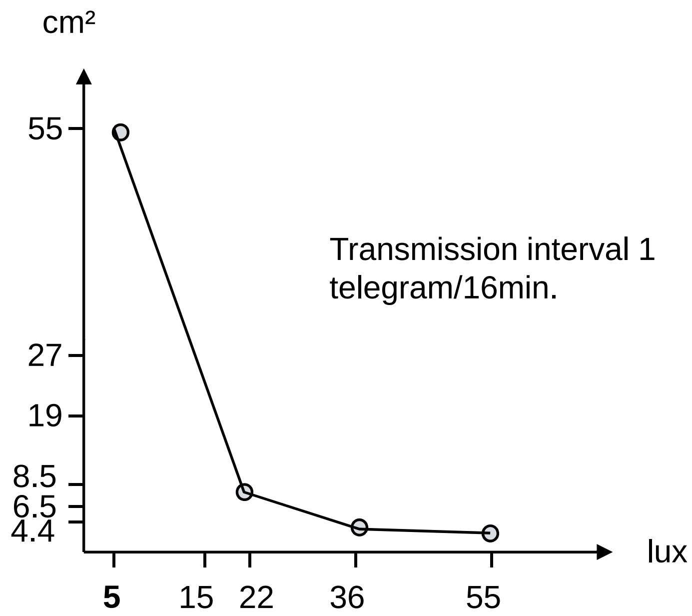
Operational readiness versus luminous intensity



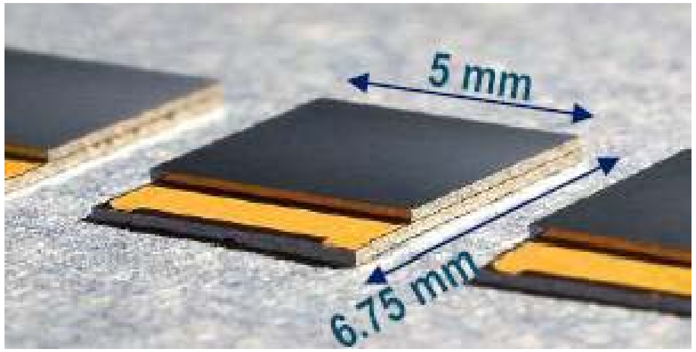


The graphic shows the required minimum luminous intensity (in lux) for operational readiness of the STM100, dependent on differently sized solar generators.

Thermal transducer designs

- 25 mm design[2] available:
  MPG-D901 with 240 leg pairs
  MPG-D902 with 480 leg pairs

- Mechanically stable modules: Manta SSMv1.0



To minimise thermal resistance:

- Bond with silver-filled epoxy (Hereaus)
- Soldering with indium (150°C)

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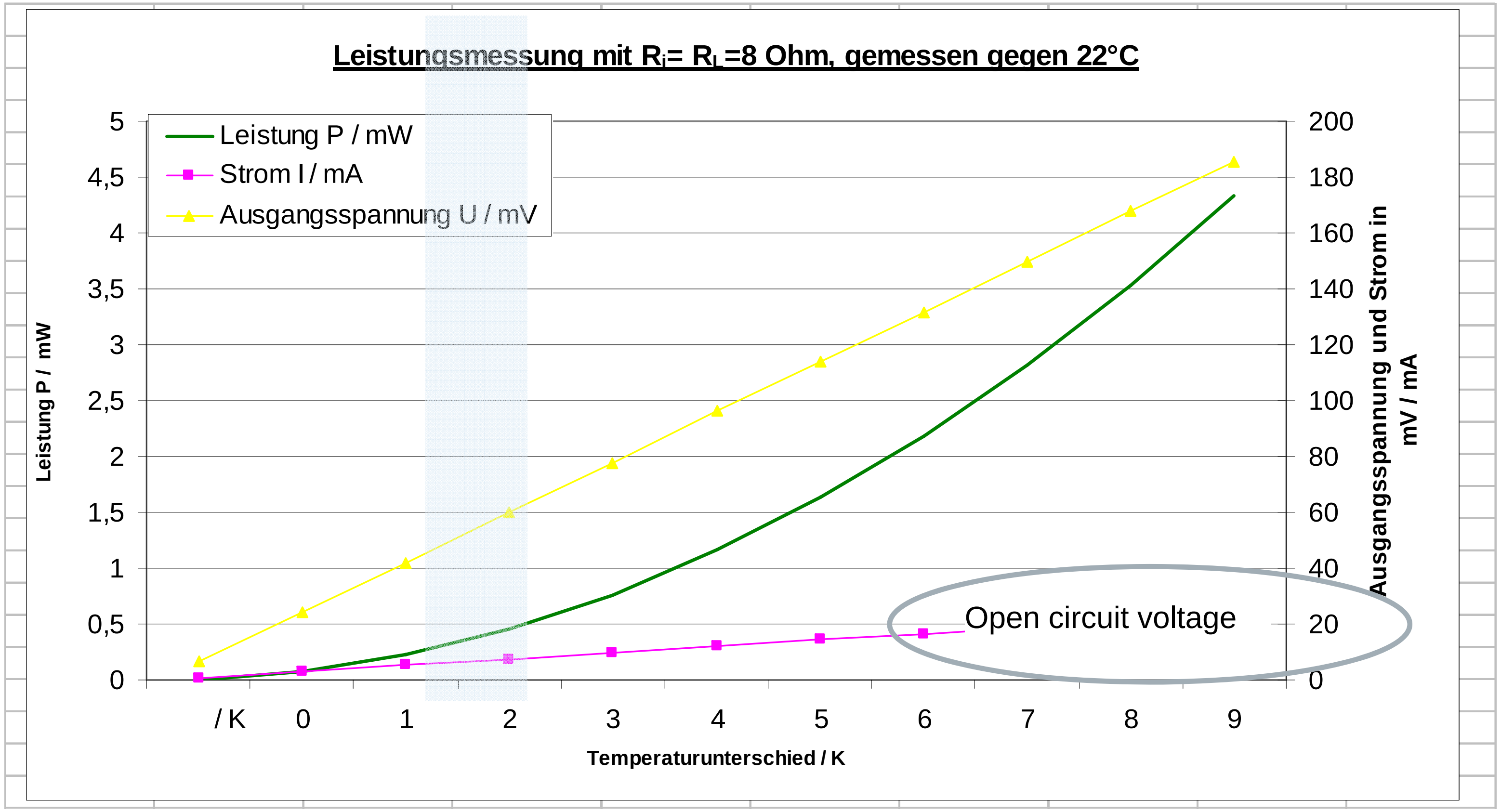
Fig.: Micropelt's Manta module

Micropelt module measurements



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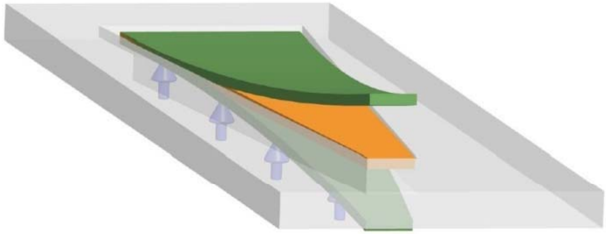
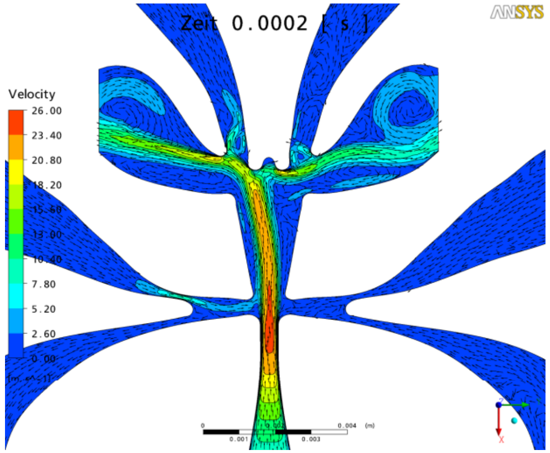
Energy Harvesting in Fluids

Piezoelectric cantilever in air stream

- Piezoelectric cantilever



Fluidic oscillator for generation of oscillations
(Fluidic Flip-Flop)



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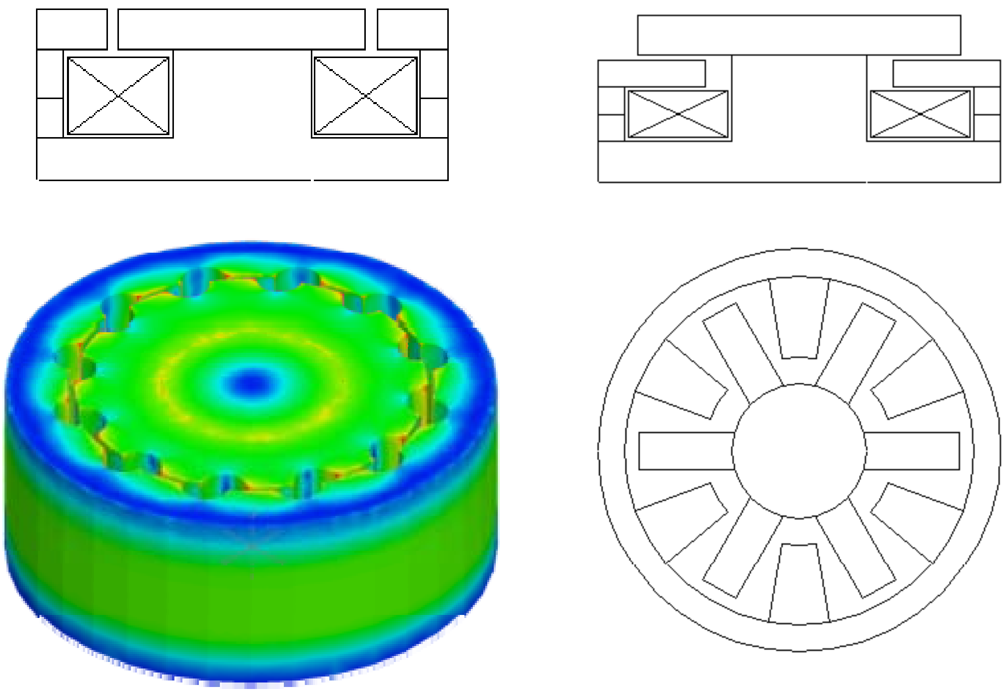
Electrodynamic rotary transducer

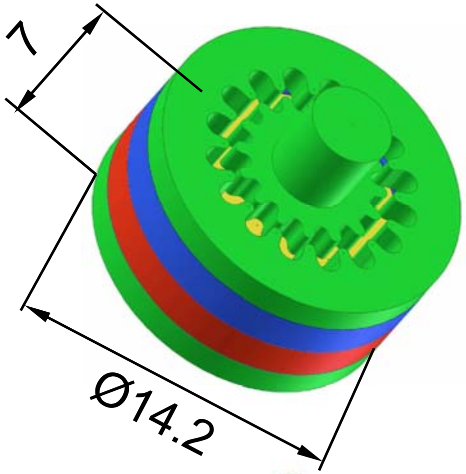
- Very good scalability
- High power output
- Technologies also available in micro system dimensions
- Different construction variants were investigated



Miniaturised rotary magnetic generators

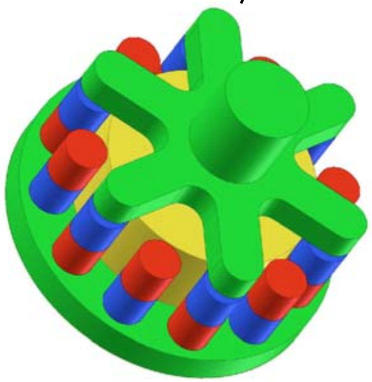
Model A:

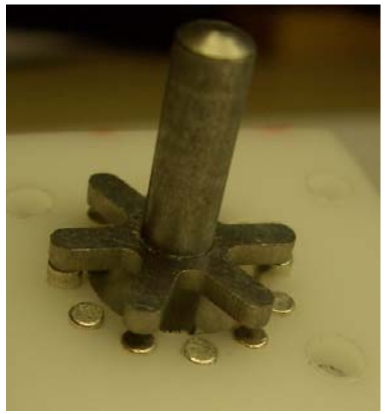
Synchronous machine
with reluctance rotor



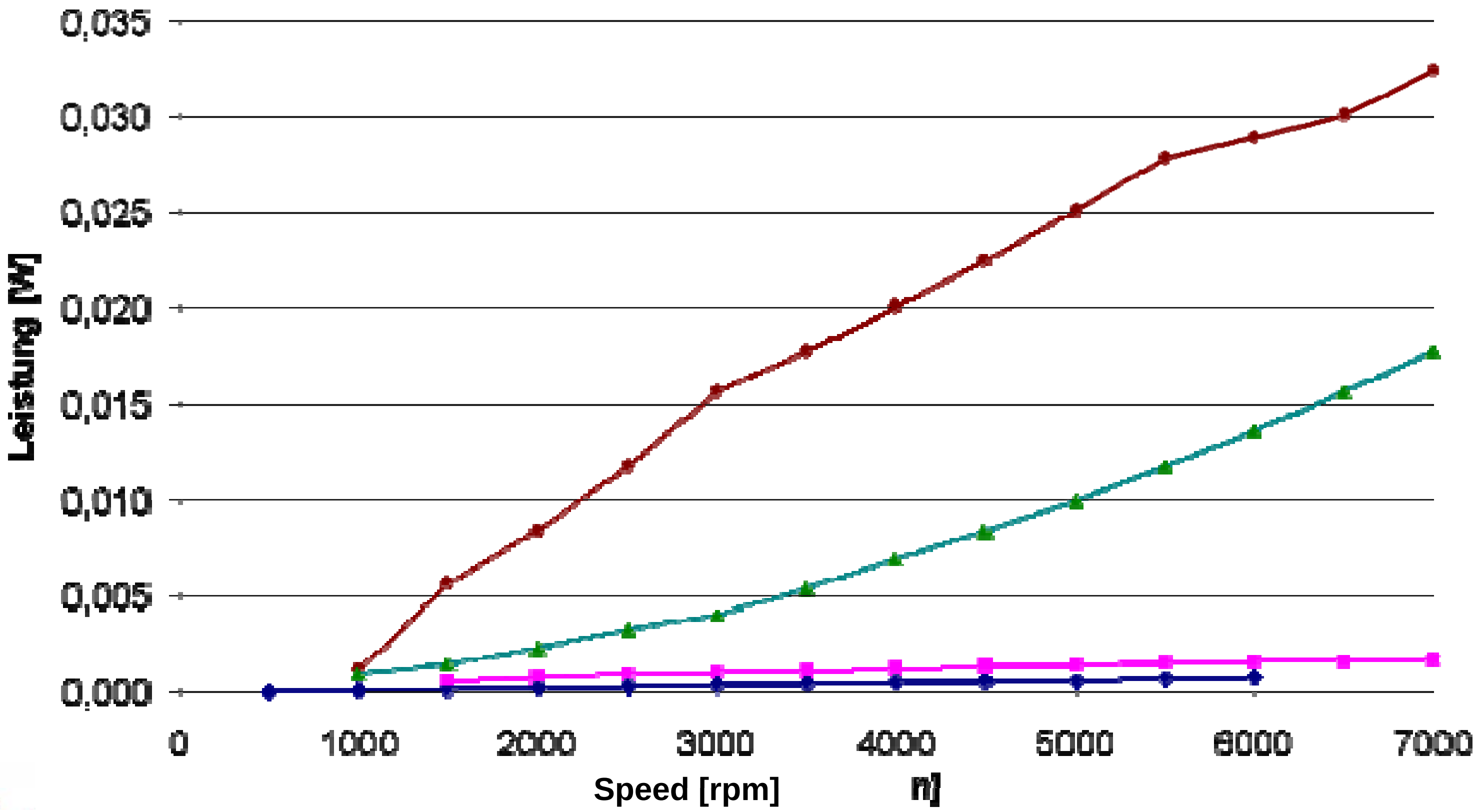
Model B:

Claw pole generator
with reluctance rotor





Power comparison



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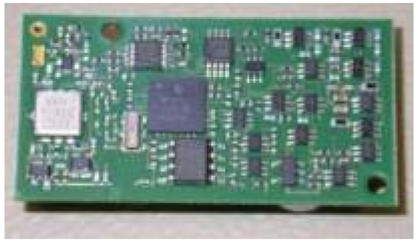
Universal sensor module useful for industry



Goals:

- Features for industrial use,

In particular:

- Option of configuration via serial interface
- Extended operating voltage range
- Short reaction times and accurate timer
- Optimised light sensitivity

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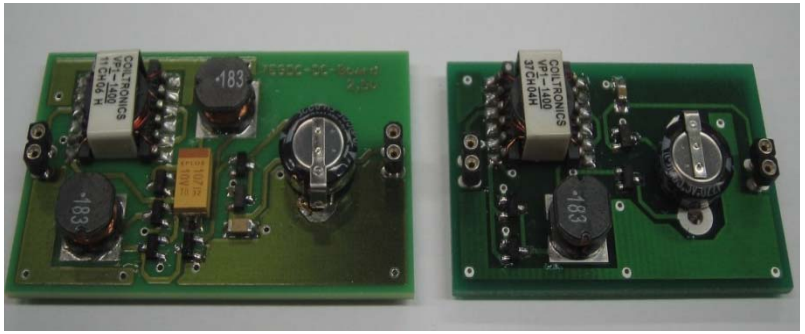
Electronic circuits

Low-voltage and low-power DC/DC-converters for solar cells and thermoelectric generators



Self powered intelligent
thermo flask demonstrating application of DC/DC converter.

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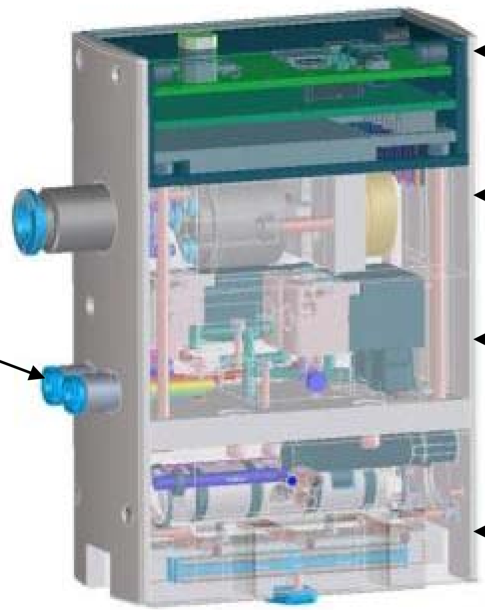
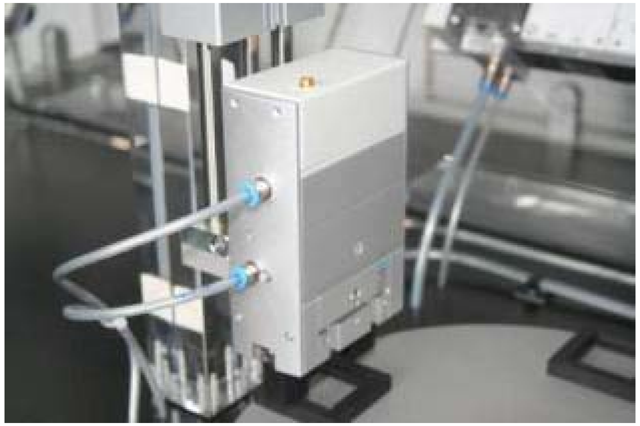
Demonstrator: monoenergetic grippers

- All important functions could be integrated into a sub-assembly





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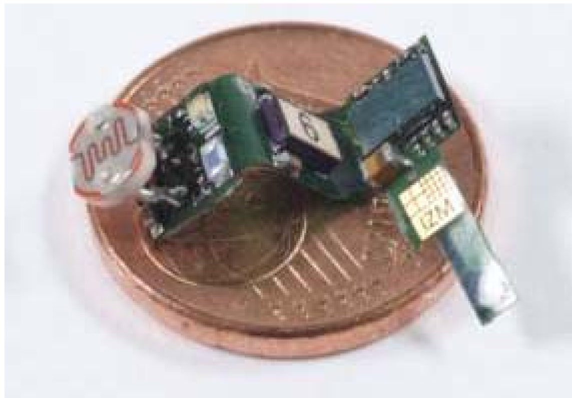
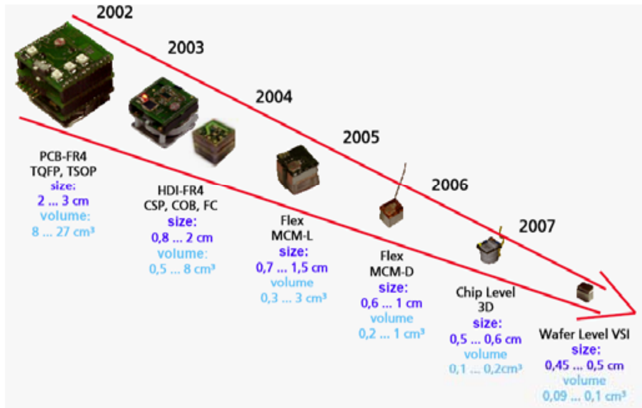
Outlook

- The feasibility of real time wireless communication has been proven. There is still further potential with regard to reliability and availability, however
- Several solutions for supplying power have been investigated.
  Smaller size is still desired, however
- The range of functions will be implemented in several demonstrators



Source: Fraunhofer IZM-SDI



Source: Fraunhofer IZM