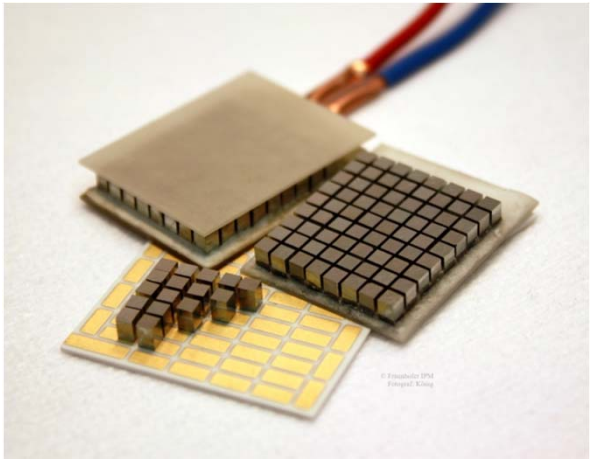
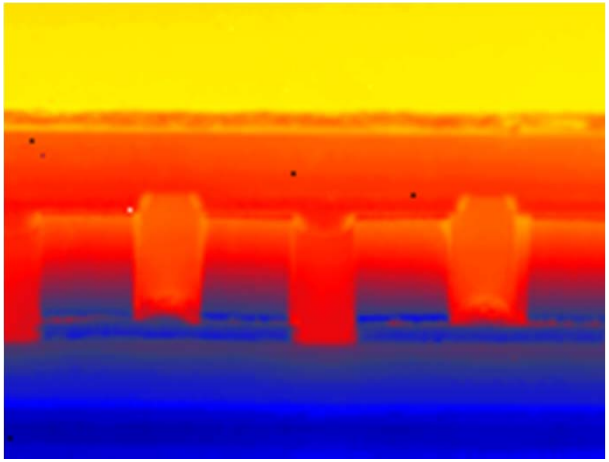
Overview of Fraunhofer IPM Activities in High Temperature Bulk Materials and Device Development

2011 Thermoelectrics Applications Workshop, Hotel Del Coronado, San Diego, CA, January 3-6



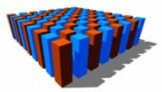


Jan D. König, K. Bartholomé, M. Jägle, H. Böttner

Fraunhofer Institute for Physical Measurement Techniques IPM

Dept. Thermoelectrics and Integrated Sensor Systems

Freiburg, Germany



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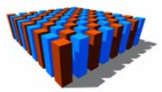


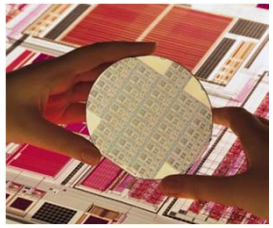
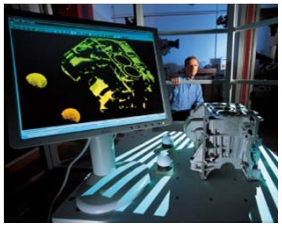
Fraunhofer IPM

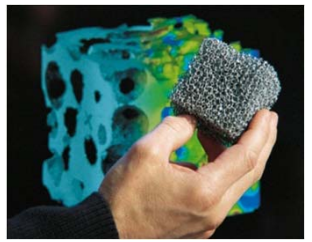
Fraunhofer-Gesellschaft

one of the leading organizations for application-oriented research in Europe

~13 000 number of employees

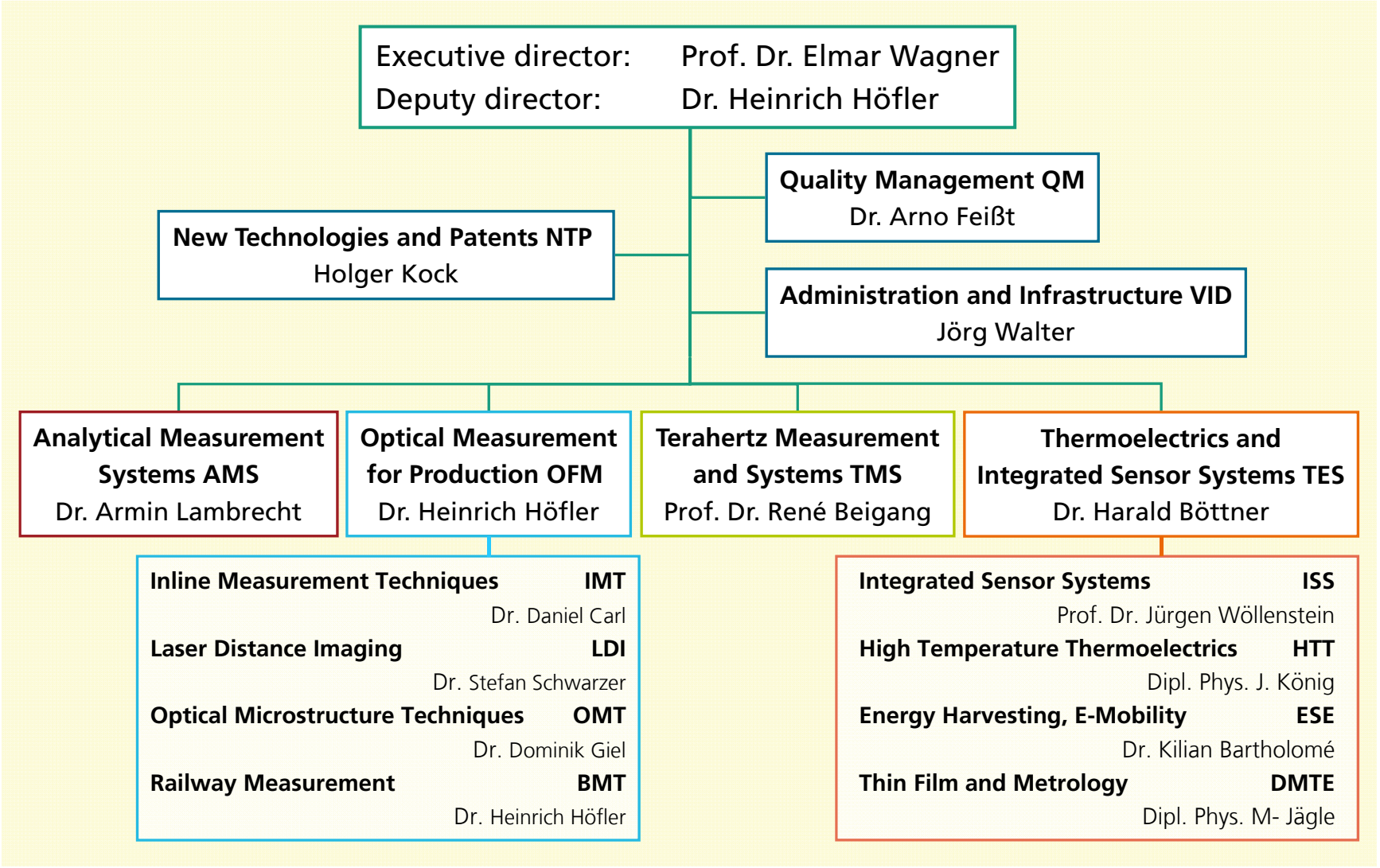
Fraunhofer has more than 80 research units, including 60 Fraunhofer Institutes in Germany.

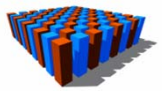




Fraunhofer IPM

Fraunhofer IPM's organization

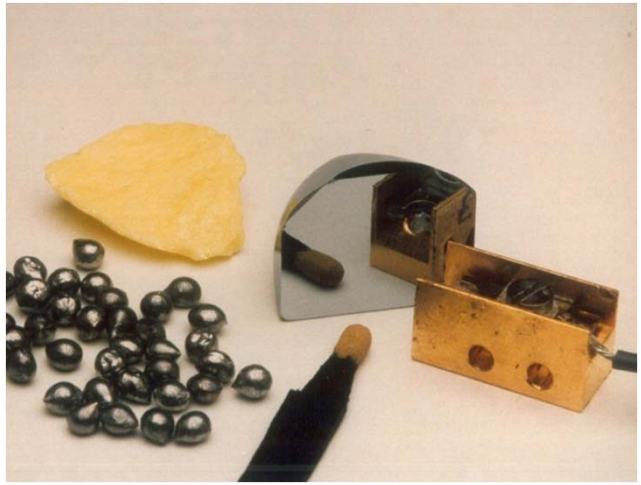


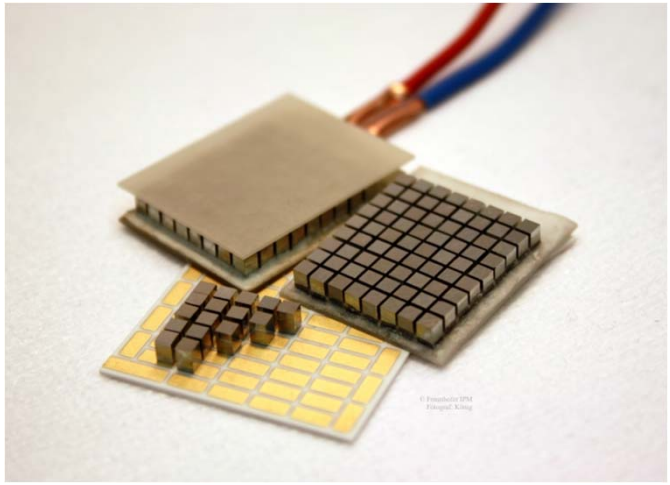


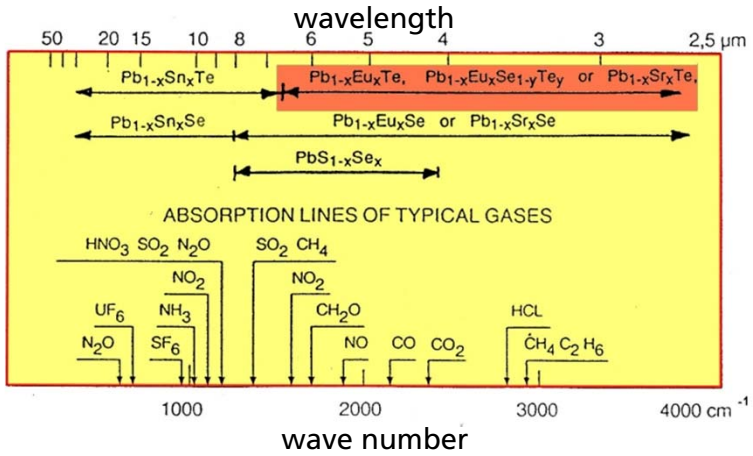
Fraunhofer IPM

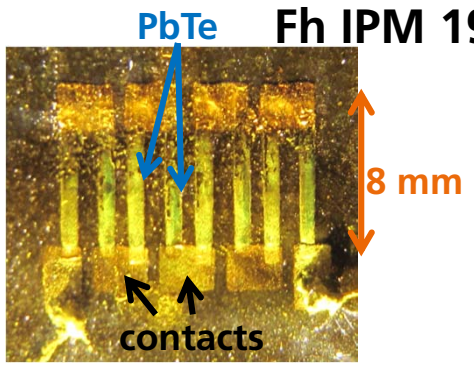
Starting Point of thermoelectrics at Fraunhofer IPM

Chalcogenides: From MIR-laser to thermoelectricity









Fraunhofer IPM

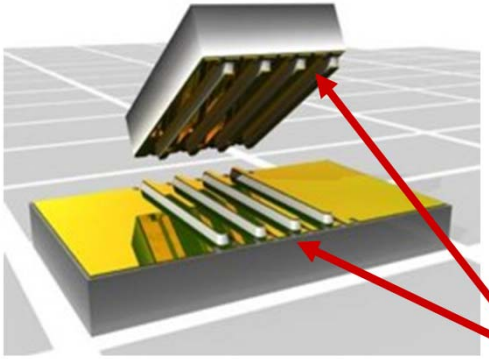
Thermoelectricity at Fraunhofer IPM

micropelt
Thin film thermoelectrics.

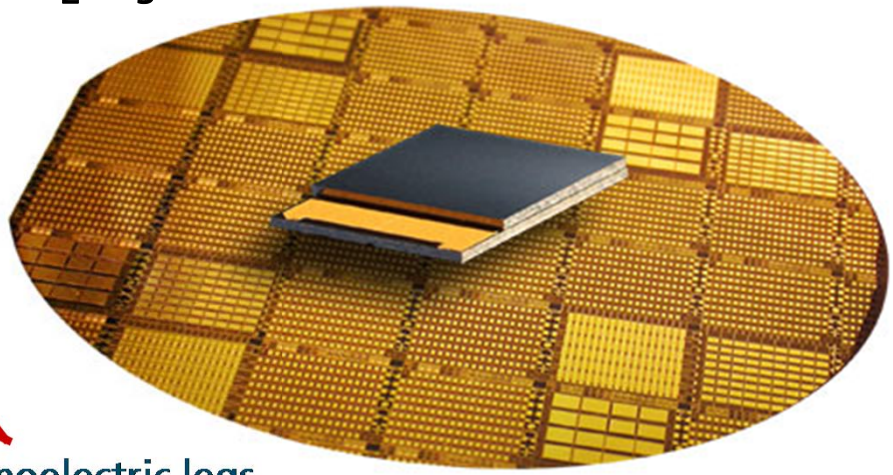
First Si-wafer based module fabrcation based on Bi_2Te_3

n/p-„Bi_2Te_3“

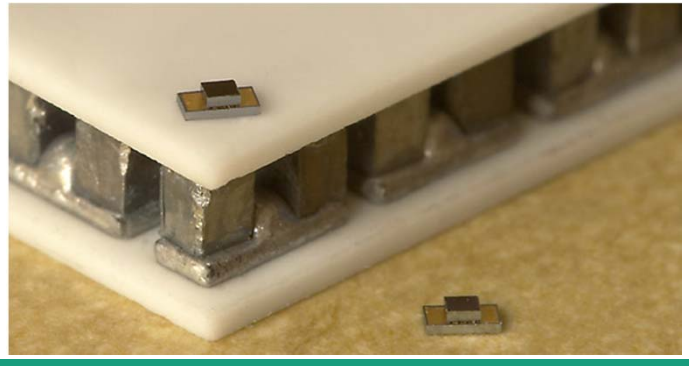
1998
-
2006



Micropelt device before soldering



Thermoelectric legs structured on wafer



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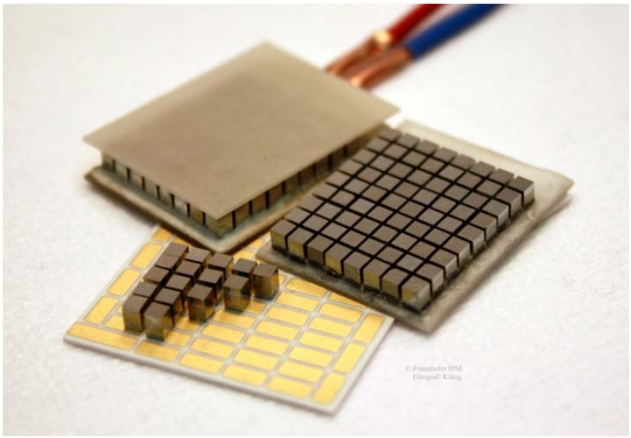
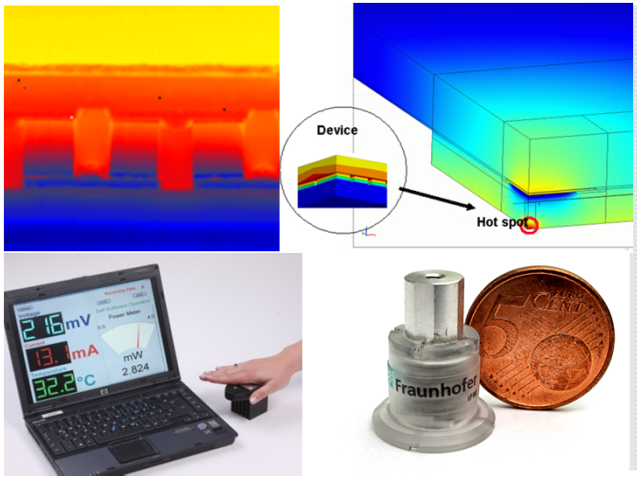
Thermoelectrics at Fraunhofer IPM

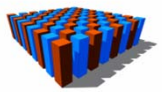
Converters for power generation and cooling



- High-Temperature and Nano materials
- Simulation
- System technology
- Development of production process
- Measuring station for materials



- Residual heat
  - Automobile
  - Large-scale facilities
- Energy-autarkic sensors
  - Monitoring of structures



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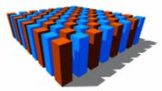


Fraunhofer IPM

New funding situation in Germany

Energy Technology Perspectives: Scenarios and Strategies to 2050

energietechnologien 2050

Gefördert durch:

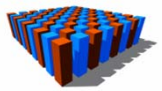
Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

"… Guidelines for a clean, reliable and affordable energy supply by the year 2050 are to be outlined in an energy concept. The aim of the energy concept is to provide a road map towards the era of renewable energies. In future, Germany aims to rank amongst the world's most energy-efficient and environmentally friendly national economies, offering competitive energy prices and a high level of prosperity. …"

Joint press release 2010-8-30

R. Brüderle, Federal Minister of Economics and Technology
N. Röttgen, Federal Minister for the Environment, Nature Conservation and Nuclear Safety



Fraunhofer IPM

New funding situation in Germany

Energy Technology Perspectives: Scenarios and Strategies to 2050: Energy efficiency in Industry

energietechnologien 2050

Gefördert durch:

Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

Dr. Harald Bradke
Fraunhofer Institut für System- und Innovationsforschung

Berlin, 26. Mai 2009

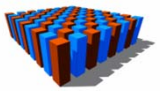
Technologies for energy harvesting:

1. *Thermoelectricity*
2. *Organic Rankine Cycle (ORC)*
3. *Kalina Cycle*
4. *Heat exchanger*
5. *Industrial heat pumps*

Result:
public R&D is impotant

Recommendations for public R&D funding:

- *Evaluation of usable waste heat source*
- *New thermoelectric materials*
- *Industrial production technologies for thermoelectric generators*
- *Improvement of heat exchanger*
- *New concepts for ORC*
- *New refrigeration substances for heat cycle*

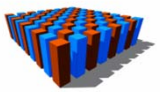


Fraunhofer IPM

New funding situation in Germany

2008-2013

	Funding (M€)	Project volume
DFG (German Research Society)	8.7	8.7
BMBF Scientific Fed. Min. of Education and Research	5.5	5.5
BMBF Applied Fed. Min. of Education and Research	25	40
BMWI Fed. Min. of Economics and Technology	11	19
	=======	=======
total	50.2	73.2



New funding situation in Germany

2008-2013

*Designed by
A. Jacquot

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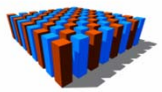

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Thermoelectric Research in EU

EU FP 7

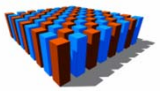
NMP.2010.1.2-3 Thermoelectric energy (TE) converters based on nanotechnology
aspects of the manufactured nanoparticles as well as the composites that would be part of the researched TE converters.
Expected impact : through improved TE materials

??? proposals, 4 funded,
all contracts are currently under negotiation
⇒ no additional information about contents

- NANOHIGHTECH
- THERMOMAG
- NEAT
- NEXTEG

FUNDING 13-14 Mio €
⇒ > 20 Mio € project volume

ESA / ESTEC starts with thermoelectric



Fraunhofer IPM

New funding situation in Germany

Driving force

Energy efficiency, waste heat recovery

Thermoelectric as a chance for better energy efficiency

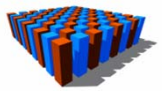
demand on high temperature materials, modules, systems

Key account

Automotive industry (W to kW)

Rising market

Energy self powered systems (µW to mW)



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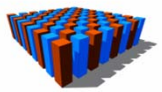
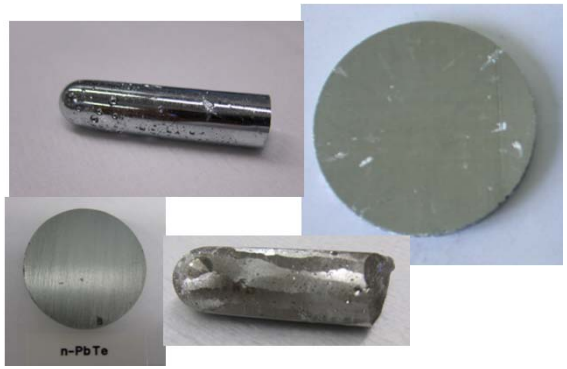


Fraunhofer IPM

Thermoelectric at Fraunhofer IPM

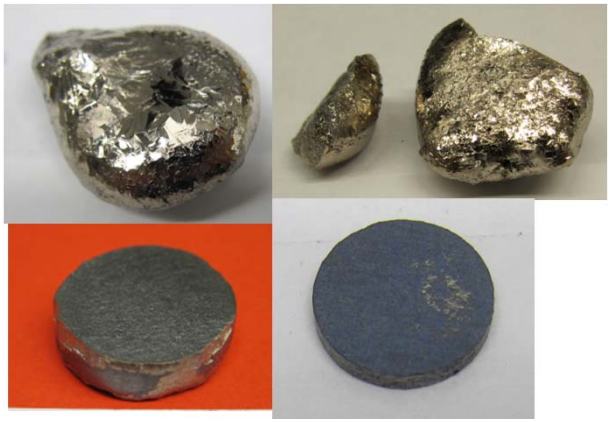
High temperature materials

Chalcogenides



Silicide

Half-Heusler

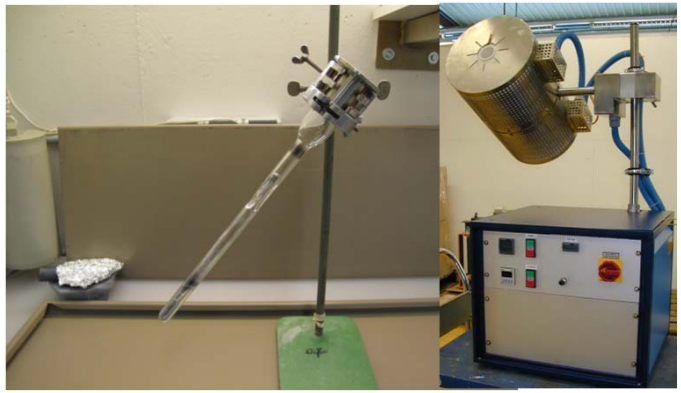


Skutterudite

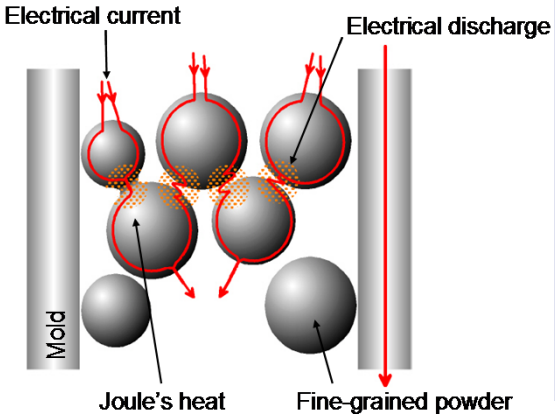
Fraunhofer IPM

Thermoelectric at Fraunhofer IPM

material synthesis

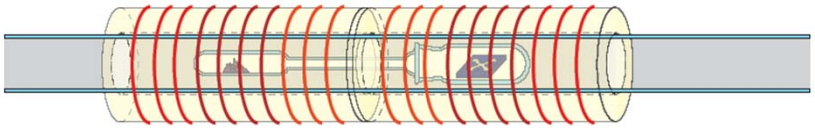


Synthesis from melt



Spark plasma sintering

Milling / mechanical alloying



2 zone annealing setup

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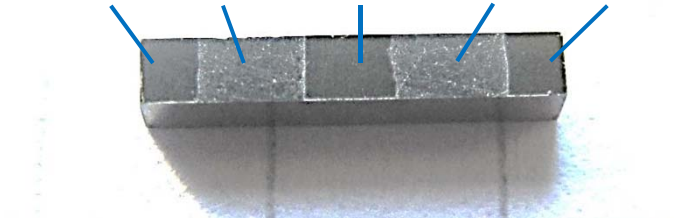
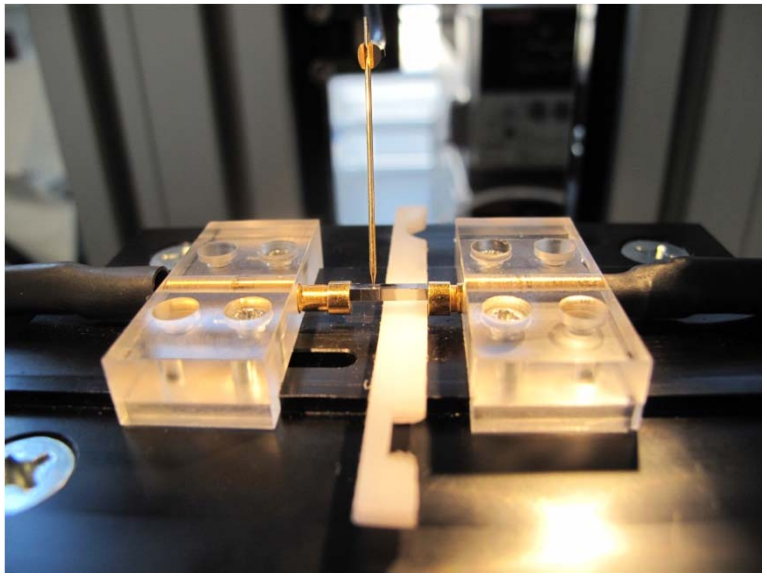
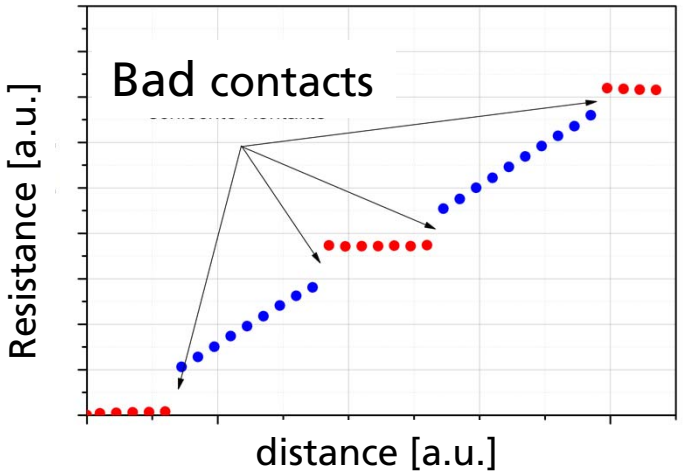
Thermoelectric at Fraunhofer IPM

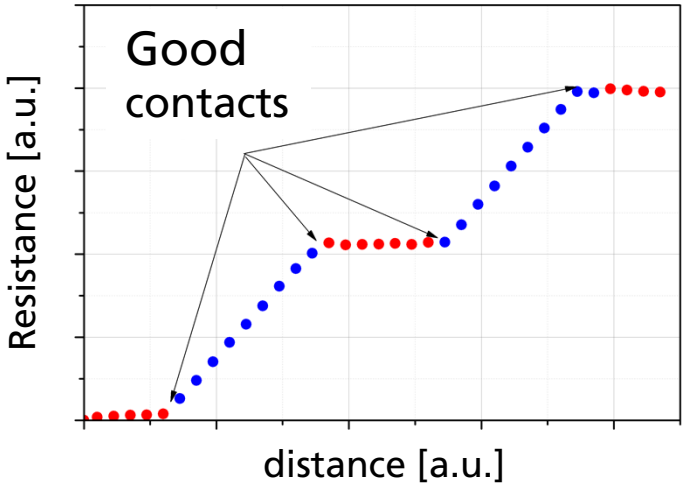
contact development

metal – TE – metal – TE – metal



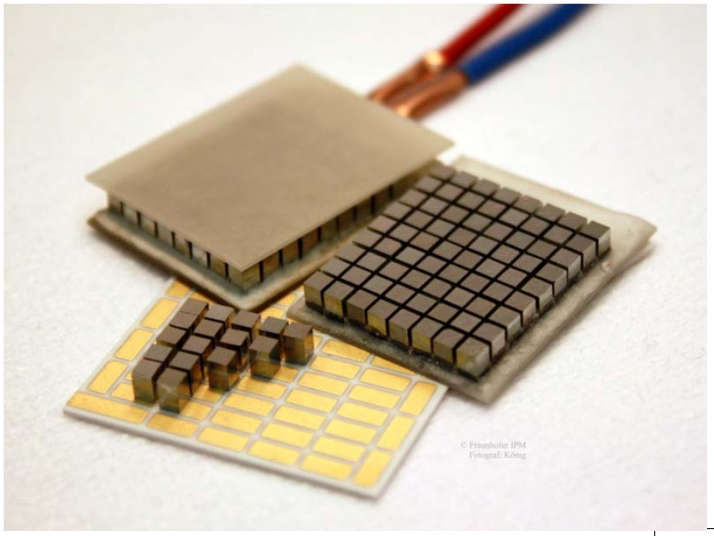


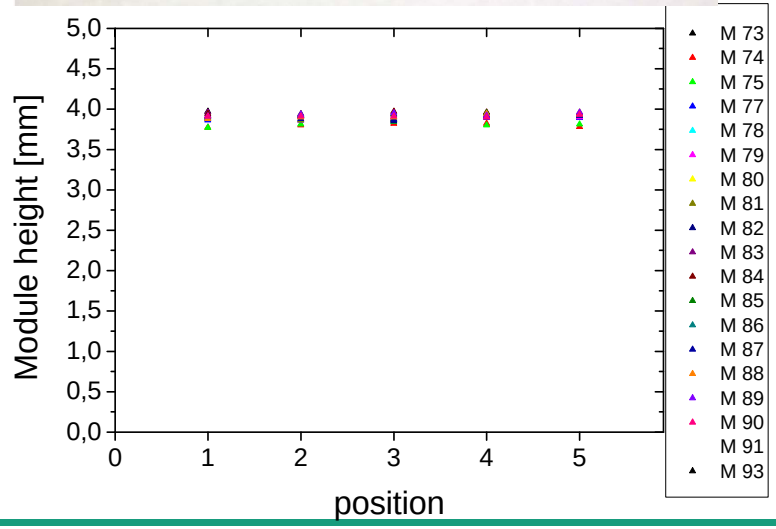




Fraunhofer IPM

Thermoelectric at Fraunhofer IPM
module fabrication





position

Fraunhofer IPM

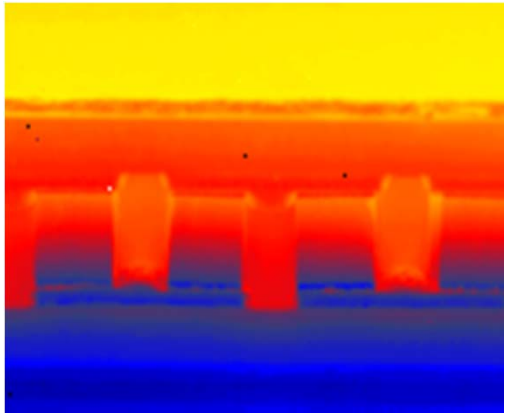
Thermoelectric at Fraunhofer IPM
module characterisation

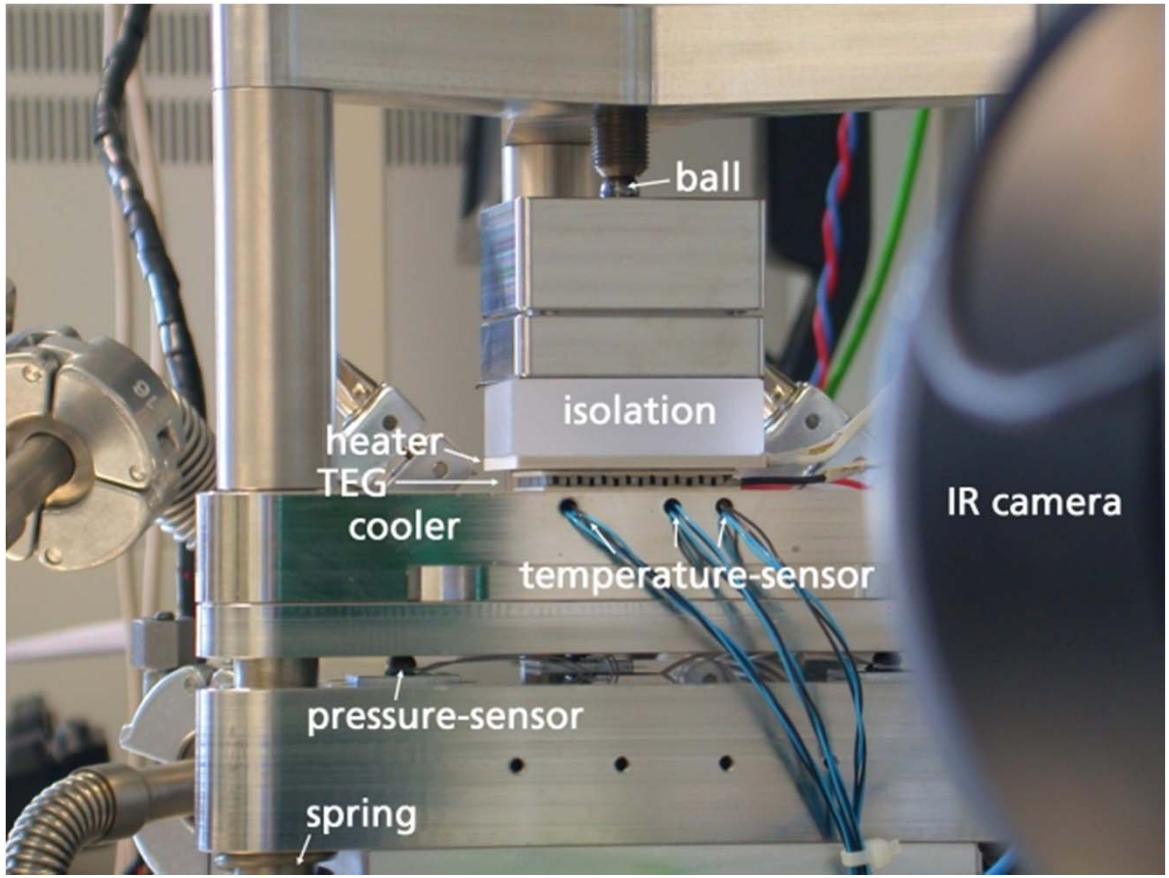
T_{Cold} : 0°C – 130°C

T_{Hot} : RT– 600°C (700°C)

In-situ pressure distribution measurement

IR-Thermography





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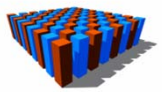
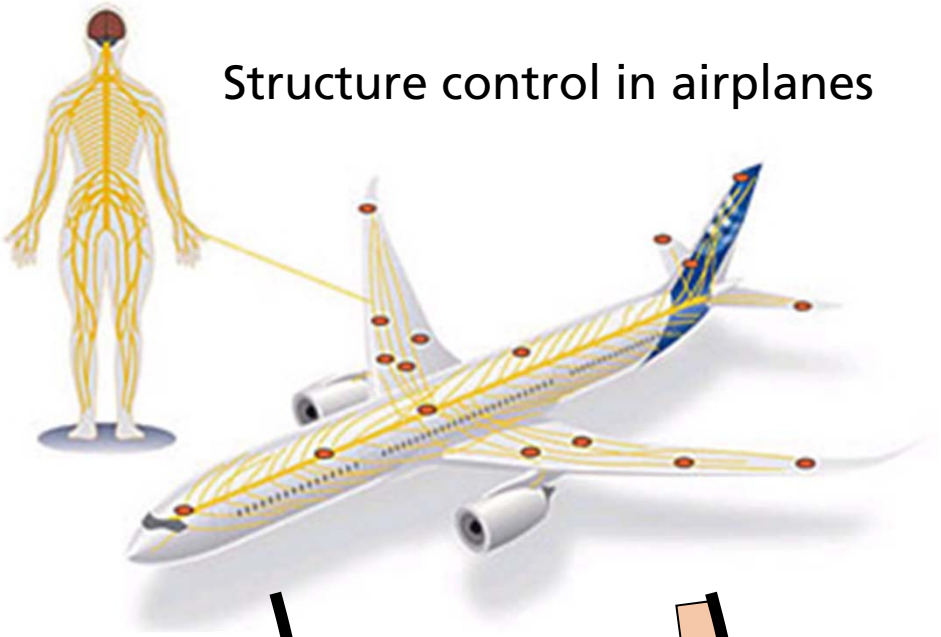


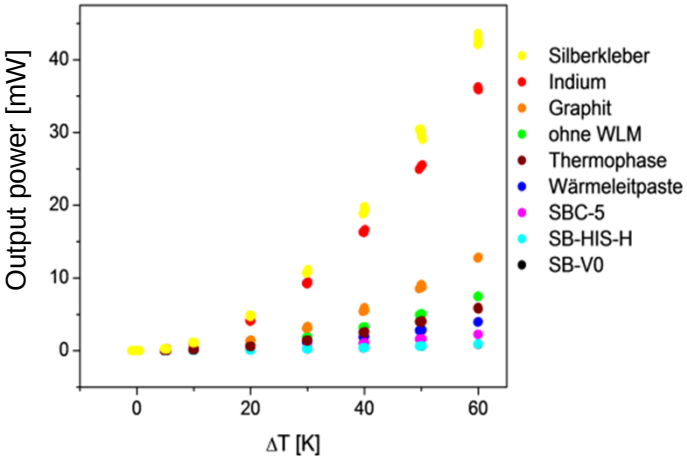
Fraunhofer IPM

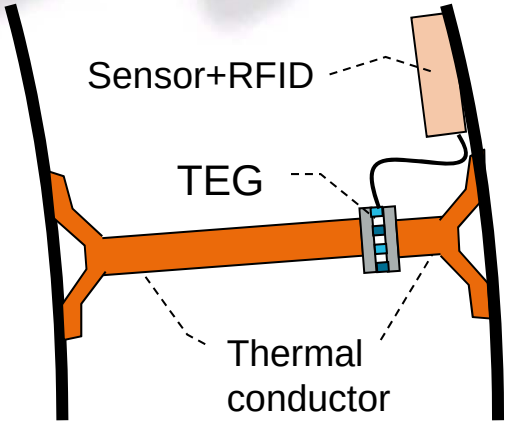
Thermoelectric at Fraunhofer IPM

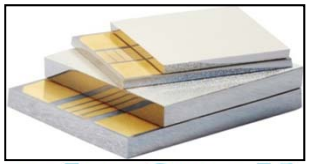
Energy-autarkic sensors



Structure control in airplanes



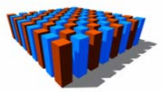




micropelt

~8mW output power with a 10g system

Source: EADS

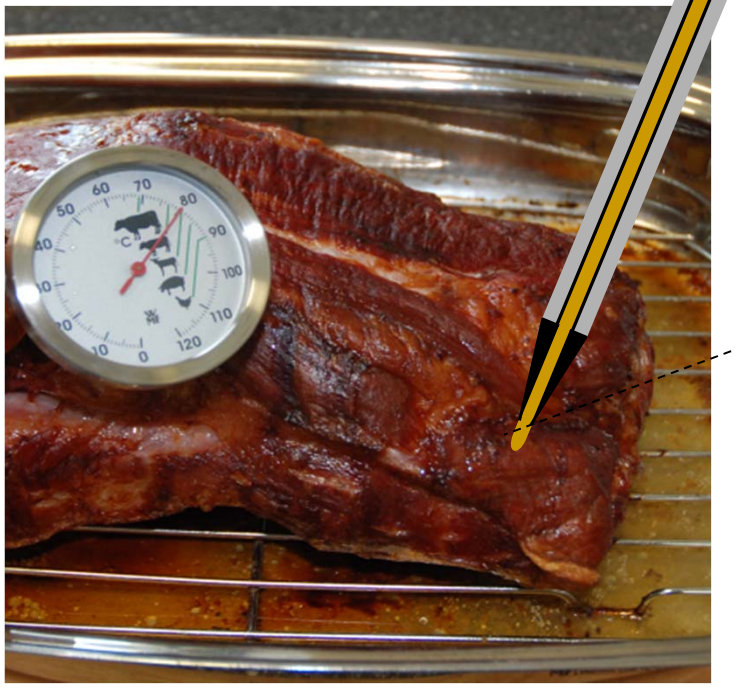


Fraunhofer IPM

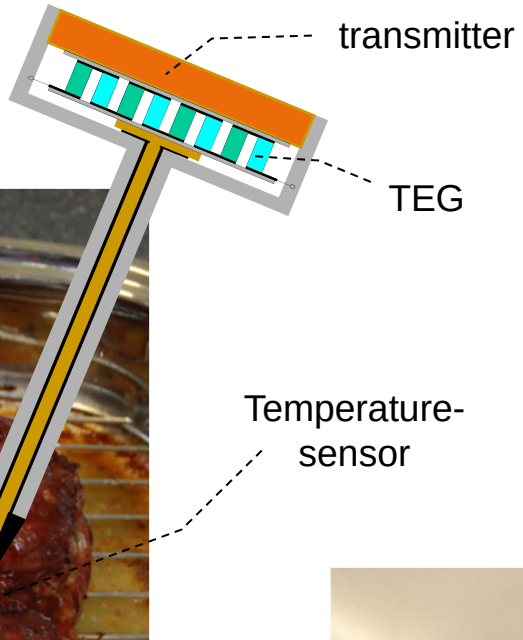
Thermoelectric at Fraunhofer IPM

Energy-autarkic sensors

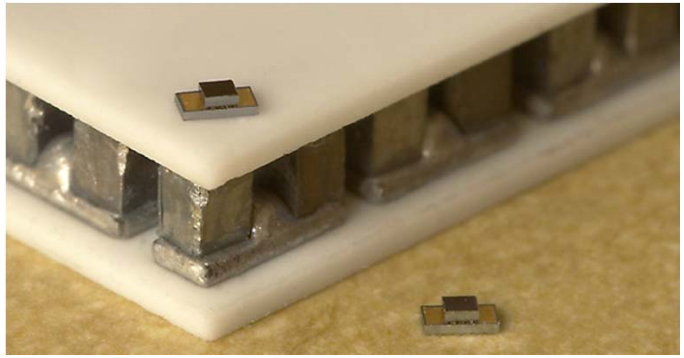
insertion thermometer for cooking and food control

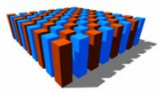


Source: E.G.O.



M. Jägle





Fraunhofer IPM

Content

Overview about Fraunhofer IPM

New funding situation in Germany

High temperature material and modules

Energy-autarkic sensors

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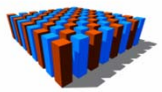
Summary



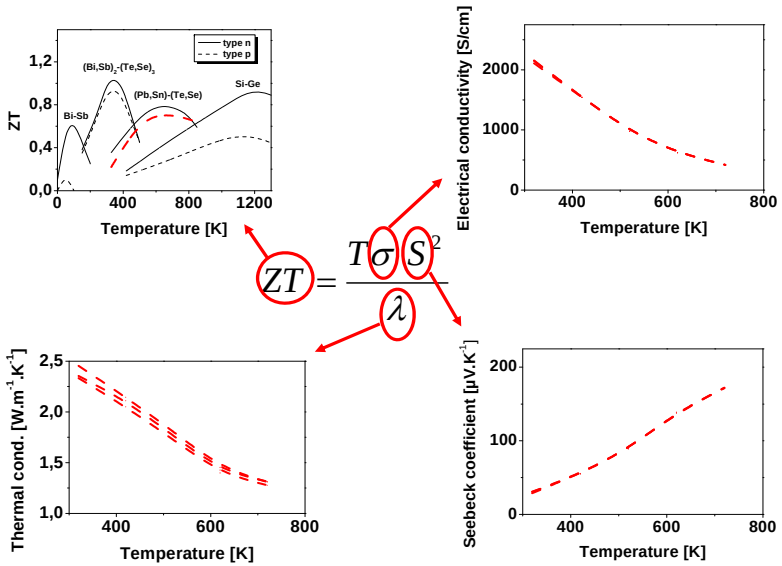
Fraunhofer IPM

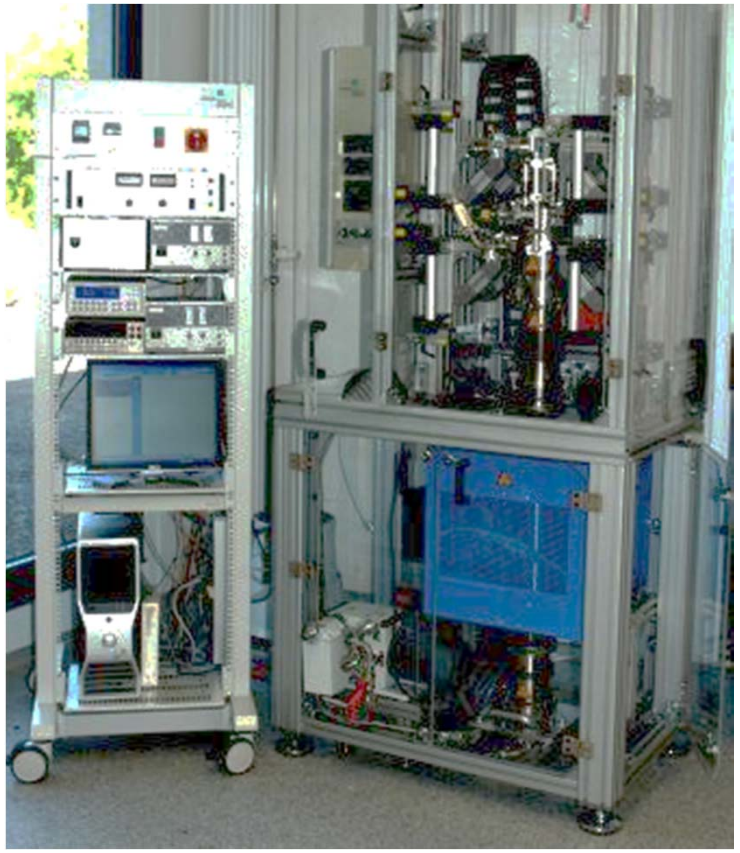
Thermoelectric at Fraunhofer IPM

Thermoelectric Metrology

ZT-meter

Combined measurements of all TE-properties up to 600°C





Fraunhofer IPM

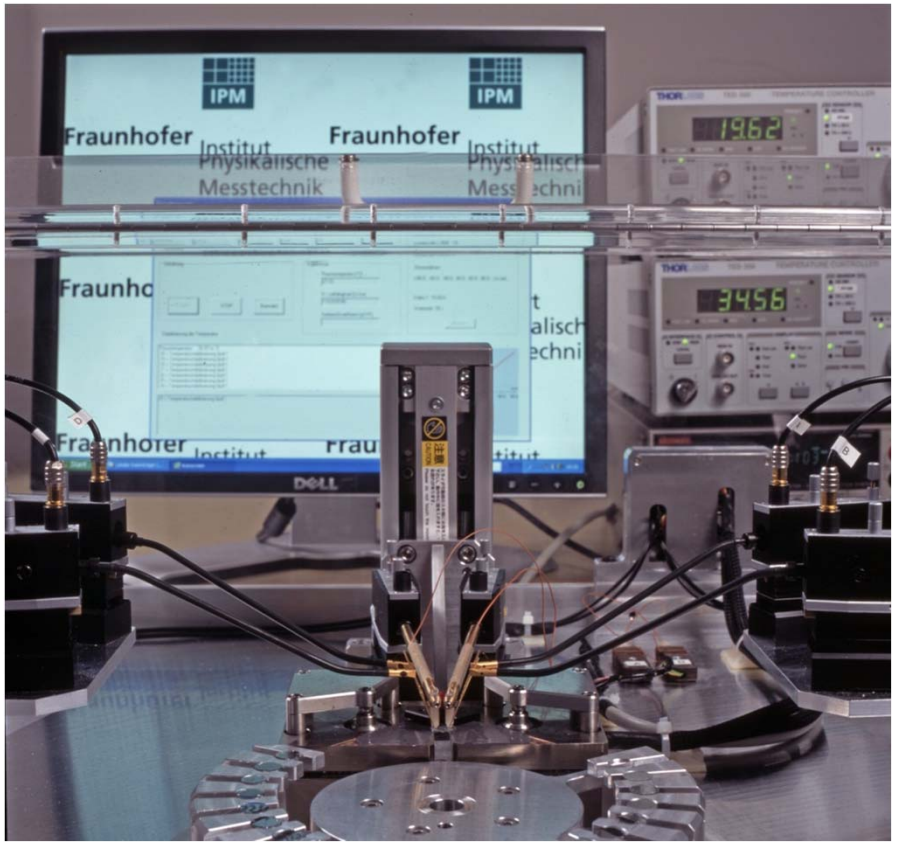
Thermoelectric at Fraunhofer IPM

Thermoelectric Metrology

In-line material control for large scale TEG production

Seebeck-coefficient and electrical conductivity

High through-put



Autoscreen-System

Fraunhofer IPM

Thermoelectric at Fraunhofer IPM

Thermoelectric Metrology

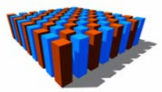
Bulk and thin film measurement setup

Seebeck-coefficient and electrical conductivity

Rectangular and round sample shape

Temperature range 300K-900K

Fraunhofer IPM-SRX



Fraunhofer IPM

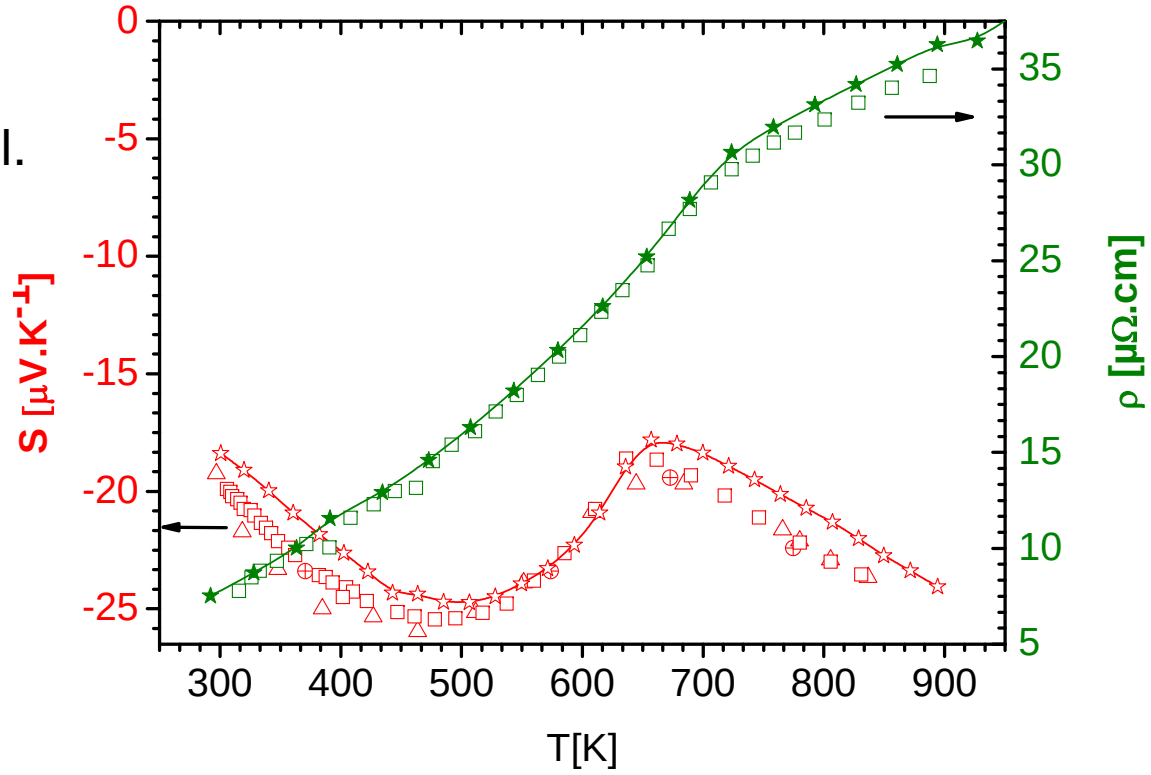
Thermoelectric at Fraunhofer IPM

Thermoelectric Metrology

Validation with Nickel

☆ and ★, our measurement.
○ and □, data of Burkov et al.
⊕ data of Nemschenko et al.
△ data of Beylin et al

Fraunhofer IPM-SRX



Fraunhofer IPM

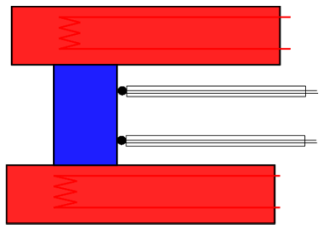
Thermoelectric at Fraunhofer IPM

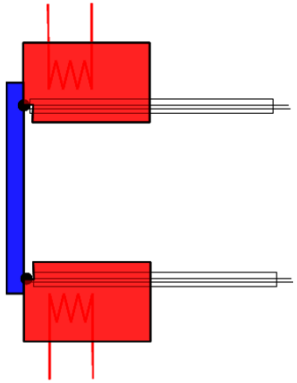
Thermoelectric Metrology

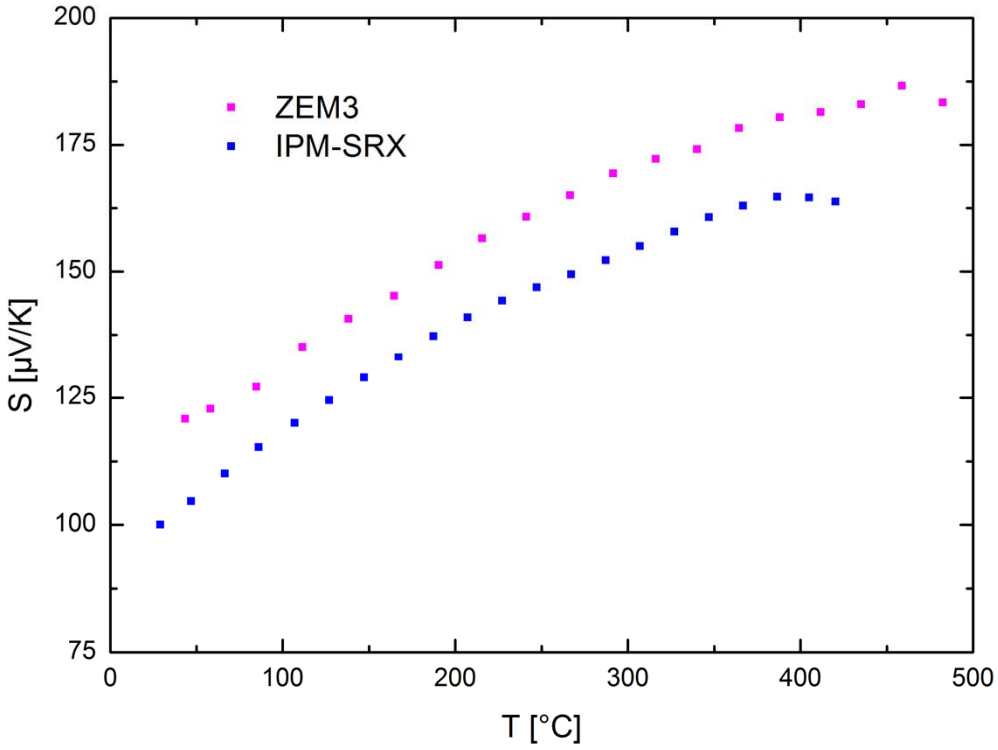
Comparison of different measurement setups

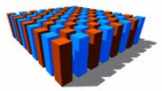
ZEM-3:

IPM-SRX:









Fraunhofer IPM

Thermoelectric Standardisation

Thermoelectric Metrology

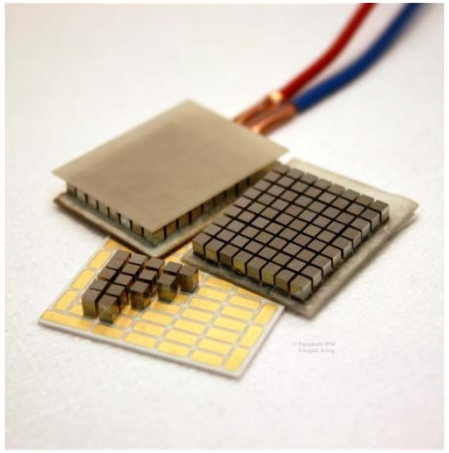
New Project: ThermoElectric-Standardisation *„TESt“*

Start date: 01.01.2011

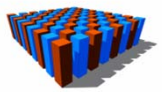
Projektträger Jülich
Forschungszentrum Jülich

Bundesministerium
für Bildung
und Forschung



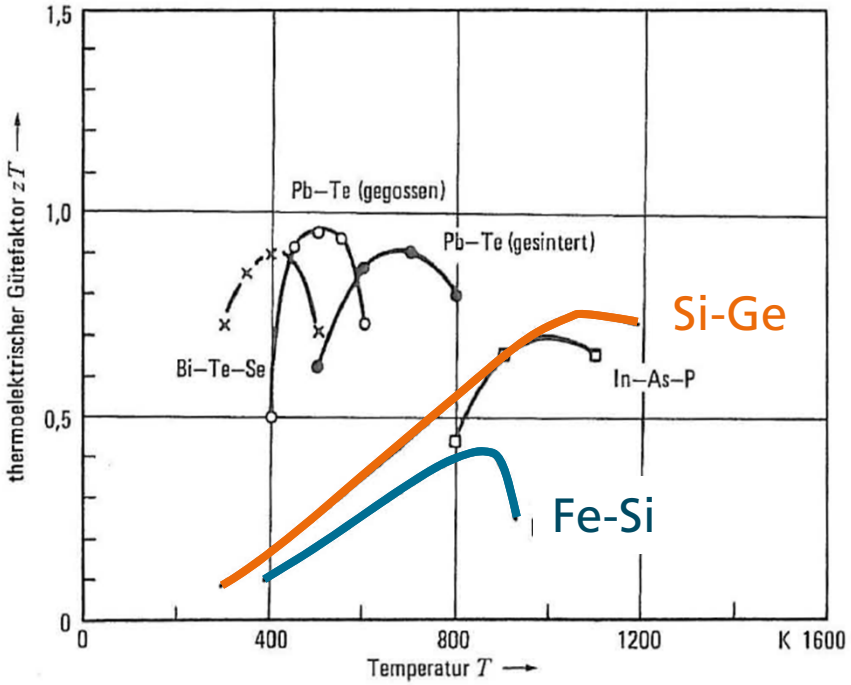



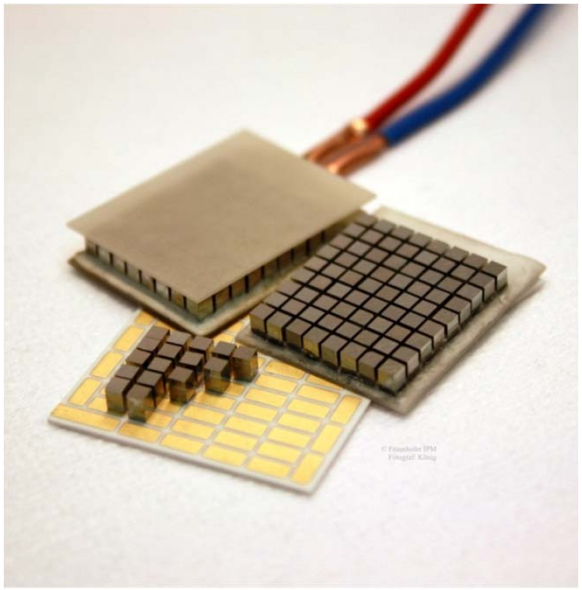
DLR PTB NETZSCH Fraunhofer IPM



Thermoelectric Standardisation
Thermoelectric Metrology

High temperature materials & thermoelectric generator





Fraunhofer IPM

Thermoelectric Standardisation

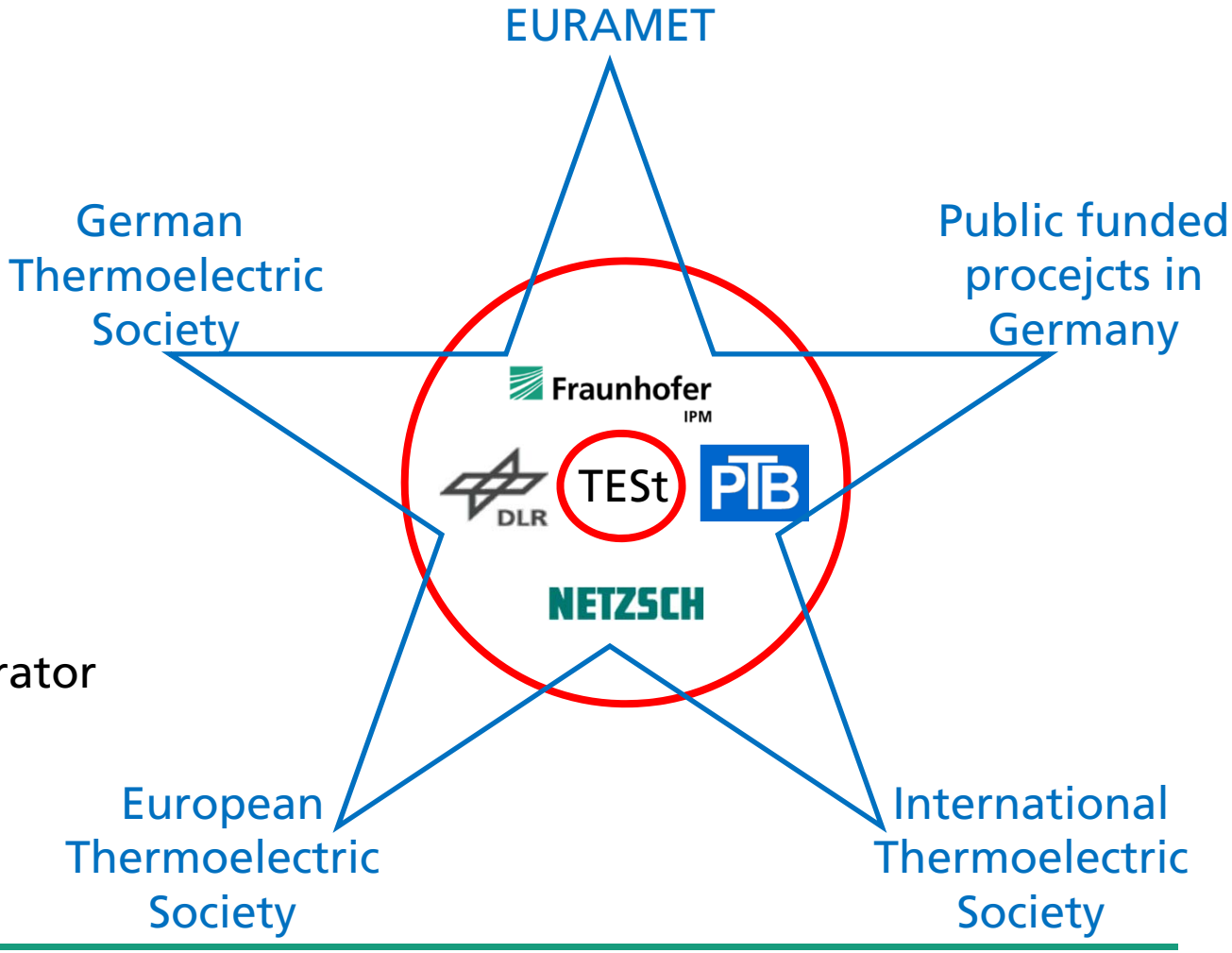
Thermoelectric Metrology

Round Robin Tests

High temperature materials

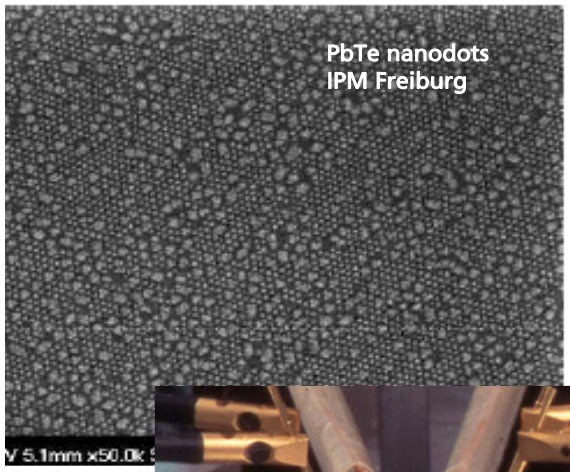
And

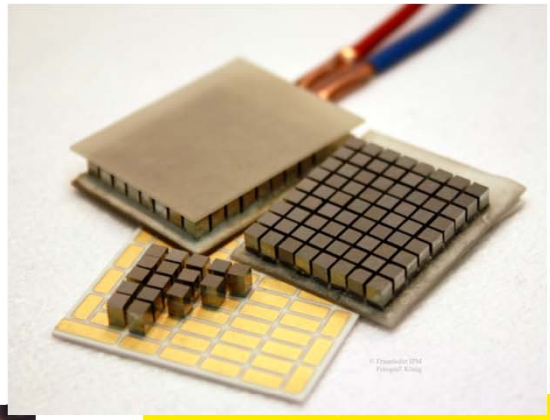
thermoelectric generator

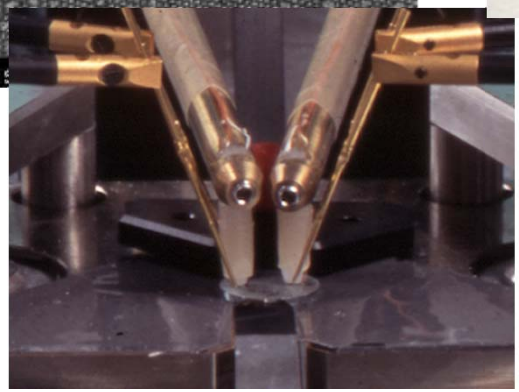


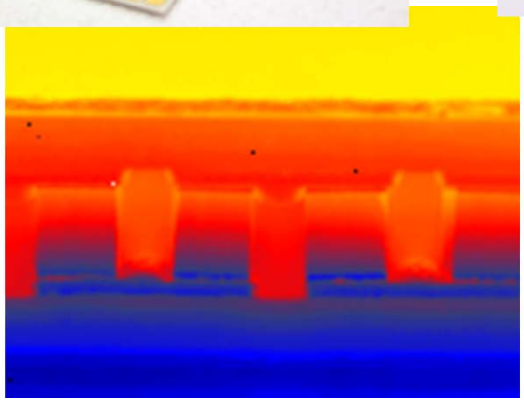
Fraunhofer IPM

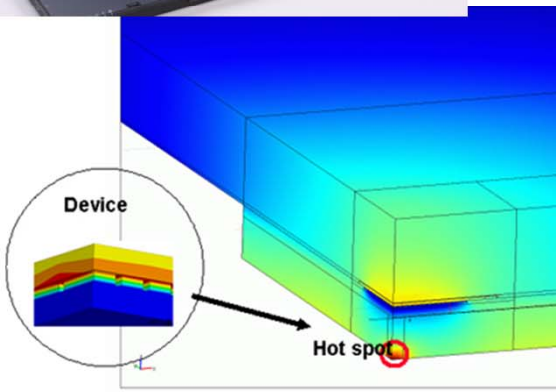
Thermoelectricity at Fraunhofer IPM - materials, modules, systems and metrology





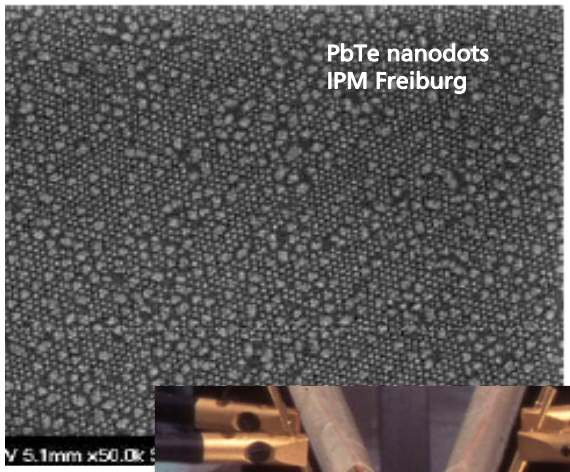


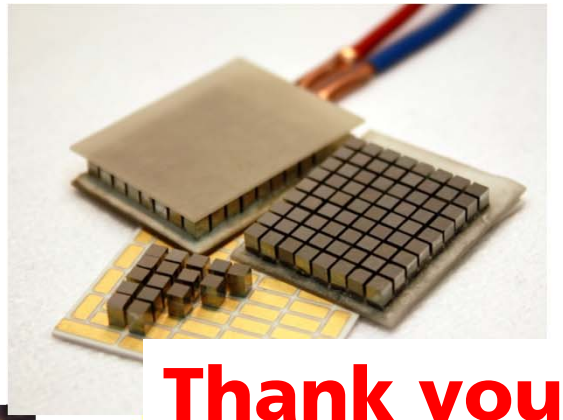


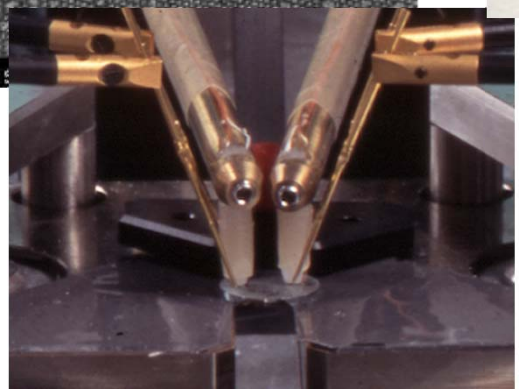


Fraunhofer IPM

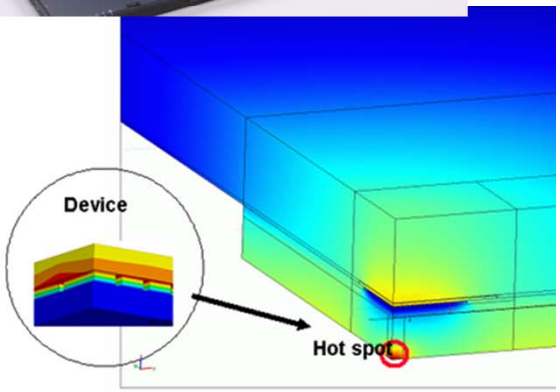
Thermoelectricity at Fraunhofer IPM - materials, modules, systems and metrology







Thank you!



Fraunhofer IPM