
FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE



Fraunhofer Institute for Solar
Energy Systems ISE

DAAD-Alumni Summer School
Freiburg, Nov. 8, 2014

www.ise.fraunhofer.de

Fraunhofer Institute for Solar Energy Systems ISE

Director:
Prof. Eicke R. Weber

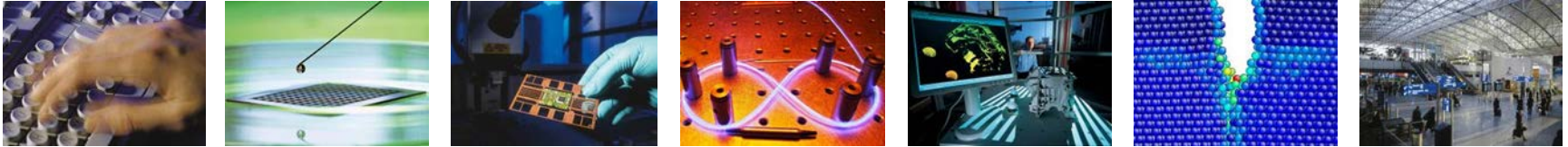
Staff: 1300

2012 Budget: € 77 million

Established: 1981



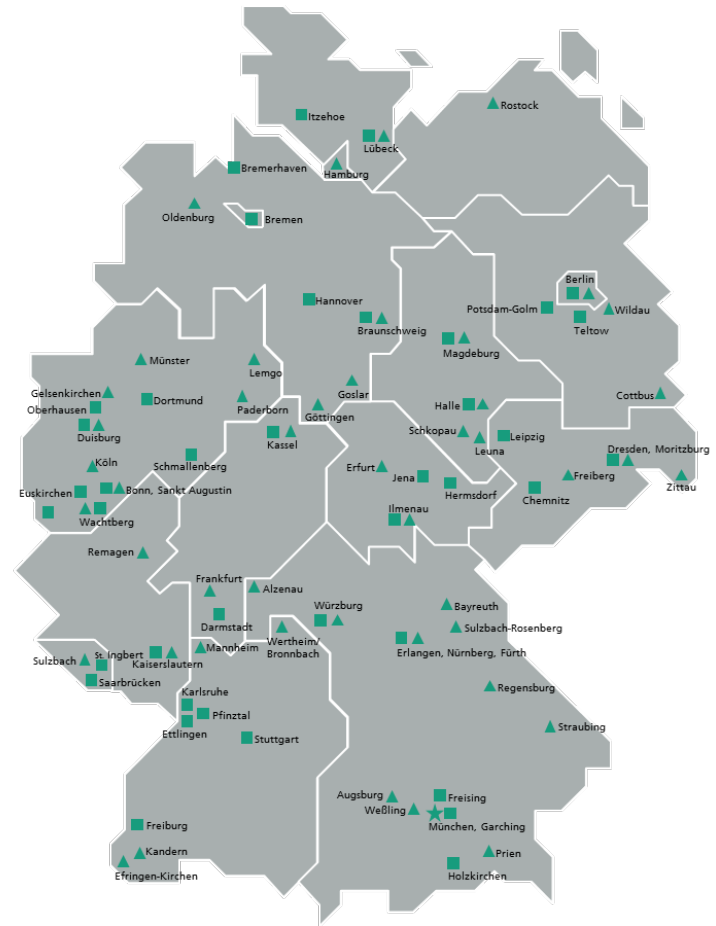
Fraunhofer-Gesellschaft, the largest organization for applied research in Europe



- 66 institutes and independent research units
- Staff of more than 22,000
- €1.9 billion annual research budget totaling
 - Roughly two thirds of this sum is generated through contract research on behalf of industry and publicly funded research projects
 - Roughly one third is contributed by the German federal and state governments in the form of base funding
- International cooperation

The Fraunhofer-Gesellschaft Locations in Germany

- 66 institutes and independent research units
- more than 22,000 staff



- Institute/independent research unit
- ▲ Other research units
- ★ Headquarters



Joseph von Fraunhofer



Fraunhofer-Gesellschaft

Discovery of the Fraunhofer lines in the solar spectrum

New processing techniques for lenses

Director and partner in a glassworks

Researcher

Inventor

Entrepreneur

R&D commissioned from industry and governing bodies

Audio format MP3, white LED, high resolution thermocamera

Research volume: c. 1.8 billion euros annually

The Most Active Patent Registrants at the German Patent Office (DPMA) in 2012

Registrants	Amount	Country
1. Robert Bosch GmbH	3972	DE
2. Daimler AG	1991	DE
3. Siemens AG	1921	DE
4. Schaeffler Technologies GmbH & Co. KG	1854	DE
5. GM Global Technology Operations LLC	1565	US
6. Bayerische Motoren Werke AG	829	DE
7. Volkswagen AG	805	DE
...
13. Continental Automotive GmbH	435	DE
14. DENSO Corporation	428	JP
15. Fraunhofer-Gesellschaft e.V.	424	DE

Source: DPMA Jahresbericht 2012

Fraunhofer worldwide

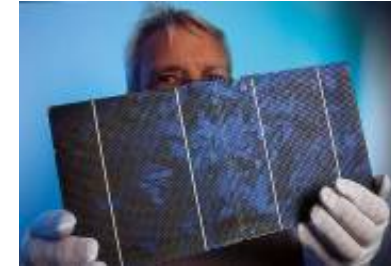


Fraunhofer ISE

Research, Development and Services



Research
Materials,
Modeling,
Methods



Development
Components,
Prototypes,
Systems, Procedures



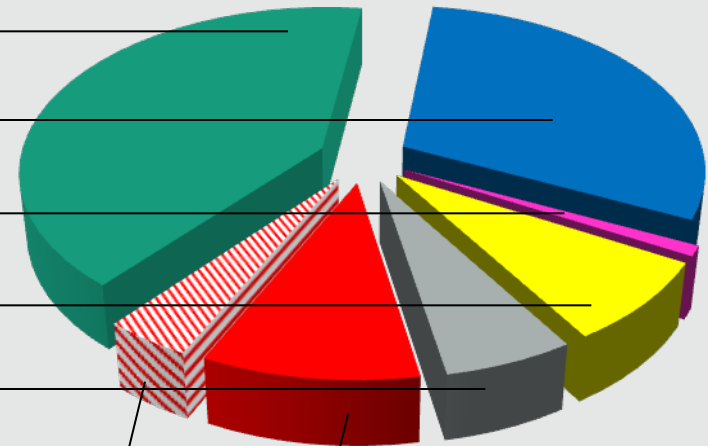
Services
Consulting, Tests,
Monitoring,
Quality Assurance



Revenue Structure, Operation 2012

Operation: €66.8 million
Investment** : €10.2 million
Total: €77.0 million

Industry	41 %
Federal Gov. Projects	30 %
Regional Gov. Projects	1 %
European Union	8 %
Other	6 %
Special Programms, FhG	4 %
Basic Funding*	10 %



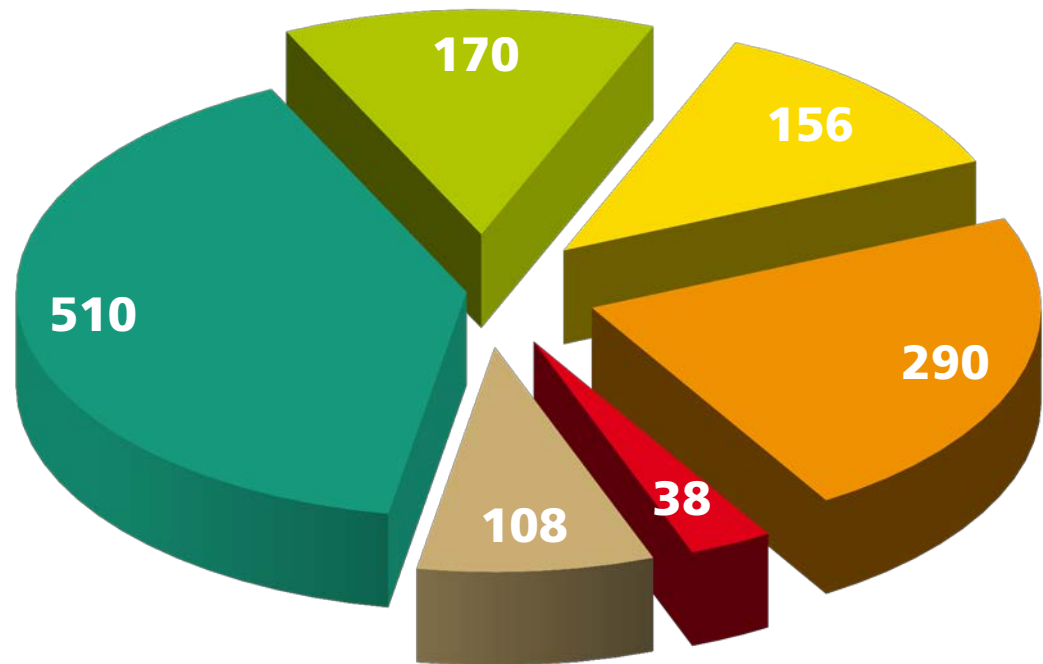
* of which 90% federal and 10% state funds

** without building investment and economic program

Status: March 2013

Personnel at Fraunhofer ISE

- Staff Members
- Doctoral Students
- Diploma Students
- Scientific Assistants
- Trainees
- Others



Total: 1272

Status: 31 Dec. 2012

Areas of Business at Fraunhofer ISE

- Energy Efficient Buildings
- Applied Optics and Functional Surfaces
- Solar Thermal Technology
- Silicon Photovoltaics
- Photovoltaic Modules and Systems
- Alternative Photovoltaic Technologies
- Renewable Power Supply
- Hydrogen Technology



Business Area: Energy Efficient Buildings

- Façades and Windows
- Building Concepts, Analysis and Operation
- Heat Storage for Heating and Cooling
- Energy-Efficient and Solar Cooling
- Energy Supply Systems for Buildings
- Lighting Technology
- Building-Integrated PV



Building Renovation

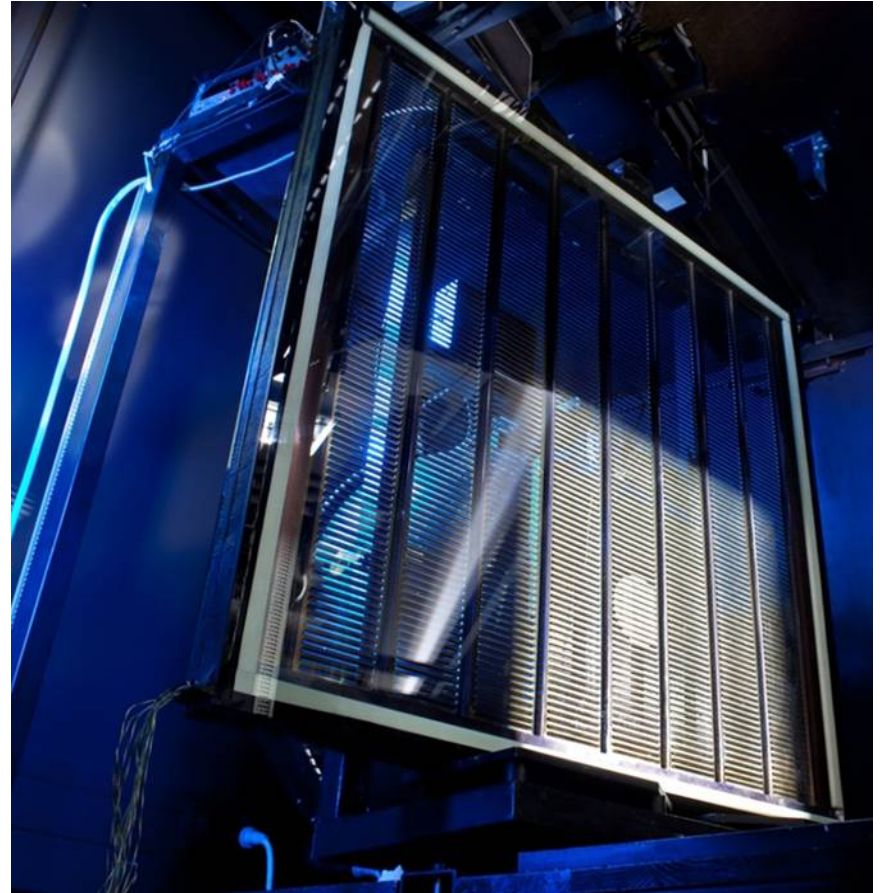
- First residential high-rise modernized to passive house standards
 - Increased living area from 7300 m² to 8200 m²
 - Built 1965, Renovated 2010
- Technologies
 - LowEx Concept to reduce heating load
 - Aerogel insulation for critical thermal bridges
- Optimize heating supply for Weingarten
 - District heating based on CHP



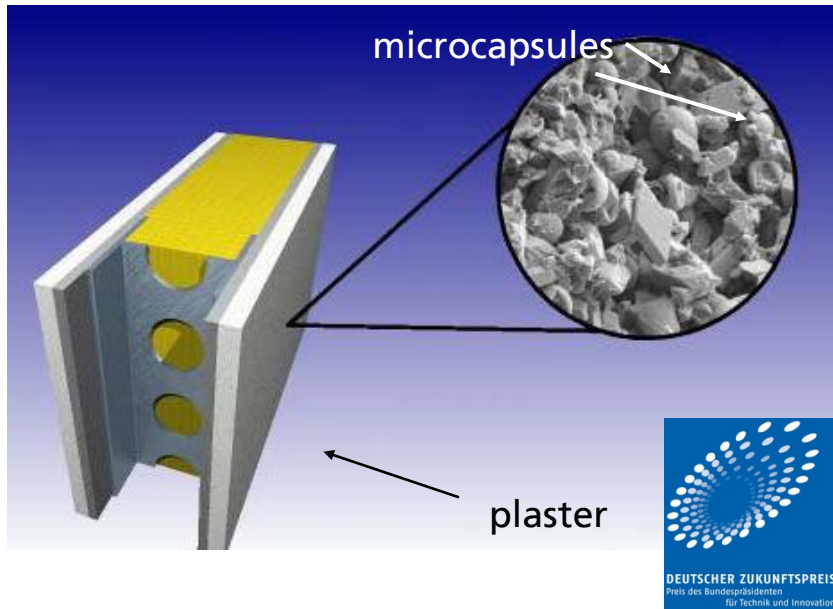
"Buggingerstraße 50"

Solar Façade Collectors

- Solar heating
- Solar control
- Glare protection
- View to outside
- Pilot application planned in Slovenia



Hot and Cold Storage



Building materials with phase change material (PCM) increase the thermal comfort indoors

Nominated for the German Future Prize 2009

Energy-Efficient and Solar Cooling

Solar Cooling

- Demonstration projects and monitoring
- Planning, Consulting
- Across-the-board investigations

Adsorption Technology

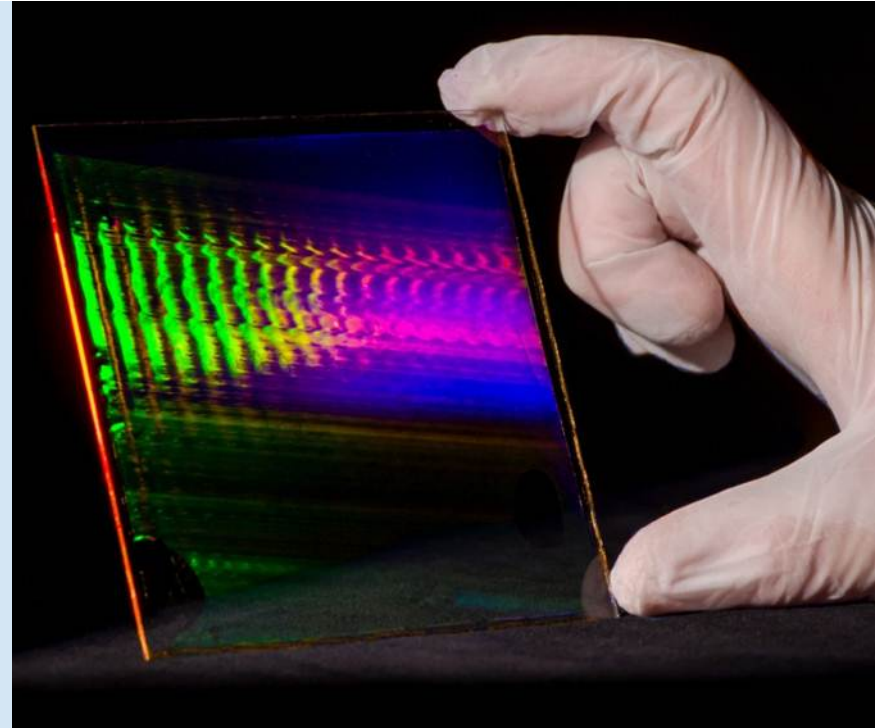
- Process development
- Materials research



First autonomous solar air-conditioning system in Germany, Chamber of Commerce Upper Rhine

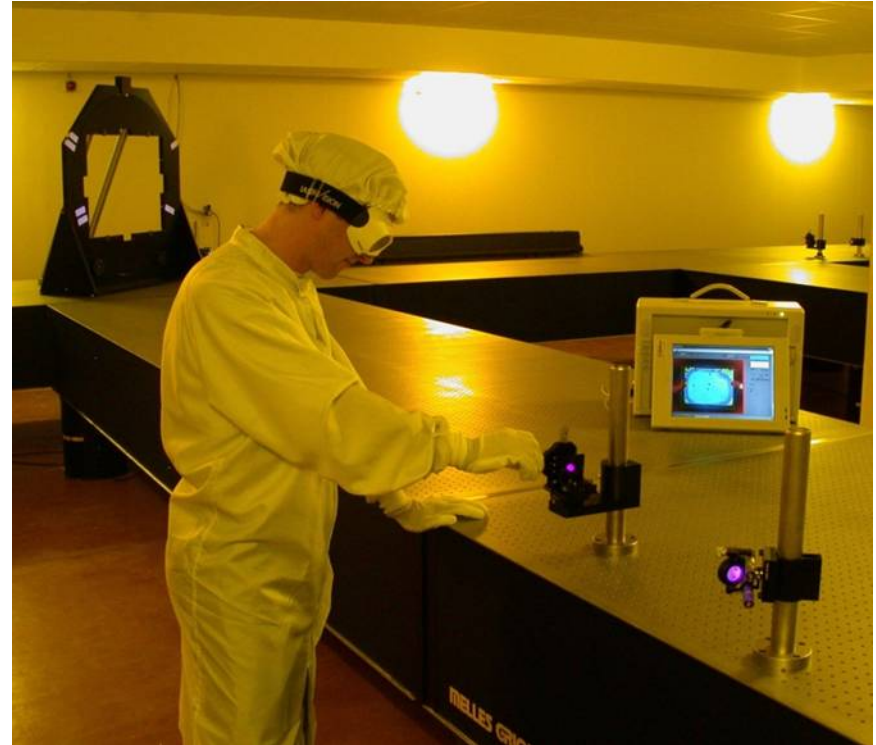
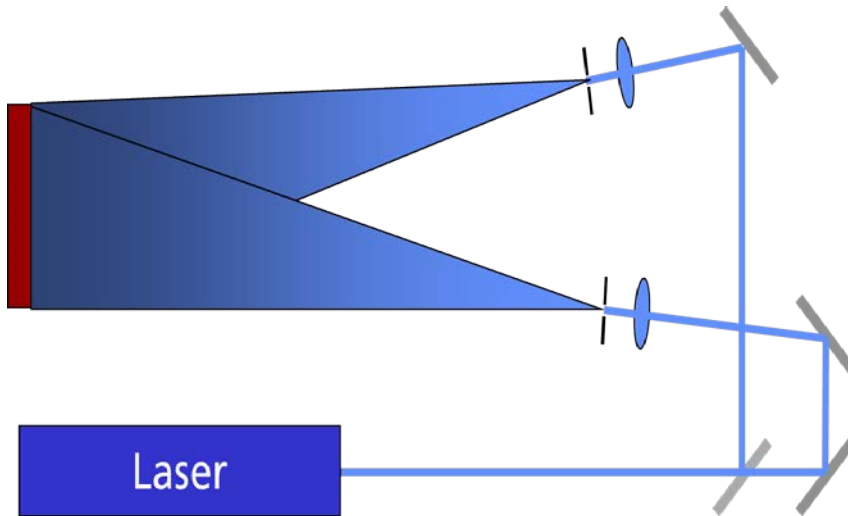
Business Area: Applied Optics and Functional Surfaces

- Coating - Technology and Systems
- Microstructured Surfaces
- Façades and Windows
- Lighting Technology
- Concentrator Optics



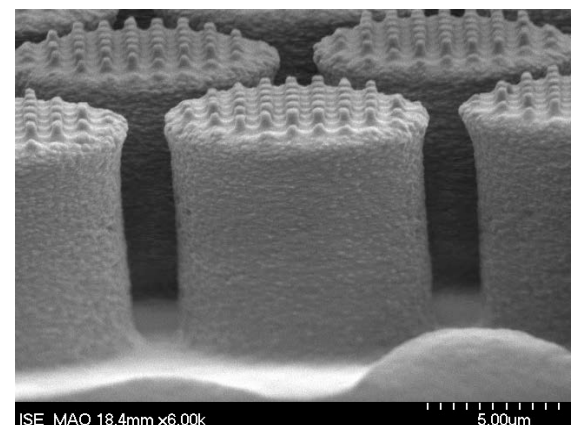
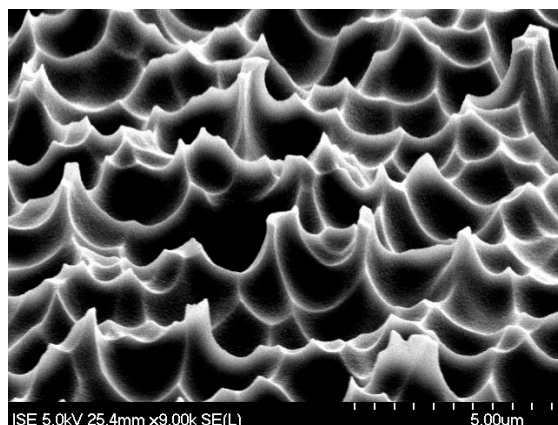
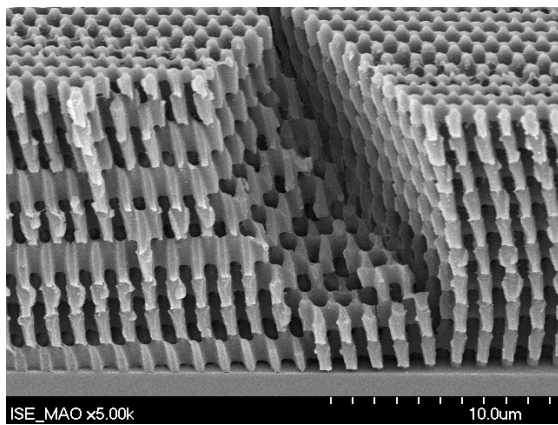
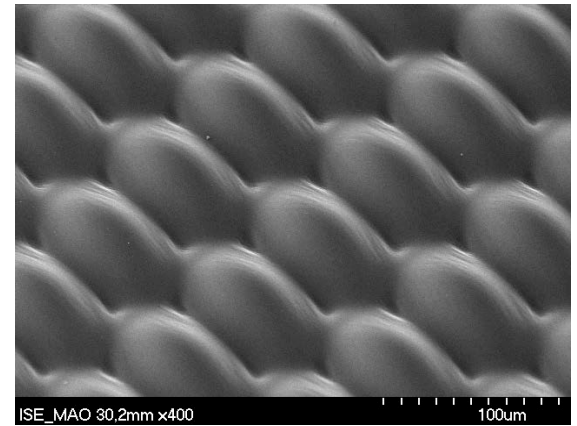
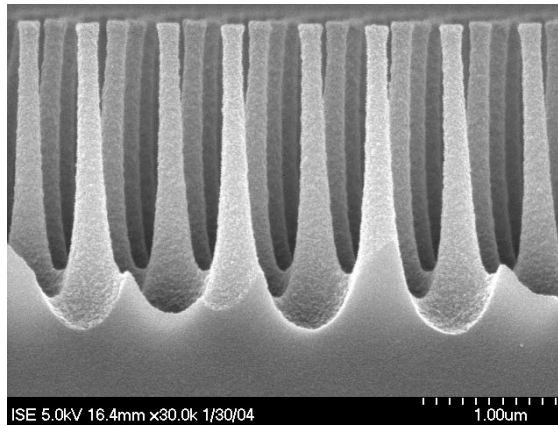
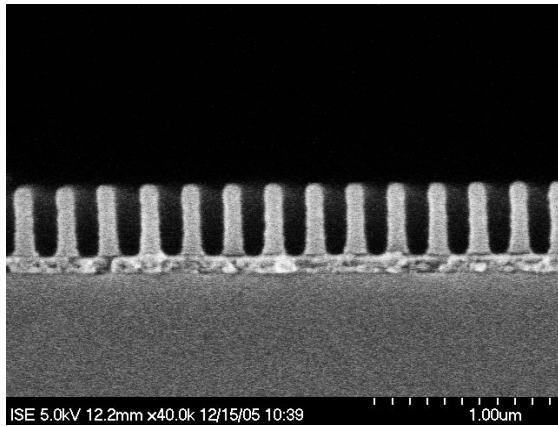
Microstructured Surfaces: Structure Origination

Interference lithography on surfaces up to $1.2 \times 1.2 \text{ m}^2$



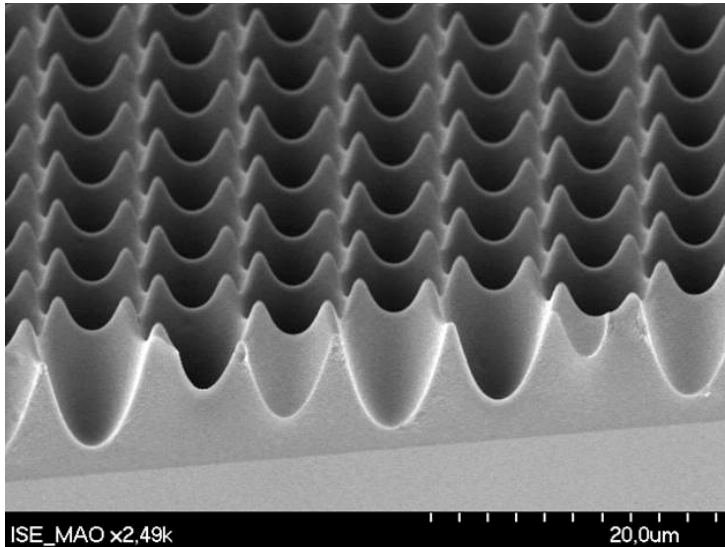
Microstructured Surfaces: Interference Lithography

Examples of Generated Structures

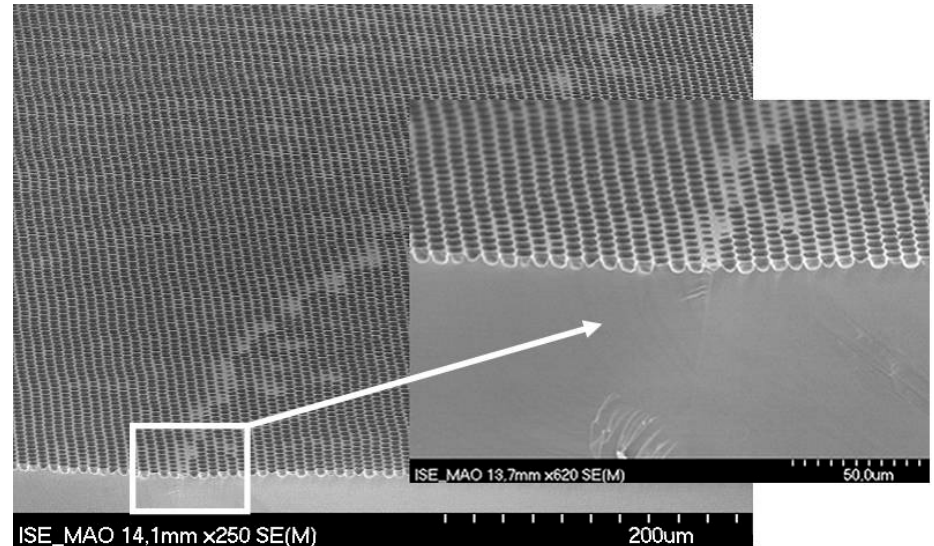


Structure Transfer via Roller Nanoimprint Lithography

Honeycomb Front Side Textures for mc-Si Solar Cells



Interference Lithography:
Hexagonal structure with
period and depth of 8 μm



Structure in mc-Si (with grain
boundary)
at the end of the NIL process chain

→ Very efficient reduction of front side
reflection

Sputter Machine for Coating



Sputter machine



Selectively coated absorber tube



Parabolic trough power plant

Solar Thermal Technology

- Thermal Solar Systems
- Energy-Efficient and Solar Cooling
- Solar Process Heat
- Solar Thermal Power Plants
- Heat Storage for Heating and Cooling

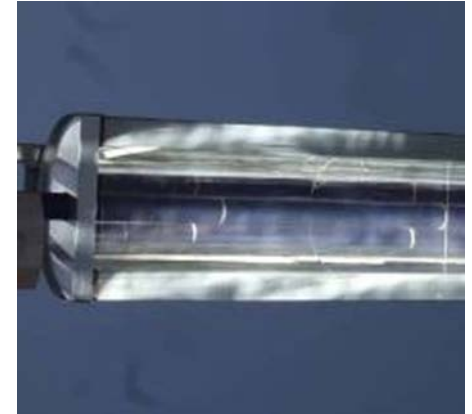


Solar Thermal Demonstration Plant/Fresnel Concept

- Optimizing Fresnel Design
- Coating for secondary concentrating mirror
- Optical quality assurance
- Measurement and analysis



Solar thermal demonstration system in Almeria, Spain



Absorber tube with selective coatings developed at Fraunhofer ISE

Solar Thermal Systems

Indoor and Outdoor Testing Facilities



Outdoor tests as part of the complete series of tests performed on solar thermal collectors in the TestLab Solar Thermal Systems



Indoor laboratory with solar simulator

TestLab
Solar Thermal
Systems



Storage and Complete System Tests

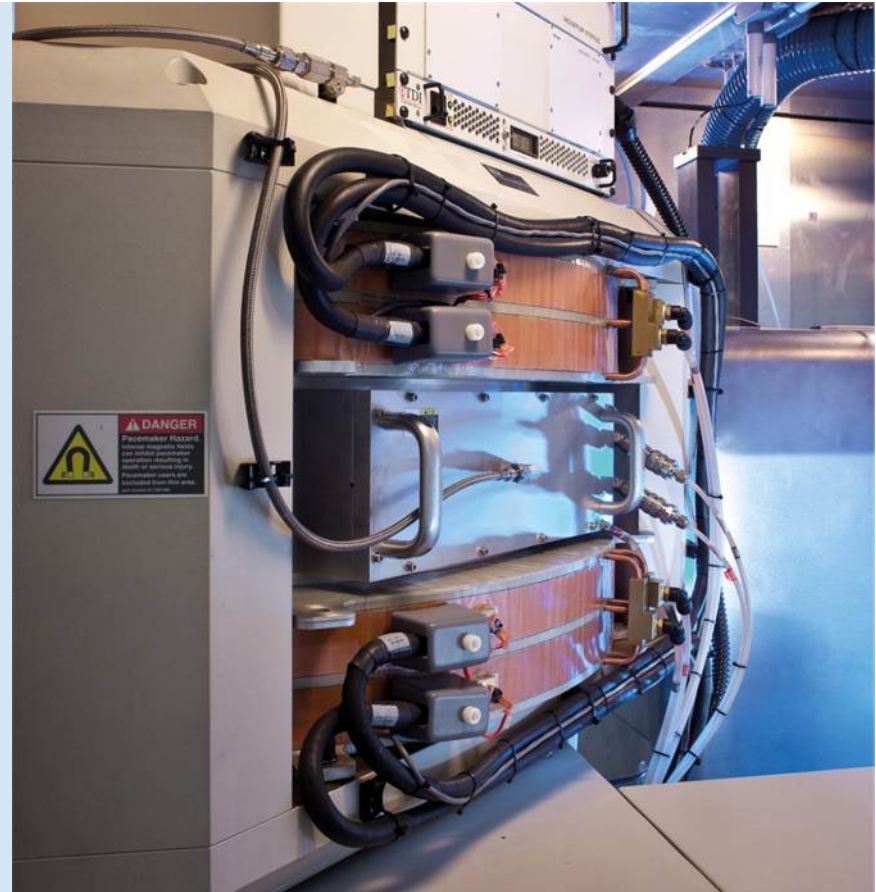
- Storage measurements based on standardized procedures
- System characterization based on standardized procedures
- Measurements on systems and storage to support development and optimization



Laboratories for measuring complete systems and thermal storage systems. Both outdoor test facilities and air-conditioned indoor laboratories are available.

Business Area: Silicon Photovoltaics

- Feedstock, Crystallization and Processing
- Crystalline Silicon Thin-Film Solar Cells
- Industrial and Novel Solar Cell Structures
- Production Systems and Process Development
- Characterization, Quality Control and Development of Measurement Technology: Materials, Cells and Modules



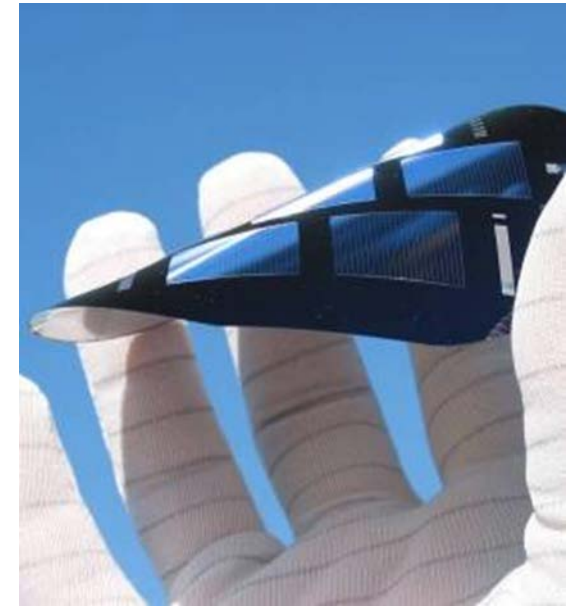
From Si Feedstock to High Efficiency Solar Cells



Industrial crystallization facility to produce multi-crystalline silicon ingots up to 250 kg



Multi-wire slurry saw (MWSS)



20.2 % solar cell (37 μm) with LFC backside

Crystalline Silicon High Efficiency Solar Cells

Ultrathin monocrystalline silicon solar cells

- Excellent light-trapping and surface passivation
- High efficiency (>20 %)
- Extremely thin (37 μm)
- Flexible



Photovoltaic Technology Evaluation Center PV-TEC

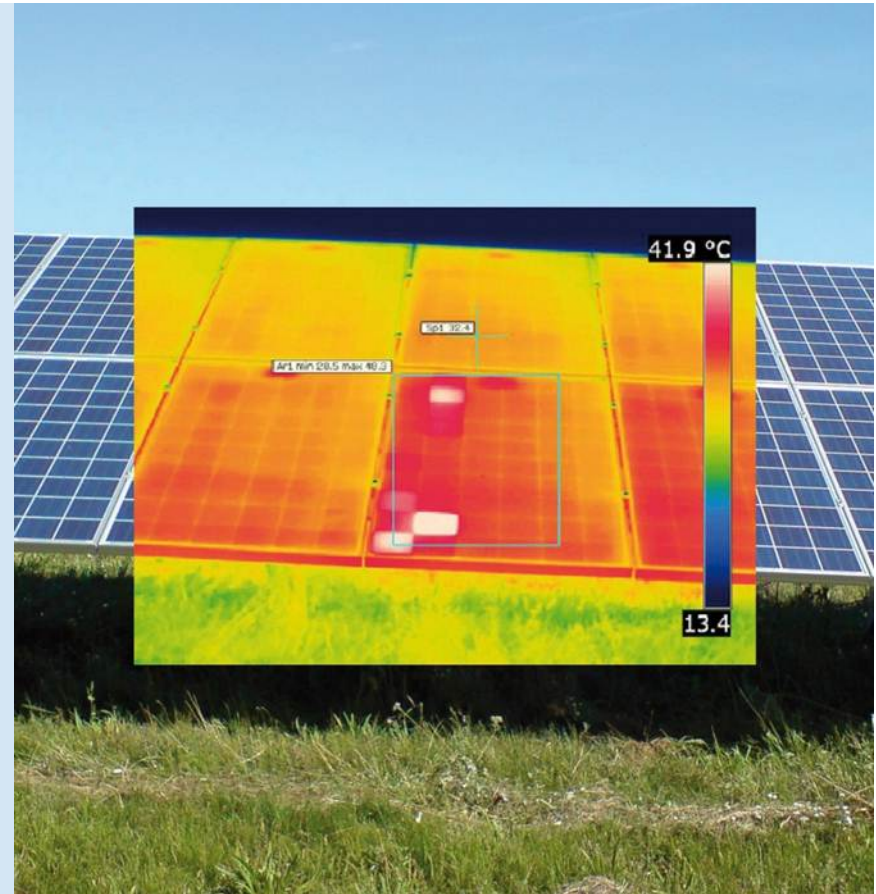
- Faster transfer of technology to the PV industry
- Service center for producers of
 - Wafers
 - Solar cells
 - Modules
 - Production equipment



Automated oxidation and diffusion oven

Business Area: Photovoltaic Modules and Systems

- Module Technology
- Durability Analysis and Environmental Simulation
- Quality Assurance for PV Modules, Systems and Power Plants



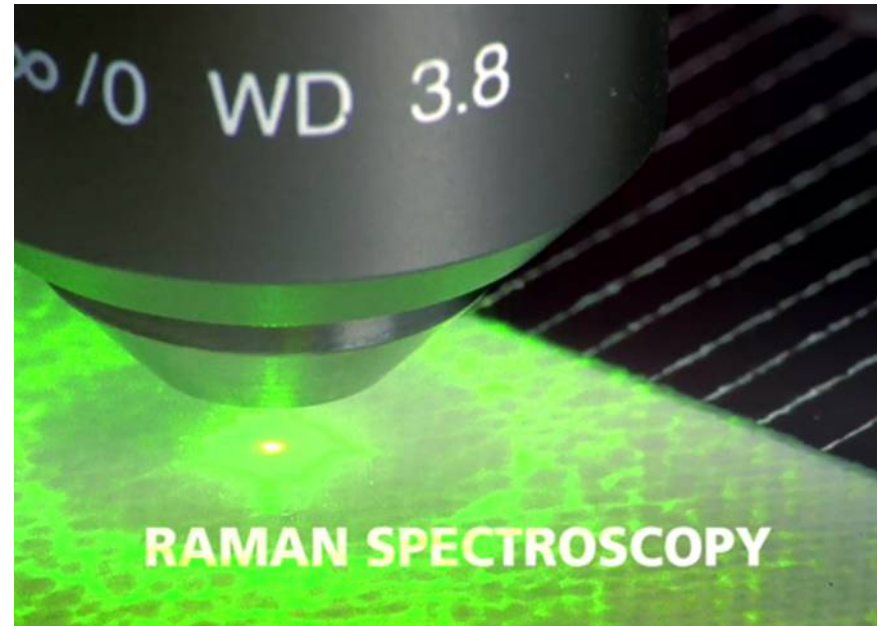
PV Module Technology Center (MTC)

- Interconnection and encapsulation technology
- Module efficiency
- Production quality assurance
- Material testing
- Approach of industrial scale production



Weathering and Reliability

- Material testing, e.g. Permeation, optical properties, weatherability
- Failure analysis
- Development of service life tests for PV modules and components



Raman spectrometry for degradation analysis of polymers

Lifetime Analysis of PV Modules and Materials

- Natural weathering of 60 commercial and experimental modules in e.g.:

- Alpine climate (Zugspitze)
- Tropics (Indonesia)
- Desert (Israel)
- Maritime climate (Gran Canaria)

GOAL: Verify the accelerated lifetime tests



Natural weathering on the "Schneeferner Haus" in the Alps



Fraunhofer ISE Quality Circle

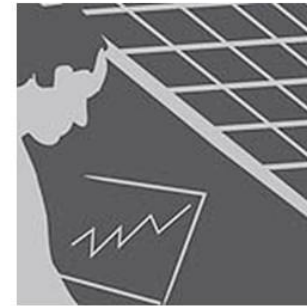
Yield Assessment



Module Measurements



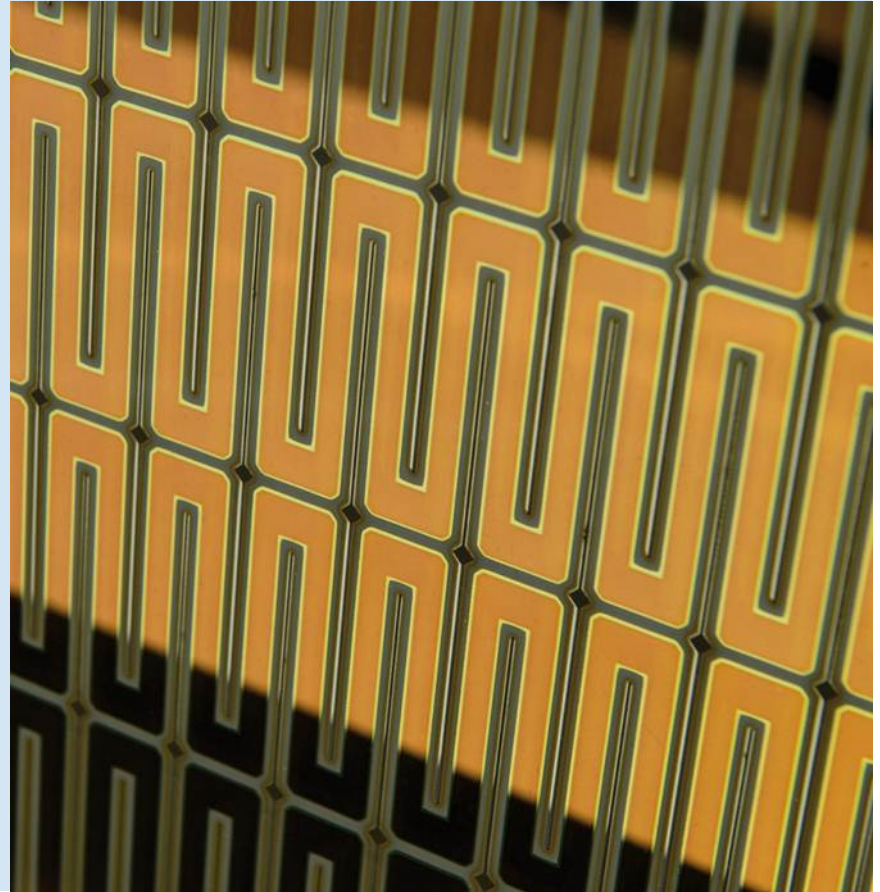
Yield Monitoring



System Testing

Business Area: Alternative Photovoltaic Technologies

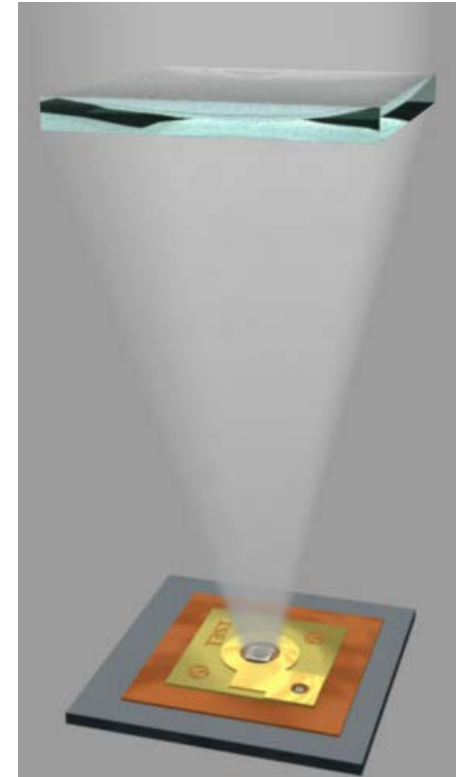
- III-V Epitaxy, Solar Cells and Components
- Dye and Organic Solar Cells
- Concentrator Systems
- Novel Solar Cell Concepts and Photon Management



III-V Solar Cells and Epitaxy

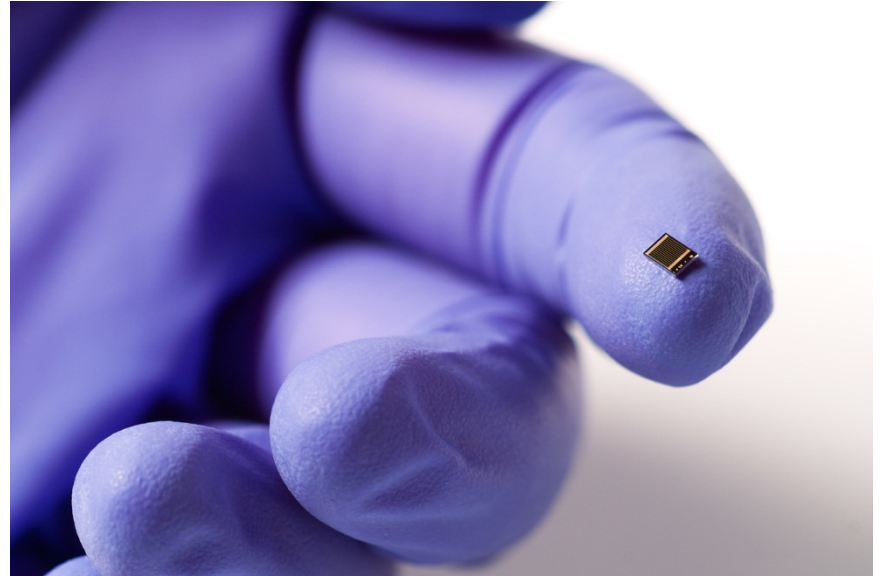
FLATCON™ Module
(**F**resnel **L**ens **A**ll-Glass
Tandem Cell
Concentrator)

The FLATCON™
technology was
developed and tested
in concentrator
systems at Fraunhofer
ISE



World Record Solar Cell at Fraunhofer ISE, Sept. 2013

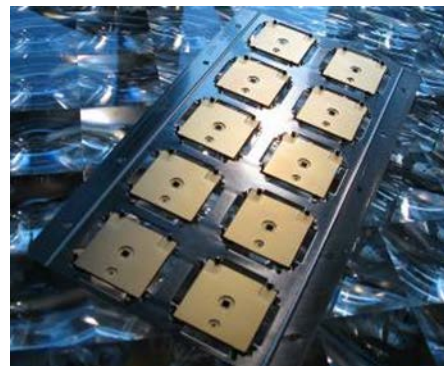
- 44.7 % efficiency
@ C=297 suns
- Four-junction solar cell
- Wafer Bonding
- Partners: Soitec, CEA-Leti,
Helmholtz Zentrum Berlin



23 September 2013: World record solar cell
with 44.7 % efficiency

ConTEC – Concentrator Technology & Evaluation Center

- Concentrator PV
Development of sub-assemblies and modules for
 - increased efficiency
 - increased reliability
 - increased lifetime
- Industrial-type equipment for development of high volume processes
 - die bonding
 - reflow process
 - wire bonding



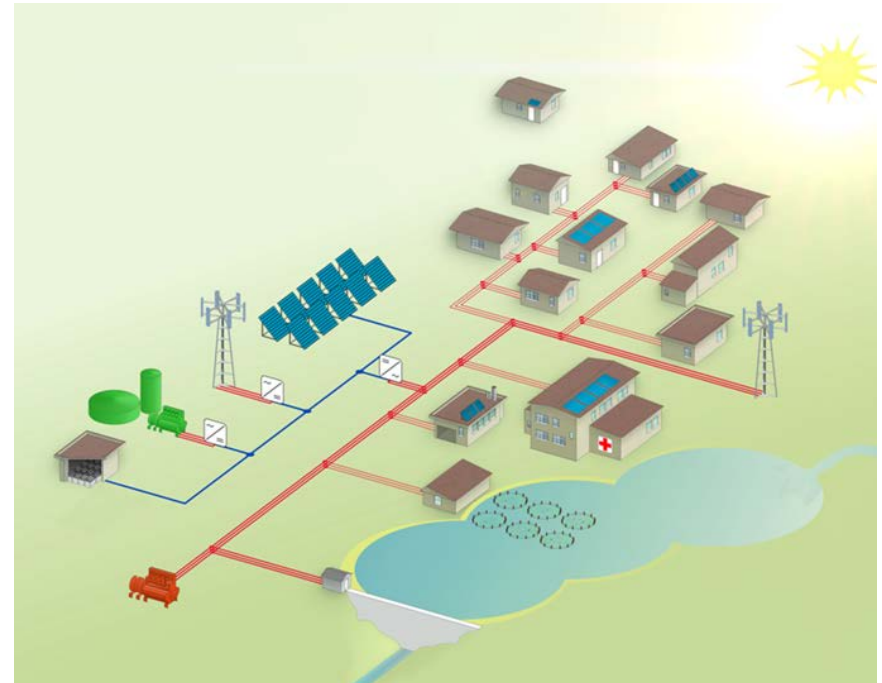
Business Area: Renewable Power Supply

- Autonomous Power Supplies and Mini-Grids
- Smart Grids
- Power Electronics and Control Systems
- Electric Storage Systems
- Solar Power Plants
- Decentralized PV Water Purification Systems
- E-Mobility



Next Generation of Hybrid PV Mini-Grids

- Simple integration of different energy sources (PV, wind, hydro, etc.)
 - ➔ Least-cost option
- Increasing quality of energy services
- Support local infrastructure and economic development
- Alternative solution to the national electrical grid



Autonomous Village Power Supply

- Socio-economic/socio-technical analyses
- Consulting, promotion, training
- Implementation strategies, financing concepts
- Development, testing and optimizing of components
- Development of operating strategies, energy and battery management systems
- Demonstration projects, system monitoring and quality assurance



Stand-alone PV-wind power supply in remote Chinese village

Power Electronics and Controls Technology

99.03% record efficiency for inverter using SiC components (2009)

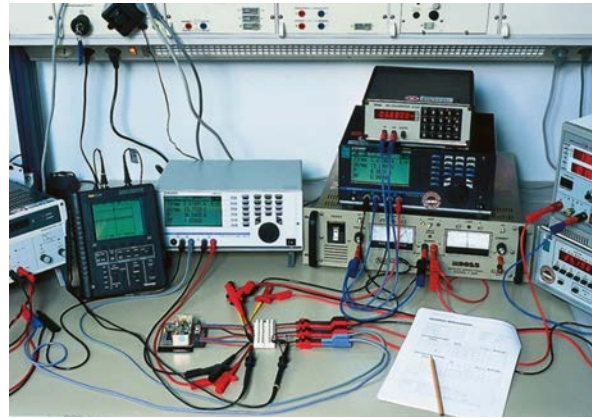
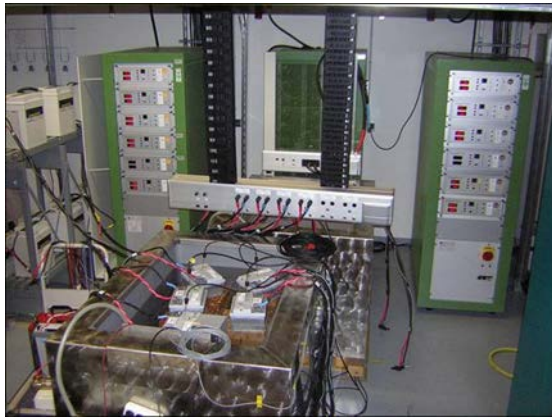


Inverter circuit board with SiC devices

Testing and Optimization of Electrical Components

Laboratory for characterizing and qualification testing of

- Battery cells
- Battery systems
- Battery periphery (e.g. charge controllers)



Solar Powered LED Lighting Systems

Transfer of Know-how

- LED Technology: solid-state lighting
- Simulation of PV LED systems and optics

Research and Development

- Portable lights, street lighting, ambient lights, etc.
- Electronics: DC/DC converters, ballasts

Quality Assurance and Tests

- Electrical tests and measurements: efficiency, performance and reliability
- Photometric Measurements: efficacy, luminance, temperature behavior



Photos: Gocke/GTZ, Fraunhofer ISE

Electromobility – Grid Integration of Electric Vehicles

- Conversion to efficient electric drive
 - with electrochemical energy storage
 - primarily using electricity from renewable energy sources
- Overall concept
 - renewable energy generation
 - energy distribution (grid)
 - vehicle
 - interface vehicle/grid
 - infrastructure



Charging station, Fraunhofer ISE

Solar Membrane Distillation Systems

- 100% solar thermal and hybrid (solar/waste heat) operation
- Two systems developed at ISE
 - Oryx 150 (capacity 50 m³/day)
 - Modular MD (containerized MMD, capacity 2-10 m³/day)
- Fundamental studies, modeling and simulation
- Development, fabrication and marketing
- About 20 systems in field operation, since 2004



MD module



Mexico 2010



Tunesia 2010, Oryx 150

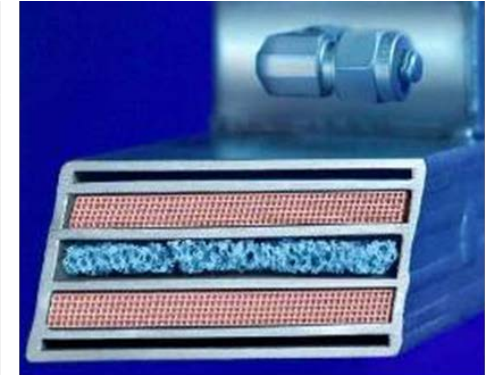
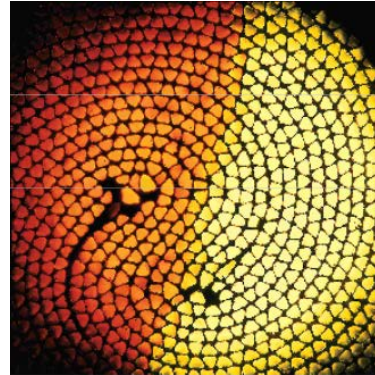
Business Area: Hydrogen Technology

- Fuel Cell Systems
- Micro-Energy Technology
- Hydrogen Production and Storage



Hydrogen Production and Storage

- Development of **reformer systems** to generate hydrogen from liquid and gaseous hydrocarbons
- Development of **electrolyser systems** to produce hydrogen from water



PEM Fuel Cell Development

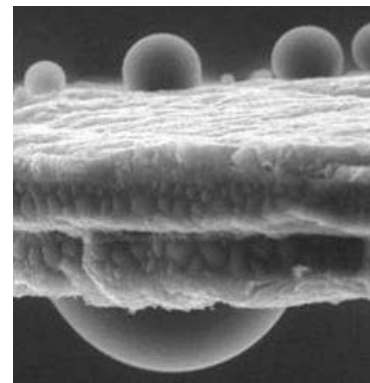
Automobile, Backup Power and Portable Applications

- Portable fuel cells (NT and HT-PEMFC stacks) for operation with hydrogen and reformat; power range up to 1 kW_{el}
- System technology for membrane fuel cells; power range from 100 mW_{el} to 5 kW_{el}
- Characterization and modeling from the cell to system level (up to 20 kW_{el} / from micro fuel cells up to automobile fuel cells)



TestLab Fuel Cells

- System-oriented stack testing up to 1000 A
 - Controllable balance-of-plant
 - Single cell monitoring under extreme climate conditions
- Characterization of cell and peripheral components
 - Operating and long-time behavior
 - Chemical stability
- Standardized tests
- Development of test stands for scientific experiments



Fraunhofer Research: Future Mobility



350W mobile service robot

Automated hybrid fuel cell system for small traction ($<1 \text{ kW}_{el}$)



"hydrogenia" - a joint development from Fraunhofer ISE and Fraunhofer IFAM

Solar Hydrogen Filling Station at Fraunhofer ISE

From solar energy to sustainable mobility

- Research platform and publicly accessible filling station
- On-site grid-connected 16 kWp PV system (expansion planned)
- On-site hydrogen production by PEM water electrolysis (0.5 kg/h, 7 kg/d)
- Fast-fill 700 bar in accordance with SAE J2601 standard and slow fill at 350 bar
- Max. 3 minutes to fill-up car tank
- Publicly accessible after briefing and receipt of fuel card

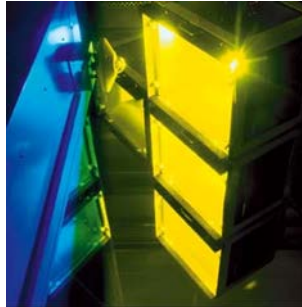


www.h2move.de

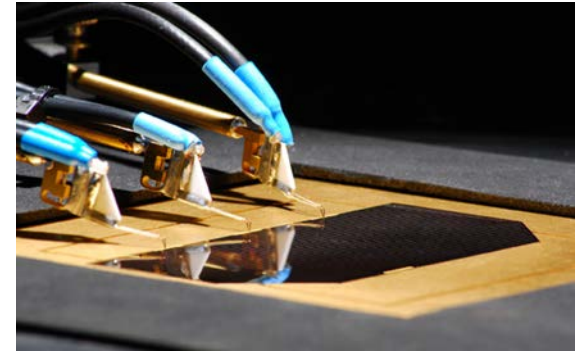
Service Units

Accredited Test and Service Centers

TestLab
Solar Façades



CalLab
PV Cells



TestLab
Solar Thermal
Systems



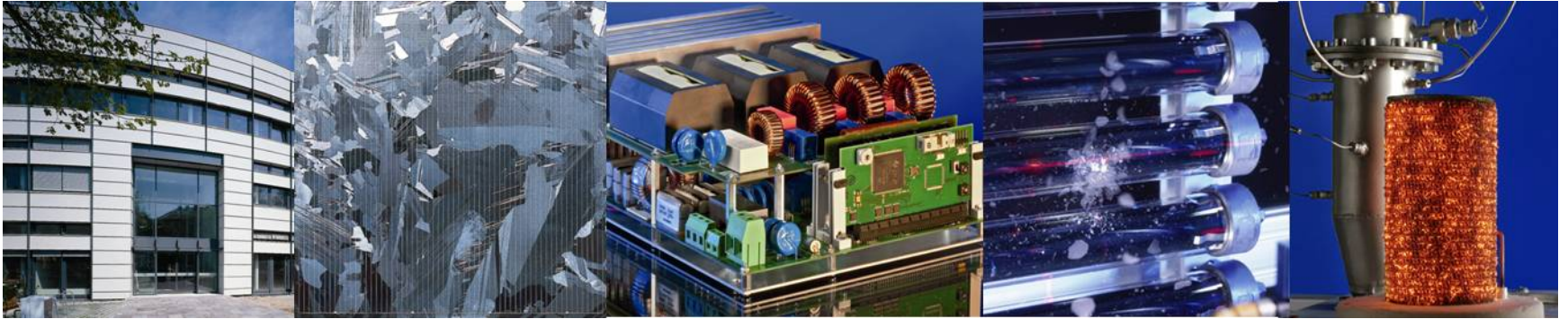
CalLab
PV Modules



TestLab
PV Modules



Thank you for your Attention!



Fraunhofer Institute for Solar Energy Systems ISE

www.ise.fraunhofer.de