Power Electronic Systems Laboratory

ETH zürich

Contactless Gripping – Paving the Way Towards Flexible Micromanipulation

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Power Electronic Systems Laboratory
CEO & co-founder No-Touch Robotics GmbH

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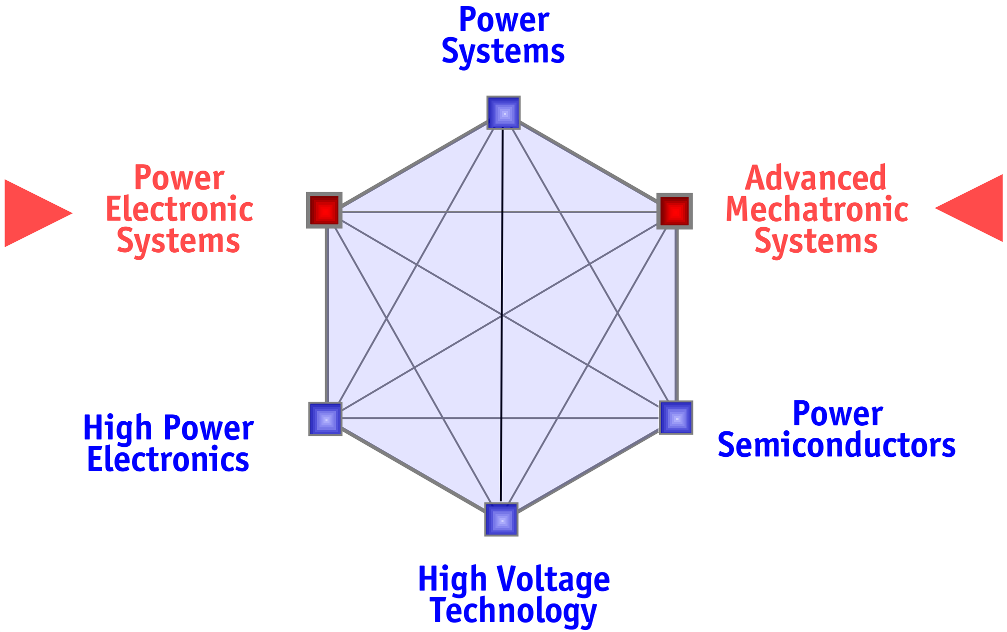
Introduction of the Power Electronic Systems Laboratory (PES)

21	Nobel Prizes
413	Professors
6240	T&R Staff
2	Campuses
136	Labs
35%	Int. Students
110	Nationalities
36	Languages
150th	Anniv. in 2005

Departments of ETH Zurich

ARCH	Architecture
BAUG	Civil, Environmental and Geomatics Eng.
BIOL	Biology
BSSE	Biosystems
CHAB	Chemistry and Applied Biosciences
ERDW	Earth Sciences
GESS	Humanities, Social and Political Sciences
HEST	Health Sciences, Technology
INFK	Computer Science
ITET	Information Technology and Electrical Eng.
MATH	Mathematics
MATL	Materials Science
MAVT	Mechanical and Process Engineering
MTEC	Management, Technology and Economy
PHYS	Physics
USYS	Environmental Systems Sciences

Energy Research Cluster @ D-ITET



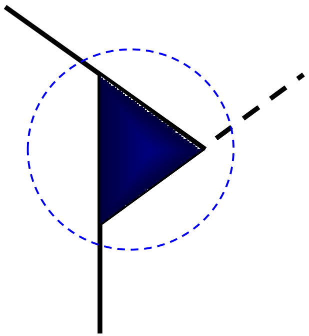
- Balance of Fundamental and Application Oriented Research

PES Research Scope

Power Electronics

Cross-Departmental

Mechanical Eng., e.g. Turbomachinery, Robotics
Microsystems
Medical Systems
Economics / Society



- *Airborne Wind Turbines*
- *Micro-Scale Energy Systems*
- *Wearable Power*
- *Exoskeletons / Artificial Muscles*
- *Hybrid Systems*
- *Pulsed Power*

Actuators / EL. Machines

Innovation in Mechatronics and Electric Drives

■ Key Components Available Today

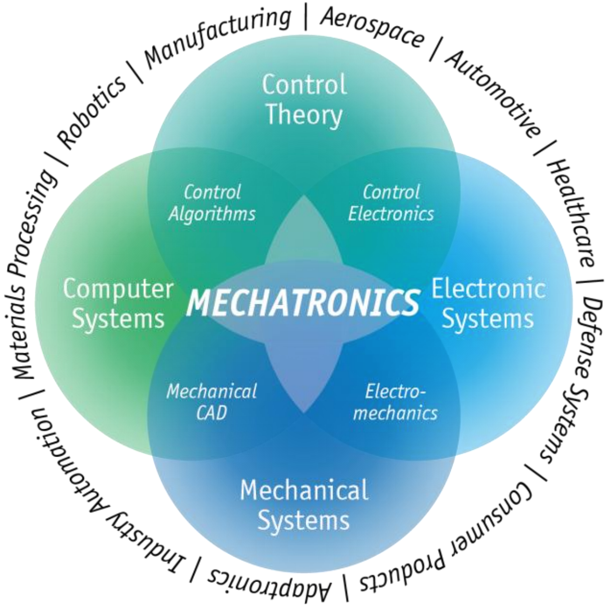
Ultra-Compact & Efficient
Power Converter

Precision Sensors

High-Speed Digital
Signal Processing

Ultra-Compact & Efficient
Electrical Machines

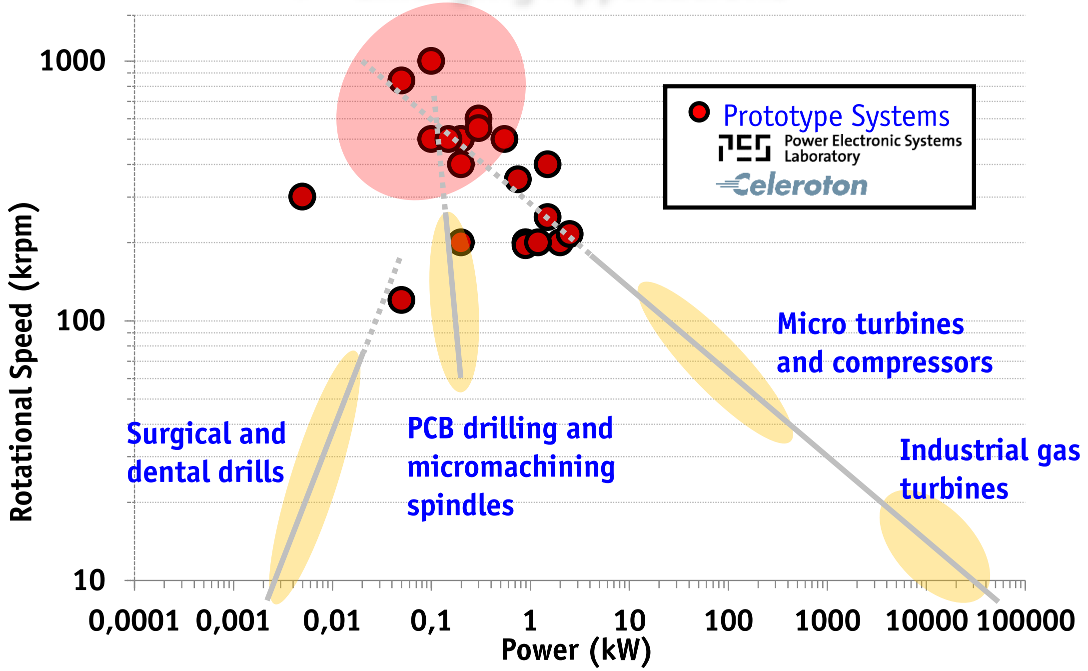
High-Performance
Mechanical Actuators



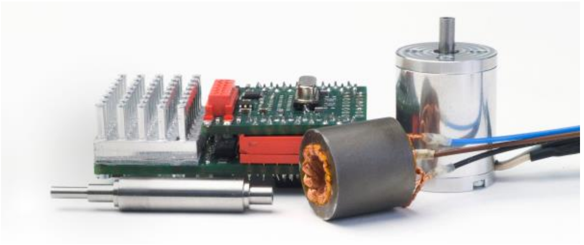
■ Extremely Wide Application Areas

Industry Trend: High Rotational Speed for High Power Density

▶ Emerging Applications



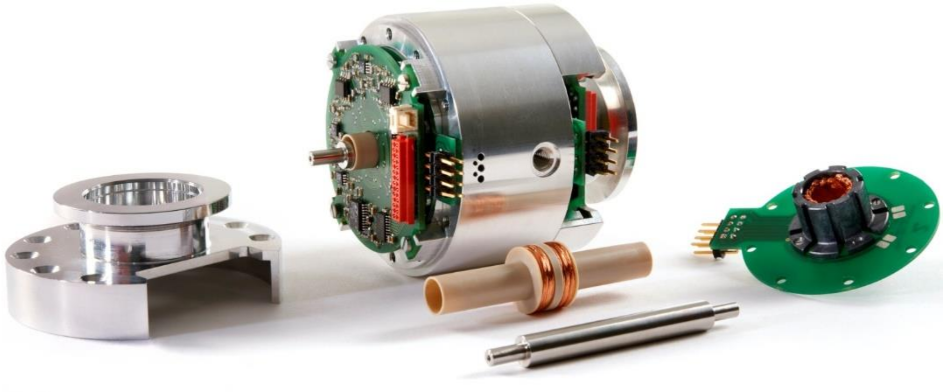
1'000'000 r/min, 100 W
World Record Drive System



- ▶ µm-Scale PCB Drilling
- ▶ Dental Technology
- ▶ Laser Measurement Technology
- ▶ Turbo-Compressor Systems
- ▶ Air-to-Power
- ▶ Artificial Muscles
- ▶ Mega Gravity Science

Source: Zwyssig et. al., Megaspeed Drive Systems: Pushing Beyond 1 Million r/min, IEEE Transactions on Mechatronics 2009

World Record Magnetic Bearing with 500’000 r/min

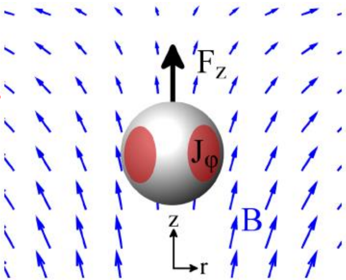


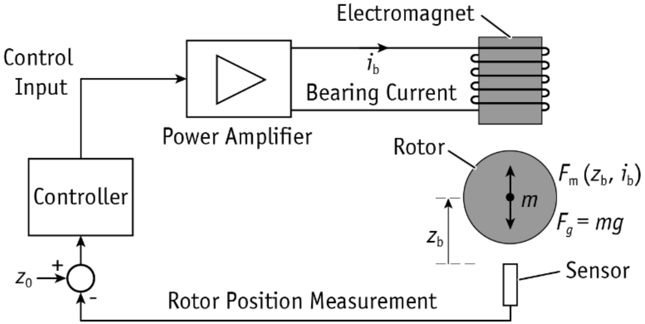
Source: Baumgartner and Kolar, Multivariable State Feedback Control of a 500 000-r/min Self-Bearing Permanent-Magnet Motor, IEEE Transactions on Mechatronics 2015

Source: nasa.gov

High Complexity of Active Levitation Systems

- **Active Magnetic Levitation**
  - Sensing Difficult for Small Rotors
  - High Bandwidth / Complex Control

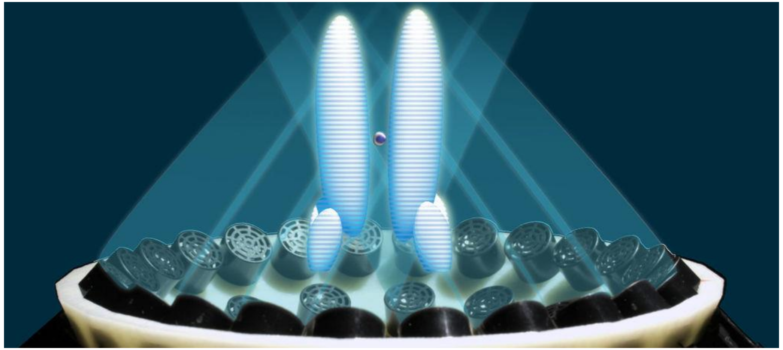




- **Passive Magnetic Levitation**
  - High Eddy Current Losses

- **Passive Acoustic Levitation**
  - **Particle < Wavelength**
  - Acoustic Pressure Field
  - Ultrasound Transducers

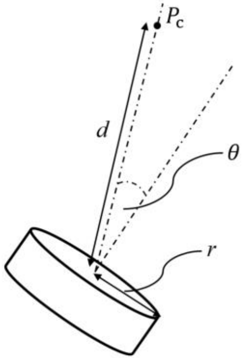
+ Passively Stable
+ Low Losses
- Low Load Capacity



Source: https://www.instructables.com/id/Acoustic-Tractor-Beam/

Transducer Arrangements and Modelling

- **Individual Excitation of Transducer Arrays**
  - Manipulation of all Degrees of Freedom Possible
  - Achievable Force/Torque Dependent on Transducer Arrangement

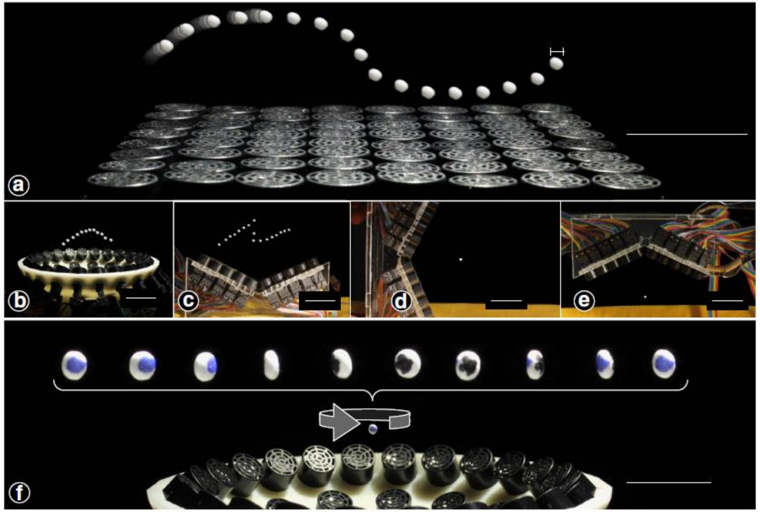


Transducer Piston Model

$$p = \sum_{j=1}^{N} p_j$$

$$p_j = e^{i\phi} M_j$$

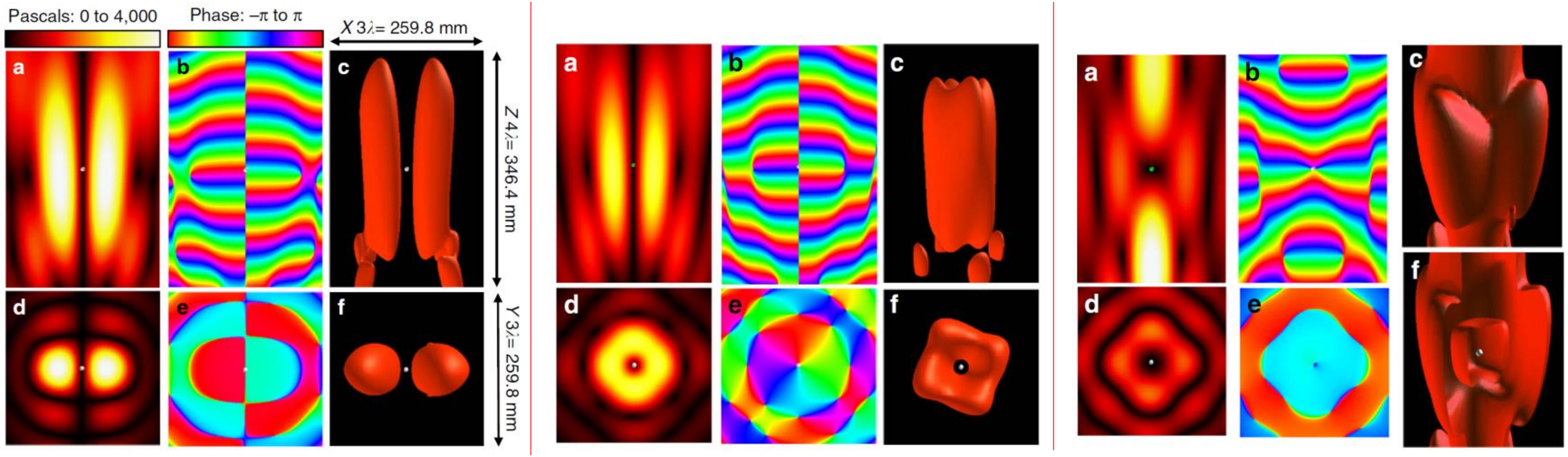
$$M_j = P_0 J_0(kr \sin\theta) \frac{1}{d} e^{ikd}$$



Source: Marzo et. al., Holographic acoustic elements for manipulation of levitated objects, Nature Communications 2015

Types of Acoustic Traps

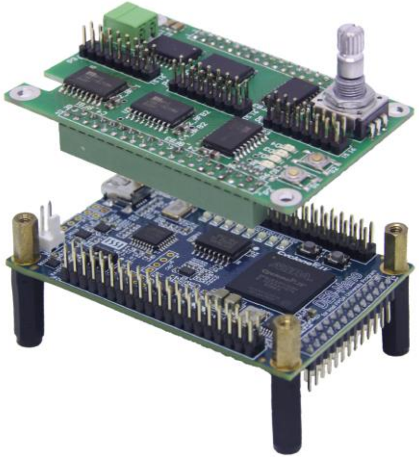
Twin Trap Vortex Trap Bottle Trap



Source: Marzo et. al., Holographic acoustic elements for manipulation of levitated objects, Nature Communications 2015

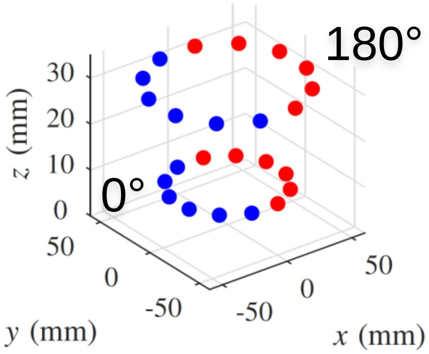
- Twin Trap Provides Sufficient Load Capacity and High Radial Stiffness
  - Spatial Rotation of Trap

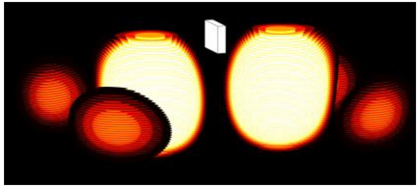
High Speed Rotation in Acoustic Traps

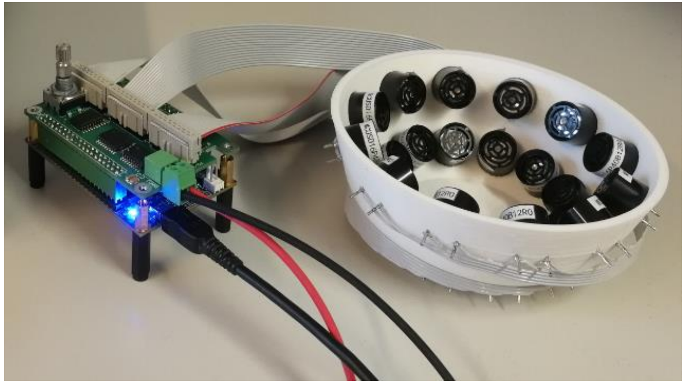


Power Electronic
Converter System

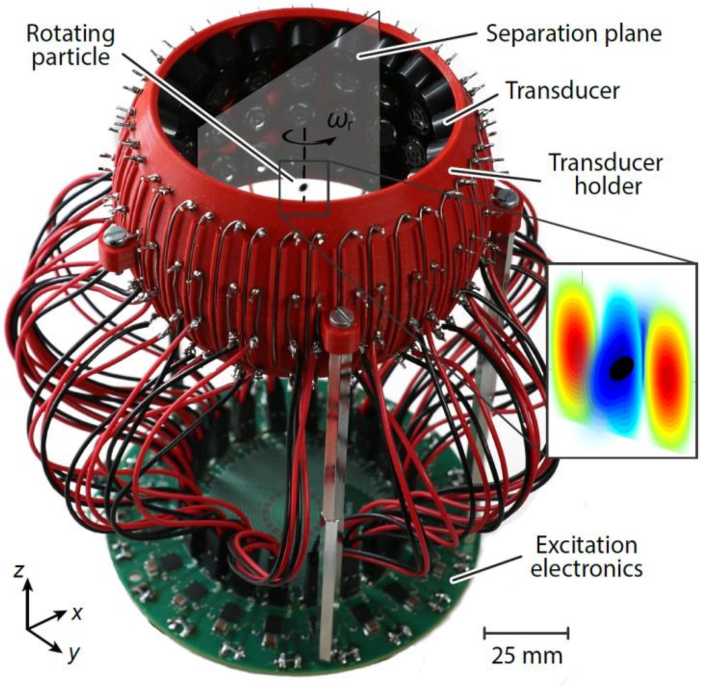
Twin Trap
- Approx. Constant Suspension Forces by Non-Linear Phase Shift
- Stability over Wide Speed Range

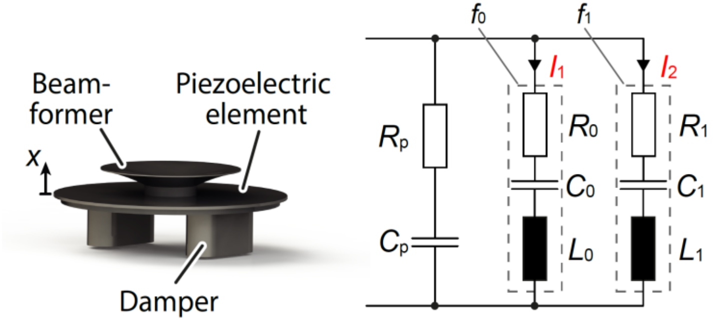


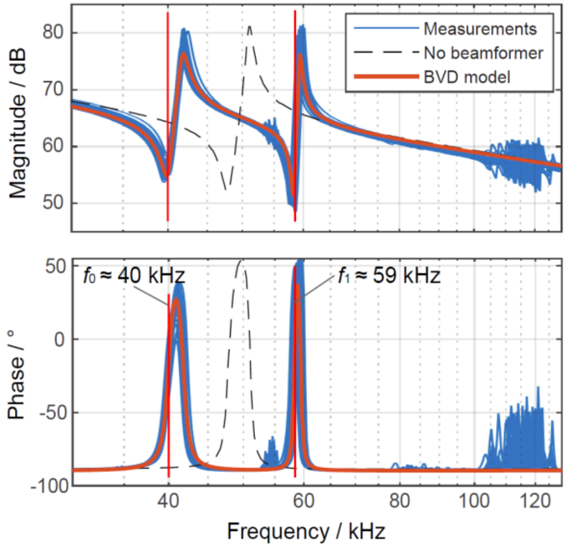




Highest Rotational Speed of 216’000 r/min



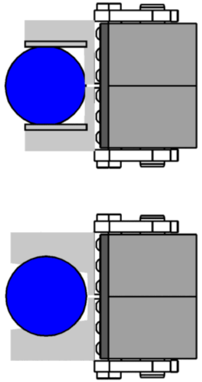




Robotic Grippers Lag Miniaturization Trend

The Information

"What Apple Learned From Automation: Humans Are Better"



Contact-based gripping increasingly unsuitable for small objects

Acoustic Robotic Gripper

No-Touch Robotics Spin-off | ETH zürich

Handling of Components

- Without Mechanical Contact
- Damage and Contamination Free
- Handling of Small Objects and Liquids
- Multiple Object Geometries

Processes Automation

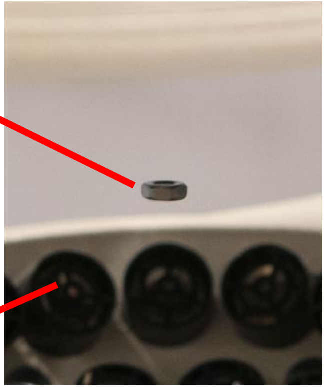
- Automated Insertion of Components Required for Pick & Place Processes

Mechatronic System for Precise Force Generation

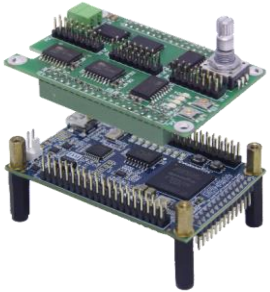
Object size	< 8 mm
Mass	< 250 mg
Accuracy	≤ 100 µm
Range	± 30 mm

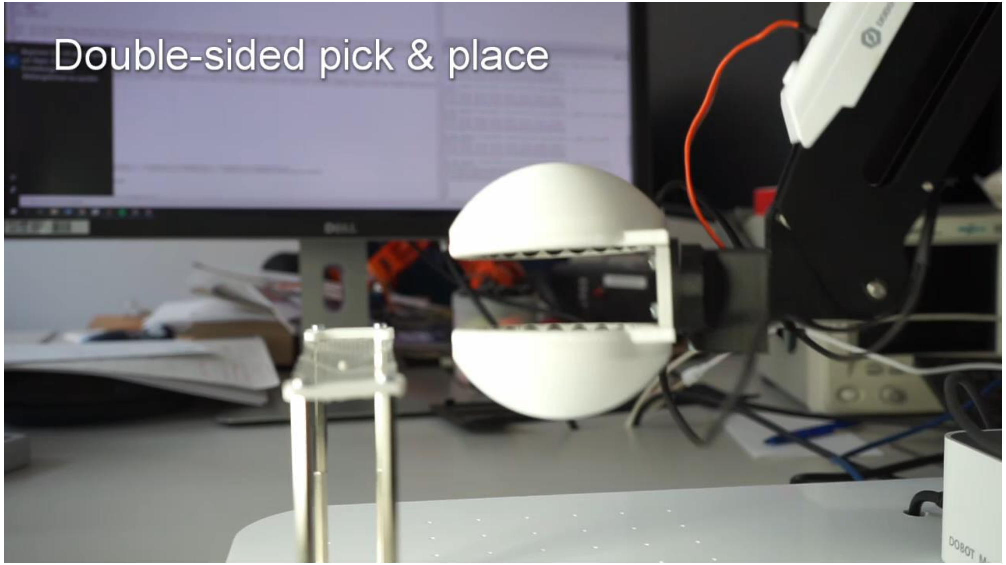
M3 hex nut

Ultrasound transducers (72 x)



Control software

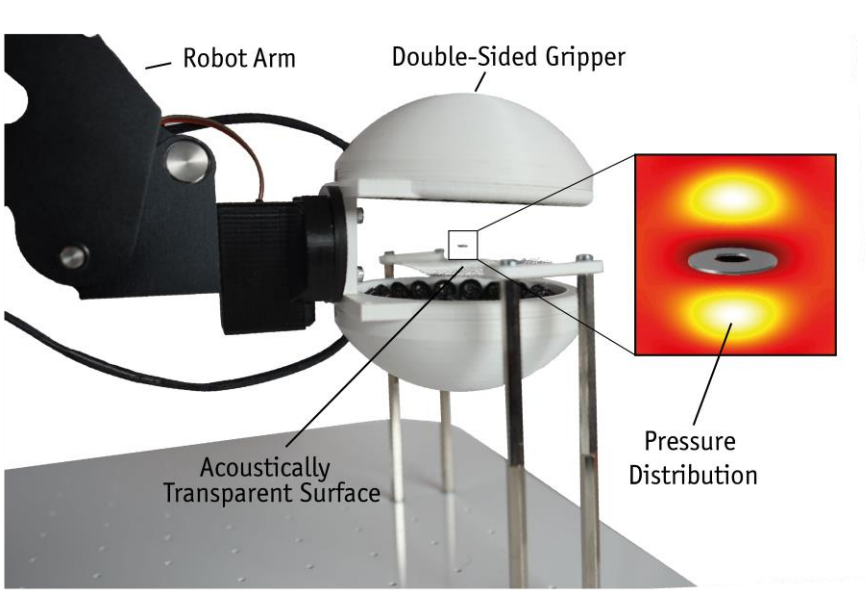


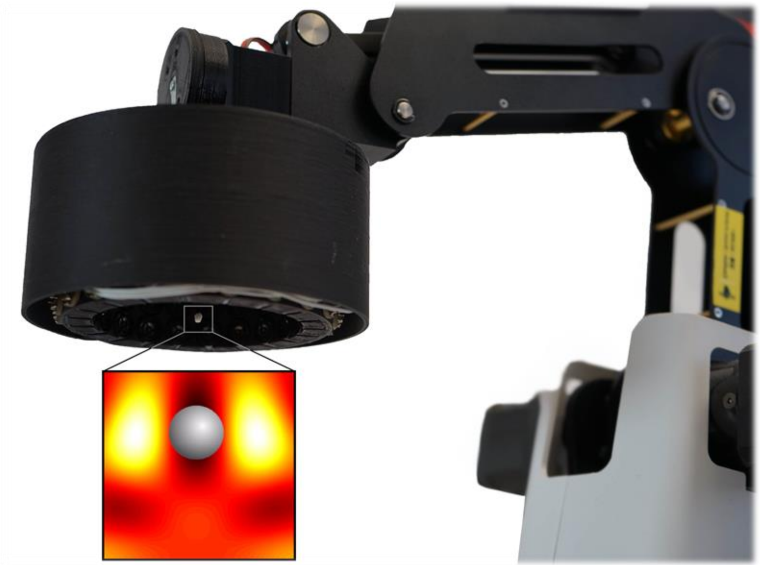


Picking Process: Double and Single-Sided Gripper

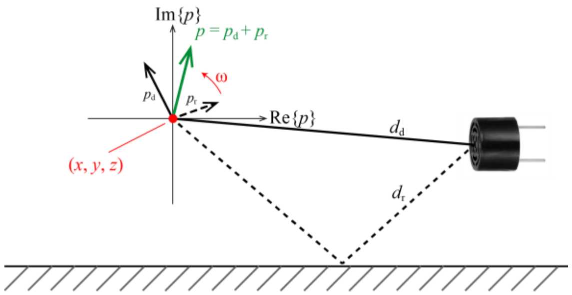
"Automated Insertion of Objects Into an Acoustic Robotic Gripper"
Marc Röthlisberger, Marcel Schuck, Laurenz Kulmer and Johann W. Kolar

IeCAT 2020
MDPI



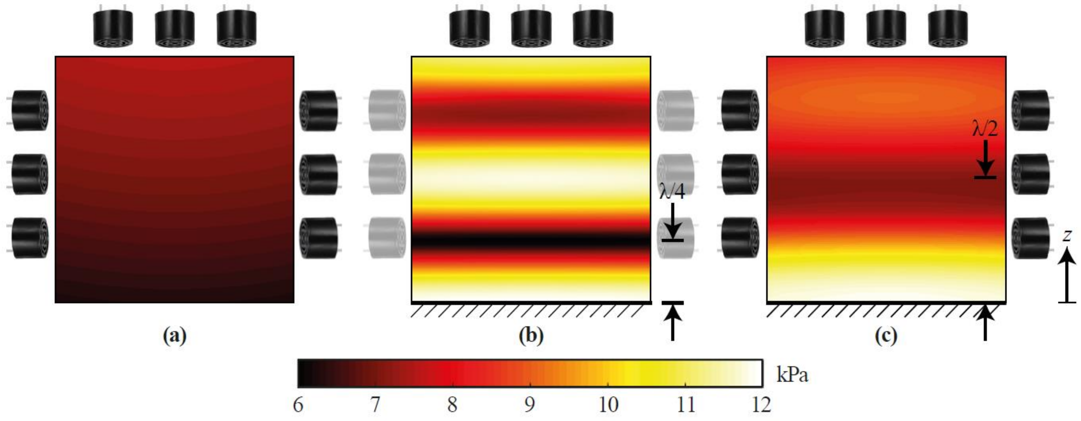


Single-Sided Picking from Reflective Surfaces

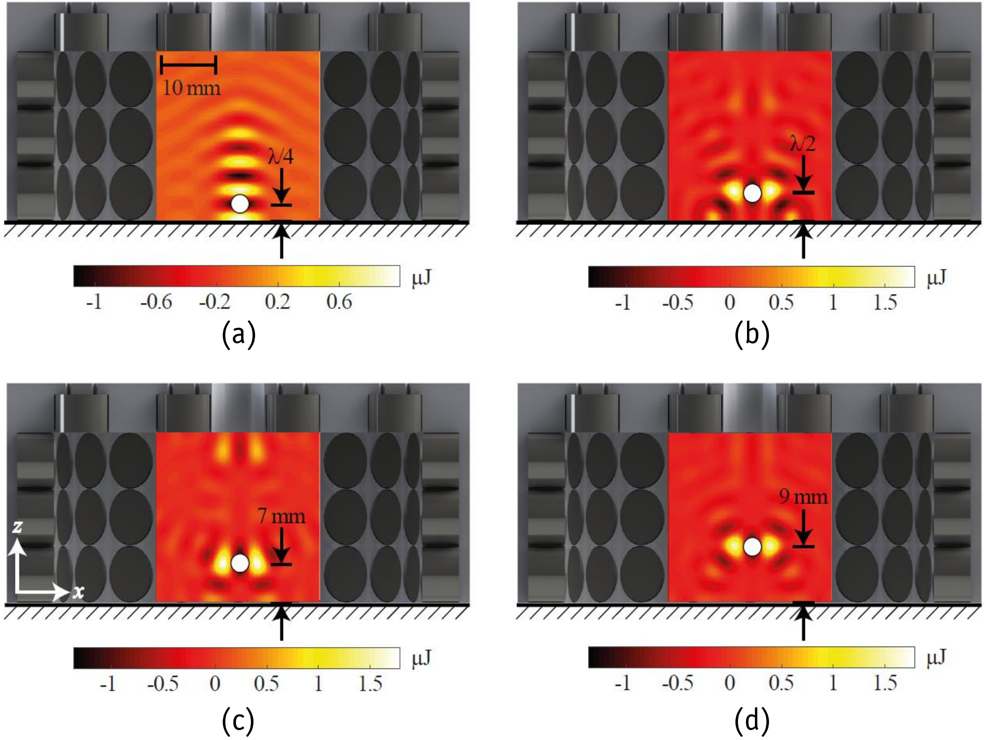


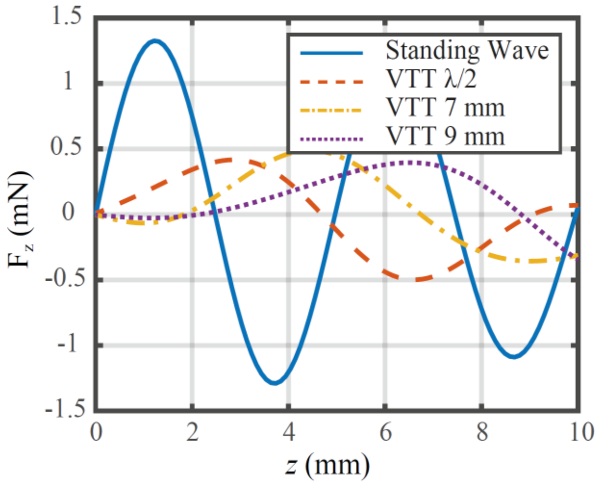
Maximum attainable pressure for each point in space

$$M(x,y,z) = \sum_j \left| V_{\mathrm{RMS}} P_0 \left(\frac{J_0(kr \sin\theta_{\mathrm{d},j})}{d_{\mathrm{d},j}} + R \frac{J_0(kr \sin\theta_{\mathrm{r},j})}{d_{\mathrm{r},j}} \right) \right|$$



Single-Sided Picking from Reflective Surfaces





Application Example: Liquid Handling

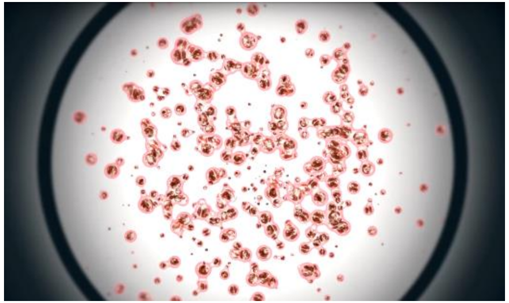
GRIP OBJECTS WITHOUT TOUCHING THEM
Automate processes that had to be performed manually before.

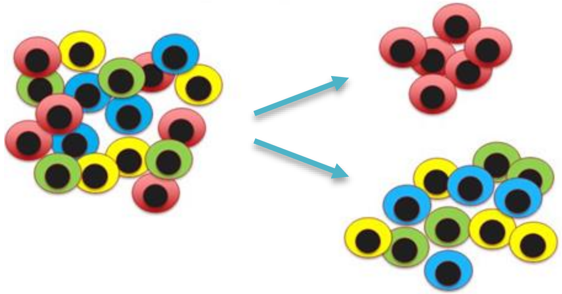
SAVE TIME AND MONEY
The same gripper can be used for a variety of object shapes.

INCREASE QUALITY AND YIELD
Damage and contamination-free handling of precious components.

IMPROVE ENVIRONMENTAL FOOTPRINT
Reduced production rejects.

Application Example: Cell Manipulation

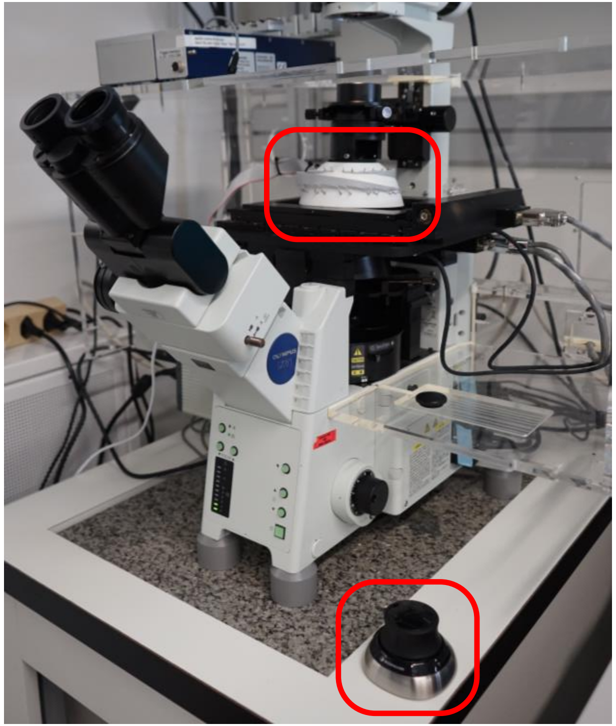


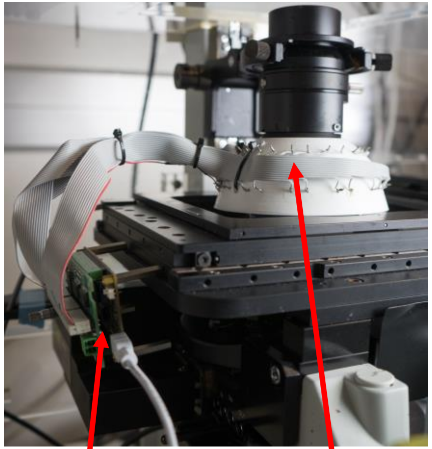


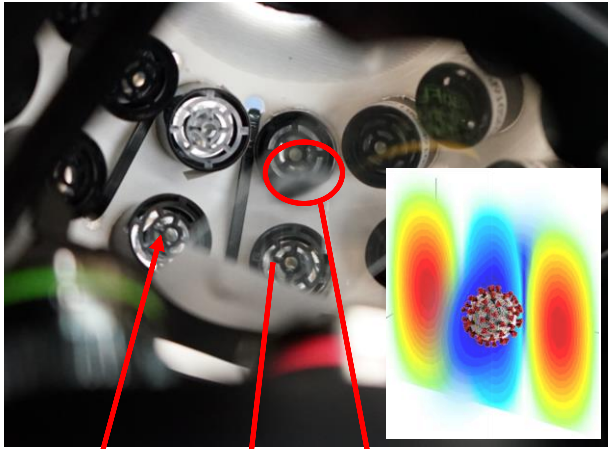
- Manual cell sorting is slow and unreliable
- Results are difficult to replicate
- Precision too low
- Contamination and damage

→ **High cost and low yield**

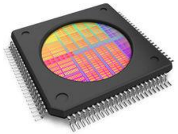
Application Example: Cell Manipulation



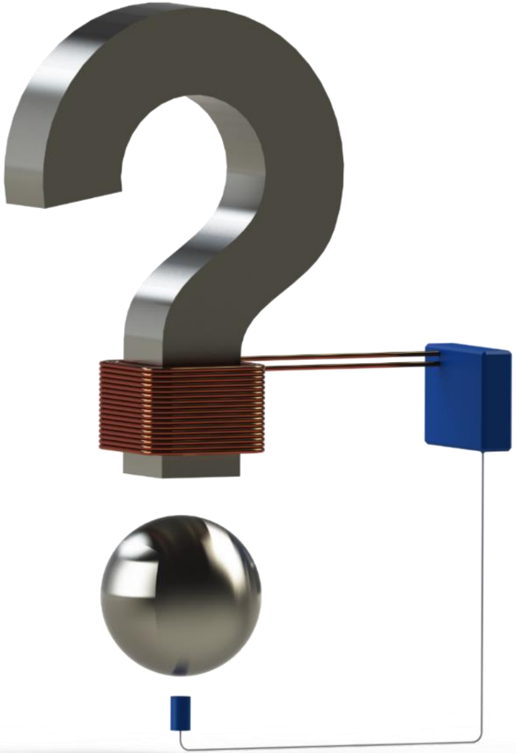




Plattform Technology With a Wide Range of Applications

No-Touch Robotics	Micromechanics & Watchmaking 	Semiconductor Industry 	Life Sciences 
Automate manual processes	✓		
Contamination and damage free	✓	✓	✓
Variable shape components	✓		
Fluid handling/dispensing		✓	✓
Improved quality & yield	✓	✓	✓
No particle generation		✓	✓
Isolation of hazardous substances		✓	✓

Thank You!



(Image courtesy of Daniel Steinert)