Hybrid Positioniersysteme für Picometer Auflösung mit Millimeter Stellbereich

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Motivation

- Wie groß ist ein Picometer?
- Welche Applikationen gibt es?
- Welche Actuatoren nutzen wir?
- Wie kommen Meter lange Bewegung mit Picometer zusammen?
- Beispiele

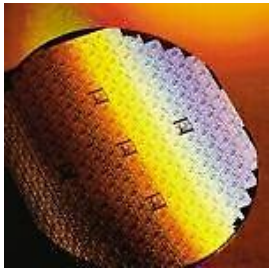
- Hybrid Actuatoren für lange Stellbereiche
- Piezo und Lorentz Force Actuatoren

Wie groß ist ein Picometer?

- Klein gegenüber alltäglichen Abmessungen
- = 0.000 000 000 001m
- 1/60 000 000 Haardurchmesser
- 1/100 Atomradius Wasserstoffatom

- Groß gegenüber der Planck- Länge von 10^{-35} m

Picometer… für High-Tech Märkte ?



Semiconductor technology

Data storage technology

Microscopy

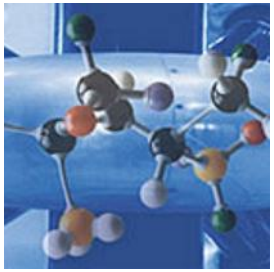
Metrology / laser systems

Life science / biotech

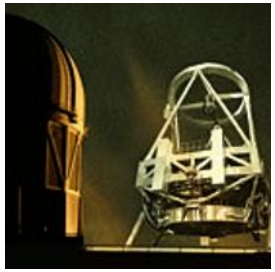
Photonics/ optics

Precision machining

Automation / handling



Nano-technology



Astronomy / aeronautics

Quelle: PI Katalog

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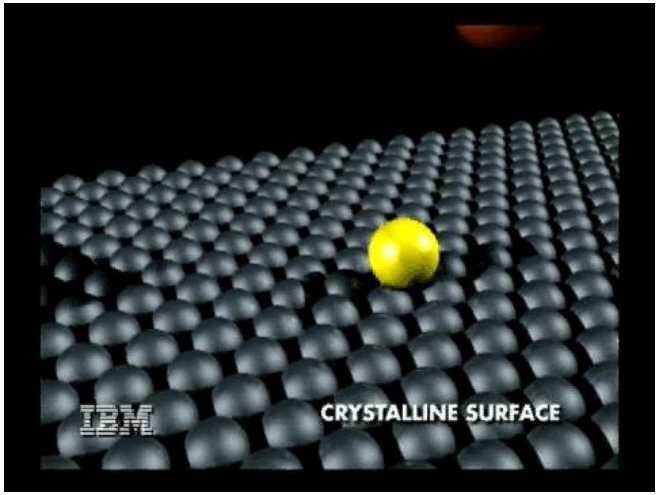
Nanometer Size



1nm

0,000 000 000 01 m

100's meter with nanometer accuracy

100m

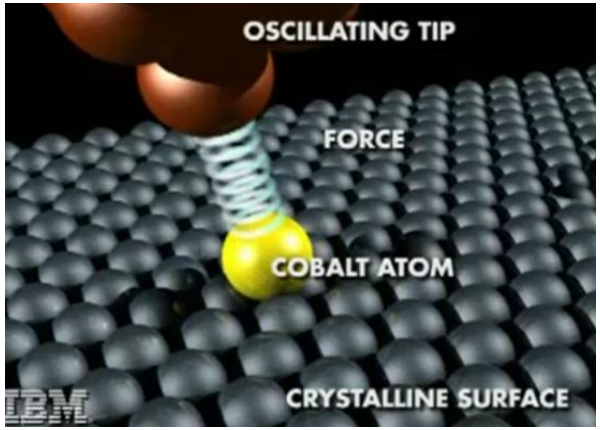
100m

LAMOST telescope / China

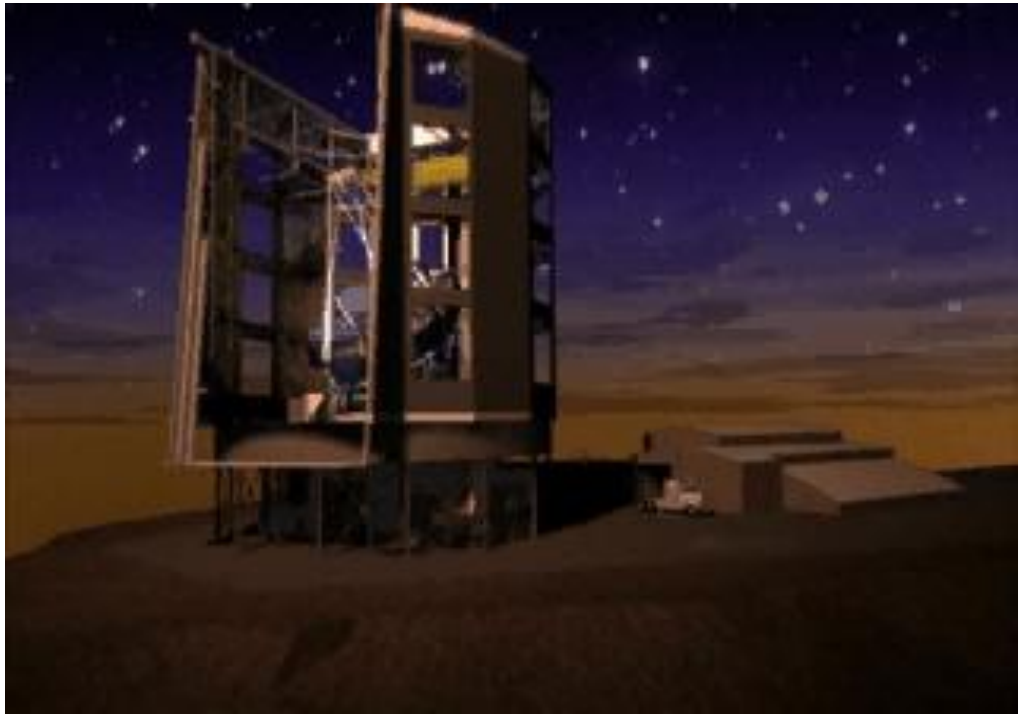
…

Nanometer Size

100’s meter with nanometer accuracy



Quelle: IBM research



Quelle: ESA

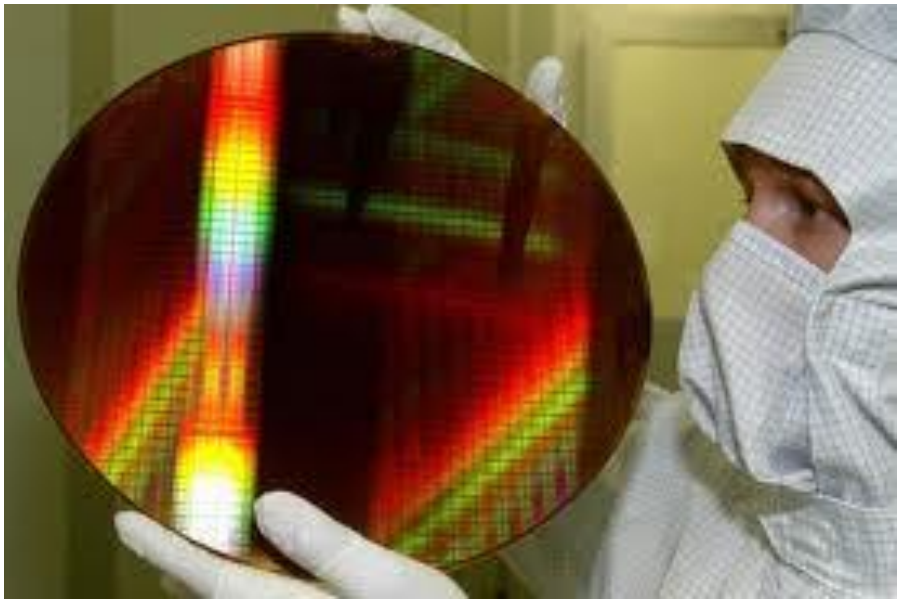
1nm

100m

Nanometer or even Picometer Resolution in Semiconductor Technology

- Wafer stepper
- Wafer handling
- Reticle alignment
- Optics control
- ……

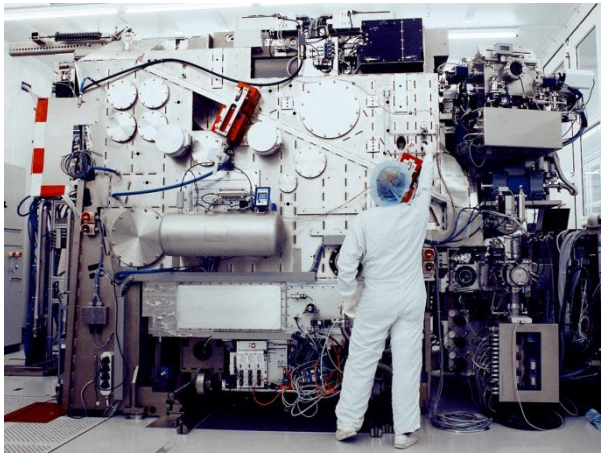
- Wafer inspection tools
- Optics inspection
- Reticle inspection
- Reticle repair
- ……



Quelle: welt.de

Roadmap of Wafer Stepper → EUVL

Quelle: ZEISS



Quelle: ASML

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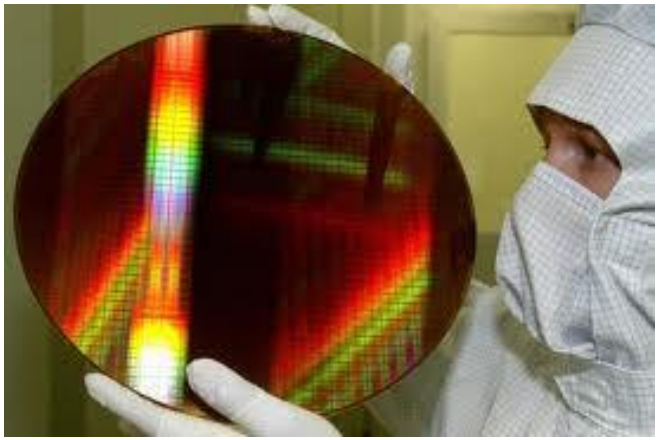
Wo sind Positionierungen kleiner 1nm erforderlich?

- Beispiel:



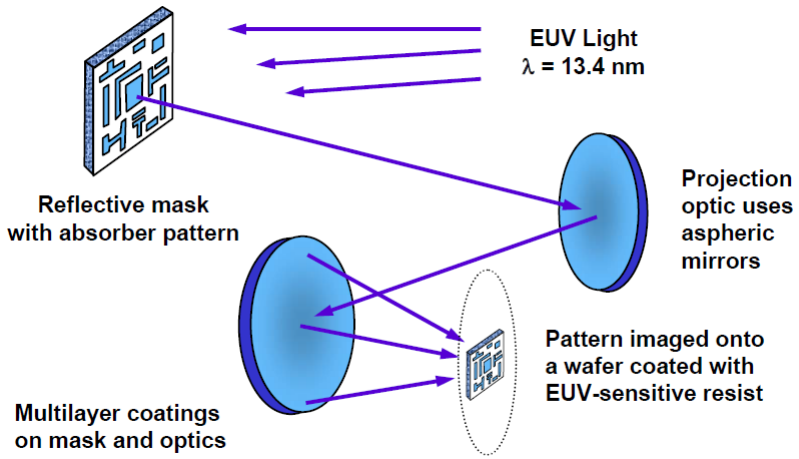
- 12 “…15” Wafer

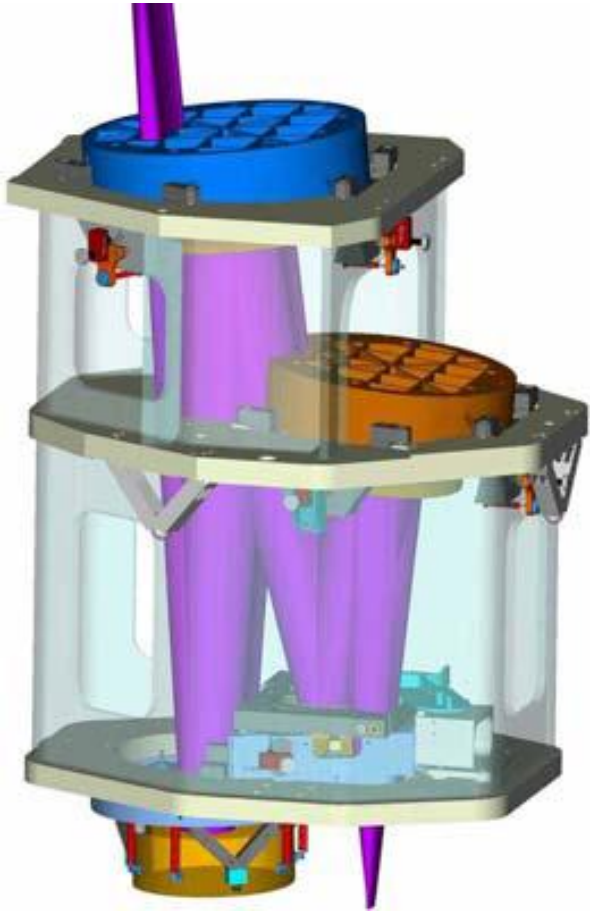
- Wafer 1mK Temperaturdifferenz beim Auflegen auf den Wafer- Chuck
- Ausdehnungskoeffizient: Si 2,6* 10^{-6}
- 300 000 000nm * 2,6*10^{-6}/K = 780nm Verformung /K

  bei Aluminium ergeben sich ca.7µm Verformung

< 1nm

- EUVL Optik 150pm Absolutabweichungen von der Parabolform,
- 30pm Kurzwelligkeit

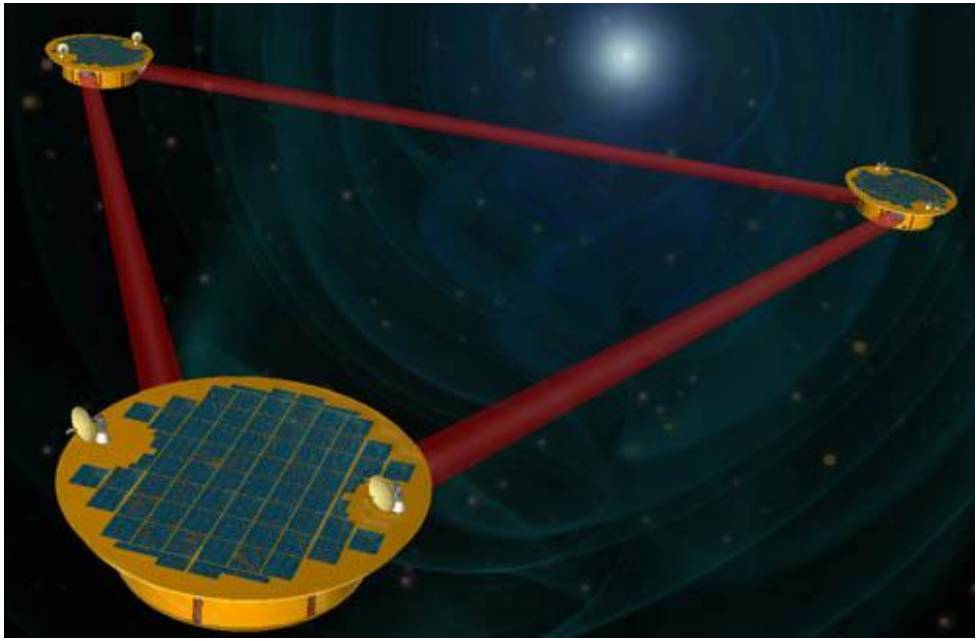




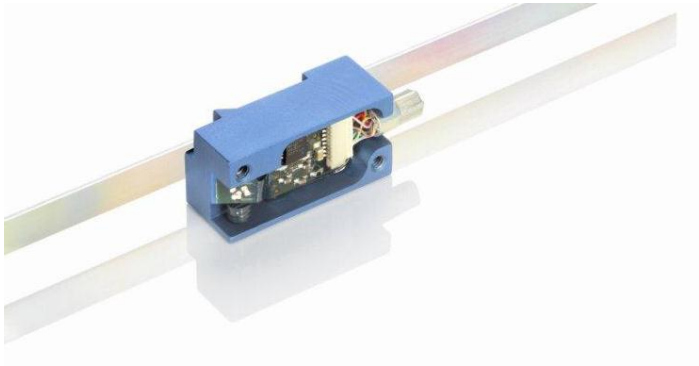
Quelle: ASPE 2009

< 1nm in kosmischen Dimensionen

- LISA
- NASA / ESA
- Gravitationswellen Experiment 5Mio km , 20pm Auflösung



PI‘s optischer inkrementaler Sensor



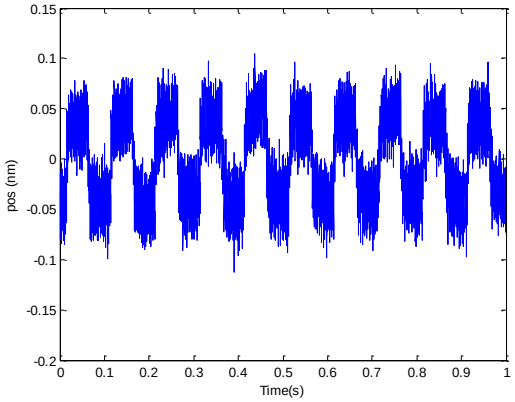
Basis: zwei Beugungsgitter

L x W x H =	23mm x 12mm x 9,5mm
Bewegte Grating Periode	2 µm
Feststehende Grating Periode	1 µm
Signal Periode	0.5 µm
Laser	655nm (LP red)
Auflösung	< 20pm (Picometer) RMS

Mach-Zehnder interferometer

Beispiel:

100pm steps



Phasengitter

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Piezo vs. Voice coil

- Steifigkeit
- Ladungsverschiebung → mechanische Verschiebung
- Leistungsloses Halten der Position
- Kann auch open loop gesteuert betrieben werden

- Steifigkeit gegen Null
- Strom → Kraft
- Leistungsverbrauch bei Gegenkraft
- Um Positionstabilität zu erreichen ist immer eine Regelung erforderlich
- (gilt auch für Reluktanz-Aktuatoren)

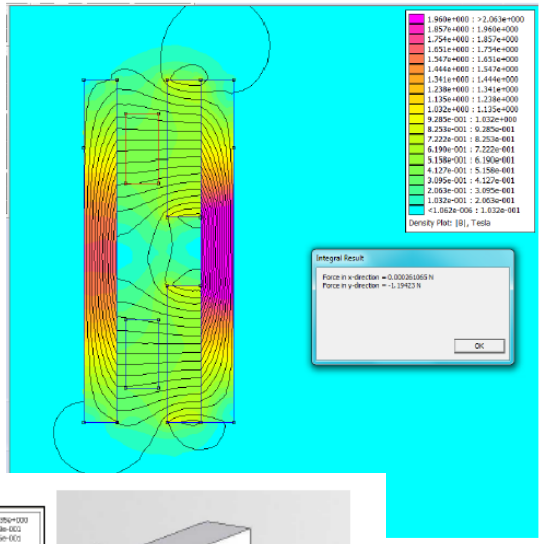
Welche Actuatoren sind für den Bereich <1nm geeignet ?

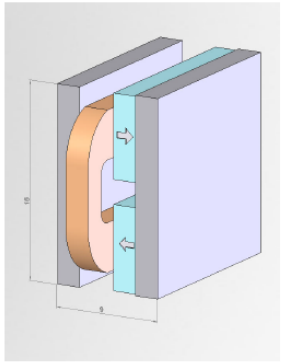
- Piezo Stapel Aktuatoren
- Piezo Bieger
- Walk Drive Systeme, NEXLINE®
- Lorentz Force (Voice Coil Actuatoren)
- Reluktanz- Aktuatoren

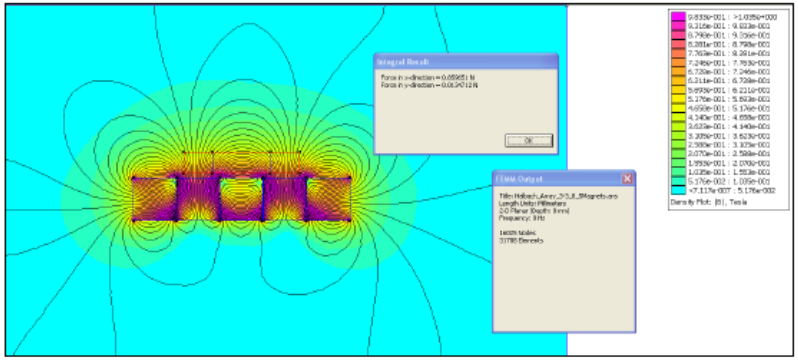
- Bedingt geeignet Ultrasonic Systeme

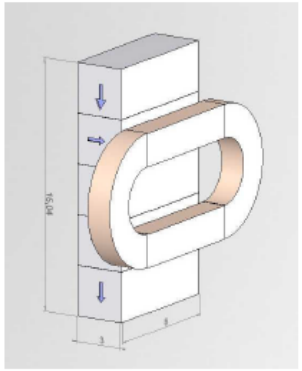
Magnetic Actuators

- Special design
- Free in design of magnet field structure





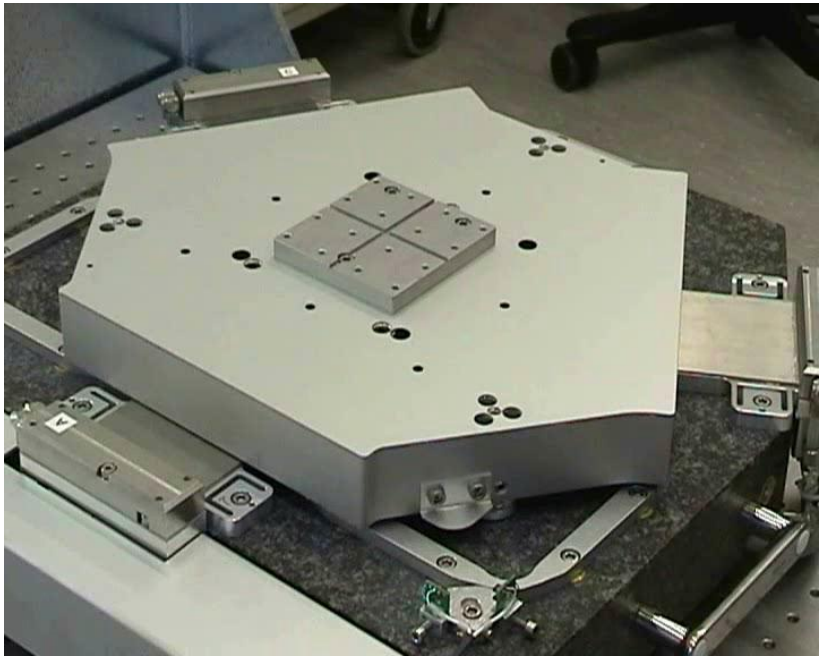




3 Magnets

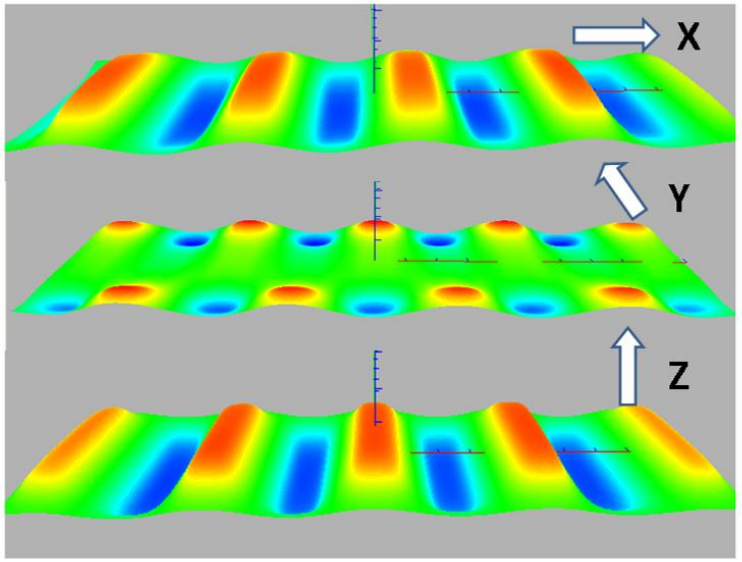
Halbach array

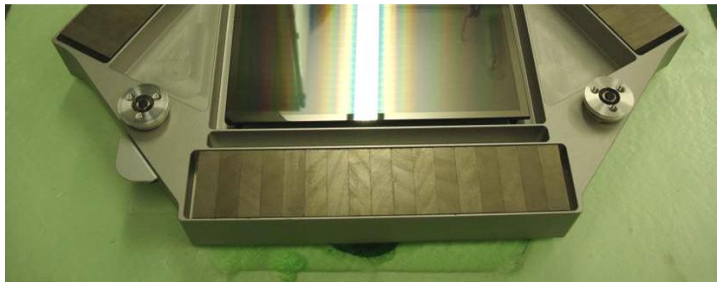
- Magnetic Levitation – der fliegende Tisch



http://www.youtube.com/watch?v=DQwqOYSzDl4

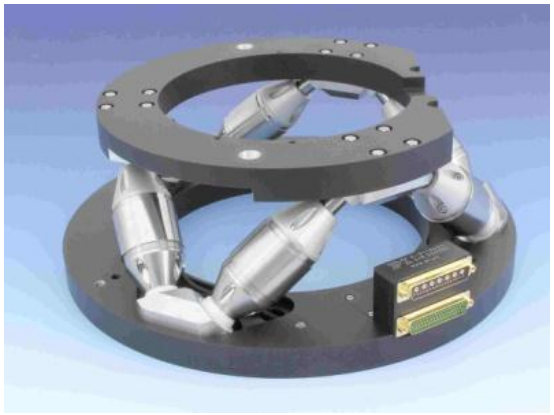
Flux density

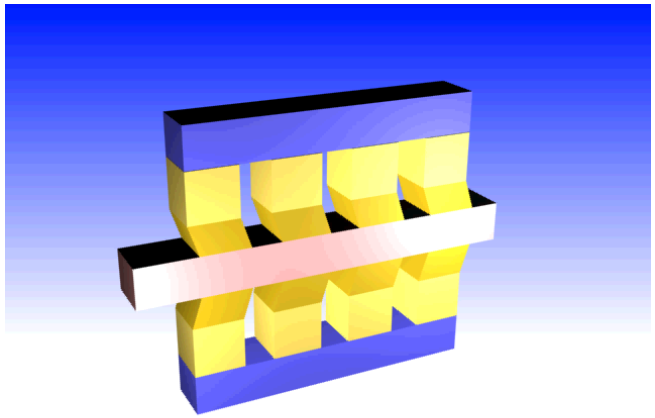




Nicht magnetische Piezo Applikationen

- Piezo Walking Drive
- NEXLINE® oder NEXACT® Module

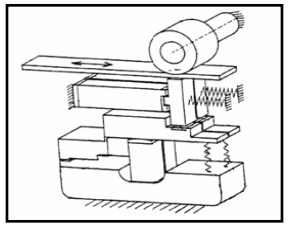


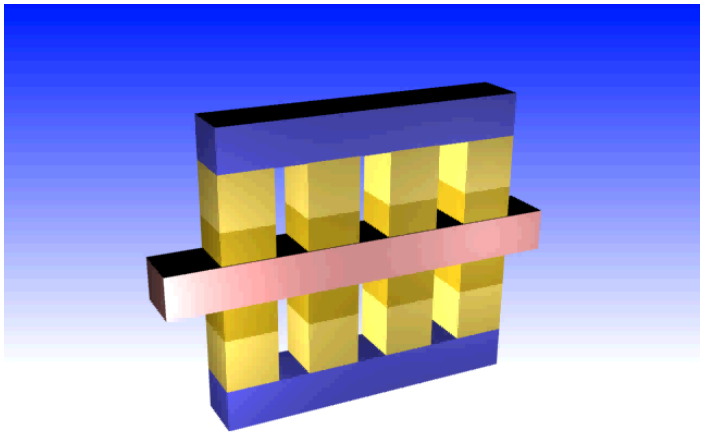


Hybrid System Design

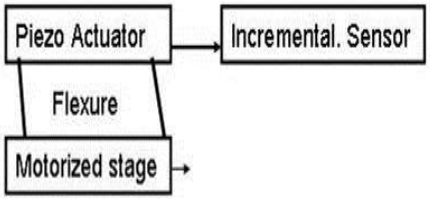
Two Designs for Long-Travel Motion

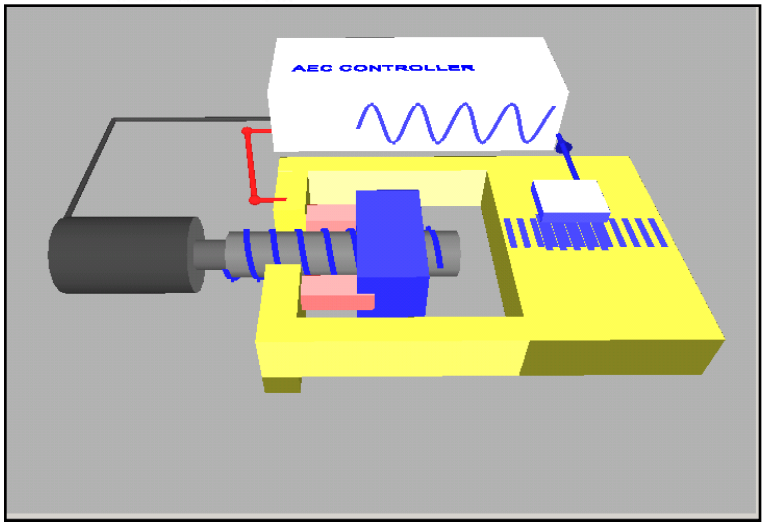
Piezo Walking Drive





Piezo Hybrid Actuator

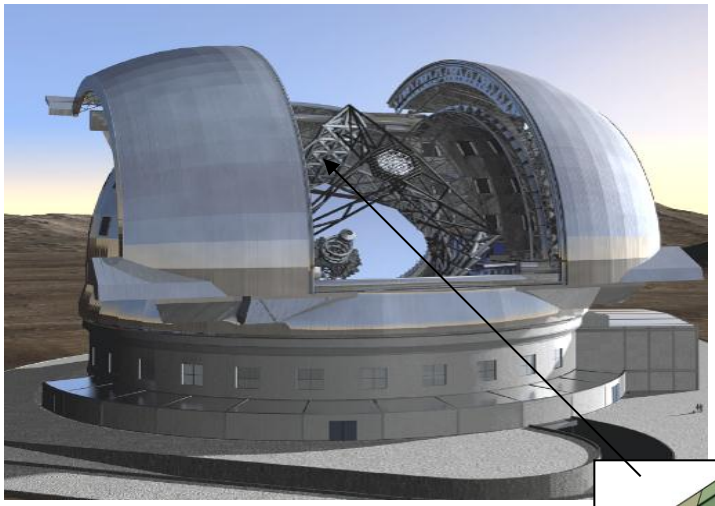




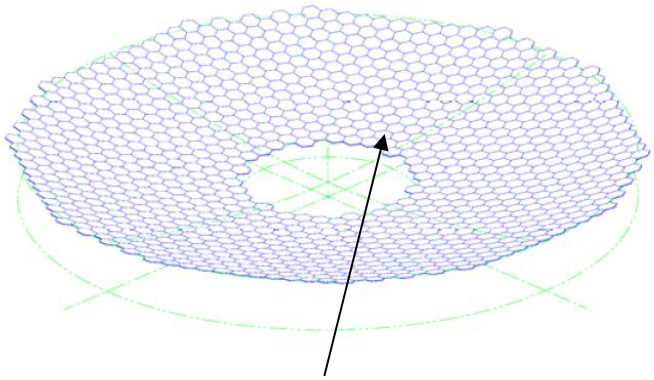
Hybrid positioning system

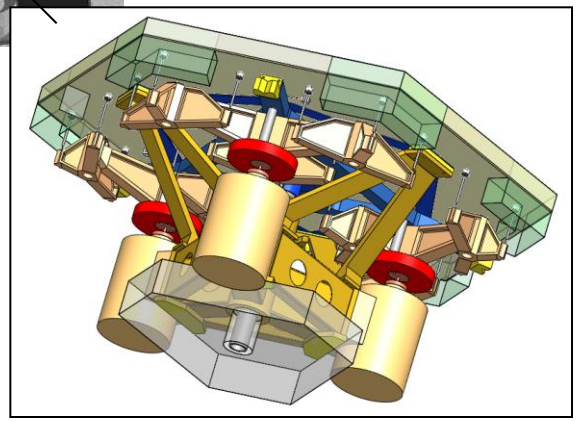
ESO: E-ELT Telescope

42m (39m)Primary mirror



100m





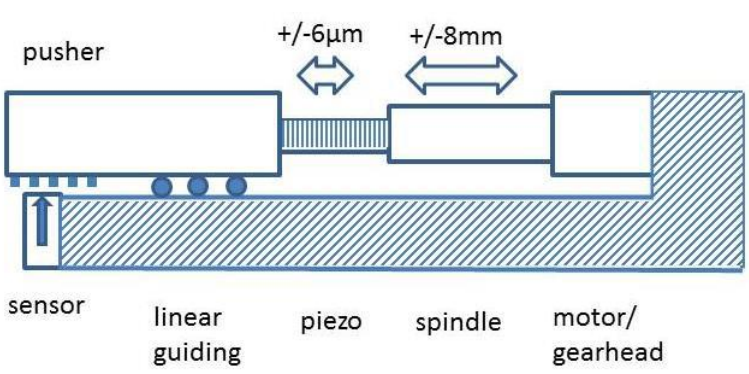
Hybrid= Motor
+Piezo

800 single mirror

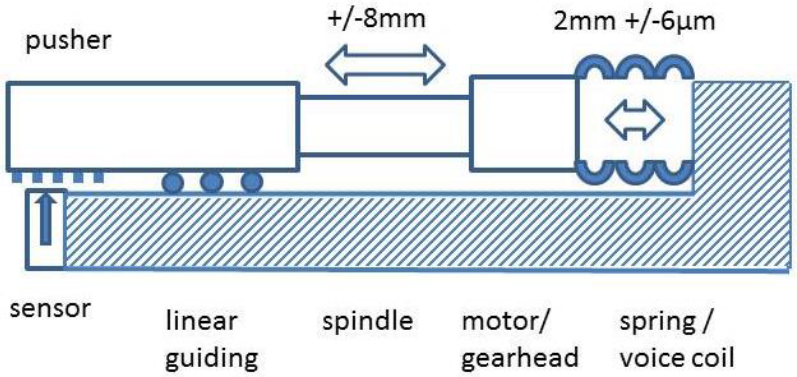
Hybrid mit zwei verschiedenen Actuatoren

- Piezo-Hybrid

Hermetisch
geschirmter Piezo

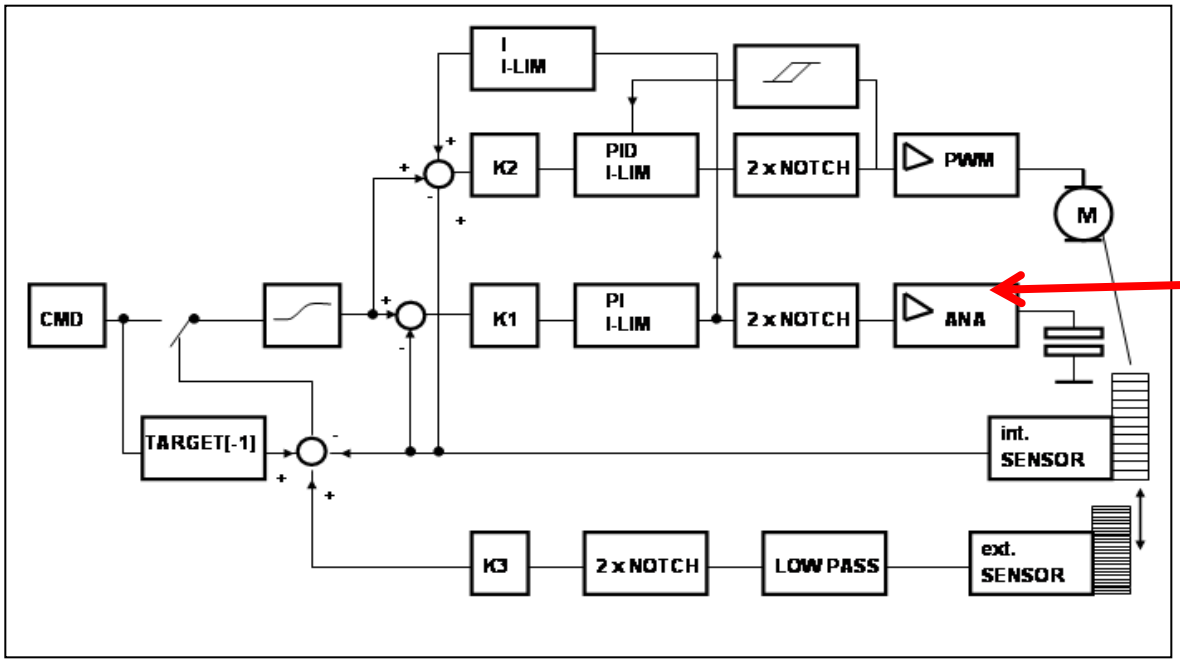


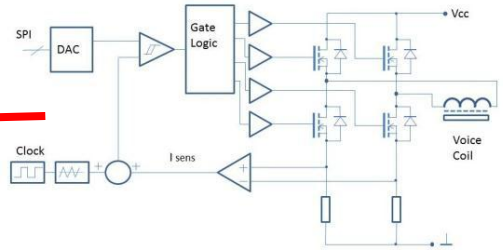
- Lorentz-Force Hybrid



Hybrid Controller Firmware Structure

- Two independent separate control loops using a single incremental sensor
- Both control loops are always running
- Integral term coupling piezo loop to the motor loop to reduce the piezo voltage when the system is in position (statically)



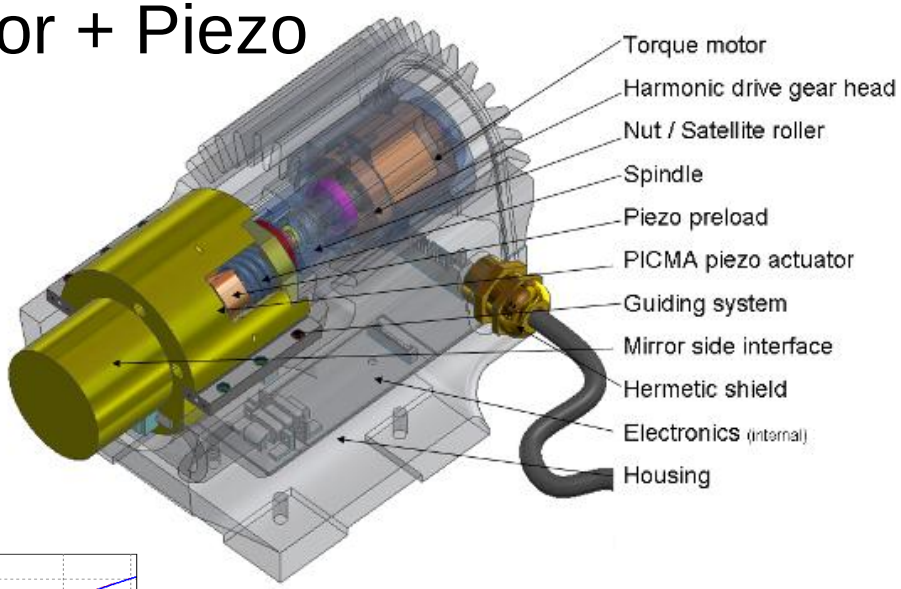


Current source for Lorentz Force Actuator

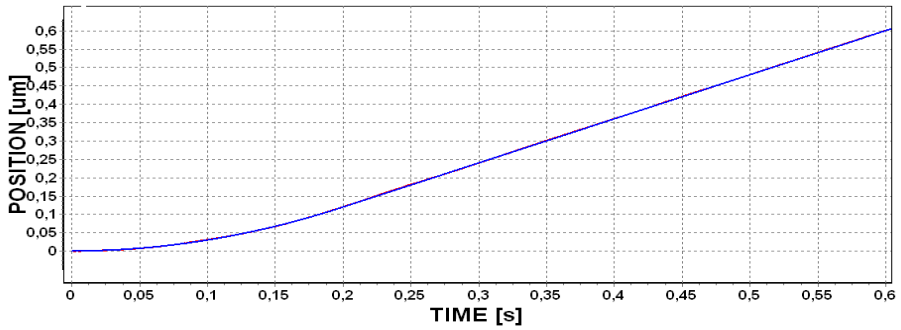
Hybrid Positionierer / Motor + Piezo

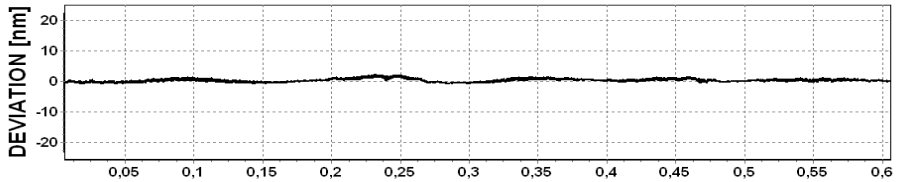
Requirements:

- **Travel range** **15 mm**
- **Load capacity** **88 kg**
- **Resolution** **0.125 nm**
- **Power dissipation** **< 1W**
- **Slewing** **1.2 µm/s**
- **Command sequence** **1 kHz**



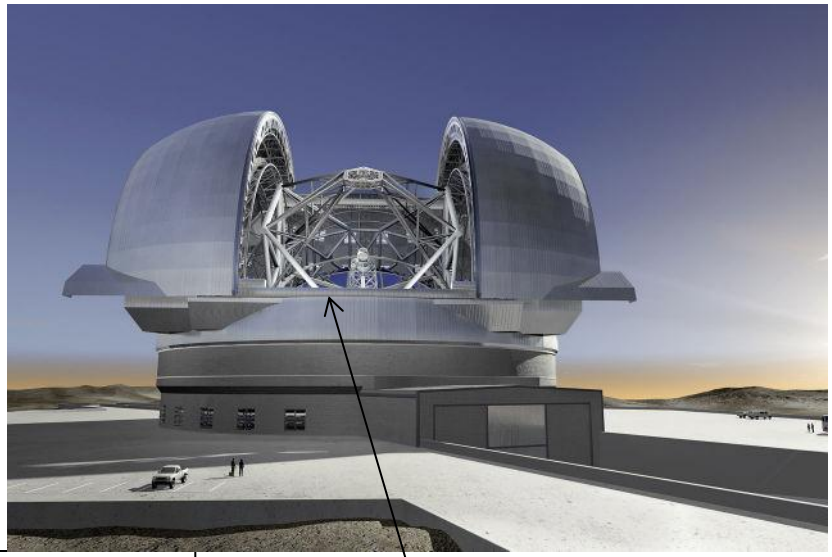
Tracking accuracy: <1nm

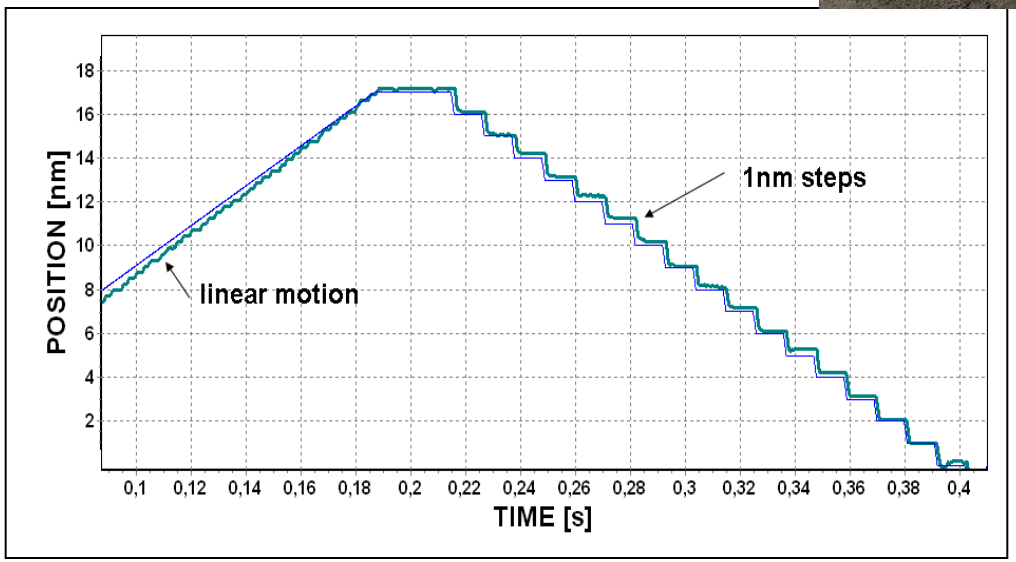




Hybrid Positionierer

Für große Systeme	100m
Stahlkonstruktion	3350t
Bewegte Optomechanik	755t
Für mittlere Stellwege	15mm
Hohe Auflösung	125pm





2400 x

Vielen Dank für Ihre Aufmerksamkeit

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