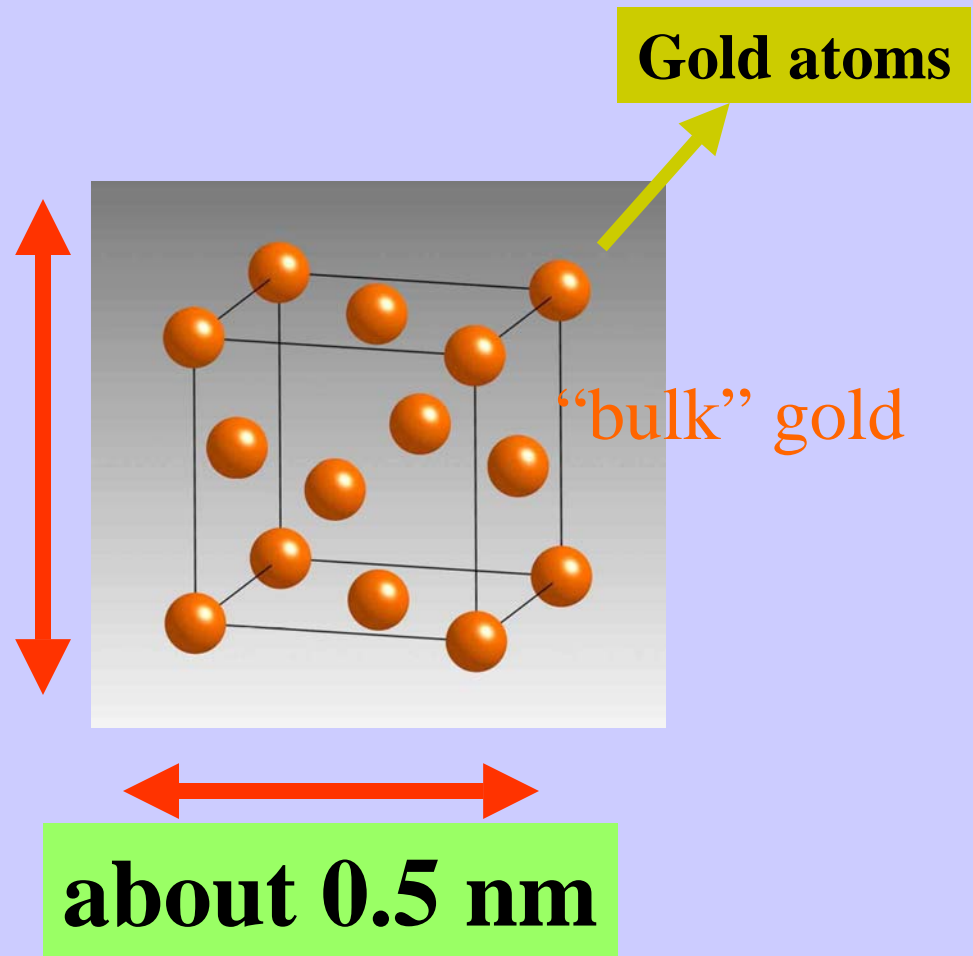


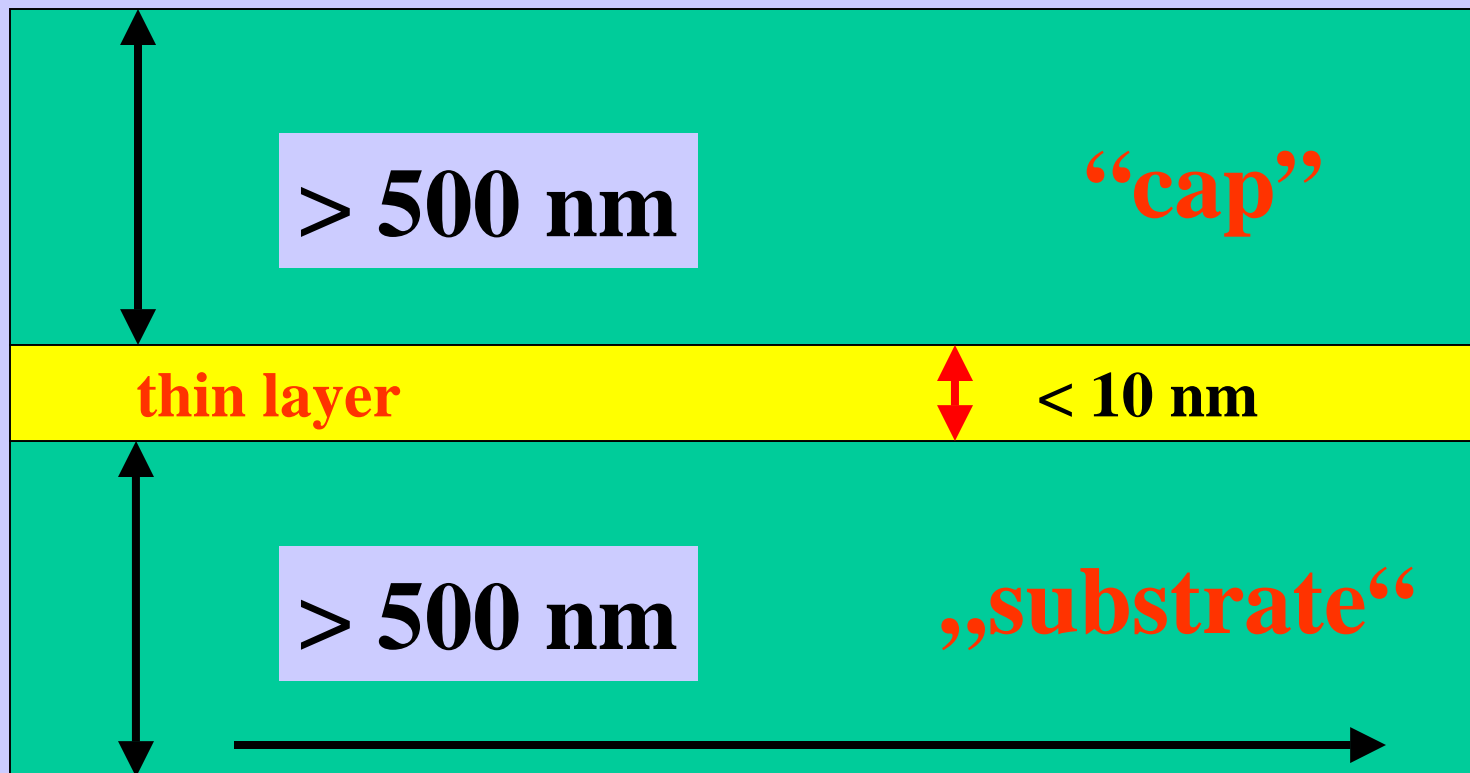
**Nano-scales: 1 nm =  $10^{-9}$  m**



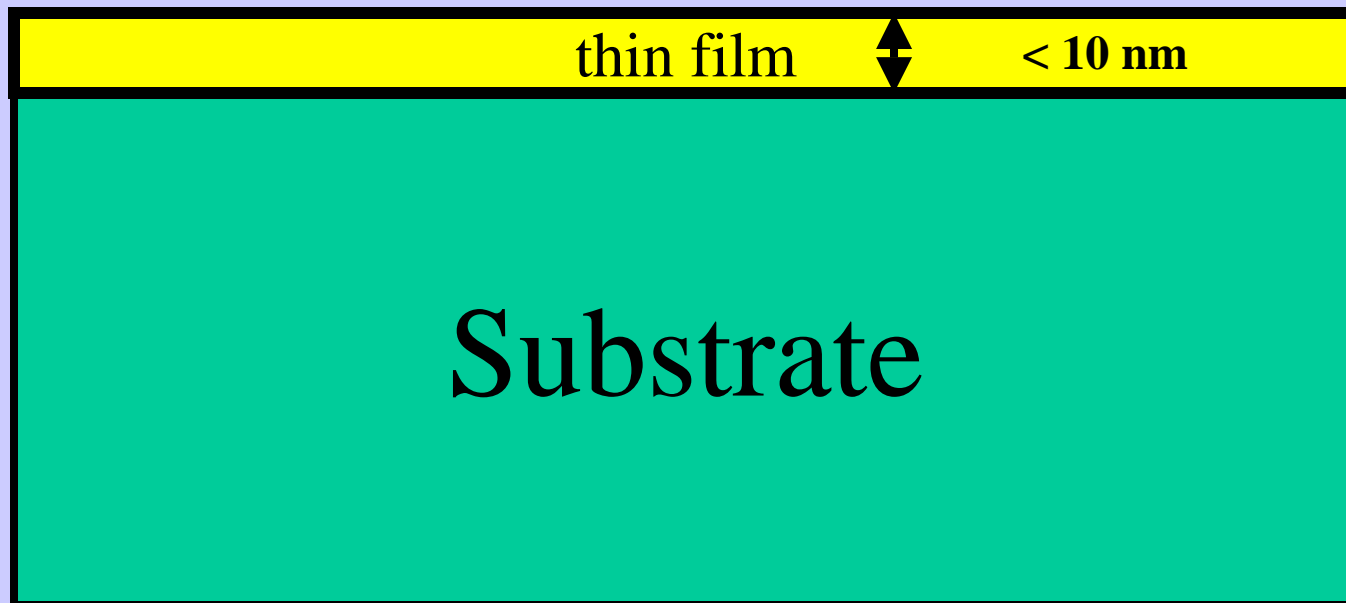
**Golden Precolumbian  
statue**



**Nano-scaled in one dimension: a thin layer of atoms  
between other material**

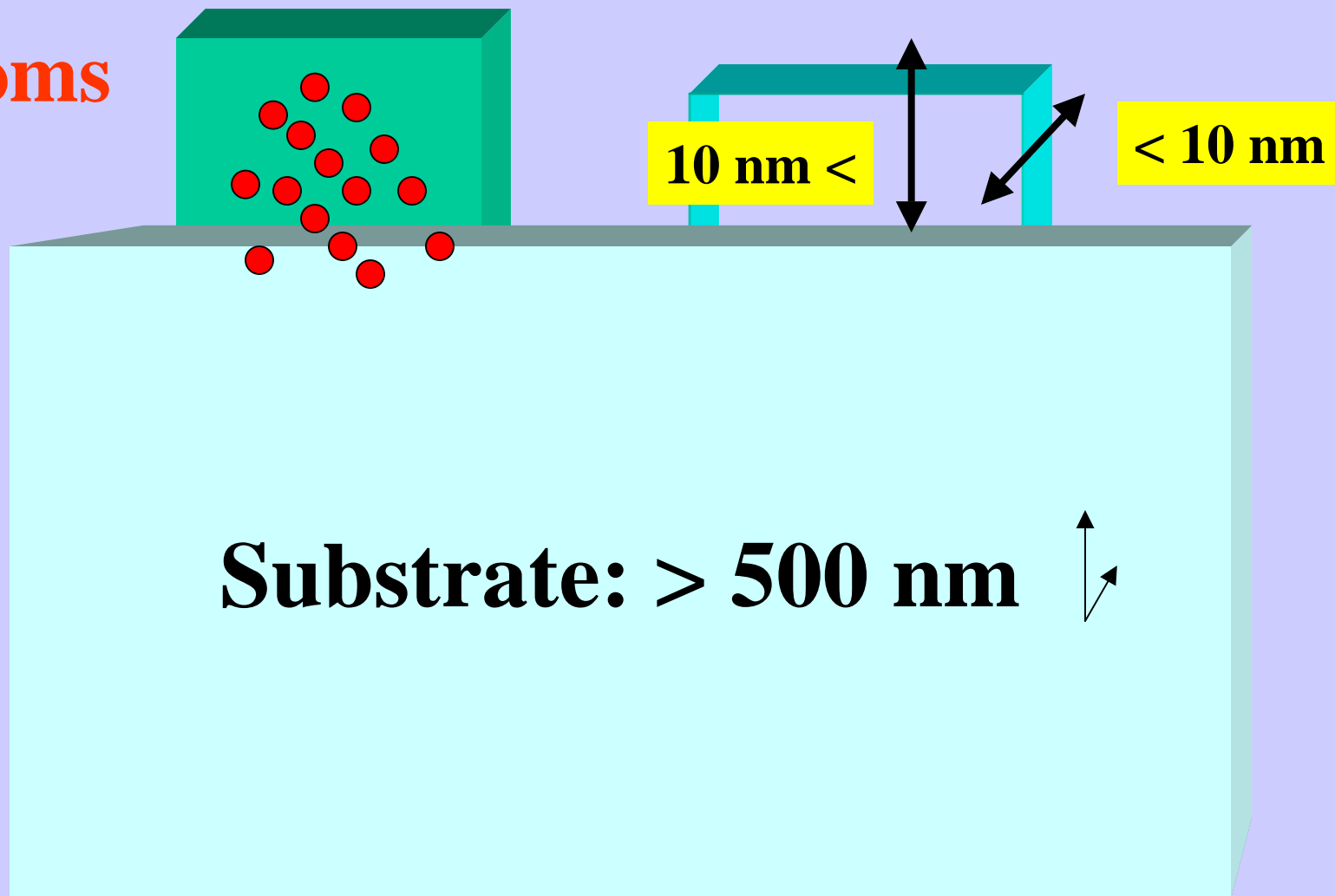


**Nano-scaled in one dimension:  
a thin layer of atoms on top of the surface of a substrate**

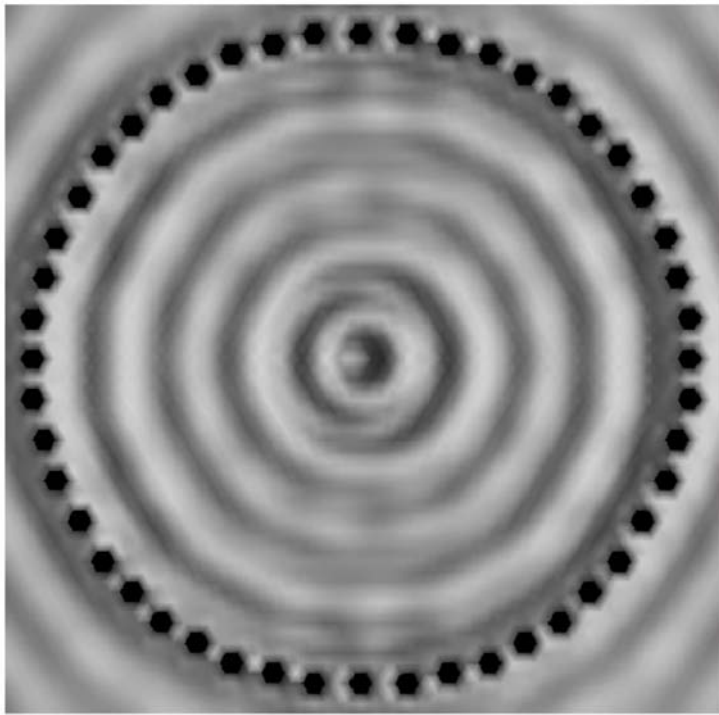


**Nano-scaled in two dimensions: ensemble (cluster) of atoms on top of or embedded in the surface of a substrate**

**atoms**

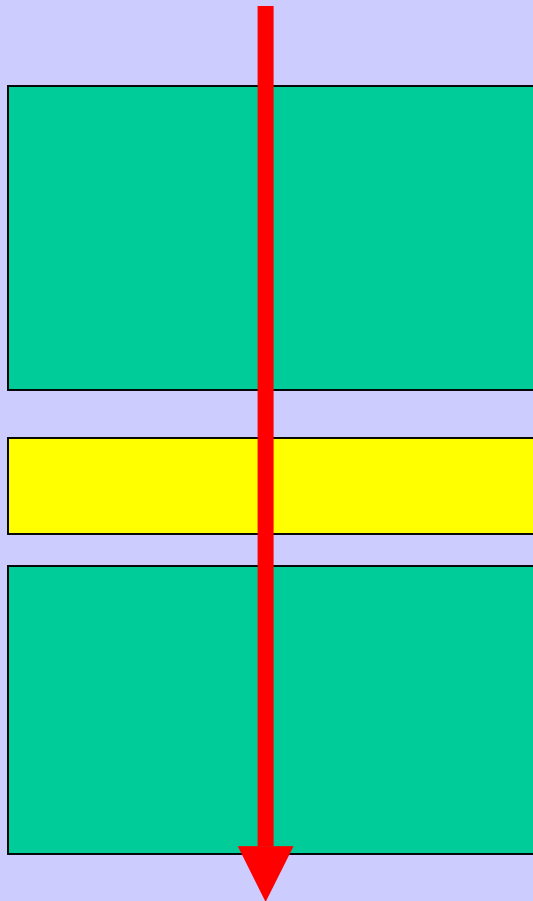


... an image of „nano“



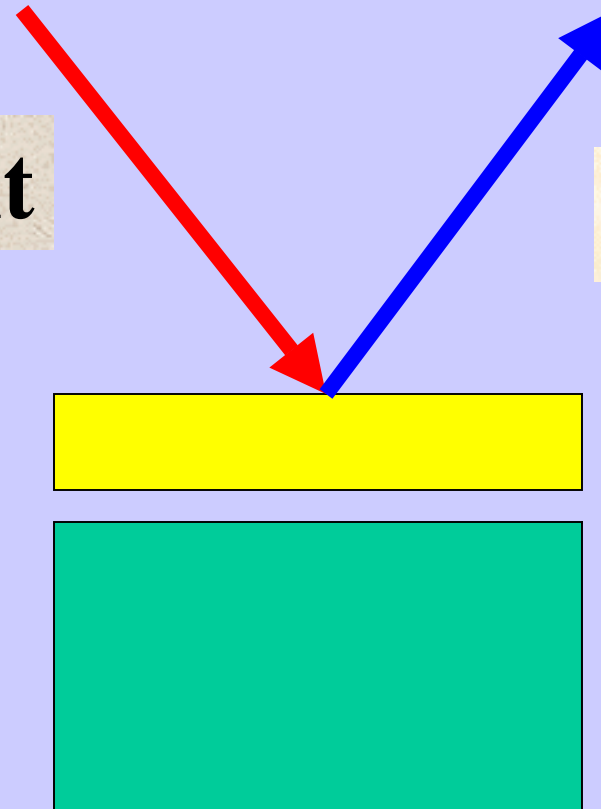
A „quantum corral“  
of 48 Fe atoms em-  
bedded circularly  
on top of a Cu(100)  
substrate

# Technology-related probes:



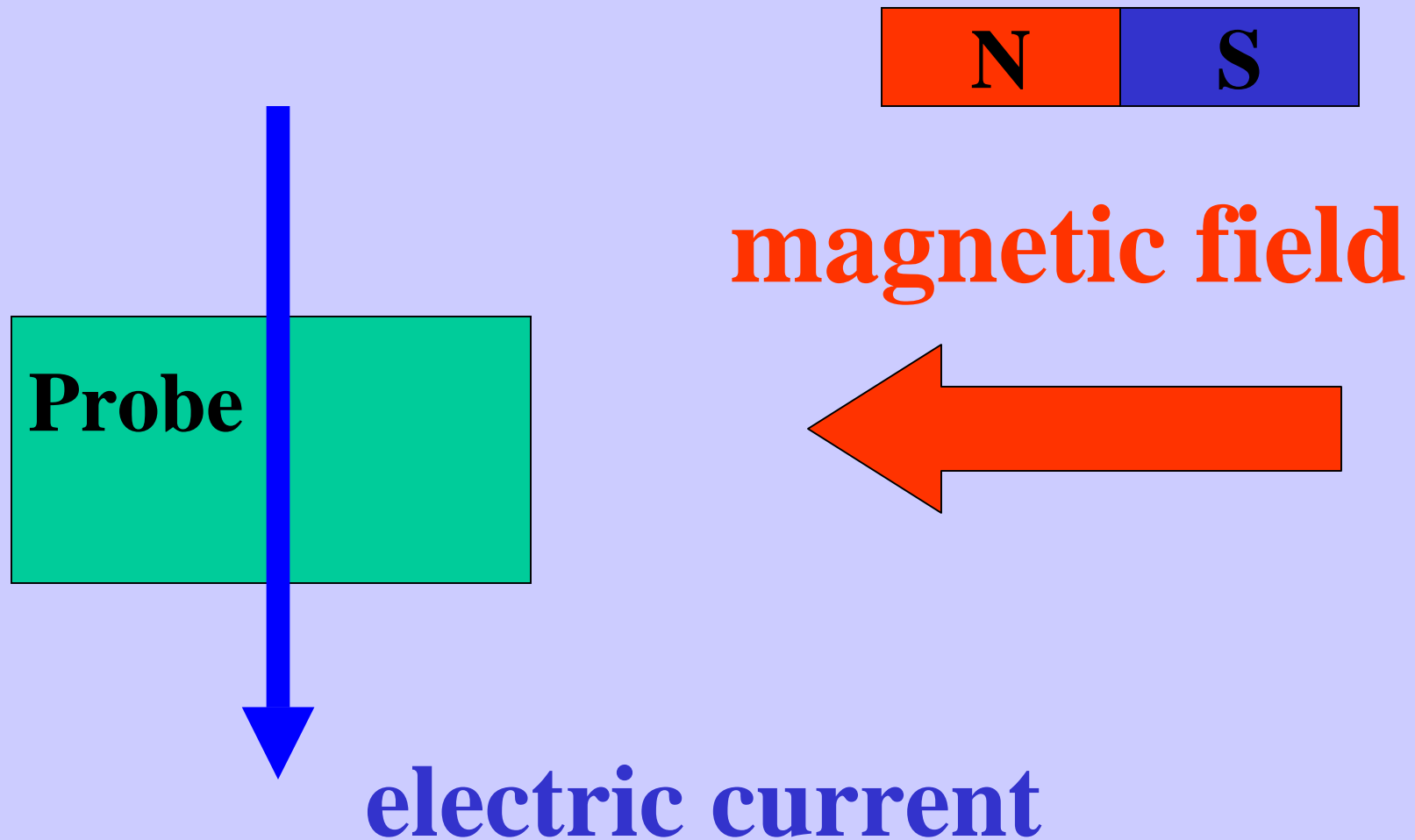
**Electric current**

**light**

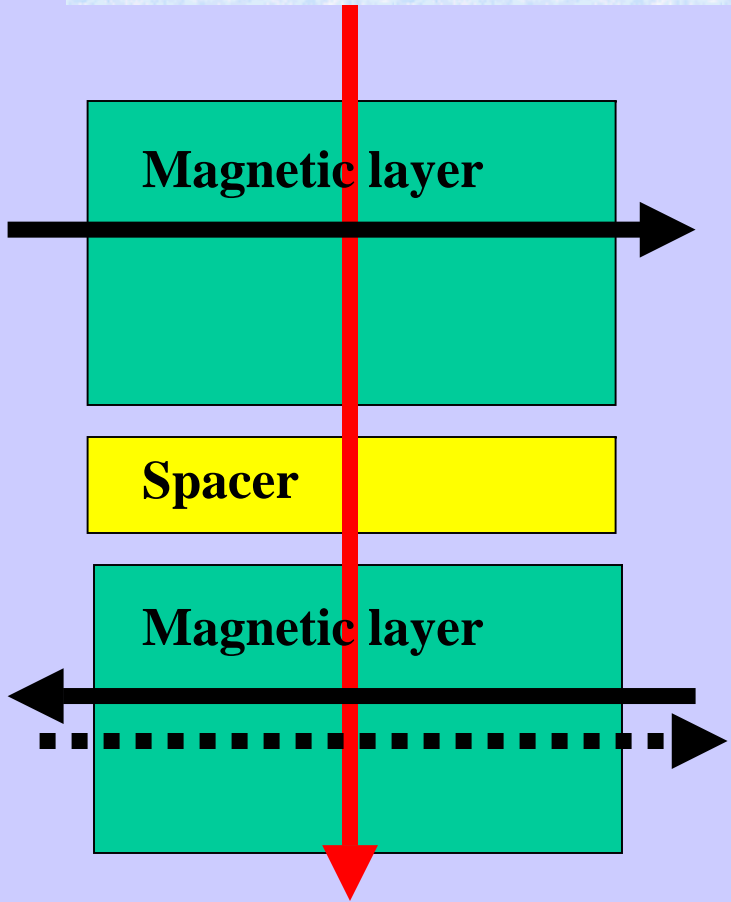


**light**

# Combination of probes

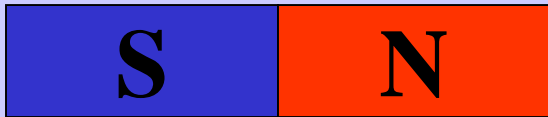
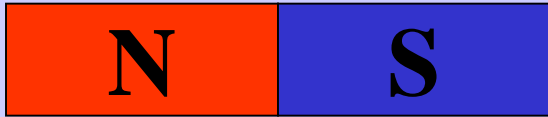


**electric current**

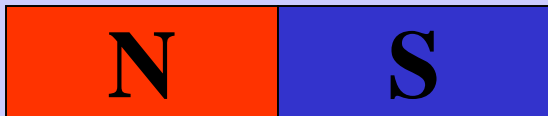


**GMR, TMR**

**Electric  
Devices:**



Antiparallel

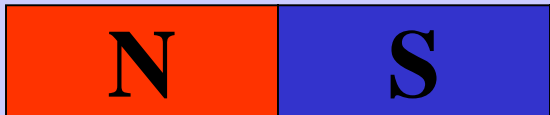


Parallel

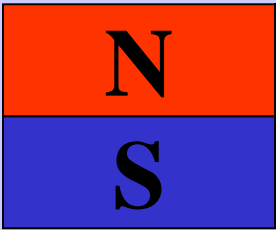
**Magnetization**

# Optical Devices:

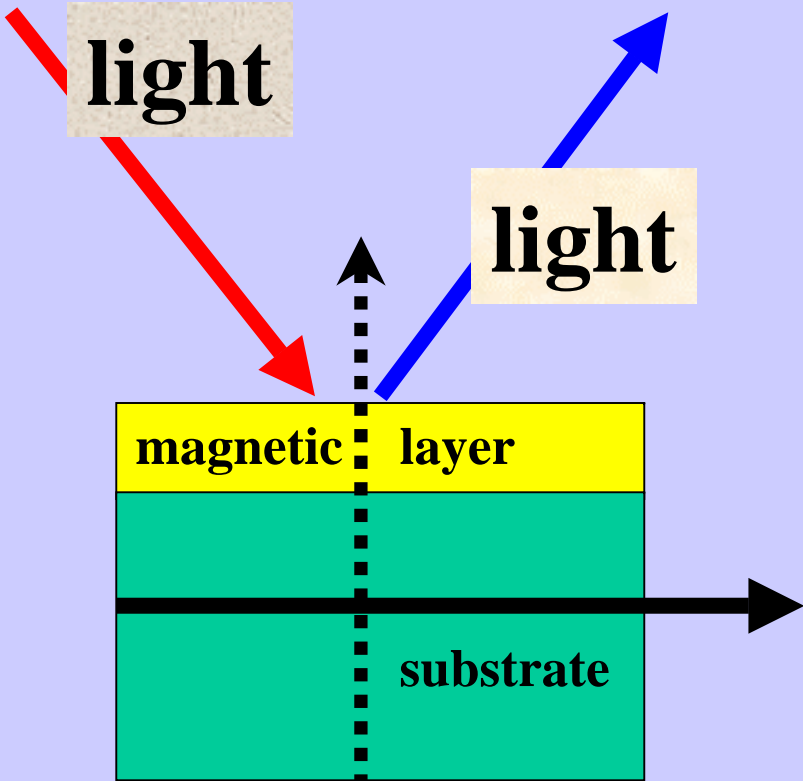
## Magnetization



in-plane



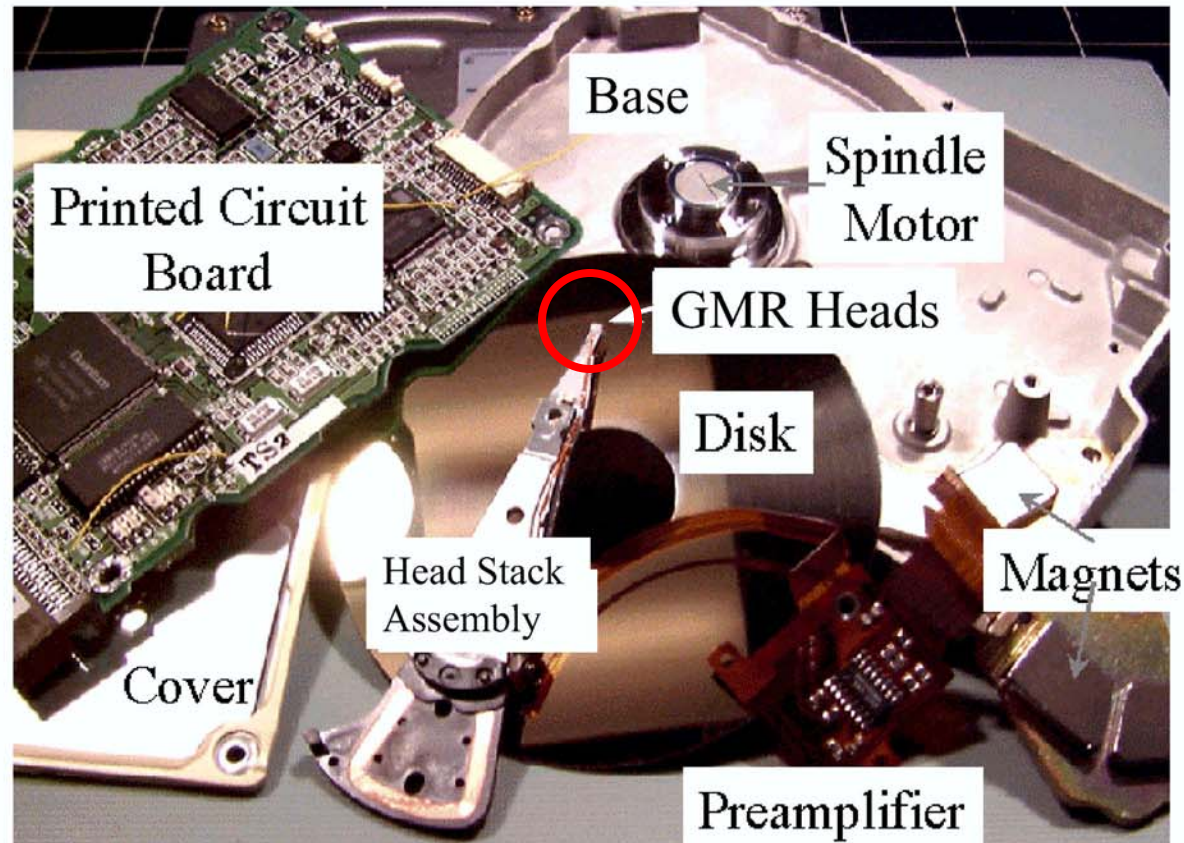
perpendicular



MO Kerr effect

# ... & present technology

## Anatomy of a hard disk drive

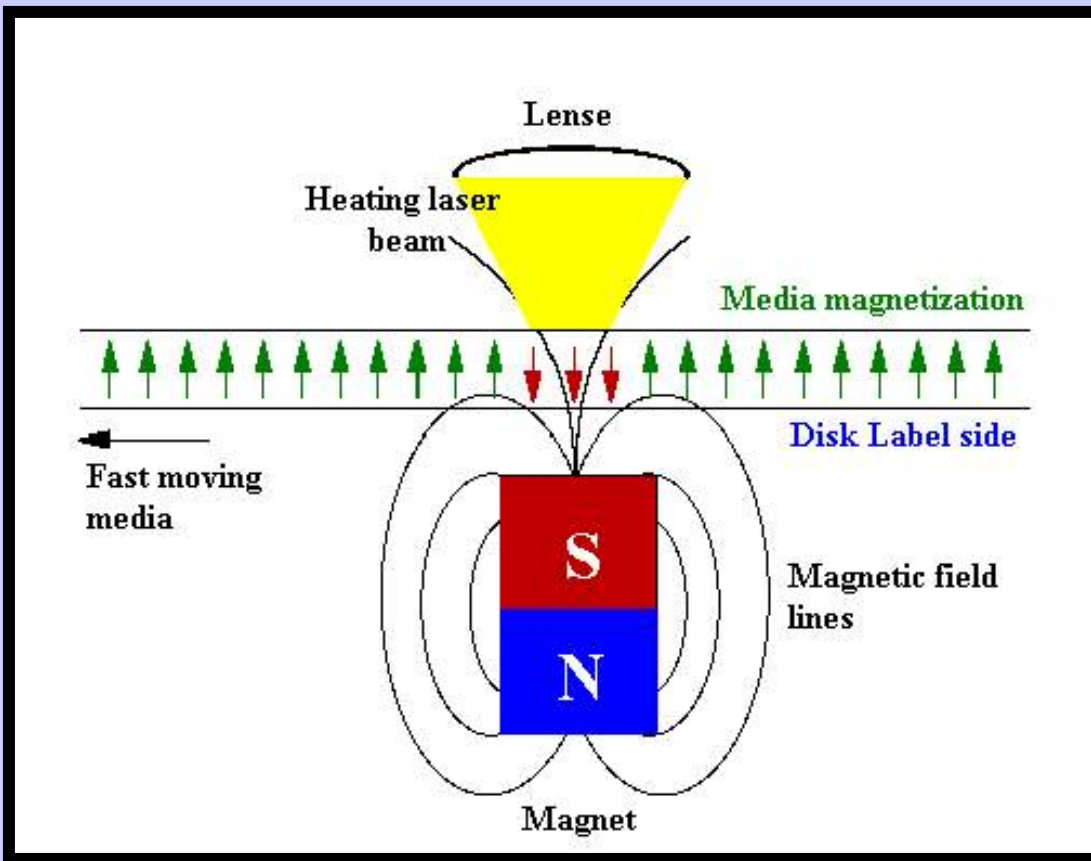


–Base, motor, disk, head stack assembly, circuit board

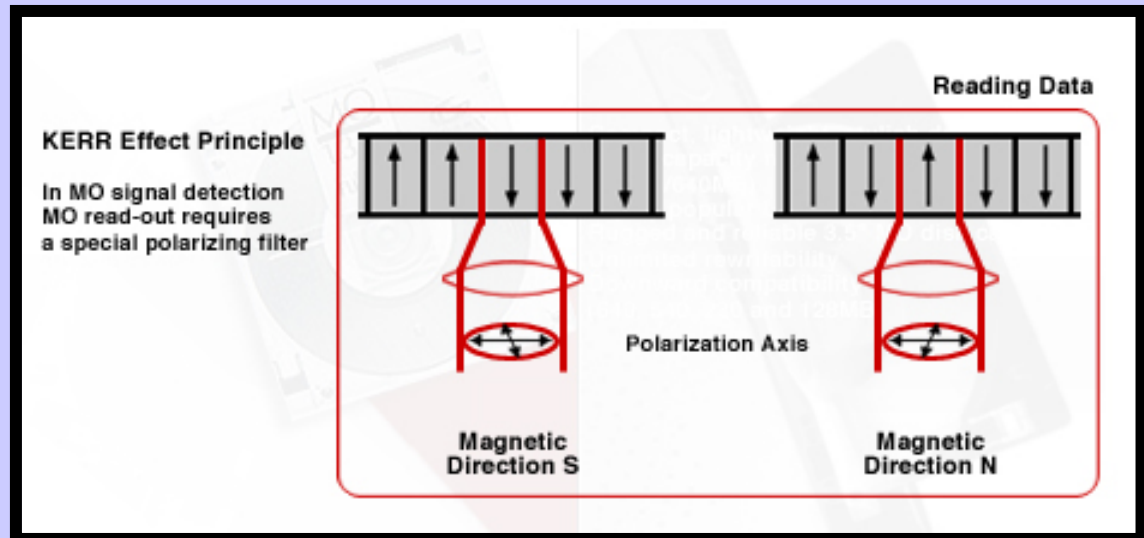
–Head stack: recording head(s), preamp and voice coil

# Magneto-optical discs

← Write



Read →



# The next stage: nano + pico (femto)

**1 Femtosecond =  $10^{-15}$  sec**

**1 Picosecond =  $10^{-12}$  sec**

**1 Nanosecond =  $10^{-9}$  sec**

**Time-resolved probes:**

**Fast alternating currents (nano, pico)**

**Fast alternating magnetic fields (femto)**

# ... & overnext technology

2 Laser set-up:  
(pump-probe)  
delay: 20 –100 fs

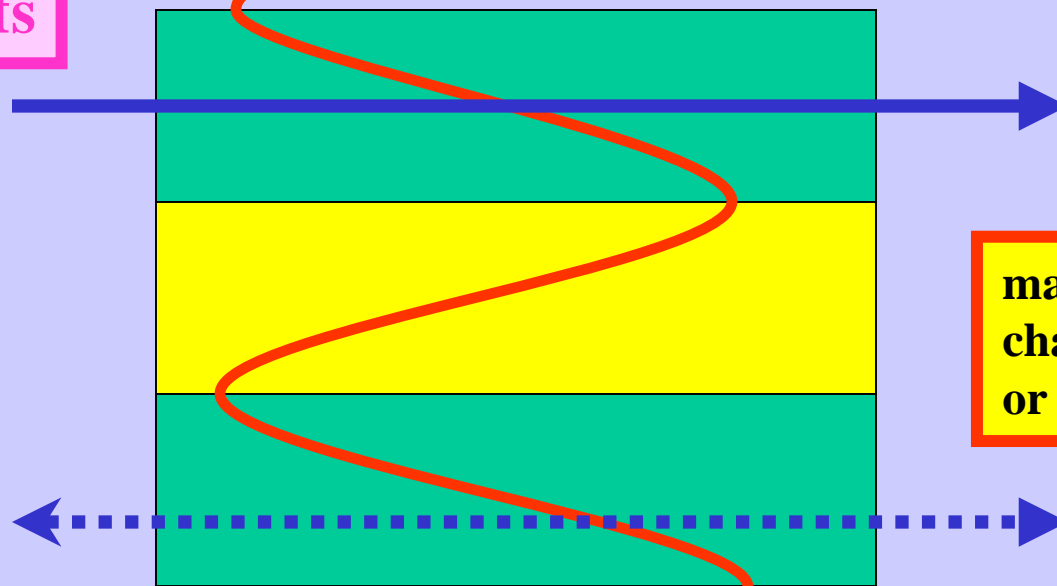
electric field:  
Nano- or picoseconds

switching of  
magnetization

magnetoresistance  
changes in nano-  
or picoseconds

fast spin dynamics

**Current-induced  
switching**

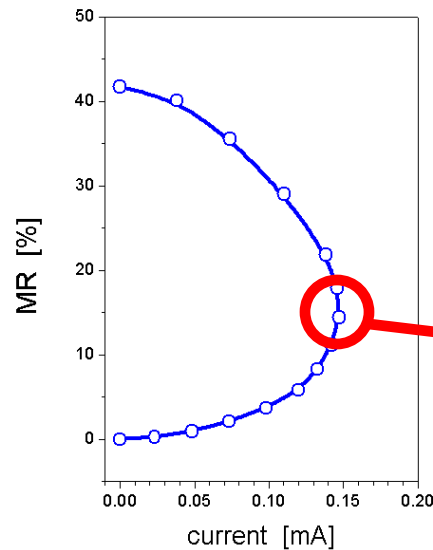
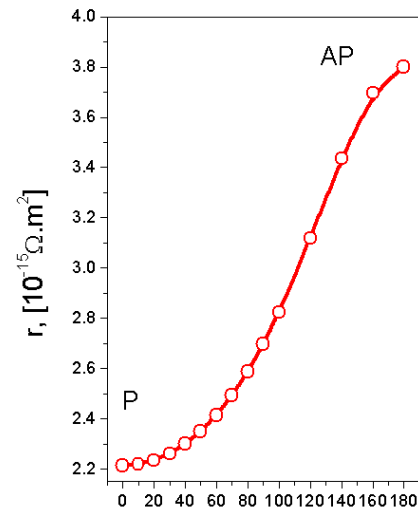
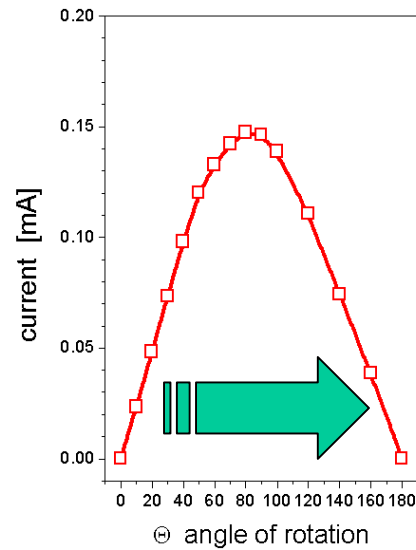
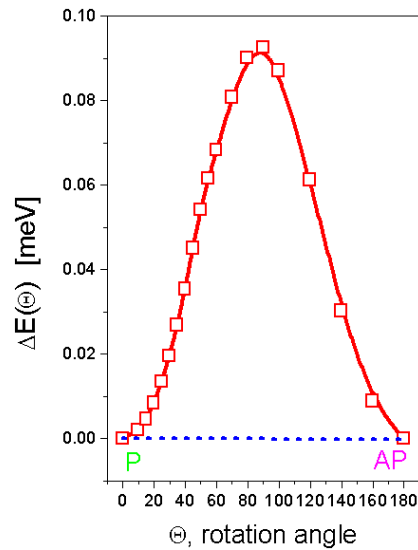


# Current-induced switching

switching time:  
1.1 – 2.8 ns

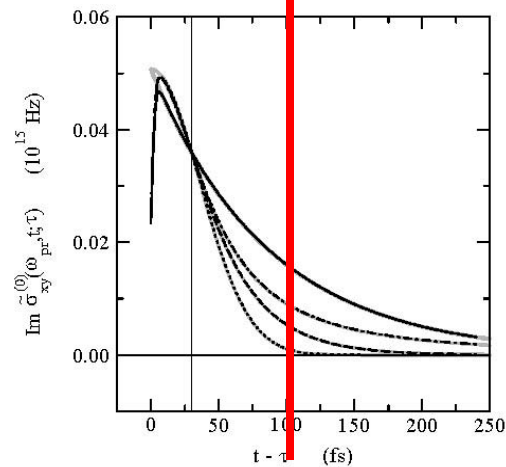
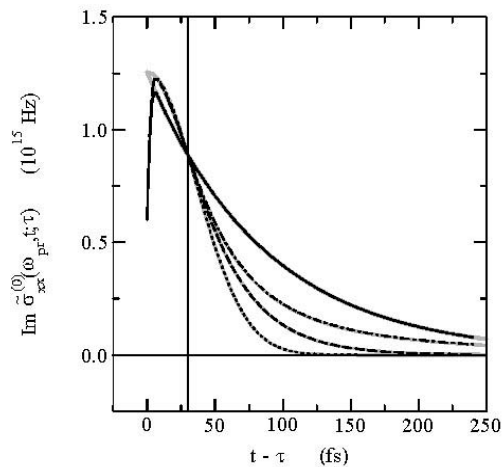
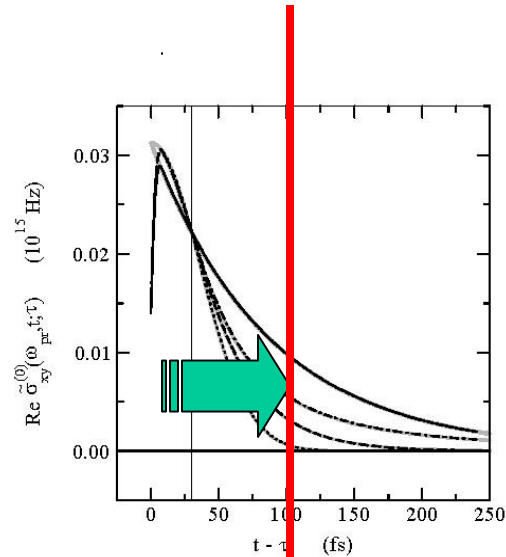
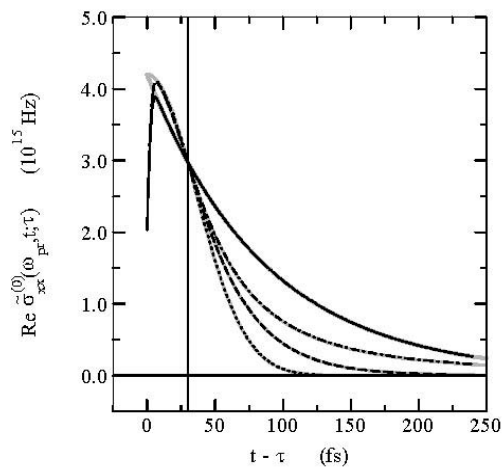
critical current  
for switching

Co(100)/Co<sub>12</sub>/Cu<sub>25</sub>/Co<sub>11</sub>/Co(100)



$d = 43.32$  [Å]

# Laser-induced ultrafast magnetization reversal



„switching“  
time:  
about 100 fs

„demagnetization“ time  
of Ni(100)

# Requirements:

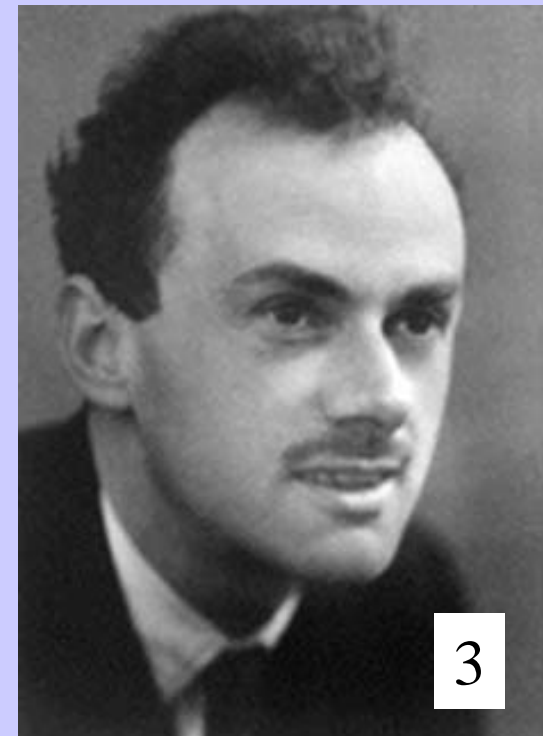
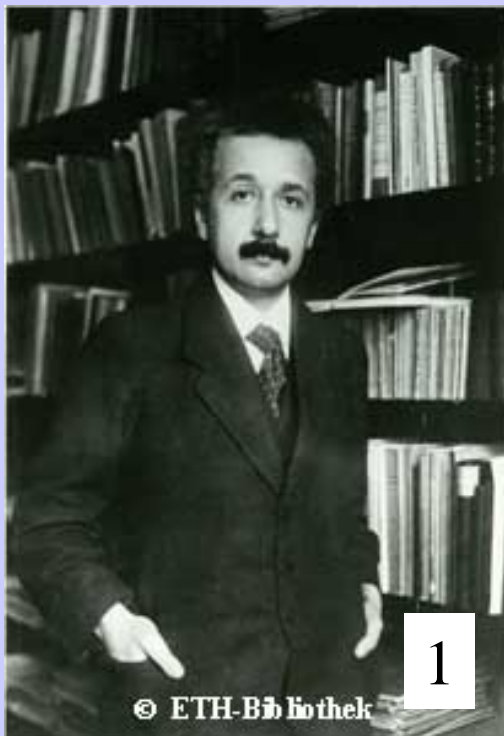
- Fully relativistic quantum mechanical descriptions (because of magnetic properties)
- Time dependent response theories (because of interaction with femto-second lasers)



completely new physics,  
approaches & technology

# The grandfathers:

A. Einstein (1), W. Pauli (2), P. Dirac (3)



# The fathers:

J. Luttinger (1), R. Kubo (2) and W. Kohn (3)

