Modern Atomic Physics

Introduction

The Goal of Atomic Physics

An understanding of :

- The structure of atoms
- The interaction with one another
- The interaction with electric and magnetic fields.

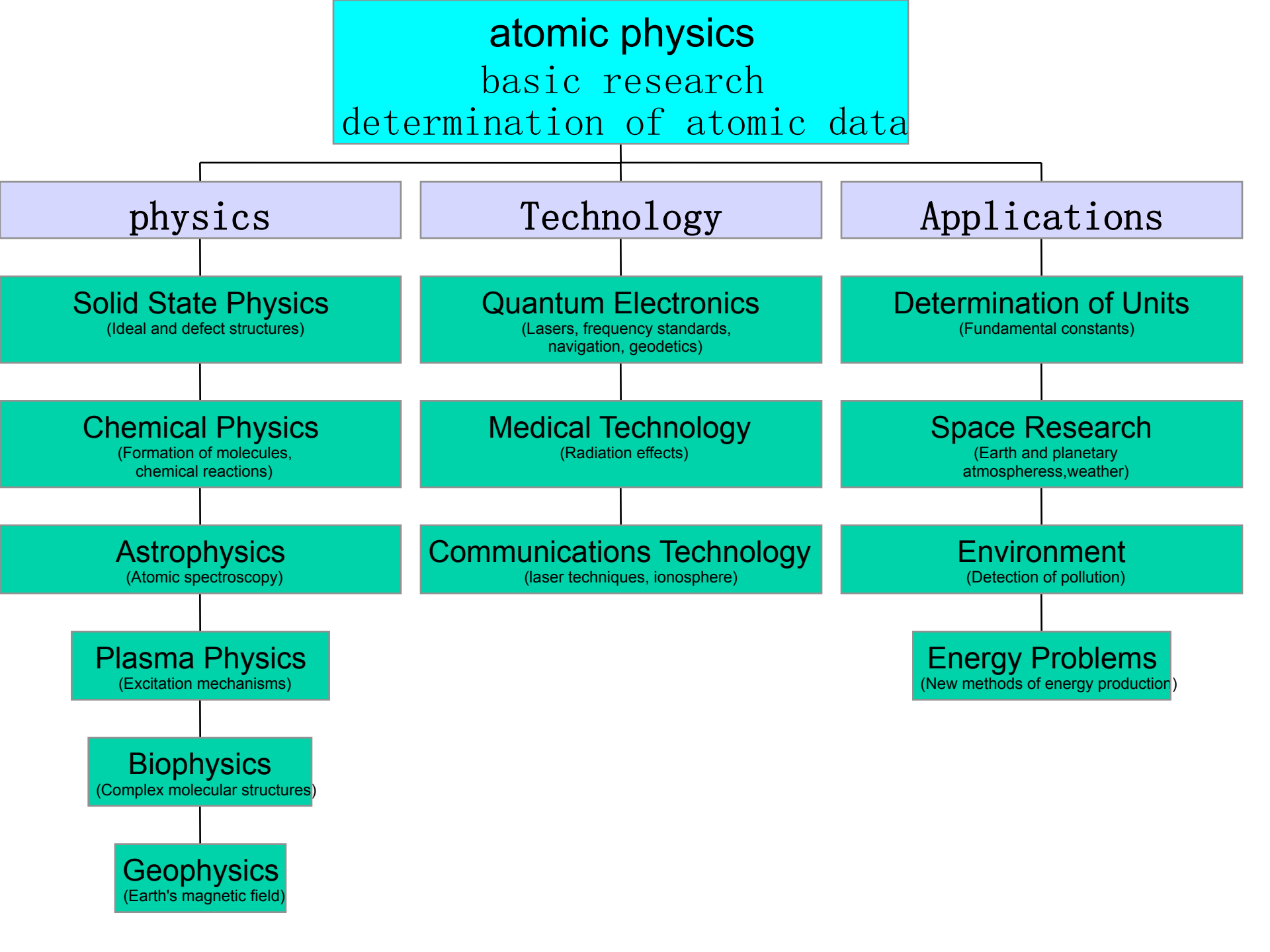
Key Points

- Building physics pictures
- Clear description of physics concepts

Motivations

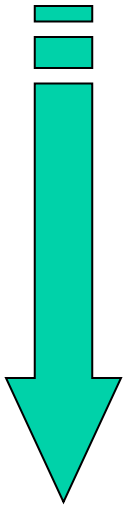
- Atomic physics is the products of the early time of 20th century.
- The study of the micro-world of atoms caused a revolution of physical thoughts-- a revolution of fundamental ideas of classical physics, such as mechanics, acoustics, thermodynamics, and electricity.
- A basis for other fields:

  Physics, Technologies, and Applications.


atomic physics
basic research
determination of atomic data
physics
Technology
Applications
Solid State Physics
(Ideal and defect structures)
Quantum Electronics
(Lasers, frequency standards, navigation, geodetics)
Determination of Units
(Fundamental constants)
Chemical Physics
(Formation of molecules, chemical reactions)
Medical Technology
(Radiation effects)
Space Research
(Earth and planetary atmospheress,weather)
Astrophysics
(Atomic spectroscopy)
Communications Technology
(laser techniques, ionosphere)
Environment
(Detection of pollution)
Plasma Physics
(Excitation mechanisms)
Energy Problems
(New methods of energy production)
Biophysics
(Complex molecular structures)
Geophysics
(Earth's magnetic field)

Explosion of atomic bomb

Classic physics



Atomic physics

Modern physics

The curriculum form

- Lectures (by prof.)
- Seminars (prof. & students)
- Summary & Exercise (prof. &TA)

Includes lectures and exams, and involves presentation and discussion

Evaluation of the course:

Attendeance & participation (10%)

Homework （20%)

Mid-term (25%)

Final test（45%）

contents

- Chapter 1.Theory of Relativity
- Chapter 2. Basic aspects of Atom (Rutherford)
- Chapter 3. Bohr model of the Hydrogen atom
- Chapter 4. Fine structure (Spin)
- Chapter 5. Many-electron atoms (Pauli-Blocking)
- Chapter 6. X-Ray

* Chapter 7. Introduction to Quantum Mechanics

Textbooks & References

1. Modern atomic and Nuclear physics , by F.J Yang J.H Hamilton , 2010 World scientific Publishing Co.

2. 原子核物理 杨福家等编 复旦大学出版社 **2008** 年

3. 原子物理学 褚圣麟 编著 人民教育出版社 **1979** 年

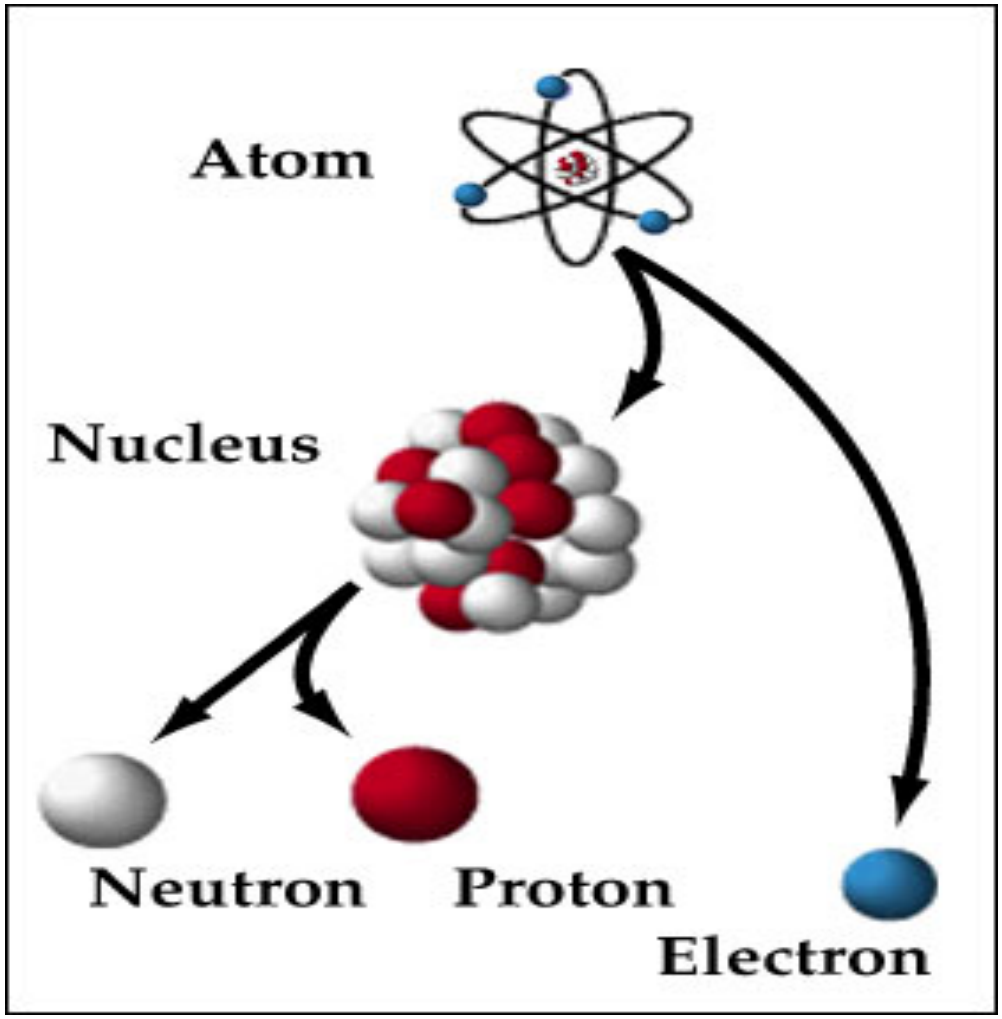
4. The Physics of Atoms and Quanta, sixth edition, by H. Haken and H. C. Wolf，2003，published by Springer-Verlag and World scientific publ. Co.

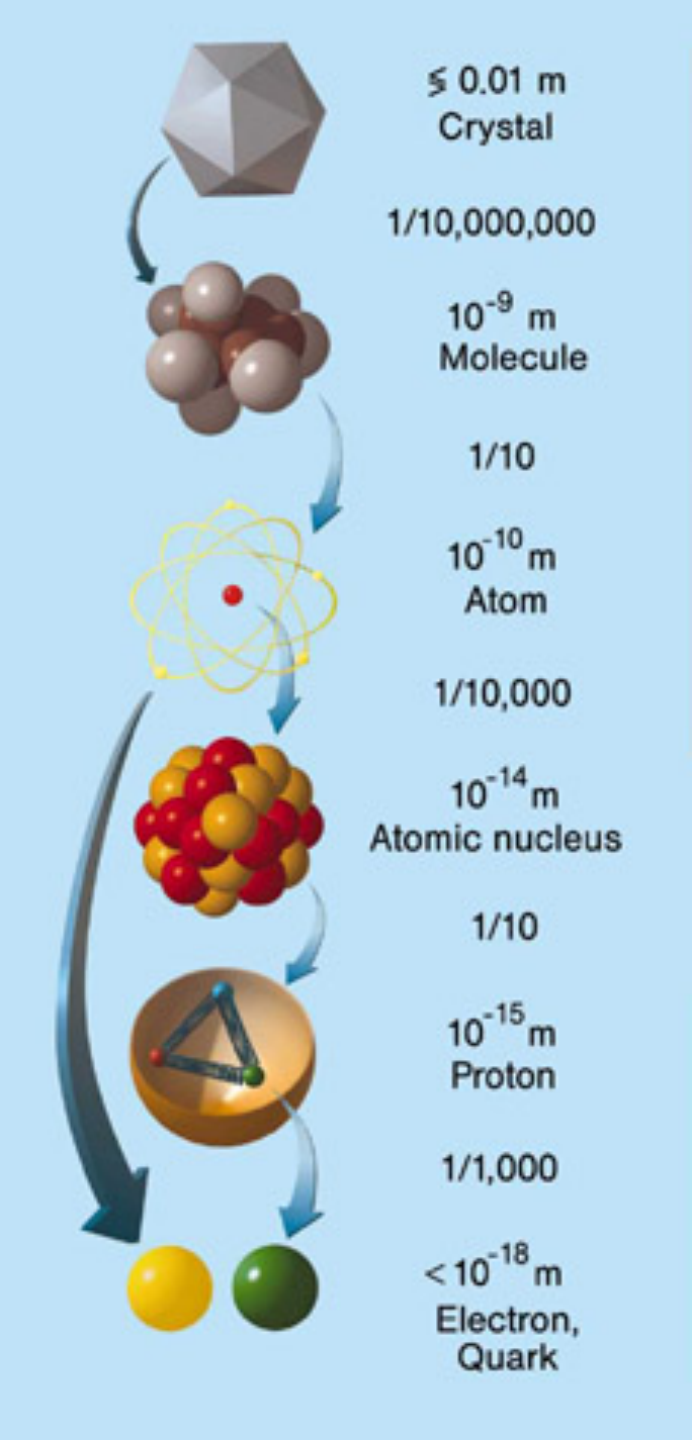
5. 近代物理基础及其应用 **P. A. Tipler** 著 上海科技出版社 **1981** 年

- **6** 、原子物理学 陈宏芳 编 中国科技大学出版社 **2001** 年

- **7** 、原子和亚原子物理学 高政祥 编 北京大学出版社 **2001** 年
- **8** 、原子物理 郑乐民 编 北京大学出版社 **2000** 年
- **9** 、近代物理（上册） 郑广垣 编著 复旦大学出版社 **1991** 年
- **10** 、原子物理学 苟请泉编 高等教育出版社 **1983** 年
- **11** 、原子结构与原子光谱 郑乐民等 北京大学出版社 **1988** 年
- **12** 、高等原子与分子 徐克尊著 科学出版社 **2000** 年
- **13** 、原子论与原子结构 吴大猷著 科学出版社 **1983** 年
- **14** 、近代物理学 王正行著 北京大学出版社 **2000** 年
- **15** 、近代物理学 **[** 美 **]** **R.** 戈特罗等著 科学出版社 **2002** 年
- **16** 、原子核物理导论 蒋明，卢希庭 著 原子能出版社 **1983** 年

The components of atoms





The scale of the matter in different levels

The experimental technique of using high energy probe to detect the most basic structure of matter(DIS)

What is the atom?

An atom is the smallest unchangeable components of a chemical elements

Unchangeable means in this case by chemical means, i.e. by reactions with acids, or basis, or the effects of moderate temperature.

Can we “see” the atoms?

By *Eyes* — *no*

By Optical microscope — *no*

By Electron microscope — *possible*

Modern methods:

- The field emission microscope

  To visualize single atom or large molecules on the tip of fine metal points

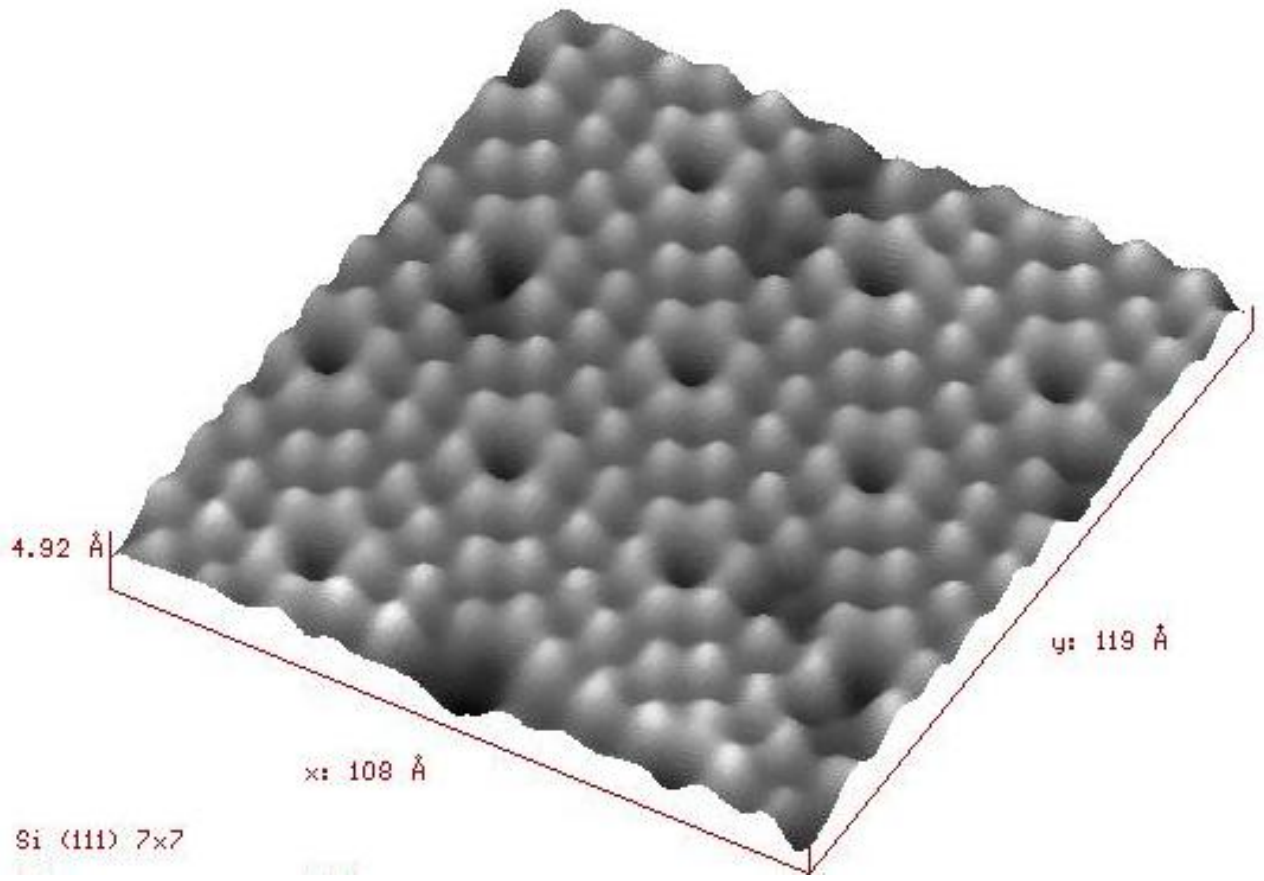
- SEM(Scanning Electron Microscopy)

  To image the individual atoms in molecules and in crystals.

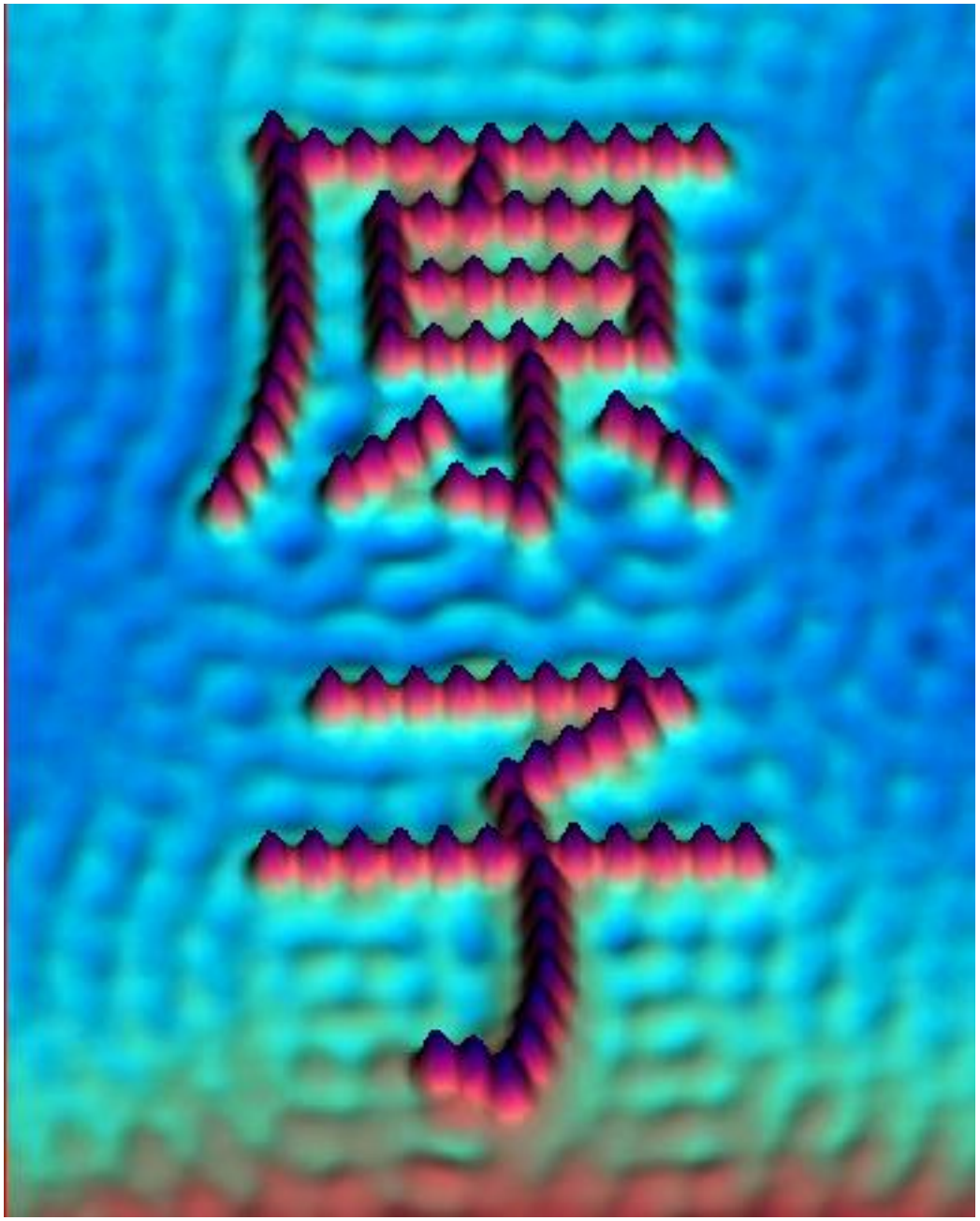
- TEM (Transmission Electron Microscopy)
- STM (Scanning Tunneling Microscopy)

Lattice defects of CdTe

Transmission Electron Microscopy



Scanning Tunneling Microscopy



Atom manipulation

By STM

Fe atoms on Cu(111)

Short historical review

- The word atom comes from the Greek and means "**the indivisible**", the smallest components of matter.

- In 5th and 4th centuries BC, **the concept** of atom was first introduced by Greek natural philosophers. **The first theories** of the structure of matter were those of ***Democrites*** (460-370 BC), ***Plato*** (429-348 BC), and ***Aristotle*** (384-322 BC).

- *It required more than two millennia until this speculative atomism grew into an exact atomic physics in the modern sense.*

- The atomism as understood by modern science was first discovered for ***matter***, then for ***electricity***, and finally for ***energy***.

The atomism of matter:

- From chemical investigations, ***the laws of constant and multiple properties*** (weight) formulated by ***J. L. Proust*** (1799) and by ***Dalton*** (1803):

  $14g\ N + 16g\ O_2 — 30g\ NO;$

  the volumes of gases by Gay-Lussac (1808):

  $1\ volume\ N + 1\ volume\ O_2 — 2\ volumes\ NO$

- ***Proust*** (1815) assumed that that the atoms of all elements are put together out of Hydrogen atoms. ***The periodic system*** of ***L. Meyer*** and ***D. I. Mendeleev***.
- ***The hypothesis of Avogadro***(1811): equal volumes of gass under similar conditions (pressure, temperature) contain equal numbers of molecules.
- The explanation of heat led to ***the kinetic theory of gases*** by ***Clausius*** and ***Boltzmann*** in about 1870.

The atomism of electricity:

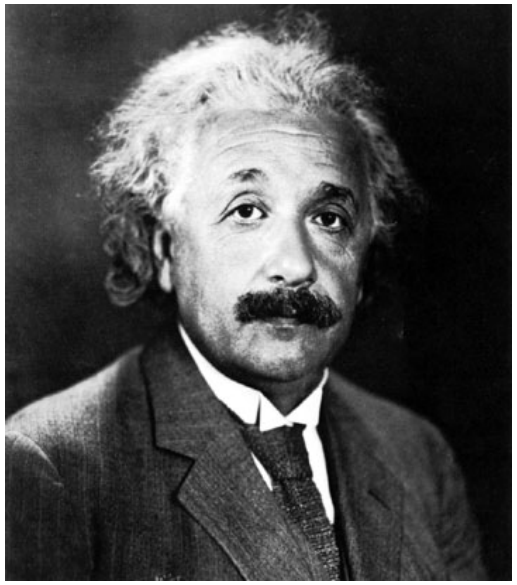
- Based on the quantitative evaluation of exceedingly careful measurements of the electrolysis of liquids, ***Michael Faraday*** (in 1833):

The quantity of an element which is separated is proportional to the quantity of charge transported in the process.

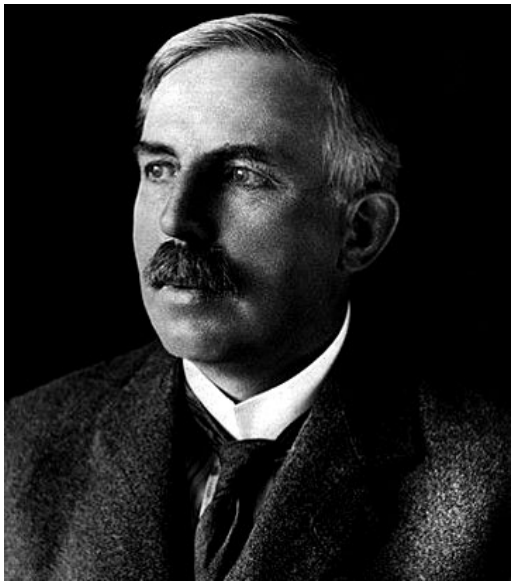
The "atoms" of electricity was later known as the electrons.

The atomism of energy:

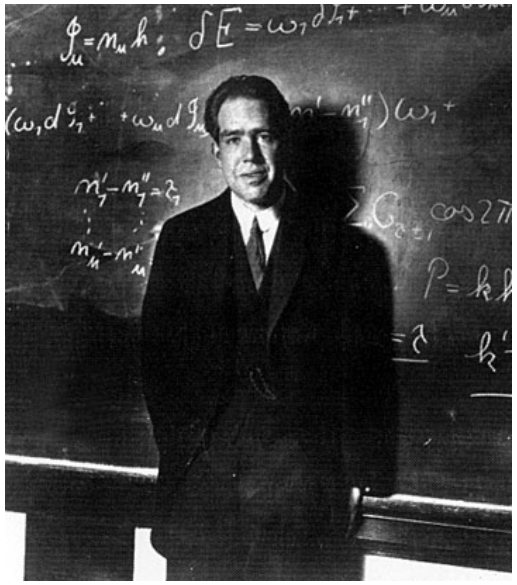
- On Dec. 14, 1900, ***Planck*** announced that: the energy of harmonic oscillations, for black body radiation, can only take on discrete values (the concept of quanta) — ***the birth of quantum theory***.
- 1860, ***Kirchhoff*** and ***Bunsen***: optical spectra are characteristic of the elements which are emitting or absorbing the light.
- 1885, ***Balmer***: finding an ordering principle in spectral lines emitted from Hydrogen atoms.
- 1911, ***Rutherford***: the planet model of the atom; 1913, Bohr: ***Bohr model of Hydrogen atom***.
- By ***De Broglie***: the concept of ***matter waves***.
- 1920~1930, ***Born***, ***Heisenberg***, ***Schrödinger***, ***Pauli***, ***Dirac***, and other researches: ***Quantum theory***.



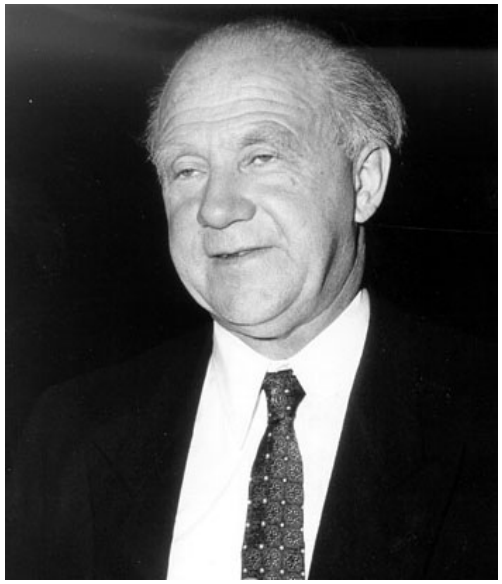
Albert Einstein (1879-1955)



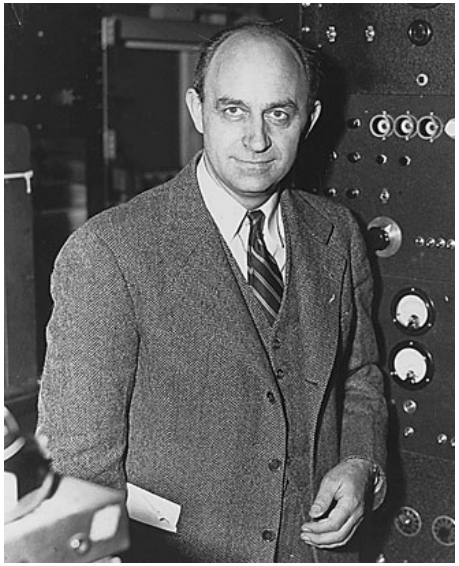
Ernest Rutherford (1871-1937)



Niels Bohr (1885-1962)



Werner Heisenberg (1879-1976)



Enrico Fermi (1901-1954)

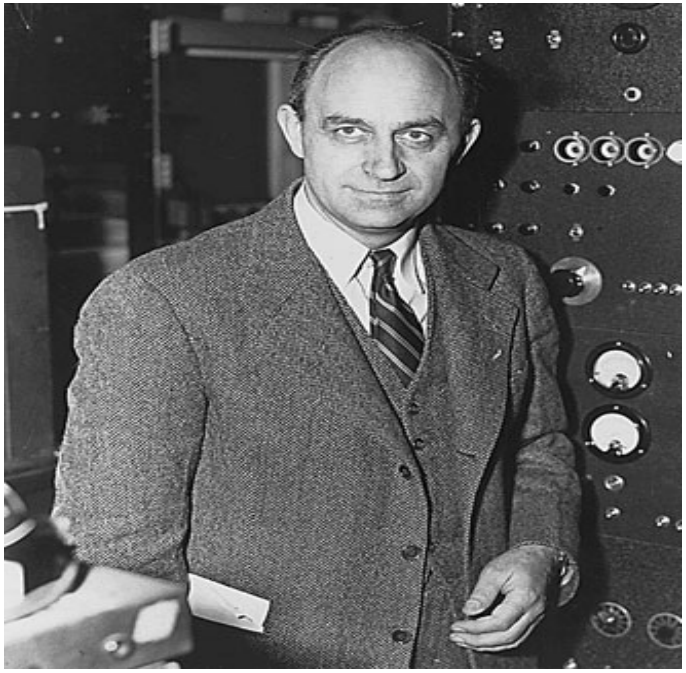
J. Robert Oppenheimer (1904-1967)

Albert Einstein (1879-1955)

A hundred times every day I remind myself that my inner and outer life depend on the labours of other men, living and dead, and that I must exert myself in order to give in the same measure as I have received.

There are two possible outcomes: If the result confirms the hypothesis, then you've made a measurement. If the result is contraryto the hypothesis, then you've made a discovery.

—**Enrico Fermi**



Enrico Fermi (1901-1954)

Enrico Fermi was born in Rome on September 29, 1901. He is best known for his contributions to nuclear physics and the development quantum theory.

Fermi attended the University of Pisa, graduating in 1922. He became a lecturer at the University of Florence for two years and then professor of theoretical physics in Rome. In 1934, while at the University of Rome, Fermi began experiments where he bombarded a variety of elements with neutrons. He discovered that slow moving neutrons were especially effective in producing radioactive atoms. Not realizing he had split the atom, Fermi announced what he thought were elements beyond uranium. Fermi won the 1938 **Nobel** Prize for physics for his work on nuclear processes. Also in 1938 two German physicists, Lise Meitner and Otto Frisch performed a similar experiment where they split a uranium atom. They named the process of splitting atoms "nuclear fission."

In 1938 Fermi left Italy. The "official" reason was that his wife was of Hebrew origin and he feared for her safety. The "un-official" story was that he needed funds to continue his research in nuclear physics. Italy was a poor country at that time and there were no resources to be found to continue his research. He was one of a large group of intellectuals who left other European countries with the rise of National Socialism (the Nazi Party) in Germany and Fascism in Italy. Fermi settled in the United States in 1939, and became professor of physics at Columbia University in New York City.

Fermi continued to conduct nuclear fission experiments at Columbia University. In 1940, Fermi's team confirmed that absorption of a neutron by a uranium nucleus can cause the nucleus to split into two nearly equal parts, releasing several neutrons and enormous amounts of energy. The potential for a self-sustaining nuclear chain reaction had become a strong possibility.

Fermi was placed in charge of the Manhattan Project at the University of Chicago in 1942. His team developed the first atomic pile and produced the first nuclear chain reaction. The project was moved to New Mexico in 1944, and on July 16, 1945, the first atomic bomb was detonated at Alamogordo Air Base.

After the war, Fermi continued his pioneering research on high energy particles. In 1953, Fermi visited Italy for the final time. On November 28, 1954, he died of cancer at the University of Chicago. Fermi is remembered as the "father of the atomic bomb."

The element Fermium, the 100th in the periodic table, was named after Enrico Fermi.