Advanced Materials 2: Phase transformations

1. Introduction
2. Microscopic Interactions
3. Cooperativity
4. Universal aspects of phase transitions
5. Landau Theory

Introduction

- What's common to
  - Superalloys' ageing

    Coexistence of different structural phases and their kinetics of transformation

  - Rewritable CD's or DVD's

    Melting and re-crystallization of polymer dye

  - Computers' Hard Disks

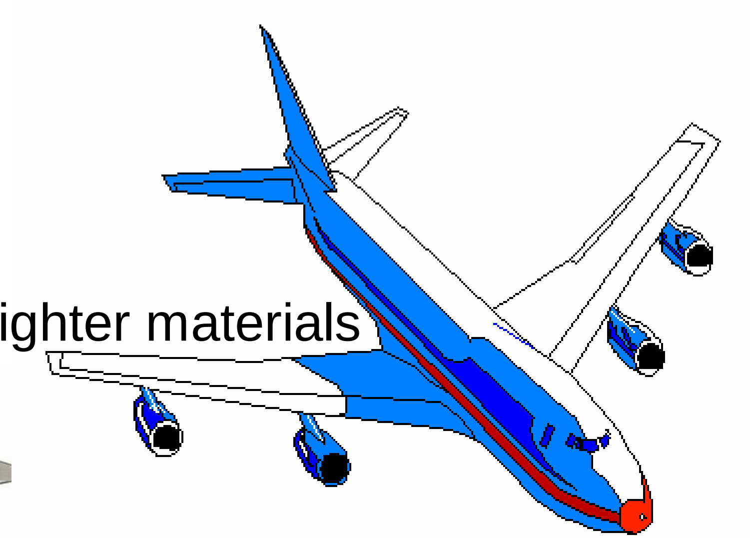
    Flip-flop of magnetic "digits"

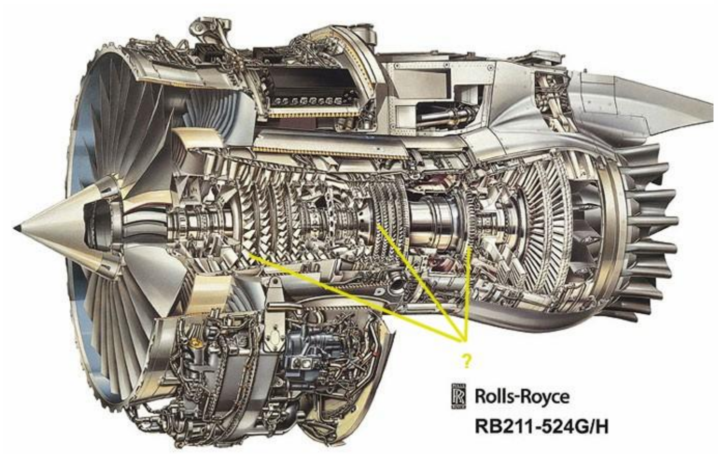
Thermodynamics of phase transitions

Super Alloys

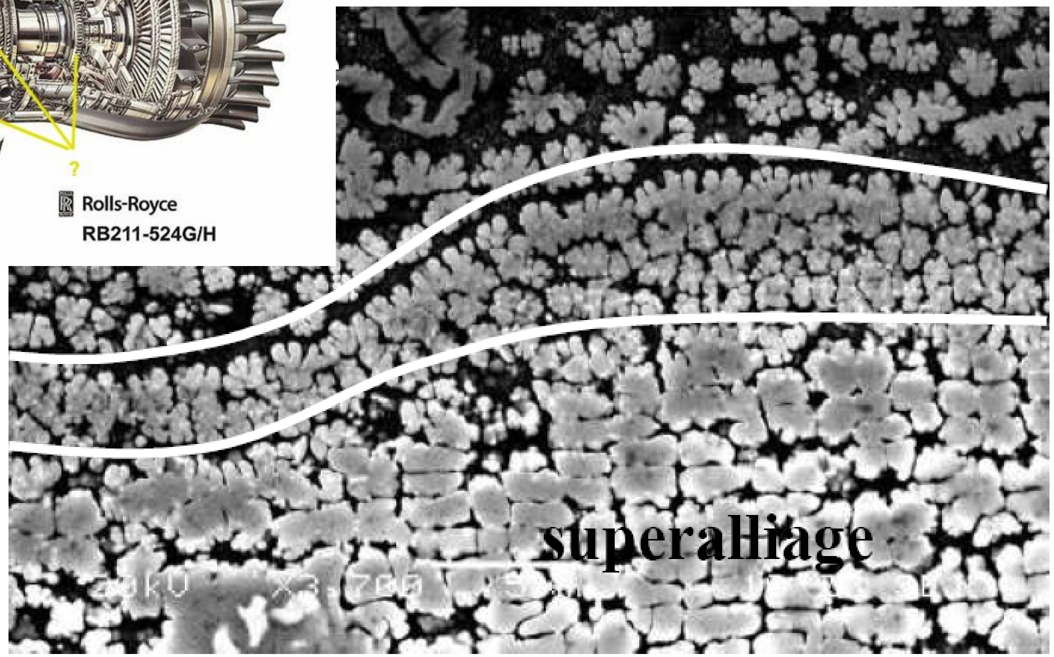
Air Transport:

- ✓ reducing energy consumption
- ✓ increasing reliability
- ⇒ improve mechanical properties with lighter materials





Superalloys



SEM picture of a Ni based superalloy

Super Alloys

The term "superalloy" was first used shortly after World War II to describe a group of alloys developed for use in turbosuperchargers and aircraft turbine engines that required ***high performance at elevated temperatures.*** *The range of applications for which superalloys are used has expanded to many other areas and now includes aircraft and land-based gas turbines, rocket engines, chemical, and petroleum plants. They are particularly well suited for these demanding applications because of their ability to retain most of their strength even after long exposure times above 650°C (1,200°F). Their versatility stems from the fact that they combine this high strength with good low-temperature ductility and excellent surface stability.*

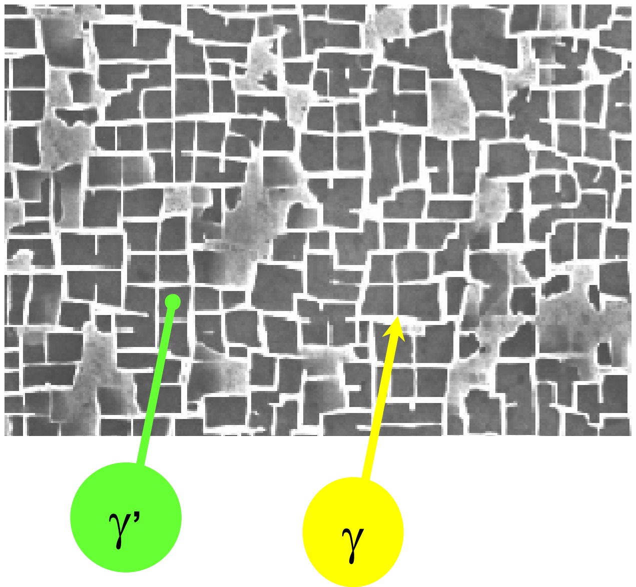
http://www.tms.org/Meetings/Specialty/Superalloys2000/SuperalloysHistory.html

•Gamma (γ): The continuous matrix is an **face-centered-cubic** (fcc) nickel-based phase that usually contains a high percentage of **disordered** solid-solution elements such as Co, Cr, Mo, and W.

SOFT

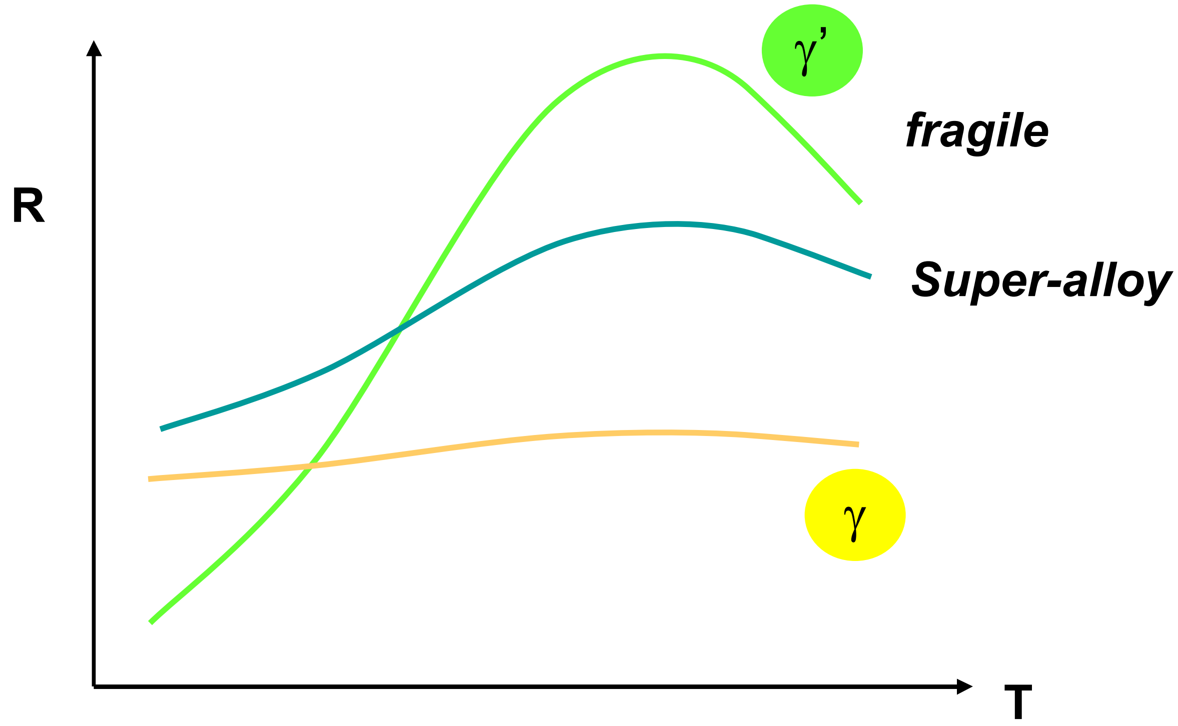
•Gamma Prime (γ '): The primary strengthening phase in nickel-based superalloys is $Ni_3(Al,Ti)$. It is a coherently precipitating phase (i.e., the crystal planes of the precipitate are in registry with the γ matrix) with an **ordered crystal structure**. The close match in matrix/precipitate lattice parameter (~0-1%) combined with the chemical compatability allows the γ ' to precipitate homogeneously throughout the matrix and have long-time stability.

HARD



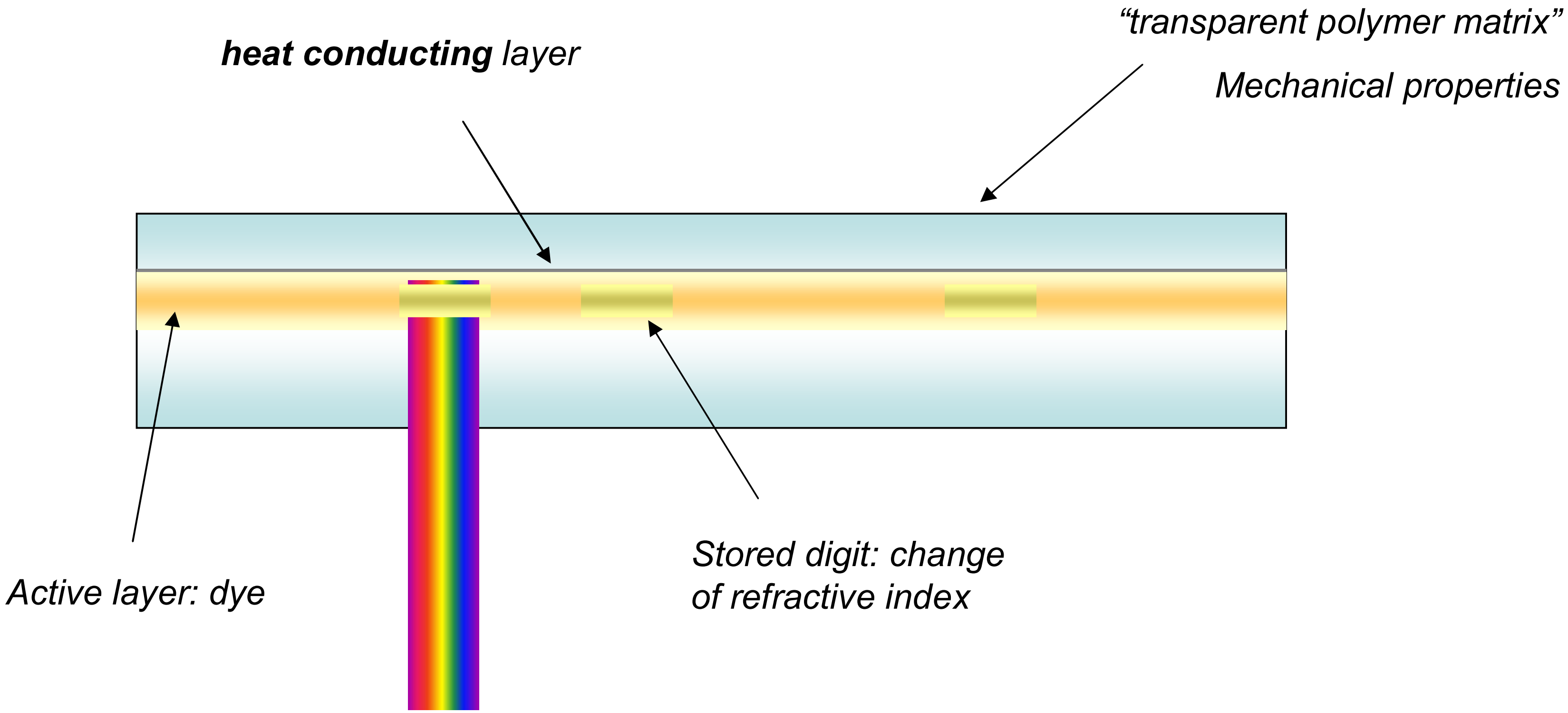
Super Alloys

Mechanical Resistance vs. Temperature:



The composite structure of superalloys (ie. coexistence of "soft" disordrered γ phase and "ordered" γ' phase brings new mechanical properties together with a light material

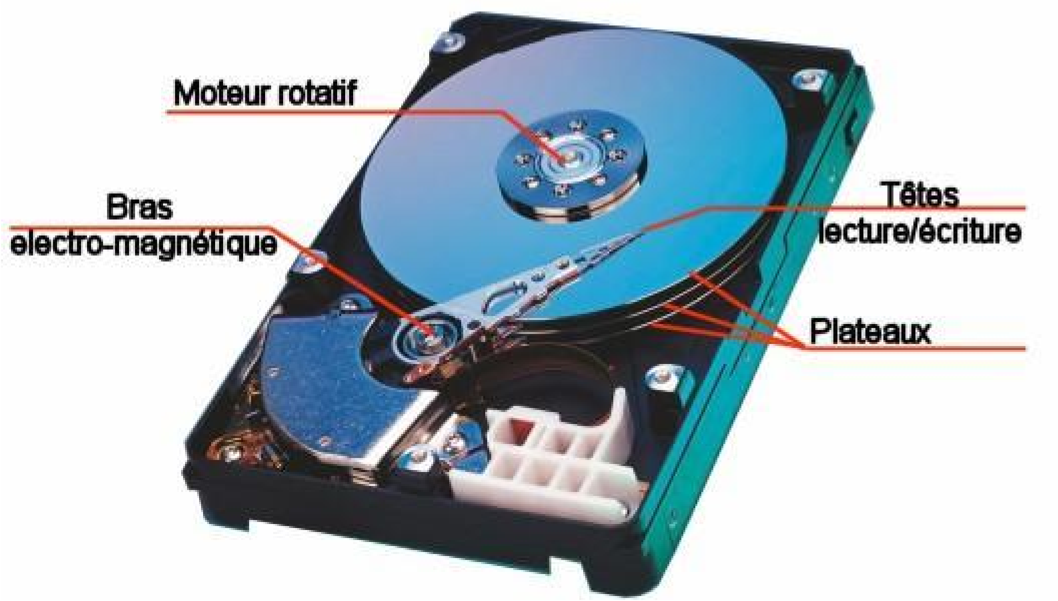
Rewritable CD's or DVD's

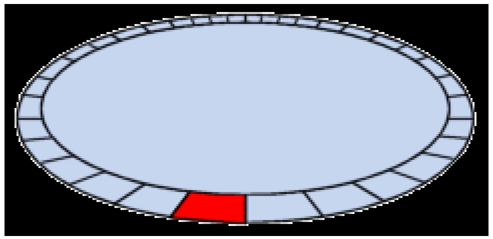


Read & Write Laser

- *low power: Reading based on refraction index variations*
- *high power: melting*
  - *- **low cooling rate**: crystallization ⇔ n_{cryst}*
  - *- **high cooling rate**: glassy state ⇔ n_{glass}*

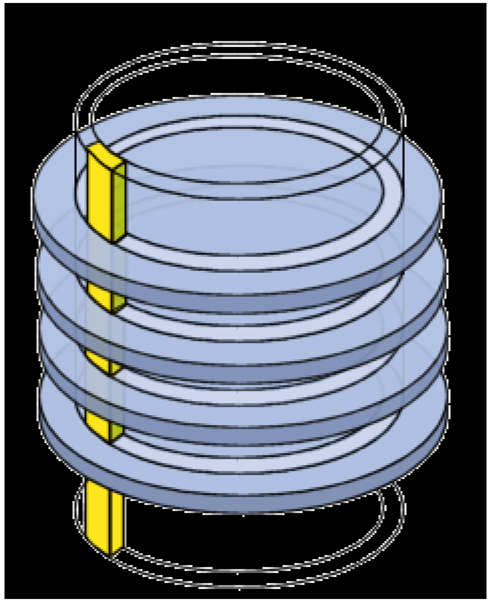
Hard Disks

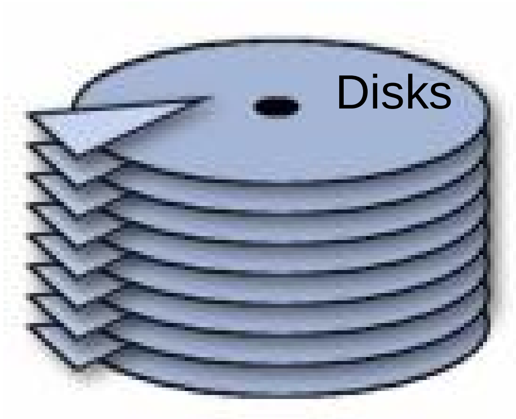




Sectors

Clusters



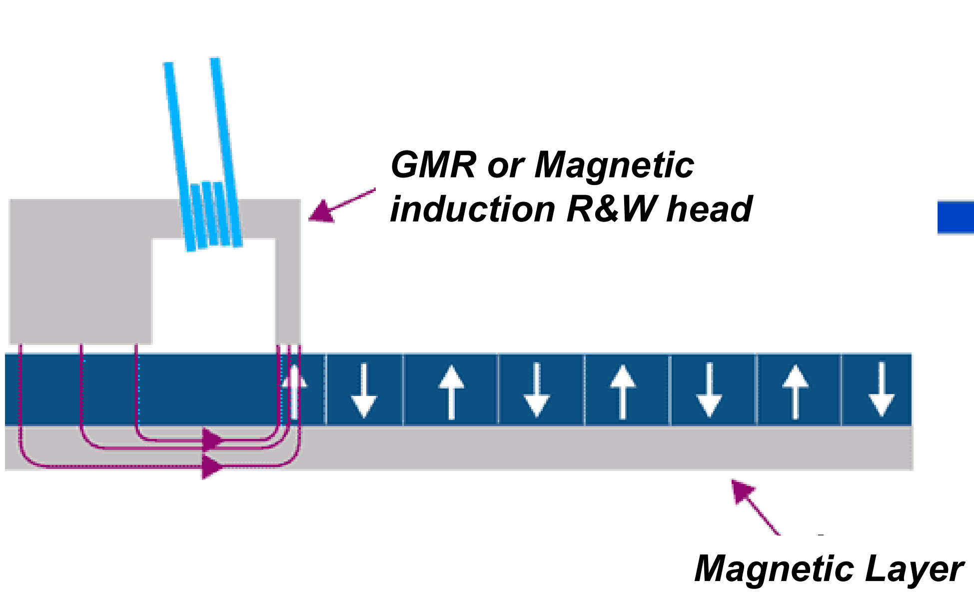


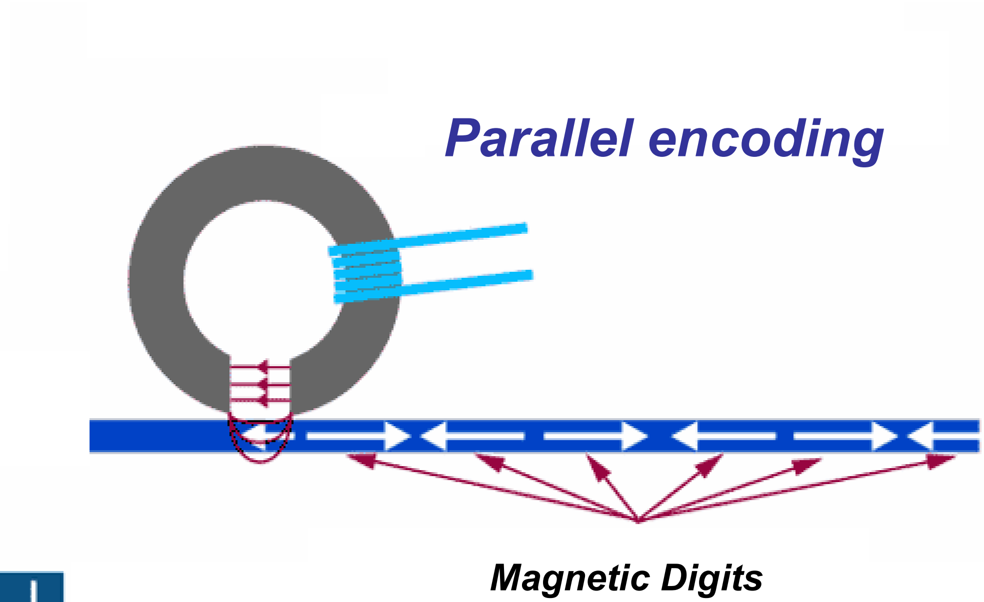
Motorized Arms

with

Read & Write heads

Hard Disks





Flip & flop magnetic moments: ferromagnetic domains

Perpendicular encoding: higher digits density, better storage capacity

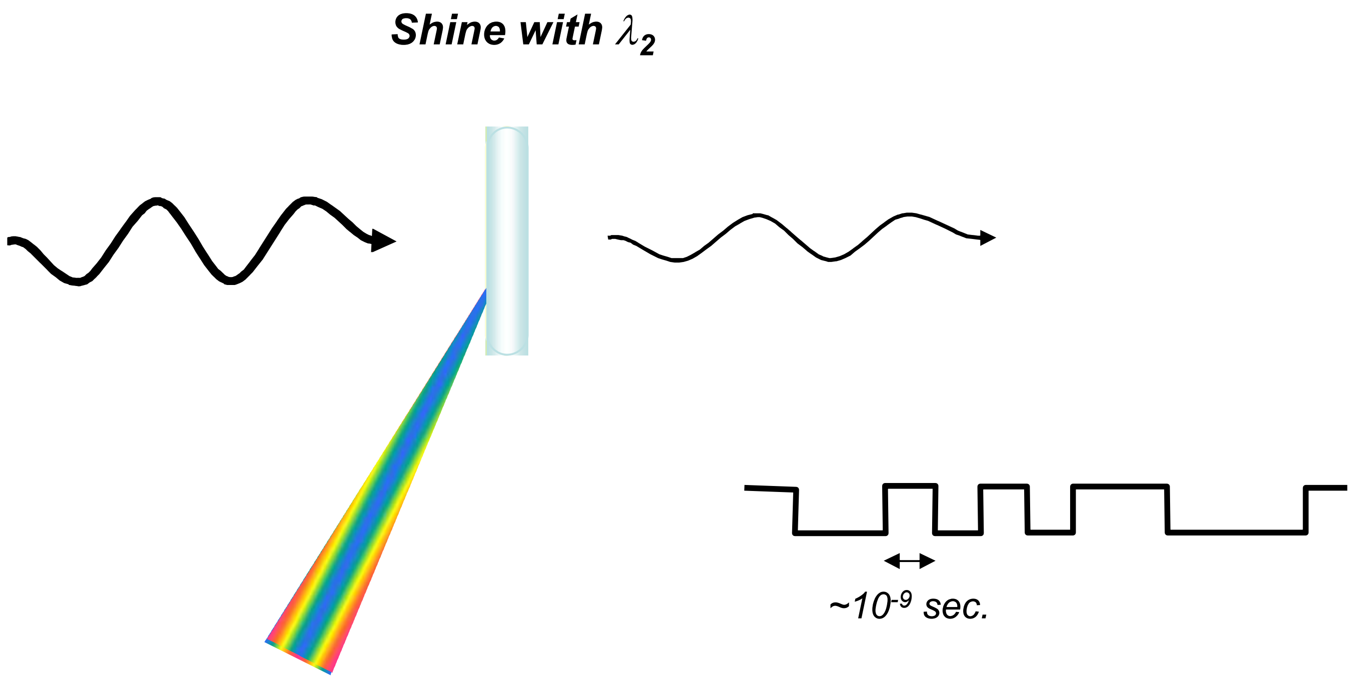
http://www.vulgarisation-informatique.com/disque-dur.php

Ultrafast Switching

"Tomorrow TeraHertz" communications …

needs ultra-fast commutation between different states (nano-second digit means pico-second switching time scale !!!)

For instance Photoinduced Metal to Insulator Phase Transition,



Microscopic Interactions

2. Interactions vs. Temperature

I. Orders of magnitude of microscopic interactions

II. Cooperativity and universal aspects of phase transformations

III. Order parameter, susceptibility