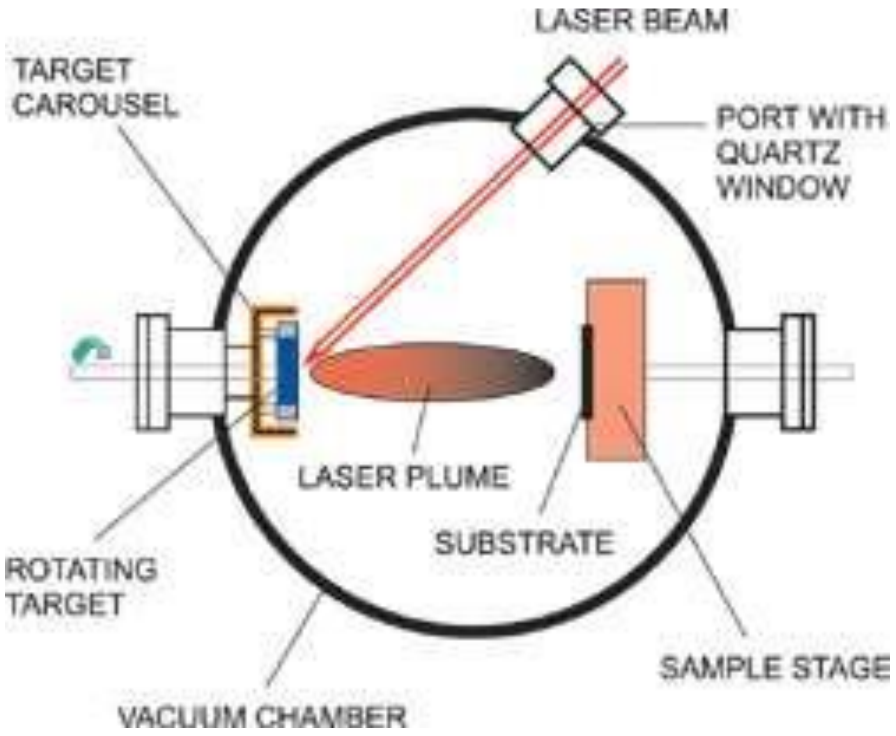
Physics of Nanotechnologies

Pulsed Laser Deposition (PLD)

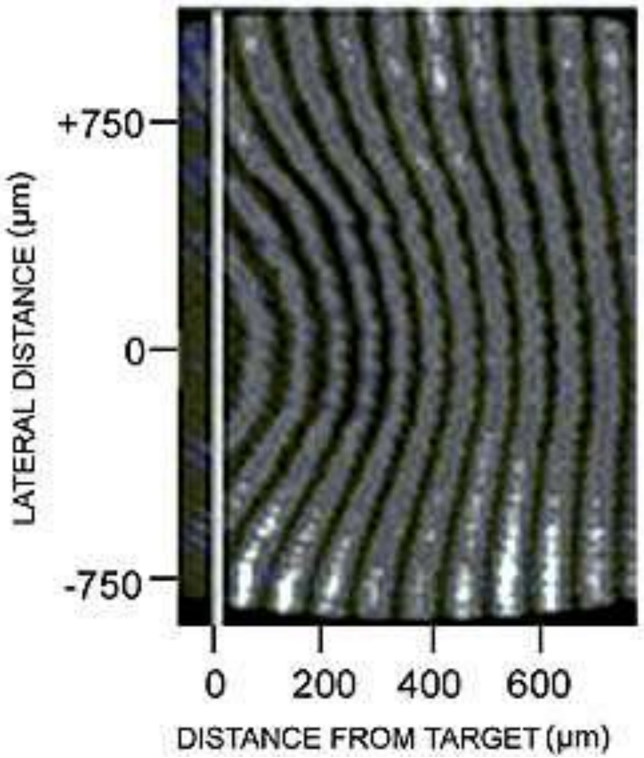
The technique of PLD has been used to deposit high quality films of materials for more than a decade.The technique uses high power laser pulses (typically ~108 Wcm-2) to melt, evaporate and ionize material from the surface of a target. This "ablation" event produces a transient, highly luminous plasma plume that expands rapidly away from the target surface. The ablated material is collected on an appropriately placed substrate upon which it condenses and the thin film grows. Applications of the technique range from the production of superconducting and insulating circuit components to improved wear and biocompatibility for medical applications. In spite of this widespread usage, the fundamental processes occurring during the transfer of material from target to substrate are not fully understood and are consequently the focus of much research.

- In principle PLD is an extremely simple technique, which uses pulses of laser energy to remove material from the surface of a target, as shown schematically on the right.



- The vaporized material, containing neutrals, ions, electrons etc., is known as a laser-produced plasma plume and expands rapidly away from the target surface (velocities typically ~106 cms-1 in vacuum).
- Film growth occurs on a substrate upon which some of the plume material recondenses. In practice, however, the situation is not so simple, with a large number of variables affecting the properties of the film, such as laser fluence, background gas pressure and substrate temperature.
- These variables allow the film properties to be manipulated somewhat, to suit individual applications. However, optimization can require a considerable amount of time and effort.
- Indeed, much of the early research into PLD concentrated on the empirical optimization of deposition conditions for individual materials and applications, without attempting to understand the processes occurring as the material is transported from target to substrate.

- The technique of PLD was found to have significant benefits over other film deposition methods, including:
- 1. The capability for stoichiometric transfer of material from target to substrate, i.e. the exact chemical composition of a complex material such as YBCO, can be reproduced in the deposited film.
- 2. Relatively high deposition rates, typically ~100s Å/min, can be achieved at moderate laser fluences, with film thickness controlled in real time by simply turning the laser on and off.
- 3. The fact that a laser is used as an external energy source results in an extremely clean process without filaments.Thus deposition can occur in both inert and reactive background gases.
- 4. The use of a carousel, housing a number of target materials, enables multilayer films to be deposited without the need to break vacuum when changing between materials.



Interferogram of a Magnesium plasma plume expanding into vacuum taken 46nS after the ablation pulse struck the target surface. Laser fluence (2.0 ±0.2) JCM -2 on target, 2nS ICCD gate width. Image courtesy of Physics Department, Queen's University, Belfast