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Laser Nano-processing within NANOTEIRE National Nanoscience Programme

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Ollscoil na hÉireann, Gaillimh

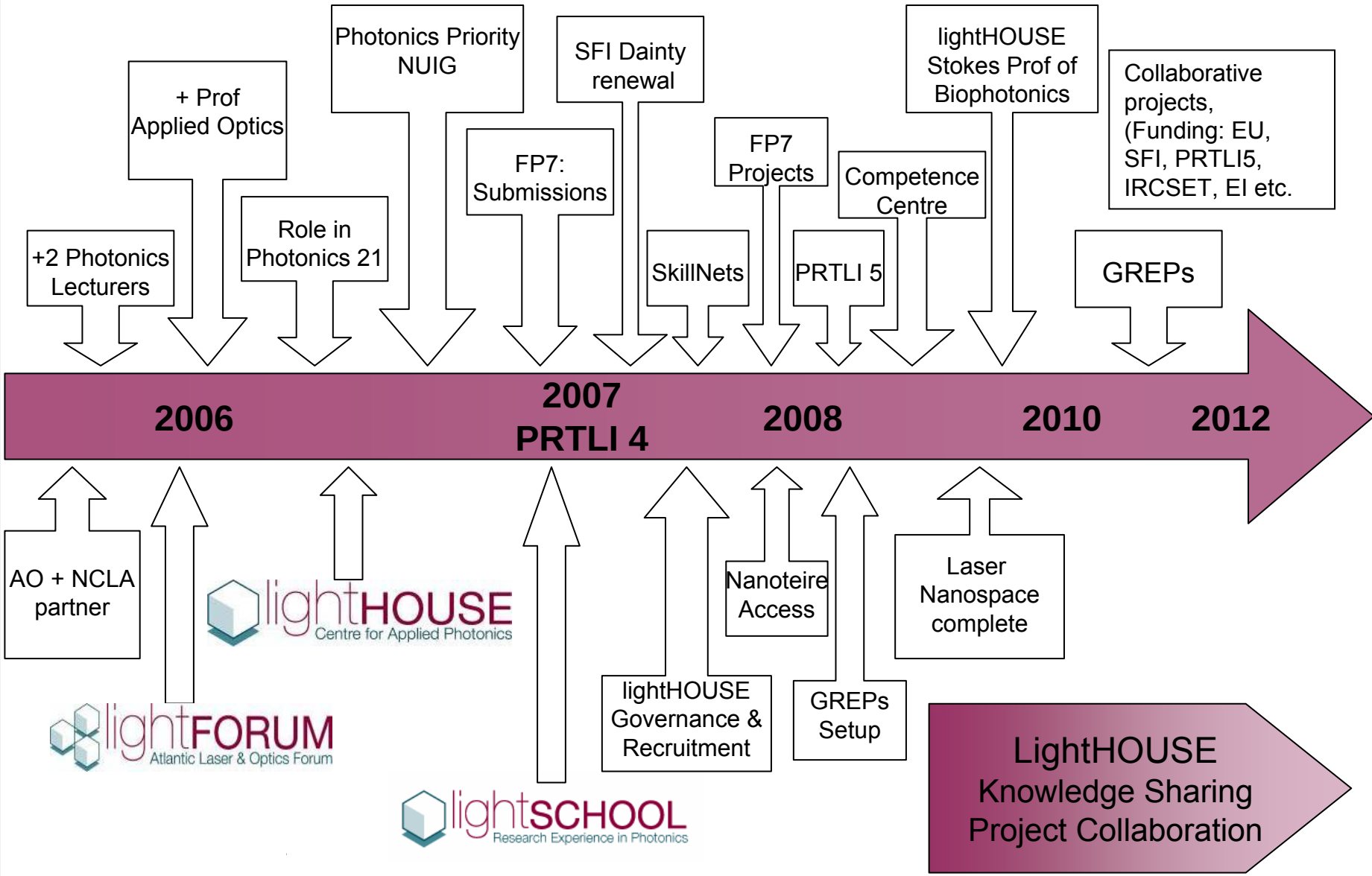
Outline

- Update on progress in LightHOUSE
- Potential for laser technology in nano-scale manufacturing
- Laser nano-processing are not limited by diffraction limit
- LightHOUSE in NANOTEIRE
- Conclusions

LightHOUSE: Progress & Plan

Sustainability

Implementation



Some drivers for nano-structured surfaces

- "Nano-scale" in ICT well in-progress!
- Healthcare
  - Reports: ESF Nanomedicine, ETP Nanotechnology for Health
  - Emphasis point of care: diagnostics, therapeutics.
  - Biospecifivity requires nanostructures
- Auto components
  - Kyoto agreements, fuel costs….
  - "50% of friction generated by auto engines is internal".
  - Nano-textured surfaces to improve internal tribology and wear
- Solar Energy
  - Predictions of 30% market growth per annum
  - ETP Photovoltaics
    - Emphasis on high productivity, high efficiency devices
  - Laser nano-textured surfaces: 60% increase in photocurrent

Functionalities enabled by
nano-scale are happening now

At a practical level, which technology ?

Basic Requirements
Precision,
Throughput
Prototyping
Low barrier for use

Economics
Capital / operational costs,
SME accessible/ innovative
"Future Sustainable"

Volume Production
Scalability,
Low maintenance
Integration with microscale
Health & Safety
Environmental impact

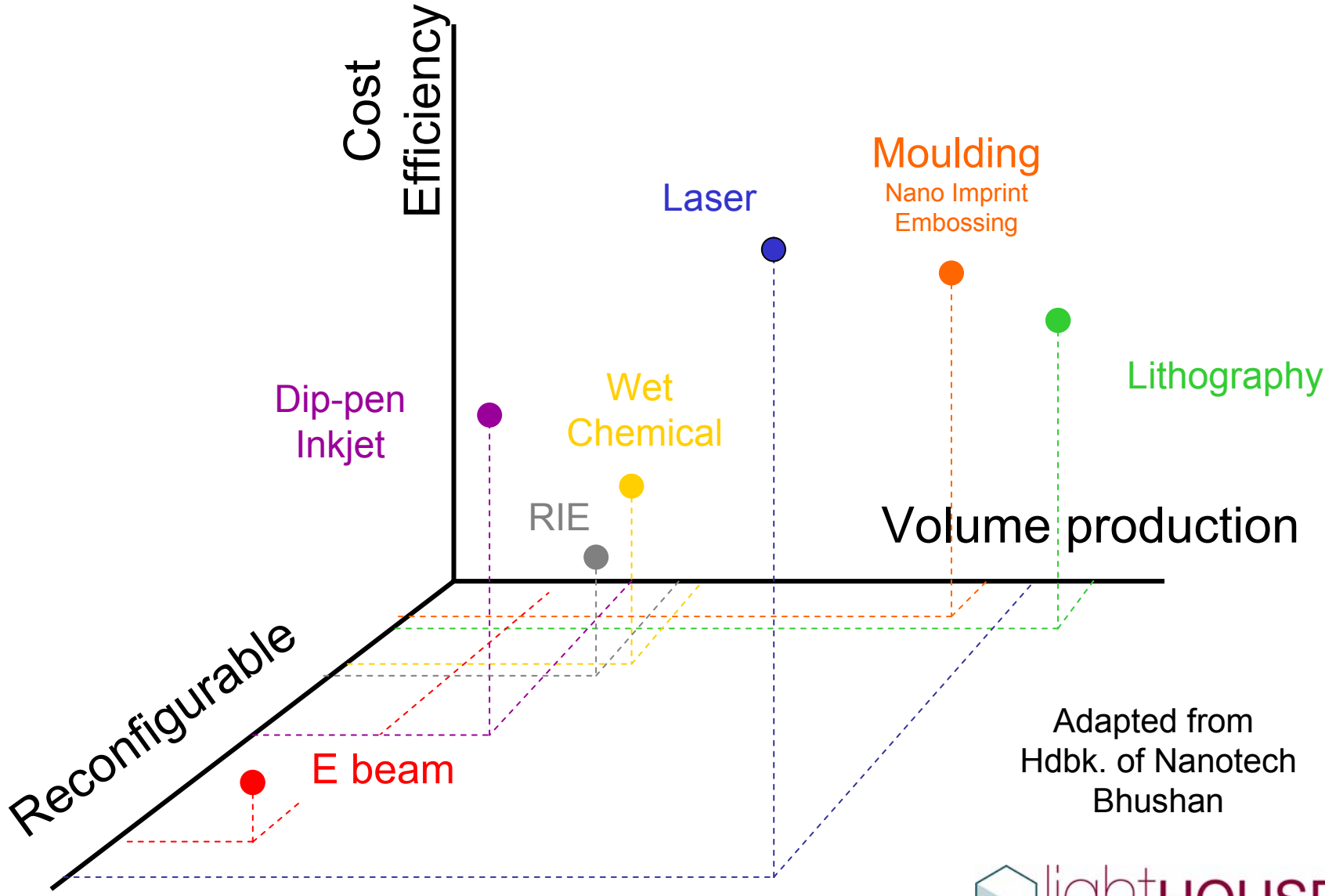
What is the potential of laser & optics compared with alternatives ?

Process Control
Process parameters
On-line monitoring
Adaptive control

Re-configurability
New designs
New processes

Versatility
Metals,
polymers,
glasses,
Semiconductors,
ceramics

Nano manufacturing space



Adapted from
Hdbk. of Nanotech
Bhushan

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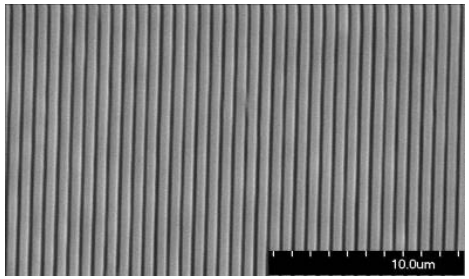
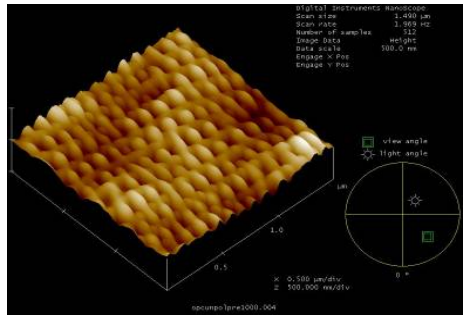
Laser based nano-structured surfaces

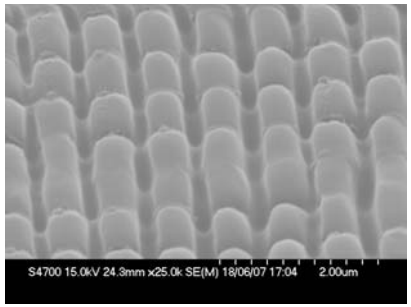
- Laser structuring is not always limited by the diffraction limit



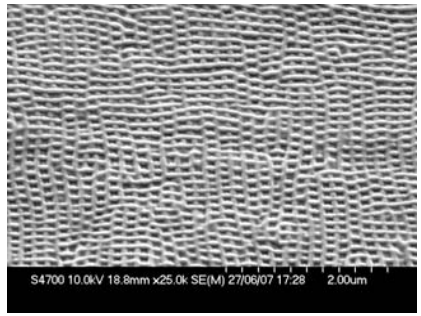
Periodic (650nm) structures produced by laser. (Best 160nm attained).



Laser patterned sub micron "egg box" structure



Phase mask structure produced on OPC



Nano- mesh produced by LIPSS on OPC

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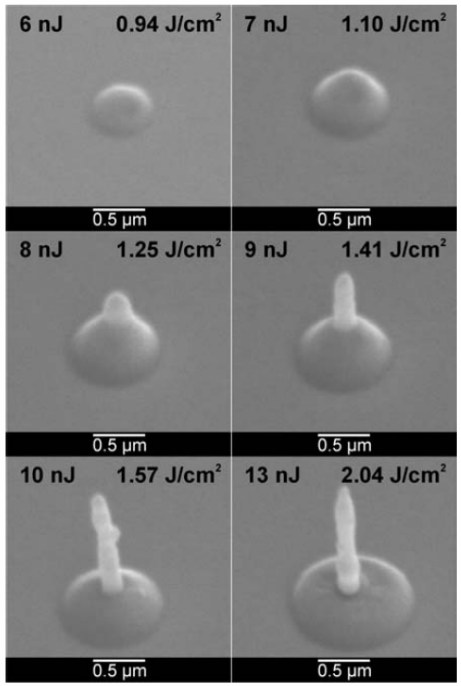
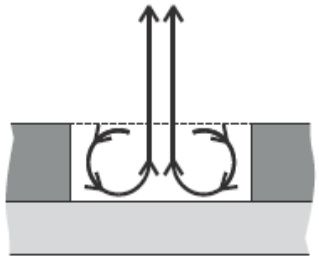
Laser Material (Ambient) interaction is important

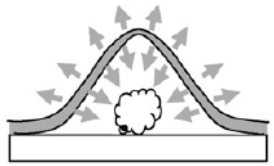
30 fs Gaussian laser
tip on 60 nm Au film



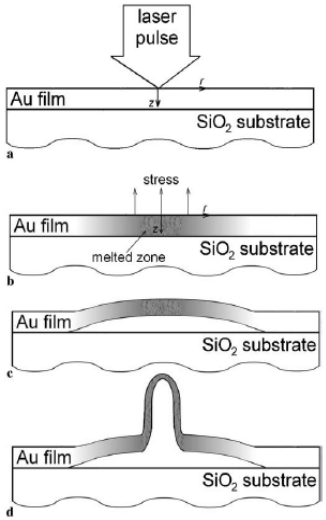
F. Korte, et. Al.
Appl. Phys. A **79**, 879 (2004).
Laser Zentrum Hannover



Marangoni effect
Appl. Phys. A 79, 879 (2004).



Peeling due to evaporation
Y. Nakata, *Appl. Surf. Sci.* **253**, 6555 (2007).



Plastic deformation
Y.P. Meshcheryakov
Appl. Phys. A 82, 363 (2005).

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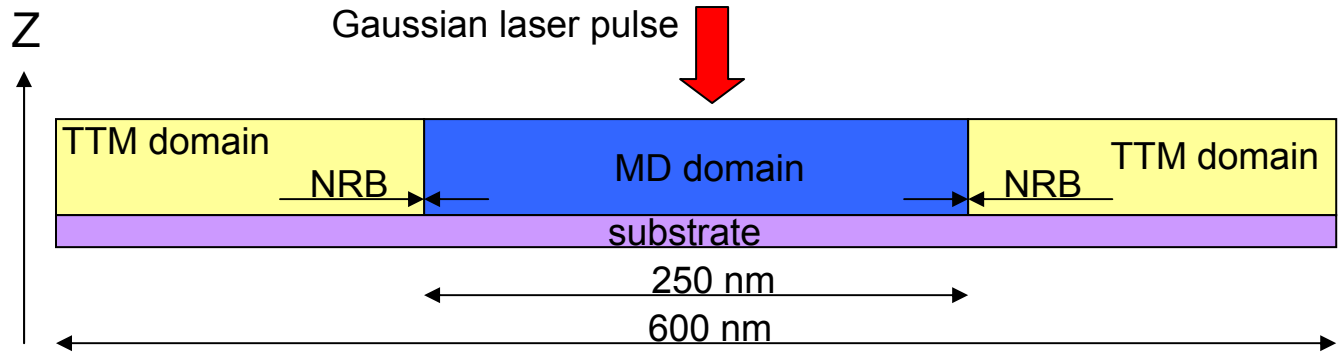
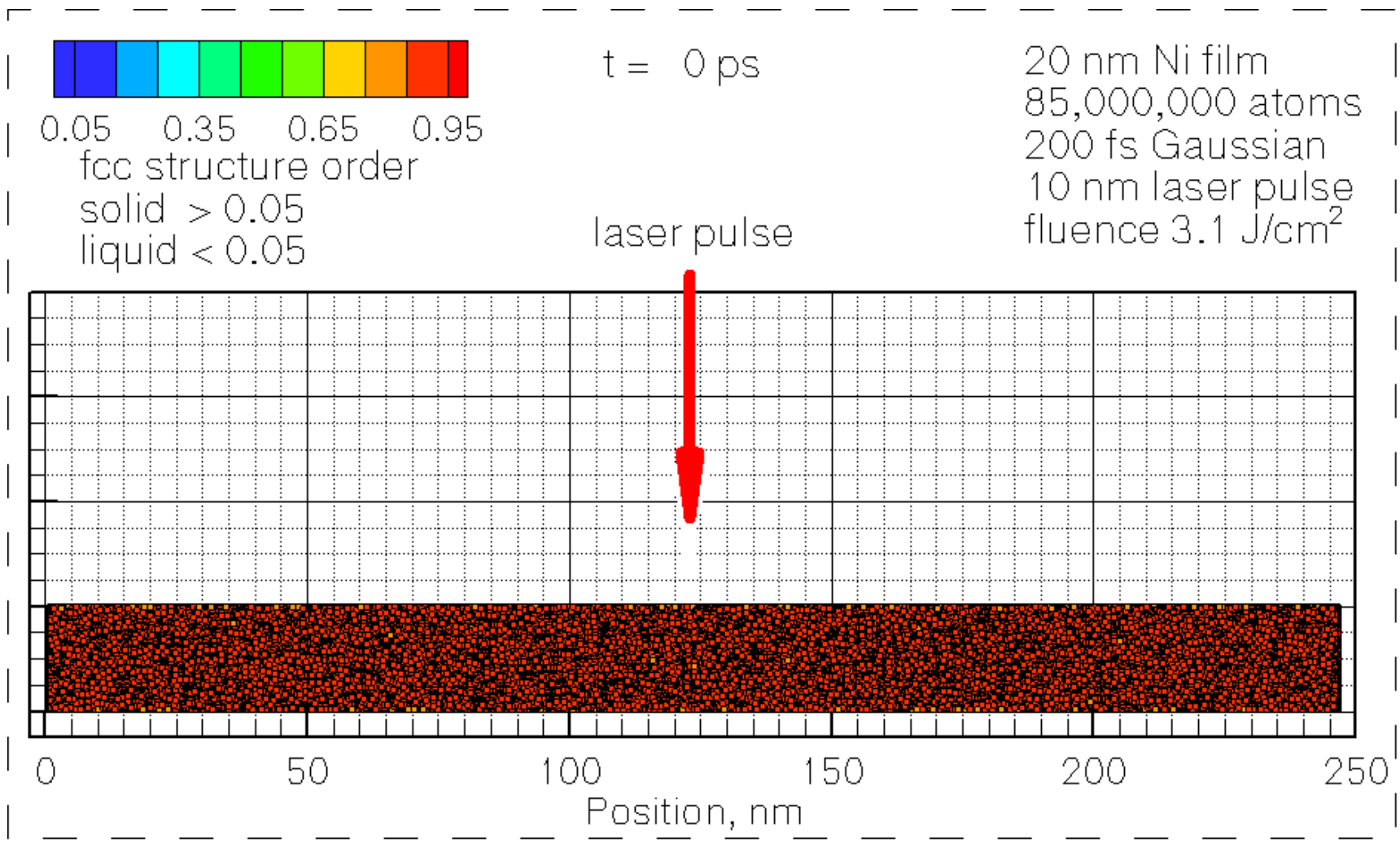
Computational model of nano-bump formation

- Developed an atomistic-continuum model
  - Molecular dynamics (MD) to describe atoms (atomistic)
  - Two Temperature Model (TTM): Electrons-Lattice (continuum)
- Simulated Ni circular slab of 250 nm in diameter, 20 nm thickness (85,000,000 atoms), Scaled laser spot 10nm
- Used 1000 hours, 128 processors of Walton Cluster at ICHEC, (Irish Centre for High End computing)



Simulation of nano-bump formation (structure)



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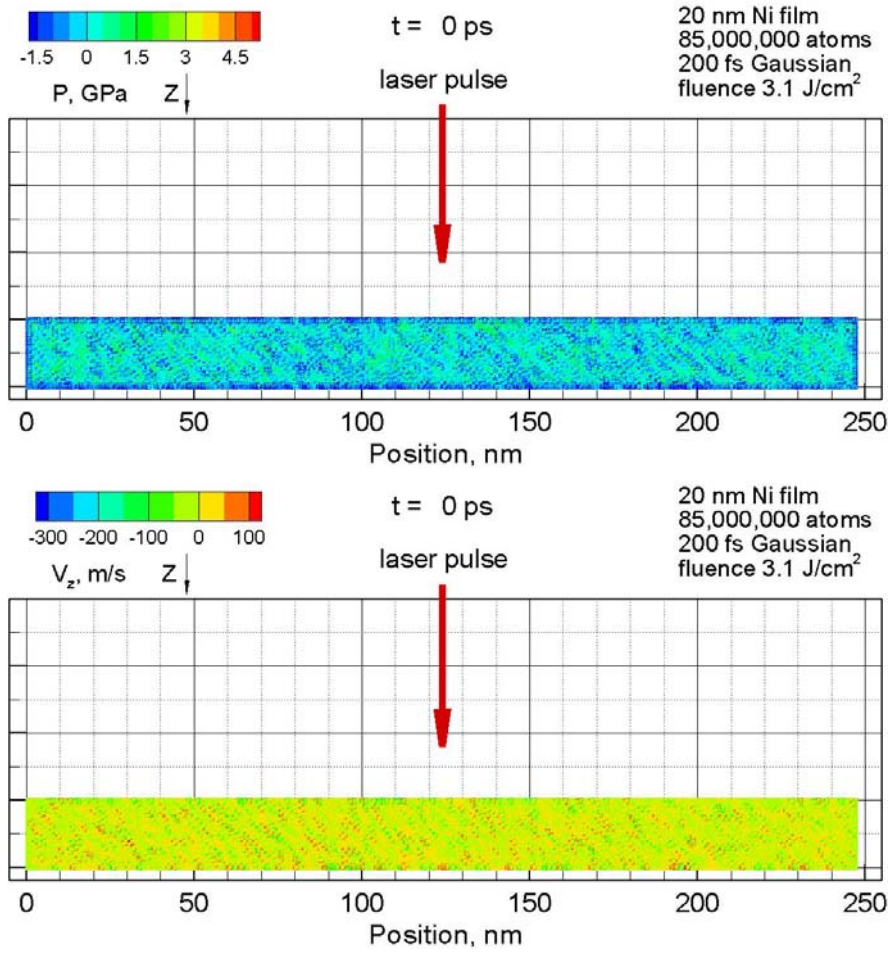
Mechanism of the nanobump formation

- Laser energy absorption by conduction band electrons
- Fast heating of lattice under conditions of inertial stress confinement
- Strong temperature and pressure gradients in 2D
- Relaxation of the laser-induced pressure
- Establishment of hydrodynamic motion in the molten part



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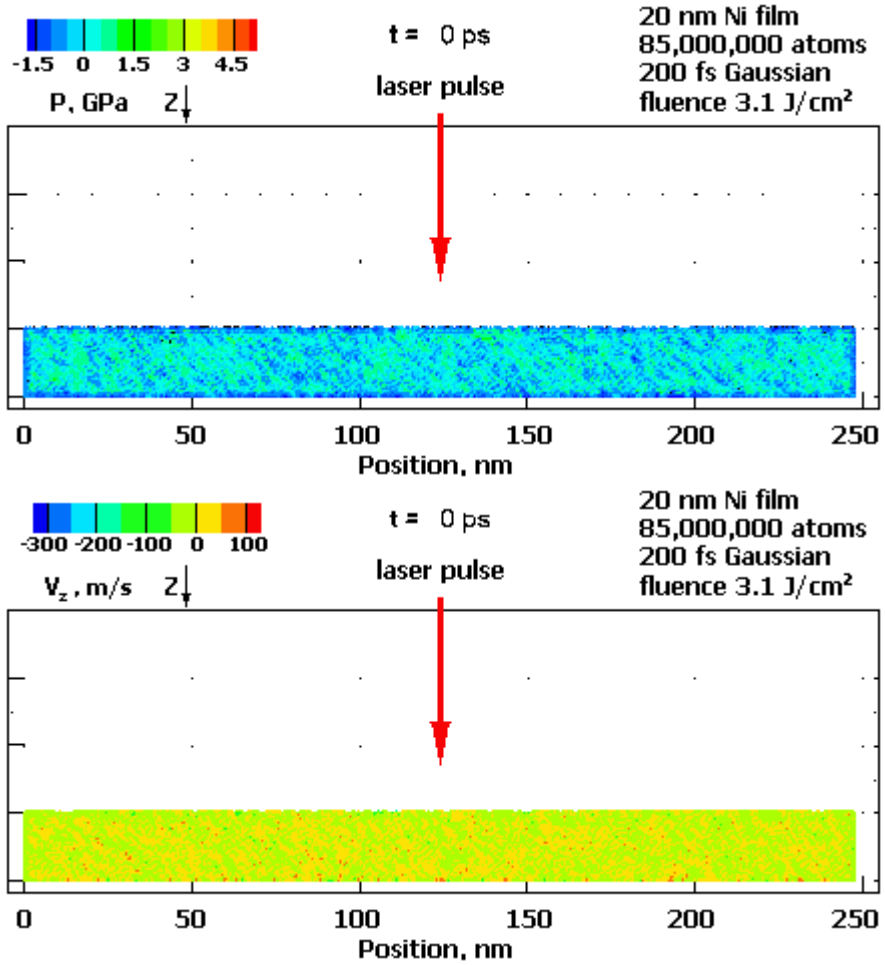

Relaxation of the laser induced pressure is the driving force for the nanobump growth

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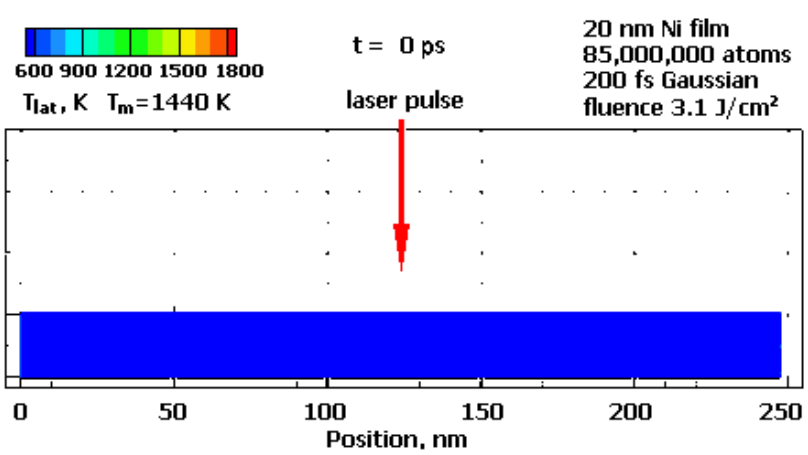
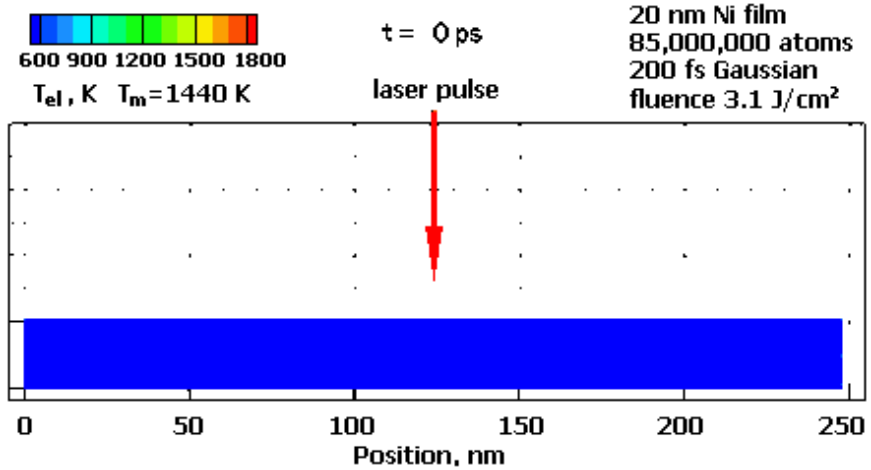
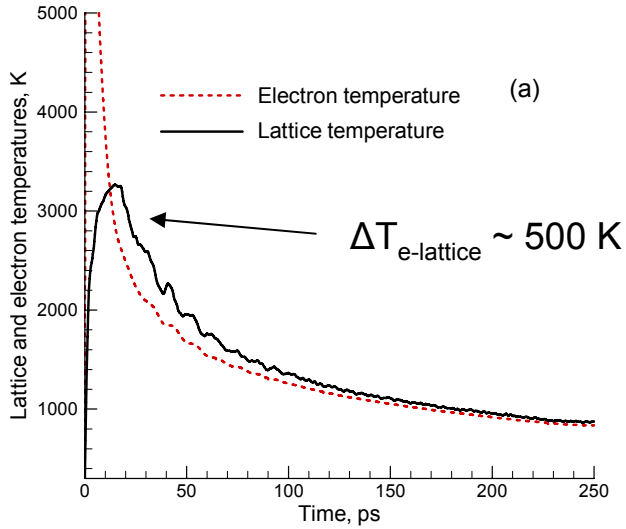
“Electronic” freezing of the nanobump







Fast electron heat conduction in 2D provides strong cooling rate to freeze nano-bump structure

Recrystallisation of bump follows

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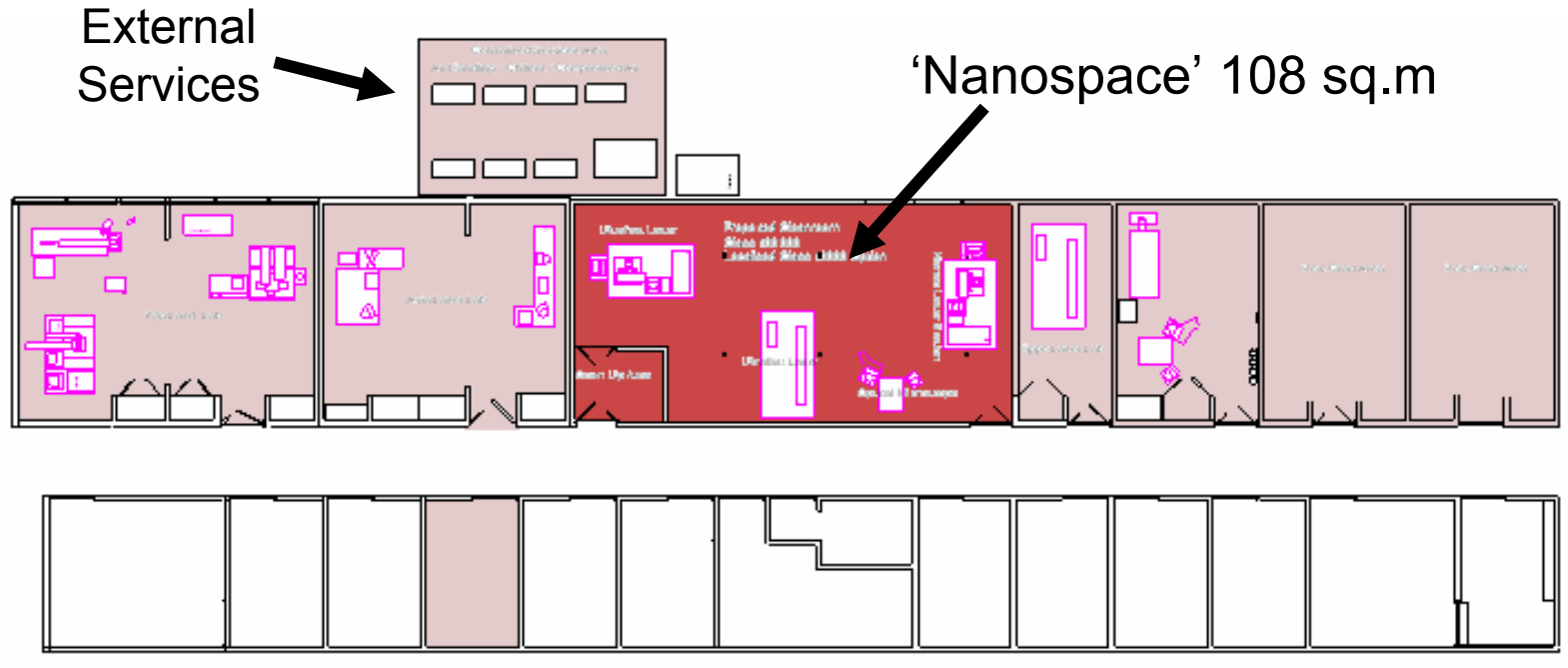
Creation of Laser ‘Nanospace’

- Refurbishment of existing space
- Upgrade 400 sq.m of research space
- Clean room, environment controlled Laser Nanotech Capable Laboratories

Relevant Floor Plan



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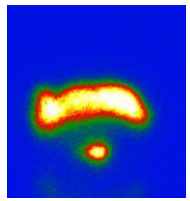
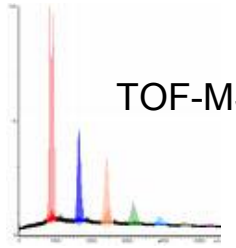
Implementation: Equipping the ‘Nanospace’

Ultrafast Direct Laser Nanostructuring

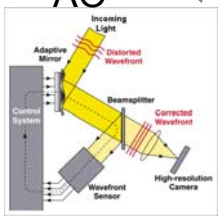
High-speed Imaging

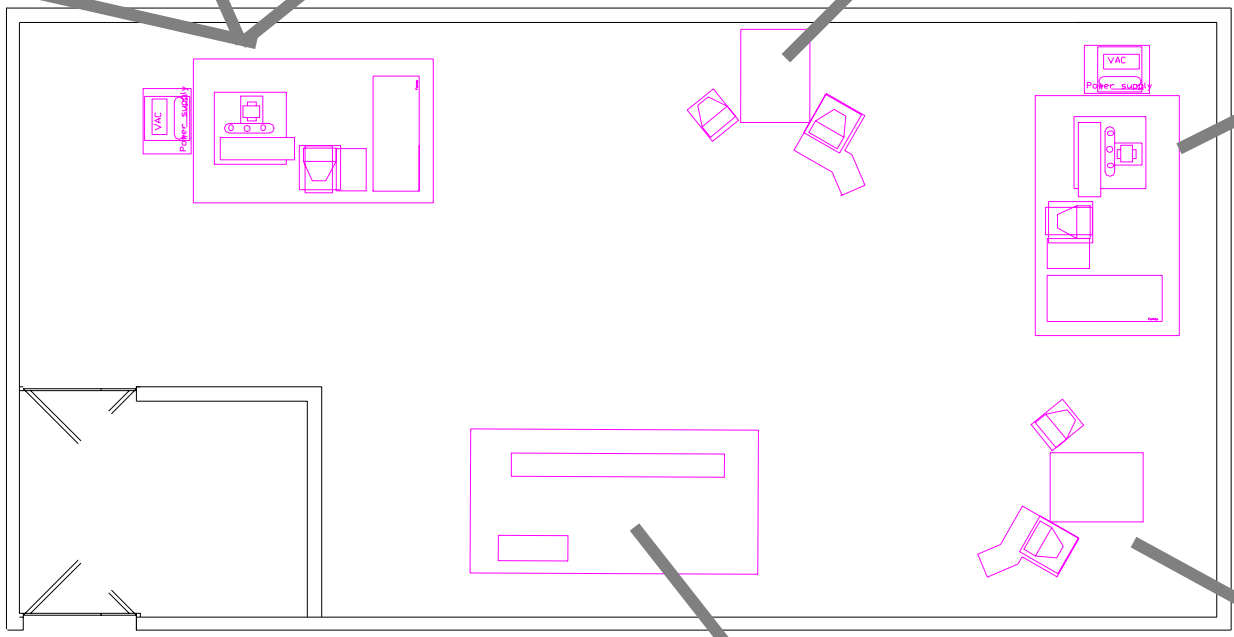


TOF-MS

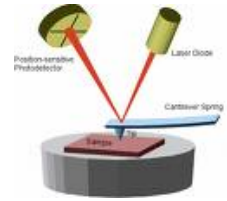


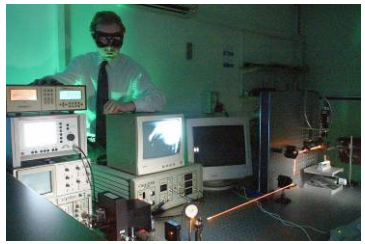
MEMS-AO





AFM-Laser





Existing Ultrafast Laser System (NCLA)

Sample Prep. & Analysis Station

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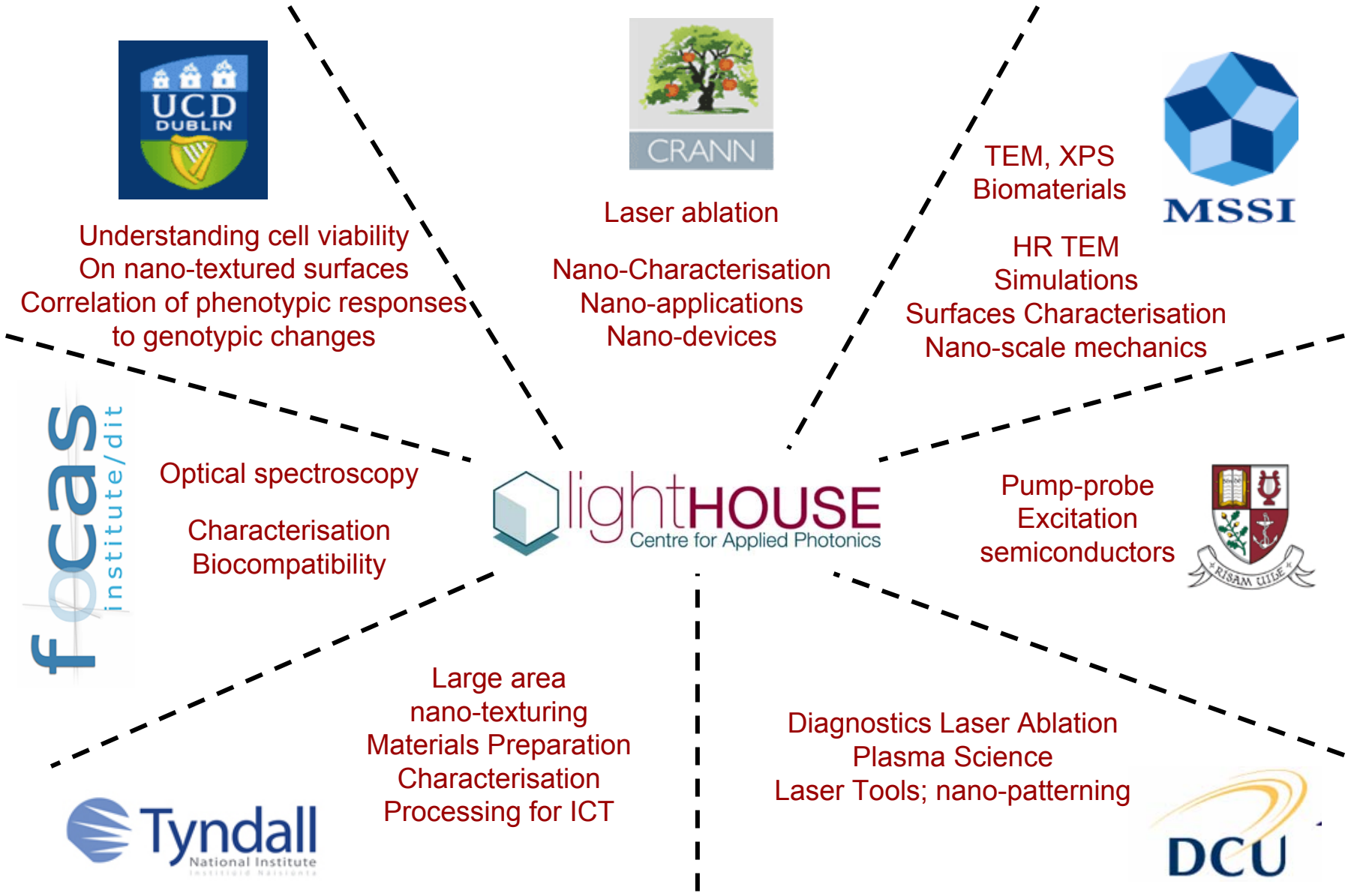
Accessing wider expertise in NANOTEIRE Partnership



Summary

- Laser technology continues to be a versatile tool for micro-, nano-scale processing
- The Nanoscience & Nano-scale Technologies platform (Nanoteire) offers collaborative opportunities.

- Acknowledgements
  - Colleagues at LightHOUSE
  - Dmitriy Ivanov for simulations
  - Richard Sherlock, Claire O'Connell, Una Prendergast

- Thank you for your attention

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