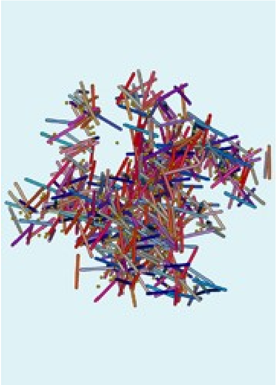
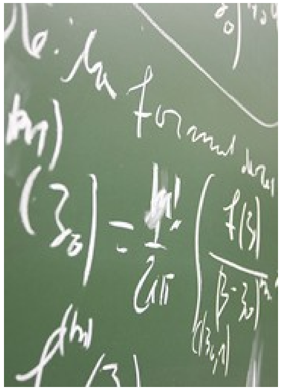
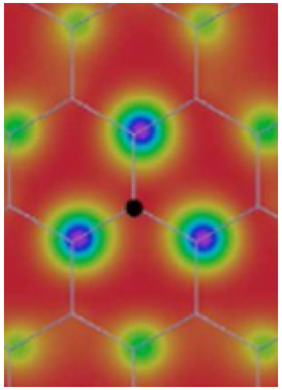
UNIVERSITÉ DU LUXEMBOURG

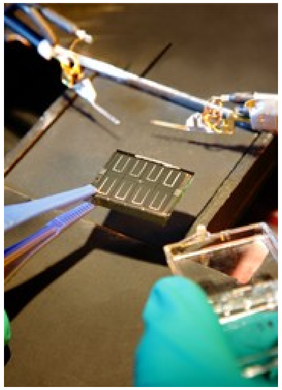
Strategy for Physics and Materials Science at the University of Luxembourg

Ludger Wirtz







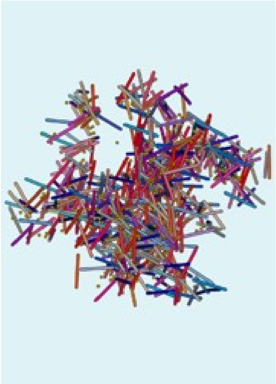
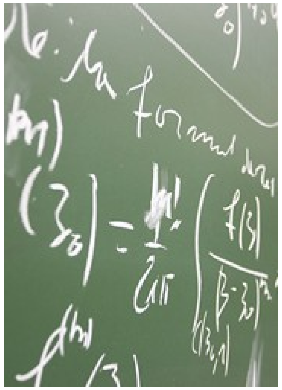
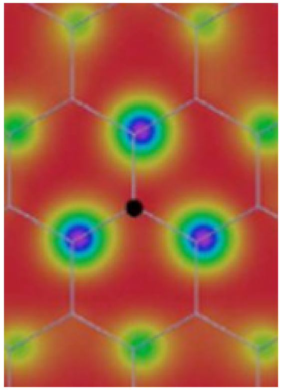
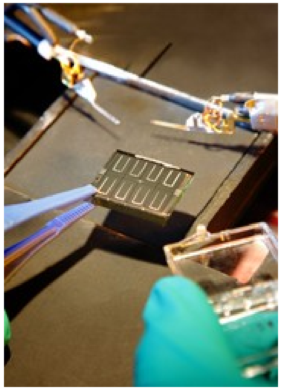


PHYMS | PHYSICS AND MATERIAL SCIENCES RESEARCH UNIT

Brief Overview

UNIVERSITÉ DU LUXEMBOURG

Research Unit in Physics and Materials Science: focus on condensed matter physics

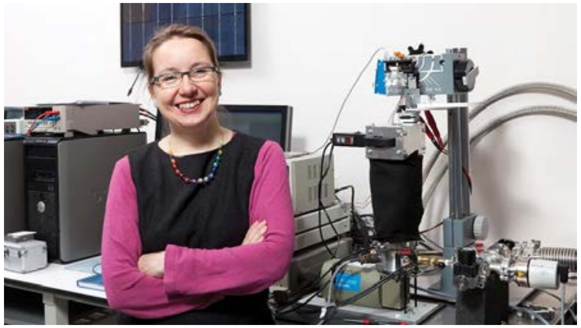
- 10 research groups
- 89 members (10 PIs, 34 Postdocs, 34 PhD students, 11 support)
- 50% third-party funding
- 3 ERC grant holders, 5 ATTRACT fellows
- 86 publications in 2016

PHYMS | PHYSICS AND MATERIAL SCIENCES RESEARCH UNIT

Milestones in History

- 2003: Foundation of the University:
  Members of the “centre universitaire” build a research unit in physics:
  - Polymer Physics (R. Sanctuary together with J.-K. Krüger, Saarbr.)

- 2006: TDK Europe chair for "New Materials for Solar Cells”
  Foundation of the “Laboratory for Photovoltaics” (S. Siebentritt)



Milestones in History

- 2015: Grand Prix en Sciences Physiques de l'Institut Grand-Ducal

Mission

- Fundamental and applied research in physics and materials science
- Providing high-quality teaching for students on the undergraduate Master and PhD level, and training for researchers at the post-doctoral level
- Contributing to the intellectual life of the country

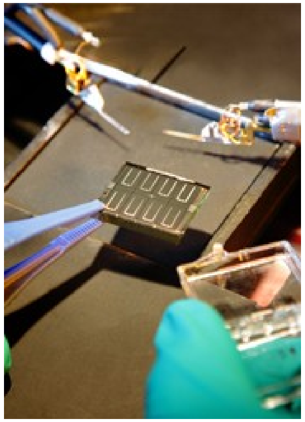
Mission

UNIVERSITÉ DU LUXEMBOURG

- Fundamental and applied research in physics and materials science
- Providing high-quality teaching for students on the undergraduate Master and PhD level, and training for researchers at the post-doctoral level
- Contributing to the intellectual life of the country

4 Research Clusters

UNIVERSITÉ DU LUXEMBOURG

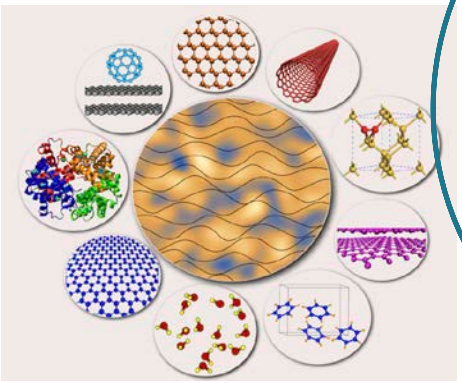


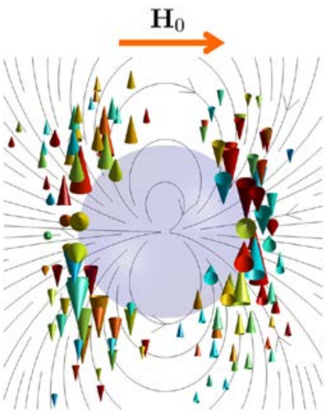
Soft & Living Matter

Photovoltaics & Semiconductors

Theory & Materials Modelling

Magnetic & Multiferroic Materials

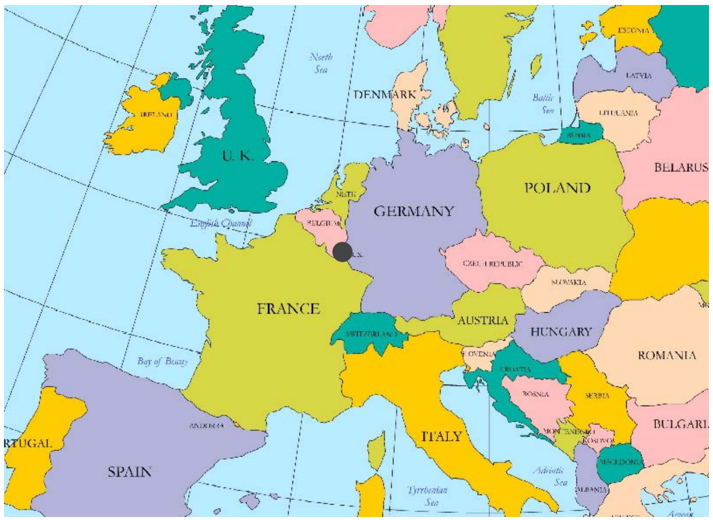




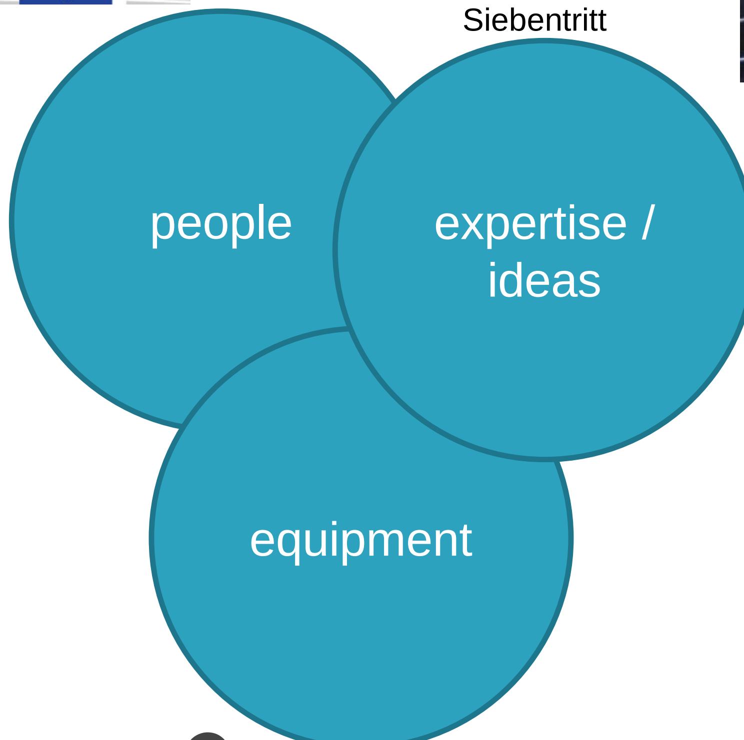
PHYMS | PHYSICS AND MATERIAL SCIENCES RESEARCH UNIT

Photovoltaics and Semiconductors

Fonds National de la Recherche Luxembourg



A PV hub in Europe?



equipment fund?

Susanne Siebentritt

Philipp Dale

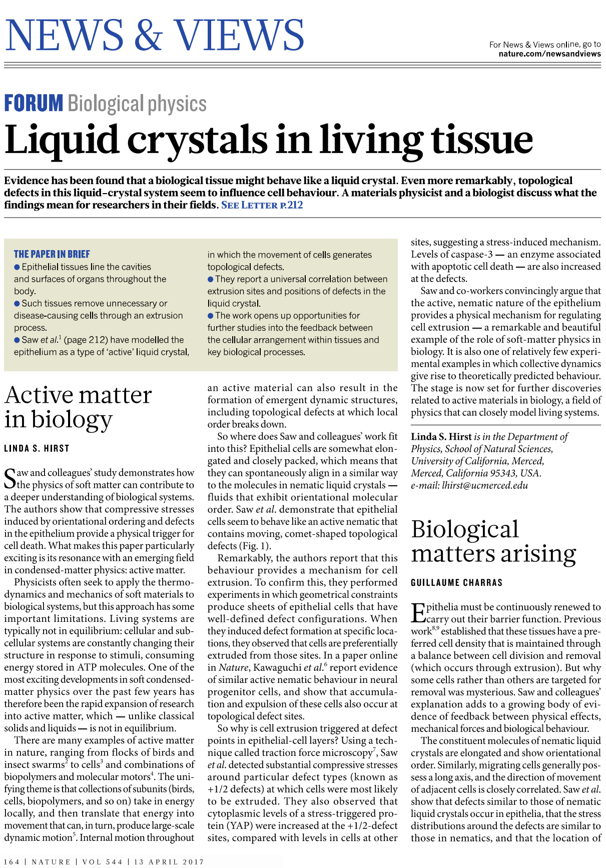
Alex Redinger

Ludger Wirtz

Soft and Living Matter

Emergence of function from complex molecular interactions

Nature, 13th April 2017



NEWS & VIEWS

For News & Views online, go to nature.com/newsandviews

FORUM Biological physics

Liquid crystals in living tissue

Evidence has been found that a biological tissue might behave like a liquid crystal. Even more remarkably, topological defects in this liquid–crystal system seem to influence cell behaviour. A materials physicist and a biologist discuss what the findings mean for researchers in their fields. SEE LETTER P.212

THE PAPER IN BRIEF

- Epithelial tissues line the cavities and surfaces of organs throughout the body.
- Such tissues remove unnecessary or disease-causing cells through an extrusion process.
- Saw *et al.*[1] (page 212) have modelled the epithelium as a type of 'active' liquid crystal, in which the movement of cells generates topological defects.
- They report a universal correlation between extrusion sites and positions of defects in the liquid crystal.
- The work opens up opportunities for further studies into the feedback between the cellular arrangement within tissues and key biological processes.

Active matter in biology

LINDA S. HIRST

Saw and colleagues' study demonstrates how the physics of soft matter can contribute to a deeper understanding of biological systems. The authors show that compressive stresses induced by orientational ordering and defects in the epithelium provide a physical trigger for cell death. What makes this paper particularly exciting is its resonance with an emerging field in condensed-matter physics: active matter.

Physicists often seek to apply the thermodynamics and mechanics of soft materials to biological systems, but this approach has some important limitations. Living systems are typically not in equilibrium: cellular and subcellular systems are constantly changing their structure in response to stimuli, consuming energy stored in ATP molecules. One of the most exciting developments in soft condensed-matter physics over the past few years has therefore been the rapid expansion of research into active matter, which — unlike classical solids and liquids — is not in equilibrium.

There are many examples of active matter in nature, ranging from flocks of birds and insect swarms[2] to cells[3] and combinations of biopolymers and molecular motors[4]. The unifying theme is that collections of subunits (birds, cells, biopolymers, and so on) take in energy locally, and then translate that energy into movement that can, in turn, produce large-scale dynamic motion[5]. Internal motion throughout an active material can also result in the formation of emergent dynamic structures, including topological defects at which local order breaks down.

So where does Saw and colleagues' work fit into this? Epithelial cells are somewhat elongated and closely packed, which means that they can spontaneously align in a similar way to the molecules in nematic liquid crystals — fluids that exhibit orientational molecular order. Saw *et al.* demonstrate that epithelial cells seem to behave like an active nematic that contains moving, comet-shaped topological defects (Fig. 1).

Remarkably, the authors report that this behaviour provides a mechanism for cell extrusion. To confirm this, they performed experiments in which geometrical constraints produce sheets of epithelial cells that have well-defined defect configurations. When they induced defect formation at specific locations, they observed that cells are preferentially extruded from those sites. In a paper online in *Nature*, Kawaguchi *et al.*[6] report evidence of similar active nematic behaviour in neural progenitor cells, and show that accumulation and expulsion of these cells also occur at topological defect sites.

So why is cell extrusion triggered at defect points in epithelial-cell layers? Using a technique called traction force microscopy[7], Saw *et al.* detected substantial compressive stresses around particular defect types (known as +1/2 defects) at which cells were most likely to be extruded. They also observed that cytoplasmic levels of a stress-triggered protein (YAP) were increased at the +1/2-defect sites, compared with levels in cells at other sites, suggesting a stress-induced mechanism. Levels of caspase-3 — an enzyme associated with apoptotic cell death — are also increased at the defects.

Saw and co-workers convincingly argue that the active, nematic nature of the epithelium provides a physical mechanism for regulating cell extrusion — a remarkable and beautiful example of the role of soft-matter physics in biology. It is also one of relatively few experimental examples in which collective dynamics give rise to theoretically predicted behaviour. The stage is now set for further discoveries related to active materials in biology, a field of physics that can closely model living systems.

Linda S. Hirst *is in the Department of Physics, School of Natural Sciences, University of California, Merced, Merced, California 95343, USA.*
e-mail: lhirst@ucmerced.edu

Biological matters arising

GUILLAUME CHARRAS

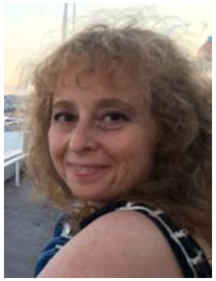
Epithelia must be continuously renewed to carry out their barrier function. Previous work[8,9] established that these tissues have a preferred cell density that is maintained through a balance between cell division and removal (which occurs through extrusion). But why some cells rather than others are targeted for removal was mysterious. Saw and colleagues' explanation adds to a growing body of evidence of feedback between physical effects, mechanical forces and biological behaviour.

The constituent molecules of nematic liquid crystals are elongated and show orientational order. Similarly, migrating cells generally possess a long axis, and the direction of movement of adjacent cells is closely correlated. Saw *et al.* show that defects similar to those of nematic liquid crystals occur in epithelia, that the stress distributions around the defects are similar to those in nematics, and that the location of

Massimiliano Esposito

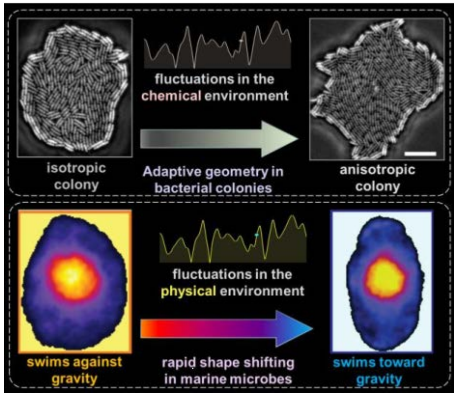
Alexandre Tkachenko

Roland Sanctuary



Giusy Scalia

Jan Lagerwall



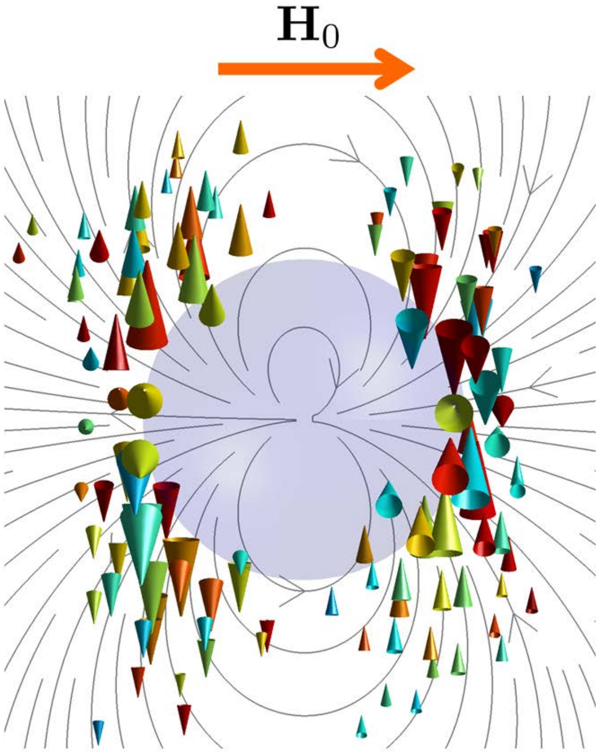
collaboration

LCSB

Magnetic and Multiferroic Materials

Andreas Michels

Jens Kreisel (affil. prof.)



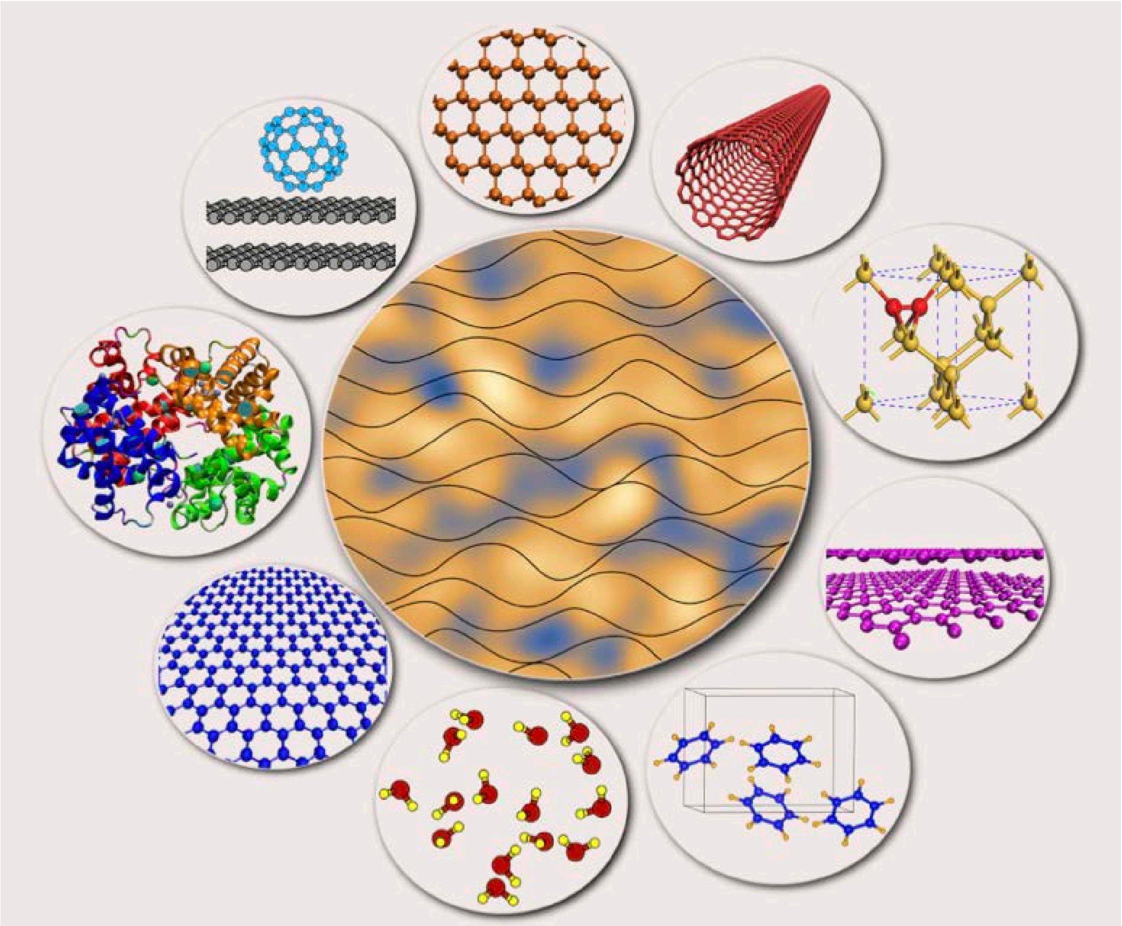
Theory and Materials Modelling

Thomas Schmidt

Ludger Wirtz

Alexandre Tkatchenko

Massimiliano Esposito



Times Higher Education ranking 2016/2017

- Position **178** among the 980 best universities in the world (195 in 2015)
- Position **14** among the 150 universities under 50 years of age in the world

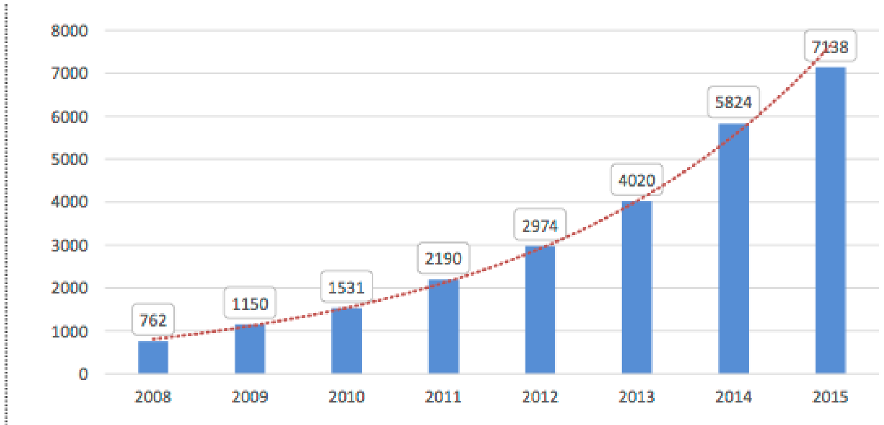
30% of ranking determined by citations
UL score in citations: 85.5 %

Publication Output

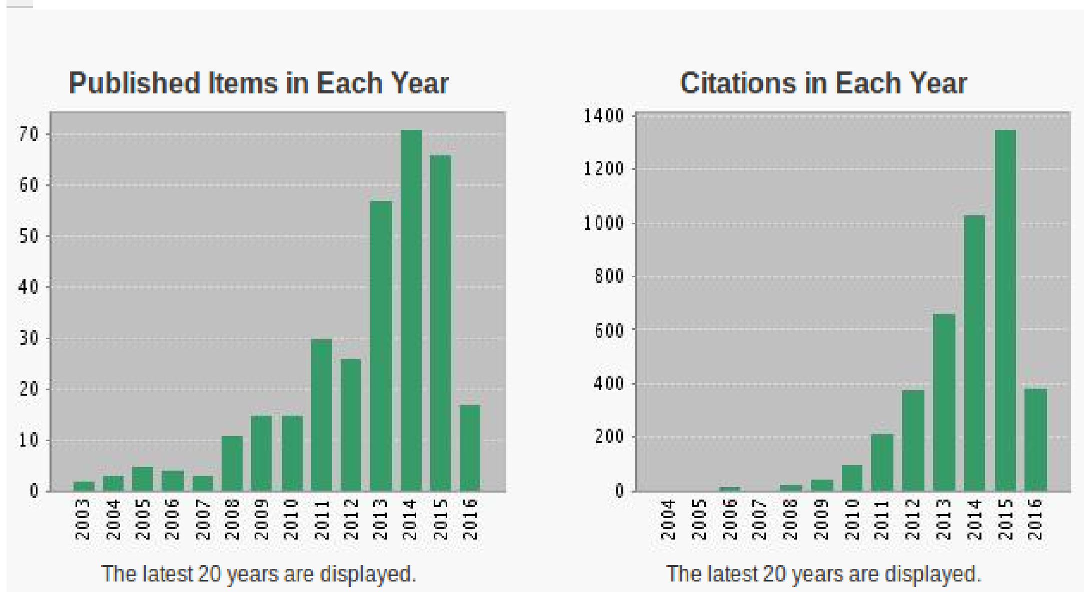
UNIVERSITÉ DU LUXEMBOURG

Citations per year,
whole university*
(240 PIs):
7100 citations in 2015

Number of citations - Web of Science



Publications and
citations per year,
RU PhyMS (10 PIs):
1400 citations in 2015



*UL report on KPI 2015

Mission

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Teaching & Training

UNIVERSITÉ DU LUXEMBOURG

- Teaching of full bachelor and master programmes
- Doctoral training
  - 34 (internal) PhD students
  - (Co)supervision of external PhD students (LIST, industry)
  - Establishing of doctoral school programme
  - PRIDE with 22 PhD students in collaboration with LIST
- Postdoctoral training

Mission

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Outreach activities

- Science festival
- Researcher's night
- Visits of school classes
- Newspaper and radio contributions
- Public evening lectures
- Scienteens lab

SCIENTEENS LAB
DE LABO FIR JONKER

Future Plans
Collaboration with MRT-LIST: current state

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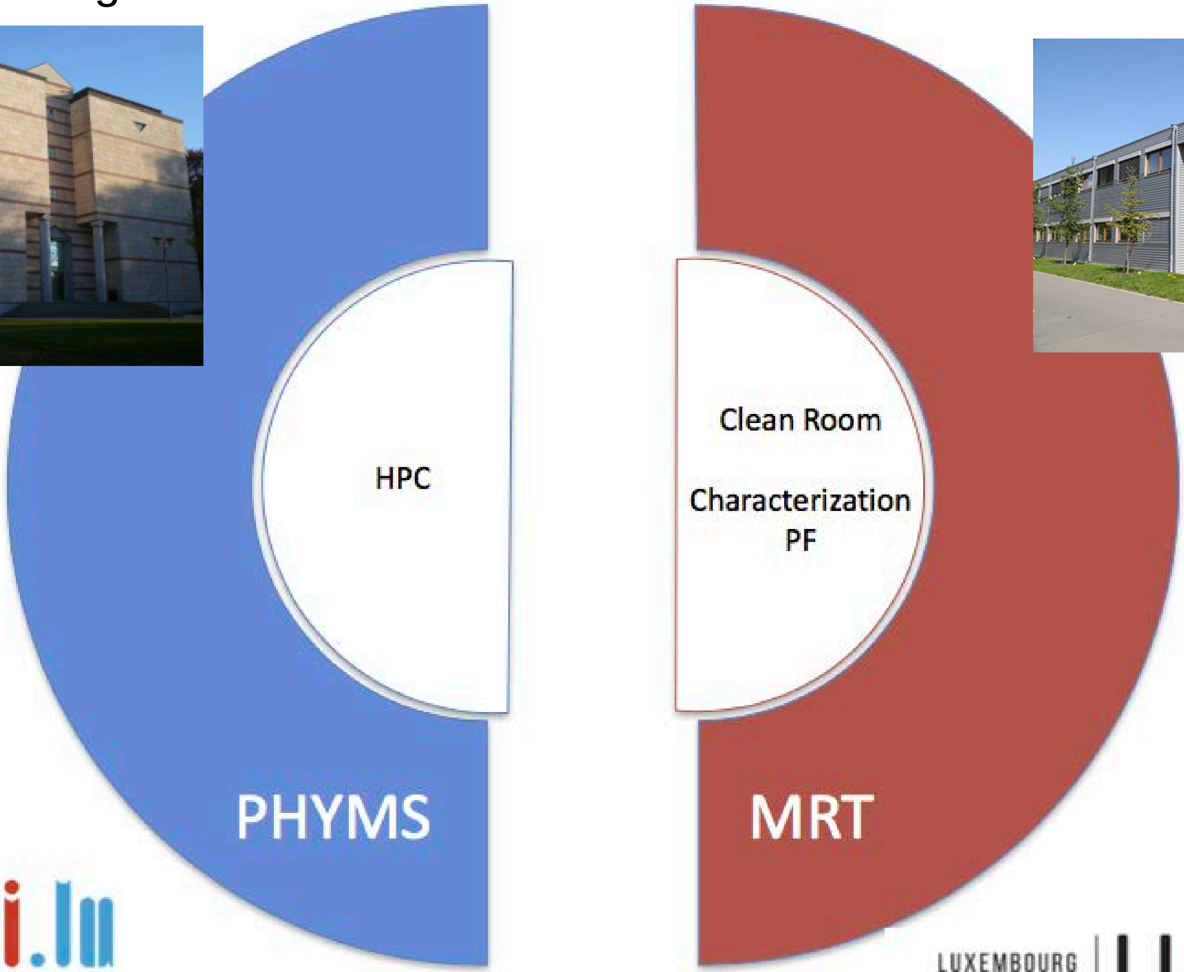
Limpertsberg

Belval



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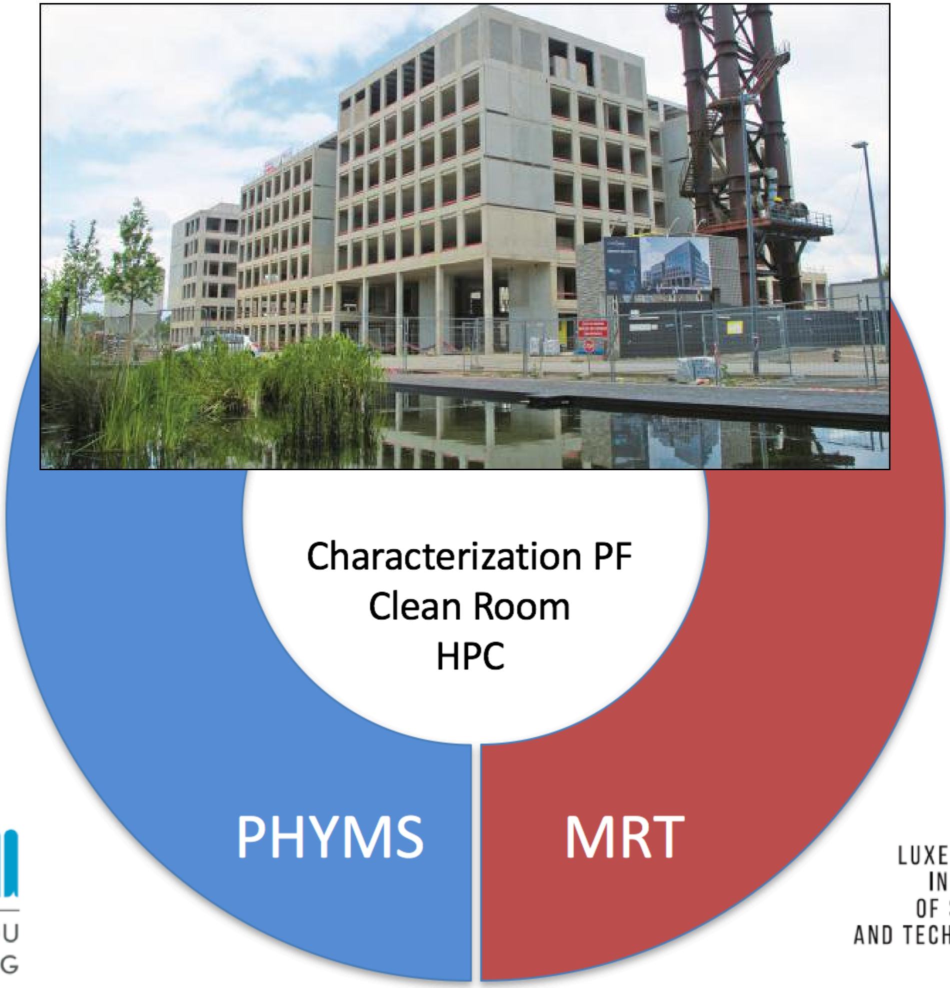
LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY

LIST

Future Plans
Collaboration with MRT-LIST: plans for joint research infrastructure

Belval:
Aile Nord- Aile Sud



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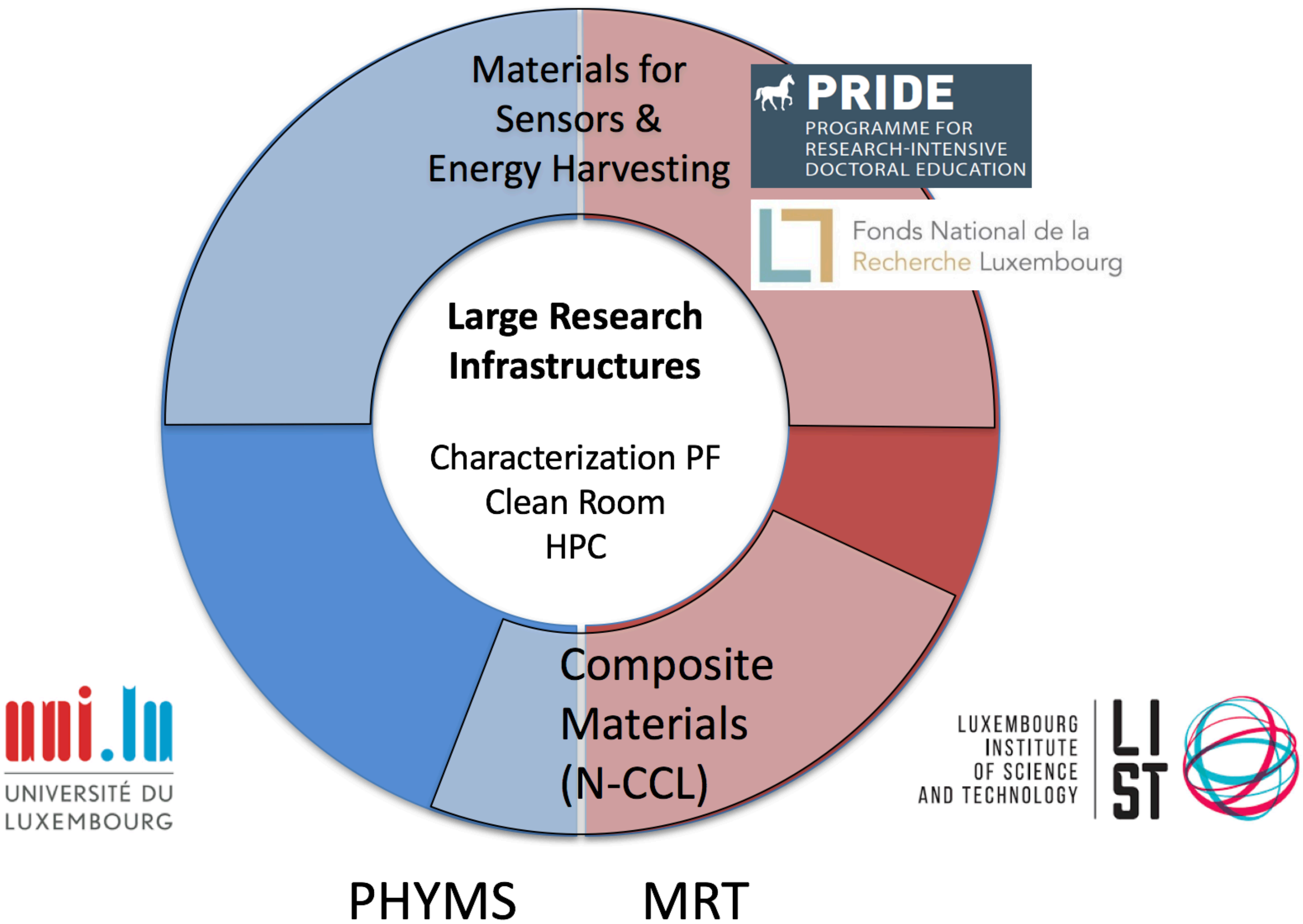
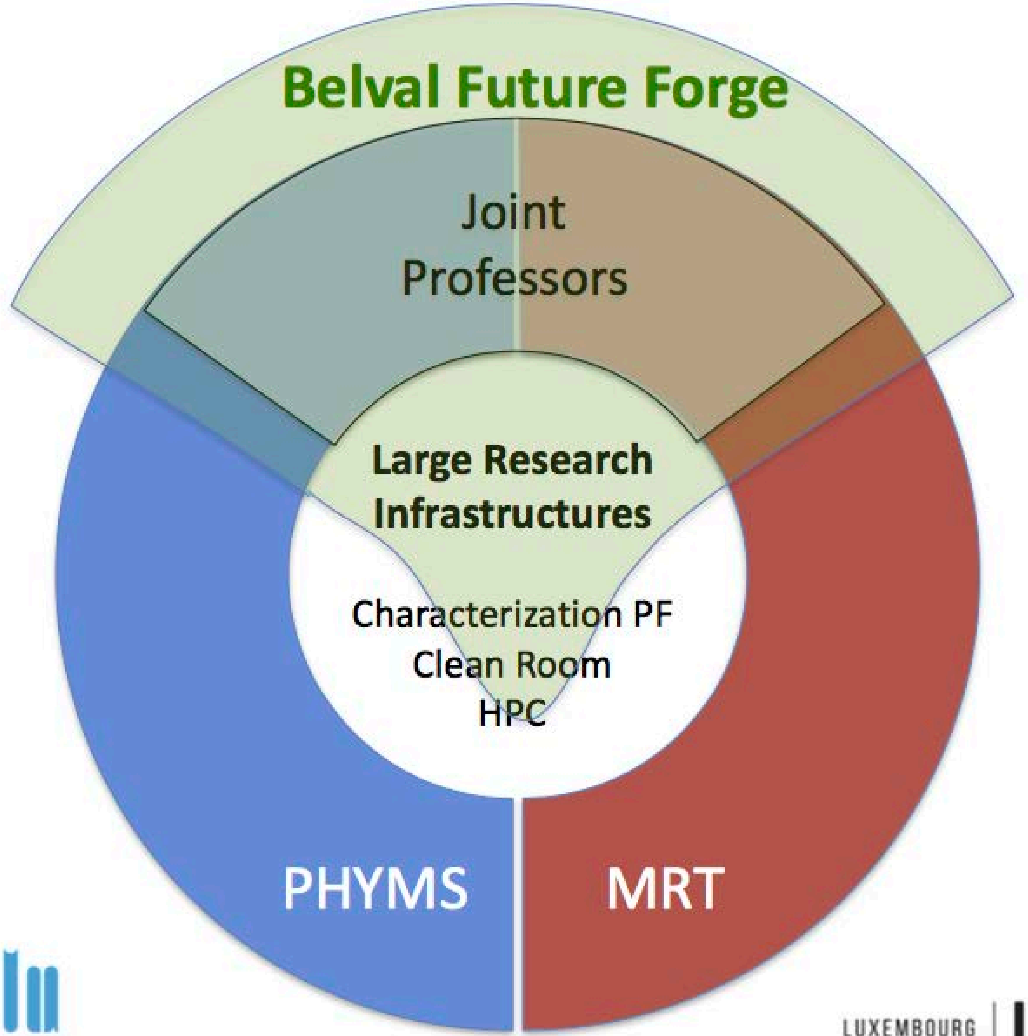
LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY

Future Plans
Collaboration with MRT-LIST: existing collaborations



Future Plans
Collaboration with MRT-LIST: plans for joint research infrastructure

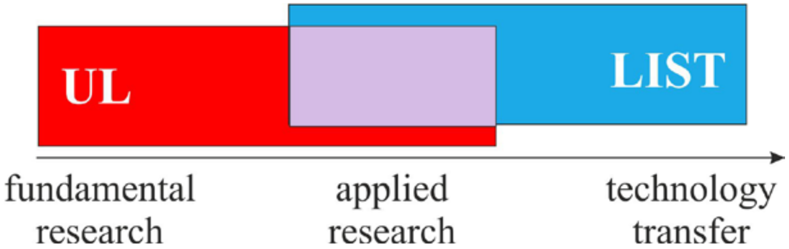


Belval Future Forge

Vision:

to establish Luxembourg as a hub for materials research, where the intellectual pleasure of understanding meets societal and industrial needs for novel materials and products.

- Activities of RU PHYMS and MRT-LIST complementary:



- Joint Technology Platform and shared computing facilities
- Joint professorships:
  - Atomic and electronic-structure analysis (spectroscopy)
  - Nano-Visualization (TEM, APT)

Finally

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Why Fundamental Research?

“Because of this fundamental reality, the university is being called upon to produce knowledge as never before – for civic and regional purposes, for national purposes, and even for no purpose at all beyond the realization that most knowledge eventually comes to serve mankind.”

Clark Kerr, The uses of the University, 1963