FAST determination of fatigue properties of MATerials beyond one billion cycles

N. Ranc, V. Favier, O. Castelnau, V. Michel, T. Ors

Procédés et Ingénierie en Mécanique et Matériaux
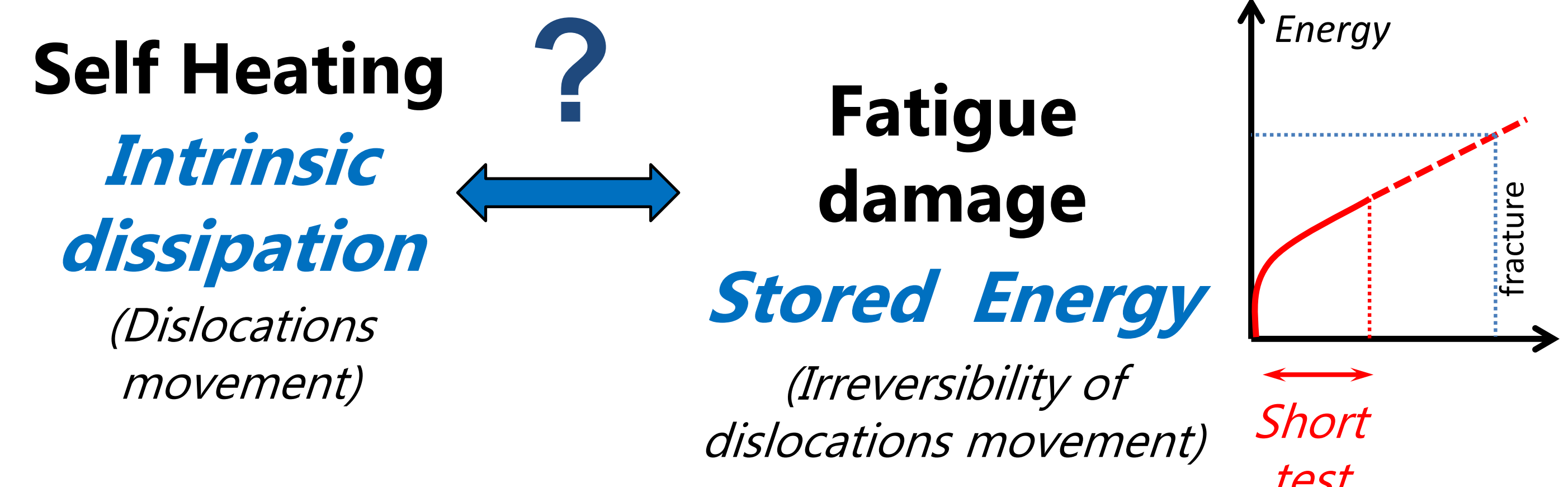
Fatigue of materials

- **80% of fractures** in transport and energy production industries are attributed to fatigue
- Increase of the lifespan: very high number of cycles
- Fatigue design: SN curve (Standards ISO12107, ASTM-E739…)
- Limitations:
  - More than one month to draw a SN curve until 10^7 cycles; **3 years** for one billion cycles (10Hz)
  - Difficulties to explore the fatigue behavior beyond 10^7 (VHCF domain)

Stress amplitude [MPa] vs *Number of cycles*: High Cycle Fatigue domain / Very High Cycle Fatigue domain
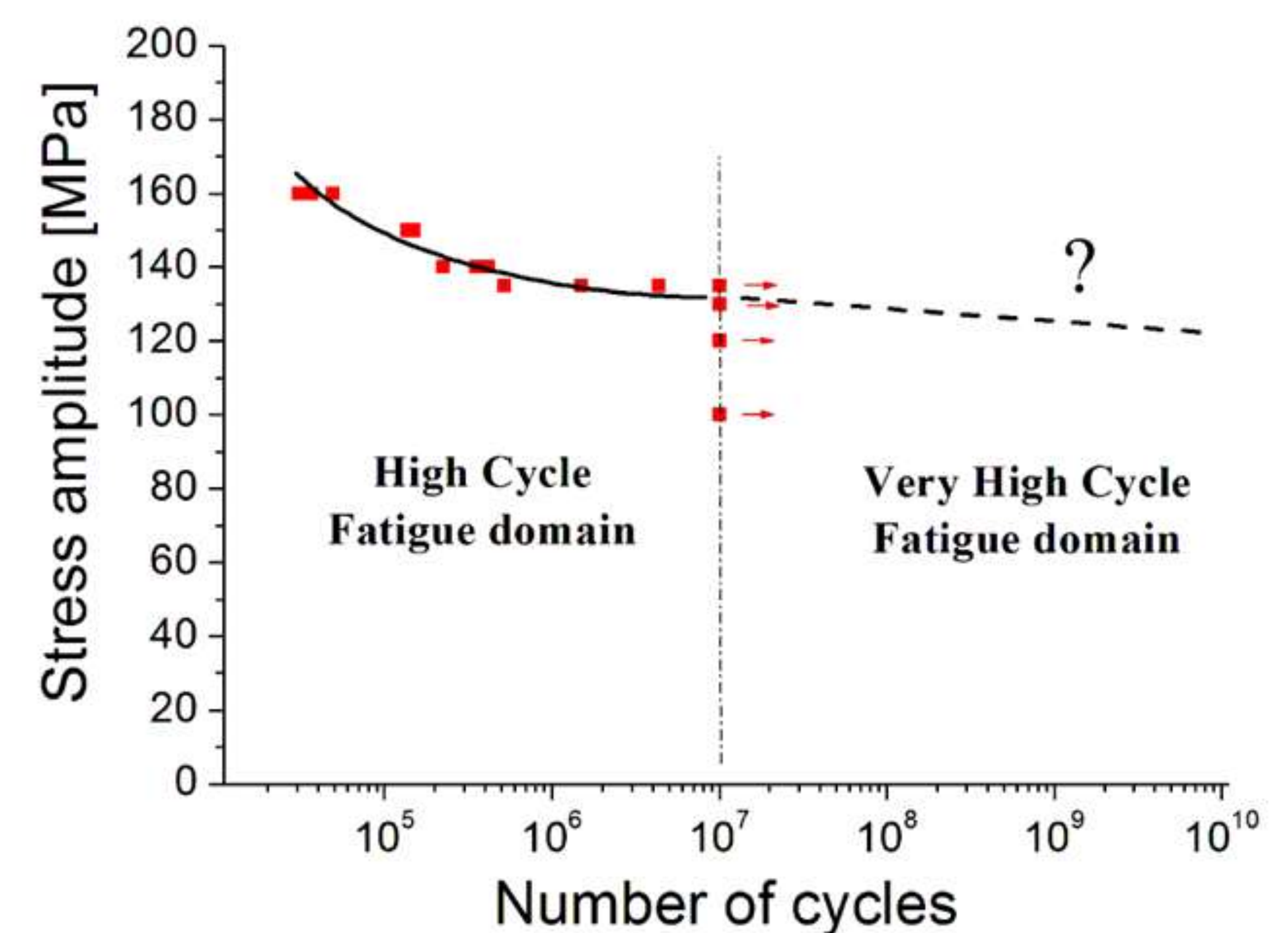
Objectives of FastMat project

- Technological challenges
  - Testing time reduction
  - Exploring the VHCF domain
- Focus on metallic materials
- Develop a new method for fatigue design:
  Short interrupted fatigue tests
  + Self heating measurement

Main scientific difficulties

Self Heating
Intrinsic dissipation
(Dislocations movement)

?

Fatigue damage
Stored Energy
(Irreversibility of dislocations movement)

Stored Energy / fracture / *Short test*

Methodology adopted in the Fast Mat

Experimental study

Temperature *(thermography)* → **Intrinsic Dissipation** D_{int} *(heat equation)*

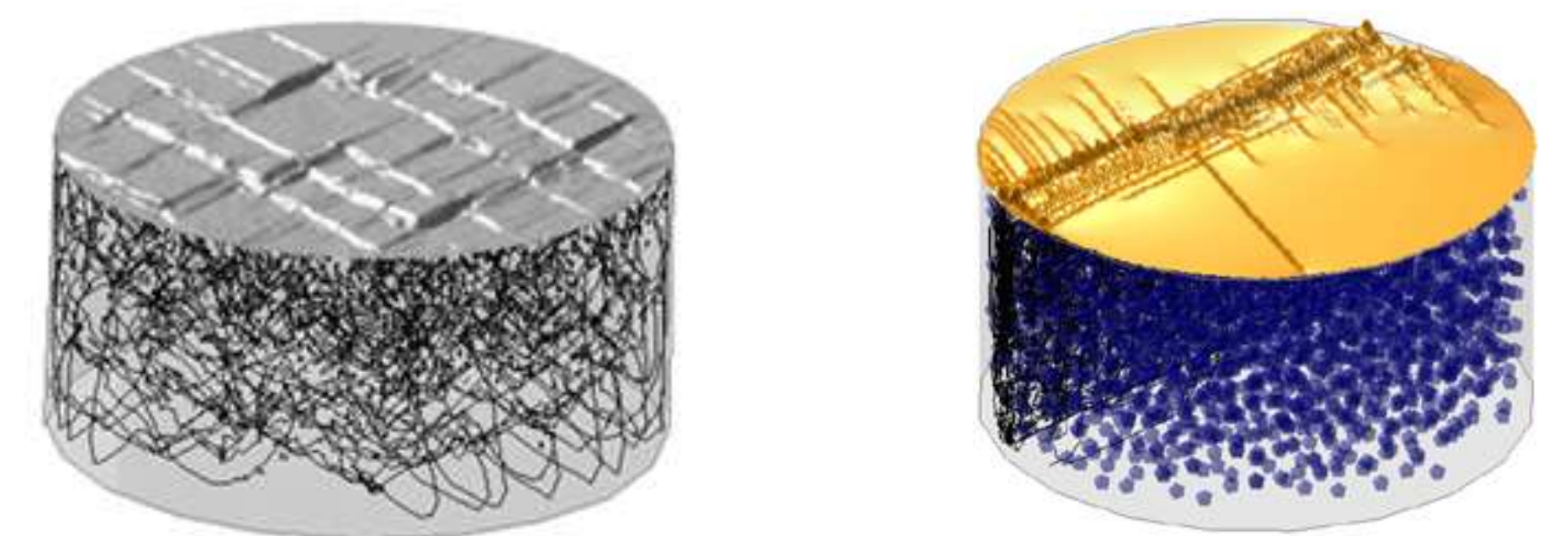**Stress, strain** *(XRD, gages)* → **Mechanical work** $(W = \int_{cycle} \sigma \dot{\varepsilon} dt)$

NOVELTY: time resolved XRD using intense X ray sources
- Improve the time resolution (time shift: 10ns):
  - Continuous method (1µs)
  - Flash method (0.1ns)

TEAM & facilities: *1PhD, 1 Engineer, 1 post doc, SOLEIL synchrotron*

Modelling at the dislocations scale

DDD simulations

Thermal signature ↔ **Fatigue mechanisms**

NOVELTY
- Cyclic irreversibility: cross slip
- Stored energy and dissipation output
- Time integration (1000 cycles)

TEAM & facilities: *joint PhD, TRIDIS DDD code*

Stored energy
Energy balance
$(E_s = W - D_{int})$

Help to interpret the experimental results

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pimm-contact@ensam.eu
http://pimm.ensam.eu/