

A New Generation of Trapped Atom Interferometers

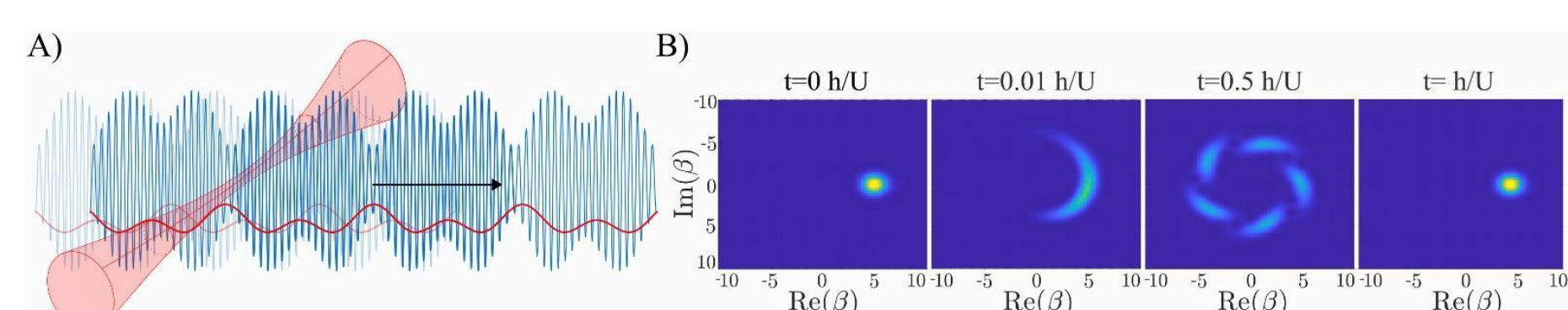
INTEGRA will develop quantum sensors that hold and manipulate atomic matter waves in tailored light fields. Trapping removes the short interrogation times and limited spatial resolution imposed by free fall. Five European partners will combine optically painted and shaken lattices, optimal control, cavity-enhanced trapping and quantum correlations to create long-lived, widely separated superpositions. The project targets compact sensors for force microscopy, gravimetry and inertial sensing, together with new tools for fundamental physics.

Core challenge Large separation and long coherence in compact sensors

Target coherence time **> 1 min** Target mode separation **≥ mm** Force-mapping resolution **sub-μm**

Four complementary experimental routes

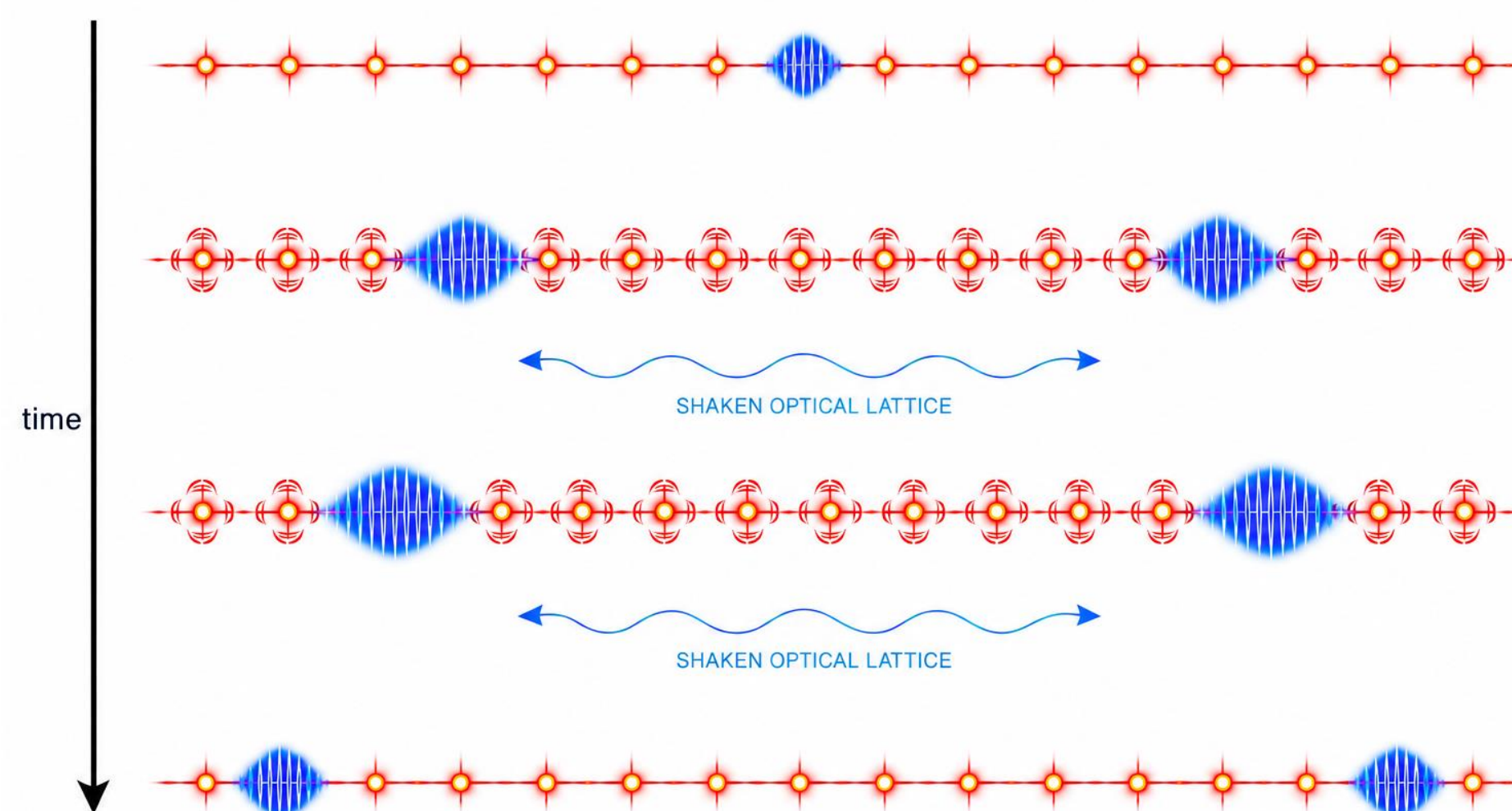
LENS | High-resolution force sensing



The possibility to perform **sub-micron force mapping** with arrays of double-well interferometers will be explored. Simultaneous operation of several interferometers will allow to cancel common mode fluctuations of the trapping potential.

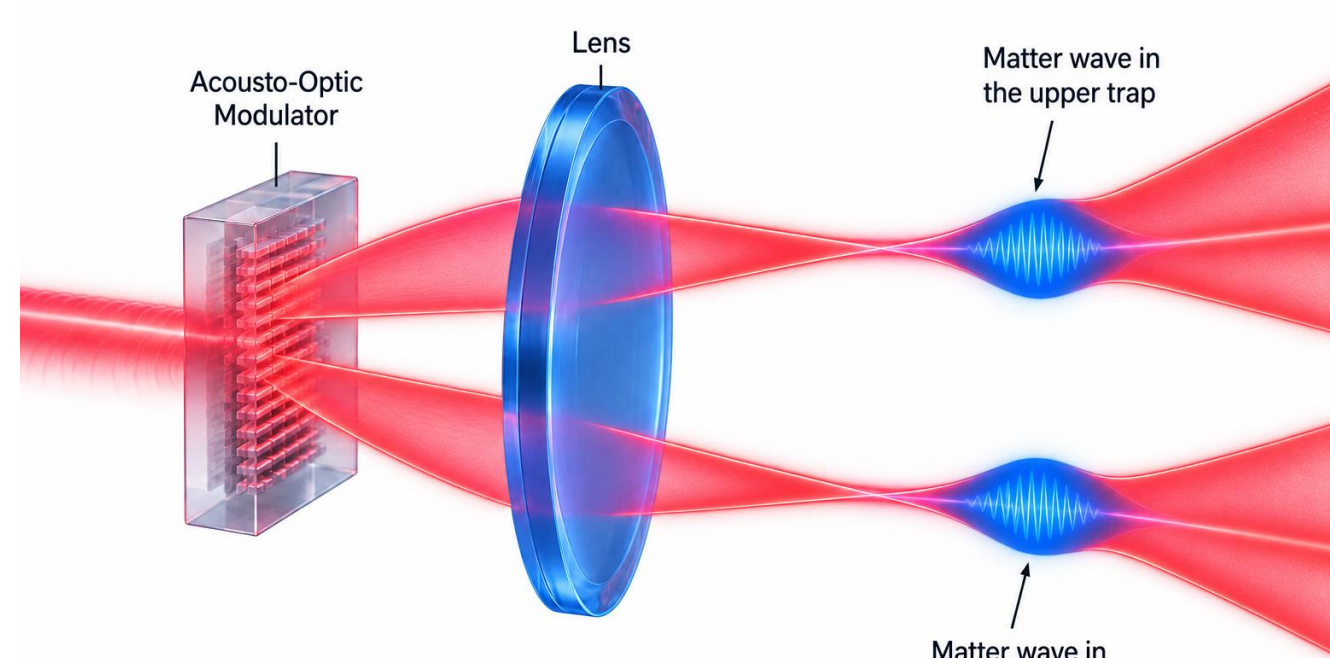
Study of the phenomenon of collapse and revival of coherence in interacting ³⁹K BECs with few hundreds atoms. This will allow the production of highly entangled states and atom interferometry with non magnetic atoms with residual inter-particle interactions.

LTE | Shaken-lattice inertial sensing



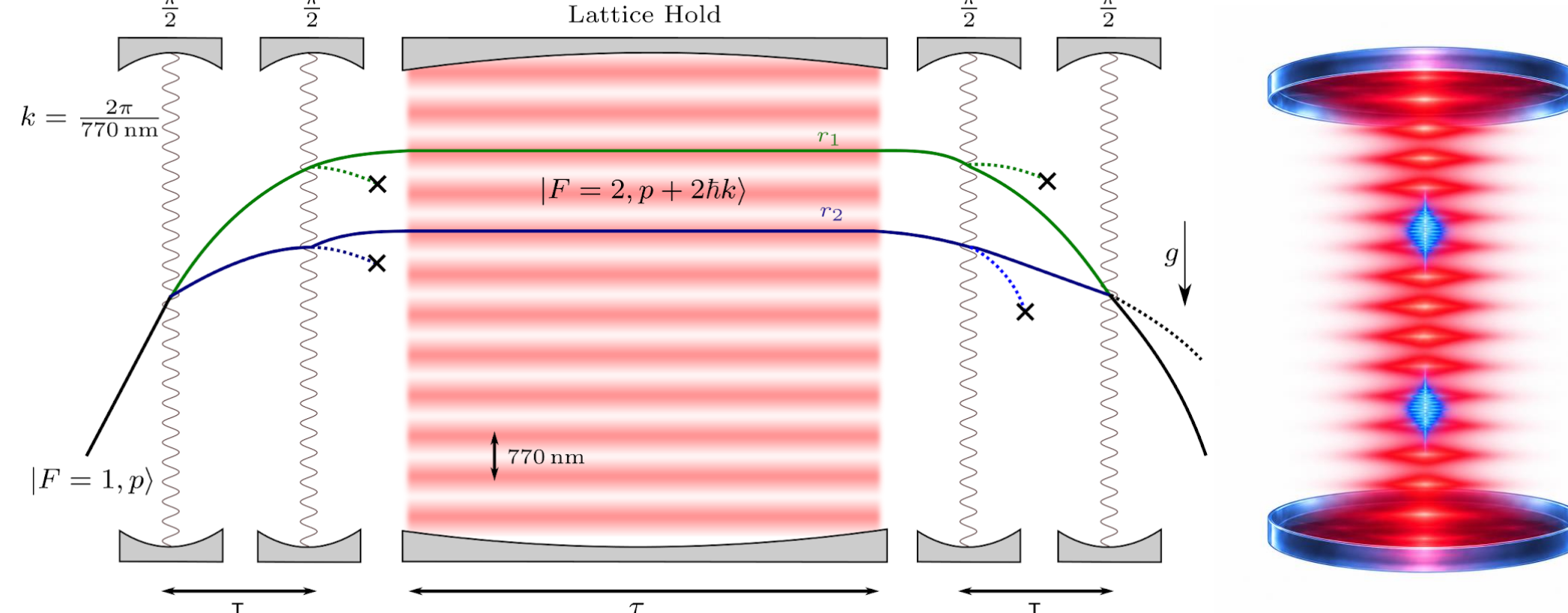
Optimal-control splitting, reflection and recombination in **shaken lattices**. **Differential gradiometry** for common-mode noise rejection. Both horizontal and vertical configurations will be explored.

LUH | Large-separation painted potentials



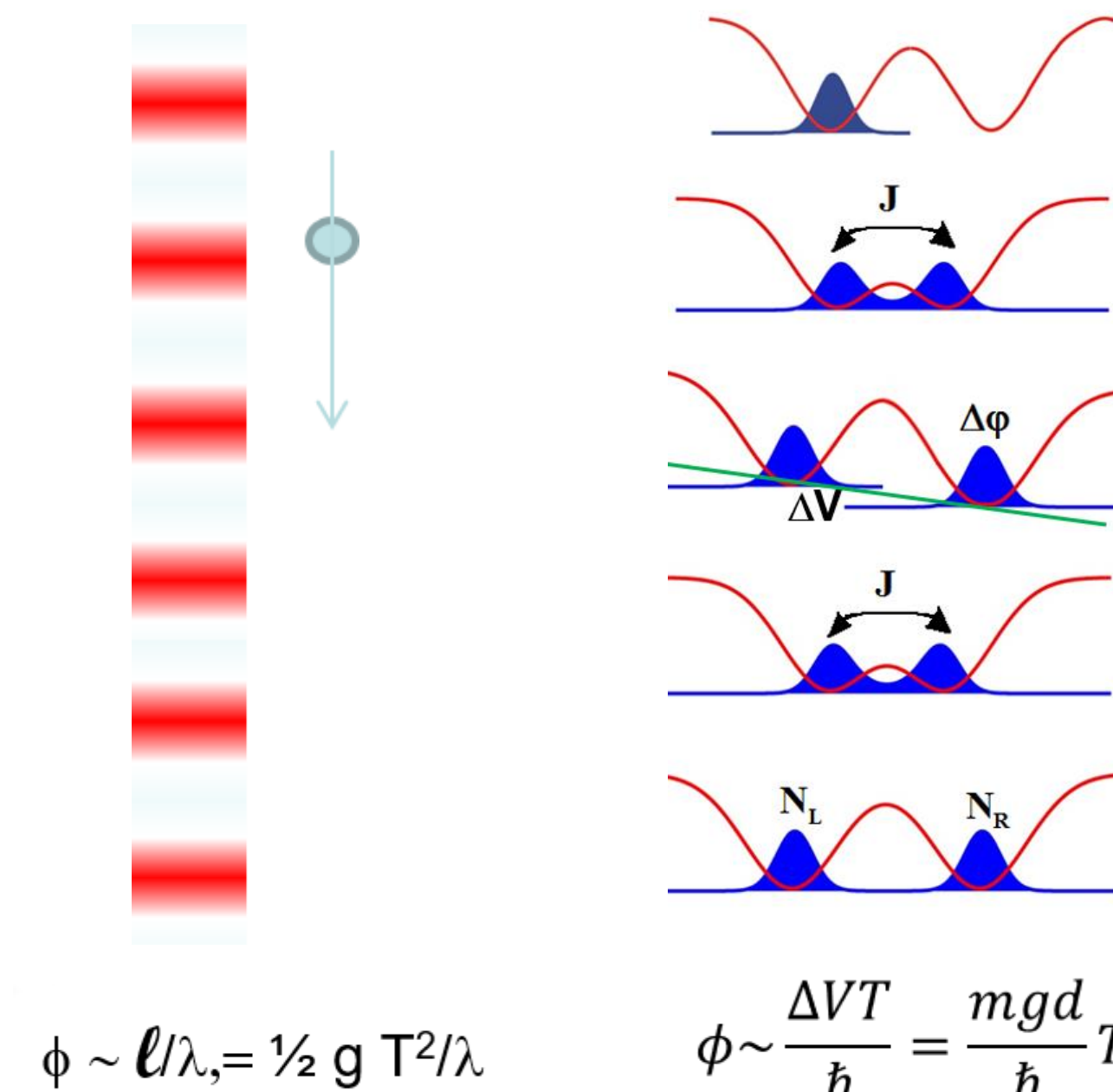
Fast coherent splitting with **reconfigurable optical potentials**
Target separation: **hundreds of micrometres** for high-bandwidth operation

TUW | Cavity-enhanced gravimetry



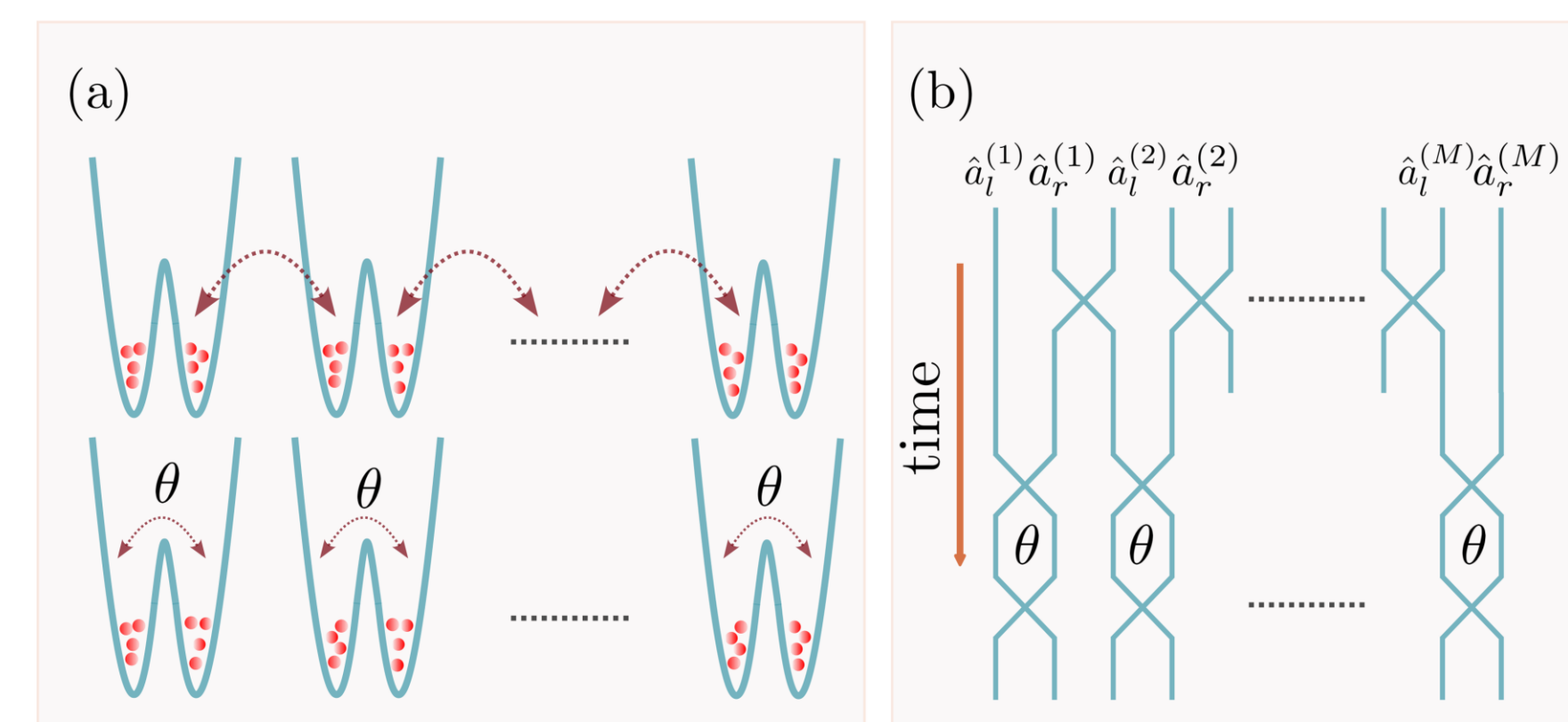
Vertical ³⁹K interferometer inside a **high-finesse cavity**
Cleaner optical modes for long hold times and **stable gravity measurements**

Free falling vs Trapped Atom Interferometers



Theory and metrology

WU + consortium theory teams



Multimode interferometry beyond the standard two-mode picture

Quantum correlations across **sensor arrays**
Bayesian estimation of differential phase and dephasing

Create correlations between different sensors with two methods:

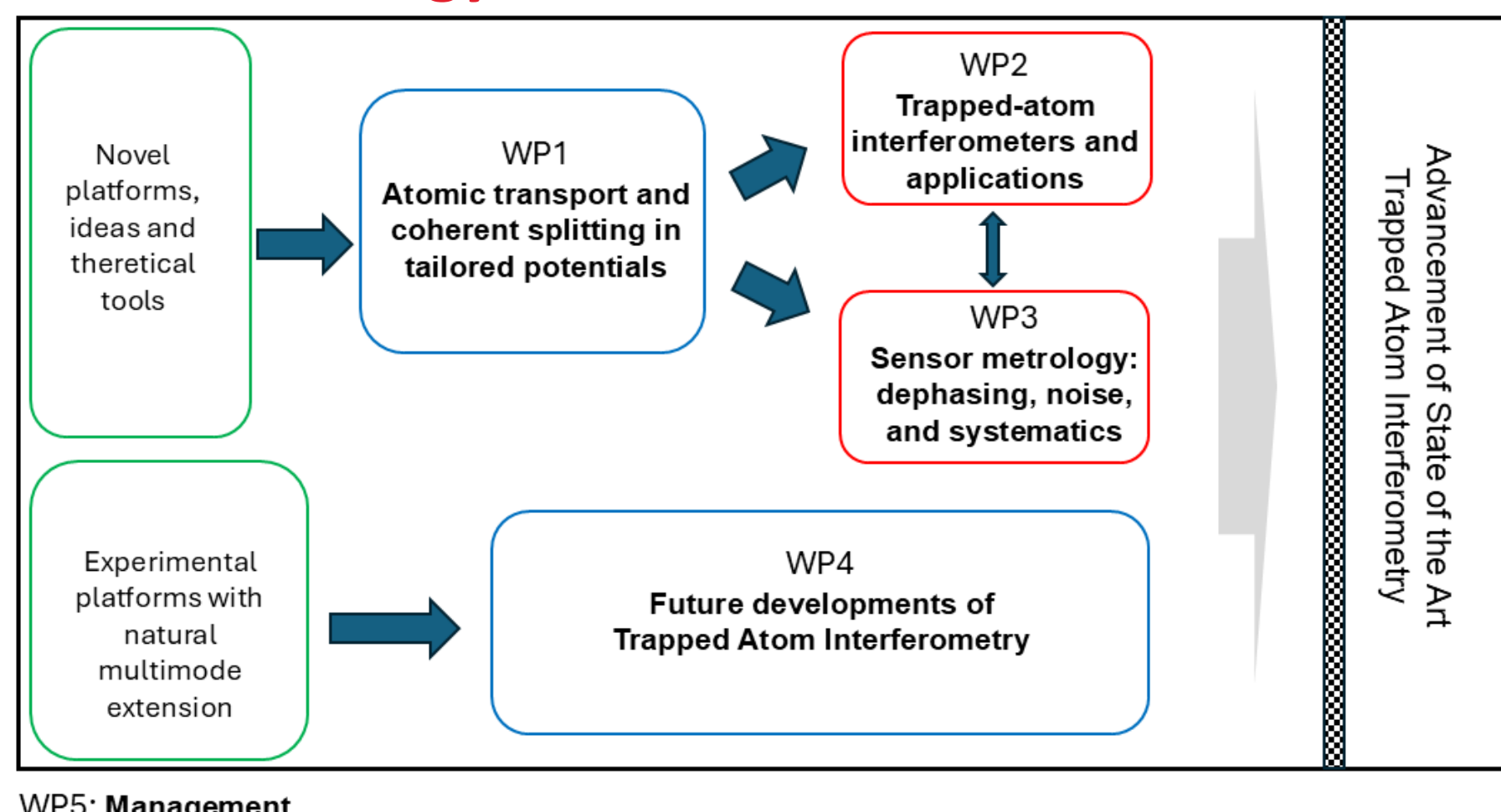
- Long range interactions between the modes, ex. Long range dipolar interactions
- Tunable barriers between the modes of each interferometer and between the different interferometers

Entangled gradiometers beyond the standard quantum limit
Chains of coupled interferometers for remote readout
Multimode protocols tailored to each experimental platform

MAIN TARGET

Sensing of the multiparameters with sensitivity beyond the shot noise

Shared strategy



Optimal control, tunable interactions and differential readout connect the four platforms and turn their complementary strengths into common design rules.

Expected impact

Scientific reach

Precision tests of atom–surface and short-range forces, long-lived macroscopic matter-wave superpositions, quantum-enhanced networks of atomic sensors

Applications

Compact gravimetry for geophysics and subsurface sensing, transportable inertial sensors for navigation, high-resolution field mapping near surfaces

Funding Information



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DFG Deutsche
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NATIONAL SCIENCE CENTRE
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FWF Austrian
Science Fund

anr[®] agence nationale
de la recherche

Selected references

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