

TeRaRy — Precision terahertz-radiation detection with Rydberg atoms

Towards single-photon sensitive GHz–THz detectors

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Motivation & objectives

Single-photon detectors are standard in the optical domain but remain elusive between **10 GHz and a few THz** [1]. Existing sensors are cryogenic, non-tunable and incompatible with high magnetic fields (TES, SNSPDs), or suffer from high dark counts (bolometers). **Rydberg atoms** offer strong, frequency-**tunable** GHz–THz transitions, **self-calibration**, no thermal population of the sensing states and strong, controllable **interactions**.

TeRaRy explores two complementary protocols towards single-photon sensitivity:

1. **avalanche amplification** of single absorption events
2. **interferometric detection** with Rydberg polaritons

Both protocols will be benchmarked against TES and SNSPDs.

Impact

- **Fundamental physics:** frequency-tunable detectors that work in cryogenic, high-field environments open new routes for axion and dark-matter searches — INFN brings the demanding end-user perspective [2].
- **Science & industry:** THz spectroscopy identifies polar molecules by their rotational fingerprints; applications in pollutant sensing, security screening, quality control and Earth observation.

- **From lab to market:** the SME partner **Lytid** anchors TeRaRy in the THz industry — market study, technology watch and exploitation plan, with Lytid THz sources as the reference for detector benchmarking.
- **Quantum technology:** a new application line for neutral-atom quantum-computing hardware, bridging quantum computing and quantum sensing.

Avalanche amplification

A single absorbed THz photon unleashes the strong Rydberg interactions and triggers an easily detectable **excitation cascade** [3]. The cascade amplifies the signal and imprints characteristic correlations that suppress read-out noise. The avalanche — a limitation for Rydberg quantum computing — is turned into a resource.

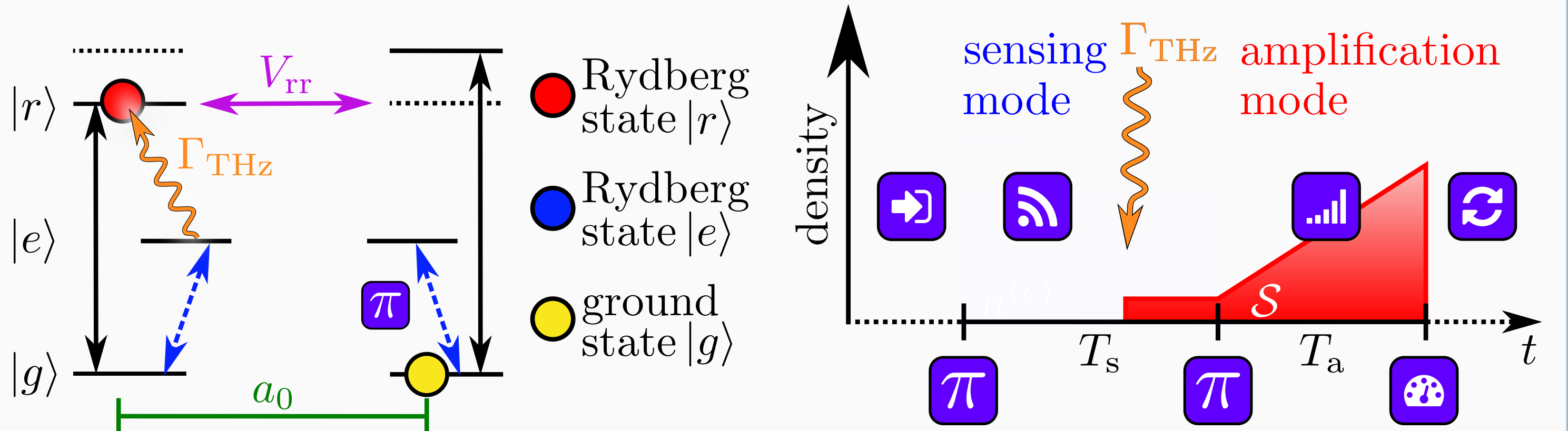


Figure 1: Level scheme. An absorbed THz photon (Γ_{THz}) swaps $|e\rangle \rightarrow |r\rangle$; a second laser biases the detector at detuning V_r to $|r\rangle$.
Figure 2: Protocol: preparation, sensing mode after a π -pulse, amplification mode after a second π -pulse, read-out.

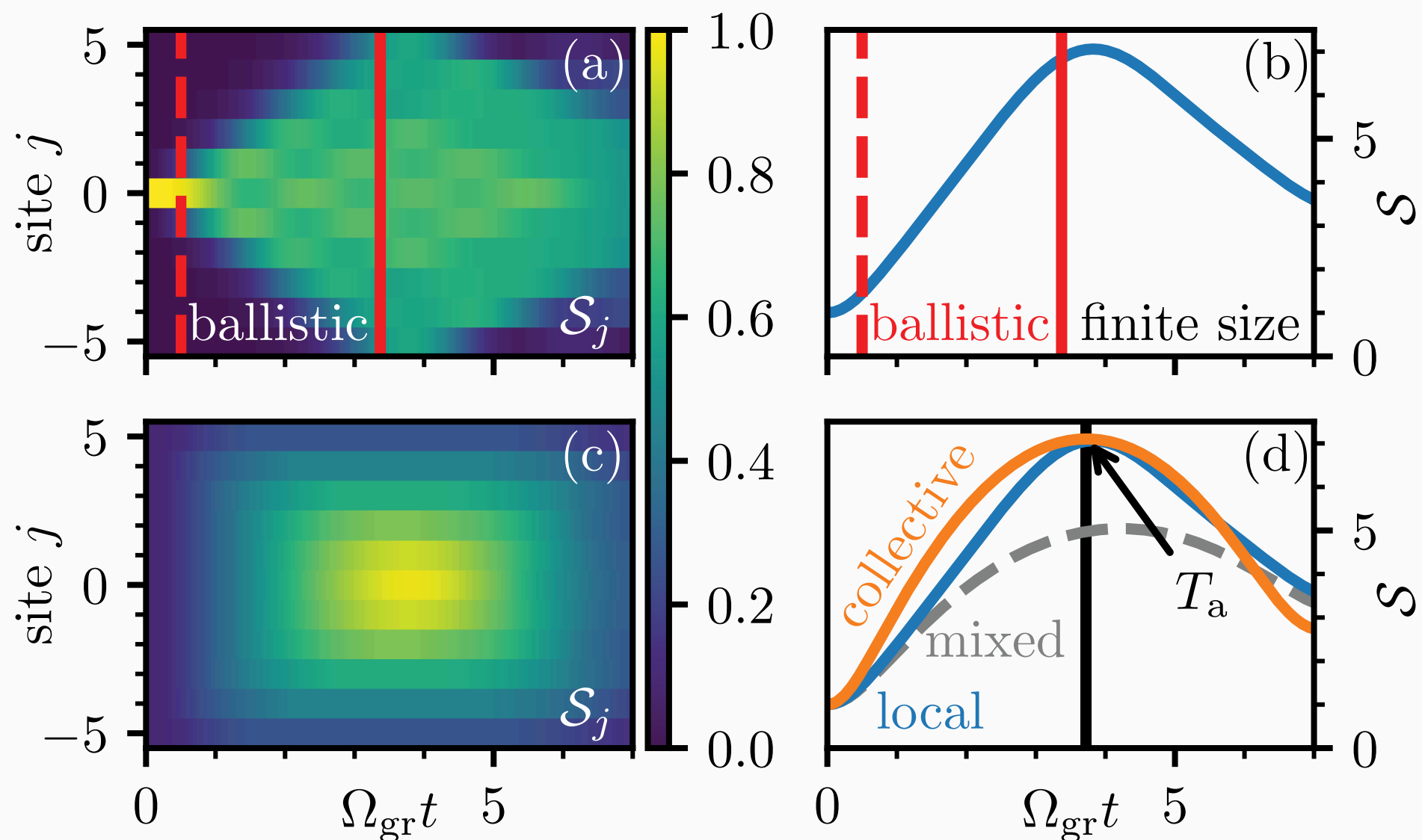


Figure 3: Simulated avalanche in a 1D tweezer array: ballistic growth of the signal until the finite system size is reached [3].

Two avalanche platforms

Tübingen — tweezer arrays. Hundreds of single K atoms with full microscopic control and single-atom read-out [4]: extract interaction parameters, access correlations, compare quantitatively with theory.

Pisa — dense cold clouds. Rb in an optical dipole trap with high optical density for efficient photon absorption, random atom positions and minimal technical overhead [5].

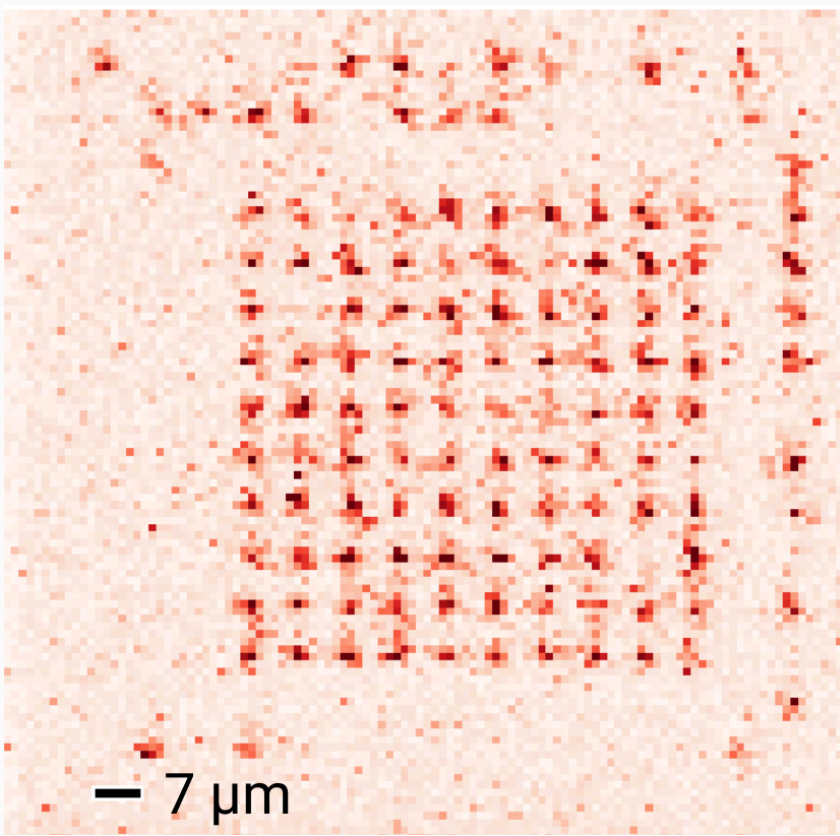


Figure 4: Sorted 10 × 10 array of single K atoms (single shot).

Interferometric detection

Durham — Rydberg polaritons. About 1000 ultracold Rb atoms store a single optical photon as a **Rydberg polariton** [6]. The THz field drives it to a second Rydberg state, read out interferometrically [7] — 10^4 measurements every 20 ms.

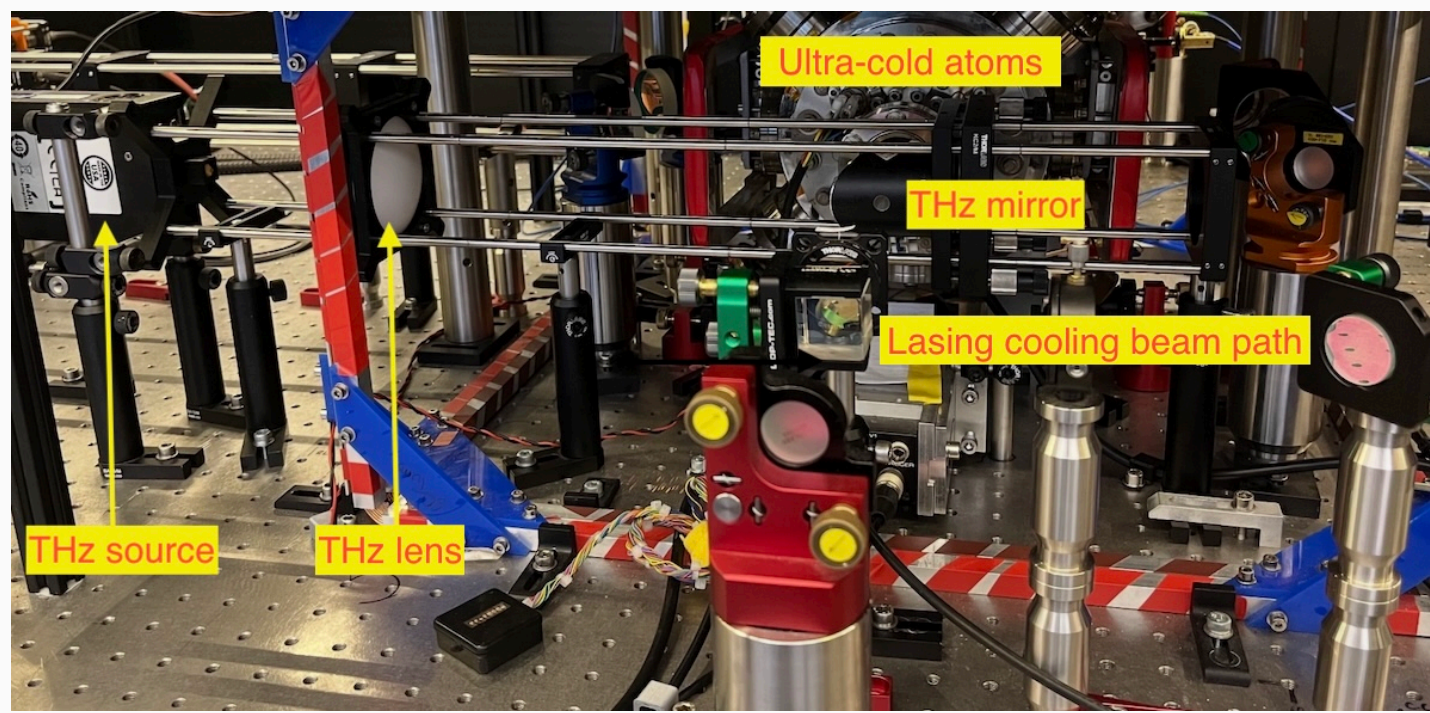


Figure 5: Durham platform: THz source and optics around the ultracold atoms.

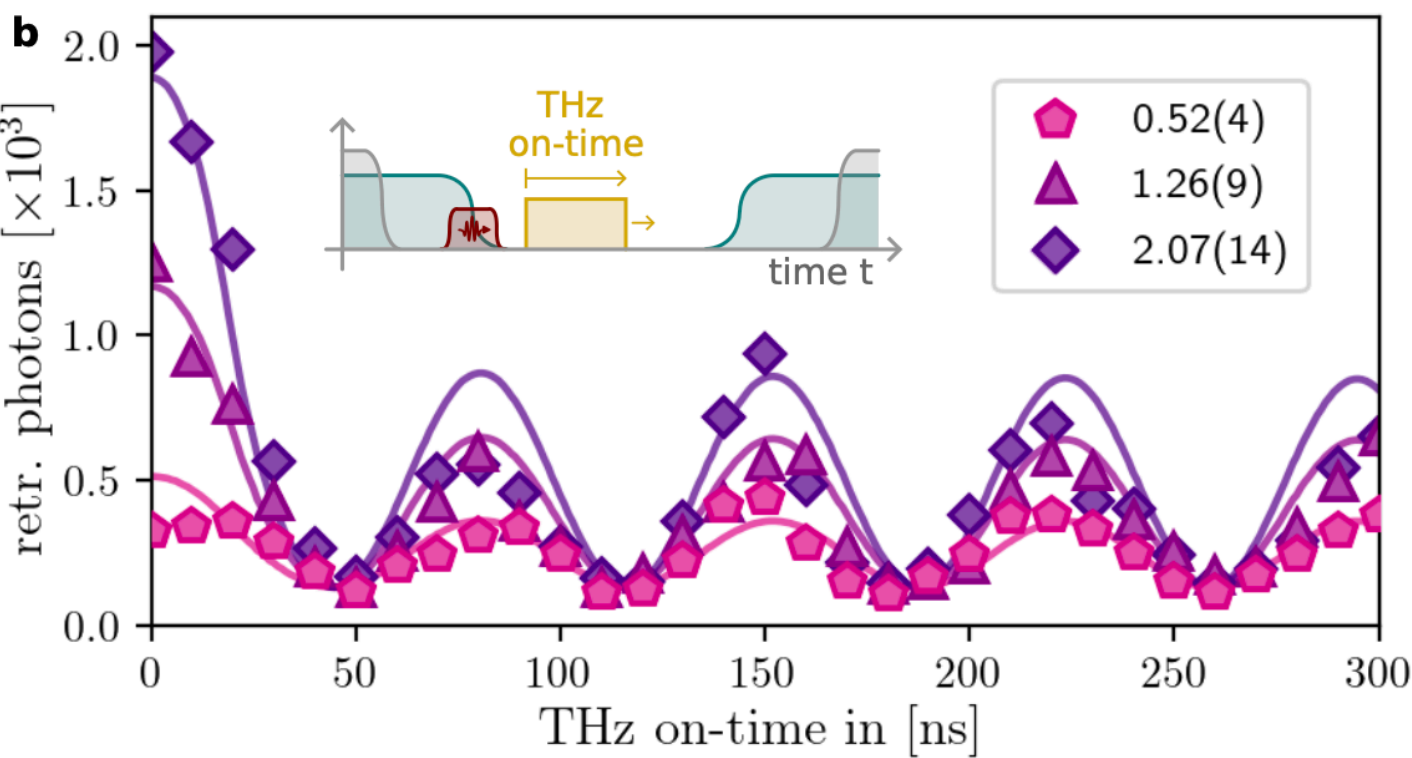
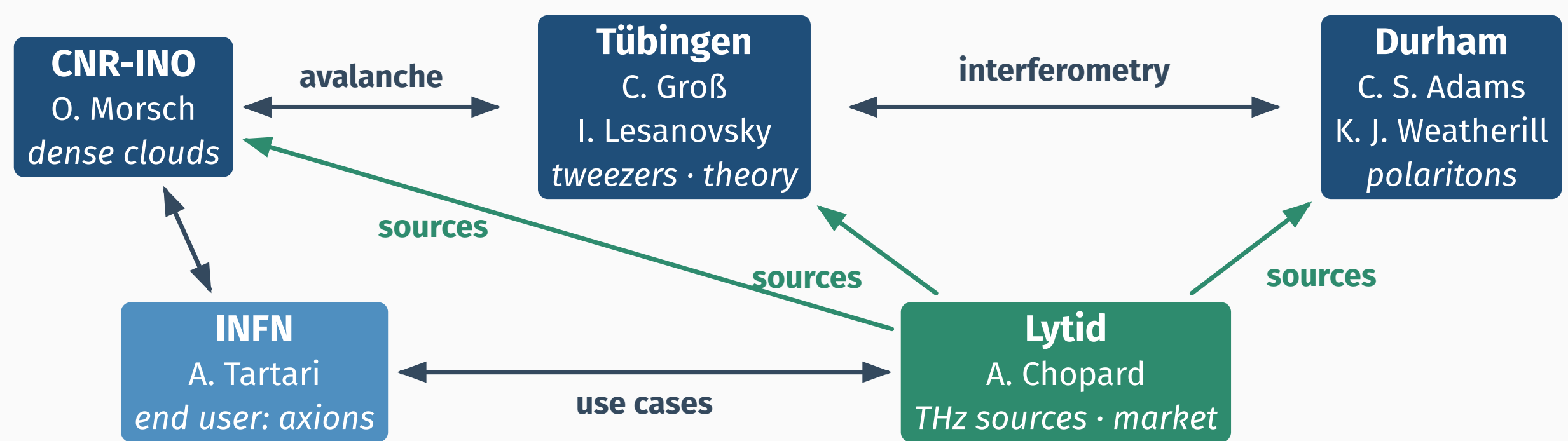


Figure 6: THz-driven Rabi oscillations between two Rydberg states.

THz sources & benchmarking

Lytid — THz sources and market. Tailored THz sources for all three experiments; benchmarking of noise-equivalent power, dark counts and response time against TES and SNSPDs.

Consortium



References

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