Random search for a dark resonance

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At a glance
Quantum systems can act as sensitive probes and field sensors [1], and the paradigm question in such applications concerns the scaling of the sensing error with the number of physical resources.

Search protocol
As an alternative to a systematic scanning and accumulation of signal at different, discrete laser frequencies, we suggest a random search protocol (Fig. 1) in which the probe laser frequency may come arbitrarily close to the dark resonance. That event is witnessed by the complete absence of signal and suggests the following adaptive protocol for the duration $T$ of the experiment:

- Far from resonance, the probability for an early photon detection and a shift to a different frequency is high, while close to resonance, the photon emission rate is very small, and these frequencies are maintained for a long time.
- The longer we probe the atom, the more likely are long intervals with frequencies close to the dark resonance.
- The instantaneous, stochastically tuned laser frequency thus constitutes a good estimate of the atomic transition frequency.

Simple random walk with a break at time $T$.

Setup

**Fig. 1:** Driven A-type three-level system subject to photo detection.

**Fig. 2:** Fluorescence rate as a function of detuning from dark resonance.

**Fig. 3:** Simulation of continuous monitoring and random frequency jumps.

**Fig. 4:** Proportion of trajectories with $|\delta|<\delta_0$ as a function of time.

**Fig. 5:** Asymptotic frequency distribution: Blue area (95%–98.2%) have $|\delta|<\delta_0$.

**Fig. 6:** Comparison of information per time to systematic frequency scan as a function of search width $\delta_0$.

**References**