

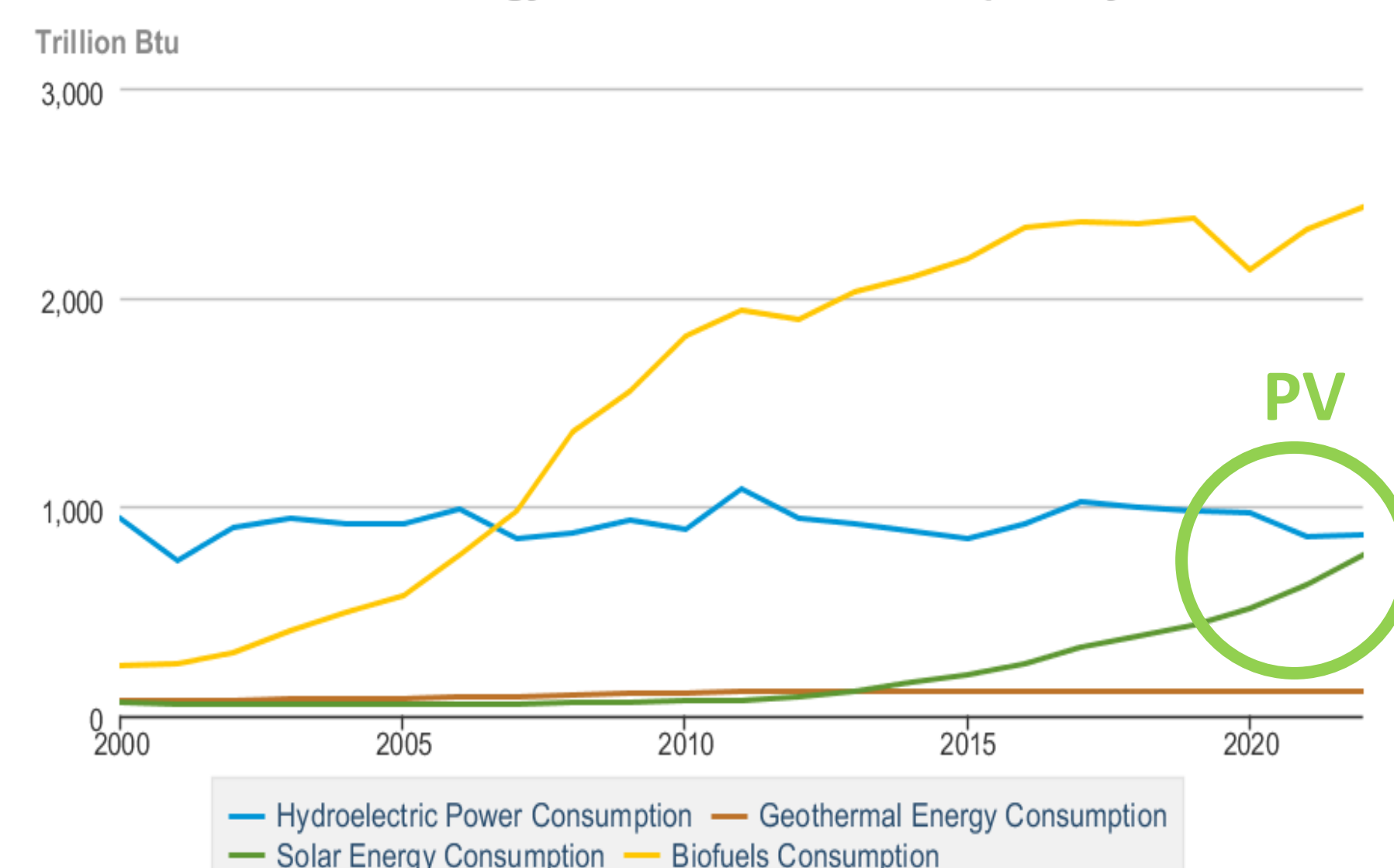
Dynamic calibration of the injection-dependent carrier lifetime in GaAs

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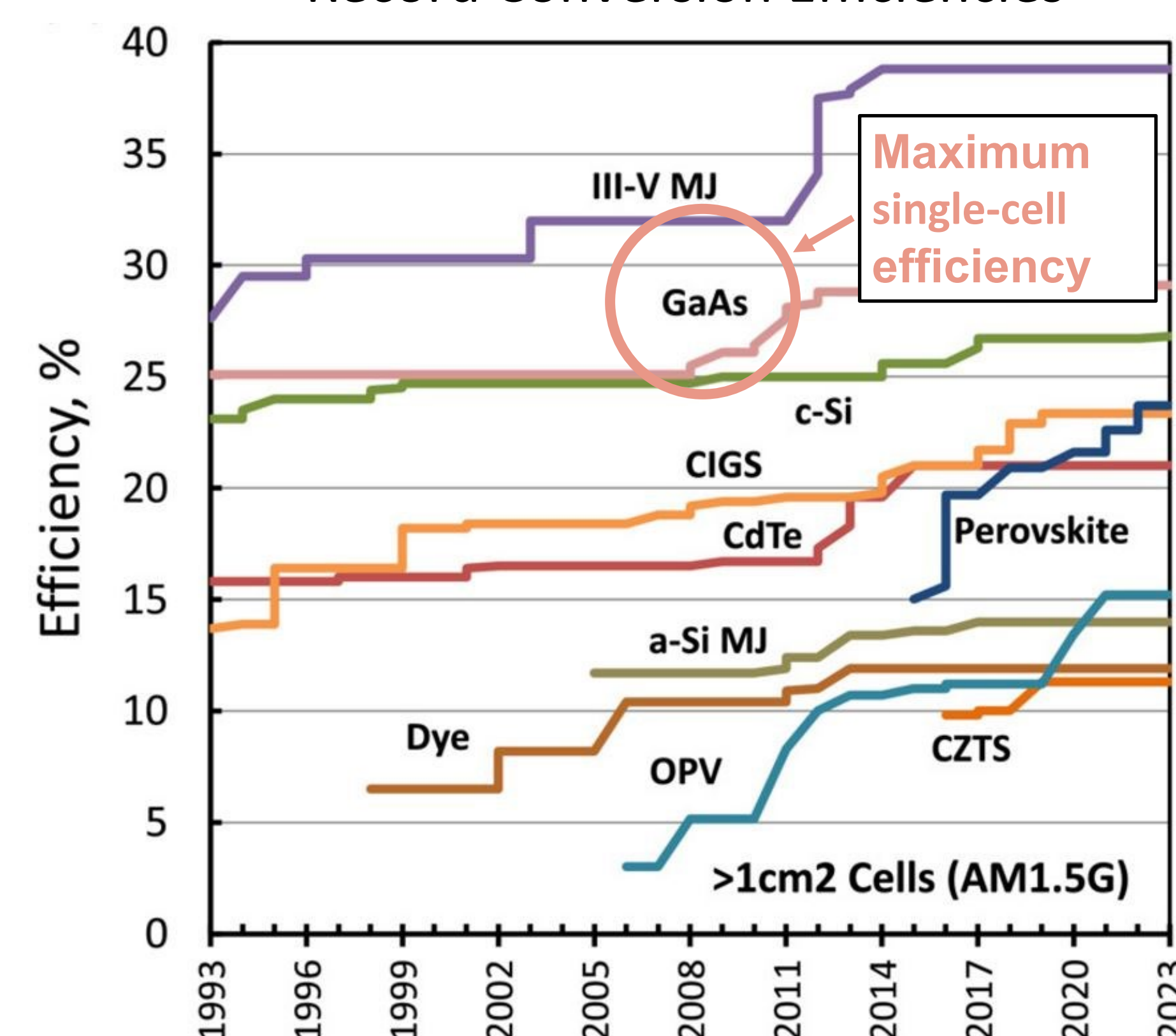
Motivation: GaAs Photovoltaics

Table 10.1 Renewable Energy Production and Consumption by Source



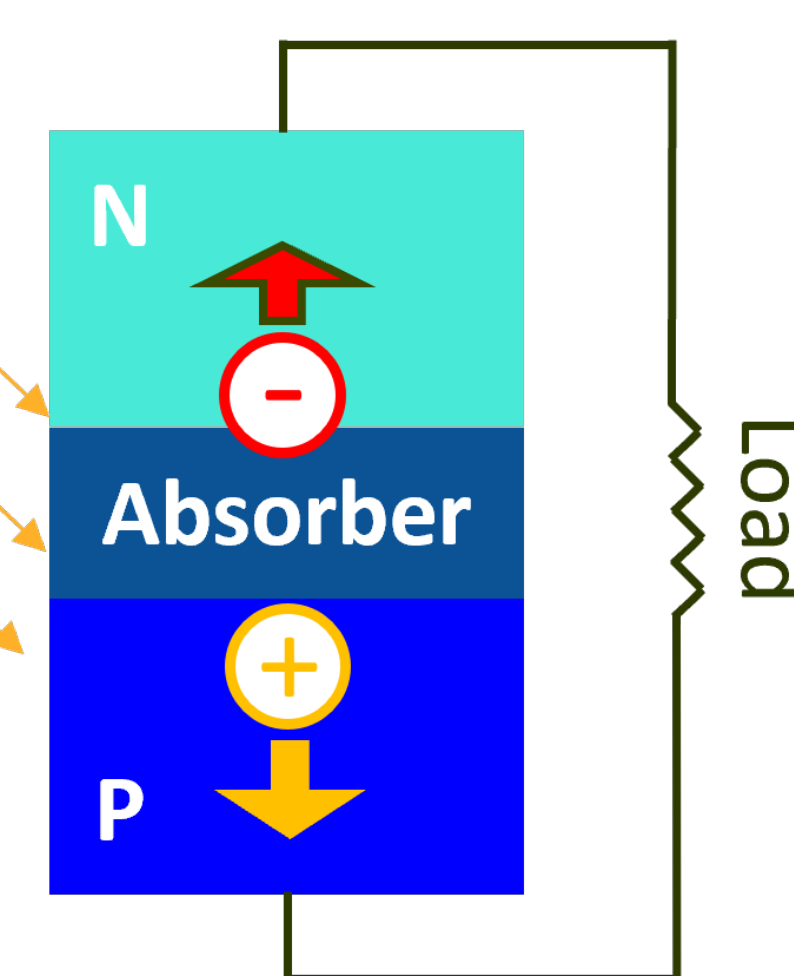
eia Data source: U.S. Energy Information Administration

Record Conversion Efficiencies



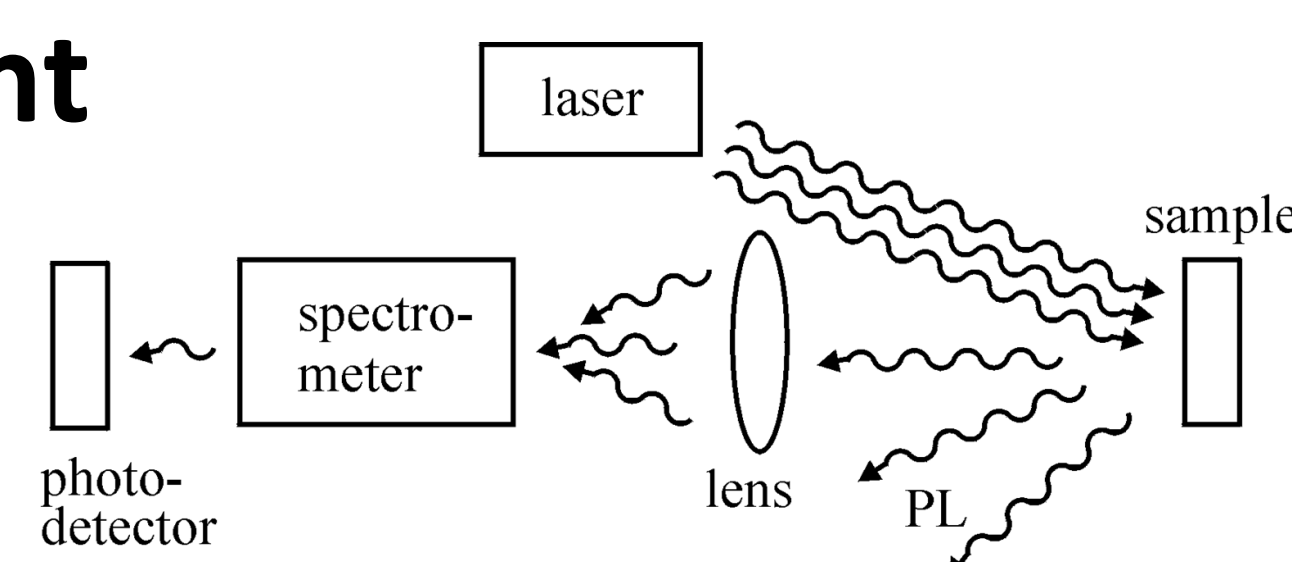
Solar Cell Operation

Convert excitation of electron-hole pairs (from sunlight!) into electricity



Photoluminescence Experiment

Use fast optics to measure lifetimes

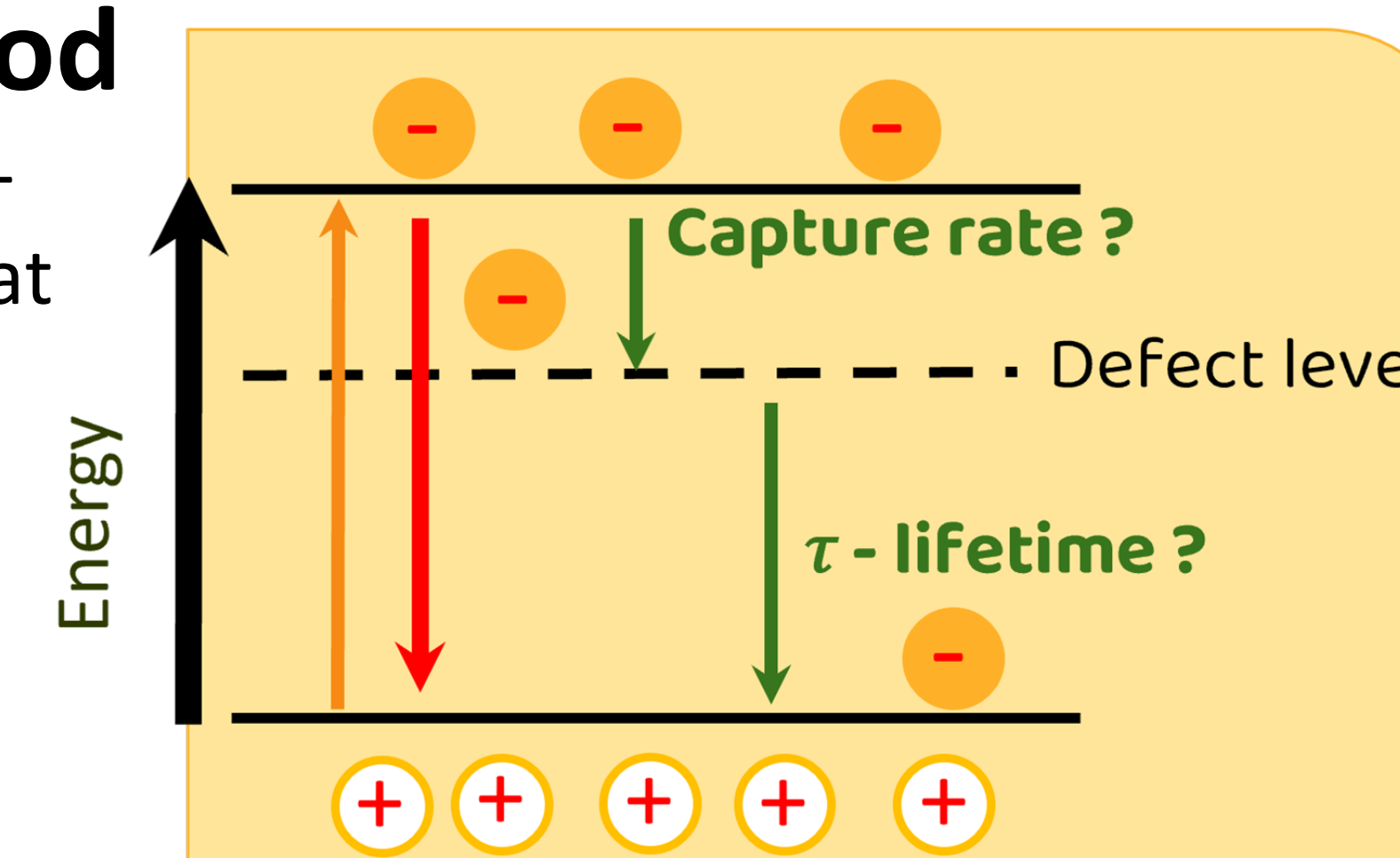
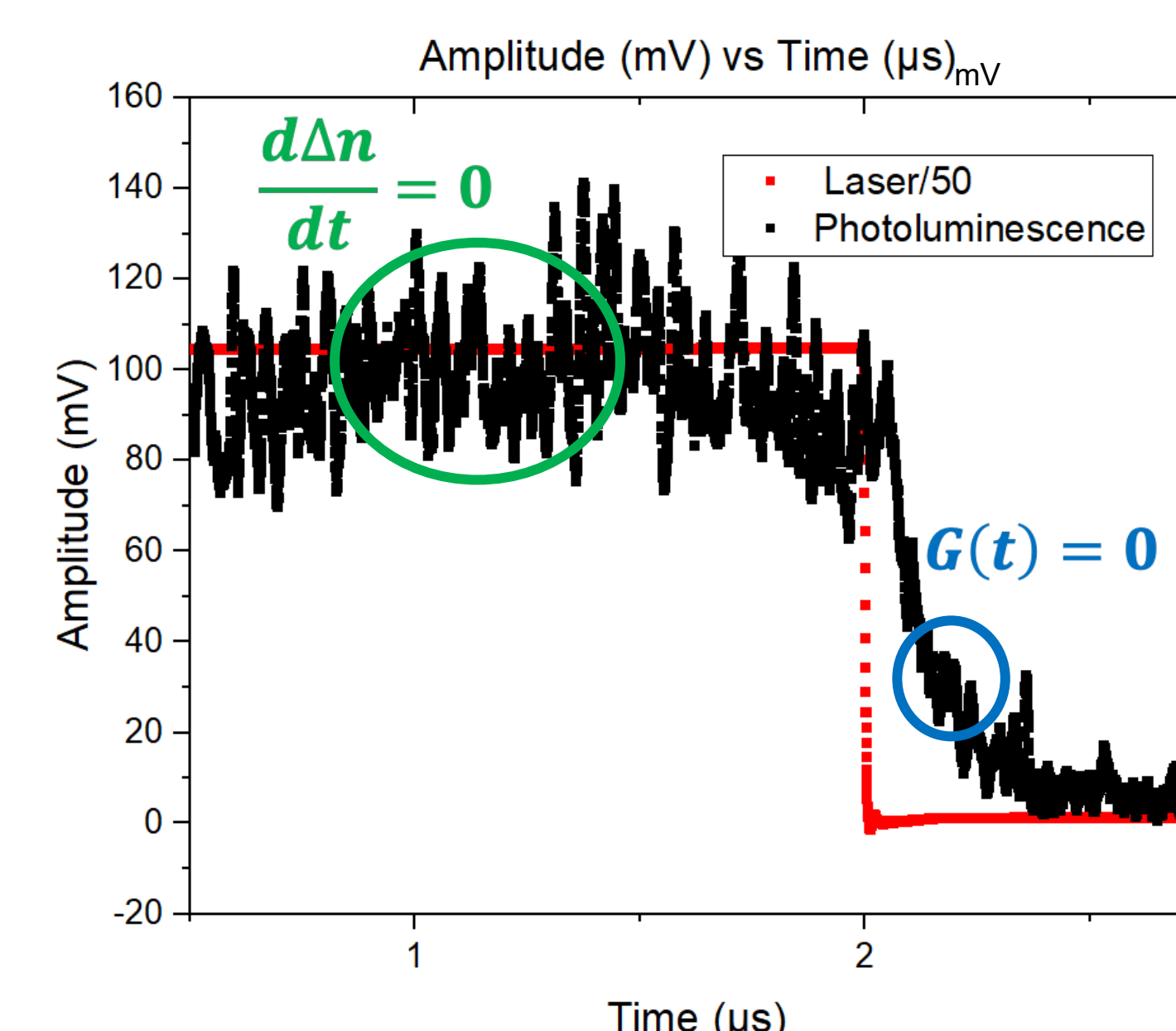


Abstract

The characterization of defects and their impact on recombination rates in solar cells is crucial for evaluating and improving photovoltaic performance. Injection-dependent lifetime spectroscopy is a sensitive and commonly used technique for investigating recombination rates in semiconductors. However, determination of the photoexcited carrier density during the lifetime experiment can be challenging. We employ a new dynamic calibration approach, which relies on a combination of quasi-steady-state and transient measurements, to obtain the lifetime as a function of charge carrier density in a GaAs/GaInP heterostructure.

Dynamic Lifetime Calibration Method

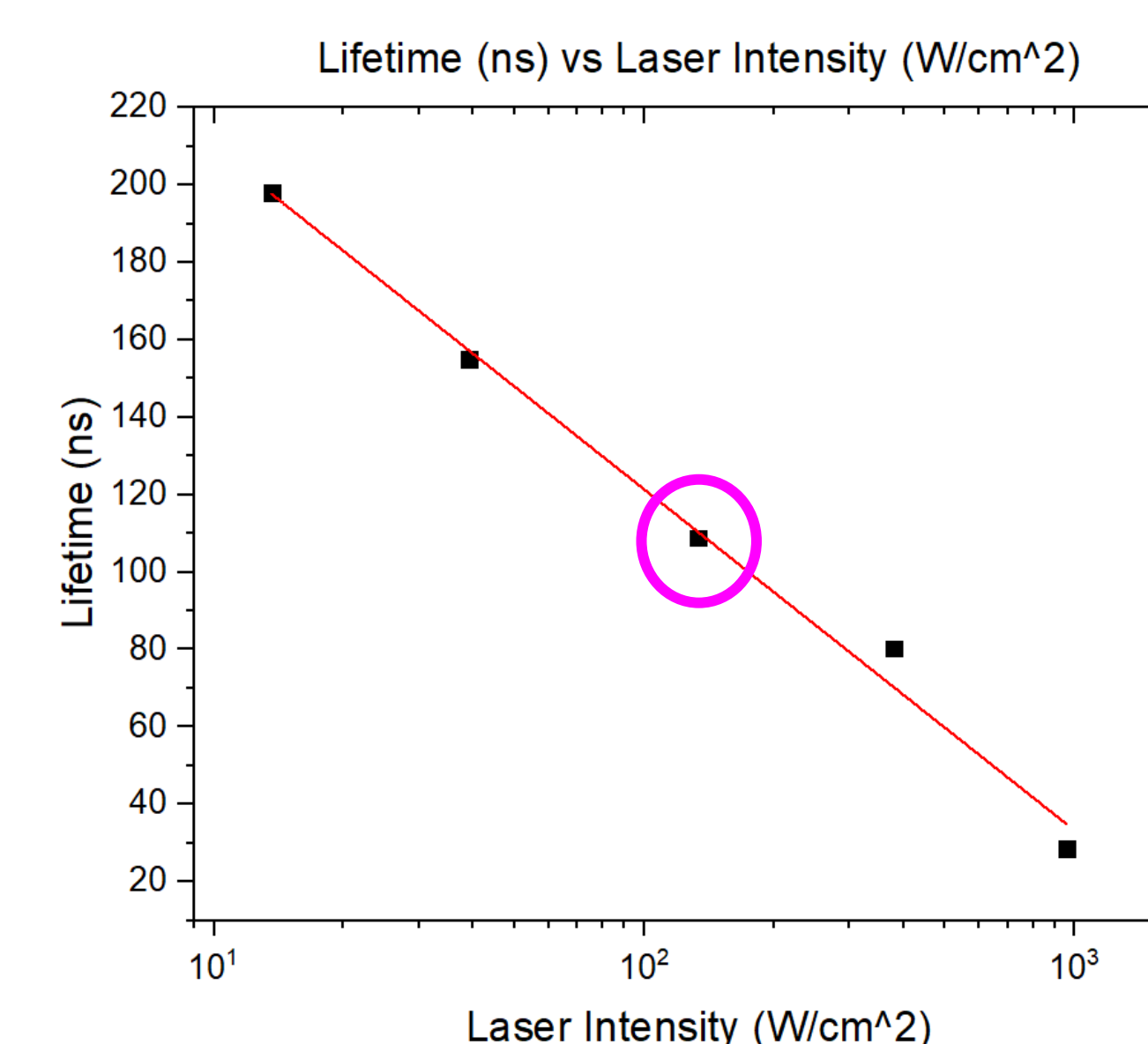
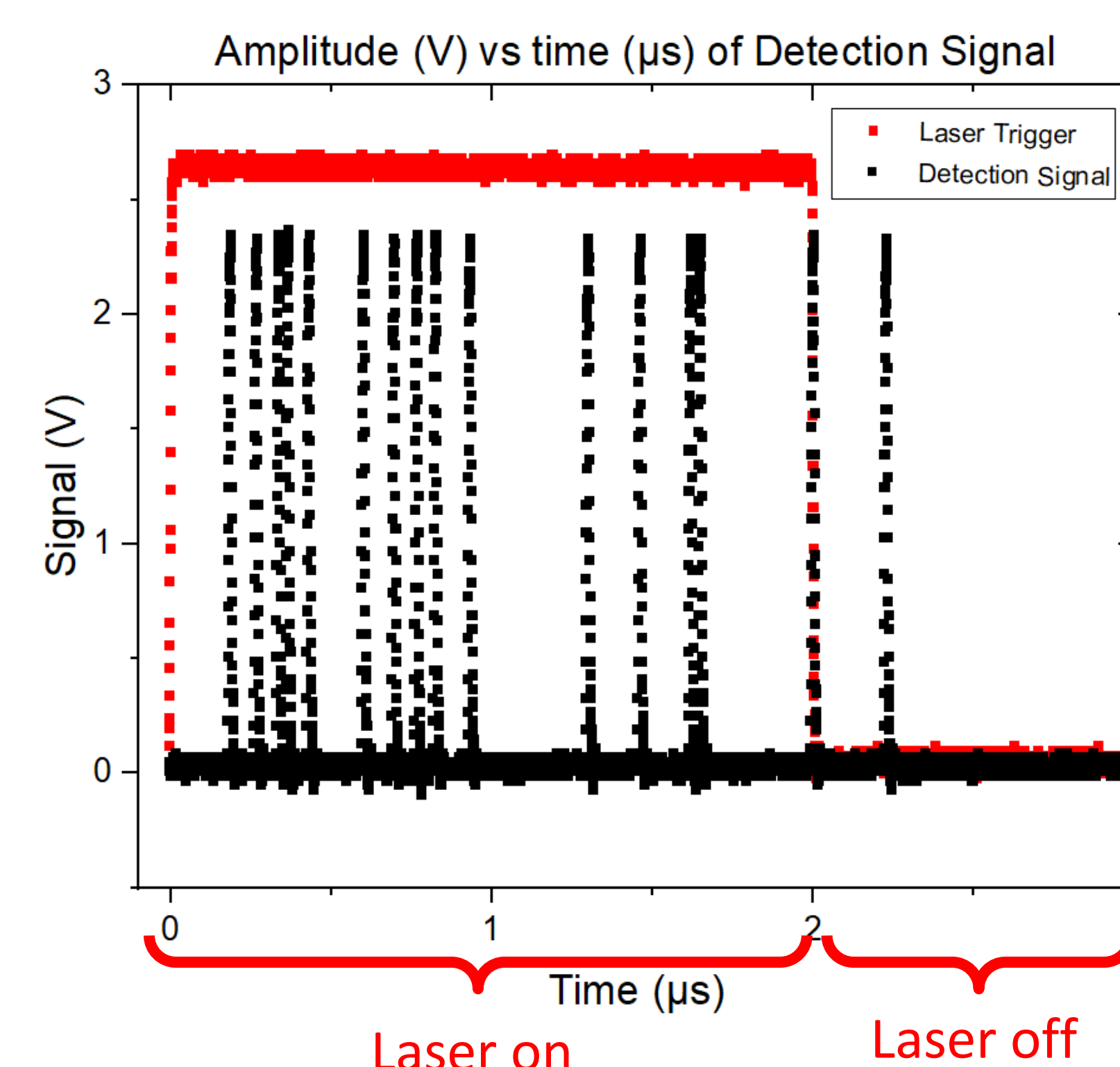
Defects augment recombination of excited electron-hole pairs and cause the dissipation of energy as heat



→ Continuity Equation: $\frac{d\Delta n}{dt} = G(t) - \frac{\Delta n(t)}{\tau(\Delta n)}$
where Δn = e-h pair concentration, t = time, G = generation rate, and τ = effective lifetime

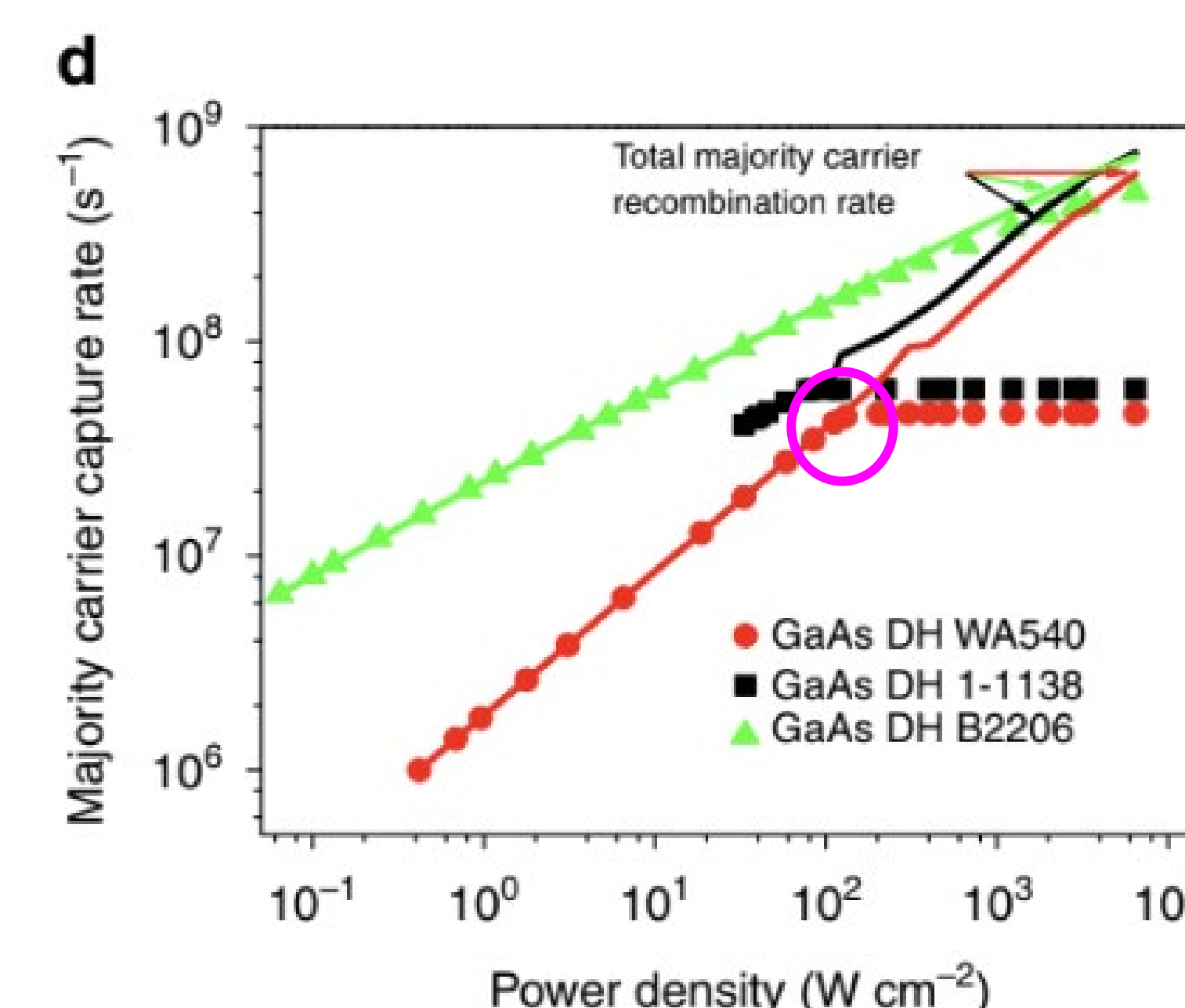
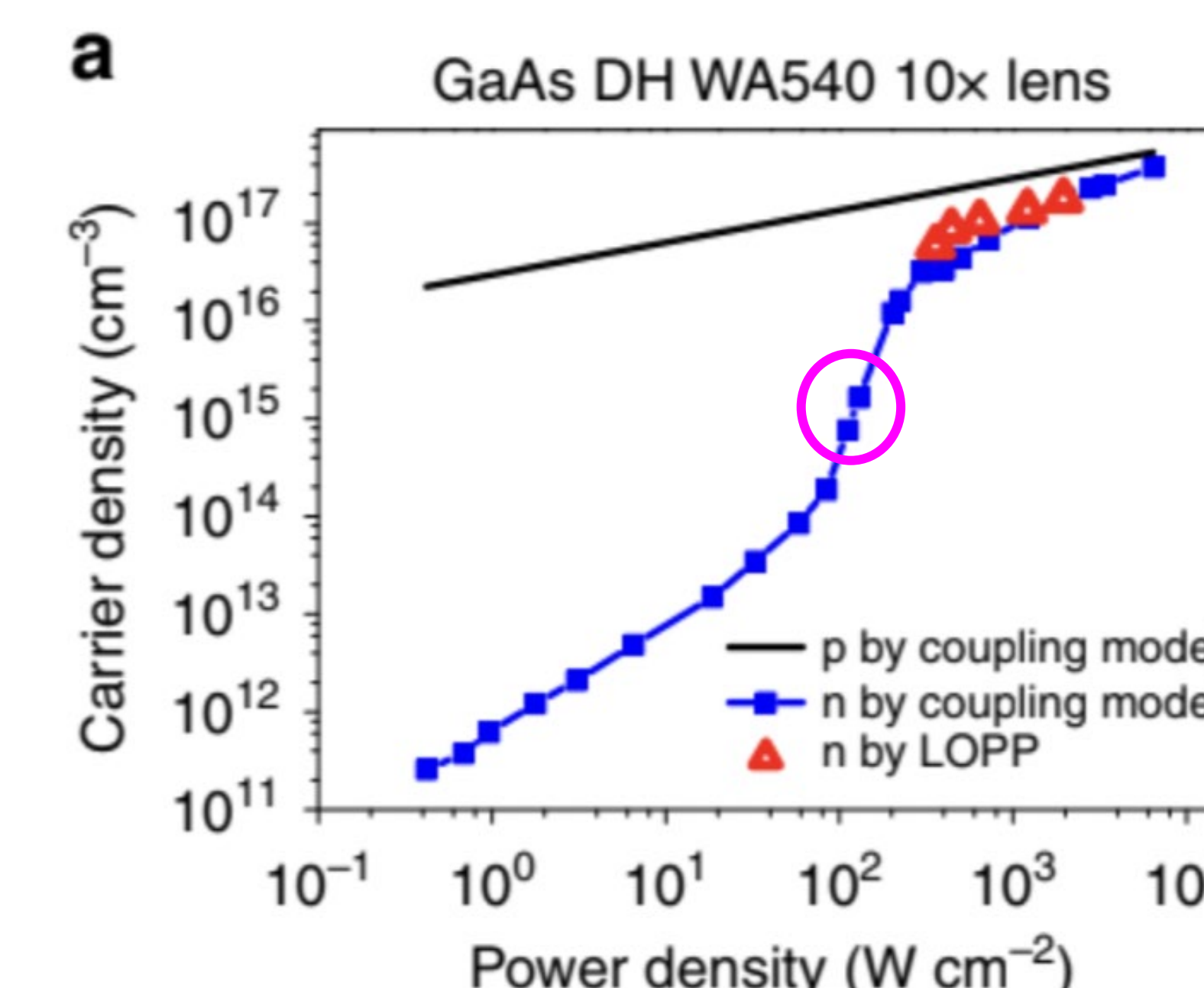
Quasi-steady-state (QSS) condition $[d\Delta n/dt = 0]$:
 $\tau(\Delta n) = \Delta n(t)/G(t)$

Transient condition $[G(t) = 0]$:
 $\tau(\Delta n) = \Delta n(t)/(-d\Delta n/dt)$



Experimental Goals

Figures from *Light: Science & Applications*. **11**, 137 (2022), where all measurements were made under steady-state conditions.



At 100 W/cm², the measured lifetime (~100 ns) is longer than the theoretical majority carrier capture time (~25 ns) in our previous model, suggesting that recombination is limited by minority carrier capture.

Current Progress

We have completed our first round of data acquisition, but the single photon counting response limits our confidence in the linearity of the detection signal. Our next step is to proceed with the dynamic calibration analysis, but we may need to rethink our detection strategy to ensure consistency and reproducibility of results.