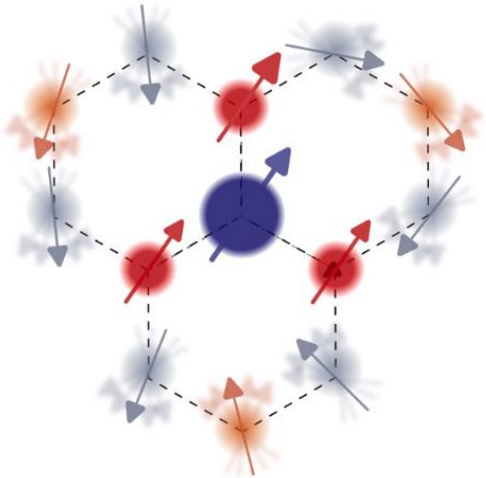
The US-Korea Forum on Nanotechnology, July 3-4, 2025

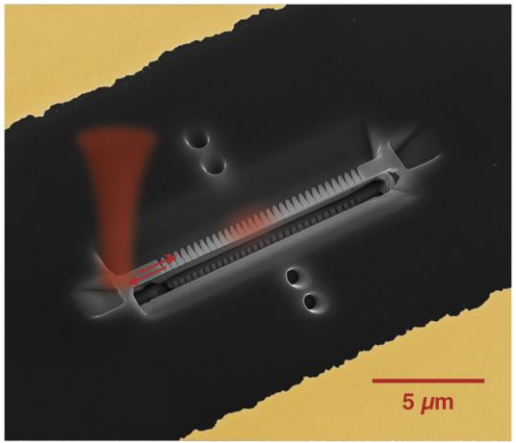
Stanford University

Advancing Nanoscale Quantum Sensing in Quantum-Photonic Hybrid Solid-State Devices

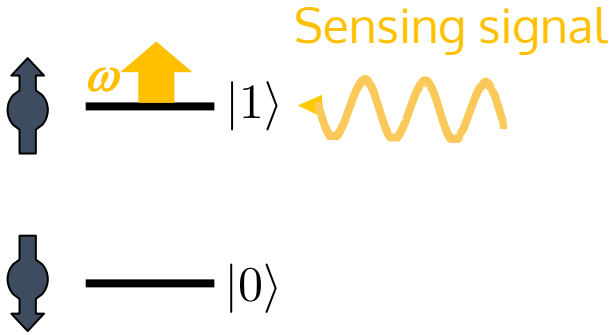


Joonhee Choi

Electrical Engineering
Stanford



Quantum sensing

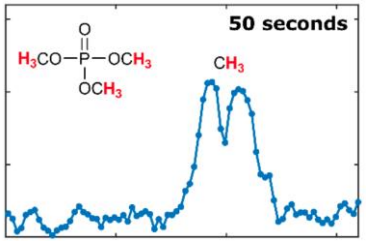


Dephasing due to external signal

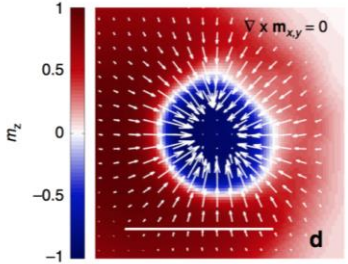
$$\frac{|0\rangle + |1\rangle}{\sqrt{2}} \rightarrow \frac{|0\rangle + e^{-i\omega t}|1\rangle}{\sqrt{2}}$$

Applications to a wide variety of fields

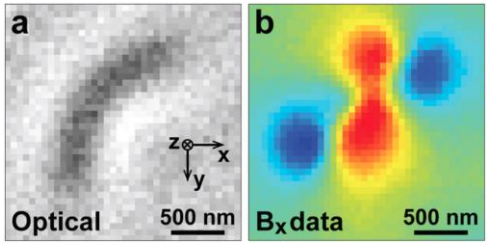
Nanoscale NMR



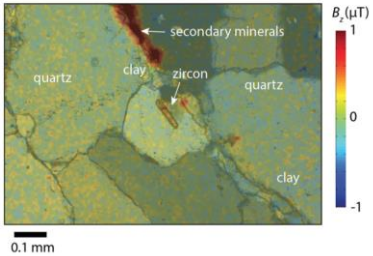
Material Science



Biological Magnetism

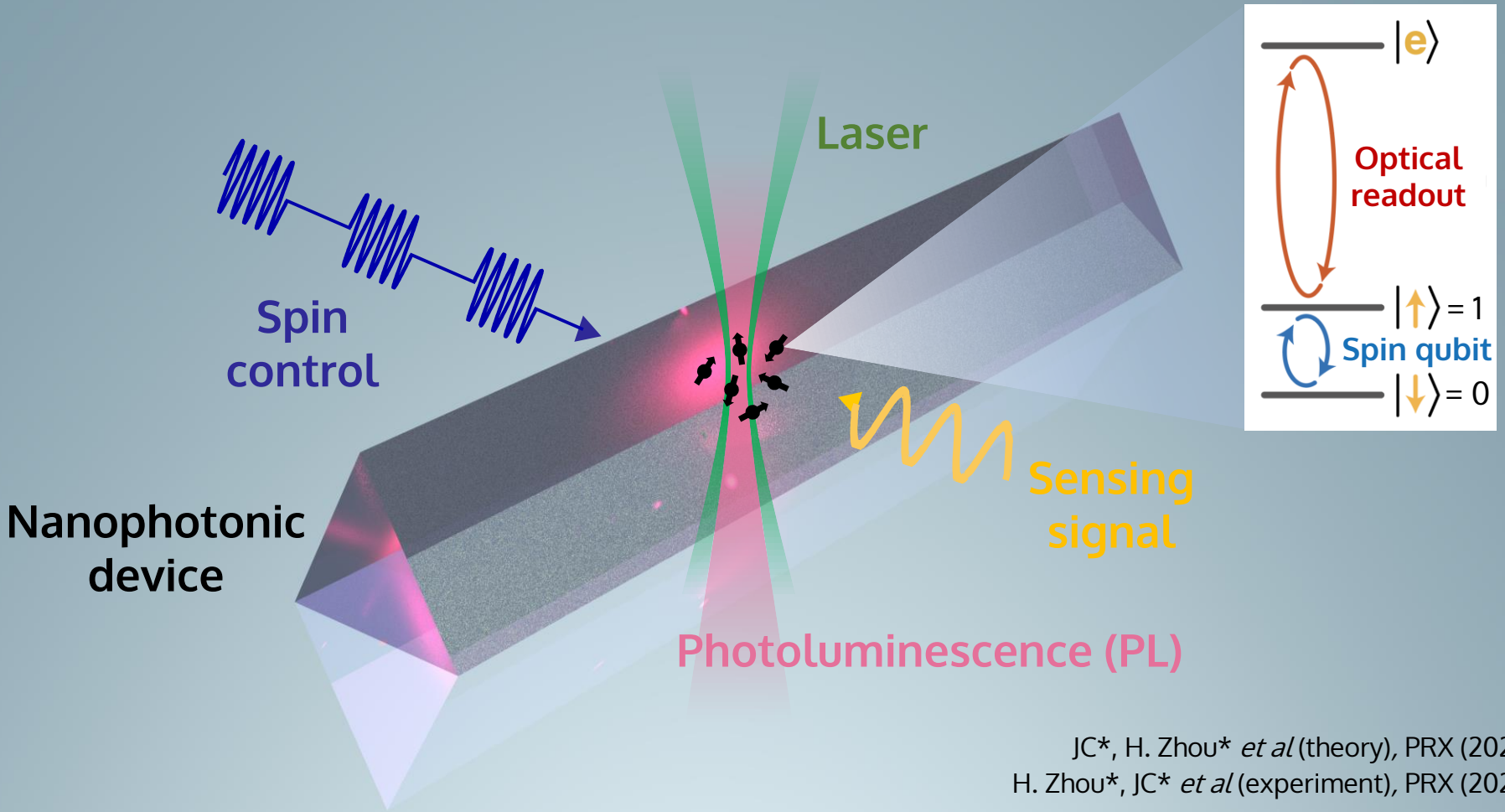


Geophysics



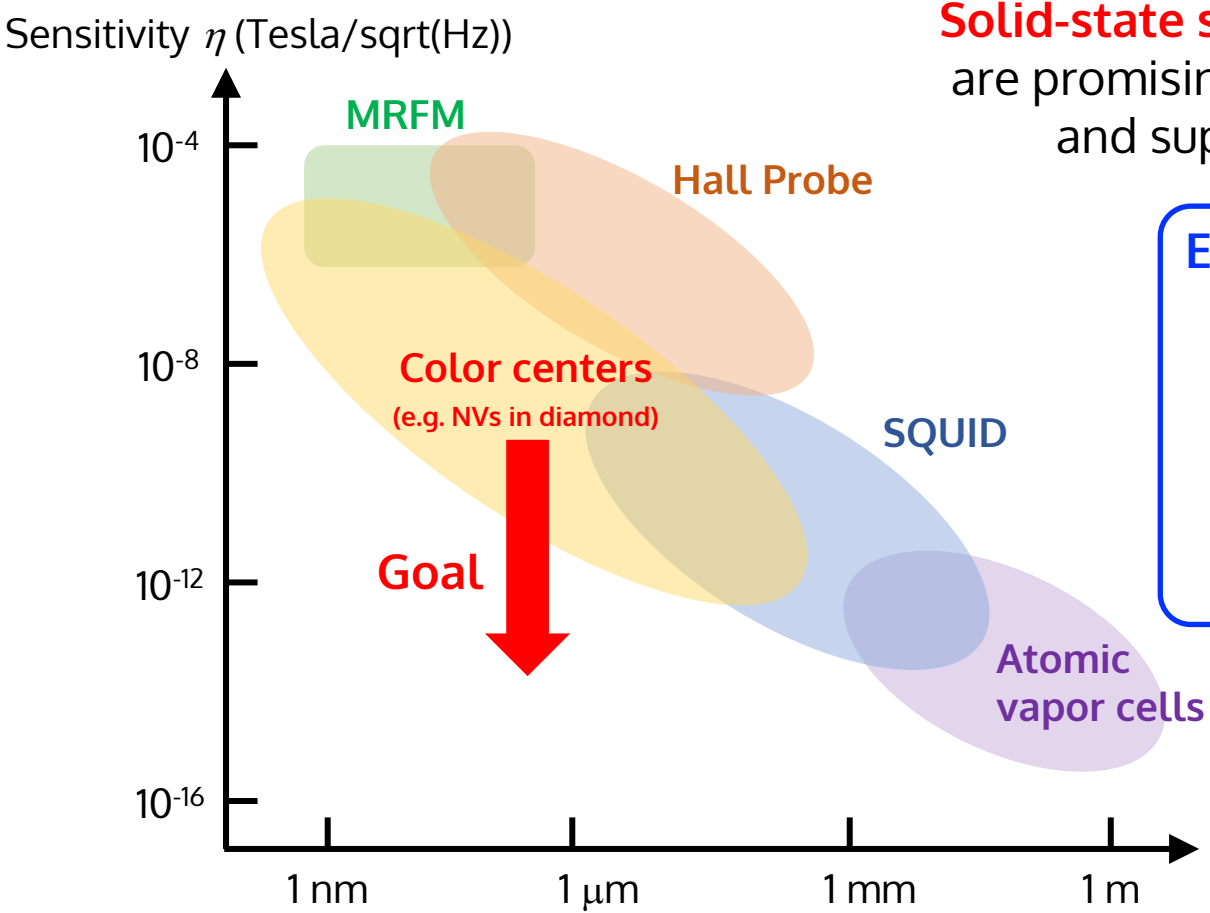
Science **357**, 990 (2017), Nature Rev. Mat. **3**, 17088 (2018), Science **357**, 67 (2017), Nature **555**, 351 (2018)
Rev. Mod. Phys **89,** 035002 (2017), Nature **496,** 498 (2013), Science **346**, 1089 (2014); Nature Comm. **9**, 2712 (2018)

Quantum sensing with solid-state spins



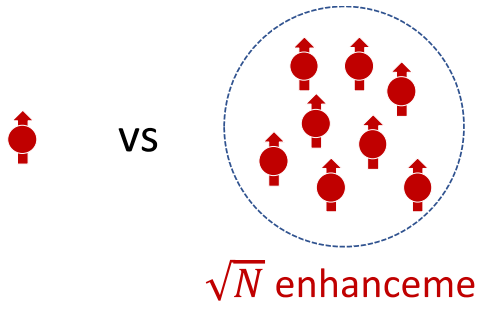
JC*, H. Zhou* *et al* (theory), PRX (2020)
H. Zhou*, JC* *et al* (experiment), PRX (2020)

Benchmarking magnetic field sensors



Solid-state spins based on color centers are promising sensors for high sensitivity and superior spatial resolution!

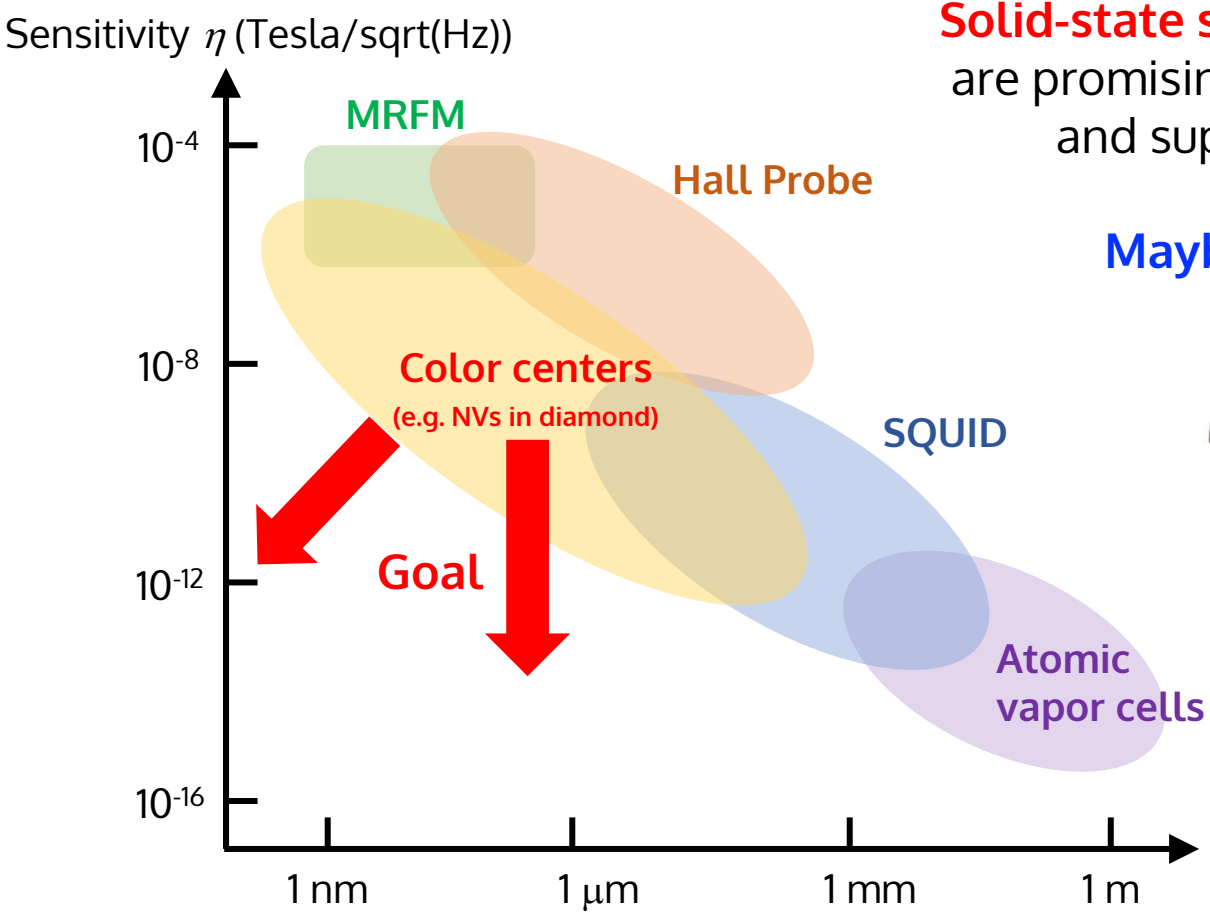
Ensemble quantum sensing



H. Zhou*, JC* *et al,* PRX (2020)

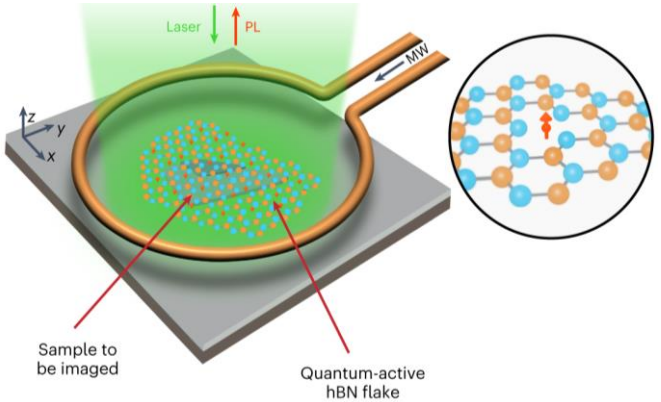
IQC's NanoMRI conference (2015)

Benchmarking magnetic field sensors



Solid-state spins based on color centers are promising sensors for high sensitivity and superior spatial resolution!

Maybe, 2D quantum sensors?

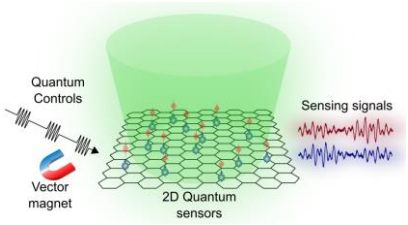


Nature Physics 19, 87 (2023)

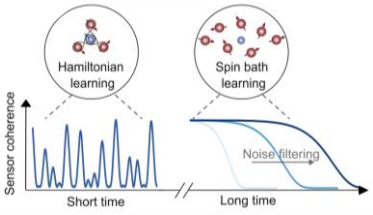
IQC's NanoMRI conference (2015)

Towards ultra-sensitive quantum sensors in 2D materials

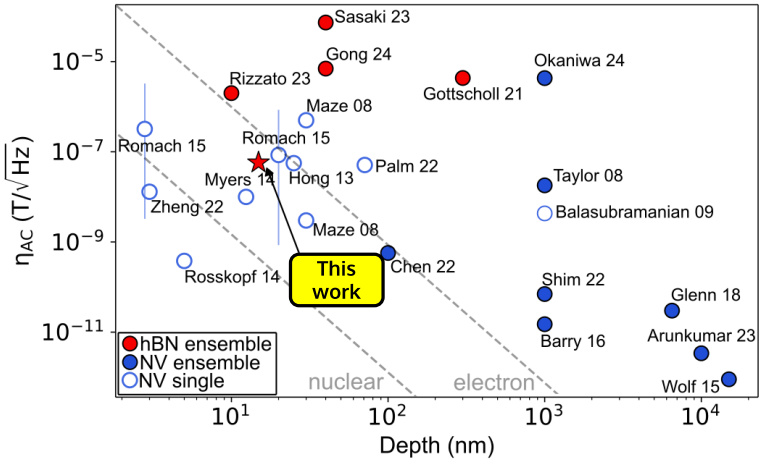
Quantum sensing using 2D materials



Hamiltonian and noise learning

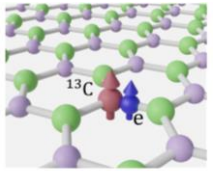


Towards superior, ultra-sensitive nanoscale quantum sensors



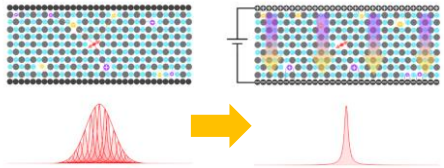
Current research interests

Probing novel coherent and bright spin defects in 2D materials



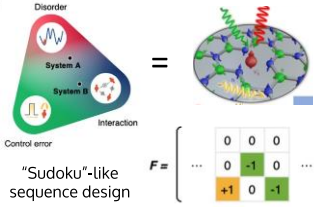
Gao *et al*., arXiv (2024)

Electric, strain, and photonic control and stabilization of spin & optical transitions



Akbari *et al*, Nano Letters (2022)

Co-design approaches for demonstrating system-tailored sensing applications

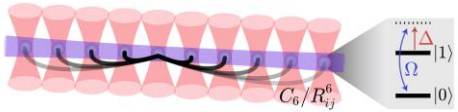


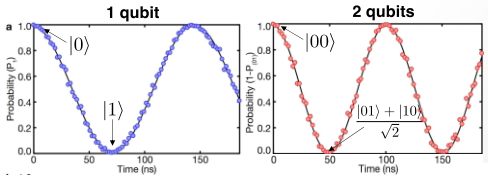
"Sudoku"-like sequence design

Choi *et al*., PRX (2020)

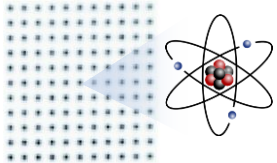
The Choi Lab at Stanford University

Quantum Computing and Benchmarking





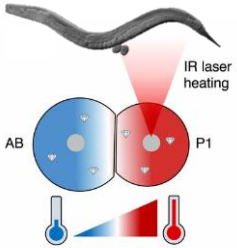
Quantum Device + Robust Control

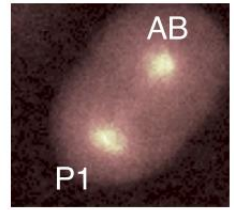


$$F = \begin{bmatrix} \cdots & \begin{matrix} 0 & 0 & 0 \\ 0 & -1 & 0 \\ +1 & 0 & -1 \end{matrix} & \cdots \end{bmatrix}^N$$

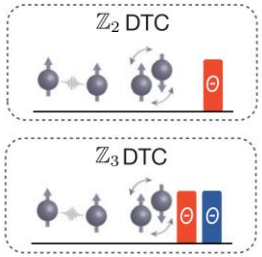
- ✓ Probing **new physics**
- ✓ Practical **applications**

Interdisciplinary Quantum Applications

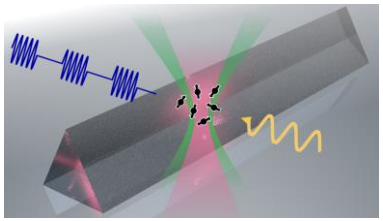


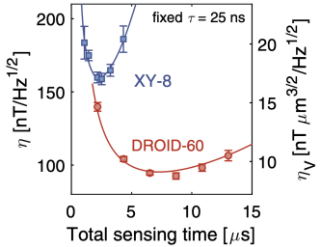


Quantum Simulation

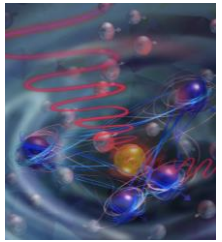


Nanoscale Quantum Sensing





Quantum Communication



Nuclear spin wave

$$|W_v\rangle \equiv$$